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# College Biology

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*Designed, Printed and Published in Nigeria by*

Idodo Umeh Publishers Limited
No. 52, Ewah Road,
P.O. Box 3441,
Benin City,
Edo State, Nigeria.

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Dr. G. Idodo-Umeh, 1996, 2004., 2009

First Published 1996.

Second Edition 2004.

Third Edition 2010.

Fourth Edition: 2011



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# PREFACE

**Biology** is an interesting subject and as such I have taken pains to write an interesting book, packed with **fascinating examples** and **drawings.**

For some years now, there is a serious problem of having a biology text book that is **comprehensively written** to cover syllabuses of **West African Senior School Certificate Examinations (WASSCE)**, and **Joint Admission and Matriculation Board (J.A.M.B.)** and other examining bodies. The West African Senior School Certificate Syllabus has imported many new and advanced topics which are not easily available in most **traditional biology text books** of today. And if available such topics are **scantily** treated. Lack of **up-to-date biology text books** has brought frustrations and miseries to many candidates as their expectations of having a credit pass are dashed to the rock. Biology teachers are not left out as they still rely on **out-dated** biology books to **impart** knowledge to their students. These problems are fully addressed by this book.

Since this book is to help prepare you for your examinations, I have tried to write in **style** and **simple language** that an **average student** of biology can use for easy **learning** and **reference**.

The **order** of reading the **chapters** is left for you but it is my suggested option that if the topics are studied as arranged by the author, it may be rewarding as many of the chapters are arranged in an **evolutionary trend.**

Key words are being presented in **bold type** in order to emphasize important **concepts** and **facts.**

At the end of each **chapter**, **thought-provoking questions** or **past examination questions** are asked to test your knowledge of the chapter.

Even though my target audience is **West African Senior Certificate Examinations (WASSCE), National Examinations Council (NECO), National Business and Technical Examinations Board (NABTEB), General Certificate of Examinations (G.C.E.)** and **Joint Admission and Matriculation Board (J.A.M.B.)** students, it is my sound judgement that **National Certificate of Education (N.C.E.)** and **University Students** who are majoring in biology will find it extremely useful. **Post graduate students** would also find some background information provided here very rewarding.

I will appreciate **suggestions** and **criticisms** properly designed to improve the **usefulness, quality** and **accuracy** of this text from students, teachers and other interested readers.

Dr². G. Idodo-Umeh 1996.

## PREFACE TO THE SECOND EDITION

The need to keep this book current and to maintain the interest, knowledge and development of biology form the driving force for its revision. There are many changes both in text, tables and diagrams. Some topics have been expanded.

The use of colour clarifies some topics, enhances the quality of the book and makes reading pleasurable.

In a book of this large volume, inaccuracies and errors cannot be totally avoided. The author will gladly welcome such errors that will be spotted and corrected during reprint.

Dr². G. Idodo-Umeh 2004.

## PREFACE TO THE THIRD EDITION

Global warming is supposed to be treated under the chapter on pollution but I have decided to give it prominence, hence creating a separate chapter for it as it is now attracting global interest. Today global warming which is causing climate change has become one of the environmental disasters facing mankind. Serious efforts are going on to seek the full cooperation of all nations of the world to sign an agreement to reduce the level of global warming, if not mans existence on earth is heading for destruction.

Glossary has been added at the end of the book to further enhance the quality of the book.

Dr². G. Idodo-Umeh, 2010.

## ACKNOWLEDGMENTS

Words are not adequate enough to express my deep and sincere appreciation to Mr David Sunday Okun, a Principal Lecturer in Biology at Institute of Continuing Education, Benin City for putting in so much energy, time, personal sacrifice, and endless patience for the successful completion of this book. Indeed, he coordinated much of the work and put his biological experience to the forefront to make the text a warm reality.

I thank the Late Prof. L.S. Gill of the Department of Botany, University of Benin, Benin City for his immense contribution in area of ecology. His criticisms and constant supply of recent literature were of great asset on ecology. He was very anxious to see the birth of this book but death robbed him of the opportunity.

I also wish to credit Mr. F.O. Obikwu, Assistant Director, Institute of Continuing Education, Asaba for his contributions in genetics.

It is impossible for me to acknowledge fully all the sources of assistance. However, there is a great debt of gratitude to the following persons for thoroughly reading through the manuscript and making useful corrections: Dr. F. Alohan and Dr. A.E. Ogbeibu both of the Department of Zoology, University of Benin, Benin City; Mrs E.E. Iyamu, Head of Biology Department, Adesuwa Grammar School, Benin City; Mr. A.J. Aibanegbee, Senior Biology Teacher, Evbareke Secondary School, Benin City; Mr R.O. Ogbeide, Senior Biology Teacher, Akenzua II Secondary School, Benin City; Mr G.O. Adewo, Vice Principal, Eghosa Grammar School, Benin City; Mrs A.O. Chime, Supervisor of Biology, University Demonstration Secondary School, Benin City, and Mr F.O.K. Salami. Messrs S.A. Omoruyi, U.X. Orhue, A.A. Akerobo and C.I. Aghimien are thankfully acknowledged for their immense contributions in the area of agriculture.

Mr R. Odio of Olomoro Comprehensive High School, Olomoro, Mr Andrew Okogba of the Ministry of Information, Asaba and Elvis Obeng are gratefully thanked for transforming my rough sketches into finished line drawings.

I profoundly thank **West African Examination Council (W.A.E.C.)** and **Oxford Delegacy of Local Examinations** for granting me permission to reproduce some of their past examination questions. The following abbreviations have been used: **S.S.C.E.** -Senior School Certificate Examination, **W.A.S.C.** - West African School Certificate, **OXF** - Oxford Delegacy of Local Examinations.

This text book which has taken me twelve years to complete would have been impossible if my wife Mrs Dorah Idodo-Umeh had not given me the required encouragement, care, co-operation and unconditional understanding. To her, I am sincerely thankful and grateful.

To many other individuals, publishers and institutions who contributed and their names not mentioned are gratefully acknowledged.

If this book goes into publication before receiving permission to use some already published materials, kindly forgive me as this may be due to postal delay.

Dr. G. Idodo-Umeh


## DEDICATION

*This text book is dedicated to*
*my late father,*
Chief Umeh Otobo
*who did so much to make me*
*what I am today.*

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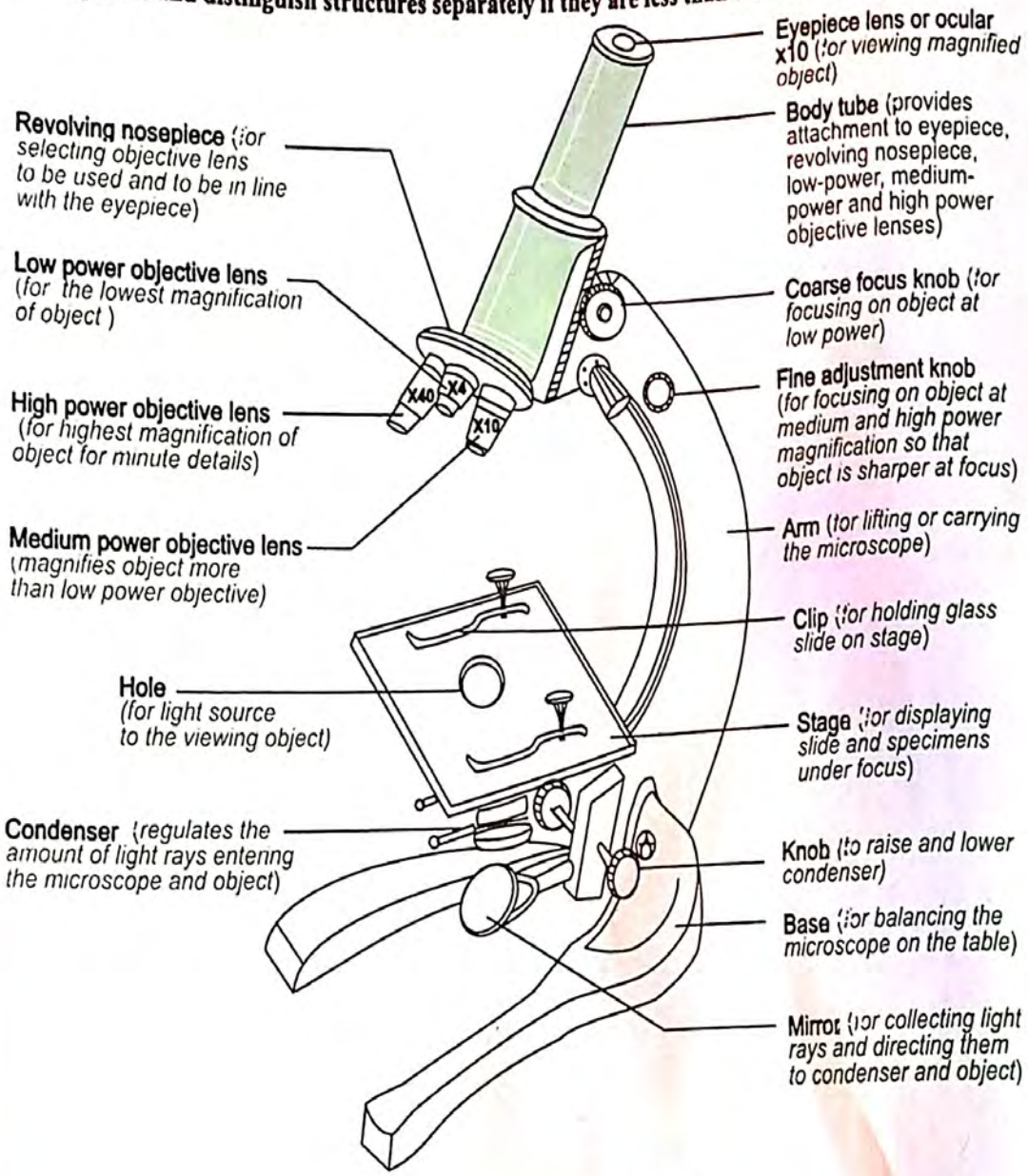
# MICROSCOPE

**A microscope is an instrument used in magnifying and viewing organisms smaller than 0.1mm that are too tiny to be seen by human naked eyes. However, light microscope has a limit in which it can separate and distinguish structures separately if they are less than 0.002mm apart.**




**An anotated diagram of a compound light microscope**

# 1

# CONCEPT OF LIVING THINGS

## LIVING AND NON-LIVING THINGS

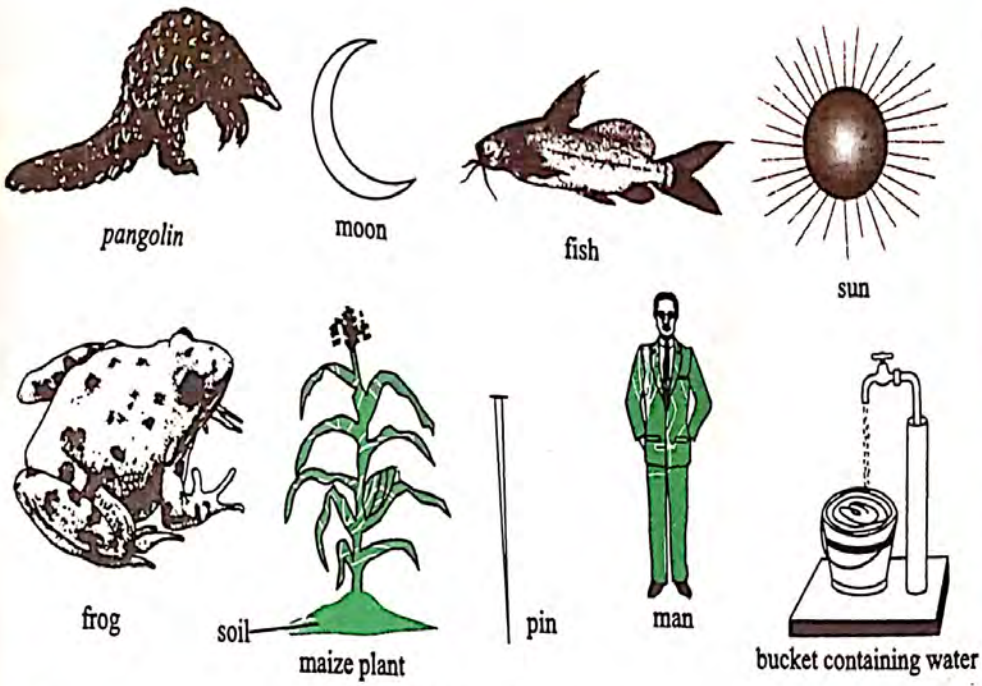



**Fig. 1.1. Living and non-living things**

The world is composed of living things and non-living things. Look at figure 1.1 above. It is easy to separate living things from the non-living things. The pangolin, fish, frog, maize plant and man are the living things or organisms while moon, sun, soil, pin and bucket with water are the non-living things.

It is a fact of biology that substances making up living things are derived directly or indirectly from water, air and soil which are non-living. Both living and non-living things are made up of chemical elements. It is also a fact that when living things die, their substances return to the realm of the non-living things. Therefore, there is a close relationship between living and non-living things. However, living things have basic characteristics which distinguish them from the non-living things.

### Characteristics of living things

1. **Movement:** Generally, living things are capable of carrying out one form of movement or the other. Most animals move from place to place on their own accord, either in search of food, mates, shelter or escaping from enemies. Most plants are fixed and can only move certain parts of their body such as shoots and roots in growth movement, opening and closing of some flowers and leaves. However, some non-living things move. The air moves in form of winds. The wind carries dust particles in the atmosphere. Water moves in form of current. These movements are mainly caused by external factors. For example, wind is caused by one region having a low pressure and the other

having a high pressure. Wind therefore moves from high pressure region to low pressure region. No structures are involved in this movement. But in living things, structures such as muscles, bones, flagella, cilia are involved in their movements.

2. **Respiration**All living things respire. All living things need energy for work. The chemical energy for work is released by the oxidation of respiratory substrates in living cells.
3. **Nutrition**:All living things feed to provide chemical energy for work and materials for growth and repair of worn out parts.
4. **Irritability (Sensitivity)**:If you unknowingly touch a hot object, you quickly withdraw your hand. The hot object is the stimulus (plural: stimuli). The withdrawal of your hand is the *response*. **Irritability is the ability of living things to respond to changes in external and internal stimuli such as light, water, sound, temperature, hunger, chemical and physical substances.** The shoots of green plants bend towards the source of light while the roots bend towards the source of water. An animal will move from a region of excessive heat to a cool region.
5. **Growth and Development**
   ***Growth is an irreversible enlargement of an organism.*** Growth occurs when outside substances are built into structure of the body, that is they become part of the body. When the food you eat becomes a part of your body (assimilation) growth occurs. In other words, when anabolism (building up of materials) exceeds catabolism (breaking down of built materials) growth occurs.
   ***Development is the change in shape and form of an organism as it ages.*** However, some non-living things grow. For example, crystals grow. But the growth of crystals is not a true growth. The growth of crystals is by external addition. Development is a change in form, shape and size as an organism grows to maturity.
   A crystal in a solution of similar materials grows by mere addition of the solute particles to its surface. This growth is reversible. A man does not grow by adding food to the surface of the body **but** by only assimilation of food substances into the body.
6. **Excretion**Living things must get rid of waste poisonous substances from the body. If waste products are allowed to accumulate in the body, they will cause the death of the organism. The removal of the metabolic waste products is called **excretion**.
7. **Reproduction**All living things reproduce their own kinds. Since the life time of living things is limited, reproduction must be carried out for the continuation of life. Therefore, living things must reproduce themselves either asexually or sexually.
8. **Limited size**All living things have a limited size. Each species has its own limited size. For example, a dog can never grow to the size of an elephant. No matter how well you feed a pigeon it can never grow to the size of a turkey.
9. **Life Span** All living things have a definite period of existence. No organism lives forever. When conditions become unfavourable for existence, life ceases. All living things pass through the following stages: (a) **origin** or **birth** (b) **growth** (c) **maturity** (d) **productivity** (e) **ageing** and (f) **death**.
10. **Competition**Competition is the struggle for survival of the fittest among living things. All living things struggle for the existence of life. The struggle for light, space, water and food are some forms of competition for existence.
11. **Adaptation**All living things must have the ability to adapt to their environments if they are to survive the exigencies of the unstable earth.
12. **Maintenance of constant internal environments (Homeostasis)**All living things have the ability to keep their internal environment (eg pH, temperature, salt content) in a constant form (or within tolerable conditions) despite changes in the external environments.

## Non-living things

Non-living things have no life in them. They do not have the characteristics of living things. Some non-living things exist as gases (e.g oxygen, carbon (IV) oxide and hydrogen), liquids (e.g water, and mercury) and solids (stone, iron and glass).

## Similarity between living things and non-living things

1. Both have size.
2. Both possess shape
3. Both have weight.

## Differences between living things and non-living things

| Living things | Non-living things |
|---|---|
| 1. Living things have life in them. | They have no life in them |
| 2. Living things feed, respire, excrete, reproduce and respond to stimuli | They do not feed, respire, excrete, reproduce and respond to stimuli. |
| 3. Movement by living things is carried out by structures such as muscles, bones, flagella and cilia. | Movement by non-living is caused by external factors such as wind and current. Wind carries dust particles from place to place. Current moves water. |
| 4. Growth is by assimilation of food substances into the body, that is, growth is internal. Growth is not reversible. | Growth in non-livings is by external addition of substances to the body. For example, the growth of crystals is by external addition. A crystal in a solution is by mere addition of the solute particle to its surface. This growth is reversible. |
| 5. Living things age and die. | They do not age and never die. |
| 6. Living things can never exist without non-living things. For example, most living things need oxygen for respiration to exist. All living things need water to exist. | Non-living things can exist without living things. |
| 7. No living thing is made up of one element. | 1. Some living things such as oxygen, hydrogen, sulphur, calcium, magnesium and iron, are made up of one element. |

## The Inter-relationship between living and non-living things

Living and non-living things inter-relate. Non-living things provide nutrients for living things. Green plants manufacture their food from carbon (IV) oxide and water using sunlight energy which are non-living things. Animals depend upon plants for their food. During respiration almost all living things use oxygen and give out carbon (IV) oxide. All the components of living things are derived from non-livings. When living things die, all their components (by process of decay) revert to the realm of the non-living things.

## Inter-relationship between plants and animals

1. Green plants during photosynthesis manufacture their food with the aid of sunlight, chlorophyll, carbon (IV) oxide and water. Animals which can not manufacture their food feed on plants.
2. During the respiratory process, animals give out carbon (IV) oxide as a waste product. Plants make use of this carbon (IV) oxide to manufacture their food.

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

3. Plants during photosynthesis give out oxygen as a by-product which animals use for respi-ration.

$$6H_2O+6CO_2 \xrightarrow[\text{sunlight}]{\text{chlorophyll}} C_6H_{12}O_6+6O_2$$

(Green plants - photosynthesis)

$$C_6H_{12}O_6+6O_2 \xrightarrow[\text{respiration}]{\text{Animal}} 6CO_2+6H_2O+\text{Energy}$$

4. When organisms die, micro-organisms (bacteria and fungi) cause their decay. The decayed organisms form manure which plants absorb as soil nutrients.

## Dead things

Dead things once lived and had all the characteristics of living things but once they become dead (lifeless) they are referred to as dead things and no longer possess the characteristics of living things.

Wood and wooden materials such as box, chair, bed, table, books are derived from plants that once lived. Animal leather and skeleton are derived from animals that once lived.

## Characteristics of dead things

1. The body of a dead thing is mad up of dead cells.
2. Dead things decay if not properly preserved.
3. Dead things lack characteristics of living things.

**Table 1.** **Differences between plants and animals**

| | | Plants | Animals |
|---|---|---|---|
| 1. | Nutrition | Possess green colouring pigments called chlorophyll, therefore can manufacture their own food by photosynthesis. Exceptions being fungi and certain bacteria. | Have no chlorophyll, therefore cannot manufacture their food by photosynthesis. They have to depend upon the food of green plants. |
| 2. | Locomotion | Generally plants do not move to search for their food, hence there are no organs of locomotion. | They move to search for their food, hence they have organs of locomotion. |
| 3. | Sense organs | Sense organs are absent | Sense organs are present to enable them detect their food and escape from enemies. |
| 4. | Organs of respiration | There are no real organs to carry out respiration hence the absence of respiratory movements. | Have organs of respiration hence respiratory movements are carried out. Lungs as in mammals are examples. (Note respiratory organs are not present in lower animals e.g.*Amoeba).* |
| 5. | Energy | They are energy transforming organisms (anabolic). | They are energy spending organisms (catabolic) |
| 6. | Excretory organs | No special excretory organs. | Excretory organs are present e.g. kidneys in vertebrates to eliminate waste products. |
| 7. | Growth | Growth is indefinite. | Growth is limited. |
| 8. | Cell wall | Cell wall has a dead rigid cellulose cell wall, hence a definite shape. | Cell wall has a living flexible membrane hence it can change its shape e.g.*Amoeba.* |
| 9. | Vacuole | A plant cell has a large central vacuole. | Animal cell usually has no vacuole but if present is very small. |
| 10. | Cytoplasm | Cytoplasm is thin. | Cytoplasm is large. |
| 11. | Food stored | Generally starch. | Glycogen. |
| 12. | Centriole | Centriole is absent. | Centriole is present. It initiates cell division in animals. |

## CLASSIFICATION (TAXONOMY) OF LIVING THINGS

There are over 2,000,000 known different organisms in the world today and probably over 1,000,000 are left to be discovered and named. All these living things have different characteristics such as shape, size, colour, and height. It will, therefore, be extremely difficult to study these millions of living things without arranging them into groups. Classification (taxonomy) helps to give a universal scientific name to every species so that students of different languages know the scientific name of that species. Common names vary from language to language while scientific names are internationally accepted.

Biologists, in arranging living things into groups have developed systems of using similarities to unite species into groups and using differences to separate groups. **The science of arranging living things into groups based on structural, genetic or cellular organization is called classification or taxonomy.** Examples of structural similarities and differences exist in fish, frog, lizard, bird and man. They are grouped together as vertebrates because they all possess backbones (vertebral column).

**Figure 1.2. Similarities and differences between vertebrates.**

On the other hand they are grouped differently because frog has a moist and scaleless skin, fish has gills and fins, lizard has a dry scaly skin and tail, bird has beak and feathers while man has hair, mammary glands and three tiny bones (hammer, anvil and stapes) in the inner ear.

The relationship between organisms can also account for groupings. If two animals have the same number of similar chromosomes, then the two animals are closely related and can be grouped together. For example, *Gorilla* and *Chimpanzee* have 48 chromosomes each hence they are grouped into the family **Pongidae**. The same reason goes for cellular organization for grouping. For example, all animals with one cell are grouped as **Protozoa** (unicellular organisms) and those with more than one cell are grouped as **Metazoa** (multicellular organisms).

## Taxonomic grouping

Living things are first separated into large groups called **kingdoms**. The division of king-doms into smaller groups is called **phyla** (sing-ular: phylum). The term **division** rather than phylum is usually used for plants. Phyla are divi-ded into smaller groups called **classes**. Each class is further divided into **orders**. Orders are further divided into **families**. Families are again divided into **genera** (singular: genus). A **genus** is broken into **species**.

1. A **species** is a population of related organisms that can interbreed within themselves to produce fertile offspring.
2. Thus a **genus** is a group of a closely *related species*.
3. A **family** is a group of related genera.
4. An **order** is a group of related families.
5. A **class** is a group of related orders.
6. A **phylum** is a group of related classes.
7. A **kingdom** is a group of related phyla.

Kingdom
Phylum
Class
Order
Family
Genus
Species.

## Classification of human being

| | | Characteristics features |
|---|---|---|
| Kingdom | Animalia | 1. Cells is covered with a thin flexible living layer called cell membrane (plasma membrane).<br>2. The nucleus is surrounded by nuclear membrane.<br>3. It is heterotrophic in nutrition that is, it cannot make its own food. |
| Phylum | Vertebrata | Possesses vertebral column (backbones) |
| Class | Mammalia | 1. Mammary glands present.<br>2. External ears and hairs present. |
| Order | Primate | 1. Well developed arms and hands with five digits.<br>2. Thumb opposable (that is, thumb prehensile of touching other four fingers)<br>3. Reel gonad length.<br>4. Forwarding facing eyes with binocular vision (two fields of vision). |
| Family | Hominidae | 1. Upright position with S-shaped backbones<br>2. Upright walking position.<br>3. Small incisors<br>4. Short face. |
| Genus | Homo | 1. Reduced invisible tail.<br>2. Narrow nasal septum. |
| Species | *Homo sapiens* (wise man) | 1. Largest and highly developed brain for clear speech, problem solving, intelligence, thought, learning, retention of information, manufacturing of things.<br>2. Upright walking with two legs. |

**Table 2. Classification of maize plant.**

| | |
|---|---|
| Kingdom | Plantae |
| Division | Tracheophyta (plant with vascular tissues). |
| Class | Angiospermae (flowering plants with seeds inside fruits). |
| Subclass order | Monocotyledon Graminales (grasses). |
| Family | Gramineae (leaves in 2 rows around the stem). |
| Genus | *Zea* (corn plant). |
| Species | *Zea mays* (cultivated corn plant). |

**Table 3. Classification of *Paramecium*, housefly, domestic cat, *Gorilla* and man**

| | *Paramecium* | Housefly | Domestic Cat | Gorilla | Man |
|---|---|---|---|---|---|
| Kingdom | Animalia | Animalia | Animalia | Animalia | Animalia |
| Phylum | Protozoa | Arthropoda | Chordata | Chordata | Chordata |
| Class | Ciliata | Insecta | Mammalia | Mammalia | Mammalia |
| Order | Holotricha | Diptera | Carnivora | Primate | Primate |
| Family | Paramecidae | Muscidae | Felidae | Pongidae | Hominidae |
| Genus | *Paramecium* | *Musca* | *Felis* | *Gorilla* | *Homo* |
| Species | *Paramecium caudatum* | *Musca domestica* | *Felis domesticus* | *Gorilla gorilla* | *Homo sapiens* |

## The system of naming living things (Nomenclature)

Scientifically, every living thing has two names. The first name is the **genus** (started with a capital letter) to which closely related species belong. Different species can belong to the genus just as the surname of our family is being shared with other members of the family.

The second name is the **species** (started with a small letter) to which the organism belongs. This name belongs to one kind of organism only. It does not share it with other members of the genus. The first and second names are also known as the generic and specific names respectively. For example *Homo sapiens* (man),*Musca domestica* (housefly) *Ipomea batata* (potato) and *Hibiscus esculentus* (okra).

Both the **genus** and **species** are written in **italics** or underlined. The system of giving two names to an organism is known as **binomial nomenclature** and it was developed by a Swedish botanist, Carl Linnaeus in the 18th century.

Sometimes we call living things their common names such as cat, dog, lion, rabbit and goat. These names are regarded as nicknames. These names are not definite as one common name can be used for so many organisms.

**Figure. 1.3. Carl Linnaeus (1707 - 1778) father of taxonomy**

## Major groups of living things:

Living things are divided into two kingdoms - the **Plantae** (plants) and **Animalia** (animals) according to the old system of classification of Carl Linnaeus still being in use by some people.

## Classification of plants

Classification of plants may be based on the following criteria:

1. Botanical classification.
2. Agricultural classification or classification of crops according to economic uses.
3. Life cycle.
4. Tillage or cultivation practices.
5. Number of cotyledons

## Botanical classification

The plant kingdom is divided into five groups. These are:

1. **Schizophyta** (bacteria).
2. **Thallophyta** (the algae and fungi).
3. **Bryophyta** (the liverworts and mosses).
4. **Pteridophyta** (the ferns).
5. **Spermatophyta** (the seed-bearing plants). The **Spermatophyta** consists of gymnosperms and angiosperms (flowering plants).

## Schizophyta (Bacteria)

1. They are microscopic and non-cellular organisms.
2. No organised nucleus. They are therefore procaryotic cells
3. The cell wall does not contain cellulose. It is made up of protein and fatty materials.
4. Bacteria reproduce asexually by binary fission
5. Bacteria exist in various shapes. For example, the **cocci** are rounded or spherical, **bacilli** are rod-shaped, **spirilla** are spirally twisted while the **vibrios** are comma shaped.

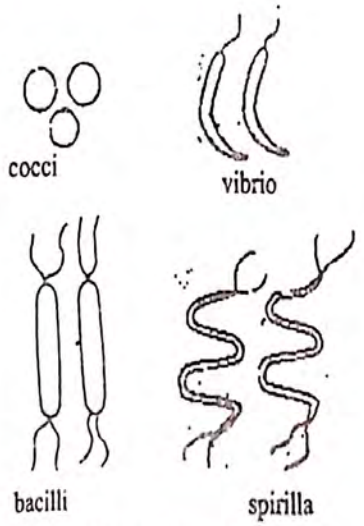



**Figure 1.4. Different shapes of bacteria**

## Thallophyta (Algae)

### Characteristic features

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*.

**Figure 1.5. Different forms of algae**

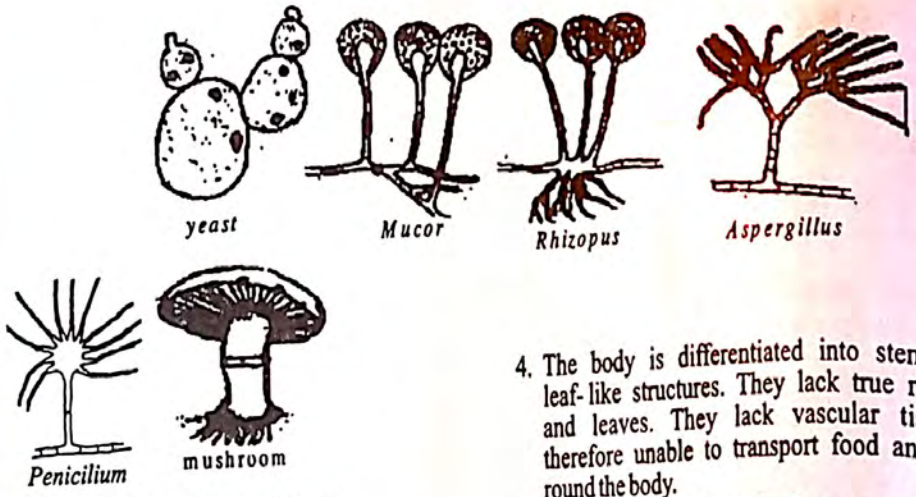



**Figure 1.6. Different forms of fungi.**

## Fungi

### Characteristic features

1. They are non-green plants.
2. They are simple multicellular plants.
3. The body is not differentiated into root, stem and leaves.
4. The vegetative body (hypha) is collectively known as mycelium.
5. Reproduction is by means of spores.
6. The cell wall is composed of cellulose and chitin.
7. Carbohydrates are stored in form of glycogen as in animals.
8. They are either saprophytic or parasitic. Examples are *Mucor*, *Rhizopus*, yeast and *Fusarium*.

## Bryophyta (Mosses) and Liverworts

### Characteristic features

1. They are non-vascular multicellular organisms.
2. They have chlorophyll as the only photosynthetic pigment.
3. They are terrestrial but live in moist environment.
4. The body is differentiated into stem-like and leaf- like structures. They lack true roots, stem and leaves. They lack vascular tissues and therefore unable to transport food and material round the body.
5. The leaves of some are spirally arranged on the stem.
6. Asexual reproduction is by spores while sexual reproduction is by gametes. Water is needed in sexual reproduction hence they are regarded as the amphibians of the plant kingdom. They show alternation of generations.
7. Some are thalloid in form e.g. Liverworts Examples are *Marchantia* sp. (liverwort) and *Funaria hygrometrica* (a moss).

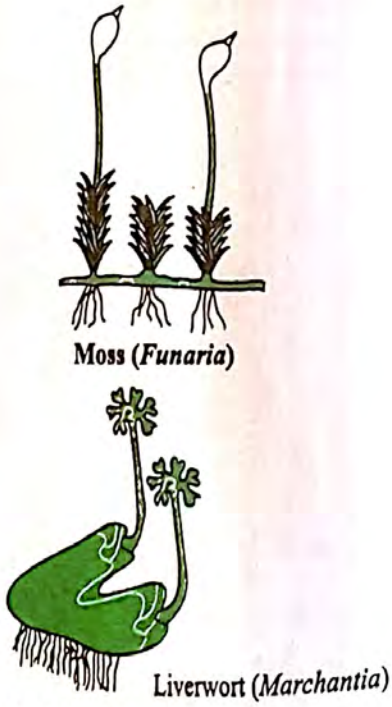



**Figure 1.7. Some Bryophytes**

## Pteridophyta (Ferns)

### Characteristic features

1. The body is differentiated into true roots, stem and leaves with well developed vascular bundles comprising xylem and phloem. The young leaves are coiled.
2. The stem is a rhizome.
3. Reproduction is by means of spores.
4. Asexual reproductive organ consists of *sori* while the sexual reproductive organ is a heart-shaped prothallus.
5. Water is needed for sexual reproduction (prothallus).
6. They are mainly terrestrial, with a few aquatic members. Examples are *Dryopteris, Cyclosorus, Platycerium, Phymatodes* are terrestrial while *Nephrolepis, Salvinia oblongata* and *Azolla* are aquatic members.

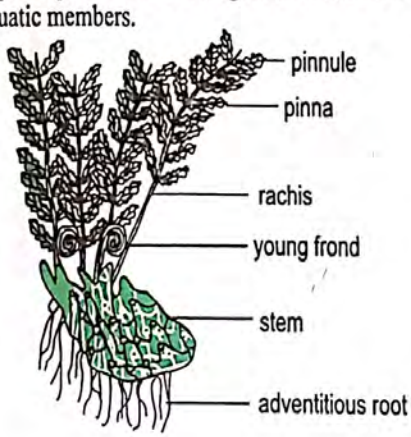



**Figure. 1.8. A Pteridophyte *(Dryopteris)***

## Spermatophyta

Spermatophyta is divided into Gymnosperms and Angiosperms.

## Gymnosperms

Characteristic features

1. Large plants with well developed vascular bundles with true roots, stem and leaves.
2. The leaves are green in colour, small, scaly and needle-like.
3. They have cones where naked seeds are formed because there is no ovary. Fruit is not formed.
4. They are terrestrial in habitat. Examples are whistling pine (*Casuarina* sp.) and *Cycas*.

## Angiosperms (Flowering Plants)

### Characteristic features

1. They possess true flowers for sexual reproduction.
2. Well developed true roots, stem and leaves are present.
3. Well developed vascular bundles are present.
4. Seeds and fruits are produced after fertilization. Seeds are enclosed in an ovary.
5. They are terrestrial but few are aquatic. Examples are oil palm tree, goatweed, mango tree and maize

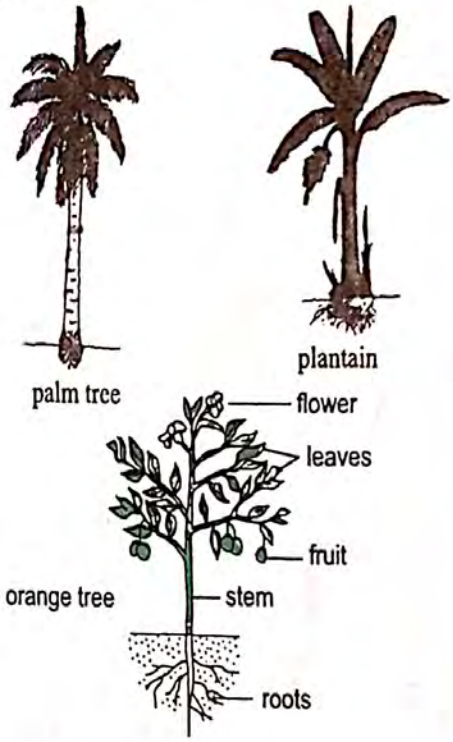



**Figure 1.9. Aniosperms.**

## Agricultural classification

In this case, crops are classified according to the main food substances existing in them or according to the use to which the crop is put. These are:

1. Legumes: These crops have nodules or swellings in their roots. They are capable of converting atmospheric nitrogen to nitrates which they absorb. These crops are very rich in proteins. Examples are cowpea,soya beans, groundnuts, pigeon pea and mucuna.
2. Cereals: These are grain crops grown mainly for their seeds which are very rich in carbohydrates. Examples are maize, rice, Guinea corn (*Sorghum*),

groundnut, melon, soya bean, orange and mango.

## Classification of animals

The animal kingdom (Animalia) is divided into two subkingdom namely invertebrata (animals without backbones and vertebrata (animal with back bones) The animal kingdom (Animalia) is divided into two subkingdoms namely invertebrate (animals without backbones) and vertebrates (animals with backbones).

## Invertebrates

The subphylum invertebrate (the invertebrates is made up mainly of the following phyla: Protozoa, Coelenterata, Platyhelminthes, Nematoda, Annelida, Mollusca, Echinodermata and Arthropoda.

## Phylum: Protozoa

### Characteristic features

1. They are one-celled, microscopic animals or colony of one-celled animals.
2. They are either free-living or parasitic organisms.
3. They are either aquatic or endoparasitic in habitat. Examples are *Amoeba*, *Paramecium*, *Plasmodium*, *Trypanosome* and *Volvox*.

## Phylum: Coelenterata

### Characteristic features

1. They are multicellar organisms.
2. They have two distinct body layers (diploblastic), ectoderm (outer layer) and endoderm (inner layer), separated by a featureless middle layer called mesogloea.
3. They have only one body cavity called enteron.
4. There is only one opening called mouth to the outside world. No anus.
5. Mouth surrounded with tentacles.
6. Possession of stinging cells called nematocysts
7. They have specialized cells such as glandular, nerve, sensory and absorptive cells.
8. Asexual reproduction is by budding. *Hydra*, *Obelia*, sea anemone, jelly fish, coral and *Physalia* are examples.

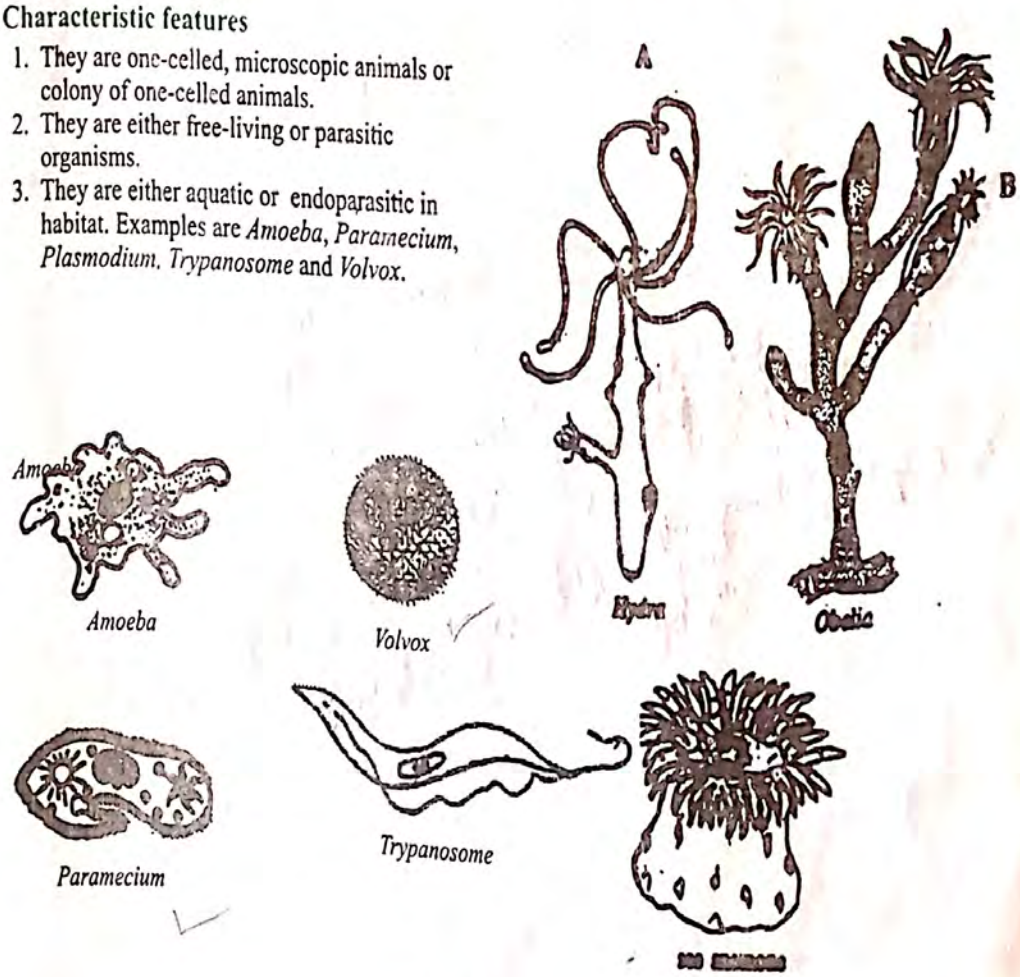



Figure 1.10. Protozoa.

groundnut, melon, soya bean, orange and mango.

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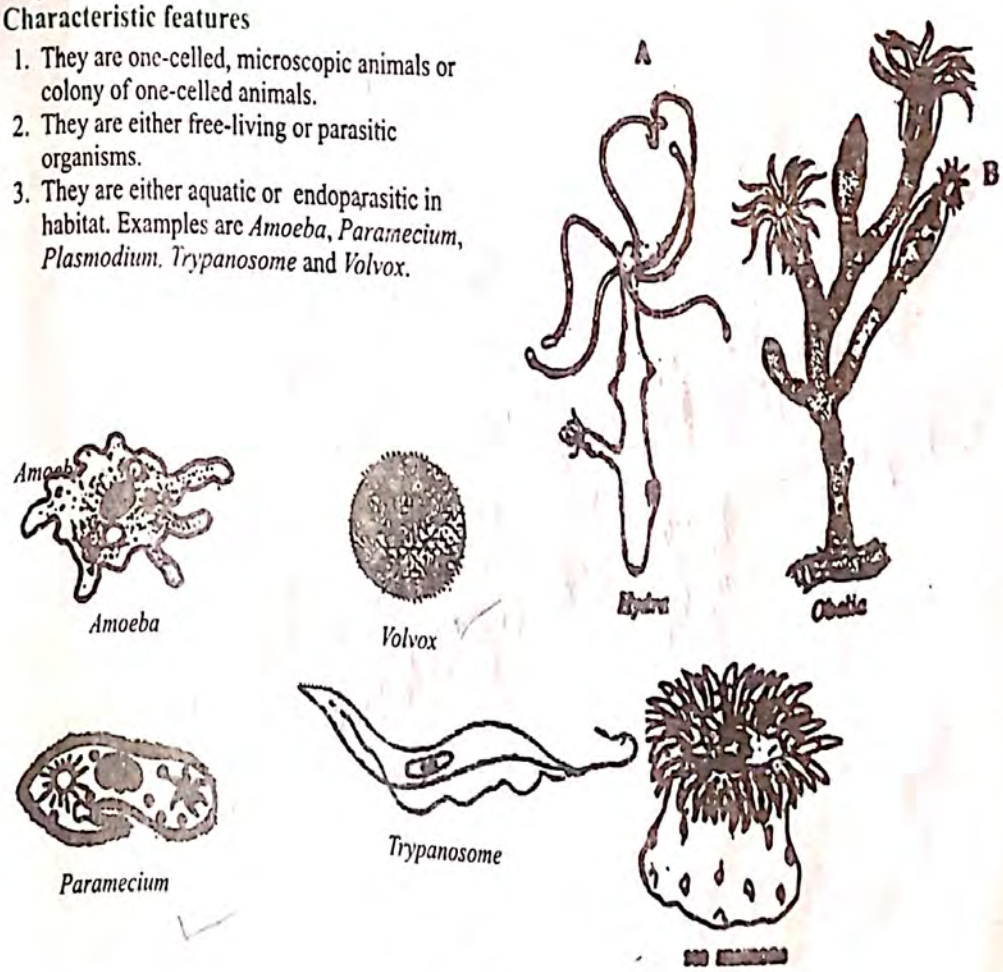


Figure 1.10. Protozoa.

millet, wheat, barley and oats.

3. Roots and tubers: These crops store food in their roots or stems in form of tubers. They are very rich in carbohydrates. They form the staple food of many people in Nigeria especially in the southern region. Examples of such crops include cassava, yam, sweet potatoes, irish potatoes and carrot.

4. Vegetables: These are crops whose leaves and fruits are used as vegetables in foods. The crops are rich in vitamins and minerals. Examples are tomato, onion, fluted pumpkin, okro, green (*Amaranthus spp*), lettuce and cabbage.

5. Fruits crops: These are crops grown for their fruits and supply vitamins, minerals and sugars. Examples include orange, mango, guava, pineapple, pawpaw,banana and cashew.

6. Beverage crops: These are grown for use as beverage drinks or a sort of refreshment. They supply minerals to the body. Examples of beverage crops are cocoa, coffee and tea.

7. Oil crops: The seeds or fruits of these crops are rich in oils and fats. Such crops include oil palm, groundnut, cotton and coconut.

8. Latex crops: These crops produce milky fluid called latex. The latex is used for various industrial purposes such as making of tyres, tubes and plates. A good example of latex crop is rubber.

9. Fibre crops: These supply ropes and threads for textile industry. The crops include cotton and jute.

10. Spice crops: These are crops which are used in flavouring foods. Examples include ginger, onion, pepper and thyme.

11. Stimulants: These are crops that produce substances used as stimulants for medical purposes. Examples are cocaine plants, kola, lime, Indian hemp or marijuana and neam plant.

12. Forage crops: These are crops grown for feeding farm animals. They are mainly grasses. They include guinea grass, elephant grass, gamba grass, *Centrosema, Calapogonium* and *Stylosantes*.

13. Nuts: These are crops whose fruits consist of hard shells that enclose fleshy parts which are edible. They include coconut, cashew and oil palm.

## Classification of crops according to life cycle

Based on life cycle or life span, crops may be classified into three groups. These are:

1. Annual crops: These are crops which complete their life cycle in one year. They include maize, yam, groundnut, rice, beans and millet.
2. Biennial crops: These are crops which complete their life cycle in two years. The first year is for growth and storage of food while the second year is for reproduction, maturity and death. Examples are pineapple, cocoyam, cassava, plantain and sugar beet.
3. Perennial crops: These are crops that take three or more years to complete their life cycle. They are mainly tree crops and include cocoa, rubber, mango, oilpalm and orange.

## Classification of crops according to tillage or cultivation practices

On the basis of tillage, crops could be classified into:

Arable Crops: These are also referred to as food crops. Many of them are grown and harvested within a year. The cultivation of arable crops in most cases involve total tillage. The crops include:- maize, guinea corn, yam and rice.

Non-arable crops: These are crops whose cultivation does not require total tillage of the land before propagation. Only the spots where the crops are to be established are opened. The crops in this group include oil palm, cashew, rubber and cocoa.

Number of cotyledons

Based on the number of cotyledons or seed leaves crops can be classified into:

1. Monocotyledonous crops: These are crops that have one seedleaf or one cotyledon. Examples of monocots are maize, oilpalm and guinea corn.
2. Dicotyledonous crops: These are crops that have two cotyledons or seed leaves. Examples are

groundnut, melon, soya bean, orange and mango.

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## Phylum: Coelenterata

### Characteristic features

1. They are multicellar organisms.
2. They have two distinct body layers (diploblastic), ectoderm (outer layer) and endoderm (inner layer), separated by a featureless middle layer called mesogloea.
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4. There is only one opening called mouth to the outside world. No anus.
5. Mouth surrounded with tentacles.
6. Possession of stinging cells called nematocysts
7. They have specialized cells such as glandular, nerve, sensory and absorptive cells.
8. Asexual reproduction is by budding *Hydra*, *Obelia*, sea anemone, jelly fish, coral and *Physalia* are examples.

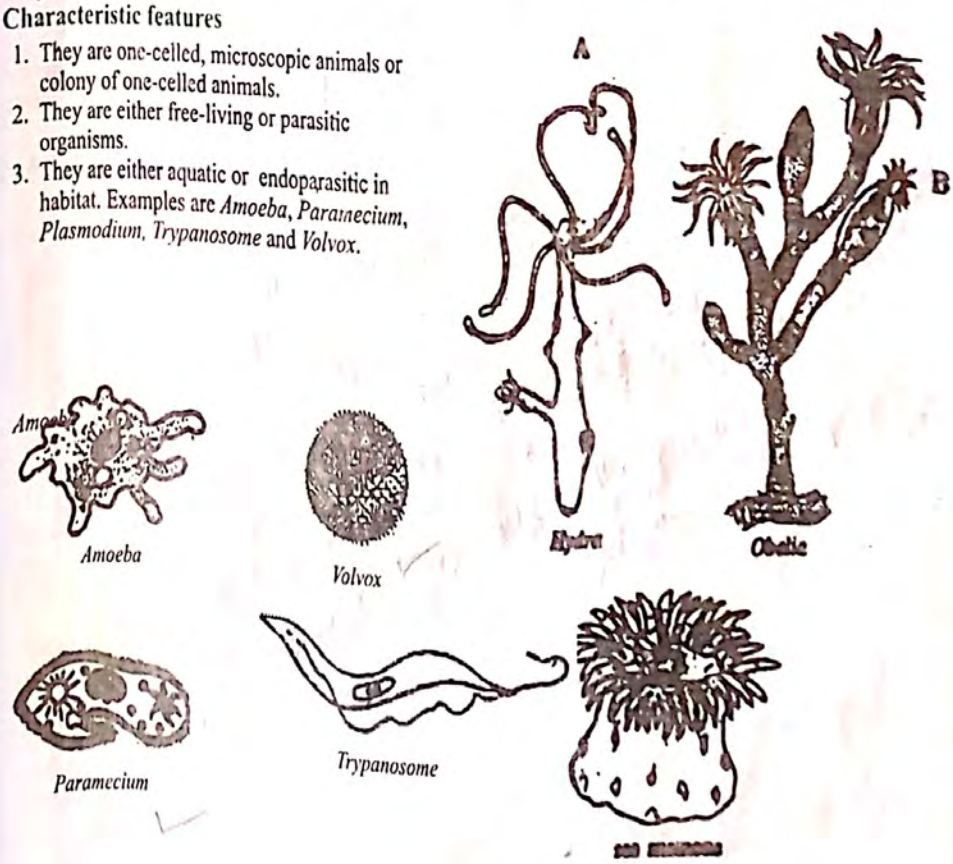



Figure 1.10. Protozoa.

*Physalia physalia* ("Portuguese man-of war") (Courtesy, New York Zoo-logical Society)

**Figure 1.11. A - D Coelenterates**

**Phylum: Platyhelminthes**

**Characteristic features**

1. Soft, flat and unsegmented body.
2. They are bilaterally symmetrical.
3. They have no body cavity (acoelomate).
4. They possess alimentary canal with highly branched diverticula. No anus.
5. Some are free living e.g *Planaria*, while others are parasitic e.g liver flukes and tapeworms.

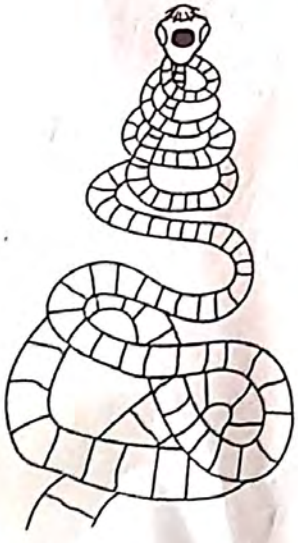


**Figure 1.12. Tapeworm**

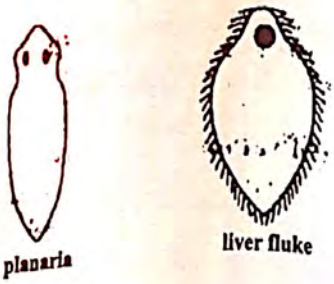



**Figure 1.13. Platyhelminthes (Flatworms)**

**Phylum: Nematoda (Roundworms)**

**Characteristic features**

1. They have soft, cylindrical and slender bodies pointed at both ends.
2. Body is not segmented.
3. They have alimentary canal with both mouth and anus.
4. They are bilaterally symmetrical.
5. They have false body cavity (Pseudocoelomates).
6. They are mostly parasitic but few are free living. Examples are *Ascaris* (roundworms), hookworms, threadworms, guinea worms and vinegar eel (free living).

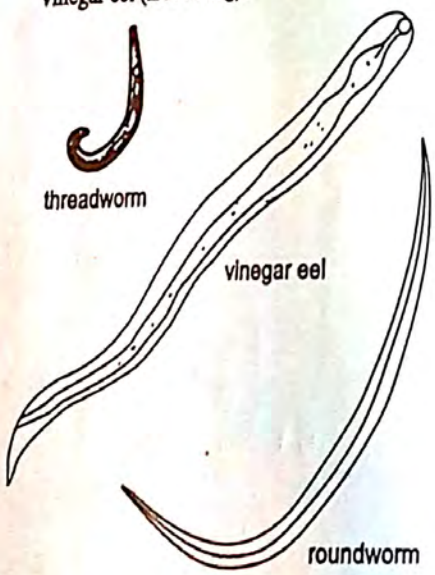



**Figure 1.14. Nematodes**

## Phylum: Annelida

### Characteristic features

1. The body is segmented with each segment separated from other by septa.
2. Body is cylindrical in shape.
3. They have alimentary canal with mouth and anus.
4. They possess true body cavity (coeloma) with a distinct head.
5. The appendages (setae) are not jointed. Examples are earthworms, tubeworms and leech.

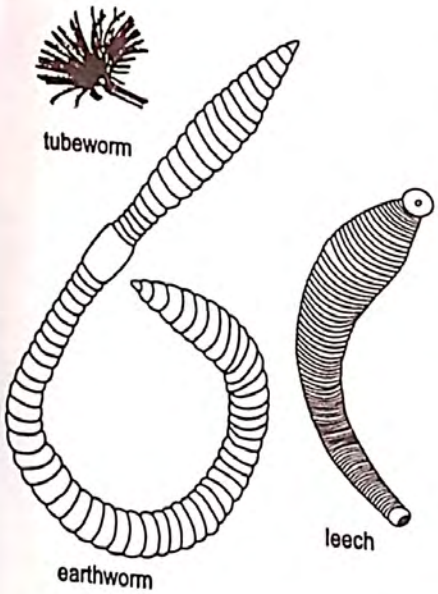



**Figure 1.14. Segmented worms**

## Phylum: Mollusca

### Characteristic features

1. They possess soft and unsegmented bodies.
2. Tentacles are present in most members.
3. The bodies of most of them are covered with shells e.g. land snail, *(Archatina)* while others are not e.g. octopus and squid.

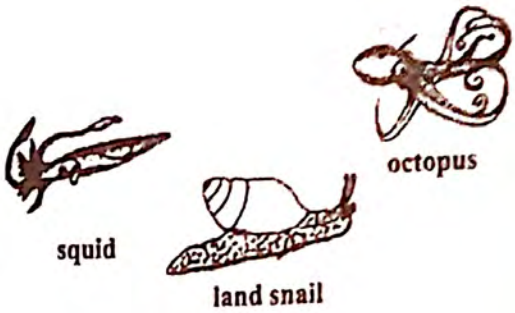



**Figure 1.15. Mollusc**

## Phylum: Echinodermata

### Characteristic features

1. They possess tough spiny and calcareous exoskeleton.
2. They are radially symmetrical in adults but bilaterally symmetrical in larvae.
3. The head is not usually distinct.
4. Most of them are star shaped.
5. They are all marine organisms.

Examples are bristle star, starfish, sea urchin, sea cucumber and sea lily.

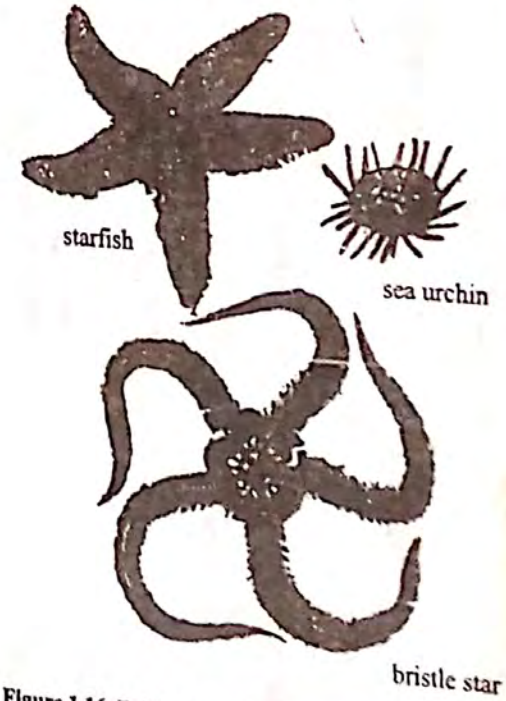



**Figure 1.16. Echinodermata (Echinoderms)**

## Phylum: Arthropoda

**Characteristic features**

1. Their bodies are covered with hard exoskeleton of chitin.
2. Their appendages are jointed.
3. Often the bodies are divided into three regions - head, thorax and abdomen. In some, the head and thorax are fused together to form a cephalothorax as in crustaceans and arachnids.
4. They have bilateral symmetry.

Examples are insects (mosquito and cockroach), crustaceans (e.g. crab and lobster), diplopods (e.g millipede), chilopods (e.g centipede) and arachnids (e.g spider and tick).

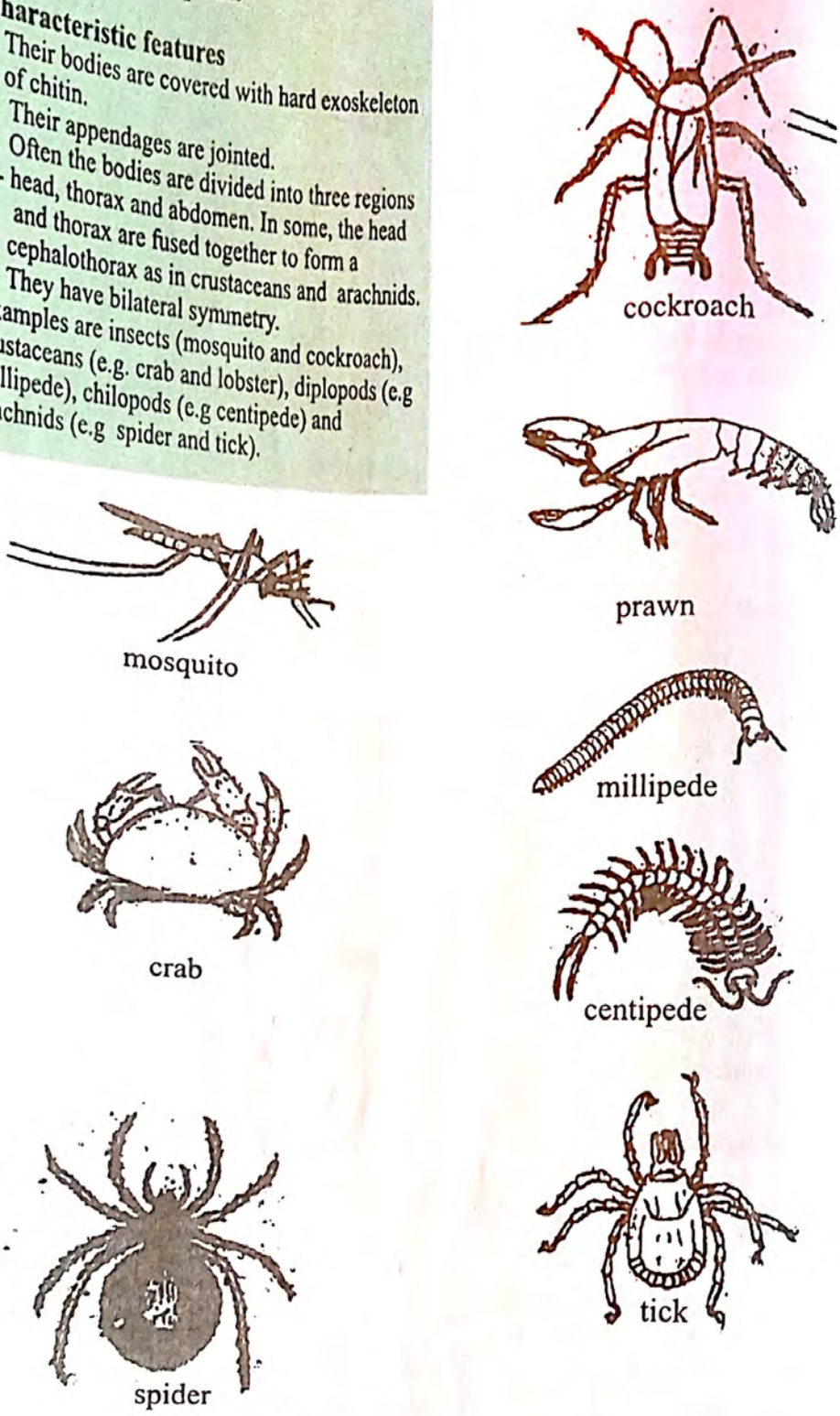



Figure 1.17. Arthropods

## Phylum: Vertebrate (the verbrates)

the phylum vertebrates consists of animals wiht backbones belonging to five classes namely:

Class: Vertebrates are represented by five classes namely: Pisces (fish), Amphibia, Reptilia, Aves (birds) and Mammalia.

## Class:

## Pisces (Fishes)

### Characteristic features

1. They are all aquatic.
2. They possess gills for respiration throughout life.
3. One-looped circulation, that is blood is pumped from the heart to the gills where oxygenated blood is passed to the rest of the body and returns to the heart.
4. They possess fins for locomotion.
5. Their bodies are streamlined in shape.
6. They are cold blooded (poikilothermic).
7. Fertilization is external.
8. Most of them have scales (e.g. *Tilapia*) while others are scaleless (e.g.*Clarias*).

Examples are *Tilapia*, *Hemichromis*, *Clarias*, electric cat fish, *Gymnarchus* and shark.

The Class Pisces is divided into two subclasses namely: Chondrichthyes and Osteichtyes

**Subclass: Chondricthyes**

Characteristic features.

1. Skeleton is made of cartilage only.
2. Mouth is inferior, that is, it is ventrally.
3. Fins are fleshy.
4. Each gill has its own opening
5. Generally, the upper lobe of the caudal tail is longer.
6. Possess placoid scales, that is, scales are tooth-like in structure.

**Subclass: Osteichthyes**

Characteristic features

1. Skeleton.is bony.
2. Mouth is either placed anteriorly (on top of snout), terminally (front of snout), ventrally (below snout). Mouth is protrusible and retractable, that is, mouth can be pushed forward and withdrawn.
3. All gills are covered with a bony plate .
4. Fins are supported by bony or soft rays.
5. Scales when present are either cycloid (margin is smooth and rounded) ctenoid (exposed posterior

African river pike (*Hepsetus odoe)*

Spinner shark (*Carcharhinus maculipinnis)*

Stingray (*Potamotrygon garouaensis)*

›African bony tongue (*Heterotis niloticus)*

Featherback (*Papyrocranus afer)*

Leaf fish (*Polycentropsis abbreviata)*

Catfish (*Clarias gariepinus*)

Tilapia (*Oreochromis niloticus*)

Sailfin (*Polypterus endlicheri endlicheri*)

Sardine (*Sardinella maderensis*)

African brown snapper (*Latjunus dentatus*)

Grasseater (*Distichodus brevipinnis*)

Snakehead (*Parachanna obscura*)

Puffer fish (*Tetraodon fahaka strigosus*)

Butterfly fish or Freshwater flying fish (*Pantodon bucholzi*)

Flatfish or tonguesole (*Cynoglossus senegalensis*)

**Figure 1.18. Fishes**

## Class: Amphibia

### Characteristic features

1. Possess moist, soft and scaleless skin.
2. They are cold blooded (poikilothermic).
3. Adults possess paired limbs with webbed toes.
4. The larval stage is aquatic while the adult is either aquatic or terrestrial. Tadpole larva is vegetarian while adult is usually carnivorous.
5. The heart is two chambered in larval stage and three chambered in adult.
6. Fertilization is external.
7. Breathing is by gills in the larval stage and by lungs, skin and mouth in the adult stage. Examples are toad, frog and newt.

leopardfrog (*Rana pipiens*)

toad (*Bufo regularis*)

Clawed toad (*Xenopus tropicalis*)

**Figure 1.19. Amphibians.**

## Class: Reptilia

### Characteristic features

1. They possess dry and scaly skin.
2. Most possess four limbs which end in claws while others (snake) have no limbs.
3. Dentition is homodont (the same type of teeth).
4. They are cold blooded (poikilothermic).
5. Breathing is by lungs.
6. Fertilization is internal with laying of soft and leathery shelled eggs. Most members are oviparous while a few others retain their eggs in their bodies until hatching (ovoviviparous).
7. They are mostly terrestrial but few such as turtles and crocodiles are aquatic. Examples are lizard, snake, crocodile, tortoise and chameleon.
8. The heart is three chambered except crocodile with four chambered heart.

lizard (*Agama agama*)

snake (coiled cobra)

tortoise

chameleon

Crocodile

**Figure 1.20. Reptiles**

## Class: Aves

### Characteristic features

1. The body is covered with feathers except the legs and the feet, which are covered with scales.
2. Their forelimbs are modified as wings.
3. The mouth is modified into horny toothless beak or bill.
4. Their bones are porous, light and in some cases filled with air.
5. Body is supported by two hind limbs, (bipedal stance).
6. They are warm blooded (homoiothermic). They are very active animals.
7. Breathing is by lungs.
8. They lay hard shelled eggs (oviparous).
9. Fertilization is internal.
10. They are mostly terrestrial.
11. Heart is four chambered.

Examples are domestic fowl, duck, eagle and pigeon.

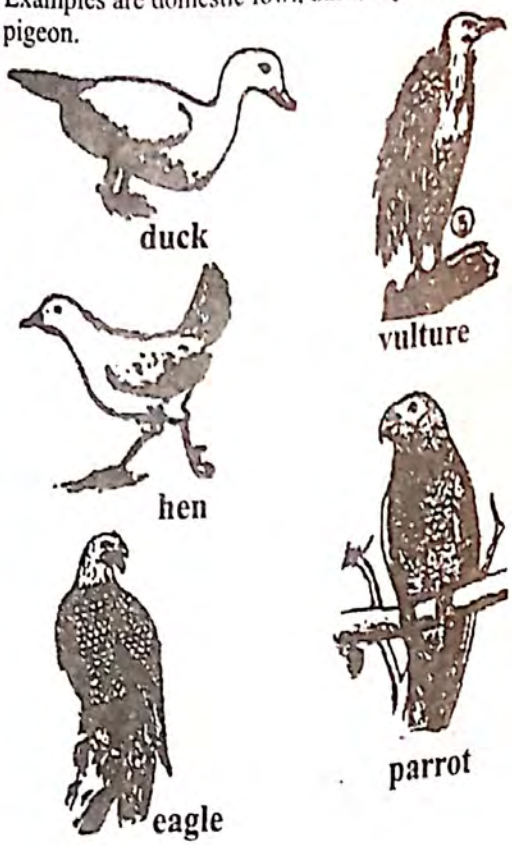



**Figure 1.21. Birds.**

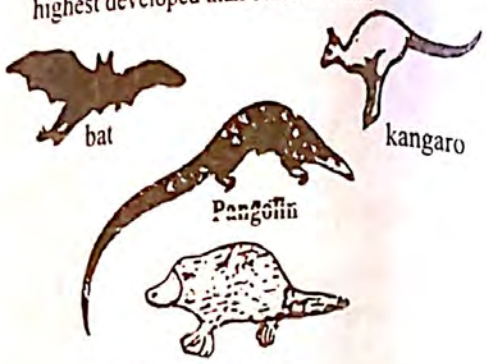
## Class: Mammalia

### Characteristic features

1. They possess hairs. However, some mammals such as whales have no hairs while pangolins have scales instead of hairs.
2. They possess mammary glands. The mother's mammary glands secrete milk used in nourishing the young after birth.
3. They possess external ears.
4. All mammals have three tiny bones in their ears namely: hammer (molleus), anvil (incus) and stapes (stirrup).
5. They are viviparous; young are nourished during development in the mother's uterus and born at an advanced stage of development. However, the monotremes lay eggs which hatch into young nourished by milk secreted by mammary glands of the mother
6. Breathing is by lungs throught life.
7. They have diaphragm (breathing muscle) separating the thoracic cavity from the abdominal cavity.
8. Mammalian heart is four chambered only left aortic arch
9. Most possess four limbs for locomotion.
10. They are warm blooded (homoiothermic) hence they are very active animals.

Examples are duck-billed platypus, kangaroo, dog, cat, pangolin, elephant, giraffe, monkey, gorilla, hippopotamus, zebra, cane rat, lion, horse, baboon, porcupine and man.

11. Most species possess seven cervical (neck) bones.
12. Possess two pairs of limbs usually for locomotion.
13. The cerebrum and cerebellum of the brain are highest developed than other animal.




**Duck-billed platypus**
**(Monotreme-egg laying mammal)**

**Figure 1.22 Different mammals**

## Primates

Primates are the most highly developed of all mammals with large brain, forward-facing eyes with bilocular vision, grasping fingers and toes equipped with flat nails.

## Characteristic features of Primates

1. **Well developed arms and hands**
   The arms and hands are well developed ending in flat nails rather than claws.
2. **Grasping (prehensile) fingers and toes**
   Their grasping fingers and toes have five digits (pentadactyl) which enable them to hang from tree branches, seize food, and use tools in some of the primates. The first digit (thumb) in many primates is opposable, that is the thumb is capable of touching and resting on other four fingers for grasping.
3. **Forward facing eyes and binocular vision (Two fields of vision)**
   Eyes are placed in front of their heads. This position of the eyes produces overlapping binocular vision that enables the brain to judge the distance between trees accurately before jumping. Binocular vision enables primates to see objects in three dimensional form.
   However, some other mammals have binocular vision but only primates have both grasping hands and binocular vision making them well adapted to their living environment. Examples of primates are: monkeys, chimpanzee, gorilla, baboon and human being.
5. Highly developed brain especially the cerebral cortex- resulting in the development of intelligence.
6. Most primates give birth to one offspring or twins.
7. One most striking feature of primates is the long period of parental care of their offspring. In lemurs, the period of parental care is $2\frac{1}{2}$ years, in monkeys, it is $3\frac{1}{2}$ to 4 years, in apes it is 3 to 5 years while in man it is 12 to 18 years or more.

## New system of classification

The modern classification system based on physiology, biochemistry and embryology have revealed distinct similarities between living organisms which external appearances of organisms will not show or discover. Not all biologists have agreed on this new classification of five kingdoms instead of two kingdoms of Plantae and Animilia of Linnaeus.

The new system of classification was introduced by Margulis and Schwartz in 1982. All cellular organisms fall into groups namely*Prokaryotae* and *Eukaryotae*. These two groups have their DNA located in different areas of their cells. The DNA of prokaryote (Pro=before; karyon=nucleus) is not enclosed by nuclear membranes and float freely in the cytoplasm. The cells of prokaryote have no true nuclei. The DNA of eukaryotes (eu=true) are enclosed with nuclear membranes and located in nucleus. Based on the cellular organization and structural similarities Schwartz recognised five kingdoms namely: **Prokaryotae** (prokaryotes), **Protoctista** (protoctists), **Fungi**, **Plantae** and **Animalia**. Of the five kingdoms, four kingdoms are classified as follows: **Protoctista, Fungi, Plantae** and **Animalia** and placed under **Eucaryotae** because their DNA is located in **nucleus** and enclosed with **nuclear membranes**. This classification places Prokaryotae as a king-dom having no regard to the fact that all organisms fall into two distinct groups namely **Prokaryotae** and **Eukaryotae**.

**For the purpose of easy understanding of the modern classification, the characteristic features earlier stated are being repeated.**

## Kingdom: Prokaryotae (Prokaryotes)

### Characteristic features

1. Lack organized DNA. That is DNA is scattered in the cytoplasm and not in nucleus.
2. They have no mitochondria in their cytoplasm.
3. The cell walls lack cellulose. The cell walls are made of protein and fatty materials.
4. They are microscopic single-celled organisms.
5. They are motile or non-motile organisms.
6. They feed autotrophically or heterotrophically.
7. They reproduce only asexually.

Examples are **bacteria** and photosynthetic blue-green bacterium *(Anabaena)* formally known as blue-green alga.

## Kingdom Protoctista (Protoctists)

### Characteristic features

1. Have well organized DNA in the nucleus bounded by nuclear membrane hence they are called

**eukaryotic organisms.**

2. They are single-celled (unicellular) organisms.
3. They are motile and non-motile organisms.
4. Protozoans (*Amoeba, Euglena, Chlamydomonas, Spirogyra Plasmodium, Chlorella* and *Fucus* are examples of **Protoctistists.**

## Kingdom: Fungi

**Characteristic features**

1. Lack chlorophyll. Nutrition is therefore heterotrophic. Food is digested outside the body and digested soluble food is absorbed into the body by diffusion.
2. They are simple multicellular organisms.
3. Their bodies are not differentiated into root, stem and leaves.
4. They are mostly non-motile organisms composed of thread-like multinucleate hyphae collectively known as mycelium.
5. Reproduction is by means of spores.
6. Carbohydrates are stored as glycogen and not starch.
7. The cell wall is made of chitin and not cellulose.

Examples are *Mucor, Rhizopus, Mushroom* and *slime mould.*

## Kingdom: Plantae

**Characteristic features**

1. They are multicellular and non-motile organisms.
2. Their cells are bounded by rigid cellulose cell walls external to the cell membrane.
3. They contain chlorophyll that enables them to manufacture their own food by photosynthesis.
4. Most of the plants store carbohydrates as starch or sucrose. The Kingdom Plantae is divided main into four phyla namely Bryophyta (Bryop-hytes), Pteridophyta (Ferns), Gynospermophyta or Coniferophyta (Conifers), and Angiosper-mophyta (Angiosperms - flowering plants).

## Phylum: Bryophyta

**Characteristic features**

1. They are non-vascular multicellular organisms.
2. They have chlorophyll as the only photosynthetic pigment.
3. They are terrestrial but live in moist environment.
4. The body is differentiated into stem-like and leaf-like structures. They lack true roots, stem and leaves. They lack vascular tissues and therefore unable to transport food and material round the body.
5. The leaves of some are spirally arranged on the stem.
6. Asexual reproduction is by spores while sexual Reproduction is by gametes. Water is needed in sexual reproduction hence they are regarded as the amphibians of the plant kingdom. They show alternation of generations.
7. Some are thalloid in form e.g. Liverworts.

Examples are *Marchantia* sp. (liverwort) and *Funaria hygrometrica* (a moss).

## Phylum: Pteridophyta (Ferns)

**Characteristic features**

1. The body is differentiated into true roots, stem and leaves with well developed vascular bun-dles comprising xylem and phloem. The young leaves are coiled.
2. The stem is a rhizome.
3. Reproduction is by means of spores.
4. Asexual reproductive organ consists of *sori* while the sexual reproductive organ is a heart- shaped prothallus.
5. Water is needed for sexual reproduction (prothallus).
6. They are mainly terrestrial, with a few aquatic members. Examples are *Dryopteris, Cyclo-sorus, Platycerium, Phymatodes* are terrestrial while *Nephrolepis, Salvinia oblongata* and *Azolla* are aquatic members.

## Phylum: Gymnospermonphyta (Coniferophyta)

**Characteristic features**

1. Large plants with well developed vascular bundles with true roots, stem and leaves.
2. The leaves are green in colour, small, scaly and needle-like.
3. They have cones where naked seeds are formed because there is no ovary. Fruit is not formed.
4. They are terrestrial in habitat. Examples are whistling pine (*Casuarina* sp.) and *Cycas.*

## Phylum: Anglospermophyta

**Characteristic features**

1. They possess true flowers for sexual reproduction.
2. Well developed true roots, stem and leaves are present.
3. Well developed vascular bundles are present.
4. Seeds and fruits are produced after fertilization.

Seeds are enclosed in an ovary.
5. They are terrestrial but few are aquatic.
Examples are oil palm tree, goatweed, mango tree and maize. This Phylum is very large and it has been divided into two classes namely **Monocotyledoneae** (monocots) and **Dicotyledoneae** (Dicots).

## Class: Monocotyledoneae

**Characteristic features**

1. Leaves have parallel veins.
2. Flowers are generally inconspicuous.
3. Embryo has one cotyledon (seed leaf)
4. Roots are fibrous
5. Pith is absent
6. Size of cortex is narrow.
7. Cambium is absent.
8. Vascular bundles scattered all over the ground tissue.

Examples are maize, palm tree, grasses (e.g. *Eleusine indica*)

## Class: Dicotyledoneae

**Characteristic features**

1. Leaves have net-like veins.
2. Flowers are generally conspicuous.
3. Embryo has two cotyledons.
4. The size of the cortex is wide.
5. Vascular bundles arranged in a ring of cambium.
6. Cambium is present.
7. Pith is present.

Examples are mango, orange, iroko and trees.

## Kingdom: Animalia

**Characteristic features**

1. All are multicellular organisms.
2. DNA is located in nucleus enclosed with nuclear membranes.
3. Cells have no cell walls.
4. All possess nervous systems except the sponges.
5. All possess true tissues except sponges.
6. Feeding is heterotrophic.

The Kingdom Animalia is divided into two divisions namely non-vertebrate and vertebrate chordates. The non-vertebrates are animals without back-bones while vertebrates are animals with back-bones. Examples of invertebrates are **Coelenterata, Platyhelminthes, Nematoda, Annelida, Echinodermata, Arthropoda** and **Mollusca.**

The vertebrates include Pisces, Amphibia, Reptilia, Aves and Mammalia.

The kingdom is divided into two sub kingdom namely - **Invertebrata** and **Vertebrata.**

## Sub-Kingdom: Invertebrata

This is a group of animals **without backbones.** (vertebral column).

## Sub-Kingdom: Vertebrata

This is a group of animals **with backbones.** (vertebral column).

## Sub-Phylum: Invertebrata

**Characteristic feature**

No vertebral column.

## Phylum: Cnidaria (Coelenterata)

**Characteristic features**

1. They are multicellar organisms.
2. They have two distinct body layers (diplo-blastic), ectoderm (outer layer) and endo-derm (inner layer), separated by a featureless middle layer called **mesogloea.**
3. They have only one body cavity called **enteron.**
4. There is only one opening called **mouth** to the outside world. No anus.
5. Mouth is surrounded with tentacles.
6. They possess of stinging cells called **nematocysts.**
7. They have specialized cells such as glandular, nerve, sensory and absorptive cells.
8. Asexual reproduction is by budding. *Hydra*, *Obelia*, sea anemone, jelly fish, coral and *Physalia* are examples.

## Phylum: Platyhelminthes

**Characteristic features**

1. Possess soft, flat and unsegmented body.
2. They are bilaterally symmetrical.
3. They have no body cavity (acoelomate).
4. They possess alimentary canal with highly branched diverticula. No anus.
5. Some are free living e.g *Planaria*, while others are parasitic e.g liver flukes and tapeworms.

## Phylum: Nematoda

**Characteristic features**

1. They have soft, cylindrical and slender bodies pointed at both ends.
2. Body is not segmented.
3. They have alimentary canal with both mouth and anus.
4. They are bilaterally symmetrical.

5.They have false body cavity (Pseudocoelomates).
6. They are mostly parasitic but few are free living. Examples are *Ascaris* (roundworms), hookworms, threadworms, guinea worms and vinegar eel (free living).

## Phylum: Annelida

### Characteristic features

1. The body is segmented with each segment separated from other by septa.
2. Body is cylindrical in shape.
3. They have alimentary canal with mouth and anus.
4.They possess true body cavity (coeloma) with a distinct head.
5.The appendages (setae) are not jointed Examples are earthworms, tubeworms and leeches.

## Phylum: Mollusca

### Characteristic features

1. They possess soft and unsegmented bodies.
2. Tentacles are present in most members.
3. The bodies of most of them are covered with shells (e.g. land snail, *(Archatina)* while others are not (e.g. octopus and squid).

## Phylum: Echinodermata

### Characteristic features

1. They possess tough spiny and calcareous exoskeleton.
2. They are radially symmetrical in adults but bilaterally symmetrical in larvae.
3. The head is not usually distinct.
4. Most of them are star shaped.
5. They are all marine organisms.

Examples are bristle star, starfish, sea urchin, sea cucumber and sea lily.

## Phylum: Arthropoda

### Characteristic features

1. Their bodies are covered with hard exoskeleton of chitin.
2. Their appendages are jointed.
3. Often the bodies are divided into three regions - **head, thorax** and **abdomen**. In some, the head and thorax are fused together to form a **cephalothorax** as in crustaceans and arachnids.
4. They have bilateral symmetry.

Examples are insects (e.g. mosquito and cockroach), crustaceans (e.g. crab and lobster), diplopods (e.g millipede), chilopods (e.g centipede) and arachnids (e.g spider and tick).

## Sub-Kingdom: Vertebrata

### Characteristic feature

They possess vertebral column (backbones).
The sub-phylum Vertebrata is represented by five classes namely: **Pisces, Amphibia, Reptilia, Aves** and **Mammalia**.

## Class: Pisces (Fish)

### Characteristic features

1. They are all aquatic.
2. They possess gills for respiration throughout life.
3. They possess fins for locomotion
4. Their bodies are streamlined in shape.
5. They are cold blooded (poikilothermic).
6. Fertilization is external.
7. Most of them have scales (e.g. *Tilapia*) while others are scaleless (e.g.*Clarias*).

Examples are *Tilapia*, *Hemichromis*, *Clarias*, electric cat fish, *Gymnarchus* and shark.

## Class: Amphibia

### Characteristic features

1. Possess moist, soft and scaleless skin.
2. They are cold blooded (poikilothermic).
3. Adults possess paired limbs with webbed toes.
4. The larval stage is aquatic while the adult is either aquatic or terrestrial. Tadpole larva is vegetarian while adult is usually carnivorous.
5. The heart is two chambered in larval stage and three chambered in adult.
6. Fertilization is external.
7. Breathing is by gills in the larval stage and by lungs, skin and mouth in the adult stage Examples are toad, frog and newt.

## Class: Reptilia

### Characteristic features

1. They possess dry and scaly skin.
2. Most possess four limbs which end in claws while others (snakes) have no limbs.
3. Dentition is homodont (the same type of teeth).
4. They are cold blooded (poikilothermic).
5. Breathing is by lungs.
6. Fertilization is internal with laying of soft and leathery shelled eggs. Most members are **oviparous** while a few others retain their eggs in their bodies until hatching (**ovoviviparous**).
7. They are mostly terrestrial but few such as turtles and crocodiles are aquatic. Examples are lizard, snake, crocodile, tortoise and chame-leon.
8. The heart is three chambered except crocodile with four chambered heart.

# 2

# DESCRIPTION OF THE REPRESENTATIVES OF MAJOR GROUPS OF PROKARYOTAE AND EUKARYOTAE

## Kingdom: Prokaryotae

**Representatives:** Bacteria

**Structure:** See page 470 for structure and description.

## Kingdom: Protoctista

**Representatives:** *Chlamydomonas, Amoeba, Paramecium, Euglena and Spirogyra.*

### *Chlamydomonas*

**Structure:** *Chlamydomonas* is oval or spherical in shape and is bounded by a cell wall consisting of **hemi-cellulose** rather than cellulose. At the anterior end, the wall projects and thickens into a colourless **papilla.** Two **flagella** which arise from the anterior end are used for movement. Close to the base of the flagella are two **contractile vacuoles** which are used for osmoregulation.

Within the cytoplasm is the **nucleus** and a cup-shaped **chloroplast** which contains **chlorophyll.** A **pyrenoid,** responsible for the storage of starch occurs within the chloroplast towards the posterior end. An **eye spot** is embedded on one side of the cell close to the cell at the anterior end. The eye spot responds to light stimulus so that the organism moves towards the source of light for photosynthesis.

*Chlamydomonas* is an organism that shares both the characteristics of plants and animals.

The presence of flagella for locomotion, eye spot which responds to light stimulus and contractile vacuoles for osmo-regulation have compelled zoologists to claim it as an animal. The presence of chloroplast containing chlorophyll for photosynthesis and storage of excess carbohydrate as starch have made botanists to place *Chlamydomonas* into plant kingdom without dispute.

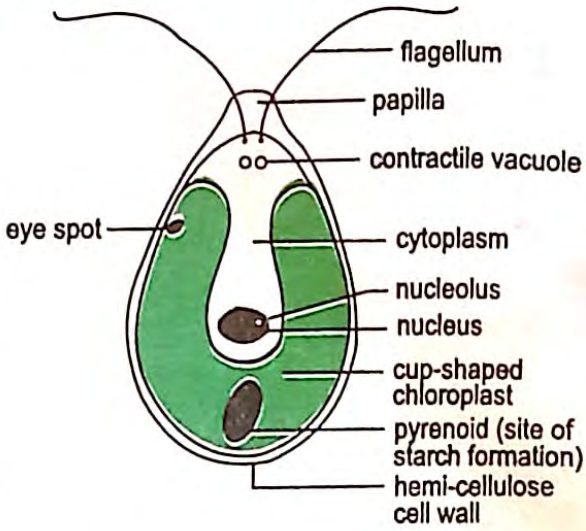



**Figure 2.1. Structure of** ***Chlamydomonas rivalis***

### *Spirogyra*

**Structure:** *Spirogyra* is an unbranched green filamentous alga consisting of a **chain of cylind-rical cells.** All the cells are similar. Each cell is cylindrical in shape with transverse end walls. The cell is enclosed in a thick **cellulose cell wall.** The entire filament is covered with a layer of **mucilage** which makes it slimy. Inside each cell is a lining of ectoplasm which encloses a large **central vacuole.** In the cytoplasm, the chloroplasts are arranged spirally. Each chloroplast contains **pyrenoids.** The **nucleus** is suspended by **cytoplasmic threads.**

## Class: Aves

**Characteristic features**

1. The body is covered with feathers except the legs and the feet, which are covered with scales.
2. Their forelimbs are modified as wings.
3. The mouth is modified into horny toothless beak or bill.
4. Their bones are porous, light and in some cases filled with air.
5. Their bodies are supported by two hind limbs, (bipedal stance).
6. They are warm blooded (homoiothermic). They are very active animals.
7. Breathing is by lungs.
8. They lay hard shelled eggs (oviparous).
9. Fertilization is internal.
10. They are mostly terrestrial.
11. The heart is four chambered.

Examples are domestic fowl, duck, eagle and pigeon.

## Class: Mammalia

**Characteristic features**

1. They possess hair.
2. They possess mammary glands. The mother's mammary glands secrete milk used in nourishing the young after birth.

They possess external ears.

1. They are viviparous; that is the young are born at an advanced stage of development. However, the monotremes lay eggs which hatch into young nourished by milk secreted by mammary glands of the mother.
2. Breathing is by lungs.
3. They have diaphragm (breathing muscle) separating the thoracic cavity from the abdominal cavity.
4. The heart is four chambered.
5. Most possess four limbs for locomotion.
6. They are warm blooded (homoiothermic) hence they are very active animals.

Examples are duck-billed platypus, kangaroo, cat, pangolin, elephant, giraffe, monkey, lion, gorilla and man.

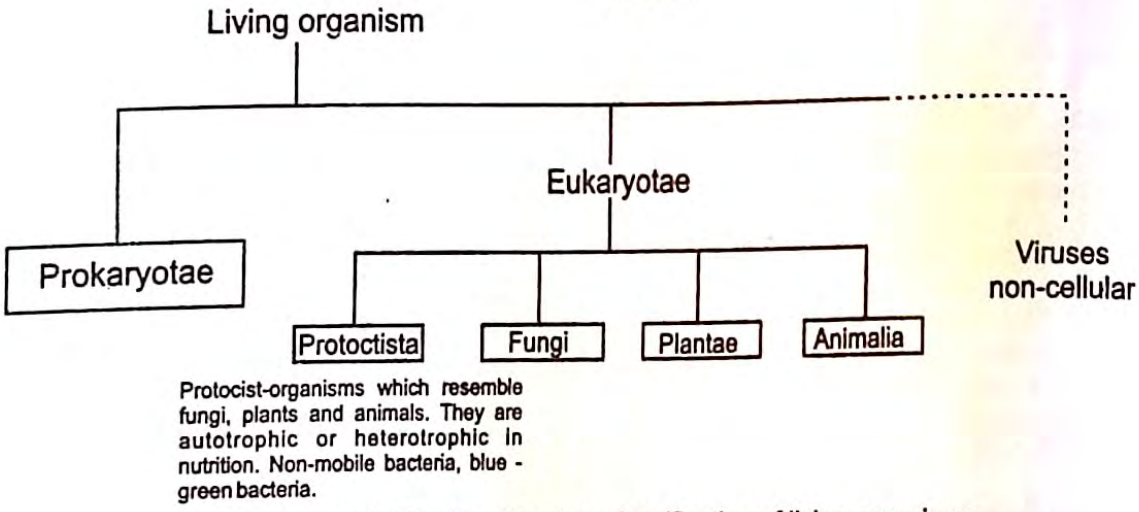



Figure 1.23. The five kingdom classification of living organisms of Mangulis and Schwartz

## *Questions*

1. *(a) What are the characteristics of living organisms?*
   *(b) In tabular form distinguish between plants and animals and state their similarities*
   *(c) Describe briefly the inter-relationship between (i) living and non-living things (ii) plants and animals.*
   *(d) Demonstrate experimentally one characteristic of a living thing.*

2. *(a) What do you understand by the word classification or taxonomy in biology? Give examples to support your answers.*
   *(b) State how living things are named.*
   *(c) Classify black rat and groundnut plant using the following headings: Kingdom, Phylum or Division, Class, Order, Family, Genus and Species.*

# 2

# DESCRIPTION OF THE REPRESENTATIVES OF MAJOR GROUPS OF PROKARYOTAE AND EUKARYOTAE

## Kingdom: Prokaryotae

**Representatives:** Bacteria

**Structure:** See page 470 for structure and description.

## Kingdom: Protoctista

**Representatives:** *Chlamydomonas, Amoeba, Paramecium, Euglena and Spirogyra.*

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Within the cytoplasm is the **nucleus** and a cup-shaped **chloroplast** which contains **chlorophyll.** A **pyrenoid,** responsible for the storage of starch occurs within the chloroplast towards the posterior end. An **eye spot** is embedded on one side of the cell close to the cell at the anterior end. The eye spot responds to light stimulus so that the organism moves towards the source of light for photosynthesis.

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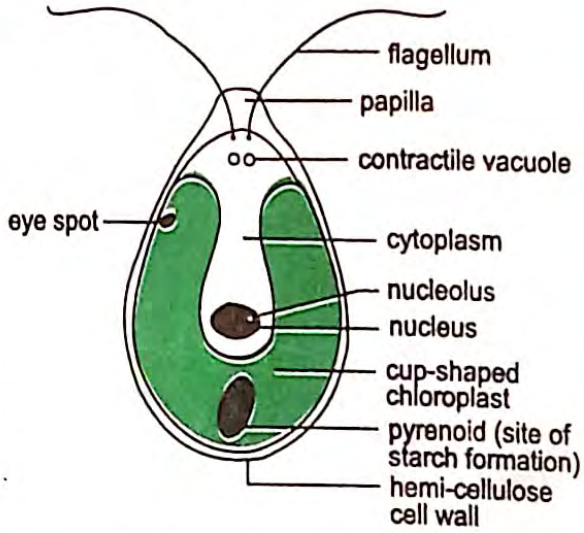


**Figure 2.1. Structure of** *Chlamydomonas rivalis*

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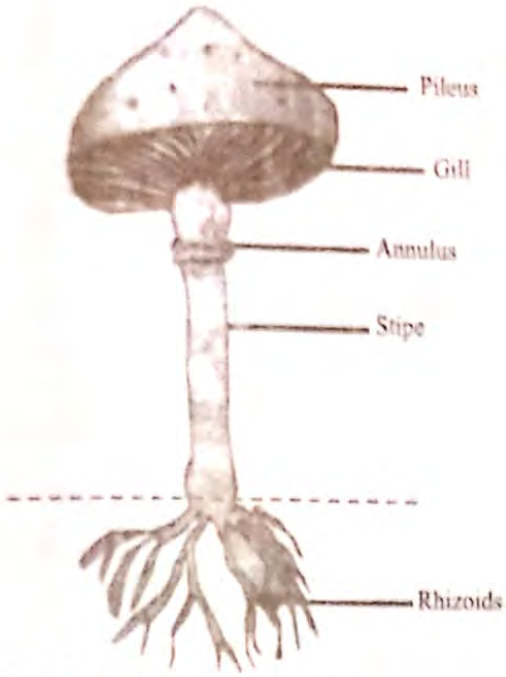


Figure 2.4. Structure of a mushroom

## Kingdom: Plantae
## Phylum: Bryophyta
**Representative:** ***Funaria hygrometrica*** (moss) and *Dryopteris* (Fern)

A common moss is *Funaria hygrometrica*. It is a land plant which grows in moist ground under the shade of big trees as epiphytes, on packed blocks and on the old block walls and rocks. *Funaria* grows in tufts to form a green carpet.

### External features

The *Funaria hygrometrica* is small and erect, measuring a little more than one centimetre in height. It consists of hair-like structures called **rhizoids, simple** stem without conducting tissues and **simple sessile** leaves without leaf-stalks. The leaves are green as they contain chloroplasts and therefore can carry out photosynthesis. The rhizoids arise from the base of the stem. The rhizoids perform similar functions as roots of higher plants. They absorb water and mineral salts from the soil and also anchor the plant firmly to the substratum. [*Rhizoids are made of cells not differentiated into tissues and organs while the roots of higher plants are organs made of specialized tissues*].

The stem is short, slender and often with a branching stem, covered by simple leaves spirally arranged along the stem and its branch. The leaves are thin and only one cell thick except along the midrib. The two branches of the stem are differen-tiated into male and female branches.

Towards the end of the life-span of the plant, a structure called **sporogonium** (sporophyte) grows from the top of the female branch. The sporogo-nium consists of a **long seta** (stalk) and a pear-shaped **capsule.**

The rhizoids, stem and leaves all together form the **gametophyte.** The gametophyte alternates with the **sporophyte** during the life cycle. This is called **alternation of generations**

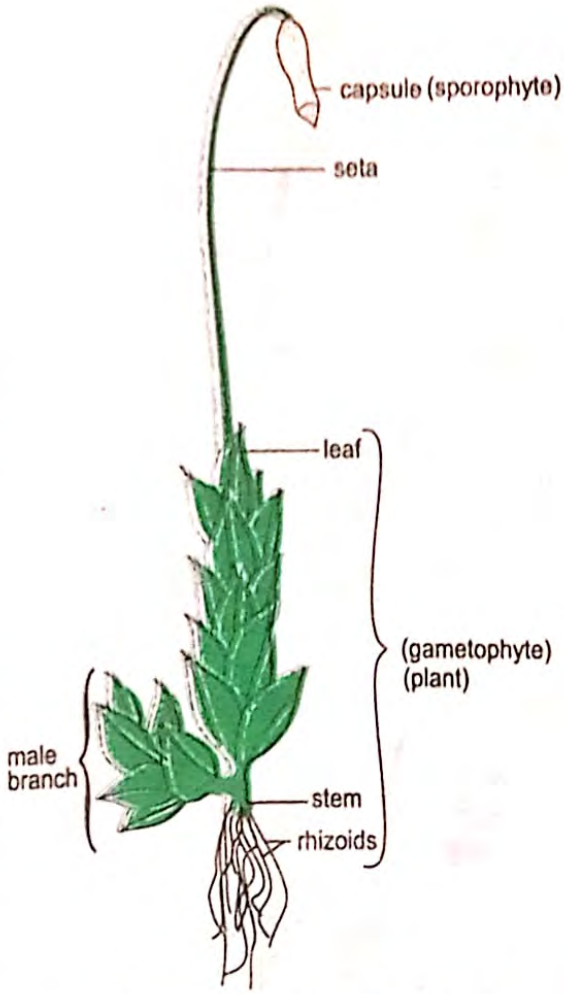


**Figure 2.5. External features of a *Funaria* (moss)**

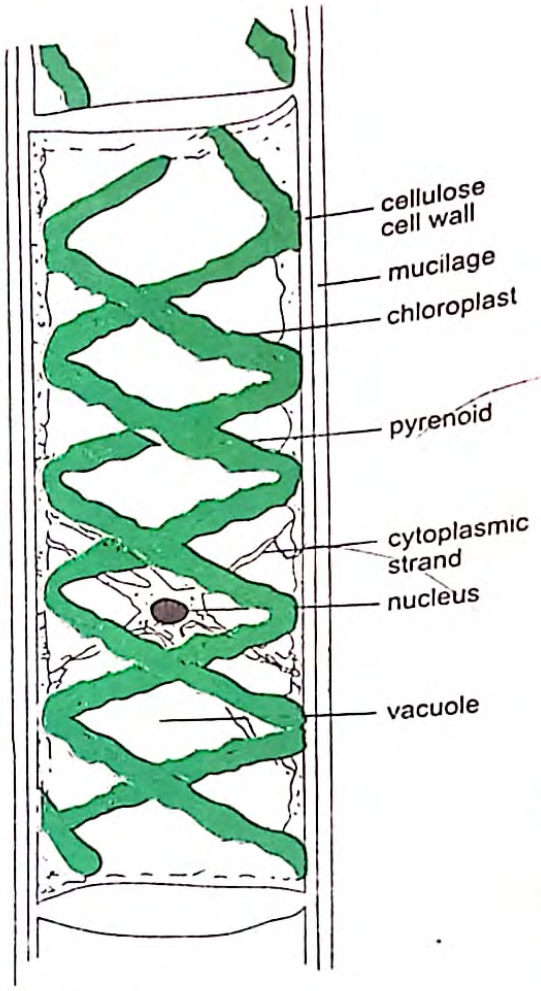


Figure 2.2. The structure of *Spirogyra*

## Kingdom: Fungi

**Representatives: Mucor and Mushroom**

**Structure:** Mucor is composed of a mass of **white delicate threads.** Each separate thread is called a **hypha** and the whole mass is termed **mycelium.** The **cytoplasm** of the hypha is surrounded by **'fungus cellulose cell wall'.**

The cytoplasm contains numerous minute nuclei, small droplets of fats, oils and glycogen and numerous vacuoles

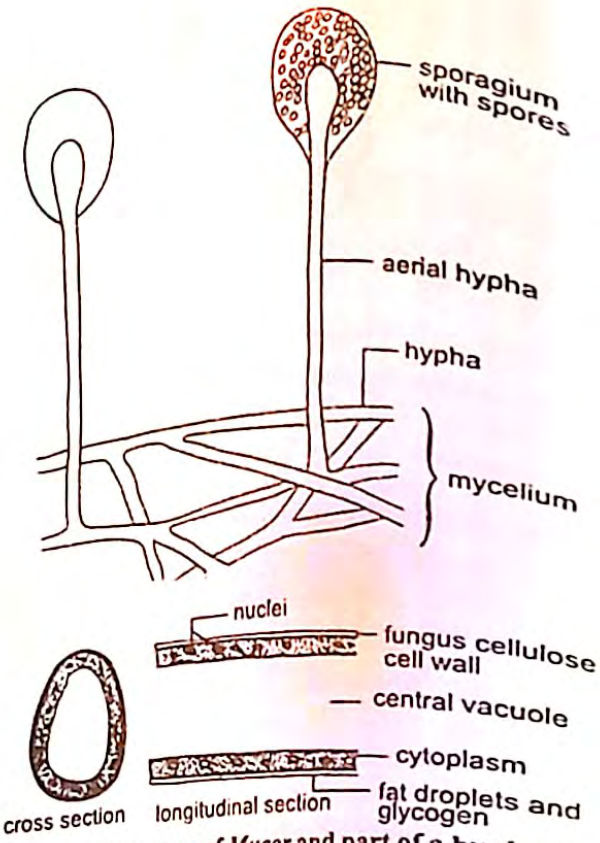


Figure 2.3. Structure of *Mucor* and part of a hypha in detail

## Mushroom (Gill fungus)

**Structure:** The mushroom is the most developed and organized form of fungi. It consists of interwoven mass of hyphae growing in the substrate as **mycelium.** It bears a macroscopic **'fruiting body'** which grows above the substrate. The **'fruiting body'** consists of a foot which attaches it to the substrate, a **stipe** which bears an **umbrella** shaped portion at its end known as **pileus.** Before the expansion of the pileus, it is attached to the stipe by an **annulus.** As the pileus expands, the annulus coils back and remains as a ring on the stipe.

At the under surface of the pileus are gill-like structures where the reproductive hyphae are situated.

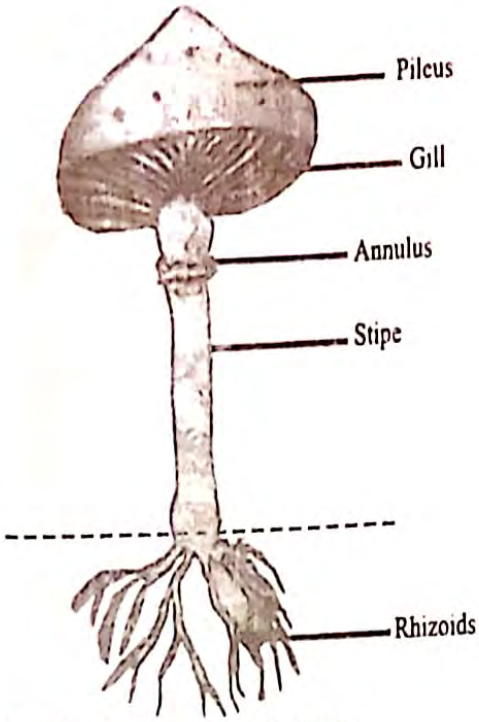


**Figure 2.4. Structure of a mushroom**

## Kingdom: Plantae
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**Representative:** ***Funaria hygrometrica*** (moss) and *Dryopteris* (Fern)

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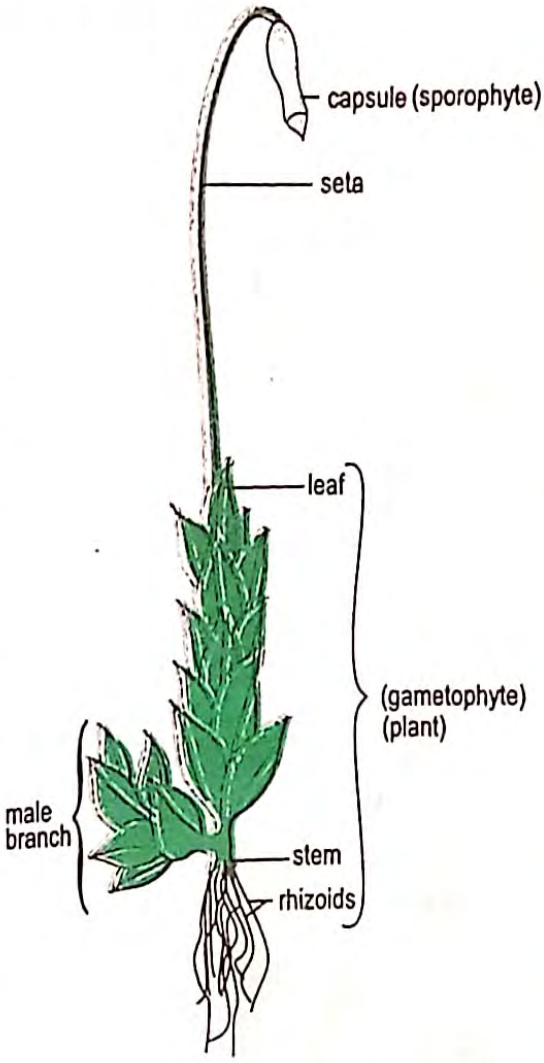


**Figure 2.5. External features of a *Funaria* (moss)**

1. A **root system** which develops from the radicle of the embryo is generally found in the soil.
2. A **shoot system** which develops from the plumule of the embryo is generally found above the soil. The shoot consists of stem, leaves and flowers.

The different parts of a herbaceous dicotyledonous plant are illustrated in figure 2.7.

## 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 systems.**

### 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** (figure 2.7).

### 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 sizes. The roots are slender in appearance.

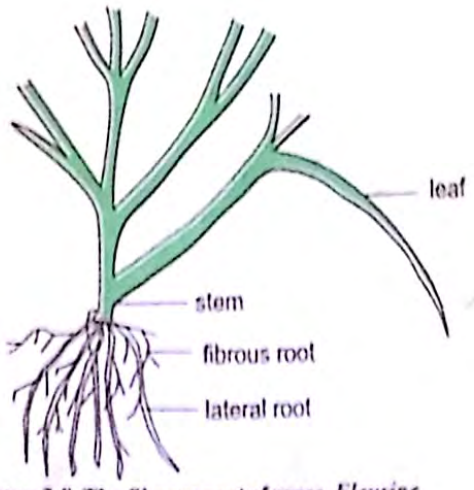


**Figure 2.8 The fibrous root of grass, *Eleusine indica***

Both the main and branch roots bear a root cap at their tips. The root cap protects the soft growing regions of the root tip. 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.

## Characteristics of roots

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.

## 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.

## Phylum: Pteridophyta

### Dryopteris (Fern)

**Representative:** *Dryopteris* (Fern)

The fern is a small group of plants in the division of plants known as **Pteridophyta.** A common and widely distributed fern is called ***Dryopteris.*** ***Dryopteris*** is a land plant that grows in wet soil and under the shade of trees. It consists of **roots, stem and leaves.**

The stem is a **rhizome.** It is short, thick and covered with numerous small brown scales called **ramenta.** The stem is non-branching. Stump of old leaf stipes are seen on the older portion of stem. The apex of the rhizome projects slightly above the soil surface. Arising from the apex of the rhizome is a cluster of compound leaves called **fronds.** Each frond has a **stipe** (stalk) and **midrib** (rachis). The midrib gives rise to **lateral pinnae** (leaflets). Each pinna is further subdivided into **pinnules.** The young leaves are coiled inwards at the apex and they are also covered with ramenta. The mature leaves bear groups of **sporangia** called **sori** (sing-ular: **sorus**) on the under (**abaxial**) surface. Each sorus encloses many sporangia that bear numerous **spores.**

The **roots** are **adventitious,** long, slender and equal in size. The roots are very strong and help to attach the plant firmly to the soil.

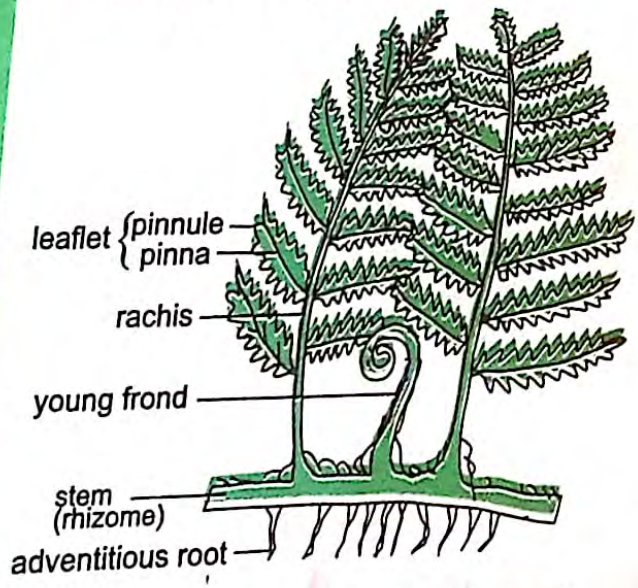


**Figure 2.6. External features of a fern** *(Dryopteris)*

## Phylum: Angiospermophyta (Angiosperms)

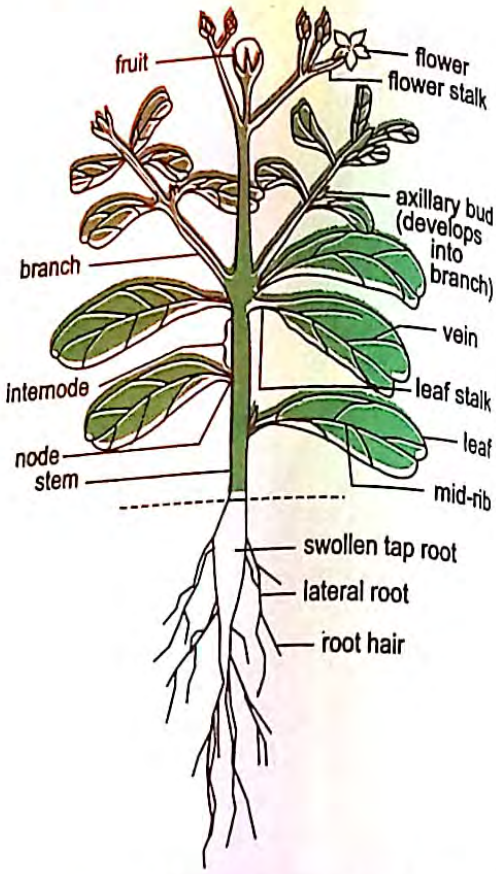


**Figure 2.7. External features of water leaf** *(Talinum triangulare)*

### External features of flowering plants

The flowering plants form a group of plants known as **Angiosperms.** They are characterized by the possession of flowers for sexual reproduction. They bear flowers in their various breeding seasons and after pollination and fertilization, seeds are formed enclosed in the carpels which become the fruits. Both fruits and seeds are variously adapted for their effective dispersal. A seed contains an embryo which under favourable environmental conditions germinates into a new plant.

A typical flowering plant such as water leaf *(Talinum triangulare)* consists of two systems; namely: **root and shoot systems.**

1. A **root system** which develops from the radicle of the embryo is generally found in the soil.
2. A **shoot system** which develops from the plumule of the embryo is generally found above the soil. The shoot consists of stem, leaves and flowers.

The different parts of a herbaceous dicotyledonous plant are illustrated in figure 2.7.

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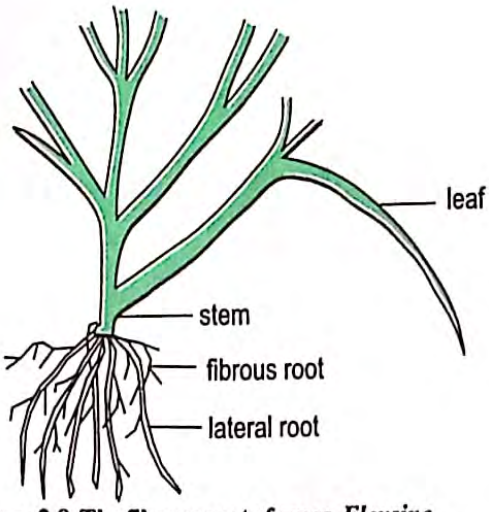


**Figure 2.8 The fibrous root of grass, *Eleusine indica***

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## 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.

## Types of modified roots

### 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, **pig weed** (*Boerhaavia diffusa*) and lateral roots of cassava (figure 2.9).

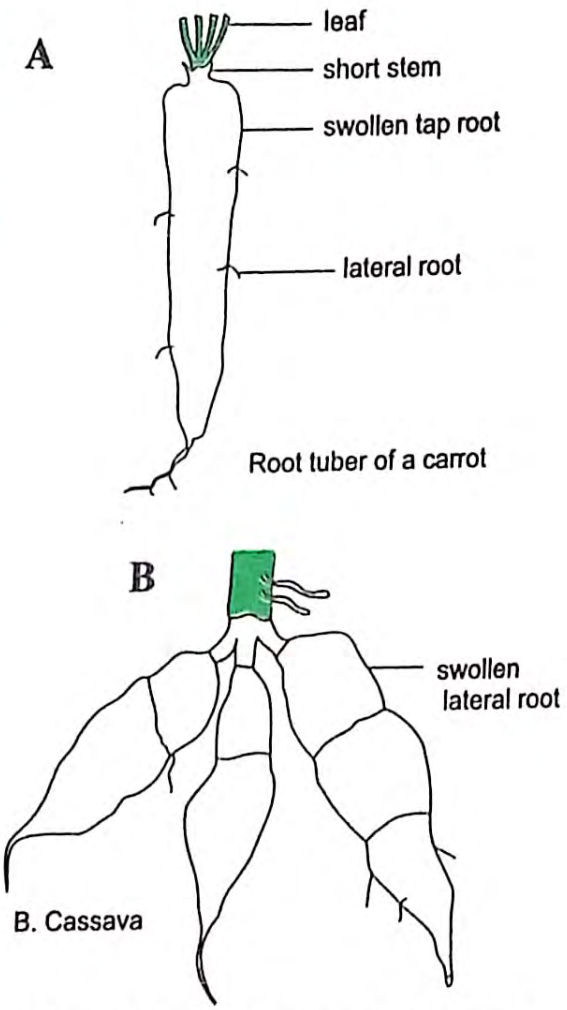



**Figure 2.9. Root-tubers of (A) carrot, (B) cassava.**

### 2. Climbing roots

They are also known as **clasping** or **adhering** roots. These are aerial roots growing into cracks of 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 laterial 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 2.10. Climbing root of black pepper.**

### 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 (Figure 2.11)

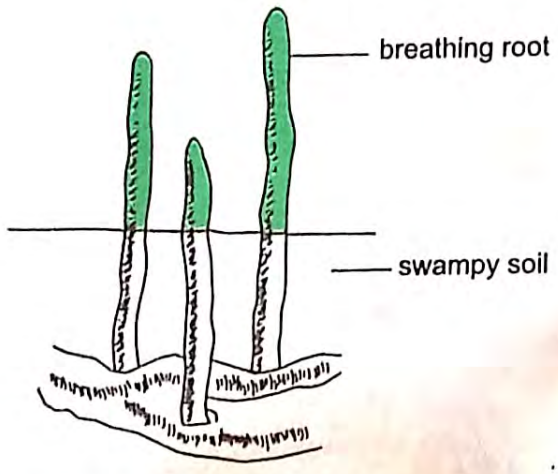



**Figure 2.11. Breathing root of white mangrove**

## 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.

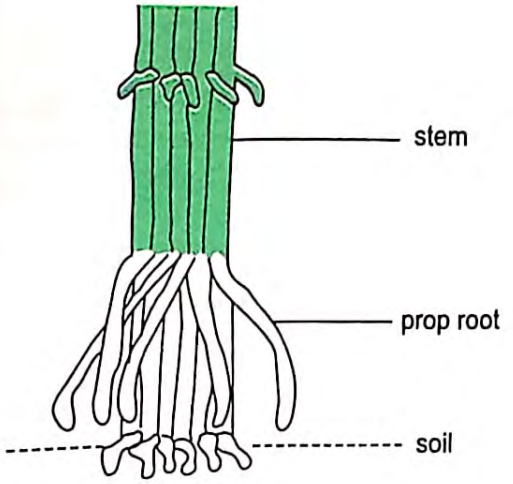



**Figure 2.12. Prop root of maize.**

## 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, (figure 2.13) 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.

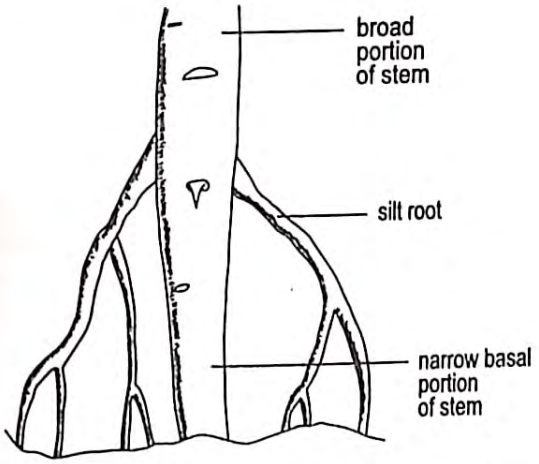



**Figure 2.13. stilt root of umbrella tree** *(Musanga cecropoides).*

## 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 (figure 2.14).

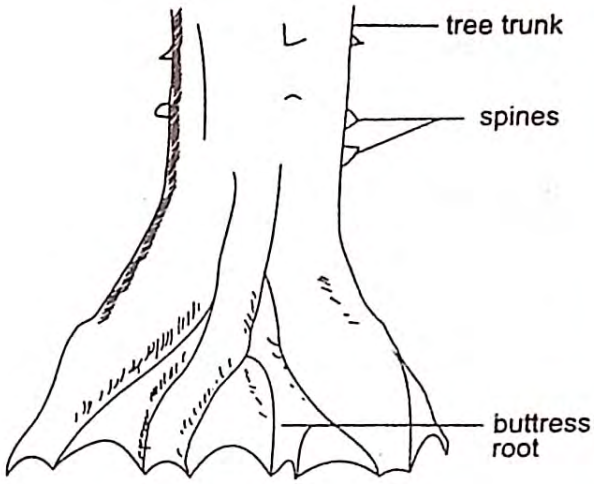



**Figure 2.14. Buttress roots of** *Terminalia superba.*

# Shoot system

This is the part of the plant which grows above the soil except the modified aerial roots. The shoot system consists of two main organs - the **stem** and the **leaves**. During the reproductive stage, flowers and fruits may be seen on different branches of the stem

## Stem

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 portions of the stem from which leaves and buds arise. The buds occur on the axil 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.

## Types of stems

Different types of stems are seen in flowering plants. With regards to their external characteristics and internal structures, stems can be grouped into the following:

### 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.

### 2. Herbaceous stem

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. Monocotyledonous stems (monocot stems)

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

### 4. Other types of stem

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

### 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.

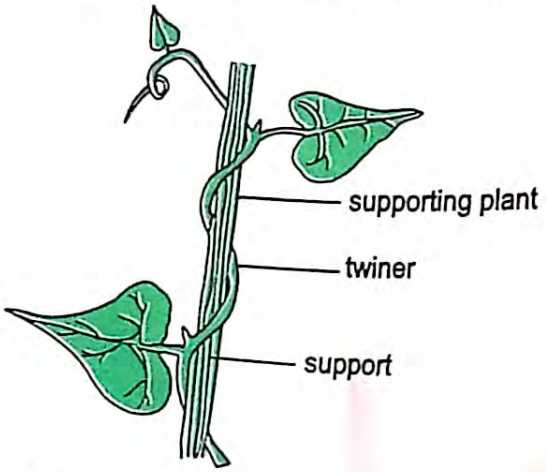



**Figure 2.15 A twining stem of yam**

### 5. 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.

### 6. 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 (fig. 2.16).Tendrils are therefore modified for climbing. They occur in passion flower, *Curcubita* and melon.

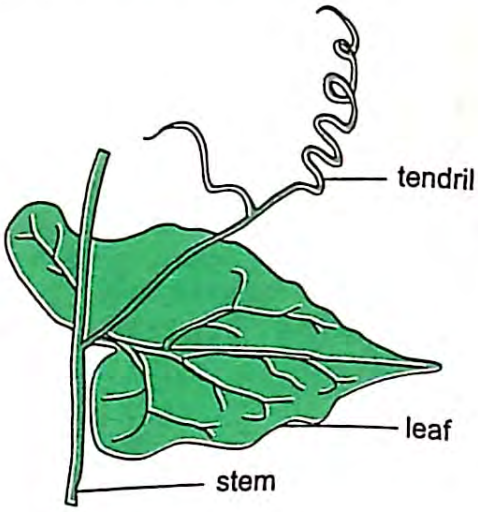



**Figure 2.16. A stem tendril**

#### b. Thorns and spines.

These are outgrowths of the stem. Thorns are from axillary buds hence they are borne on the axils of leaves. Thorns are seen in orange trees (figure 2.17) Spines appear on the stem body. Thorns and spines are stems modified for protection against animals.

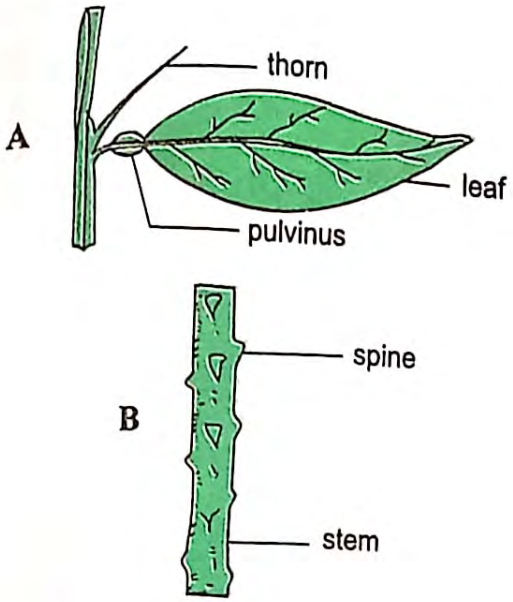



**Figure 2.17. (A) Thorn, (B) Spine of orange tree.**

### c. Underground stems

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

### d. Others

Runners, offsets, suckers and stolons are various types of stems also modified for vegetative reproduction. These organs are fully dealt with in the chapter on storage organs and vegetative reproduction.

## 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 vegetative reproduction.
5. Young parts of stems contain chlorophyll, hence they take part in photosynthesis.

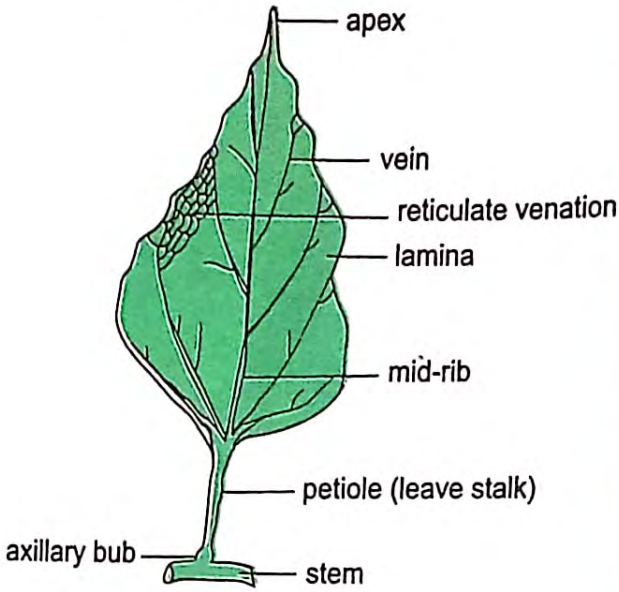



**Figure 2.18. Simple dicot leaf of Bixa**

## 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 (Figure 2.19). 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.

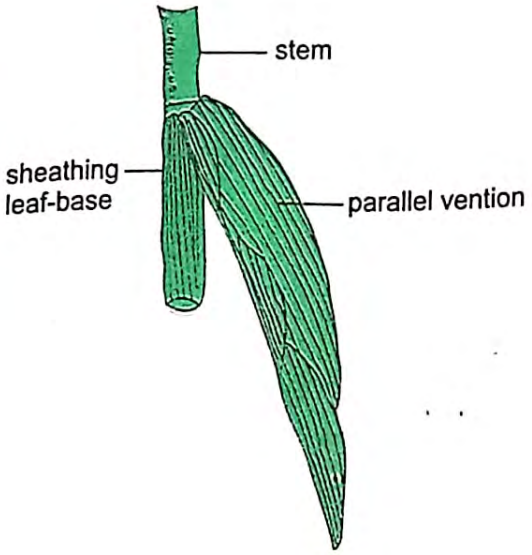
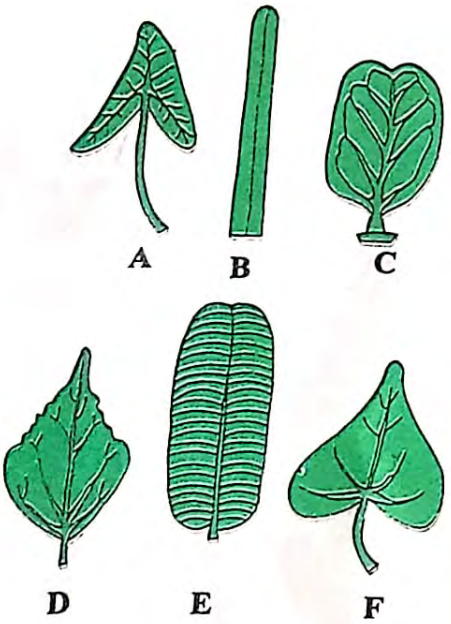



**Figure 2.19 Monocot Leaf of *Costus* with sheathing leaf-base.**

## 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 2.20.




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 2.20 A - F. shapes of leaves**

## 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 (figure 2.21).

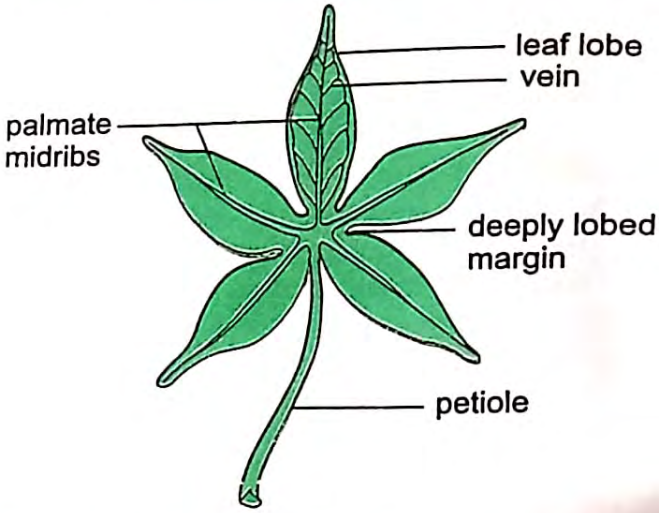



**Figure 2.21. Simple palmate leaf of cassava.**

(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 leaflets. A leaflet has its own leafbase and is either attached to a mid-rib (rachis) or directly to the petiole head. Leaflets have no axillary buds.

## 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 is made up of only three leaflets is trifoliate (figure 2.22).

**(b) Paripinnate**: The apex of the leaf terminates in two leaflets.

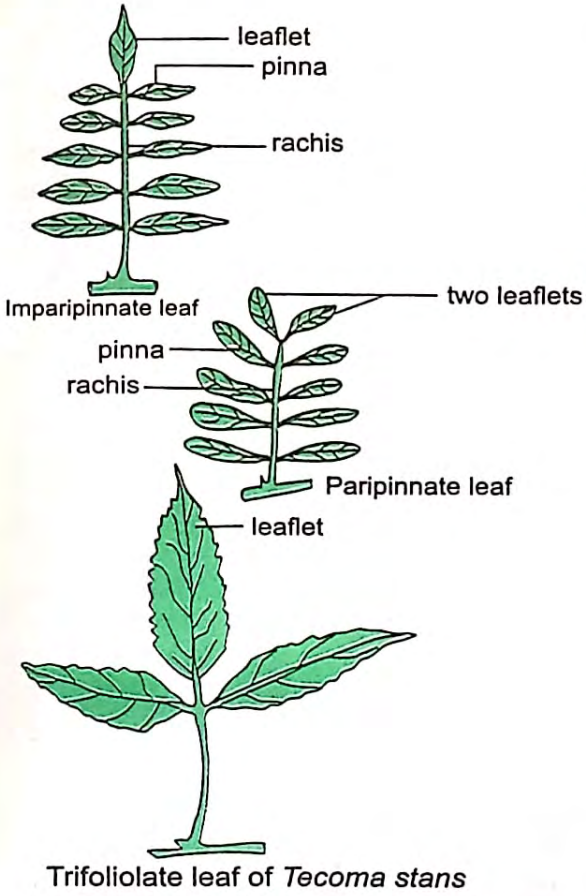



**Figure 2.22. Types of compound pinnate leaves**

**2. Bipinnate leaf**: This is a compound leaf in which the **rachis** gives off opposite branches or pinnae which bear oppositely arranged leaflets. (Fig.2.23). 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.

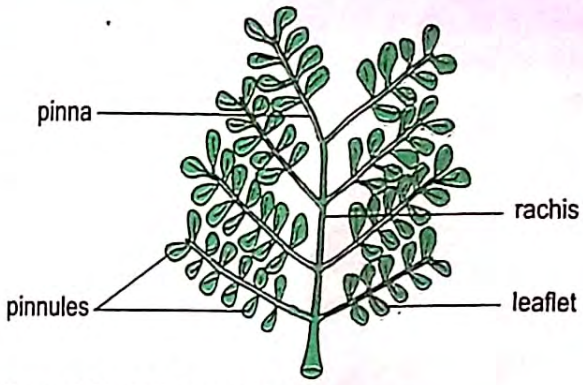



**Figure 2.23. A bipinnate leaf.**

## 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*).

**Figure 2.24. Digitate leaf of umbrella tree**

## 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.

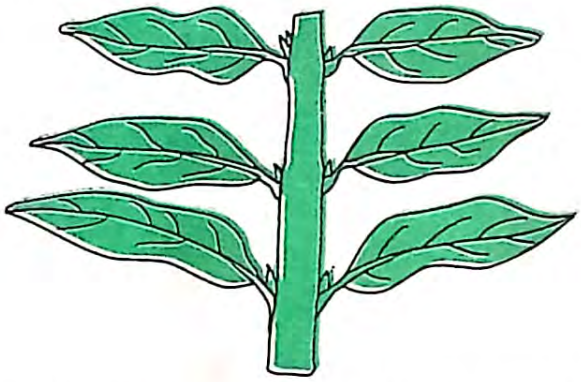


**Figure 2.25. Alternate and opposite arrangement of leaves**

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 leaves on one node are at a right angle to 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.

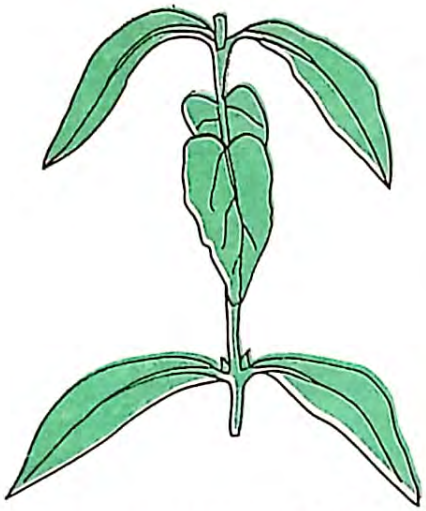


**Figure 2.26 Decussate arrangement of leaves**

**Whorled arrangement**

In another form of arrangement more than two leaves occur at each node as in *Allamanda* and *Alstonis*. This is whorled arrangement (figure 2.27).

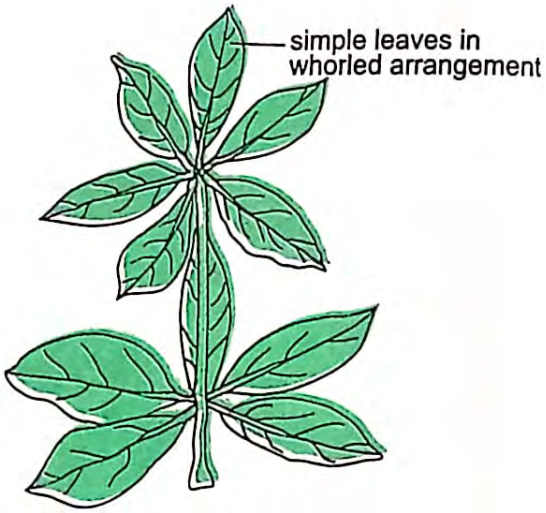



**Figure 2.27. Whorled arrangement of leaves**

## 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:** The leaves of some plants such as

cactus and palm fronds of palm trees are modified into spines for the protection of the plants.

2. **Climbing**: Some plants such as *Gloriossa superba* have the apex of its leaves modified into tendril for climbing.

3. **Storage organ**: The leaves of some plants such as the aloes are fleshy and thick. This helps in storing water which is needed during the period of drought in desert condition. Food is also stored in the leaves of onion bulbs.

4. **Feeding**: The leaves of some such as sundew (*Drosera rotundifolia*) and venu's flytrap (*Dionaea muscipula*) are modified for trapping insects for food.

5. **Vegetative reproduction**: In some plants such as life plant (*Bryophylum pinnatum*), vegetative reproduction is by the leaves.

## External features of *Delonix regia*

*Delonix regia* is popularly known as **Flamboyant** or the **"Flame of the forest".**

***General shape*:**

Flamboyant is an important ornamental tree. It is a leguminous plant, which often grows to a height of 10-12 metres. A matured tree consists of a short trunk with two or three main branches and main root with lateral roots and root hairs. These main branches give off several smaller branches which spread out into a wide crown at the top.

***Colour of stem:***

The stem has a thin bark and silvery-grey colour.

***Arrangement of leaves***

The plant has several bipinnate leaves which are spirally arranged on the branches. Each leaf consists of several tiny leaflets. Each leaflet measures about 0.5 - 1cm in length.

***Arrangement of flower buds and flowers:***

The flower buds and flowers are arranged on special branches on the stem known as **inflorescences.** The buds appear at the apex of the branch. Young flowers are found below the buds while the oldest flowers are at the base. This is described as simple **recemose inflorescence.**

***Structure of flower*:**

Each flower is large, conspicuous and often scented. It consists of five fleshy sepals and five brightly coloured petals. The sepals are coloured red on the inside but green on the back side. Four of the petals are of equal size, fan-like and reddish in colour. The fifth petal often called the **odd** or **standing petal** is smaller in size. It is coloured red on the back surface while on the inside it is white with red stripes. The flower has ten stamens and one carpel, and is pollinated by the butterfly. Because of the beautiful red colours of the flowers, the plant is called **"Flame of the forest".**

### *Fruit*

The fruit is a legume, that is, the seeds are contained inside a pod. At maturity the pod is about 60cm long, woody and dark-brown in colour.

### *Mode of dispersal of fruit and seeds:*

The seeds are dispersed by explosive mechanism. The dry pod splits into two halves with a force which scatters the seeds away from the parent plant. Sometimes the whole fruit drops to the ground without splitting.

### *Root system:*

The root system consists of tap root or main root from which lateral roots grow. At the end of each root is a protective root cap. Just above the root cap are tiny structures called root hairs which are used for the absorption of water and mineral salts from the soil.

*Changes observed in the year*:

| | |
|---|---|
| January | -Appearance of new green leaves from the terminal buds. |
| Feb. to April | -Appearance of flower buds and flowers. |
| April to June | -Flower-bloom, tree with beautifully coloured red top amidst green leaves. |
| June to July | -Appearance of young green fruits (pods.) |
| Aug. to Oct. | - Maturation of fruits |
| Oct. to Nov. | -Leaves turn yellow and begin to fall. |

| | |
|---|---|
| Nov. to Dec. | -Tree is almost leafless. Only the dry fruits remain. Some fruits fall to the ground. |
| January | - New leaves reappear, some old fruits can be found. |

**Figure 2.28.** **A scematic diagram of** *Delonix regia* with one leaf enlarged to show bipannate arrangement of the leaflets.

# Kingdom: Animalia

## Phylum : Protozoa

**Representatives** are *Amoeba proteus, Paramecium caudatum* and *Euglena viridis*

### Structure of *Amoeba proteus*

*Amoeba proteus* is a single-celled, naked, colourless, microscopic (about 0.07mm), shapeless and jelly-like animal. It is made up of **cytoplasm** and **nucleus**. The cytoplasm is divided into non-granular liquid layer called **ectoplasm** and granular layer called **endoplasm**. The ectoplasm is bounded by a thin flexible cell membrane called **plasma membrane** which performs the following functions:

1. The cell membrane (plasmalemma) keeps the cell content together as a discrete entity, thereby preventing it from dispersing in water.
2. It prevents the animal from sticking to the substratum as it moves along slowly.
3. It controls the exchange of material between the animal and its surrounding medium.
4. The cell membrane is tough and elastic enough to allow the forming and deforming of pseudopodia and the discharging of the contractile vacuole to the exterior.
5. The cell membrane (plasmalemma) allows the engulfing of food particles and formation of food vacuole.

The ectoplasm forms pseudopodia (false feet) for movement and food capture. Exchange of gases (oxygen and carbon (IV) oxide, and ammonia) occurs at the ectoplasm.

The endoplasm is divided into an outer viscous portion called **plasmagel** and an inner liquid portion called **plasmasol**. The plasmasol contains the following cytoplasmic structures: contractile vacuole, food vacuole and nucleus.

**Contractile vacuole**: This is a spherical body. The contractile vacuole performs the following functions:

1. It excretes waste liquid products such as dissolved ammonia.
2. It regulates the amount of water and mineral salts that enter and leave the cell (osmo- regulation).

**Food vacuole**: This is formed when food is engulfed. It provides site for the storage and digestion of food.

**Nucleus**: The nucleus is the most important structure in the cell. The nucleus is bounded by a nuclear membrane. The nuclear membrane has pores through which the nuclear materials have connection with the cytoplasm. Within the nucleus is a **nucleolus**. It is believed that the nucleolus initiates cell division.

### Functions of nucleus

1. The nucleus controls directly or indirectly the cellular activities.

2. It carries chromosomes which are hereditary units.
3. It initiates cell division.

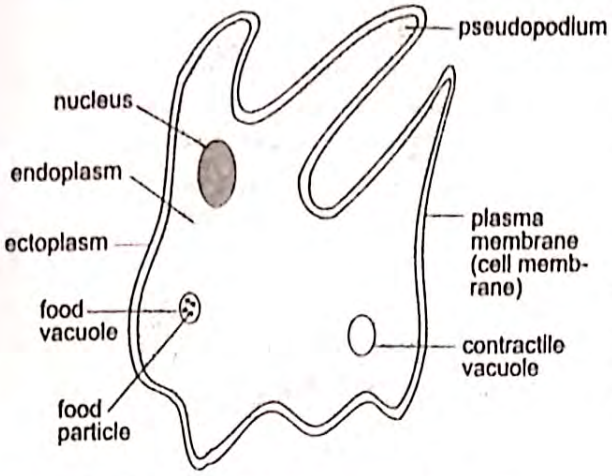



**Figure 2.29. Microscopic appearance of** *Amoeba*

## Structure of *Paramecium caudatum*

*Paramecium caudatum* is slipper shaped with a length ranging from 150 to 300 microns (0.15 to 0.30mm). The anterior part is blunt or rounded while the posterior part is pointed.

*Paramecium caudatum* is divided into two distinct parts, the **ectoplasm** and **endoplasm**. The thin layer of ectoplasm is bounded outside by a clear and elastic membrane called **pellicle** which makes the animal to have a definite and permanent slipper shape. The entire pellicle is covered with fine cilia used for locomotion. The cilia at the posterior end are longer than those of the anterior end. Below the pellicle is a clear layer of ectoplasm. Embedded in the ectoplasm are spindle shaped bodies called **trichocysts**. Trichocysts contain filaments which can be discharged either to trap a prey and hold it or used for offense and defense.

The **endoplasm** is granular, large and contains the following organelles: anterior and posterior contractile vacuoles, food vacuoles which are formed near the gullet (cytopharynx), **meganucleus** and **micronucleus.**

Each contractile vacuole consists of a central space that is surrounded by six radiating canals. The contractile vacuoles remove excess water from the animal. The food vacuole is formed at the posterior part of the gullet. When sufficient food is collected, it breaks off and drops into the endoplasm and a new food vacuole starts forming again. Food is digested inside the food vacuoles.

At one side of *Paramecium* is a depression called **oral groove**. The oral groove which is lined with fused cilia (undulating membrane) leads into a tube-like **gullet** (cytopharynx). At the posterior end, is a small opening called **anal pore** through which undigested food material is ejected from the body.

## Nuclei

The **meganucleus** and **micronucleus** are centrally placed in the endoplasm. The meganucleus is large and bean or kidney-shaped. It controls the ordinary activities of the cell. The micronucleus is small and roughly spherical in shape.

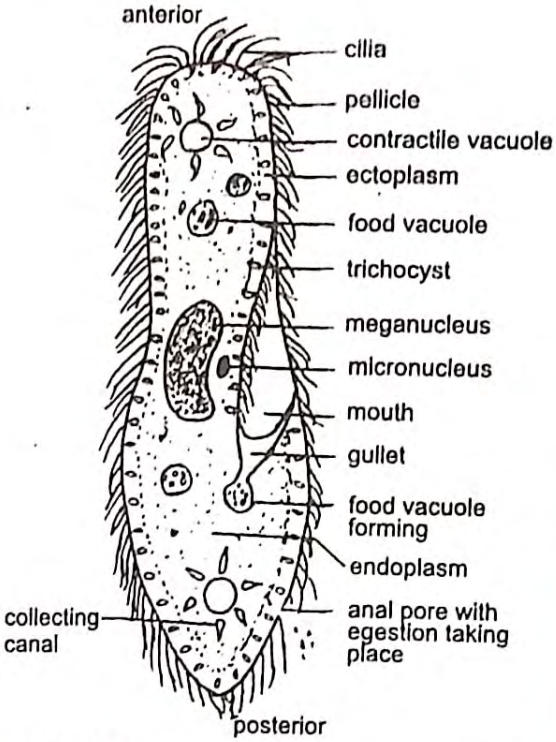



**Figure 2.30. Microscopic structure of** *Paramecium caudatum*

## Structure of *Euglena viridis*

*Euglena viridis* is a pear or spindle shaped single celled organism. It is about 60 microns (0.06mm) in length with the widest width at the middle of the body. The anterior part is blunt or rounded while the posterior part is pointed. The body is divided into **clear ectoplasm** and **granular endoplasm.**

The ectoplasm (plasmagel) is bounded by a thin, flexible, tough and elastic covering called **pellicle**.This pellicle enables the animal to carry out a type of locomotion known as **euglenoid movement**. Within the cytoplasm are rod-shaped structures called chloroplasts which contain chlorophyll hence *Euglena* is green in colour and is able to carry out photosynthesis.

The granular endoplasm (plasmasol) contains obliquely arranged myonemes (thin fibres) and paramylum granules containing starch reserve.

The nucleus with a nucleolus is embedded in the endoplasm. The nucleus is bounded by a nuclear membrane. At the anterior part of *Euglena viridis* is a flask-shaped opening called **gullet** (reservoir). Beneath the gullet is a granule called **blepharoblast**. Arising from the blepharoblast is a rhizoplast believed to initiate cell division.

From the base of the gullet, rises a whip-like flagellum used for locomotion. At the base of the gullet lies a large contractile vacuole used for osmoregulation.

*Euglena* is an organism that has a mixture of plant and animal characteristics. Botanists claim it to be plant (alga) while zoologists claim it to be an animal (flagellate). The mixture of plant and animal characteristics indicates that both plants and animals are closely related and therefore, have a common ancestry.

## *Euglena* as a plant.

1. The presence of chloroplasts. Euglena has chloroplasts used for photosynthesis (holophytic nutrition). Only green plants can photosynthesize.
2. Stores excess carbohydrates as starch (paramylum granules are starch). Only plants stores starch. Animals store glycogen.
3. Definite shape (pear-shaped). Plant cells have definite shape.

Note: (The shape is changeable during the **eugenoid movement**).

## Euglena as an animal

1. Possesses eye spot which is sensitive to light. Although eye spot is present, it is not used for sight.
2. Possesses a flagellum for locomotion.
3. It carries out holozoic feeding in the absence of sun-light hence the presence of gullet to ingest food particles.
4. Contractile vacuole for osmo-regulation is present.
5. No cellulose cell wall but flexible living pellicle.
6. No central vacuole with cell sap. Vacuole is small and not central.

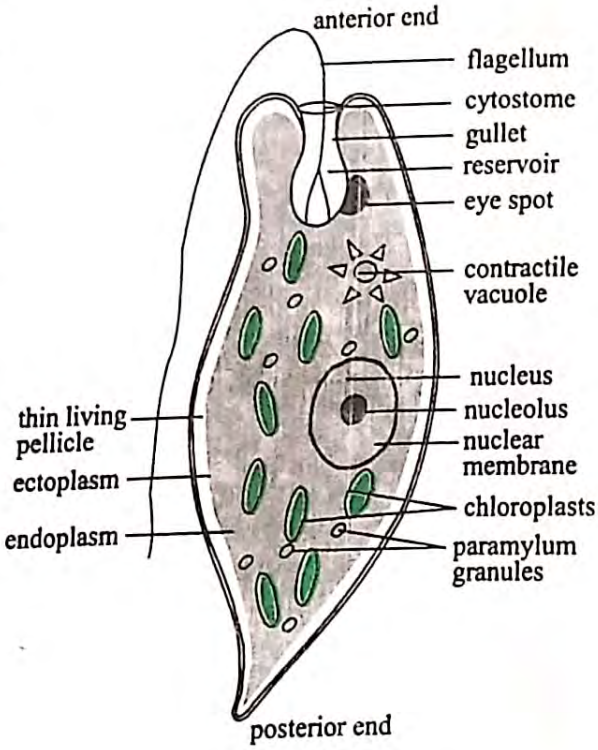



**Figure 2.31. Microscopic structure of *Euglena***

Table 4: Comparism of *Amoeba*, *Paramecium* and *Euglena*

| | *Amoeba* | *Paramecium* | *Euglena* |
|---|---|---|---|
| Shape | Shapeless | Slipper-shaped | Spindle or pear-shaped |
| **Food capture** | Food surrounded by pseudopodia. | Beating of cilia in oral groove, mouth and gullet | Photosynthesis, absorption through cell membrane. |
| **Site of food digestion** | Food vacuole. | Food vacuole. | Cytoplasm. |
| **Absorption of food** | From food vacuole by cyclosis and diffusion. | From food vacuole by cyclosis and diffusion. | From cytoplasm by cyclosis and diffusion |
| **Respiration** | Inward diffusion of oxygen ($O_2$) and outward diffusion of carbon (IV) oxide ($CO_2$). | Inward diffusion of oxygen ($O_2$) and outward diffusion of carbon (IV) oxide ($CO_2$). | Inward diffusion of oxygen ($O_2$) and outward diffusion of carbon (IV) oxide ($CO_2$). |
| **Excretion** | Via cell membrane. | Via cell membrane | Via cell membrane. |
| **Reproduction** | Binary fission. Multiple fission. | Binary fission, Conjugation. | Binary fission. |
| **Sensitivity** | Whole body responds to light, temperature, chemicals and contact. | Whole body responds to light, temperature, chemical and contact. | Eyespot sensitive to light. Whole body responds to temperature and chemicals. |
| **Movement** | Pseudopodia and cyclosis. | By beating of cilia. | By beating of flagellum and cyclosis (euglenoid movement). |

## PHYLUM: Coelenterata

## Representative: *Hydra*

### External and internal structures

***Hydra*** is cylindrical in shape and 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 stinging 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.

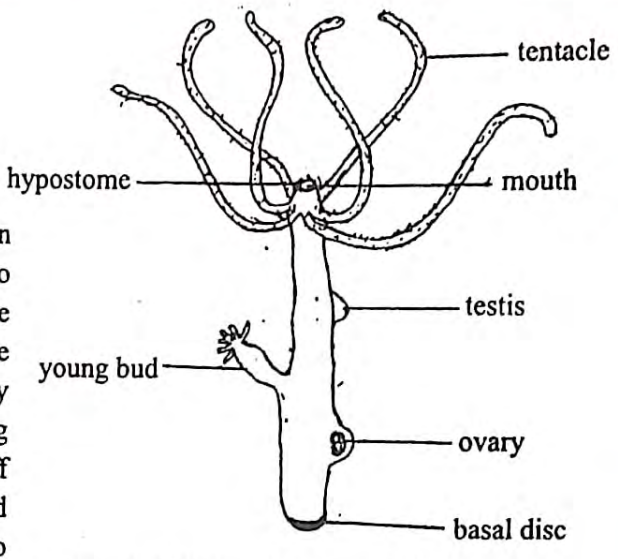



**Figure 2.32. External features of *Hydra***

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).

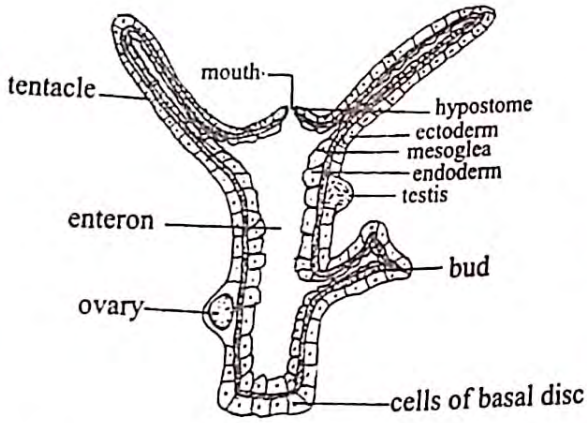



**Figure 2.33. Longitudial section of *Hydra***

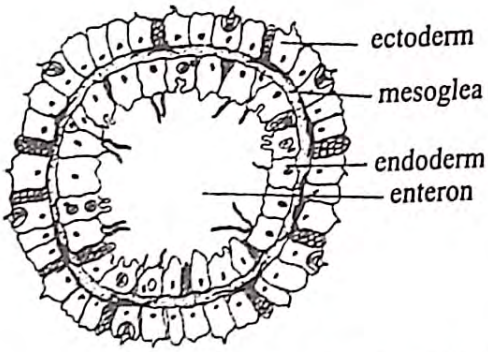



**Figure 2.34 Cross section through the body wall of *Hydra***

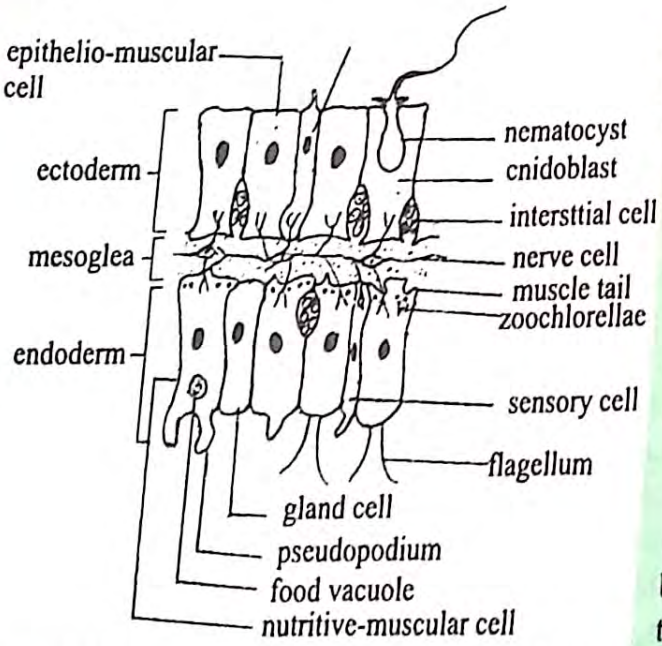



**Figure 2.35 Longitudial section of a portion of the body wall of *Hydra* to show different types of cells.**

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-musclar 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

A. They replace used up or damaged cells.
B. They can transform into cnidoblasts.
C. 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.

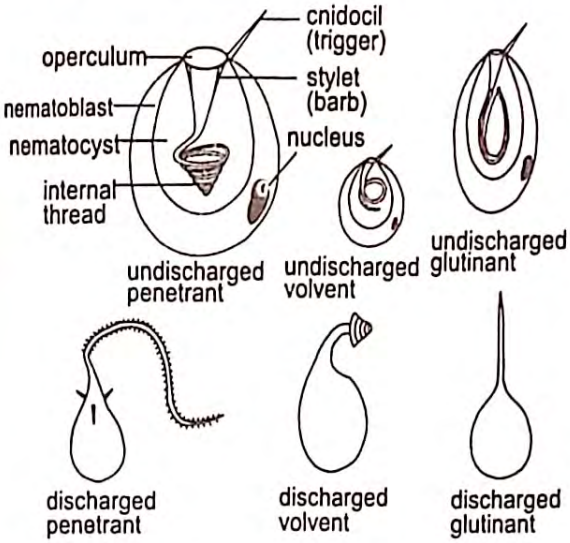



**Figure 2.36. Three kinds of nematoblasts of *Hydra*.**

**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.

1. **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.
2. **Interstitial cells**: These small cells are few in the endoderm and are found at the bases of the nutritive cells. Their function is to replace any other cells as the need arises.
3. **Gland cells**: Gland cells are found in between the nutritive cells. They secrete digestive enzymes for food digestion.

**Mesogloea**: The mesogloea is a jelly-like layer without cells of its own. It lies between the ectodermal and endodermal layers. Nerve cells of ectodermal and endodermal origin are found in the mesogloea. The mesogloea, apart from being a common layer to both ectoderm and endoderm also gives support and rigidity to the body, as it acts as an elastic skeleton.

**Sensory cells**: They have the same shape and functions as those of the ectodermal sensory cells.

**Nerve cells**: These cells are found in the mesogloea and are connected to the sensory cells of ectoderm and endoderm. Their nerve fibres interlock to form a diffuse network of nerves.

**PHYLUM: Platyhelminthes**

**Representative**: Tapeworm (*Taenia solium*)

**External features**

The tapeworm (*Taenia solium*) is a flat, ribbon or tape-like organism (Fig. 2.37). It has a minute knob-like scolex or head. The scolex has four muscular suckers on the sides. The tip of the scolex is elevated to become **rostellum** which is surrounded by hooks. A short "neck" connects the scolex with the rest of the body. The body consists of a series of proglottides of about 1,000 in number. Each proglottid is separated from the next by a transverse septum. The proglottides are identical in structure, but those at the posterior end are larger and more matured.

## Adaptations to parasitic life

1. The presence of four suckers supported by hooks in *T. solium* help to fasten the parasite onto the wall of the small intestine.
2. The long and tape-like body provides a large surface area for absorption of food (by diffusion) all over the body.
3. The tapeworm is not digested by the digestive juice of the host (man) because, it produces secretions which neutralise the effect of the digestive juice. The thick cuticle prevents it from being digested by the enzymes of the host.
4. It has a lower internal osmotic pressure than the fluid surrounding it and as a result the fluid is not removed from its body.
5. Respiration is mainly anaerobic. This is an important adaptive feature since oxygen is not easily available in the small intestine.
6. In the soil, the eggs are protected by shell membranes. The eggs ingested by the secondary host are released only in the small intestine to avoid being destroyed by the acid of the stomach.
7. A large number of eggs are produced to ensure that some survive to propagate the species.
8. The six hooks of the eggs help it to bore holes through the wall of the intestine.

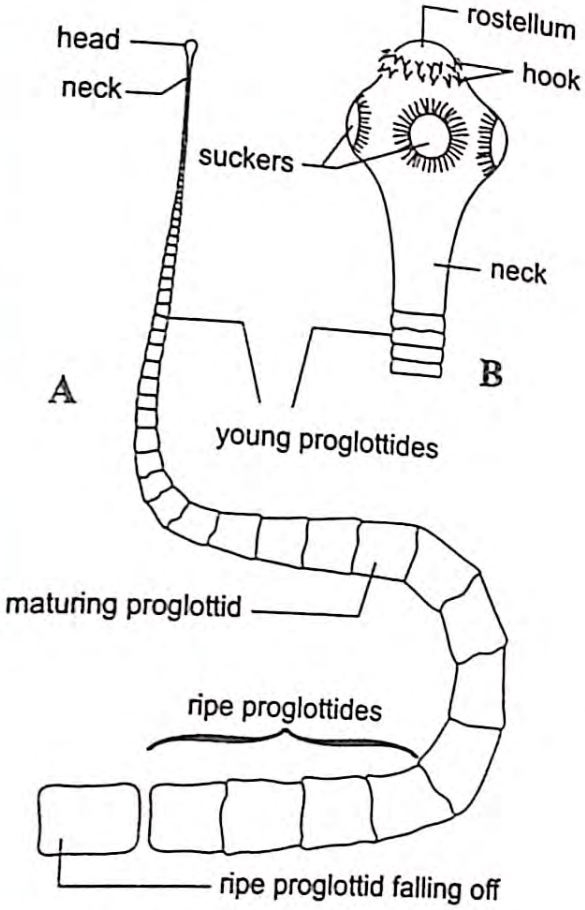



**Figure 2.37.** **(A) Diagram showing a tapeworm (B) Details of head or scolex**

## PHYLUM: Nematoda

### Representative: (*Ascaris lumbricoides*)

*Ascaris lumbricoides* (common roundworm) is one of the intestinal parasites commonly found in man especially among children.

**External features.** Round worms have two separate sexes - a male and a female. The female is about 20-30cm long while the male is about 15-20cm.

*Ascaris lumbricoides* is pointed at both ends and whitish in colour. The body is covered with tough elastic and transparent cuticle, with four brownish or whitish lines (one dorsal, one ventral and two lateral) extending through the length of the body. The head bears three lips, one dorsal, two ventrolateral and are provided with papillae.

The male can be distinguished from the female by its smaller size and by the sharply curved tail which bears copulatory spicules. The tail end of the female is straight. The anus occurs about 16cm from the tail.

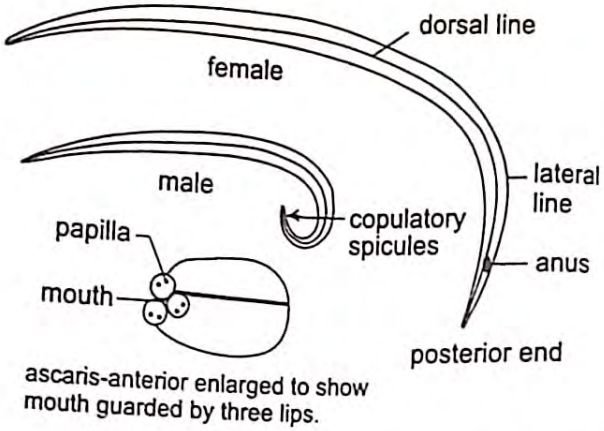



**Figure 2.38.** **External features of male and female** *Ascaris lumbricoides*

For the **life history, prevention** and **treatment** see **pages 457-458.**

## PHYLUM: Annelida

### Representative: Earthworm

### External features

The body of an earthworm is cylindrical, elongated and bluntly pointed at both ends with the head being more pointed. The length is about 12 to 13cm and the body is divided into about 115 to 170 segments by transverse grooves. The skin is moist and soft and is covered by transparent thin cuticle. The dark red colour of the skin is due to the presence of blood vessels below the skin. The dorsal surface is darker than the ventral side. The mouth is situated in the first segment overhung by a fleshy lobe called **prostomium** and the anus is located on the last segment. A structure like a saddle, slightly whitish, glandular and smooth called **clitellum** is located on segments 13 to 18 (depending on the species). The clitellum secretes materials for making **cocoons** containing eggs. On each segment except the first and last are two pairs of **chaetae** (setae) which project out slightly on the ventral and lateral surfaces. The chaetae function as a **holdfast** when the worm is burrowing or moving on the surface of the ground.

## Openings

Besides the mouth and anus, other openings are:

1. Opening of the paired sperm ducts on segment 15 easily recognized as swollen lips on the ventral surface.
2. Opening of the oviducts on the ventral surface in segment 12.
3. Openings of the seminal receptacles in the grooves between segments 9 and 10, and 10 and 11.
4. Excretory openings located ventro-laterally on each segment except segments 1 to 3 and the last segment.
5. Dorsal pores, each located on the middorsal line at the anterior edge of each segment. The dorsal pores start from segments 8 to 9 to the last segment.

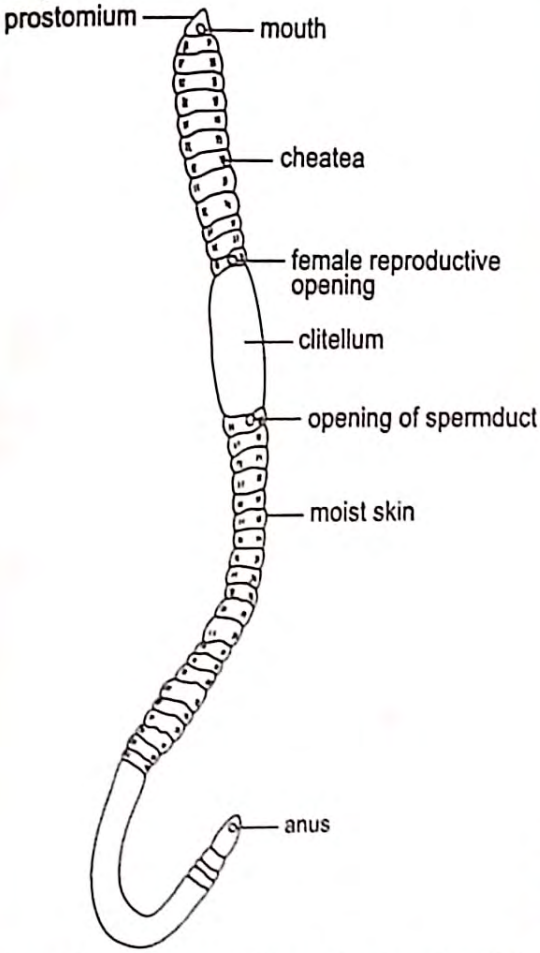



**Figure 2.39. External features of an earthworm (ventral view)**

# PHYLUM: MOLLUSCA

## Representative: Giant land snail (*Achatina sp*)

## External features

The body is soft and consists of the head, large muscular foot and visceral mass (hump).

**Head:** The head is fused to the foot anteriorly. It is recognized by the presence of two pairs of **retractile tentacles**, the anteriorly placed lower **shorter tactile tentacles** and posteriorly placed longer upper or **occuliferous tentacles**. At the tips of the longer upper tentacles are **black eyes** used for sight. The lower shorter tentacles are sensory in function.

The ventral mouth is equipped with three lips.

**Foot:** The foot is muscular, soft long and wide. It is always kept moist by its own secreted slime from the **mucus gland**. A **genital pore** occurs near the mouth. Respiratory and anal pores occur on the mid upper region of the foot.

**Visceral mass:** The visceral mass is coiled in similar way as the shell that houses it. The visceral mass is soft and non-muscular and permanently inside a coiled shell made up of calcium carbonate.

The whole body of a snail can be withdrawn into the shell.

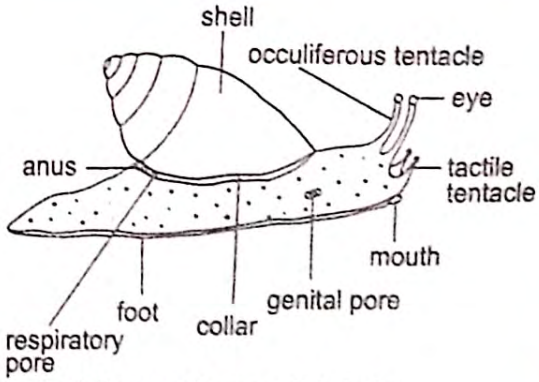



**Figure 2.40. External features of *Archatina*.**

## Phylum: Arthropoda

The phylum Arthropoda is represented by five major classes namely, **Crustacea, Chilopoda, Diplopoda, Arachnida** and **Insecta.**

# Class: Crustacea

e at at i v e : Ri e r p r a w n ( *P a l a e m o n s p*)

## External features

The body which is elongated, narrow, segmented is about 6 to 8cm long and is covered with hard exoskeleton made up of chitin and calcium carbonate.

The body is divided into two main parts: cephalothorax and abdomen.

**Cephalothorax**: The head and thorax are fused together to form a single structure called **cephalothorax**. The cephalothorax is dorsally and laterally covered with a very hard, thick and shield-like exoskeleton called **carapace**. The anterior part of the carapace is modified into a saw-like and pointed structure called **rostrum**. On each side of the rostrum is a **stalked compound eye**. Just below the stalked eyes are two pairs of **antennae**. The first short pair just below the eyes is called **antennule**. Each antennule which is divided into two branches anteriorly, is used for smelling, hearing, balancing and also sensitive to touch. The second pair of antennae which lies below the first pair is very long and unbranched. It is sensitive to touch. The thoracic section of the cephalothorax has eight pairs of jointed appendages. The first three pairs are **maxillipeds** or "**Jaw feet**". They help to hold food material during feeding. The remaining five pairs are called **walking legs** with the first two pairs ending in **claws**. The second pair of the walking legs which is called **chela** (cheliped) is enlarged, massive and ends up in powerful **claws** for performing the functions of grasping food and weapon of offence. At the base of the walking legs are **gills** used for respiration.

**Abdomen**: The abdomen has six segments with the first five segments bearing paddle-like structures called **swimmerets** which are used for swimming. The sixth segment ends in triangular flat plate called **telson** and two pairs of broad flat and fan-like structures called **uropods**. When prawn encounters danger, the abdominal muscles suddenly pull the sixth segment forward and the animal shoots backward out of danger. Under the telson is the **anus** used for defaecating.

Scanned with CamScanner

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segments are three pairs of organs called **spinnerets** used for silk spinning. The spinnerets open to the surface through small tubes through which the silk passes out. As the silk passes out and comes into contact with atmospheric air, it becomes hardened and thus used for the construction of **spider web**. The anus is situated just below the spinnerets.

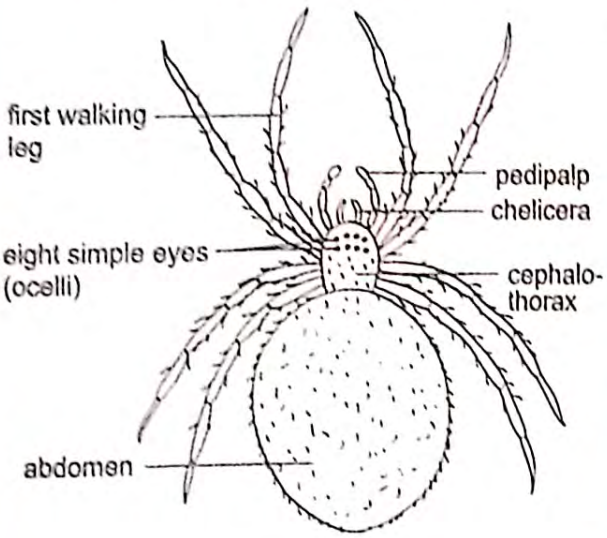


**Figure 2.44. External features of a spider**

## Class: Insecta

### Representative: Cockroach (*Periplaneta americana*)

### External features

The body which is about 4cm long in the adult is dorsoventrally flattened and olive brown in colour. It is divided into three distinct parts - **head, thorax** and **abdomen**. Covering the whole body is the hard exoskeleton (cuticle) made of chitin.

**Head:** The head is relatively small compared to the thorax and abdomen. It is oval in shape and is attached to the thorax by a soft area called **cervicum**. The head carries a large pair of **compound eyes**, one on each side of the head. In front of each compound eye is a slender , whip-like and numerously segmented antenna. Antennae are sensitive to touch and used for perceiving odour and vibrations.

A little below the antennae are the mouth parts, consisting of **labrum** (upper lip), a **pair of mandibles** (jaws) **first maxillae, second maxillae** and **labium** (lower lip).

**Labrum:** This is a wide flap which covers the upper mouth parts. Nerve endings which are sensitive to different chemicals are contained in the inner surface of labrum.

**Mandibles (first pair of jaws):** Two mandibles, each on one side of the mouth, have their outer edges toothed, serrated or saw-like. They are used for cutting and crushing food.

### First maxillae (second pair of jaws)

Lying below the mandibles are the paired maxillae (singular-maxilla). The inner edge of each maxilla is serrated or saw-like, while the outer edge is modified into long and jointed structure called **maxillary palp**. The serrated edges of the maxillae are used together with mandibles to cut and crush food and also helps to direct food into the mouth. The maxillary palps contain nerve endings and are therefore sensitive to chemicals, and touch. Together with other sensory areas such as antennae they are able to detect food.

**Second maxillae:** The second maxillae have also their inner edges serrated and outer edges modified into sensory and jointed palps. They perform the same functions as first maxillae.

**Labium (Lower lip):** The labium is a wide flap. It is formed from the joining of the two bases of the second maxillae.

**Thorax:** The thorax contains three segments called **prothorax, mesothorax** and **metathorax**. The prothorax is covered by a dorsal plate. Each segment bears a pair of jointed legs on the ventral side. Each leg is made up of **coxa, trochanter, femur, tibia** and **tarsus**. The stout coxa is attached to the body, the trochanter which is very short joins the coxa to the femur. The femur with two rows of small spines at the posterior side joins the slender tibia. The tibia is bordered by three rows of spines. The four-segmented **tarsus** is attached to the tibia. The last segment of the tarsus ends in **a pair of claws**. The dorsal side of the mesothorax and metathorax bear two pairs of wings. The first **pair of wings** (forewings or tegmina) which are dark brown in colour are attached to the mesothorax while the second pair of wings which are light brown in colour are attached to metathorax. The forewings are not used for flight. The legs of cockroach are adapted for running and climbing.

**Abdomen:** The abdomen consists of **eight visible**

**segments** when viewed from the dorsal side but when viewed ventrally it contains six segments. Each abdominal segment is made up of dorsal covering called **tergum** and lower covering called **sternum**. Two small openings called **spiracles** occur, one on each side of the sternum. The last abdominal segment bears small antenna-like structures called **cerci** (singular-cercus) one on each side. The cerci are sensory in function. In male cockroach, just below each cercus is a needle-like and antenna-like structure called **anal style**. In the female, just below the cerci are boat-shaped plates called **ovipositors**, one on each side.

### How cockroach is adapted to its environment

1. The body is flat. This enables it to move about in between small cracks, thereby making it difficult to be destroyed by its enemies.
2. The body is covered with exoskeleton which prevents it from dessication.
3. It has a well developed toothed pair of mandibles for tearing hard food.
4. The pair of sensitive antennae is used for detecting vibrations and smell.
5. The three pairs of jointed legs are used for fast running and quick escape from its enemies.
6. The wings are used for a short flight when there is an emergency.
7. The spiracles and tracheae are effective organs of respiration.
8. The nocturnal habit of the cockroach helps it to avoid most of its enemies in the day time.
9. The dark-brown colour gives it an effective camouflage in its hiding places.

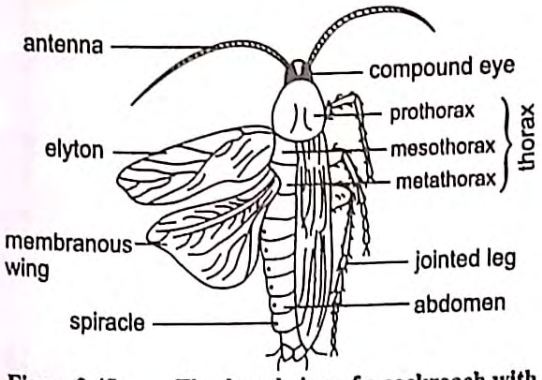


**Figure 2.45. The dorsal view of a cockroach with a pair of its wings spread out to illustrate its external features.**

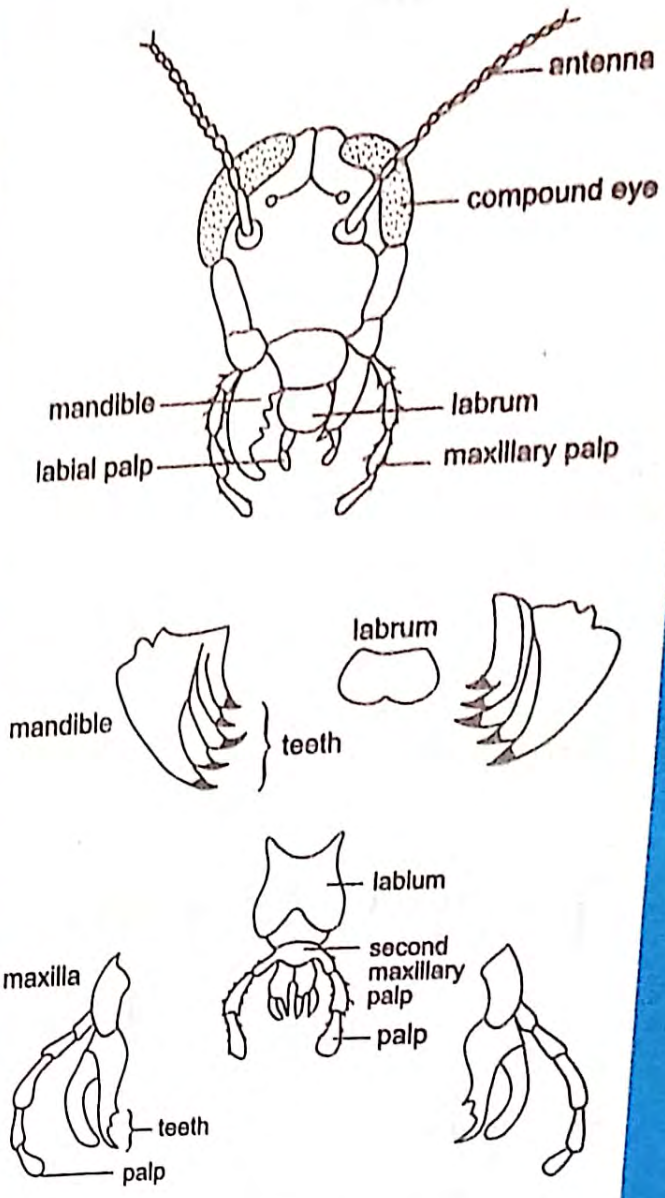


**Figure 2.46. The mouth parts of a cockroach.**

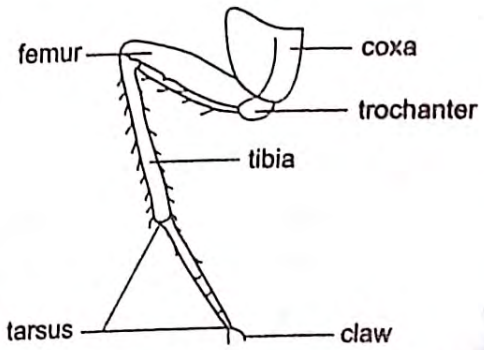


**Figure 2.47. Leg of a cockroach.**

## Characteristic differences among the classes of Arthropoda

| Features | Crustacea | Insecta | Chilopoda | Diplopoda | Arachnida |
|---|---|---|---|---|---|
| Body division | Two (Cepha-thorax and abdomen) | Three (head, thorax and abdomen) | Two (distinct head with other body segments similar) | Two (distinct head with other body segments similar) | Two (cephalo-thorax) ie. head and thorax not clearly separated and abdomen |
| Antennae | Two pairs | One pair | One pair | One pair | No antennae |
| Eyes | A pair of compound eyes carried on stalks | A pair of compound eyes and simple eyes | A pair of compound, simple or absent | A pair of compound, simple or absent | Four pairs of simple eyes |
| Mouth parts | Usually three pairs of mouth-parts | Usually three pairs of mouth parts | One pair of mouth parts (mandibles only) | One pair of mouth parts (mandibles only) | No true mouth parts |
| Legs | Five pairs of legs with the first pair modified for feeding | Three pairs of legs on the thorax only | Identical one pair of legs per segments | Identical two pairs of legs per segment | Four pairs of legs on the cephalo-thorax |
| Wings | Absent | Present | Absent | Absent | Absent |
| Structures for gaseous exchange | Gills | Tracheae | Tracheae | Tracheae | Lung books, gill books or tracheae |
| | Examples: Crab and lobster | Example: Cockroach, housefly and mosquito | Example: Centipede | Example: Millipede | Example: Spider, Scorpion. |

# Sub-Kingdom: VertebrataClass: Pisces (Fish)

**Representative:** *Tilapia zilli*

## External features

The body: The body of *Tilapia zilli* is laterally flattened and stream-lined shape. This allows for easy movement through water. The body is divided into three parts namely: **head, trunk** and **tail.** There is no neck to interfere with movement. The skin is covered with cycloid scales except the head. The skin glands secrete mucus which covers the entire body and helps for easy movement in water, and also protects the fish from attacks of parasitic bacteria, fungi, protozoans, and leeches.

**Head:** The head is scaleless and tapers towards the mouth to reduce resistance as it moves through the water. The mouth is moderately large and terminal in position. The immoveable tongue situated between the two lower jaws is fastened to the floor of the mouth. The upper and lower jaws bear fine teeth. On the top of the head, a little above the mouth lies a pair

of openings called **nostrils**, each on either side of the head. The nostrils are used for smell and not for breathing. Just above the nostrils is a pair of large eyes, each on either side of the head. The eyes lack eyelids hence they do not close. The pupils of the eyes are large so as to allow sufficient light to the eyes for better sight. Further from the eyes, on each side of the head is a crescent-shaped bony plate called **operculum** which covers and protects the gills beneath it. The two opercula also assist in external respiration by their opening and closing thus allowing oxygenated water to pass through the gills.

**Trunk**: The trunk which is widest is completely covered with cycloid scales except the genital organ, anus and fins. The anus is situated in front of the anal fin and very close to the genital organ. The trunk tapers to the tail and bears the fins. There are two types of fins: these are **paired** and **unpaired fins**. All fins are strengthened with fin rays (bony structures). The paired fins are the **pectoral** and **pelvic fins** while the unpaired are the **dorsal**, **anal** and **tail** (caudal) fins. The unpaired tail fin is not attached to the trunk but to the tail.

## Paired fins

**Pectoral fin**: Each pectoral fin situates just behind the lower side of the operculum.

**Pelvic fins**: The pelvic fins lie on the belly under the pectoral fins. The pectoral and pelvic fins are used for slow movement. Their movements when the fish is not in motion help to bring fresh oxygenated water and are also used for balancing and steering. They also help to act as breaks.

## Unpaired fins

**Dorsal fin:** This lies on the top of the trunk a little further from the posterior end of the anterior portion of the tail. The dorsal fin is made of spiny anterior part and soft-rayed posterior parts. The spiny anterior part contains 14 to 16 sharp spines connected to each other by membrane. The soft-rayed posterior part contains 10 to 13 soft branched rays. The dorsal fin is used as a stabilizer that keeps the fish steady when swimming. It is also used as a weapon of defence. When the dorsal fin is raised upward, the fish looks bigger, thus frightening its predator. The raised spines make the fish difficult to be swallowed by predators.

**Anal fin**: The anal fin lies just behind the anus. It is made of 3 spines and 8 to 9 short branched soft rays. It acts as stabilizer and helps to maintain a straight course during swimming.

**Tail**: The posterior ends of dorsal and anal fins is the tail. The fleshy part of the tail is called **caudal penduncle**. The posterior caudal penduncle carries a fan-shaped unpaired **caudal fin**. The caudal fin is used for steering during swimming.

**Lateral lines**: On each side of the body are two unequal lateral lines. One is dorsal to the other. The dorsal lateral line runs from the anterior upper part of the operculum to the middle of caudal penduncle while the short ventral lateral line runs behind the end of the pectoral fin to the end of caudal penduncle. Lateral line is a row of scales with canals running from the posterior part of the head to the end of caudal penduncle. These canals contain nerve endings. The lateral line acts as a sensory organ which dectects vibrations under water and changes in water pressure.

**Colour**: The dorsal and sides of the body are dark green with 6 to 8 less distinct grey bars. The ventral side (belly) is silvery white. This type of colouration makes it difficult to be seen by predators above and below.

**Adaptations of fish to aquatic environment have been treated. (See page 560).**

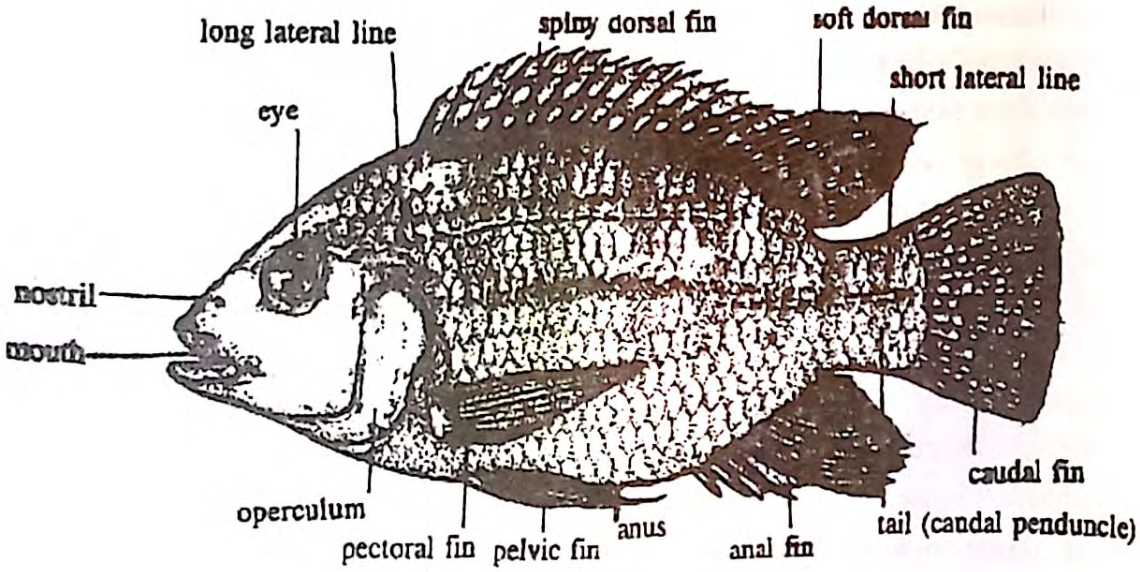


Figure 2.48. External features of *Tilapia zilli*

## Class: Amphibia

**Representative: Toad** (*Bufo regularis*)

**External features**

The body is divided into head and trunk. There are no neck and tail to interfere with movement. It is oval in shape and stout. It is about 8 to 9cm long and 4 to 4.5cm wide. The body is covered with a skin which is moist, warty and loosely attached to the body. The skin is greyish brown in colour with irregular dark patches on the dorsal sides and limbs. The ventral part of the toad is lighter in colour than the dorsal side.

Head: The head is blunt and flattened with a wide terminal mouth. On the margin of the upper jaw are fine "teeth"; and on the roof of the mouth are two patches of vomerine teeth. A thick, sticky tongue is attached to the front of the lower jaw. On the top of the head, a little distance from the mouth are two nostrils. Just behind the two nostrils are two spherical, large, and bulging eyes. Each eye has an upper and a lower eye-lid. A third transparent eyelid called **nictitating membrane** joins the lower eye-lid. Behind each eye, on each side of the head is a dark round patch of skin called **tympanic membrane** or **eardrum**. Just behind the eardrum is a glandular patch of skin called **poison-gland**.

**Trunk**: The trunk has two pairs of jointed limbs - a pair of forelimbs and a pair of hindlimbs. The forelimbs are short and consist of upper arm, fore arm and hand (fore foot). The hand (fore foot) bears four inturned digits (fingers) with rounded tips. The hindlimbs are longer than the fore limbs, and consist of **thigh, shank** and **hind foot**. The hind foot has five long slender **webbed digits**. At the posterior terminal lies the **cloaca** which functions as **urinary, reproductive** and **anal** opening.

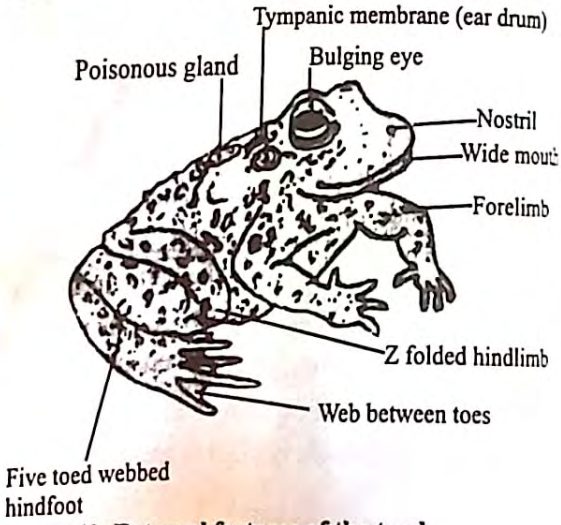


Figure 2.49. External features of the toad

**General adaptations of toad have been treated. (see page 372).**

## Class: Reptilia

## Representative: Rainbow lizard (*Agama agama*)

### External features

The body is elongated and is divided into **head, neck, trunk** and **tail**. The body is covered with a dry scaly skin.

**Head:** The head is triangular in shape when looked at from above. The mouth is wide and terminal with small uniform (homodont) teeth on both upper and lower jaws. A sticky and broad tongue is on the floor of the mouth. A little distance from the snout is a pair of nostrils. Further back from the nostrils are the two eyes. The eyes are protected with nictitating membranes. Just behind the eyes, is a pair of tympanic membranes which are semi-transparent. The gular fold (skin fold) is below the chin. The head is reddish brown in male while in female it is brown with green spots.

**Neck** : There is a short neck connecting the head and the trunk. Spiny posteriorly pointed single row of scales called **nuchal crest** is found on the mid-line of the male's neck. The neck is also reddish brown in male and brownish in female.

**Trunk:** The trunk carries the limbs. The underside of the hindlimbs is a transverse opening called **vent** with a row of thickened scales called **pre-anal pad.** The trunk carries the fore and hind limbs.

**Limbs:** The fore and hind limbs end in five digits with strong curved sharp claws. The fore-limbs are smaller and shorter than the hind-limbs. Fore-limbs are placed more or less at right angles to the body.

**Tail:** The tail extends from the posterior end of the trunk. It is relatively long and tapers from the base. It is divided into base, middle and tip. The base of the tail is bluish white, the middle is orange colour while the tip is black. The tail is covered with large spiny scales. The female is uniformly coloured with light brown scales.

### How a lizard is more advanced than a frog evolutionarily.

1. Lizard has a dry and scaly skin, an effective adaptation to life on land while frog has moist, soft and scaleless skin, an adaptation to life in water or wet environment.
2. Fertilization is internal with laying of leathery and soft eggs which resist desiccation on land. In frog, fertilization is external with laying of gelatinous covering for its eggs, an adaptation to aquatic life.
3. Lizard has well developed limbs with five toes ending in claws for climbing, digging holes for laying of eggs and running on land. A frog has limbs with webs, an adaption for swimming in water.
4. Lizard respires by lungs only while frog respires by skin, mouth and lungs (respiration through the skin and mouth are primitive features).

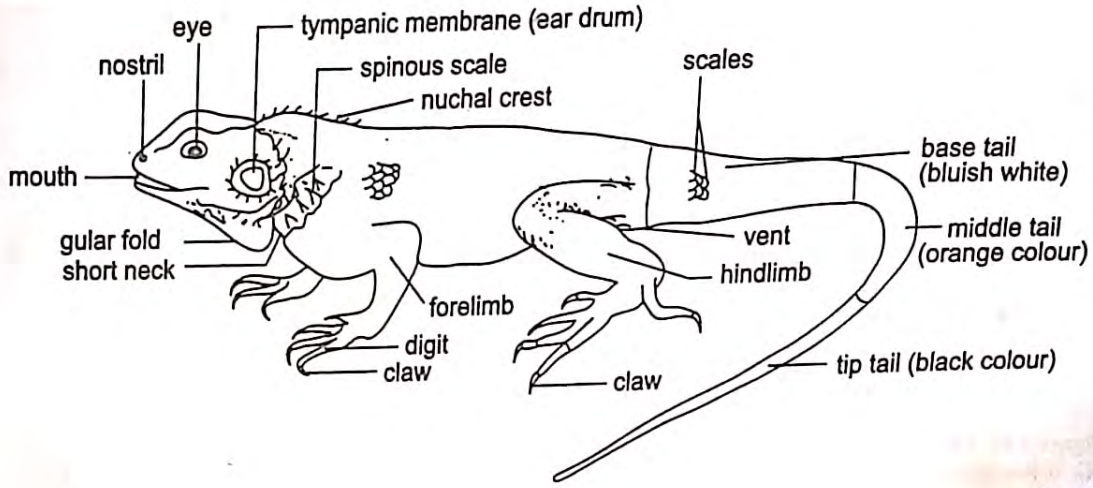


**Figure 2.50. External features of male rainbow lizard**

## Class: Aves

**Representative:** Pigeon *(Columba livia)*.

### External features

The body is divided into **head, neck, trunk** and **tail**. The body is streamlined and boat-shaped, and covered with white feathers except the feet and the beak. It is about 30cm long.

**Head**: The head is small and round. The lower and upper jaws are modified into strong pointed **beak** or **bill**. On the upper portion of the upper jaw, are two small slits called **nostrils**. On each side of the head is a large and round eye.

Each eye has a lower and an upper **eyelid** and a **nictitating membrane** which can be drawn to cover the eye ball. The nictitating membrane helps to keep the eye moist and clean. Lying behind each eye is an ear opening which is hidden with tufts of feathers.

**Neck**: The neck is fairly long and flexible.

**Trunk**: The trunk is compact and oval in shape. The trunk carries Z- shaped fore-limbs (wings) and hind-limbs (legs) on each side of the body. The slightly bent legs are covered with scales. Each foot has four digits, one pointing backward and the other three forward with each digit ending in a strong and **sharp claw**.

**A cloaca** ( a common opening for both excretory wastes and reproductive cells) lies on a little distance from the legs on the ventral side.

**Tail**: The tail is short. On the dorsal side of the tail is a small **preen** or **oil gland** used in oiling the feathers. The tail has tail feathers.

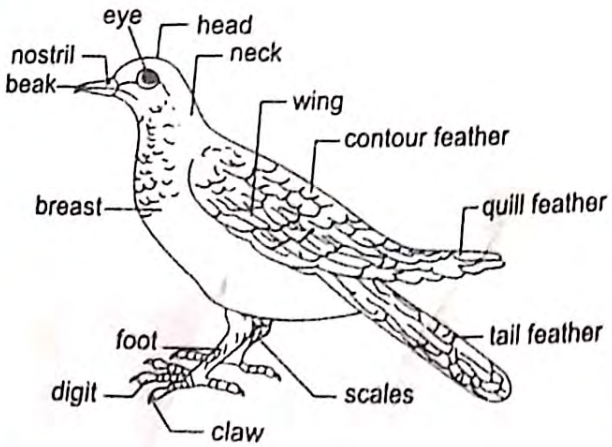


**Figure 2.51. The external features of a pigeon** *(Columba livia)*.

### Feathers

There are five kinds of feathers (Fig. 2.52). There are **quill, contour** (covert), **down feathers**, **filoplumes** and **bristle feathers**. The quill feathers are large, flat and have barbs to form smooth complete surface. They over-lap each other and have unequal vanes.

**Quill feathers**: These are found on the wings and tail. These feathers are used for flying and steering.

**Contour or covert feathers**: They are smaller than quill feathers. They help to keep the body warm.

**Down feathers**: They are small, and soft. They are found between the contour feathers. They help to keep the bird warm.

**Filoplumes**: They are small and hairlike, and are found scattered all over the body. They have unknown functions.

**Note:** Pigeons have different colours, some are grey, while others are white and grey, (but the one studied by the author is white).

**Bristle feathers**: These are small specialized hair-like feathers with **rigid rachis** and with or without barbs at their tips. They are around the eyes, nostrils and on the head. They help to prevent foreign bodies from the eyes and nostrils.

**Differences between the external features of an adult toad and a bird (eg. Pigeon).**

| | Toad | Pigeon (Bird) |
|---|---|---|
| 1. | No beak | Beak present. |
| 2. | Large and bulging eyes. | Small and non bulging eyes. |
| 3. | Wide mouth. | Mouth not wide. |
| 4. | No neck. | Long flexible neck present. |
| 5. | No feathers, skin is warty and moist. | Feathers present on the skin. |
| 6. | Flattened head. | Oval head. |
| 7. | No wings. | Wings present. |
| 8. | No tail. | Tail present. |
| 9. | No scales. | Scales present on legs. |
| 10. | Hindlimbs not webbed. | No webbed digits. |
| 11. | Digits not clawed. | Digits clawed. |

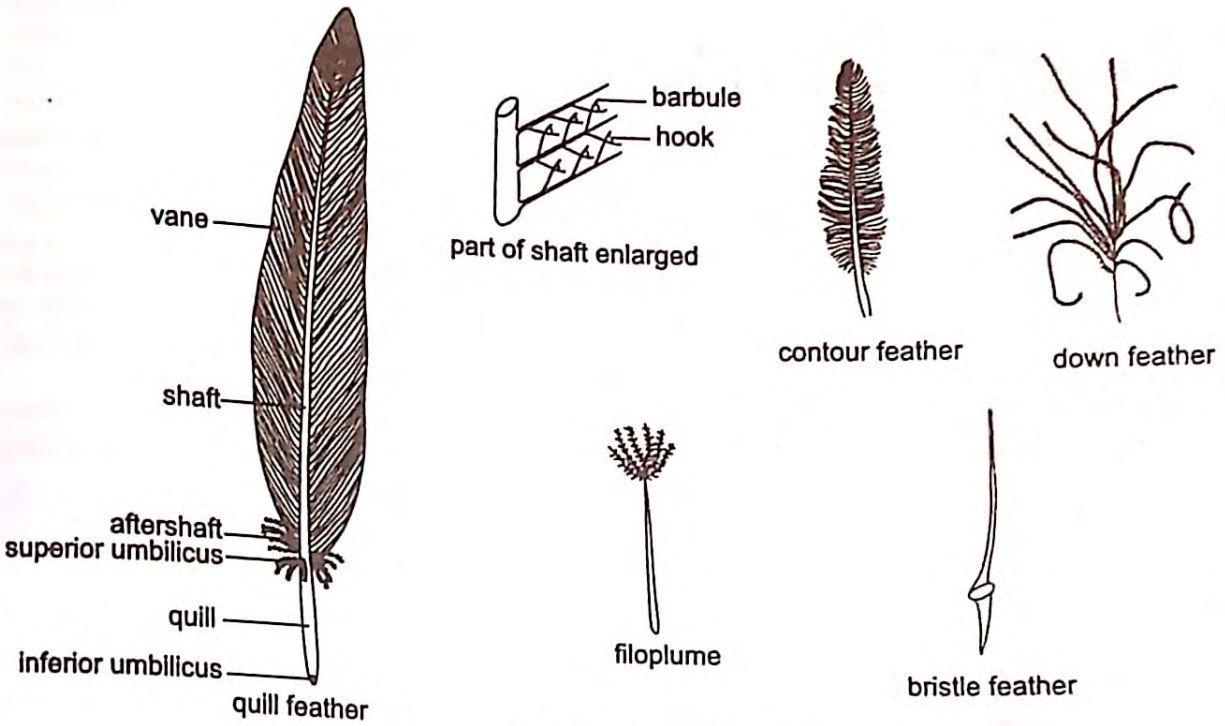


**Figure 2.52. Different kinds of feathers.**

## Class: Mammalia

## Representative: *(Rattus rattus)*

## External features

The body is long and slim but broader towards the posterior part. The entire body is covered with greyish dark hairs. The body is divided into four main parts, namely **head, neck, trunk** and **tail**.

**Head:** The head is pointed and consists of mouth, nose, eyes and external ears. The mouth is bounded by an immovable upper and movable lower jaws. Both jaws are bounded by upper and lower lips. The

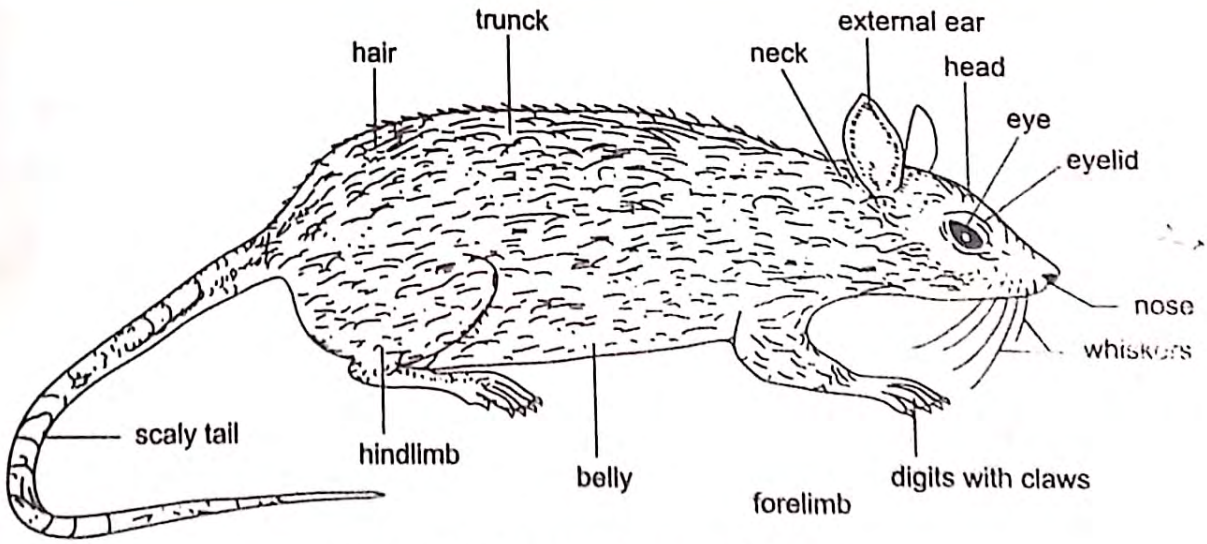


**Figure 2.53. External features of a black rat.**

[illegible]

3. [illegible] clearly a labelled diagram of (a) a bacterium, and (b) a filamentous alga. (c) State [illegible] between spirilla and a coiled fungus.

4. (a) [illegible] the structure of puccinia (or any other mould fungus).
   (b) [illegible] the structure of puccinia (or any other mould fu[illegible]
   (c) Why is [illegible] regarded as a plant?
   (d) Why is [illegible] considered to be an orga[illegible] and enlarge[illegible] characteristic of

5. (a) What are the characteristic[illegible] of organisms?
   Give two examples of ea[illegible]
   (i) algae
   (ii) fungi
   (iii) mosses
   (iv) ferns
   (v) flowering p[illegible]

   (b) State four diff[illegible] erates and flowers and give example of [illegible] Group.

6. (a) Wr[illegible] of the following groups of organisms:
   G[illegible] roup.

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[illegible]

[illegible]

[illegible]

# 3

# THE CELL

All biologists, after many years of intensive work, believe that all living things are made up of cells. Some organisms that live independent life are one-celled or non-cellular. *Amoeba, Paramecium, Euglena* and *Chlamydomonas* are examples of one-celled organisms. The bodies of many-celled organisms (multicellular) are made up of many different cells such as *Hydra*, earthworm, bird, elephant, man and orange tree.

**A cell is the basic structural and functional unit of life.** The **protoplasm** is the organized complex material of which living cells are made. All characteristics of living things are possessed by the protoplasm.

## The cell theory

The cell theory states as follows:

1. All living things are made up of a cell or cells.
2. The cell is the structural and functional unit of all living things.
3. New cells arise from pre-existing cells by cell division.

**The theory of the cell was propounded by the following scientists.**

## Robert Hooke

In 1665, Robert Hooke, a British scientist, examined thin slices of cork tissue under the compound microscope and found that the cork consisted of many neatly arranged little chambers or cavities. Since each chamber was enclosed by walls similar to cells of honeycombs, he named the chambers cells. Hooke did not, however, realise that each empty chamber once had living contents since he did not examine a thin slice of a living plant or animal.

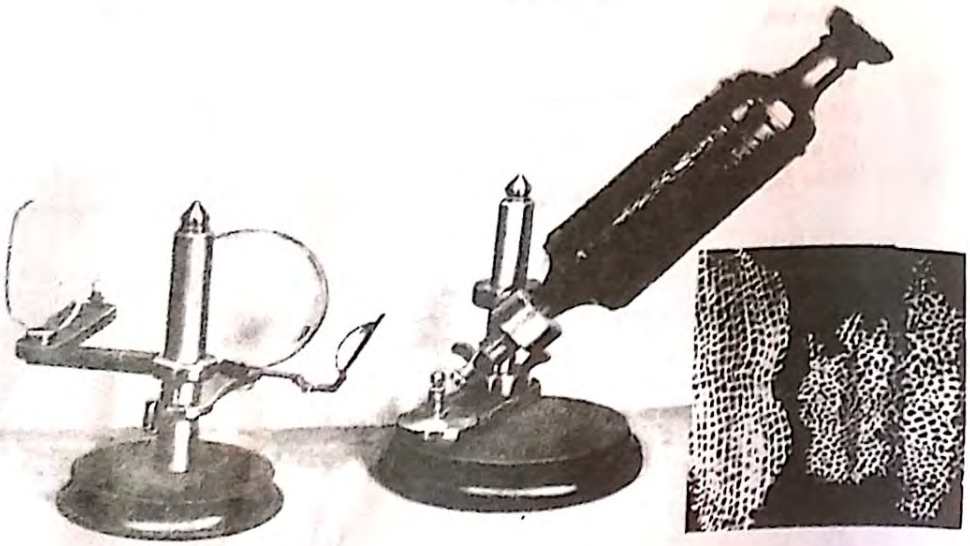


**Fig. 3.1. Robert Hooke's microscope and drawings of the cellular structure of the cork cells, 1665. (Courtesy Bettman Archive)**

## Dujardin

In 1835, Dujardin, a French biologist, examined thin slice of living plants under much improved microscope and discovered that the cells have content. He named the content **sarcode**, later named **protoplasm** by Purkinje in 1839 and Von Mohl in 1846.

## Mathias Schleiden

In 1838, Mathias Schleiden, a German Botanist, carried out an extensive study on the structures of plants and concluded that plants were composed of cells.

## Theodor Schwann

In 1839, Theodor Schwann, a German Zoologist examined bits of animals under a microscope and observed that animals were composed of cells.

## Ultrastructure of Cells

Electron microscope has revealed many structures that were invisible under light microscope. Biologists have established that both plants and animals are composed of cells. And basically both plants and animals are similar. The study of a cell is called **cytology**. Cell is composed of cytoplasm and nucleus (protoplasm).

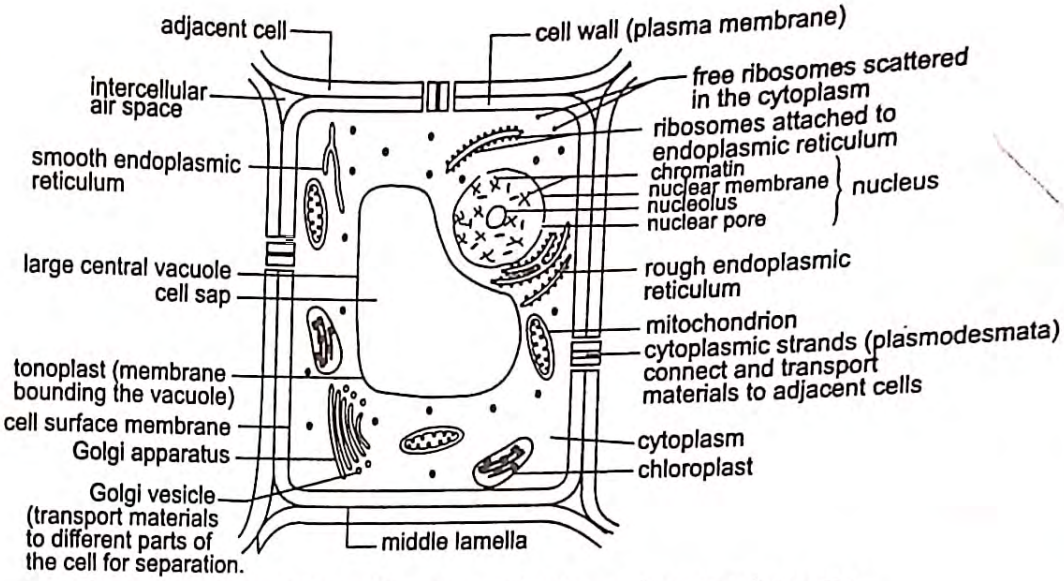



**Figure 3.2. A typical plant cell as observed under an electron microscope.**

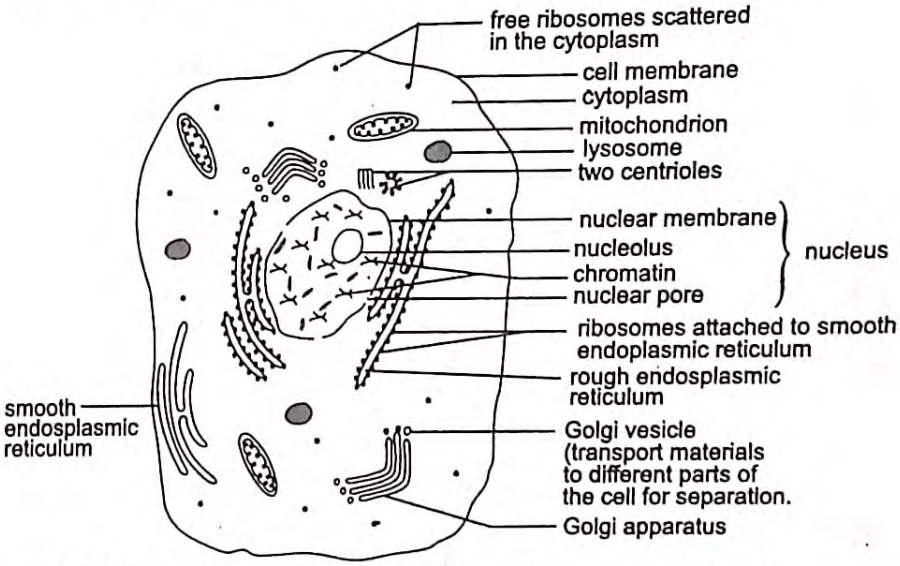



**Figure 3.3. A typical animal cell as observed under an electron microscope.**

## Structure of cytoplasm

All the living materials outside the nucleus are classified as cytoplasm. The cytoplasm is semi-fluid and consists of endoplasmic reticulum, mitochondria, lysosomes, ribosome, Golgi apparatus, centrosome and vacuoles, all bounded by the cell membrane or plasma membrane.

## Functions of cytoplasm

1. All the living substances including nucleus are suspended in the semi-fluid cytoplasm.
2. The streaming of the content of the cytoplasm brings about interchange of materials between the organelles within the cytoplasm.

## Cell wall

The cell wall is the non-living outer boundary of the cell made up of cellulose. It has tiny pores or pits through which nutrients pass from one cell to another. ***Cell wall is absent in animal cells.***

## Functions

1. It gives rigidity to cell and the plant as a whole.
2. It allows free passage of materials.

## Cell membrane (plasma membrane)

This is a thin and flexible living layer that surrounds the entire cytoplasm and separates the cell from neighbouring cells.

## Functions

1. It regulates the movement of substances in and out of the cell.
2. It protects the cytoplasm.
3. It delimits the content of the cytoplasm.4. Forms a barrier between the cell and its surrounding.

## Endoplasmic reticulum

Endoplasmic reticulum is a system of canals found abundantly in the cytoplasm. It is believed that the organelles are interconnected by endopla-smic reticulum. If ribosomes are attached to the endoplasmic reticulum, it is called rough endoplasmic reticulum and if no ribosomes are attached, it is called smooth endoplasmic reticulum.

## Functions

### Rough endoplasmic reticulum

1. They help in the formation of enzymes and protein.
2. They transport metabolic products within cytoplasm or between the cytoplasm and nucleus.
3. They assist in the formation of nuclear membrane during nuclear division.
4. They interconnect the organelles of the cell.
5. The rough endoplasmic reticulum provides surface for the attachment of ribosomes.

### Smooth endoplasmic reticulum

1. It makes lipids (fat molecules).
2. The enzymes of the smooth endoplasmic reticulum in the liver detoxificate drugs such as morphine and codeine.

### Ribosomes

These are minute and roughly spherical organelles found in large number attached to the endoplasmic reticulum or suspended in the cytoplasm. They contain roughly equal amounts of RNA and protein. The RNA is called ribosomal RNA (rRNA).

### Functions

They make proteins by joining amino acids together. They are the sites for protein synthesis.

### Mitochondria (singular: mitochondrion) - the cellular "power house"

These are tiny rod-shaped bodies or granules in the cytoplasm. They are more concentrated in very active cells such as the liver cells.

### Functions

1. They are the centre of cellular respiration in which food substances are oxidized to release energy for the activities of the cells. This is the reason why mitochondria are referred to as the "power house" of the cells.
2. Mitochondria contain enzymes and deoxyribonucleic acid (DNA). The enzymes carry out oxidative phosphorylation of adenosine diphosphate (ADP) to adenosine triphosphate (ATP).
3. The DNA helps to code the synthesis of proteins in mitochondria membranes.

### Lysosomes

Lysosomes derive it name from "lysis" meaning breaking down. These are minute and rounded bodies containing enzymes found in animal cells.

### Functions

1. They destroy worn out parts of cells by discharging enzymes into them and thereby clearing the area for a new healthy cell to grow.
2. Lysosomes discharge enzymes to degenerated tissues causing the breakdown of the cells. For example, the absorption of the tail of tadpole when it is changing to the adult toad is caused by lysosomes. The products of the disintegrated cells are used for the growth of other cells.
3. Enzymes released by lysosomes destroy bacteria and cells.

### Golgi apparatus (bodies)

These bodies were discovered by an Italian scientist Camillo Golgi about 100years ago. They are found in a group as flat tubes or threads. They are absent in mature sperm and red blood cells.

### Functions

Their functions are usually uncertain but it is believed that they play the following roles:1. May help to distribute proteins made by the cell.
2. May help in the manufacture of lysosomes.
3. May help in the formation of membranes of endoplasmic reticulum and production of cellulose of cells of plants.

### Centrioles (Centrosomes)

These are usually two small dark, cylindrical bodies found near the nucleus. The two centrioles are placed at right angles to each other. Centrioles are mostly found in animal cells. They are absent in plants except some few algae and fungi.

### Functions

1. They provide spindle fibres to which chromosomes are attached during cell division.
2. They help in the formation of cilia and flagella.

### Plastids in plant cells

#### (i) Chloroplasts

Chloroplasts only occur in green plants. The organelles called chloroplasts contain green pigments called chlorophyll. A chloroplast is surrounded by a membrane. In leaves, chloroplasts are oval or disc-shaped and in algae, they are cup-like, ribbon or plate-like.

### Functions

It is the seat of photosynthesis where organic foods are synthesized.

#### (ii) Leucoplasts

These are colourless plastids mainly for storage of starch or lipids.

#### (iii) Chromoplasts

These plastids may contain different colours. The colours of petals of flowers are due to these plastids.

### Vacuoles

Vacuoles are found in plant cells. They are very large in plant cells but when they occur in animal cells, they are usually small. A vacuole is surrounded by a membrane called **tonoplast** and is filled with water, mineral salts, sugars and pigments called cell sap.

### Functions

1. The cell sap is osmotic in function.
2. It stores nutrients and waste products.
3. Sometimes vacuoles contain colour pigments called anthocyanins which may be blue, purple, yellow, red, which give colouration to flowers, fruits, leaves and buds. Colours of flowers attract insects, birds for pollination and dispersal of fruits and seeds.
4. Some substances dissolved in the vacoules (such sucrose and minerals) are food reserves which could be used by cytoplasm in time of need.
5. Tannins and alkaloids in vacoules prevent herbivorous animals from eating plants such chemicals

### Nucleus

The nucleus is bounded by a thin living nuclear membrane which separates it from the cytoplasm. The nuclear membrane has many tiny pores orpits. These pits allow substances to go in and out of the nucleus. The nucleus floats in the cytoplasmic fluid.

Within the nucleus is a small spherical body called **nucleolus** (sometimes more than one) and chromatin materials which condense during cell division into chromosomes (hereditary units). Inside the nuclear membrane and surrounding the chromatin materials and nucleolus is a semi-fluid material called nuclear fluid or **nucleoplasm.** The chromosomes are made up of DNA (deoxyribonucleic acid).

## Functions

1. The nucleus controls directly or indirectly most of the activities of a living cell. The removal of the nucleus results in the death of the cytoplasm.
2. The nucleus carries chromosomes on which hereditary materials (genes) are coded.
3. The **DNA** in chromosomes gives information for the manufacture of the proteins in the cell.
4. The nucleolus produces several kinds of **RNA** (Ribonucleic acid) which are passed out of the nucleus to the cytoplasm to manufacture proteins (**DNA** does not pass out of the nucleus).

## Similarities between plant and animal cells

Both plant and animal cells are similar because they both possess cytoplasm, cell membrane, endoplasmic reticulum, Golgi apparatus, mitochondria, ribosomes, nuclear membrane, nucleus, chromosomes, nucleoplasm and nucleolus. They both carry out mitosis in somatic cells and meiosis in reproductive cells.

**Table 5. Differences between Plant and Animal cells**

| Plant Cell | Animal Cell |
|---|---|
| 1. Cell has a dead cellulose cell wall hence definite in shape. | Cell has living cell membrane hence it can change its shape. |
| 2. Chloroplasts present. | Chloroplasts absent. |
| 3. Large permanent central vacuole present. | Vacuoles usually absent but if present are small and temporary. |
| 4. Food is stored as starch granules. | Food is stored as glycogen and fat. |
| 5. Centriole absent. | Centriole present. |
| 6. Cytoplasm pushed to the cell wall. | Cytoplasm spreads all over the cell. |
| 7. Usually absent but if present, it is very small. | Large vacuole |

## Size of cells

Cells of living organisms have different sizes depending upon the organism and its location. Some cells are very small while others are large. For example, the cell of pneumonia bacterium is 0.0001mm while that of the yolk of an ostrich egg is 75mm.

The sizes of most cells range from 0.001mm to 0.02mm. It is interesting to know that the longest cell in human's body is the nerve cell with a length of 1000mm (1metre).

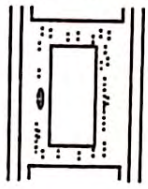
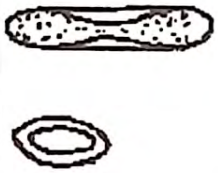
**Table 6. Examples of cells and their sizes**

| Cell | Diameter size in mm |
|---|---|
| 1. Pneumonia bacterium | 0.0001 |
| 2. Red blood cell | 0.008 |
| 3. White blood cell | 0.025 |
| 4. Man's sperm | 0.06 |
| 5. Woman's egg | 0.2 |
| 6. Ostrich's yolk | 75 |
| 7. Length of man's nerve cell | 1000 |
| 8. Leaf cell | 0.2 to 0.4 |

## Shapes of some specialized cells

Cells have different shapes depending on where they are found and the function they perform. Some cells are rectangular, disc, round, spindle-shaped needle-like and bean-shaped while others are of no definite shape.

**Table 7. Shapes, location amd functions of specialized Cells**

| Cell | Shape | Location | Functions |
|---|---|---|---|
| 1. Phloem of a plant | Rectangular  | Vascular bundle | Translocation of food. |
| 2. Red blood cell | Disc-shaped  | Blood plasma | Carrier of haemoglobin for transportation of oxygen. |
| 3. Fat cell | Round | Adipose tissues | Store fats. |
| 4. Egg of woman | Round | Ovary | Reproduction |
| 5. Sperm cell of man | Needle-like or whip-like | Testis | Reproduction |

| Cell | Shape | Location | Functions |
|---|---|---|---|
| 6. Muscle cell | Spindle-shaped | Muscle | Movement. |
| 7. Guard cells of stoma | Bean-shaped | Epidermis of leaf | Allows exchange of gases in the leaf. |
| 8. Ciliated cell | Barrel-shaped | Linings of nose and trachea | Prevents dust and germs from entering the lungs. |
| 9. Nerve cell | Indefinite shape | Brain and spinal cord | Conduction of impulses. |
| 10. White blood cell | Polymorphic (shapeless) | Blood plasma | Defence of the body against germs. |
| 11. Bone cell | Star-shaped (stellate) | Bone | Support. |

## Forms in which cells exist

Cells of living organisms exist in different forms. Some are single and free living, others may be colonial, filamentous or part of a living organism.

### 1. As single and free-living organism

*Amoeba, Paramecium, Euglena* and *Chlamydomonas* are examples of single-celled (unicellular) organisms that are free-living. These single celled organisms perform all the characteristics of living organisms. See figures 2.28, 2.29, 2.30 and 2.1.

### 2. As a colony (e.g *Volvox* and *Eudorina*)

Certain organisms are composed of numerous and similar cells joined by strands of protoplasm. Each associating cell has nucleus, cytoplasm and a pair of flagella. These flagella enable the colony to swim by rolling over and over. The cells making up the colony are not differentiated into tissues. Examples of colonial life are *Eudorina* and *Volvox*.

In *Eudorina* the cells forming the colony are independent. For example, if one cell is removed from the colony it will swim away with the aid of its flagella. It will manufacture its food by photosynthesis and undergo cell division (mitosis) to form a new colony.

In *Volvox*, each cell cannot live independently. The cells of *Volvox* somehow have become specialized. Some cells are specialized for repro-duction while others are specialized for photosyn-thesis and locomotion.

*Volvox* is interesting to biological students because it is here the **division of labour** has been established without tissues.

This division of labour and specialization of similar cells within a colony is called **differentiation.**

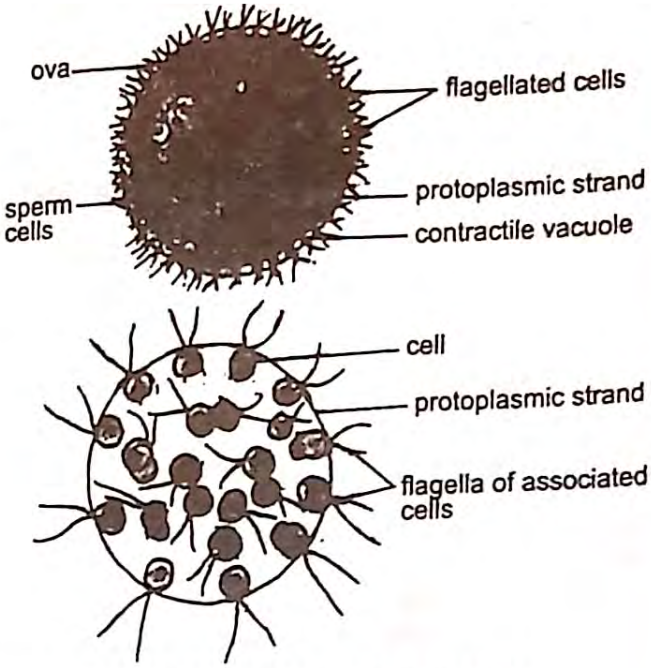



**Fig. 3.4 Associating cells of A = *Eudorina* and B = *Volvox***

### 3. As a filament

Some independent cells arranged themselves into filament. An example, is *Spirogyra*. The filament of *Spirogyra* consists of about twelve cylindrical cells all similar in size bound together by a cell wall and mucilage. Each cell is separated from the other by intercellular cell walls. Each cell can live independently and is capable of carrying out asexual reproduction to form a new filament.

**Figure 3.5. Filament of *Spirogyra***

### Difference between colonial organisms and filamentous organisms

Eventhough colonial organisms and filamentous organisms are simple in organization, there exists differences between them as follows:

1. In colonial organisms, identical cells form a **round mass** and are held together by **cytoplasmic strands** while in the filamentous organisms, identical cells are held together **end to end** by **inter-cellular walls** to form a linear structure.

2. In colonial organisms, cells are dependent physiologically on one another while in the filamentous organism, cells are independent of one another physiologically.
3. There is a **division of labor** within the cells of colonial organism. In filamentous organism, there is no **division of labor.**
4. In some colonial organisms such as *Volvox*, *Pandorina* and *Eudorina*, there are cilia for locomotion while in the filamentous organisms such as *Spirogyra*, *Zygnema* and *Ulothrix*, there are no structures for locomotion.

## 4. As part of a living organism

Most multicellular organisms are made up of groups of cells which are similar in shape and structure. The cells making up the group work together for a particular function. This specialized group of cells is called **tissue**. Each cell depends on the other for efficient performance. Multicellular organism that has graduated to **tissue organization** has to rely on different tissues making up the body to work together. Each tissue performs a particular function. For example, the cheek cells form a protective epithelial tissue that forms the lining of the mouth of a man; the epidermis of leaves is an epithelial tissue that forms a protective covering of leaves while the xylem and phloem tissues are for conduction of water and manufactured food respectively.

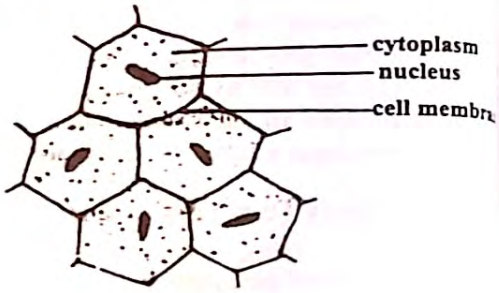



**Figure 3.6. Surface of human cheek cell**

*Questions*

1. (a) *(i) Make a labelled drawing of a typical plant cell to show its essential features.*
*(ii) Give the functions of two labelled organelles.*

2. (a) *Describe briefly two levels of cell organization in living organisms giving example of each type.*
(b) *What role do the following processes play in the activities of a living cell:*
*(i) Osmosis*
*(ii) Diffusion.*

3. (a) *(i) What is a cell?* *(ii) State the cell theory*
*(iii) Outline the cell theory as propounded by the following biologists: Robert Hooke, Dujardin, Matthias Schleiden and Theodor Schwann.*
(b) *Describe the structure of a typical animal cell and give the functions of its parts.*
(c) *In a tabular form, distinguish between a plant and an animal cell.*

4. (a) *Name and briefly describe with diagrams the forms in which living cells exist. State the dependence or interdependence that exists in your given examples.*
(b) *In a tabular form, state the shape, location and function of the following: phloem cell, muscle cell, guard cell of stomata, nerve cell, ciliated cell of man, reproductive cells of female and male mammals.*

# 4

# ORGANIZATION OF LIFE

Life exists in an organized form so as to carry out efficiently the characteristics of living things. Every living thing is made up of a cell or a number of cells. A single-celled organism is called **unicellular** while a many-celled animal is called **multicellular.**

Organization of life is therefore the existence of life from a single-celled organism to a multicellular organism with complex forms that perform different functions (**division of labour**). Four levels of organization of life exist, namely: **cell, tissue, organ** and **system.**

**Cell:** A cell is a functional and structural unit of protoplasm bounded by a membrane and containing nuclear and cytoplasmic materials.

Some living things exist as a cell capable of carrying out all the characteristics of living things. They have cytoplasmic structures such as pseudopodia, cilia, flagella and vacuoles etc. Examples are *Amoeba Chlamydomonas*, *Paramecium* and *Euglena*.

**Tissues:** A tissue is a collection of cells which are similar in structure and perform similar functions. They have the same origin and occupy the same position in the body of the organism. *Hydra* is an example of an animal that is made up of tissues only. The tables below show the names and functions of tissues of man and flowering plant.

**Organ:** An organ is a collection of different tissues that perform a common function or functions. Some organs carry out more than one function while other organs perform just one function. For example, the kidneys get rid of waste metabolic materials from the body and also regulate the amount of water the body needs. The heart only performs the function of pumping blood round the body. Example of organs are roots, stems, leaves, bulbs, rhizomes, heart, kidneys, eyes, nose, ears, brain, spinal cord, tongue, ovaries, and urinary bladder.

Table 8. Tissues of man and their functions

| Tissue of Man | Functions |
|---|---|
| 1. Epithelial tissue | Forms the skin and lines the tubes. |
| 2. Blood tissue | Conveys food and oxygen round the body. |
| 3. Skeletal tissue | Supports the body and aids movement. |
| 4. Connective tissue | Binds together other tissues. |
| 5. Nerve tissue | Co-ordinates and conducts impulses. |
| 6. Muscle tissue | Movement of the parts of the body. |

Table 9. Tissues of flowering plants and their functions.

| Tissue of flowering plants | Functions |
|---|---|
| 1. Epithelial tissue | Lining and protection of the plants surface. |
| 2. Vascular tissue | Transportation of food and water. |
| 3. Photosynthetic tissue | Manufacture of food. |
| 4. Packing tissue | Provides spaces for new cells and stored food. |
| 5. Strengthening tissue | Gives strength and support to the plant. |

**System:** A system is a set of organs which co-operate to carry out one of the vital functions of life. For example, the digestive system is made up of organs such as the mouth, oesophagus, stomach, pancreas, duodenum and ileum, the large intestine and the anus. All these organs contribute to the major function of digestion of food

**Table 10: Systems in mammals .**

| Name of system in mammal (man) | Main organs in the system | Main functions |
|---|---|---|
| 1. Respiratory system | Nose and lungs. | Intake of air and exchange of gases. |
| 2. Nervous system | Brain and spinal cord. | Nervous co-ordination. |
| 3. Reproductive system | Testes, ovaries. uterus | Reproduction. |
| 4. Digestive system | Oesophagus, stomach, pancreas and intestine. | Digestion of food. |
| 5. Circulatory system | Heart and lungs | Blood circulation. |
| 6. Skeletal system | Bones and Cartilages | Provides places for the attachment of muscles. Give support to the body. |

**Table 11: Systems in flowering plants.**

| Name of system in flowering plants | Main organs in the system | Main functions |
|---|---|---|
| 1. Reproductive system | Stamen and pistil | Reproduction. |
| 2. Transport system | Xylem and phloem | Conduction and translocation. |
| 3. Supporting system | Collenchyma, sclerenchyma, xylem, phloem | Mechanical and tensile strength. |
| 4. Root system | Roots and root hairs. | Anchorage and absorption. |
| 5. Shoot system | Stem and leaves | Support and photosynthesis. |

## Complexity of organization in higher organisms

Higher organisms are multicellular and are big enough to be seen with the naked eye. Their bodies are differentiated into specialised parts performing different functions. The different specialized parts made up of tissues, organs and systems make higher organisms more efficient to carry out various activities of life. However, there are advantages and disadvantages in being a complex organism.

## Advantages of complexity

1. Due to an increase in size and complexity of multicellular organism, different parts have become specialized to carry out particular functions leading to biological division of labour. For example, in man, the ovaries and testes are specialized for reproduction; ear, for hearing, and eyes for sight.
2. This division of labour has led to the efficiency of the various organs of the body.
3. The complexity of higher organism has led to their survival in different habitats.
4. Organisms with complex body have developed tissues, organs and systems for carrying out various vital functions, conferring efficiency on the organisms.
5. Unicellular and simple multicellular organisms are restricted to life in water. Complex organisms are able to live on land

in addition to water. Complex organisms have developed various organs of locomotion and respiration so that only very few places are not habitable to them. They live in water of different salt concentration, the driest of land, the coldest of land and water, in the air and on the mountain tops.

6. Unicellular and simple multicellular organ-isms stop all other activities when they want to reproduce but complex organisms carry out reproduction side by side with other activities.
7. Reproduction in complex organisms does not lead to the disintegration of the parents.

   Specialized reproductive parts (testes and ovaries) are only involved. In Unicellular organisms, the entire parent or parents are involved in reproduction leading to their disintegration.

## Disadvantages of complexity

1. Individual cells are not capable of existing independently and therefore depend on one another's activities to exist.
2. In complex organisms, the surface to volume ratio is small and the distance from exterior to the centre of the body is great. A transport system is developed to rectify this problem but any failure of the transport system could be fatal to the organism.
3. Complexity places greater demands upon the musculature and other supporting structures. The animal must be comparatively active to obtain enough food and oxygen within a given time to support its energy need if not the organism faces the risk of death.
4. Greater demands upon musculature and other supporting structures because of the massive structure leads to frequent wear and tear of the system or breakdown of internal organs.
5. With complexity, ability to regenerate lost parts decreases.

**(c) Differences between colonial organisms and filamentous organisms.**

| | Colonial organisms | Filamentous organisms |
|---|---|---|
| 1. | Identical cells form a r ound mass and are held together by cytoplasmic strands. | Identical cells are held together end to end by inter-cellular walls to form a linear structure. |
| 2. | Cells are dependant physiologically on one another. | Cells are independent on one another physiologically. |
| 3. | There is a division of labour. | There is no division of labour. |
| 4. | In some colonial organisms such as *Volvox* and *Eudorina*, there are cilia for locomotion. | In filamentous organisms such as *Spirogyra* and *Zygnema*, there are no structures for locomotion. |

## *Questions*

1. *(a) Define the following:*
   *(i) Cell (ii) Tissue (iii) Organ*
   *(b) Give one example each of a plant and an animal in the unicellular grade of organization.*
   *(c) Name one animal that is made up of tissues only. Make a well labelled diagram of the cross section through the body wall of the animal to show different types of cell.*

2. *(a) Name one plant in organ grade of organization and state four ways in which this plant organ is more advanced evolutionarily than a filamentous alga.*
   *(b) State four advantages and three disadvantages of a complex organism.*

3. *(a) State two advantages of complex structural organization in higher organisms.*
   *(b) (i) List two differences between colonial organisms and filamentous organisms.*
   *(ii) Give one example each of a colonial organism and filamentous organism*
   *(c) Make a labelled diagram 10- 12 cm long of a named filamentous alga (S.S.C.E. 1996).*

# 5

# THE CELL AND ITS ENVIRONMENT

## Chemical-physical processes in living systems

Diffusion, osmosis, plasmolysis and haemolysis are simple physical processes which are of vital importance to the chemical reaction taking place in any system, be it a unicellular organism, or a very large and complex multicellular organism.

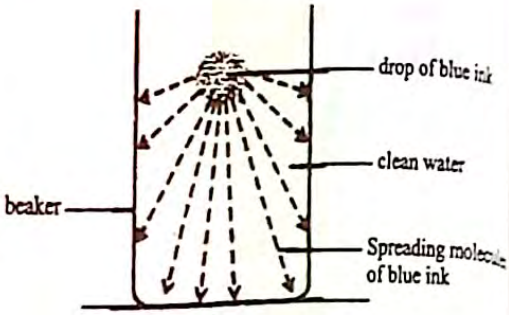


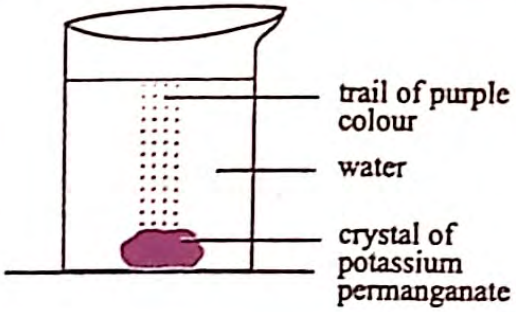
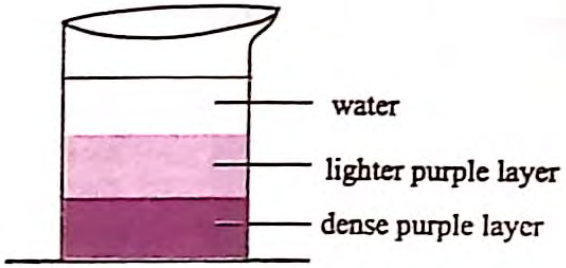
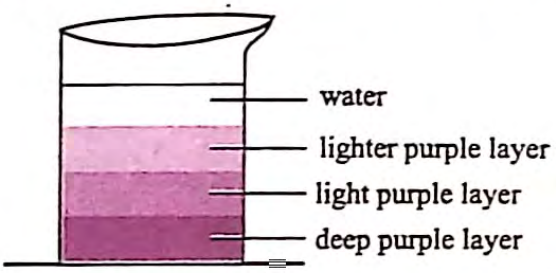
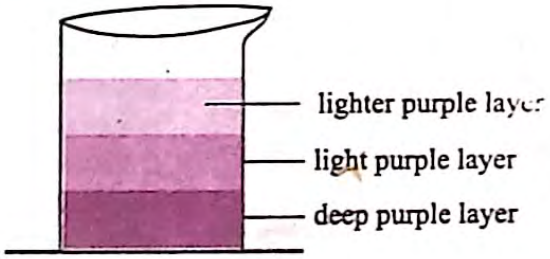

**Fig. 5.1. Diffusion of blue ink in water**

### Diffusion

When a rat dies at one hidden corner of a room, the inhabitants soon become disturbed with the unpleasant rotten smell which slowly spreads to all parts of the room. The smell is more pronounced at the very spot where the rat has died. The strong smell can therefore be used to trace the dead rat for an immediate removal.

The sweet smell of stew from the kitchen of a busy housewife soon fills the air and the appetite of passers-by becomes stimulated. If some black or red ink is dropped into a beaker of clean water and left undisturbed, the ink slowly spreads to all parts of the water imparting its characteristic colour to the water. This is illustrated in figure 5.1. when uniformly spread as will be observed after some hours or even days, the ink colour in the water is by far lighter than the colour of the original ink. The spreading of the ink in water can be made faster by stiring.

These are simple illustrations of the processes of diffusion. **Diffusion is the movement of gaseous or liquid molecules from a region of higher concentration to a region of lower concentration through the medium of air or liquid.** Such movement of molecules starts from a region where the molecules are in high concentration to part where the molecules are in low concentration. The molecules move to any space available to them unrestricted. Gases can diffuse through air or liquids. Liquids can diffuse through other liquids. Vapours can diffuse from aromatic solid compounds through the air. Solid molecules can also diffuse through liquids if they can dissolve in such liquids. The rotten smell from a dead rat mentioned above or the sweet smell of stew from the kitchen are examples of gases moving through the medium of air to our nostrils. Thus we are able to perceive and interpret the odour. The ink molecules moving in water is an example of a liquid diffusing through another liquid medium (water). If a crystal of potassium permanganate [potassium tetraoxomanganate (VII)] is dropped gently with a spatula into a beaker of water, the following will be observed.

| Time | Observation |
|---|---|
| 1. Immediately after dropping | A trail of purple colour will be seen as the crystal sinks to the bottom of the beaker.   |
| 2. After five minutes | The crystal dissolves forming a dense layer at the bottom and a light layer above.   |
| 3. After ten minutes | Three distinct layers are formed. The bottom layer is deep purple, the middle layer is light purple and the top layer is lighter purple.   |
| 4. After fifteen minutes | The whole water is purple, with deep purple at the bottom, light purple at the middle and lighter purple above.   |

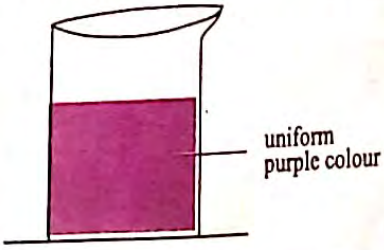
| Time | Observation |
|---|---|
| 5. After one hour | The whole water is uniformly purple   |

**Figure 5.2. Process of diffusion of solid in liquid.**

### Factors that speed the rate of diffusion

1. **Heating or increase in temperature:** When a diffusing substance is heated the molecules of the substance move faster, thereby increasing the rate of diffusion.
2. **Shaking or stiring:** This also increases the rate of diffusion as the molecules of the diffusing substance are caused to move faster through disturbance.

Each and every one of us would have observed that the size of a solid camphor exposed to air diminishes. This is because the solid vapourises into the air.In a similar manner, perfumes diffuse into the air and we inhale the pleasant smell.

## Diffusion in living organisms.

1. Digested and soluble food diffuses from the villi of intestine into the blood stream and lacteal.
2. Food and oxygen diffuse from the blood to the cells and carbon (IV) oxide diffuses from the cells to the blood.
3. Exchange of gases between *Amoeba* and water, gills of fish and water and lungs and blood in mammals is by diffusion.
4. Nutrients and gases diffuse from the mother's placenta to the foetus and waste products from the foetus to the placenta.
5. The exchange of gases in the atmosphere and the sub-stomatal air cavity of leaf is by diffusion.

## Importance of diffusion

1. The movement of air in the intercellular spaces of flowering plants is ensured.
2. Mineral salts in solution in the soil enter the roots of plants by diffusion.
3. Carbon (IV) oxide (carbon dioxide) and oxygen enter and leave the body of flowering plants through stomata and lenticels by diffusion.
4. Exchange of gases (oxygen and carbon (IV) oxide) during respiration is by diffusion.
5. Removal of waste products in a small organism such as *Amoeba* is by diffusion.
6. Digested food and mineral salts are passed to the blood stream by diffusion.
7. Digested food enters saprophytic plants such as *Mucor* by diffusion.

## Osmosis (movement of water molecules)

The process of osmosis is more or less similar to that of diffusion except that it is more technical. Whereas diffusion involves the movement of molecules of gases, liquids or solids in the medium of air and liquids, *osmosis* involves the movement of water molecules, across a semi-permeable membrane. **Osmosis can be defined as the diffusion of water molecules across a semi-permeable membrane.** Diffusion has earlier been defined as movement of molecules from a region of high concentration to a region of low concentration.

In other words, ***osmosis is the movement of water molecules from solutions where water is in higher concentration to regions where water is in lower concentration through a semi-permeable membrane, until equilibrium is reached.***

The solution which loses water in osmosis is said to be **hypotonic** and the solution that gains water is said to be **hypertonic**. When a state of equilibrium is established, that is neither solution gains nor loses water, the solutions become **isotonic**.

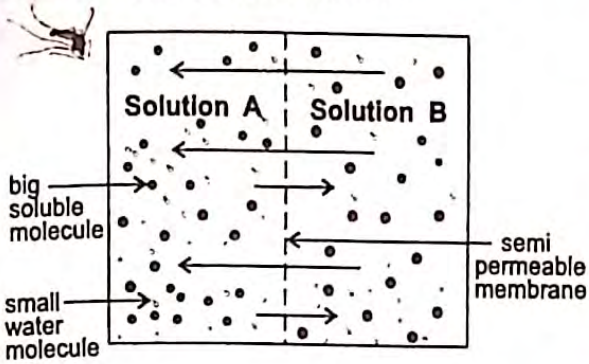



**Figure 5.3. Movement of water molecules across a semi-permeable membrane.**

Consider the illustrative diagram in figure 5.3 supposing that solution **A** has a very high concentration of solute dissolved in it and solution **B** has a smaller amount of solute dissolved in it. Obviously a solution with a higher solute concentration has a smaller amount of water left for the dissolution of more solute, while a solution with lower concentration of solute has more water available. It can thus be reasoned that in the above illustration, solution **B** has a higher concentration of water than solution **A**. Since these two solutions are separated by a semi-permeable membrane water molecules will move from solution **B** into solution **A** through the semi-permeable membrane. One can again define *osmosis as the movement of water molecules from a region of low concentration of solute to a region of high concentration of solute through a semi-permeable membrane separating the two solutions until equilibrium is attained.* Still on figure 5.3 it is observed that both solutions **A** and **B** contain water, though at different concentration. Water molecules move into **A** from **B**. There is nothing to prevent the movement of water from **A** to **B**. The arrows show that water molecules do move from **A** to **B**, but this happens at a slower rate than the movement from **B** to **A**. Since movement is faster from **B** to **A**, the tendency is for one to feel that movement occurs only from **B** to **A** (towards the region of higher concentration of solute). Any given solution has a certain amount of osmotic pressure. The osmotic pressure of pure distilled water is zero. The higher the amount of solute dissolved in a solution, the higher the osmotic pressure of that solution. Referring to the illustration in figure 5.3 the osmotic pressure of solution **A** is higher than the osmotic pressure of solution **B**.

***Osmotic pressure*** is the pressure developed by a more concentrated solution such as sugar or salt solution when water moves into it through a semi-permeable membrane.

This will give a third definition of osmosis. ***Osmosis is the movement of water molecules from a region of low osmotic pressure to a region of higher osmotic pressure through a semi-permeable membrane.***

By now the reader would have seen the importance of a semi-permeable membrane in the process of osmosis. A semi-permeable membrane has very tiny pores which can permit the free movement of smaller molecules like that of water across it. Molecules larger than water molecules cannot freely pass through.

It is worth mentioning that when water is being drawn into solution **A** from solution **B**, the osmotic pressure of **A** is slowly being reduced. A time will come when the osmotic pressure of solution **A** equals the osmotic pressure of solution **B**. At this time, the two solutions have reached an **osmotic equilbrium**. When two solutions are in an osmotic equilibrium, the rate of movement of water from **A** to **B**, equals the rate of movement from **B** to **A**.

**Necessary conditions for the occurrence of osmosis**

1. Two solutions of an unequal concentration of water molecule separated a semi-permeable membrane.
2. Difference between the concentration of water molecules in soil and cell sap in plants.
3. Difference between the concentration of water molecules in two cell.
4. The movement of organism from salt water to fresh water or from fresh water to salt water.
5. A health growing plant is up rooted and immediately place in distilled in the laboratory.

**Table is given below to summarise the differences between diffusion and osmosis.**

**Table 12. Differences between diffusion and osmosis**

| Diffusion | Osmosis |
|---|---|
| 1. Involves the movement of molecules of gases, liquids and solids. | Involves the movement of molecules of water only. Gases, solid and liquids other than water are not involved. |
| 2. A semi -permeable membrane is not involved. | A s emi-permeable membrane is involved. |
| 3. Molecules diffuse into any space accessible to them. | Water molecules move between two solutions of different osmotic pressures leading to the establishment of an osmotic equilibrium. |
| 4. Occurs in both living and non-living things. | Occurs only in living things. |

## Experiments to demonstrate osmosis

The process of osmosis can be demonstrated in both living and non-living systems.

**Aim**: To demonstrate the process of osmosis using a non-living thing.

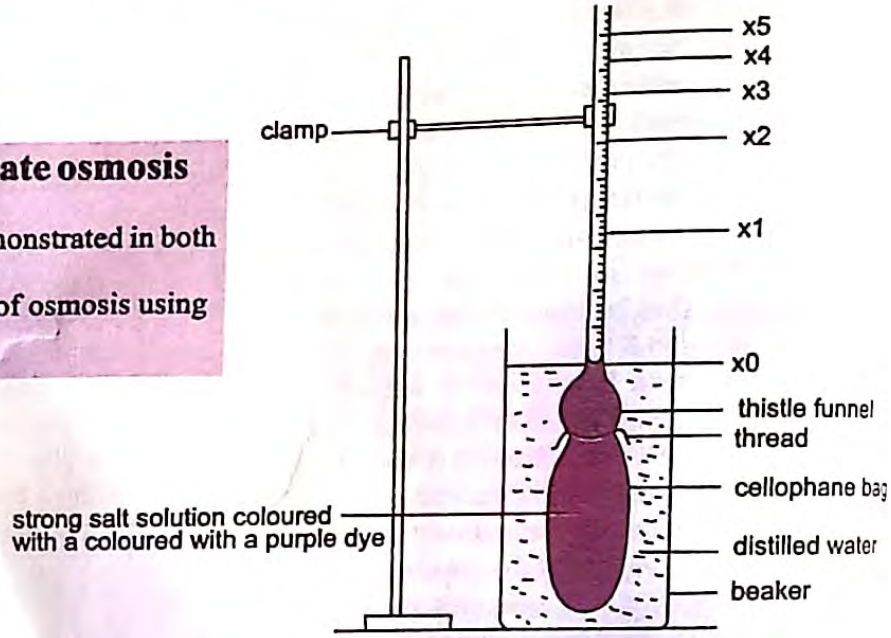



**Figure 5.4. Experiment to demonstrate osmosis using a non-living material**

**Method:** A cellophane bag is tied to the mouth of a thistle funnel connected to a long graduated glass tube. A strong salt or sugar solution is prepared and coloured with a dye. The solution is poured into the cellophane bag to the level marked $X_o$ equivalent to the level of water in the beaker. Noting the original level of liquid in the long glass tube as $X_o$, the apparatus is left to stand undisturbed for serveral hours. During this period the liquid level is read at a regular time interval, say every two hours.

**Result:** It will be observed that at each time of reading, the liquid level in the glass tube rises while the water level in the beaker falls. It is also observed that the coloured solution in the cellophane bag becomes lighter. The space between the two readings decreases at every time of reading until no more rise is observed.

**Conclusion:** From this experiment it can be concluded that the cellophane bag is a semi-permeable membrane hence it admits water molecules from the beaker into the strong salt solution, thus diluting the solution. For this reason, the purple colour changes to light purple. At level A, the solution in the beaker and that in the tube have reached osmotic equilibrium, hence no more rise is observed.

## Alternative experiment

**Aim:** To demonstrate osmosis using non-living material.

**Method:** A piece of cellophane of cigarette packet is tied over to the mouth of a thistle funnel carefully and tightly. The cup of the thistle funnel is filled with sugar solution while the beaker contains water.

The cup side carrying the semi-permeable membrane (cellophane) is immersed into the beaker of water. the experiment is left for one day. The **control experiment** is similarly arranged but instead of filling the funnel with sugar solution it is filled with water.

**Result:** After a few hours the level of liquid in the funnel has risen from its original mark. There is no rise in the **control experiment.**

**Conclusion:** Water has passed through the semi-permeable membrane (cellophane) to the sugar solution by osmosis (endosmosis).

**Osmosis:** Is the movement of water molecules from a region of lower concentration of solution to that of higher concentration of solution through a semi-permeable membrane. The cell sap of the root hair is more concentrated than soil solution.

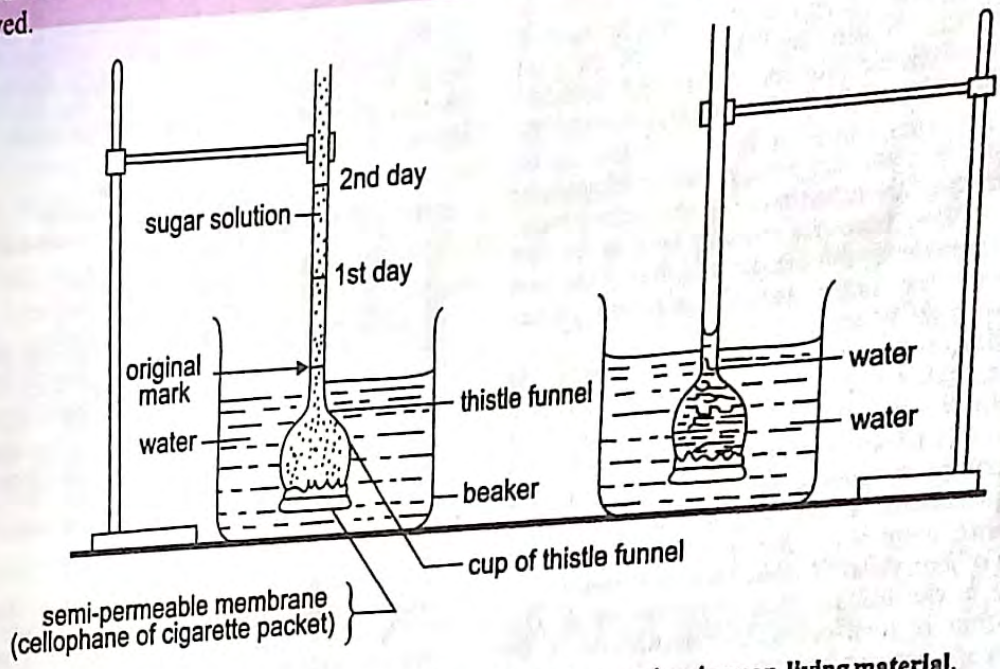



**Figure 5.5. Experiment to demonstrate osmosis using non-living material.**

Experiment 2

**Aim:** Experiment to demonstrate osmosis using yam tuber as a living plant material.

***Method:*** Two thick slices of yam tuber **A** and **B** are obtained and their "Skin" peeled off. A large cavity is made in the middle of each. A strong solution of salt is kept in yam tuber **A** and the salt solution is marked as $L_1$. Yam tuber **B** is left without salt solution to serve as a control experiment. They are both kept in a trough containing distilled water as in the diagram and allowed to stand for some hours.

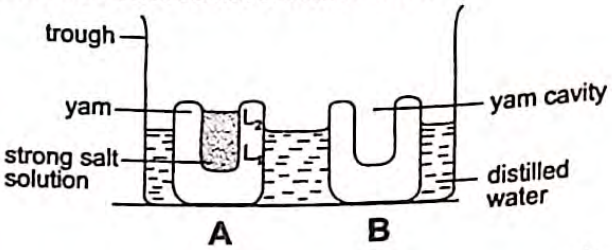



***Figure 5.6. Demonstration of osmosis using yam tuber (a living yam material)***

***Results:*** After some hours, it is observed that salt solution in **tuber A** has risen remarkably to level $L_2$ while no water enters the yam **tuber B**.

**Conclusion:** The salt solution in yam **tuber A** has a higher osmotic concentration than the water in the trough and exerted a higher osmotic pressure on the water. The water with lower osmotic concentration moves through the cells of the yam which act as semi-permeable membrane to the cavity of the yam hence the rise in the salt solution. In yam **tuber B**, water could not be drawn into its cavity because it contains no salt solution and the cells of the yam have lower osmotic concentration and osmotic pressure than the water in the trough.

*Note: (If you like, you can put a known level of water into the cavity of the tuber of the control experiment. In this case, there is no rise in water level in the yam because the water in the trough and that of the yam cavity have the same osmotic pressure, hence osmosis does not occur.*

*You can also use this experiment to demonstrate that a semi-permeable membrane is a property of living protoplasm. In this case the tuber of **B** of the control experiment is boiled to kill the protoplasm of the yam. Salt solution is introduced into both tubers **A** and **B**. At the end of this experiment; there is no rise in the level of the salt solution of yam **tuber B** while there is a remarkable increase in the salt solution of yam **tuber A**. This proves that a semi-permeable membrane is the property of living protoplasm.*

## Water absorption by living plant cells

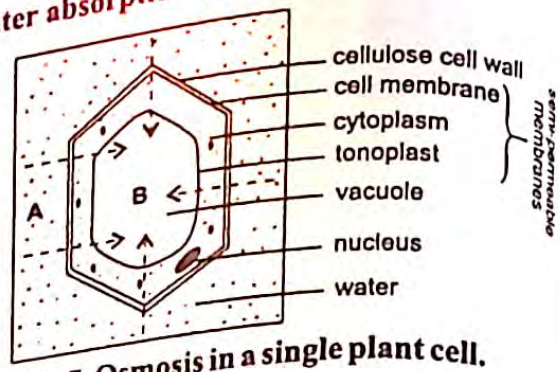



**Figure 5.7. Osmosis in a single plant cell.**

Consider a living plant cell whose structure is shown in figure 5.7. A living plant cell consists of a cellulose cell wall which is non-living and surrounds an inner cell membrane which is living. The vacuole contains water, salts, sugars and other dissolved organic substances which make up the cell sap. The contents of the cell sap keep the vacuole at high osmotic pressure. Although the cellulose cell wall is permeable to water and other materials, it is known that the cell membrane, the cytoplasm and the tonoplast are all semi-permeable membranes. Supposing such a living cell is immersed in a solution with a lower osmotic pressure A (preferably distilled water), **osmosis** occurs and water is absorbed from **A** across the cell wall, the cell membrane, the cytoplasm and tonoplast into the vacuole **B**. As water is absorbed, the vacuole slowly increases in size, narrowing and pressing the cytoplasm against the cell wall (wall pressure). Absorption of water into the vacuole continues until the osmotic pressure of the surrounding medium equals the osmotic pressure of the cell sap. At this time, the cell is said to be fully turgid. **Osmosis** is therefore a process which ensures the continuous absorption of water and dissolved minerals into a living cell.

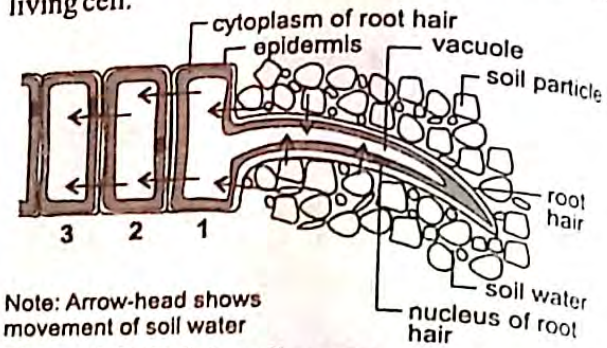



**Figure 5.8. Cell to cell movement of water after absorption by root hairs.**

When rain falls, water drains down the soil. Enough water is however trapped between soil particles. This is known as **soil water**. The water carries mineral salts in solution.

Figure 5.8 is an illustration of water absorption by osmosis in three cells of the plant roots numbered **cell 1, cell 2 and cell 3**. Cell **1** has the root hair which makes direct contact with the soil

and soil water. Assuming that the three cells are living and have equal osmotic pressure higher than the osmotic pressure of the soil solution, water is drawn into the root hair by osmosis. (The reader is once again reminded that the **cell membrane**, the **cytoplasm** and the **tonoplast** are all semi-permeable membranes). The water together with mineral salts drawn into cell 1 is reserved in the vacuole. Cell 1 is fully turgid. Its osmotic pressure falls below the osmotic pressures of **cells 2 and 3**. The process of osmosis will continue, so that water passes from the vacuole of cell **1, into cell 2. Cell 3** still with a higher osmotic pressure draws water from **cell 2** also by osmosis.

This movement of water from cell to cell continues until the water from the soil is brought to the xylem vessels of the root and then to the xylem of the stem. A pressure created in the root ("root pressure") forces the water to a certain height in the stem. A *"transpiration pull"* set up by the evaporation of water from the stomata of the leaves during the day forces up the water in the xylem of the stem to all parts of the plant including the branches, terminal buds, leaves and flowers.

**Osmosis** therefore ensures the continuous absorption of water and mineral salts needed for plant growth.

If the soil water runs down, as is often the case during the dry season, a time is reached when the salt concentration in the top soil becomes higher than the concentration of the cell sap of the plants. Most of the shallow rooted plants suffer from **plasmolysis**. The plants lose water to the soil instead of absorbing water from the soil. Their leaves become **flaccid** and **wilting** sets in. If such plants are not adequately watered, wilting becomes permanent. The leaves turn yellow and finally the plants die off. Whereas osmosis is advantageous to any living thing, **plasmolysis** leads to the death of living organisms.

## The importance of osmosis to plants and animals

### Plants

1. Absorption of water from the soil into the vacuole of the root hair is by osmosis.
2. It helps in the movement of water molecules from the root hair to the cells of the cortex.
3. It helps in the opening and closing of the stomata during the day and at night respectively.
4. It gives turgidity to the plant cell.

### Animals

1. In animals, intracellular movement of water is by osmosis.
2. The reabsorption of water in the kidney tubules of mammals is by osmosis.
3. The absorption of water from the undigested food materials in the large intestine is by osmosis.
4. It gives turgidity to animal cells.
5. Haemolysis of red blood cells is due to osmosis.

### Plasmolysis:

When a plant cell is placed in a more concentrated salt or sugar solution than that of the cell sap, water is lost by osmosis, (**exosmosis**). As a result of water loss, the vacuole shrinks and the cytoplasmic linings are pulled from the cell wall. The space between the cell wall and cytoplasm becomes filled with the concentrated solution. The cell becomes flaccid or plasmolysed. ***Plasmolysis* is therefore the skrinkage of the vacuole and pulling away of the cytoplasmic linings from the cell wall when a plant cell is placed in more concentrated salt solution.**

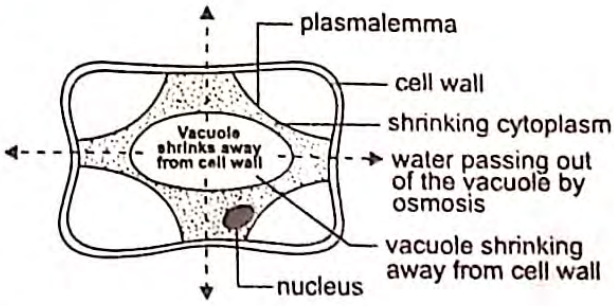



**Figure 5.9. A plamolysed plant cell**

On the other hand, when the plasmolysed cell is again placed in distilled water or pure water, water

moves into the cell sap by osmosis (**endosmosis**) because the cell sap (solution of sugar and salts) in the vacuole is more concentrated. The vacuole increases in volume and distends towards the cytoplasm and cell wall. The cell wall distends until no further distension. At this point, the cell is said to be **turgid**.

**Necessary conditions for the occurrence of plasmolysis.**

1. Placing a plant cell in a stronger salt or sugar solution.
2. Excessive transpiration.
3. Concentration of sugar in the guard cell.
4. Damage to plants parts.

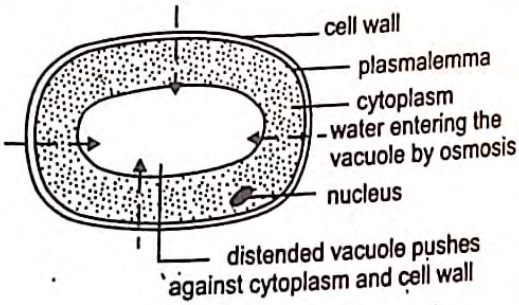



**Figure 5.10. A turgid plant cell**

Plasmolysis can lead to the death of the cells if allowed for a long time. Crops planted in a very salty soil will not survive due to effect of plasmolysis. The leaves of the plant will wilt. The stomata pores will close blocking respiration and photosynthesis.

## Experiment to demonstrate plasmolysis

**Aim:** To show the effect of plasmolysis on a cell.

**Method:** Place a fresh filament of *Spirogyra* on a slide and observe for turgidity of the cells. Add a drop of concentrated salt solution on the slide and examine under microscope for 5 to 10 minutes.

**Result**: The cytoplasmic linings start shrinking from the cell walls and cell vacuoles decrease in size and the cells become **plasmolysed.**

If the **plasmolysed filament** is placed in distilled water for about 20-30 minutes and examined again under the microscope, water passes into the cell sap. The vacuoles increase in size and the cells become distended and the cytoplasmic linings now press against the cell walls.

## Haemolysis:

**Haemolysis is the bursting of red blood cells in the plasma.** Normally, the blood plasma and red blood corpuscles are **isotonic**, that is both the red blood cells and the plasma have the same osmotic concentration. Mammalian plasma and red blood cells both contain 0.9% sodium chloride in solution.

If for some reason, the concentration of salt in the plasma falls (hypotonic), water will enter the red blood cells by osmosis (also called **endos-mosis**) through the cell membrane (plasma membrane). Continuous absorption of water into the cells will make the cells very turgid and eventually burst.

**Haemolysis** leads to anaemia which may eventually cause death if not checked. (It must be remembered that animal cells have no cellulose cell wall to resist the turgidity, hence the bursting).

On the other hand, if the concentration of salt in the plasma is higher, (hypertonic) water leaves the red blood cells by osmosis (also called **exosmosis**). The red blood cells will shrink (plasmolysed). The shrinking of the red blood cells is called **crenation**. For example, when an Epsom salt, magnesium tetraoxo sulphate (VI) is taken as a laxative, water is drawn from the blood and other body fluids because the salt does not diffuse into the blood stream since it is more concentrated than the blood. Therefore, frequent use of laxative can lead to **crenation**.

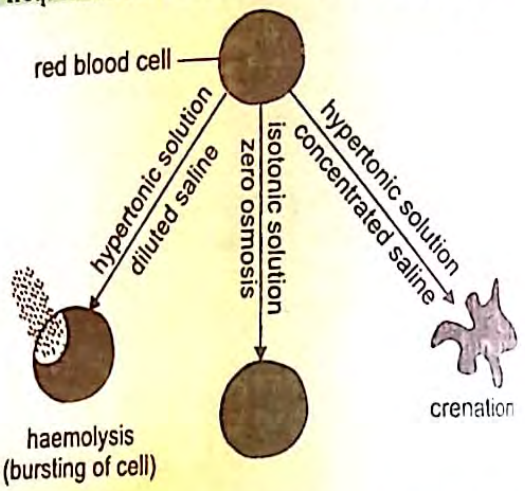



**Figure 5.11. The behaviour of red blood cell to different concentration of solutions.**

An experiment can be performed by preparing dilute saline solution of less than 0.9g sodium chloride, isotonic solution of 0.9g sodium chloride and concentrated saline solution of above 0.9g sodium chloride. Put a drop of each solution on a slide and introduce a drop of freshly drawn mammalian blood and examine what happens to the cells.

## Filtration:

**Filtration** is a mechanical process whereby certain molecules are filtered under external pressure through a membrane. A typical exampleis the blood pressure created by the pumping of the heart. The blood pressure not only circulates blood around the body but filters water and solute through the capillary walls and membrane. For example, filtration takes place between the walls of **Bowman's capsule** and **glomerulus**. Water, sugar, salts, urea and other substances in the blood except the blood cells and large plasma proteins are filtered into the **Bowmans's capsule** of the kidney nephron.

## *Questions*

1. ***(a) Describe one experiment, using non-living material to demonstrate osmosis.***
   ***(b) Use the result of your experiment to explain how water passes from the soil into the root hair of a plant. Through what cells does it then pass on its way to the stem?***
   ***(c) Explain why red blood cells swell and later burst when placed in distilled water.***

2. ***(a) Define these terms:***
   ***(i) Osmosis***
   ***(ii) Diffusion and***
   ***(iii) Plasmolysis***

   ***(b) In a room relatively free from drought, a bottle of perfume is opened by a student in a corner of the class. How does the scent reach the teacher in the front of the class?***
   ***(c) How would you demonstrate the occurrence of osmosis in a living plant material?***
   ***(d) In a tabular form distinguish between diffusion and osmosis.***

3. ***Draw:***
   ***(a) (i) A plant cell placed in a more concentrated solution than the cell-sap in the vacuole***
   ***(ii) the plant cell from (i) later placed in distilled water***
   ***(iii) briefly explain the events of (i) and (ii).***
   ***(b) What are the importance of diffusion and osmosis to plants and animals?***

4. ***(a) Write short notes on (i) haemolysis (ii) filteration.***
   ***(b) State the importance of (i) osmosis (ii) diffusion to plants and animals.***

# 6

# NUTRITION

**Nutrition** is one of the characteristics of living things. It is the process by which living organisms obtain and utilize materials from external environment for metabolic activities such as respiration, growth, excretion and reproduction.

***Food: Food is any substance which when absorbed into the body cells yields energy and materials for growth, repairs of damaged tissues and regulation of body processes without harming the living organism.***

## Modes of nutrition

Living organisms have evolved different modes of nutrition. However, organisms can be classified into two major groups based on their modes of feeding. These are **autotrophic feeders (self-feeders) and heterotrophic feeders (dependent-feeders).**

## Autotrophic mode of nutrition

**Autotrophic mode of nutrition** is carried out by **green plants** through a process called **photosynthesis** and some certain bacteria through **chemosynthetic process.**

## Photosynthetic (Holophytic) nutrition

Green plants are capable of manufacturing their own organic food from simple inorganic substances through photosynthetic process. In the presence of carbon (IV) oxide, water, sunlight energy and chlorophyll (green colouring matter), green plants manufacture their own food.

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight energy}} C_6H_{12}O_6 + 6O_2$$

From the simple sugars formed, other food substances such as proteins, oils and vitamins are manufactured.

## Chemosynthetic nutrition

Certain bacteria are autotrophic in nutrition. They are capable of manufacturing their own food from simple inorganic substances such as carbon (IV) oxide, water and hydrogen sulphide using the energy released during chemical reaction hence this process is called *chemosynthesis*. These bacteria do not depend upon the sunlight energy. They have enzyme systems capable of trapping the chemical energy.

For example, the **sulphur bacteria** in the soil can oxidize hydrogen sulphide around it to produce energy.

$$\underset{\text{hydrogen sulphide}}{2H_2S} + O_2 \xrightarrow{\text{sulphur bacteria}} S + 2H_2O + \text{chemical energy}$$

This chemical energy is capable of bringing about the combination of hydrogen sulphide and carbon (IV) oxide in the soil to form sugar, water and sulphur.

$$12H_2S + 6CO_2 \xrightarrow[\text{Energy}]{\text{chemical}} C_6H_{12}O_6 + 6H_2O + 12S$$

Also nitrifying bacteria (Nitrosomonas and Nitrobacter) in the soil oxidize ammonia to nitrites and nitrates respectively.

$$2NH_3 + 3O_2 \xrightarrow{\textit{Nitrosomonas}} 2HNO_2 + 2H_2O + \text{Chemical energy}$$

$$2HNO_2 + O_2 \longrightarrow 2HNO_3 + \text{chemical energy}$$

The energy released is used in combining water and carbon (IV)oxide to form sugar. The bacteria also use the nitrates in the soil with the sugar produced to form proteins.

All organisms that feed autotrophically are called **autotrophs.**

## Heterotrophic nutrition

This is a type of nutrition carried out by organisms that are not capable of manufacturing their own food from simple inorganic substances.

All animals and plants that lack chlorophyll (fungi, bacteria, few parasitic flowering plants) belong to this group. Organisms that practise heterotrophic nutrition are called **heterotrophs**. Heterotrophs take food items into their guts in three different forms. Animal such as mammals that take large food items which need the aid of teeth to break down before entering the digestive gut are called *macrophagous feeders*. Other heterotrophs which take tiny food particles into their gut without being broken down with teeth. These heterotrophs are called *microphagous feeders*. Examples are *Paramecium*, mosquito larvae and *Tilapia galilaea*. Some heterotrophs feed on fluids and referred to as fluid feeders. Examples are adult mosquitoes, aphids, butterflies and sunbird. There are four main types of heterotrophic nutrition. These are

1. **Holozoic**
2. **Saprophytic**
3. **Symbiotic**
4. **Parasitic**

## Holozoic nutrition

**This is a type of nutrition in which food is obtained as a solid organic material, eaten, digested and absorbed into the body.** Holozoic animals have to constantly search for their food and catch them. Therefore, holozoic animals have developed sensory, nervous and muscular structures to enable them search and catch their food.

Different efficient digestive systems have been developed to digest the solid food materials into simple materials for absorption into the body. Nearly all **animals are holozoic in nutrition.**

## Saprophytic nutrition

**This is a type of nutrition in which non-green plants feed on dead and decaying organic matter.** Enzymes are secreted from the cells to the dead organic matter and the digestion of the dead organic matter takes place outside the cells (extracellular digestion) of the saprophytic plant. The digested and soluble food substances are then absorbed by the cells.

Organisms which feed saprophytically are known as **saprophytes**. Most fungi (e.g.*Mucor*, mushroom, and yeast) and bacteria are examples.

## Symbiotic nutrition

**This is a type of nutrition in which two organisms of different species live together to take advantage of each other.** This type of association is called **symbiosis**. In some cases the two organisms become so dependent on each other that each one cannot live alone. For example, the association between an **alga** and a **fungus** in **lichens** is mutualistic. The fungus provides moisture (water) mineral salts and support for the alga which the alga uses in manufacturing food by photosynthesis for the fungus and itself. Both fungus and alga cannot live independently.

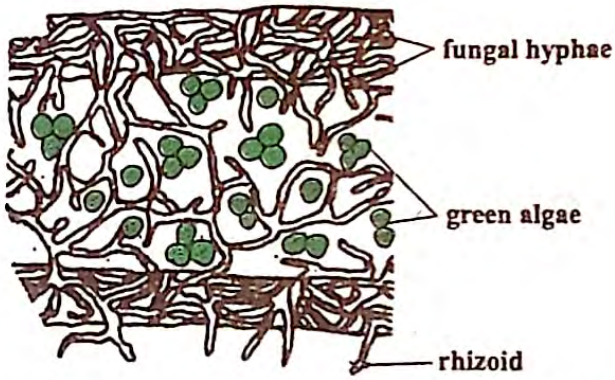



**Fig. 6.1. Sybiotic association between an algae and a fungus in lichens.**

Another example is the symbiotic feeding bet-ween herbivorous animals (e.g.goat,sheep) and cellulose-digesting bacteria that live in the caecum and colon of herbivores. The bacteria are capable of digesting the cellulose of leaves and converting the cellulose into sugar which is absorbed by the herbivore. The bacteria in turn feed on the abundant nutrients of the herbivore as well as obtaining shelter in the animal's caecum.

Symbiotic feeding is also exhibited **in hermit crab and sea anemone**. A hermit crab finds an empty snail shell and occupies it as a protective housing. It carries the shell to wherever it goes. The sea anemone attaches itself to the shell. Thus the sea anemone provides camouflage which protects the hermit crab from being seen by enemies. The sea anemone in turn gains by feeding on the scraps of food that fall away from hermit crab's meal.

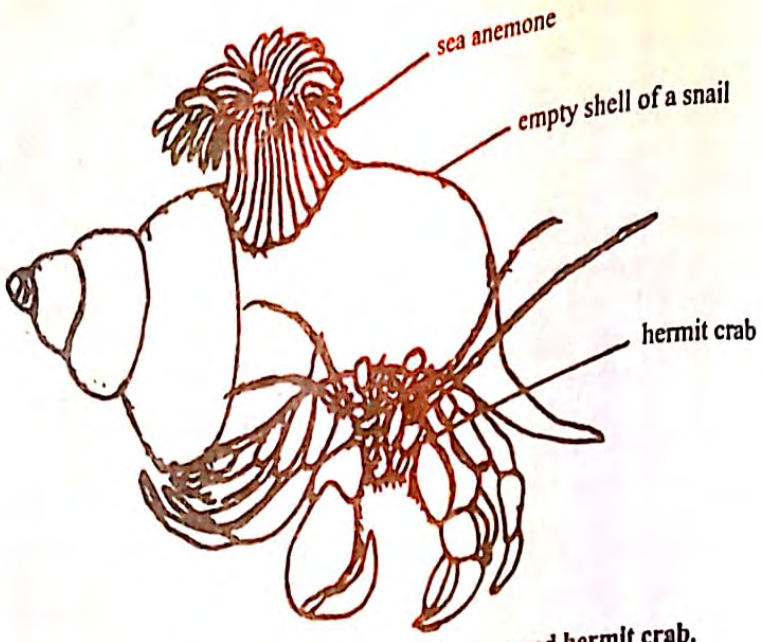



**Figure 6.2 Symbiotic association between sea anemone and hermit crab.**

## Parasitic nutrition

**This is a type of nutrition in which one organism obtains food from another organism and during the feeding process one organism is harmed and does not benefit.** The organism gaining food, protection and shelter is called **parasite** while the organism being harmed and providing food, protection and shelter is called **host**. The association between a host and a parasite is called **parasitism**. Some parasites live on the surfaces of their hosts. These are called **ectoparasites** and examples are lice (singular louse), ticks, bed-bugs, fleas and mites while other parasites that live inside the bodies of their hosts are called **endoparasites**. Examples are *Plasmodium*, hookworm (*Ancylostoma*), *Ascaris lumbricoides* (common roundworm), tape worm (*Taenia solium*) and liver fluke (*Fasciola hepatica*).

## Parasitic nutrition in flowering plants

**Dodder plant** (*Cassytha filiformis*) is a parasitic flowering plant. It has small scale leaves which are not green. The stem is thin and rope-like and coils round the stem of a host plant. Dodder develops **haustoria (suckers)** which are sent to the vascular bundles of the host from where it obtains food and water it requires for its metabolism.

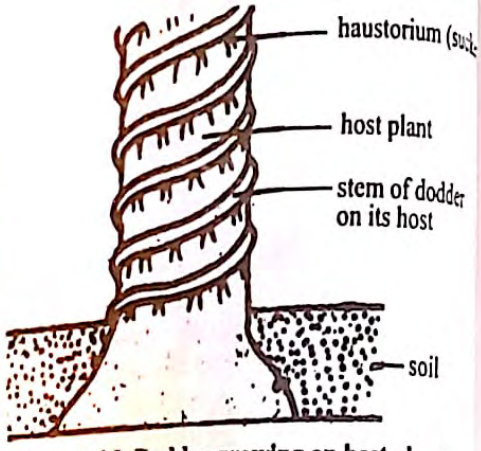
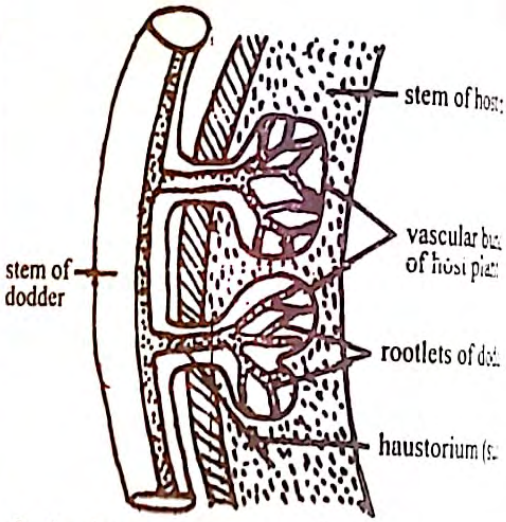



**Figure 6.3. Dodder growing on host plant.**




**Section through a host stem and dodder stem.**

## Parasitic nutrition in animals

*Ascaris lumbricoides* (intestinal roundworm). This parasitic worm stays in the small intestine of man where it sucks digested food from its host. The oesophagus is muscular and the mouth is equipped with three well developed lips. The muscular oesophagus and the three lips help the parasite to suck digested and soluble food from its host (man). The body of *Ascaris* is covered with a thick cuticle to prevent it from being digested by the host's digestive juice.

It causes abdominal pain, indigestion, anaemia and if they occur in large number, they can coil together and block the intestine leading to death.

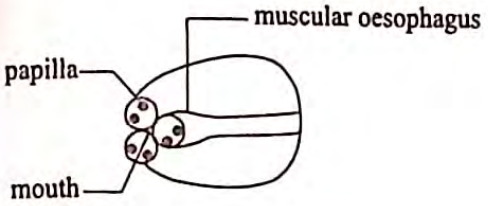



**Figure 6.4. *Ascaris* - Anterior end enlarged to show the mouth guarded by three lips.**

## Hookworm (*Ancylostoma duodenale*).

**Hookworm** inhabits the small intestine of its host (man). It has teeth-like structures or cutting plates in its mouth which it uses to cut holes into the intestinal walls and by means of its sucking pharynx, it sucks blood and other fluids from its host. To prevent the blood from clothing, it secretes anticoagulant from its mouth. After meal, it leaves bleeding wounds.

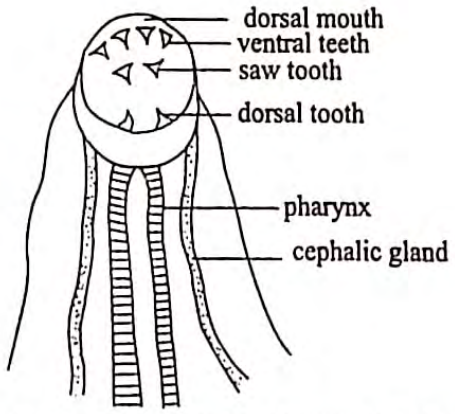



**Figure 6.5. Anterior end of hookworm showing dorsal mouth and teeth.**

They cause anaemia and abdominal pains in the host.

***Tapeworm*** (*Taenia solium*) is a flat, ribbon or tape-like parasite. The head or scolex has four muscular suckers on the sides. The rostellum is surrounded by hooks. The body consists of a series of proglottides. The long and tape-like body provides a large surface area for absorption of digested food all over the body by diffusion.

The presence of four suckers supported by hooks helps the tapeworm to fasten itself onto the wall of the small intestine.

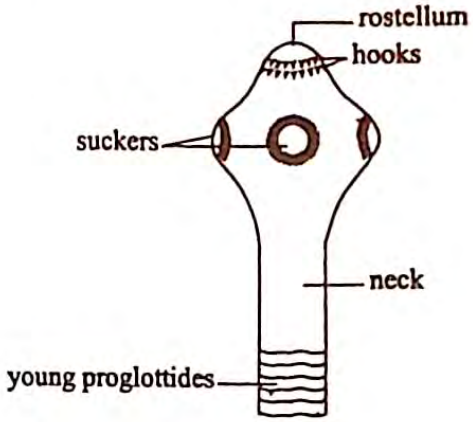



**Figure 6.6. Scolex showings suckers and hooks**

The host suffers an abdominal disorder and malnutrition and if tapeworm embryos migrate to the brain they damage the brain and may cause epilepsy.

## Carnivorous mode of nutrition in plants

A few green plants supplement their nutrients with organic food by trapping insects and other small animals. The trapped insects are digested and the amino acids are absorbed. Often, such carnivorous plants grow in soils poor in nitrogen and therefore, animal proteins are needed to supplement the nitrogenous compounds requirement of the plant.

**Sundew** (*Drosera rotundifolia*) and **Venus's flytrap** (*Dionaea muscipula*) are examples of carnivorous or insectivorous plants.

**Sundew** (*Drosera rotundifolia*). The leaves of sundew have numerous hair like tentacles. Each tentacle has a gland at its tip. The gland secretes sticky substances which help to trap small insects.

The struggling of the trapped insect stimulates the bending of tentacles nearby over the insect. Protein digesting enzymes are secreted thus digesting proteins to amino acids which are absorbed by the plant.

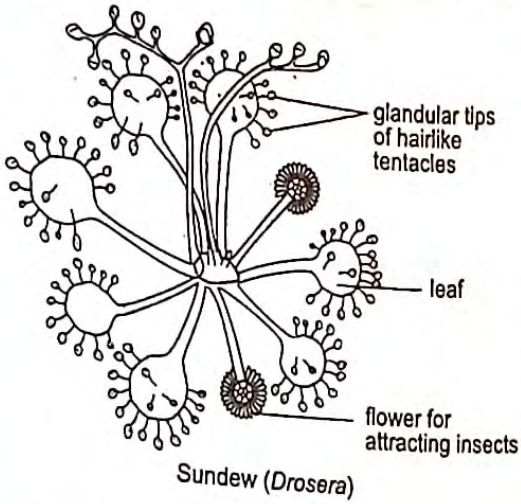



**Figure 6.7. Sundew plant.** *(Drosera)*

## Venus's flytrap (*Dionaea muscipula*)

The leaf consists of two lobes connected by midrib. In each lobe, a row of teeth-like structures are arranged along the margin of the leaf. On the surface of the leaf, there are small sensitive hairs. When an insect lands on the sensitive hairs, the lobes change their shape and quickly come together with the teeth-like structures interlocking and thus trapping the insect. The trapped insect is then digested with the enzymes secreted from the glands on the surface of the leaf. The amino acid resulting from the digestion is absorbed.

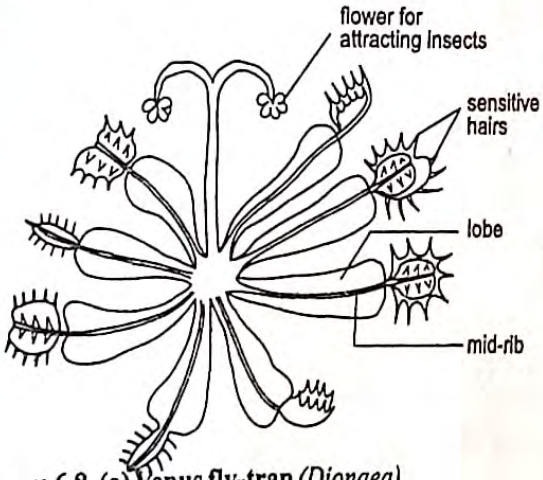



**Figure 6.8. (a) Venus fly-trap** *(Dionaea).*

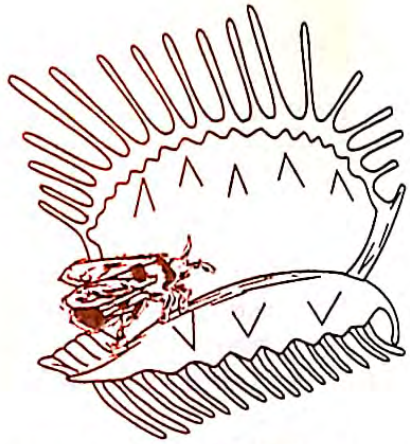


**Figure 6.8. (b) leaf of venus's fly-trap. One of the insect legs is about to touch a sensitive hair on the leaf surface.**

## Nepenthes or pitcher plant

**Pitcher plant** (or *Nepenthes)* has green leaves and obtains carbohydrates by photosynthesis. It obtains its nitrogen from insects and other small animals. Pitcher plant has pitcher-shaped leaves. (A pitcher is a container for fetching water used by the Romans in the old Roman Empire). The pitcher contains a protein digesting enzyme similar to **trypsin**. Insects are attracted to the lips of the pitcher by nectar secreted near the brim. In trying to suck the nectar the insect slips into the pitcher and gets drowned in the fluid. The end of the leaf is further modified to form a hood which covers the mouth of the pitcher when an insect falls in. The insects are further prevented from crawling out by numerous stiff downward pointing hairs. The protein of the **trapped** insect is digested by the enzymes secreted into the fluid and the product of digestion (amino acid) is absorbed by the inner surface of the leaf.

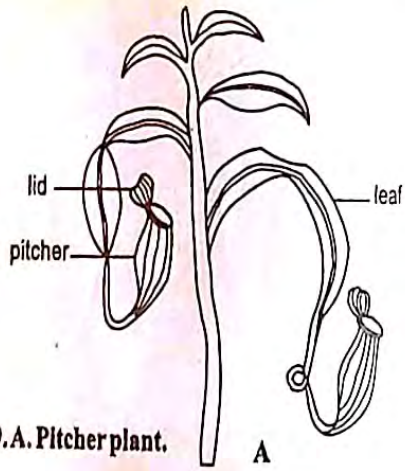



**Figure 6.9. A. Pitcher plant.**

B. Pitcher with lid enlarged

**Figure 6.9. B. Pitcher plant.**

Other examples of the carnivorous plants include:

1. **Bladderwort** (*Utricularia flexuosa*), an aquatic plant, using elaborate sacs in trapping water insects and other small animals.

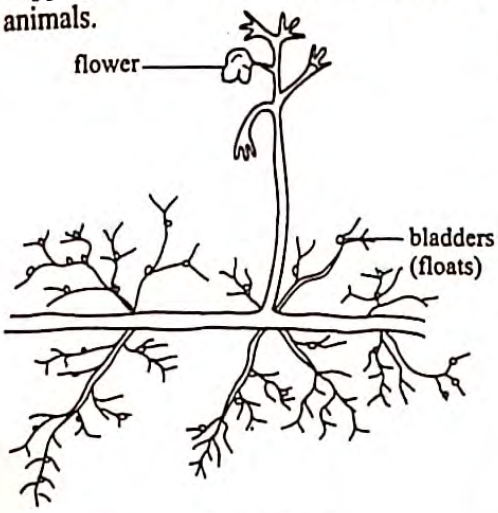



**Figure 6.10. Bladderwort** *(Utricularia)*

2. **Butterwort** (*Pinquicula alpina*) a terrestrial plant, attracting insects with bright colour and trapping the insects with sticky leaves.

**Figure 6.11. Butterwort** *(Pinquicula aipina)*

3. **Water fly-trap** (*Aldrovanda vesiclosa*) an aquatic plant, trapping insects and other small animals by sensitive hairs and bristles.

## Plant nutrition

**Photosynthesis** is the process by which carbohydrates or sugars are manufactured in the green parts of the plants containing chlorophyll by combination of carbon (IV) oxide and water with the aid of radiant energy of sunlight while oxygen is given out as a by-product.

It is a very important process which provides food not only for green plants but also for all animals and other plants which lack green pigments. The green **pigments** called **chlorophylls** when concentrated into structures are known as **chloroplasts**. The chloroplasts are disc-shaped in most plants, spiral in *Spirogyra* and star-shaped in *Zygnema*. Chlorophylls are the only structures capable of trapping the sun energy or other form of light energy. Chloroplasts are also present in very young parts of stems and herbaceous plants enabling them to carry out photosynthesis. All organs of plants with chlorophylls are green in colour.

Carbon (IV) oxide and water are inorganic compounds (raw materials). **During photosyn-thesis, these inorganic compounds are converted into organic products which are stored in plants and used as food. This type of nutrition in which inorganic compounds are converted into organic compounds is known as holophytic nutrition.** Holophytic nutrition is only possible in green plants.

The first stable product of photosynthesis is a **simple sugar (glucose)**. The reaction is represented by a chemical equation.

$$\underset{\text{Chlorophyll}}{6CO_2+6H_2O} \xrightarrow{\text{Sunlight}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

Aquatic green plants obtain carbon (IV) oxide from dissolved air in water by diffusion. In terrestrial green plants, water is absorbed from the soil by the root hairs. The absorbed water moves up the xylem to the leaves. Carbon (IV) oxide from the atmosphere diffuses into the leaves through the stomata to the mesophyll layer, (figure 6.12). The oxygen formed as a by-product diffuses out of the leaves through the stomata.

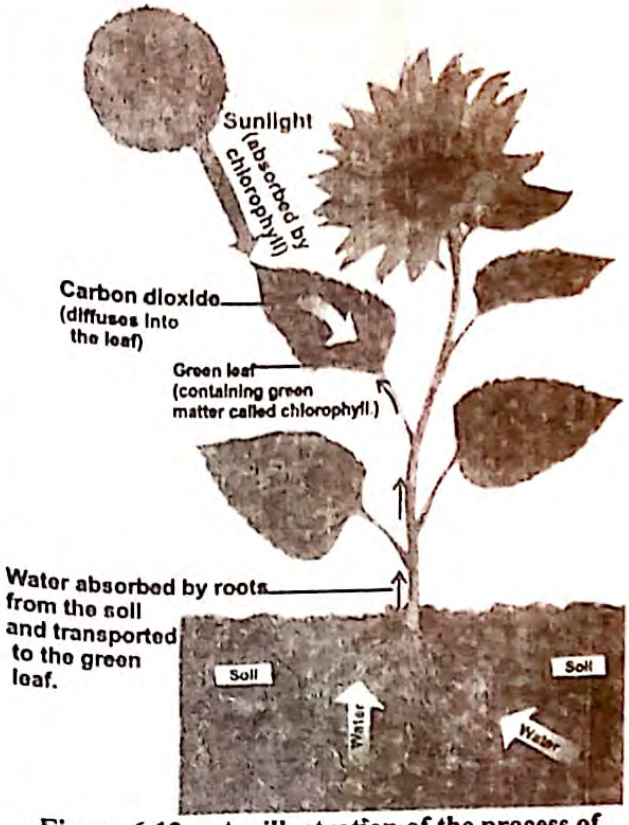



**Figure 6.12 a. An illustration of the process of photosynthesis using a flowering plant.**

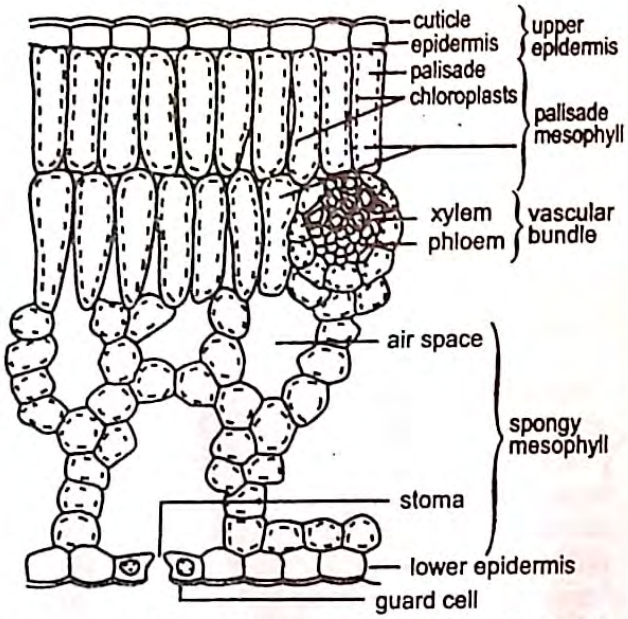



**Figure 6.12 b. Transverse section of a leaf showing chloroplast containing chlorophyll**

## Mechanism of photosynthesis

The mechanism of photosynthesis is complex. It involves series of enzymes present in the plant. Two reactions called **light** and **dark** are involved:

**A. Light reaction:** It is called light reactio because it **occurs only in the light**. In th light reaction, four steps are involved:

**Step 1**

**Chlorophyll is energized:** The chlorophy molecules absorb the sunlight energy and becom energized.

**Step 2**

**Photolysis of water:** The energized chlorophy supplies the energy (sunlight energy), that **splits** th water molecules into **hydrogen ($H^+$)** and hydrox **($OH^-$)** ions. This is called **photolysis of water**. Th hydroxyl ion ($OH^-$) gives up its negative electron to th chlorophyll molecules and forms water and oxyge The oxygen is given out as a by-product.

$$4H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} 4H^+ + 4OH^-$$

$$4(OH^-) \longrightarrow 2H_2O + O_2$$

Oxygen is given up as a by product.

**Step 3**

**Hydrogen is transferred by NADP (Nicotina-mide adenosine dinucleotide phosphate)**

The hydrogen atom ($H_2$) released above i immediately picked by a coenzyme called NADP (Nicotinamide-adenosine dinucleotide phosphate) i order to prevent its escape from the cell o recombining with oxygen to form water. NADP i now reduced to **$NADPH_2$** having accepted hydroge atoms ($2H^+$) and serves as an electron carrier o hydrogen ions.

**Step 4**

**Formation of ATP (Adenosine triphosphate)**

Chloroplasts contain **ADP** (Adenosine diphos-phate, a low energy carrier). The extra energy not used in th spliting of water molecules by the energized chlorophyl is released to **ADP** to form **ATP** (high energy carrier)which will be used in dark reaction. All these events take place in the **grana** (disc like structure chloroplasts) of the chloroplasts.

## B. Dark reaction: (Calvin cycle):

It is called **dark reaction** because it does not require light energy. Carbon (IV) oxide is reduced by combining with two atoms of hydrogen provided by a coenzyme ($NADP\ H_2$) to form sugars after undergoing a series of stepwise reactions. Each step is controlled by a specific enzyme. The energy needed for the formation of sugars is provided by ATP from light reaction. These events take place in the chloroplast surrounds the stroma of the chloroplasts. The production of glucose is not the end of photosynthetic activities. Some organic compounds at the 3-carbon sugar stage (phospho-glyceric acid) PGA are set aside for the synthesis of fats, oil, proteins and numerous carbohydrate derived substances.

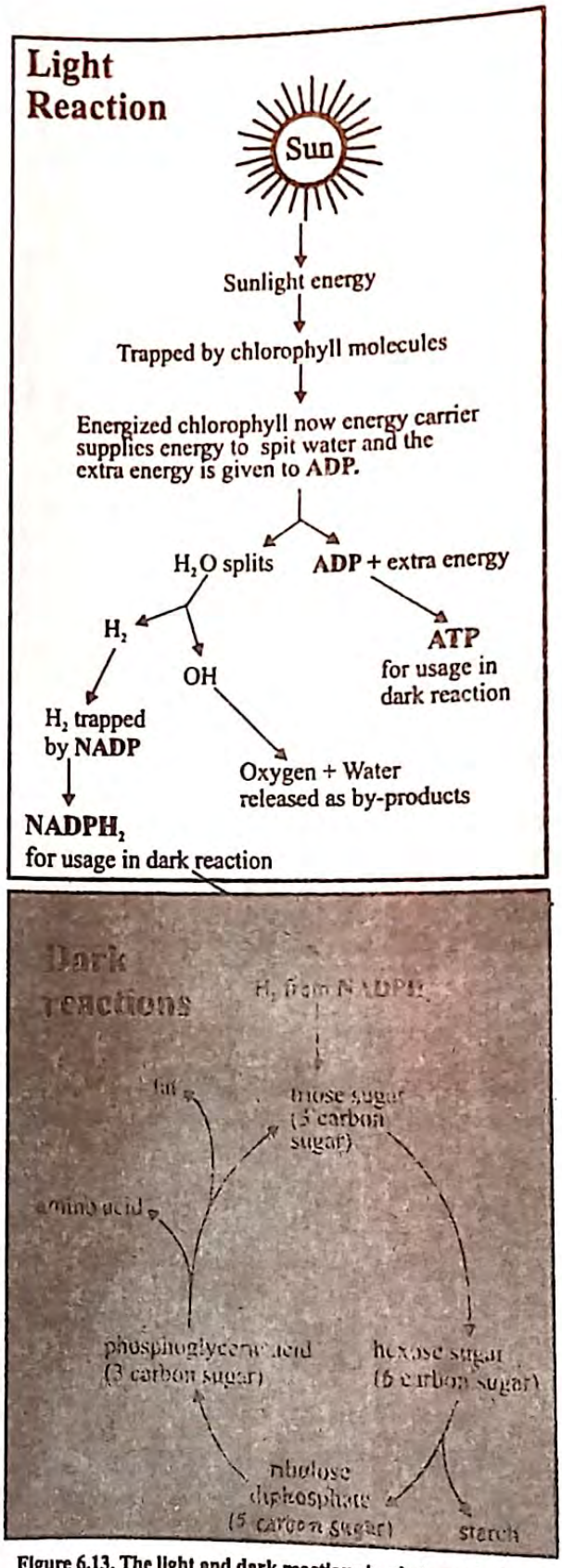



**Figure 6.13. The light and dark reactions in photosynthesis**

Add equations (a) and (b).

$$12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} 12H_2 + 6O_2 \text{--(a)}$$

$$6CO_2 + 12H_2 \longrightarrow C_6H_{12}O_6 + 6H_2O \text{--(b)}$$

$$12H_2O + 6CO_2 + 12H_2 = 12H_2 + 6O_2 + C_6H_{12}O_6 + 6H_2O$$

$$12H_2O - 6H_2O + 6CO_2 = C_6H_{12}O_6 + O_2$$

$$6H_2O + 6CO_2 = C_6H_{12}O_6 + 6O_2$$

## Factors which affect photosynthesis

Photosynthesis is affected by the following factors:

1. **Light intensity**: Light is necessary for photosynthesis to take place. The rate of photosynthesis increases with moderately high light intensity while the rate is decreased with low light intensity. Very high light intensity reduces the rate of photosynthesis as chlorophyll is bleached and enzymes denatured.
2. **Carbon (IV) oxide:** Carbon (IV) oxide is a necessary raw material in photosynthesis. The more carbon (IV) oxide in the photosynthetic cells the faster the rate of photosynthesis.
3. **Water:** Water is an essential raw material for photosynthesis.
4. **Temperature:** The light and dark reactions are controlled by enzymes. Low or high temperature will negatively affect enzyme action hence decrease in the rate of photosynthesis.
5. **Chlorophyll concentration:** The reduction of chlorophyll level decreases the rate of photosynthesis. High light intensity, mineral deficiency diseases and ageing processes reduce chlorophyll concentration.
6. **High concentration of oxygen**: High concentration of oxygen in the atmosphere decreases the rate of photosynthesis. It has been shown that oxygen competes with carbon (IV) oxide for active site in the carbon (IV) fixing enzyme (carboxylase) thus reducing the amount of carbon (IV) oxide, thereby decreasing the rate of photosynthesis.
7. **Inhibitors:** Herbicides such as **DCMU (dichlorophenyl diamethyl urea)** inhibits the electron flow of the chloroplasts thereby decreasing the rate of photosynthesis.

8. **Pollution:** Gases and materials of industrial wastes discharged into the atmosphere affect the rate of photosynthesis. Sulphur (IV) oxide and ozone for example damage the leaves of plants. Soot and dust particles block the stomata slowing down the rate of exchange of gases thus decreasing the photosynthetic rate. Soot and dust particles also reduce the intensity of sunlight, hence photosynthetic rate is reduced.

## The fate of glucose after photosynthesis

Glucose is the first stable product of photosynthesis. It is used by all living cells for respiration during which energy is liberated. In the presence of sunlight, the glucose in the leaves is quickly converted to starch. This can be proved by testing a leaf for starch. In the dark (where there is no light) photosynthesis stops and starch in the leaves is converted to sucrose (a complex sugar) and translocated out of the leaves to other parts of the plant through the phloem vessels. If present in excess, the sucrose may be reconverted to starch and stored in some of the storage organs in the plant for later use (e.g. underground stems, root tubers and seeds). If not, the sucrose is converted into glucose and used by the living cells for respiration, or used as a starting material for the synthesis of cellulose, proteins, fats, oils and other structural components of the living cells. The synthesis of proteins, fats and oils, for instance, involves the absorption of mineral salts such as nitrates, sulphates and phosphates from the soil which are incorporated into organic compounds with the help of enzymes.

Starch, proteins, fats and oils are complex organic matters stored in the plant body as food.

## The importance of photosynthesis in nature

1. All living things require energy for growth and other metabolic activities. It is through photosynthesis that the energy of the sun is converted into useful energy stored in glucose which both plants and animals use during respiration.
2. Glucose, a product of photosynthesis is a starting material for the synthesis of proteins, fats, oil and vitamins which are various forms of food for both plants and animals.
3. Animals and non-green plants which cannot manufacture their own food depend on green plants for their food.
4. Oxygen which is a by-product of photosynthesis is necessary for aerobic respiration.
5. Photosynthesis purifies the atmosphere by the constant removal of carbon (IV) oxide.

## Experiments on photosynthesis

The occurrence of photosynthesis in plants can be shown by experiments. The easiest proof that photosynthesis has taken place is to test for the presence of starch in the green leaves. Experiments should be carried out to show the importance of **carbon (IV) oxide, sunlight energy** and **chlorophyll** in photosynthesis. There is need to prove that **oxygen is given off** during photosynthesis.

## Testing a leaf for starch

The usual laboratory test for starch is to bring the testing substance in contact with iodine solution. A blue-black colour confirms the pre-sence of starch. With the green leaf, the test is not so straight forward. Green leaves contain chloro-phyll which blocks up the reaction of iodine with starch. Steps are therefore taken to remove the chlorophyll from the leaf before bringing it in contact with iodine.

The following steps must be carried out:

1. The leaf to be tested is detached from the plant after 4-6 hours of exposure to light and put into boiling water for about 10 -15 minutes. This kills the protoplasm of leaf and stops all enzyme activities in the cells. Boiling will also make iodine more easily permeable to starch granules at the time of test.
2. The boiled leaf is put into 70% boiling ethyl alcohol or methylated spirit. This is done to extract the chlorophyll from the leaf. The alcohol is heated to a boiling point in a water-bath to avoid inflammation.

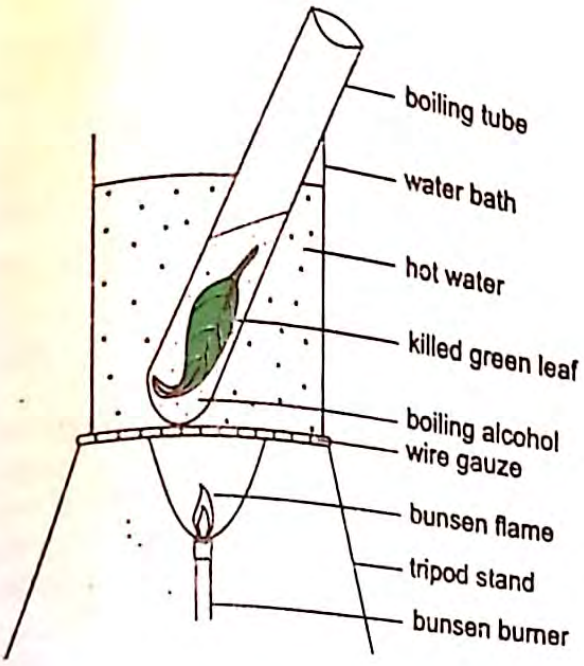



**Figure 6.14. Boiling a green leaf in alcohol**

When the chlorophyll is completely removed, the leaf becomes white and brittle. It is then dipped into hot water to soften the tissues.

3. The bleached leaf is spread out on a flat surface such as a white tile and few drops of iodine solution are added. It is then allowed to stand for a few minutes. The iodine solution is washed off in cold water. The colour of the leaf an now be observed against a light source.

(1) If the tested leaf appears bluish-black in colour, it contains starch.

(2) If the colour is yellowish-brown, it contains no starch.

## Destarching the leaves of a plant

It has earlier been stated that the presence of starch in a leaf is an evidence that photosynthesis has occurred in that leaf. It is very important that in any experiment on photosynthesis, the leaves to be used must be destarched. Green leaves can be destarched by keeping a potted plant in a dark cupboard for 48-72 hours. During this period photosynthesis stops. The starch already formed in the leaves is hydrolysed to sugar and translocated to other parts of the plant to be used for respiration. At the end of 48 hours it is expected that all the starch in the leaves must have been completely hydrolysed and translocated. The leaves are therefore without starch. This can be confirmed by testing one of the leaves for starch as previously described. If the leaves have been destarched. the starch test result is negative, that is a yellowish-brown colour with iodine solution. Potted plants are more suitable for experiments on photosynthesis as the pots can easily be carried to different environmental conditions without destroying the plant. A living plant uprooted and kept in the dark will wither before 48 hours.

## Experiment to show the Carbon (IV) oxide is necessary for photosynthesis.

Aim: To show that carbon (IV) oxide is necessary for photosynthesis.

Method: Two potted plants well watered are kept in darkness for 24 hours or more to render them starch free. The leaves of both plants are tested for starch until the leaves are starch free. Each of the potted plants is placed on vaselined glass plate (to prevent air containing carbon (IV) oxide from leaking into the bell jar) and covered with a large bell jar.

A dish containing water is placed in bell jar "A" with air containing carbon (IV) oxide as a

The soil surface together with the body of the pot is covered with a polythene bag to prevent the output of respiration by soil organisms. This is the control experiment.

In bell jar "B" is placed a dish containing lime water to absorb carbon (IV) oxide.

The two bell jars are exposed to sunlight for about 4 hours. Some leaves are taken from each plant at the end of the experiment and tested for starch.

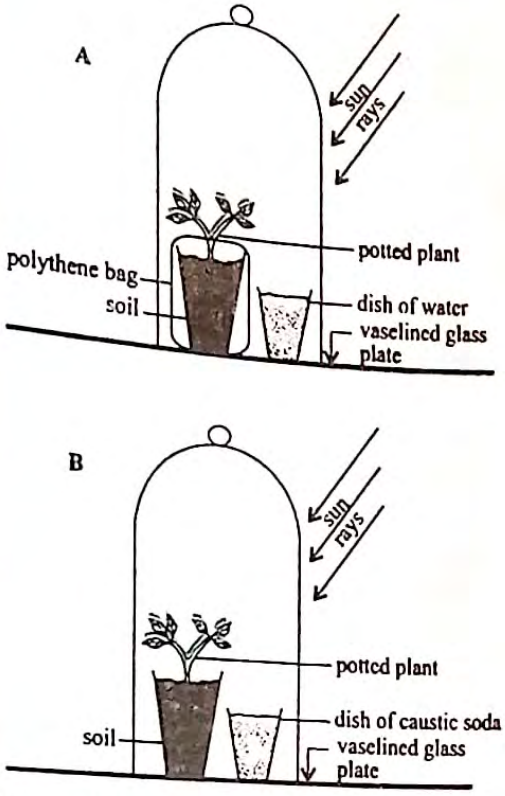



**Figure 6.15. Experiment to show that carbon (IV) oxide is necessary for photosynthesis**

**Result:** The leaves of the plant in bell jar"A" turns blue black while the leaves of the plant from jar "B" remains brown in colour showing absence of starch.
**Conclusion:** Starch is not formed in the absence of carbon (IV) oxide. Therefore carbon (IV) oxide is necessary for photosynthesis.

## Experiment to show that sunlight it important for photosynthesis.

**Aim:** To show that light is necessary for photosynthesis.

**Method:** Two potted plants well watered, are kept in darkness for 24 hours or more. The leaves of both plants are tested for starch until they are starch free. One of the potted plants is exposed to sunlight for 4 hours. The other potted plant remains in darkness for 4 hours. The leaves from the two potted plants are then tested for starch.

**Result:** The leaves from the potted plant exposed to light turns blue black while the leaves of the plant kept in darkness remains brow showing absence of starch.

**Conclusion:** Without light starch is not formed therefore light is necessary for photosynthesis.

## Experiment to show that chlorophyll is necessary for photosynthesis

**Aim:** To demonstrate that chlorophyll is necessary fo photosynthesis.

Variegated leaves in which chlorophyll is distribute in parches are required for this experiment. Som leaves of ice plant, *Acalypha, Croton* and *Calladiu* are good examples for this experiment. The areas wit chlorophyll are green while the other areas withou chlorophyll are coloured red, blue, yellow or white.

**Method:** The plants with variegated leaves ar allowed to receive sunlight for 4-6 hours. Some of th leaves are taken and mapped. The leaves are the boiled in water to kill the protoplasm. They ar decolourized by placing them in boiling alcohol. Th leaves are then washed in water to soften the tissue The decolourized leaves are spread on white tile Iodine solution is spread over them.

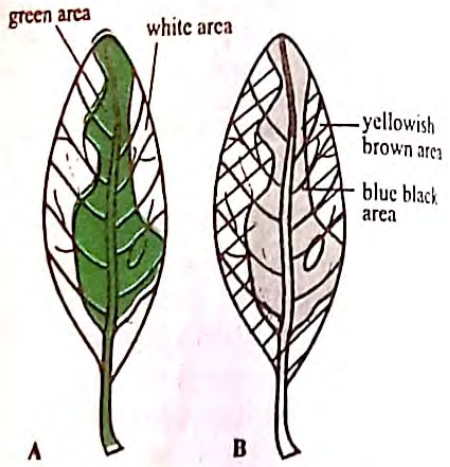



**Figure 6.16. Experiment to show that chlorophyll i necessary for photosynthesis**

**Result:** Some areas of the leaf turn blue-black whil the other areas turn yellowish brown. Match the leave with their maps. By comparing the tested leaf diagram "B" with the first drawing of diagram "A the blue-black areas correspond to the areas wi

chlorophyll while the yellowish brown areas correspond to the areas without chlorophyll.

**Conclusion:** Since starch is formed only in the areas with green pigments (chlorophyll) chlorophyll is therefore necessary for photosynthesis.

## Experiment to show that oxygen is a by product of photosynthesis

**Aim:** To show that oxygen is released during photosynthesis.

**Method**: Green aquatic plants such as *Ceratophyllum* or *Spirogyra* filaments are collected in a beaker together with some water in which the plants are growing. A glass funnel is inverted over the plants. A test tube filled with water is then inverted over the stem of the glass funnel. The apparatus is then placed in sunlight. A little quantity of sodium tri-oxo carbon (IV) acid is dissolved in the water to increase the quantity of carbon (IV) oxide needed for photosynthesis. A **control experiment** is set in a similar way, but kept in a dark room to stop photosynthesis. As photosynthesis occurs, some gas bubbles are collected on the stem, which eventually break off and collect in the test tube. The gas displaces the water in the test tube. When sufficient quantity has been collected, the test tube is removed while closing the mouth with the thumb. The gas is tested with a glowing splint.

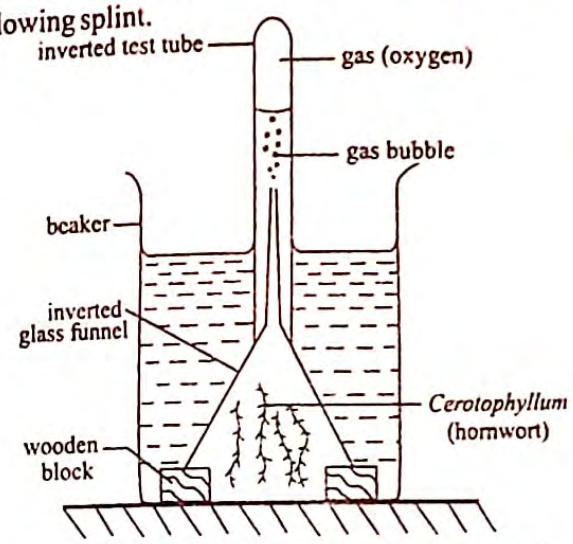



**Figure 6.17. Experiment to show that oxygen is a by product of photosynthesis.**

**Result**: The gas rekindles a glowing splint. No gas collects in the **control experiment.**

**Conclusion**: Since oxygen is the only colourless gas that rekindles a glowing splint, the gas released is oxygen.

**Table 13. Differences between respiration and photosynthesis**

| Respiration | Photosynthesis |
|---|---|
| 1. It is a catabolic process associated with the break down of organic matter. $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$ + 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 liberate d. | 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 tim e. |

(b) **Similarities between respiration and photosynthesis**

1. Both convert energy from one form to another.
2. Both require mechanisms for exchange of gases (oxygen and carbon (IV) oxide).
3. Both require specialized organelles, mitochondria in case of respiration and chloroplasts in case of photosynthesis.
4. Both involve cycle 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 resemble respiration in that both expend energy in the form of ATP.

## Mineral requirement of plants

Mineral elements are required for normal growth and development of green plants. In addition to carbon, oxygen and hydrogen, other mineral elements which green plants need in form of salts in large amounts are: nitrogen (N) phosp-horus (P) sulphur (S) potassium (K) magnesium (Mg) calcium (Ca) and iron (Fe). These seven elements are called major elements (essential elements or macronutrients). A major or an essen-tial element is an element which the plant or animal needs for normal growth and development.

Plants also require tiny amount of some elements. These are manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl). These elements are micronutrients or trace elements.

Mineral salts are absorbed from the soil in solution through the roots of plants. If any of the macronutrients or micronutrients is absent from the soil, plants may show poor growth.

Table 14: Macronutrients

| Macronutrients | Importance | Deficiency |
|---|---|---|
| Nitrogen (N) | 1.Protein synthesis.<br>2.Nucleic acids sysnthesis.<br>3. Proper root development component of chlorophyll and enzymes | 1. Stunted growth and chlorosis (yellow leaves).<br>2. Poor flower and fruit formation. |
| Phosphorous (P) | 1.Formation of ATP, DNA and RNA.<br>2.Stem and root formation.<br>3. Seed and fruit formation<br>4.Co-enzyme and protein formation. | Stunted growth particularly the roots.<br>Poor root development. |
| Sulphur (S) | Components of some amino acids and proteins. | 1. Stunted growth, chlorosis.<br>2. Chlorosis (yellow leaves). |
| Potassium (K) | 1.Protein synthesis.<br>2.Cell membrane formation.<br>3. Crop maturation.<br>4.Activates respiration and photosynthesis. | 1. Leaf margin turns yellow and brown.<br>2. Premature death. |
| Magnesium (Mg) | 1. Formation of chlorophyll.<br>2. Helps in cell division.<br>3. Synthesis of oil in plants.<br>4. Promotes growth.<br>5. Activates many co-enzymes. | 1. Poor growth.<br>2. Chlorosis. |
| Calcium (Ca) | 1.Formation of cell walls.<br>2.Activates some enzymes.<br>3.Gives rigidity to plant.<br>4. Helps in the storage of proteins and carboy-drate in seeds and tubers. | 1.Stunted growth.<br>2.Death of terminal bud. 3.Roots develop poorly. |
| Iron (Fe) | 1.Formation of chlorophyll.<br>2.Formation of protein. | 1.Poor growth.<br>2.Leaves turn yellow. |

Table 15:

## Micronutrients

| Micronutrients | Importance | Deficiency |
|---|---|---|
| Manganese (Mn) | Activates some enzymes involved in cellular respiration photosynthesis. | Death of shoot. |
| Zinc (Zn) | 1. Necessary for the synthesis of the starting material (tryptophan) of auxin.<br>2. Activates some enzymes.<br>3. Plays a role in the synthesis of protein. | Poor growth. |
| Copper (Cu) | 1. Component of respiratory enzymes.<br>2. Present in the material which acts as electron carrier for chlorophyll. | Poor growth. |
| Boron (B) | Translocation of sugar and calcium | Poor growth, poor growth of pollen tubes. |
| Molybdenum (Mb) | 1. Necessary for nitrogen fixation by nitrogen fixing bacteria.<br>2. Activates the enzyme that reduces nitrate to nitrite. | Poor growth. |
| Chlorine (Cl) | Necessary for oxygen release during photosynthesis. | May affect growth. |
| Nickel (Ni) | Necessary for nitrogen metabolism | Stunted growth and chlorosis |

## Water culture experiment
## Experiment

**Aim:** To demonstrate the effects of **nitrogen, phosphorus, sulphur, potassium, magnesium, calcium** and **iron** deficiencies in flowering plants.

**Method:** Eight clean and sterilized jars are obtained. They are labelled A to H. A culture solution is prepared by adding the right proportions of nitorgen, phosphorus, sulphur, potassium, magnesium, calcium and iron. The eight bottles are then filled as follows:

Jar A: Culture solution containing nitrogen, phosphorus, sulphur, potassium, magnesium, calcium and iron. This is the control.
Jar B: Culture solution without nitrogen.
Jar C: Culture solution without phosphorus.
Jar D: Culture solution without sulphur.
Jar E: Culture solution without potassium.
Jar F: Culture solution without magnesium.
Jar G: Culture solution without calcium.
Jar H: Culture solution without iron.

Eight healthy bean seedlings are obtained. Each seedling is then placed in each jar. Each jar is then wrapped with black paper to prevent penetration of light thereby preventing the growth of algae.

Each jar is kept in a warm place that receives sunlight for about three weeks. Observe daily throughout the period of experiment.

**Result:** The seedling in jar A is luxuriant in growth, healthy with green leaves and well developed roots. Seedling of jar B shows stunted growth and yellow leaves. Seedling of jar C shows stunted growth, particularly the roots. Seedling of jar D shows stunted growth and yellow leaves. Seedling of jar E shows yellow and brown leaf margin with stunted growth. Seedling of jar F shows poor growth and yellow leaves. Seedling of jar G shows stunted growth, death of terminal buds and poor root development. Seedling of jar H shows yellow leaves and poor growth.

**Conclusion:** Deficiency of the essential minerals can affect the normal growth of plants.

## Precautions

In carrying out this experiment, the following precautions are necessary for successful results.

1. Air must be bubbled to the solution daily for the healthy growth and aeration of the roots.
2. The seedling must be healthy, and the same size and age.
3. All the jars must be kept under the same conditions.
4. The culture solution must be renewed weekly to prevent depletion of some nutrients.
5. All the jars used must be covered with black paper or cloth to prevent light from entering thereby preventing the growth of algae in the culture solution. If algae grow in the culture solution, they will compete with the seedling for nutrients.
6. The cork and cotton wool must be kept dry so as to prevent the stem from rotting. Cotton wool is used to hold the stem to avoid damage to the young and delicate stem.
7. The jars are sterilized to prevent the growth of bacteria which may cause diseases.

**Table 16: Culture solution as modified from Hewit. 1974**

| Mineral | $gdm^{-3}$ Water | $gdm^{-3}$ Water |
|---|---|---|
| **Macronutrients** | | |
| $KNO_3$ | 0.404 | K 0.156 |
| $Ca(NO_3)_2$ | 0.656 | N 0.057 |
| $Ca(NO_3)_2$ | 0.656 | Ca 0.160<br>N 0.113 |
| $MgSO_4.7H_{20}$ | 0.368 | Mg 0.036<br>S 0.048 |
| $NaH_2PO_4.H_2O$ | 0.208 | P 0.041 |
| Fecitrate $5H_2O$ | 0.03350 | F 0.005 |
| **Micronutrients** | | |
| $MnSO_4.4H_2O$ | 0.00223 | Mn 0.00055 |
| $ZnSO_4.7H_2O$ | 0.00029 | Zn 0.00006 |
| $CuSO_4.5H_2O$ | 0.00025 | Cu 0.00006 |
| $H_3BO_3$ | 0.00310 | B 0.00054 |
| $Na_2MoO_4.2H_2O$ | 0.00012 | Mo 0.00005 |
| NaCl | 0.00580 | Cl 0.00350 |

**Table 17: Knop's Culture Solution**

| Mineral Salt | $gdm^{-3}$ Water |
|---|---|
| $KNO_3$ | 0.2 |
| $Ca(NO_3)_2$ | 0.8 |
| $KH_2PO_4$ | 0.2 |
| $MgSO_4.7H_2O$ | 0.2 |
| $FePO_4$ | 0.1 |
| **Sach's Culture solution** | |
| $MgSO_4.7H_20$ | 0.5 |
| $CaSO_4$ | 0.5 |
| $Ca(PO_4)_2$ | 0.5 |
| NaCl | 0.5 |
| $KNO_3$ | 0.1 |
| $FeCl_3$ | 0.005 |

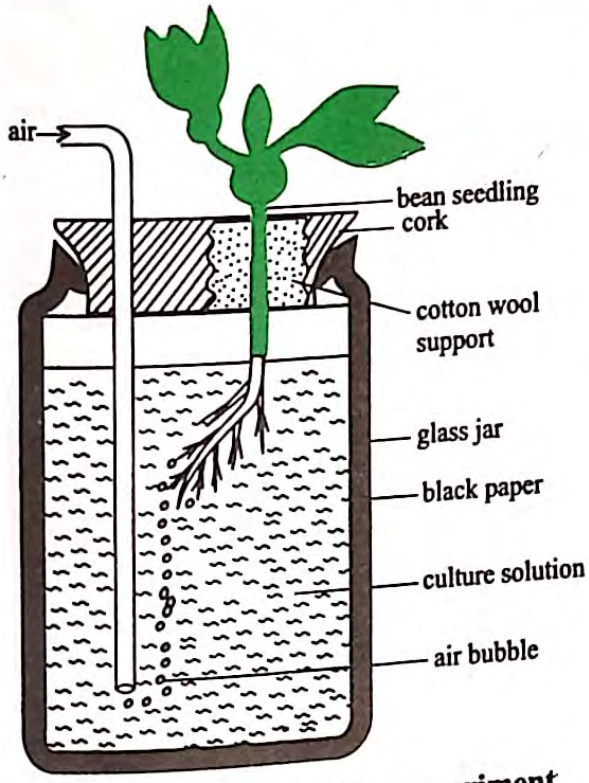



**Figure 6.18: Culture solution experiment**

# ANIMAL NUTRITION

## Importance of food to animals

1. Provides materials for growth and repairs of worn out tissues.
2. Provides energy for work and warmth.
3. It keeps the organism healthy so that it can fight against diseases.

## Classes of food

Food substances are classified as follows:

1. **Carbohydrates**
2. **Proteins**
3. **Fats and oils**
4. **Vitamins**
5. **Mineral salts**
6. **Water**
7. **Roughage**

## Carbohydrates

Carbohydrates are organic compounds containing carbon, hydrogen and oxygen atoms. The ratio of hydrogen to oxygen is 2:1 in all carbohydrates. Starch, sugar, glycogen and cellulose are carbohydrates. They are classified into three major groups namely:-

1. **Monosaccharides**
2. **Disaccharides and**
3. **Polysaccharides.**

## Monosaccharides (one molecule sugars)

These are simple sugars which consist of one molecule each. These sugars may contain six or less carbon atoms per molecule. Examples are **glucose** ($C_6H_{12}O_6$), **fructose** ($C_6H_{12}O_6$) and **ribose** ($C_5H_{10}O_5$).

## Disaccharides (Double molecule sugars)

When two molecules of simple sugar combine and one molecule of water is removed, a **disac-charide** is formed.

Examples of food rich in animal proteins are: **milk, egg, meat, chicken, fish, and snail.** These animal proteins are sometimes called **first class proteins** because they are more useful to the body as they contain most of the essential amino acids.

Examples of food rich in plant proteins are **beans, peas and groundnut**. These plant proteins are also referred to as **second class proteins** because they are less useful to the body as they contain less of the essential amino acids. People who depend solely on plant proteins are likely to suffer from **deficiency diseases**. Vegetarians should carefully select a combination of plant proteins that will complement each other so as to make up for each other's deficiencies.

## Fats and oils (Lipids)

**Fats** are complex organic compounds containing carbon, hydrogen and oxygen. They contain high proportion of carbon and hydrogen with little oxygen.

Fats are **solid** at a room temperature while **oils** are **liquid** at room temperature. Liquid fats are called oils.

Fats are not soluble in water but soluble in solvents like kerosine, ether, chloroform and benzene. Fats are found in both plants and animals. Oils can be obtained from plant and animal fats by the process of heating (e.g. vegetable oils from groundnut, coconut, melon, kernel and oil palm fruits). The oils can be hardened into forms like butter by cooling, freezing and hydrogenation.

## Sources of fats

The sources of fats are: groundnuts, melons, butter, palm oil, codliver oil, margarine, soya bean oil, palm kernel oil fatty meat or fish, coconut oil.

## Importance of fats and oils

1. When fats and oils are oxidized, they give a great amount of energy and heat to the body. They yield more energy than carbohydrates.
2. Excess fats are stored under the skin and around some organs like intestines, eyes, gonads, kidneys and heart. These stored fats help to keep the body warm and protect the vita l delicate organs.
3. They act as insulator to nerves and cell membranes.
4. It must be noted that too much fats in the body is detrimental to health, hence the amount of fats and carbohydrates in the diet should be carefully regulated.
5. They go into the formation of cell membranes.

## Vitamins

**Vitamins** are organic substances needed in small quantities in the body for healthy growth and development.

They are not energy giving food. The most important vitamins are **A, B, C, D, E** and **K**. Vitamin **B** comprises many vitamins hence it is referred to as vitamin **B complex**.

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

Disaccharides have chemical formula of $C_{12}H_{22}O_{11}$

When one molecule of glucose combines with one molecule of fructose, one molecule of **sucrose** (cane sugar) is formed.

1 molecule of glucose +1 molecule of fructose
= 1 molecule of sucrose.

Combination of **two molecules** of glucose will form one molecule of **maltose** or **malt sugar**.
1 molecule of glucose + 1 molecule of glucose
= 1 molecule of maltose.
1 molecule of **glucose** combining with one molecule of **galactose** forms **lactose** (milk sugar).
Examples of disaccharides are sucrose (cane sugar), maltose (malt sugar) and lactose (milk sugar).

## Polysaccharides

Polysaccharides are complex carbohydrates consisting of glucose molecules in chain with general formula of $(C_6H_{10}O_5)_n$ where letter **n** shows a large number. Starch, glycogen and cellulose are polysaccharides.

Sources of starch are potato, yam, tapioca, rice, millet, wheat, bread and cassava. These are plant starches. **Glycogen** is an animal starch produced and stored in the liver and muscles. It is converted to glucose when the need arises.

**Cellulose** is derived from vegetables and fruits. It forms the cell walls in most plant cells.

## Importance of carbohydrates

1. When oxidized, they give energy and heat. The energy is used for work while the heat is used to maintain body temperature in homoiothermic animals.
2. Excess carbohydrates are converted into glycogen thus acting as food reserve only to be used when the need arises.
3. Carbohydrates provide starting materials for the synthesis of proteins, fats, oil and vitamins.

Proteins are organic compounds consisting of carbon, hydrogen, oxygen and nitrogen atoms but some proteins contain little phosphorus and sulphur atoms.

Proteins have complex structures consisting of chains of **amino acids** which are the smallest (basic) units.

## Importance of proteins

1. Proteins are needed for growth.
2. They are used for repairs of worn out or damaged tissues.
3. Proteins are used to make enzymes hormones.
4. They give certain amount of energy.
5. They are used to make white blood cells and antibodies.

## What happens when protein is inadequate in our food?

If the person is an adult, ill health results but if the person is a growing child, retarded growth, weak muscles, distended stomach, swollen legs, loss of weight, and change of hair colour usually from dark to red results. This condition is called *kwashiorkor* (a disease of protein deficiency in diet).

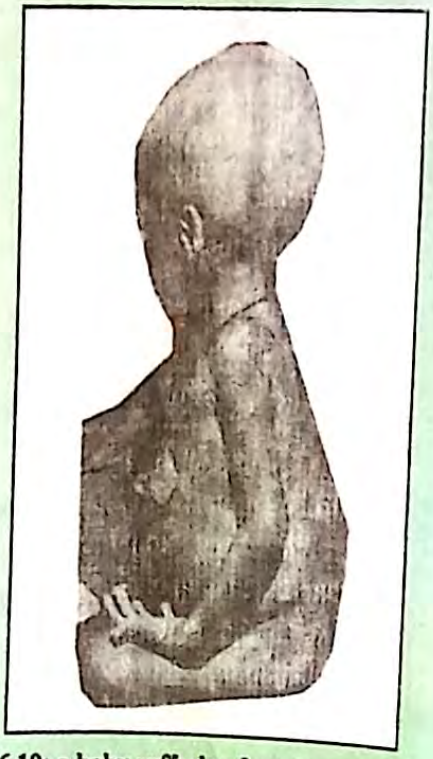

**Figure 6.19: a baby suffering from kwashiorkor**

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1. When fats and oils are oxidized, they give a great amount of energy and heat to the body. They yield more energy than carbohydrates.
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1 delicate organs.
3. They act as insulator to nerves and cell membranes.
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## Vitamins

**Vitamins** are organic substances needed in small quantities in the body for healthy growth and development.

They are not energy giving food. The most important vitamins are **A, B, C, D, E** and **K**. Vitamin **B** comprises many vitamins hence it is referred to as vitamin **B complex**.

**Table 18: Vitamins, their sources, importance and deficiencies**

| Vitamin | Sources | Function | Deficiency |
|---|---|---|---|
| **Vitamin A** (Retinol) Oil soluble | Liver, red -palm oil, kidney, tomatoes, egg yolk, carrot and green vegetables | 1. Healthy growth<br>2. Healthy eyes and skin<br>3. High body resistance to diseases | 1. Retarded growth.<br>2. Night blindness.<br>3. Dry and scaly skin.<br>4. Defective tooth formation.<br>5. Reduced resistance. |
| **Vitamin B complex** Vitamin $B_1$ (Thiamin) (Water soluble) | Yeast, milk, groundnuts, palm wine, beans, rice, wheat, liver, chicken, kidney, egg yolk and green vegetables. | 1. Proper growth<br>2. Proper functioning of the heart, muscles and nerves.<br>3. Carbohydrate metabolism | 1. Beri-beri<br>2. Retarded growth.<br>3. Loss of appetite and weight.<br>4. Nervous disorder.<br>5. Less resistance to fatigue. |
| **Vitamin $B_2$** (Riboflavin) (Water soluble). | Meat, egg, milk, yeast, liver and green vegetables. | 1. Proper growth.<br>2. Healthy skin.<br>3. Proper functioning of eyes.<br>4. Carbohydrates metabolism | 1. Visual disturbances.<br>2. Eye pain in bright light.<br>3. Over flow of tears.<br>4. Redness of eye.<br>5. Wrinkling.<br>6. A split or fissure of the skin at the corner (angle) of the mouth |
| **Niacin** (ascorbic acid) Water soluble | Meat, fish, egg yolk, liver, yeast, rice, wheat, potatoes, and green vegetables. | 1. Proper growth.<br>2. Proper functioning of alimentary canal and nervous system. | 1. Skin eruptions.<br>2. Disorder of the digestive system.<br>3. Pellagra.<br>4. Nervous disorder. |
| **Folic acid** (Water soluble) | Yeast, egg yolk and green vegetables | Necessary for growth and formation of blood cells. | Anaemia: Bones deformity in children. Bleeding of kidneys. |
| **Vitamin $B_{12}$** (cynocobalamin (Water soluble) | Green vegetable, liver, milk, egg yolk and lean meat. | Red blood cell formation. | 1. Pernicious (fatal) anaemia.<br>2. Poor growth |
| **Vitamin C** (ascorbic acid) (Water soluble) | Citrus fruits (oranges, grapes, lemons), tomatoes, leafy Vegetables and potatoes. | 1. Maintains the strength of the blood vessels.<br>2. Essential for good development of the gum of the teeth.<br>3. Healthy growth<br>4. Reduction of blood cholesterol | 1. Scurvy (bleeding of the gums).<br>2. Loosening of teeth and sore gums.<br>3. Delayed healing of wounds.<br>4. Internal bleeding of tissues<br>5. Bleeding under the skin around the joints |
| **Vitamin D** (Calciferol) (Oil soluble) | Liver, fish liver, oil, eggs, milk and sunshine | 1. Regulate calcium and phosphorus absorption.<br>2. Building and maintaining bone and teeth. | Rickets (poor development of bones leading to bow legs and knock knees in children. Poor development of pelvic bones in girls may lead to difficulties during child birth. Poor teeth development in children. Painful bones and bone fractures in old people. |
| **Vitamin E** (Tocopherol) (Oil soluble) | Green vegetables, butter, milk, meat and egg yolk. | For normal functioning of the reproductive organs. | 1. Sterility in some animals and death of embryos.<br>2. Destruction of liver cells and anaemia.<br>3. Weak muscles. |
| **Vitamin K** (Oil soluble) | Green vegetables, egg yolk, liver and tomatoes. | 1. For normal clotting of blood.<br>2. Normal liver function. | 1. Failure of blood to clot.<br>2. Bleeding. |

## Mineral salts

Mineral salts are vital to animal's metabolism in various ways. Some mineral salts are important in the formation of bones and teeth while some control the chemical reactions within the body. Yet others are important in blood formation.

Mineral salts are contained in important elements. Mineral elements have to be taken in compound forms. For example, sodium chloride (table salt) is a compound of sodium and chlorine. If sodium atom is taken like that, it could be **fatal** but when taken in a compound (sodium chloride) form, it becomes **harmless** and **useful** to the body. Below is the table of some important mineral elements.

**Table 19: Mineral salts, their sourc es, functions and deficiencies**

| Mineral element | Source | Function | Deficiency |
|---|---|---|---|
| **Iron** | Leafy vegetables, liver, kidney, plantain, meat, egg and salt. | Formation of red blood cells and enzymes. | Anaemia. |
| **Calcium** | Milk, cheese, fish, meat, egg, green vegetables and shrimps (seafood). | 1. Formation of bones and teeth.<br>2. Assist in the clotting of blood.<br>3. Helps in muscle contraction.<br>4. Helps in nerve function | 1. Poor bone development. Bones prone to fracture<br>2. Poor growth. (rickets in children)<br>3. Causes decay of teeth.<br>4. Muscular spasms. |
| **Cobalt** | Liver and red meat. | Development of red blood cells. | Anaemia |
| **Phosphorus** | Milk, meat, fish, snail,cheese, egg yolk, green vegetables, beans, yam, bread. | Formation of bones and teeth. Formation of ATP.Synthesis of DNA and RNA | Rickets and dental decay. Poor health. |
| **Sodium** | Table salt, fruits, fish, beef, chicken, yam, bacon. | 1. Proper functioning of muscles and nerves.<br>2. Maintenance of salt concentration of the tissues. | Muscle cramps. Heatstroke and fatigue. |
| **Potassium** | Green vegetables, bananas, apples, chicken, potatoes, yam, milk, butter, be ef. | Proper functioning of muscles and nerves. | Malfunctioning of muscles and nerves. |
| **Iodine** | Fish, milk, drinking water, sea salt, sea food, iodised table salt. | Proper functioning of thyroid gland. Healthy growth in children part of thyroxine (hormone) | Goitre (swelling in the neck region) and cretinism in children (poor growth and mental development. |
| **Fluorine** | Drinking water, milk, green vegetables, some tooth paste. | Components of teeth and bones; protects teeth and bones from decay. | Decaying of teeth. |
| **Magnesium** | Green vegetables, bread, apple. | Proper functioning of muscles and nerves. | May cause convulsion in children. |
| **Chlorine** | Table salt and bacon | 1. Component of hydrochloric acid in gastric juice in stomach<br>2. Osmotic balance | Muscle cramps |
| **Copper** | Fish, meat, fruit and vegetables. | Melanin production | Albinism |

## Water

Water is the driver of life; without water, life cannot be maintained.

Water does not give energy to the body but it is essential in all life processes. About 60-70% of the body and 90% of blood plasma is water.

### Importance of water to living organisms

1. Protoplasm is the physical basis of life. Water makes up more than 90% of proto-plasm. It is the medium in which substances are dispersed in the protoplasm. It is almost a universal solvent.
2. It provides natural environment for aquatic organisms.
3. It is the source of chemical hydrogen and some oxygen needed by living organisms.
4. It is the medium in which the absorption and transportation of solid materials in plants take place. In animals, the transportation of food in the body is through body fluid and more than 60% of body fluid is water.
5. It provides water pressure which helps to maintain firmness that gives support to plant and animal tissues.
6. Water has a fairly high heat conductivity hence heat is distributed evenly all over the body of a living organism.
7. When water evaporates from the body of a living organism either as transpiration in terrestrial plants or sweating in mammals, it brings a cooling effect to the organisms.
8. Before seeds germinate, water is absorbed.
9. Water is needed for the excretion of waste products from the body of an organism.
10. Water helps to disperse some fruits and seeds such as coconut.
11. Water is necessary for the digestion of food in both plants and animals.
12. Pollination in most aquatic flowering plants is achieved through water.
13. It is used to clean the body of an organism. Man, for example, uses it to bathe. Some mammals and birds use it to remove ectoparasites from their bodies.

## Roughage

Roughage is food material mostly consisting of **fibres** which add to the bulk of material in the large intestine. Roughage does not supply much nourishment to the body but helps to stimulate the muscles of the intestine, thus pushing the faeces along the large intestine for easy defaecation.

### Source of roughage

Eating food consisting of fibres such as vegetables, apples and maize.

Inadequate supply of roughage in food results in **constipation.**

### Symptoms of absence of roughage

1. Flatulence (accumulation of gas in the stomach).
2. Discomfort.
3. Constipation.
4. Headache.

### Balanced diet

**A balanced diet** is a diet containing sufficient quantities of **proteins, carbohydrates, fats, vitamins, mineral salts, water** and **roughage** to maintain good health.

It is important to eat balanced diet all the time to stay healthy, **prevent deficiency diseases, promote growth, give required energy, prevent malnutrition** and **increase body resistance** to **diseases.**

### Deficiency diseases and Remedy

**Deficiency diseases** are those diseases caused by **lack of** or **insufficient supply** of certain food substances in the diet. For examples are:

1. **Kwashiorkor** is due to **lack** or **insufficient proteins.**
2. **Scurvy** is due to **lack of vitamin C.**
3. **Pellagra** is due to **lack of niacin.**
4. **Night blindness** is due to **lack of vitamin A.**
5. **Goitre** is due to **lack of iodine.**
6. Anaemia
7. Night blindness
8. Beriberi
9. Rickets

| Deficiency disease | Causes | Remedy |
|---|---|---|
| Kwashiorkor | Lack of sufficient or lack protein | Addition of sufficient to the diet |
| Scurvy | Lack of vitamin C | Eating food containing vitamin C or taking vitamin tablets. |
| Pellegra | Lack of niacin | Addition of niacin to diet. |
| Night blindness | Lack of vitamin A in diet | Addition of vitamin A in diet, eating carrots of palm oil food. |
| Goiter | Lack of iodine | Addition of iodine in diet |
| Aneamia | Lack of sufficient iron and copper in diet. | Addition iron and copper |
| Rickets | Lack of vitamin D | Addition vitamin D and calcium to diet. Receiving sunlight |
| Beriberi | Lack of vitamin B complex in diet | Addition of vitamin B to diet. |

**Table 20: Balanced diet for a week**

| | Breakfast | Lunch | Dinner |
|---|---|---|---|
| Monday | Egg, bread and beverages (such as ovaltine, milo or bournvita). | Cassava meal, oil soup with fish and green vegetables. | Ripe plantain, beans, stew with meat and orange. |
| Tuesday | Pap, beans, cake, milk with sugar. | Rice with stew, meat and bananas. | Cassava meal, okra soup with fish and green vegetables and orange. |
| Wednesday | Plantain, stew with vegetables and meat. | Cassava meal, melon soup with fish, mango or pineapple. | Porridge (beans and yam) and paw-paw. |
| Thursday | Bread, egg, margarine and orange | Rice and vegetable stew with meat and pear. | Vegetable soup, cassava meal and pineapple. |
| Friday | Porridge (beans and yam) paw-paw. | Cassava meal, oil soup with meat. | Plantain, vegetable stew with fish. |
| Saturday | Beans (moi-moi), pap with milk. | pounded yam, melon soup with meat and orange. | Rice, fish, stew and vegetables. |
| Sunday | Potato with vegetable stew and egg. | Porridge, meat and mango. | Cassava meal, oil soup and milk. |

## Food tests

Food substances are chemical compounds and therefore can be tested chemically.

## Test for carbohydrates

**Test for glucose** (a reducing sugar)

To a little solution of glucose, add small quantities of Fehling's solutions **A** and **B** (equal amount) and heat gently.

**A brick-red precipitate** shows the presence of glucose.

## Benedict's Test

Equal quantities of glucose solution and Benedict's solution in a test-tube are boiled and allowed to cool.

**Result: Red** or **orange precipitate** is formed showing the presence of glucose.

## Test for starch

### Iodine test:

To a starch solution, add few drops of iodine solution.

**Result: Blue black colour** shows the presence of starch.

**OR**

To a surface of potato or yam, add few drops of iodine. Blue black colour shows the presence of starch.

## Test for sucrose/maltose (non-reducing sugar)

Put small quantities of sucrose or maltose solution into two different test tubes. Labelled them **A** and **B**. To test-tube **A**, add Benedict solution and boil gently for three minutes and allow to cool.

**Result:** No red precipitate.

To test tube **B**, add a few drops of dilute hydrochloric acid and boil gently for few minutes. The hydrochloric acid will hydrolyse the sucrose or maltose to glucose sugar. Then add Fehling's solution **A** and **B** or Benedict's solution to the hydrolysed solution and boil gently for few minutes and cool.

**Brick-red precipitate** shows presence of reducing sugar in the hydrolysed solution, that is, sucrose or maltose is present.

## Test for protein

### 1. Millon's test

Add an equal volume of a protein solution (such as the albumen of an egg) and Millon's reagent and boil for few minutes. **Brick-red precipitate** is formed showing the presence of protein.

### 2. Biuret's Test

To $1cm^3$ of protein solution, add $1cm^3$ of 20% sodium hydroxide and a drop of 1% copper(II) sulphate solution.

**Result: Violet** or **purple colour** shows the presence of protein.

## Xanthoproteic test

To small amount of protein material, add small quantity of concentrated trioxonitrate (V) acid (nitric acid) and concentrated ammonium solution in excess. The mixture is gently warmed and cooled. **Red or orange precipitate** during warming and on cooling a **deep yellow** colour shows the presence of protein.

## Test for fats and oils

## Translucent white paper mark

Put a drop of oil on a white paper or rub a food substance containing fats against a white paper. Hold the paper against any source of light.

**Result:** A **translucent spot** indicates the presence of oil or fats.

## Sudan III solution test

To small quantity of oil or melted fats, add a few drops of sudan III solution.

**Result:** A **red colour** shows the presence of oils or fats.

## Osmic acid test

To small quantity of oil or fat in a test tube, add 1% of osmic acid and boil.

**Result:** A **black precipitate** shows the presence of oil or fat.

## Digestive enzymes

Enzymes are organic catalysts of protein origin produced by living cells which help to speed up or slow down the rate of chemical reactions but remain chemically unchanged at the end of the reaction.

## Classes of enzymes

Enzymes are usually classified according to the type of food they act upon. Generally three classes are known.

They are **amylases, proteases** and **lipases.**

## Amylases

**Amylases** act on carbohydrates (starches and complex sugars) changing them to glucose which the body can absorb. Some amylase enzymes are maltase, sucrase,lactase and ptyalin. **Maltase** changes maltose to glucose. **Sucrase** changes sucrose to glucose and fructose.

**Lactase** changes lactose to galactose and glucose. Ptyalin changes starch to maltose sugar.

## Proteases

Proteases act on proteins changing them into amino acids. Some proteases are pepsin, renin, trypsin and erepsin.

**Pepsin** changes protein to ***peptones.***

**Renin** coagulates milk proteins.

**Trypsin** changes proteins to peptones while **erepsin** changes peptones to ***amino acids.***

**Lipases** act on fats and oils changing them into **fatty acids** and **glycerol.**

## Characteristics of enzymes

1. Enzymes act as catalysts which help to speed up or slow down the rate of most chemical reactions within the body of the organism.
2. They remain chemically unchanged at the end of the reaction.

Enzyme + substrate Enzyme - substrate.....1
Enzyme - substrate Products + enzyme . . .2

3. They are specific in action, that is, one or a group of enzymes will act on specific substrate. For example, the **ptyalin** in the saliva can only act on cooked starch changing the cooked starch to **maltose sugar**. Proteases (protein enzymes) will only act on proteins and nothing else.
4. Enzymes are required in small quantity. A single molecule of one particular enzyme can change 40,000 molecules of its food in a second.
5. Enzymes act best over a small range of temperature. They are denatured or destroyed at high temperature and inactive at a very cool temperature. Their reactions increase with a rise in temperature of 37□C.
6. They are pH specific (acidity or alkalinity) and act best at certain level of pH. For example, the stomach enzymes act best in acidic medium while the enzymes of the small intestine act best in alkaline medium.
7. Most enzyme actions are reversible. For example, starch is changed to sugar and from sugar to starch by enzyme diastase.

$$\text{Starch} \underset{\text{diastase}}{\overset{\text{diastase}}{\rightleftharpoons}} \text{sugar}$$

8. Enzymes are retarded by poison or inhibitors. 9. They are protein in nature.
10. Some enzymes are inactive and therefore require co-enzymes or agents to activate them. For examples, the enzyme **trypsinogen** requires **enterokinase** to activate it into *trypsin* while **pepsinogen** requires dilute hydrochloric acid to activate it into pepsin.

a. Trypsinogen $\xrightarrow{\text{enterokinase}}$ Trypsin

b. Pepsinogen $\xrightarrow{\text{dil. HCl}}$ Pepsin

The activators of inactive enzymes are **called zymogens**. Thus the zymogens of trypsinogen **and** pepsinogen are enterokinase and dilute hydrochloric acid respectively.

11. Enzymes can function outside the body **of the** organism that produces them.

**Table 21: Enzymes**

| | Names of enzyme | Location | Juice | pH | Site of action | Food acted upon | Products |
|---|---|---|---|---|---|---|---|
| 1. | **Ptyalin** | Salivary glands | Saliva | Alkaline | Mouth | Cooked starch | Maltose |
| 2. | **Pepsin** | Glands in the walls of stomach | Gastric juice | Acidic | Stomach | Protein | Peptones |
| 3. | **Rennin** (in children mainly) | Glands in the walls of stomach | Gastric juice | Acidic | Stomach | Milk protein (liquid) | Solid milk protein |
| 4. | **Amylase** | Pancreas | Pancreatic juice | Alkaline | Duodenum | Starch | Maltose |
| 5. | **Trypsin** | Pancreas | Pancreatic juice | Alkaline | Duodenum | Protein | Peptones |
| 6. | **Lipase** | Pancreas | Pancreatic juice | Alkaline | Duodenum | Fats and oils | Fatty acids and glycerol |
| 7. | **Erepsin** | Small intestine | Succus entericus (intestinal juice) | Alkaline | Ileum, small intestine | Peptones | Amino acids |
| 8. | **Maltose** | Small intestine | Succus entericus | Alkaline | Ileum | Maltose | Glucose + Glucose |
| 9. | **Sucrase** | Small intestine | Succus entericus | Alkaline | Ileum | Sucrose | Glucose and fructose |
| 10. | **Lipase** | Small intestine | Succus entericus | Alkaline | Ileum | Fats and oils | Fatty acids and glycerol |
| 11. | **Lactase** | Small intestine | Succus entericus | Alkaline | Ileum | Lactose | Glucose and galactose |

## Experiments to show the characteristics of enzymes

### Experiment 1

**Aim:** To demostrate the action of ptyalin (saliva) on cooked starch

**Method:** Some saliva is introduced into a test tube **X** and diluted with little amount of water.

Two test tubes are labelled **E** and **F**. To test tube **E**, cooked starch solution is introduced and saliva is added. To test-tube **F**, only starch solution is added and thus acts as a control.

The two test tubes **E** and **F** are then placed in water-bath maintained at the temperature of 37□C and stirred at every 1 minute interval.

After five minutes, one drop of solution from each test tube is put on a white tile with a glass rod. A drop of **iodine solution** is added to each drop on the white tile. Fehling solutions A and B are added to the contents of test-tubes **E** and **F** and heated.

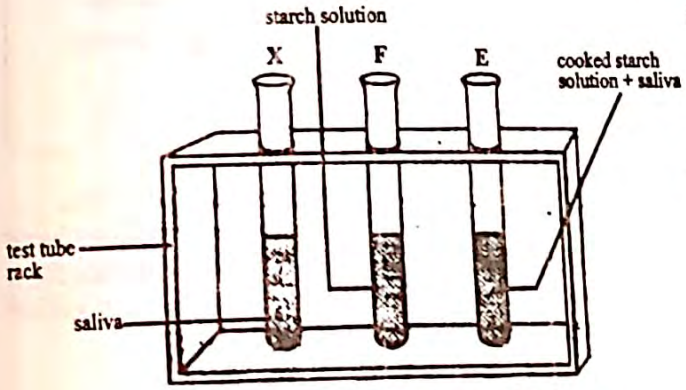



**Figure 6.20. Experiment on the action of ptyalin on cooked starch.**

**Results**

1. A reddish brown colour is observed when one drop of iodine is added to one drop of solution in **E**.
2. A blue-black colour is observed when one drop of iodine is added to one drop of solution from test-tube **F**.
3. With Fehling solution A and B, the contents of test-tube **E** indicates brick-red colour while the test-tube **F** shows blue colour.

### Conclusion

A reddish brown colour with iodine solution in test-tube **E** shows that cooked starch has been digested by ptyalin.

The brick-red precipitate with Fehling's solutions **A** and **B** in test-tube **E** shows that cooked starch has been digested to simple sugar. The blue black colour with iodine solution in test-tube **F** shows that starch is not digested and the deep blue colour with Fehling's solutions A and B shows that sugar is absent.

### Experiment 2

**Aim:** To show the effect of high temperature and acid on enzymes.

**Method:** $3cm^3$ of starch solution is added to each of the four test-tubes labelled **A,B,C** and **D**. Some fresh saliva is added to test-tube **A**, the same volume of boiled saliva is added to test-tube **B**. To test-tube **C**, water of the same volume is added while test-tube **D** receives three drops of dilute hydrochloric acid. Test-tube **C** thus provides control for other three.

The four test-tubes with their contents are placed in a beaker of warm water kept at approximate temperature of 37□C. They are left for about 30 minutes and are later tested for both starch and sugar.

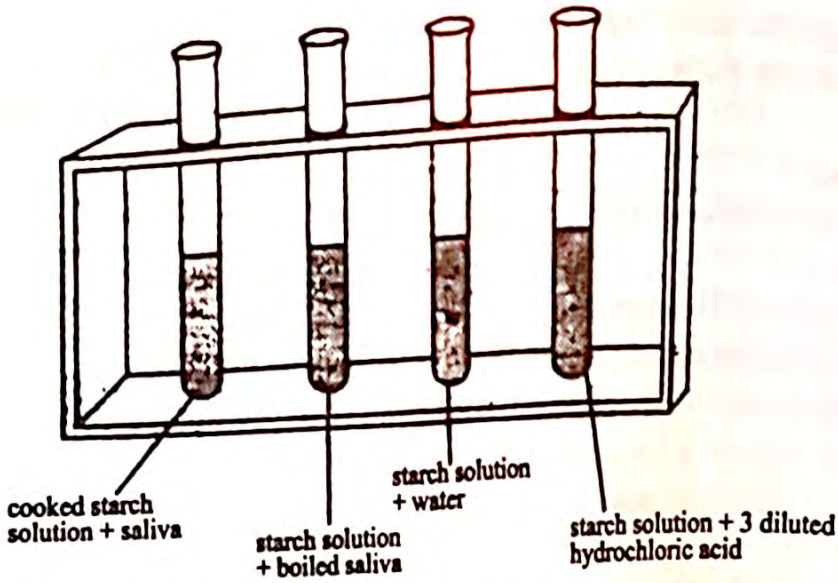



**Figure 6.21. Experiment on the effect of high temperature and acid on enzyme**

**Table 22: Results of high temperature and acid on enzymes.**

| | Test tube A | Test tube B | Test tube C | Test tube D |
|---|---|---|---|---|
| | Starch + fresh saliva. | Starch + boiled saliva. | Starch + water | Starch + 3 drops of dilute HCl. |
| Test for starch Add iodine solution | Brown colour shows starch absent. | Blue-black colour shows starch present. | Blue black colour shows starch present. | Blue black colour shows starch present. |
| Test for sugar Add Fehling's solutions A and B and boil. | Red precipitate shows sugar present. | Deep blue colour shows sugar absent. | Deep blue colour shows sugar absent. | Deep blue colour shows sugar absent. |

**Conclusion:** The presence of sugar in the test-tube **A** shows that ptyalin in saliva has changed starch to sugar (maltose). The absence of sugar in test-tube **B** containing starch and boiled saliva indicates that an enzyme is denatured or destroyed when boiled. The absence of sugar in test-tube **D** indicates that ptyalin in saliva does not work in acid medium. The absence of sugar in test-tube **C** shows that water has no action on starch.

## Alimentary system

Animals depend upon already made complex food since they cannot manufacture their food. This complex food cannot be absorbed into the body of an animal without being broken down into smaller units. While a unicellular organism can break down complex food into simpler forms within their single cell, multicellular organisms have to develop complex systems to break complex food into simpler forms and these systems are called **digestive systems** or **alimentary canals.**

## Types of digestive tracts

There are two types of digestive tracts namely **incomplete** and **complete** tracts.

**Incomplete digestive tract** has only one opening to the outside world called **mouth** which serves for *ingestion* and *egestion*. Coelenterates (e.g *Hydra*) and flatworms (e.g. *Planaria*) are examples of animals with incomplete digestive tracts.

**Complete digestive** tract has two openings to the outside world called **mouth** and **anus**. The mouth serves for ingestion while the anus is for egestion.

Earthworm, bird and goat are examples of animals with complete digestive tracts.

The advantage of a **complete digestive tract** over **incomplete one** is that the incoming food does not mix with outgoing undigested food materials. In complete digestive tract, different portions of the tract become specialized to perform different functions. For example, in mammals, the teeth break down large food particles, the oesophagus pushes the food particles to the stomach, the stomach churns the food and if the food contains protein, digestion starts, in the small intestine, digestion is completed and absorption takes place, the large intestine absorbs water from the undigested food materials and the anus passes it away from the body.

## Alimentary canal of different animals

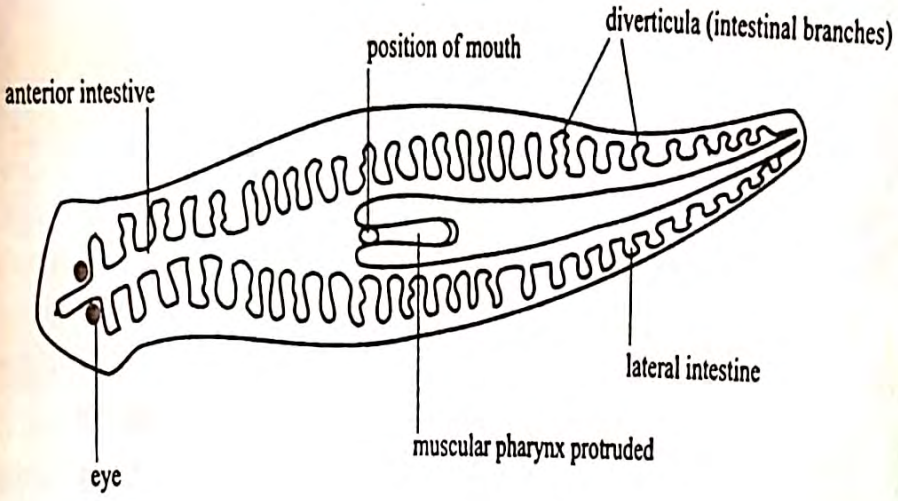
### 1. Alimentary canal of *Planaria*

*Planaria* is a free-living, flat, slender and small worm. The digestive tract consists of a ventrally placed mouth, muscular pharynx and intestine. The pharynx can be protruded from the mouth when attacking a prey. The pharynx leads into the intestine. The intestine has three main branches, one anterior and two posterior, with each giving rise to extensive lateral diverticula (branches) thus forming a **gastrovascular cavity**. The gastrovascular cavity (anterior and posterior intestines) is lined with phagocytic cells, glandular storage cells and gland cells.

Planarians are carnivorous in diet, feeding on small animals such as crustaceans, rotifers, nematodes and insects. They capture their prey by entangling them in mucus glands. The entangled prey is then wrapped with the body of the planarian and the pharynx is then protruded from the mouth and sucked in the small bits of the prey into the intestine. Digestion is mostly **intracellular**, that is, the phagocytic cells of gastrodermal cells engulf the food and digest it. The digested food is distributed by **diffusion** to all parts of the body by gastrovascular cavity. The extensive branching of the gastrovascular cavity all over the body gives it a large absorptive surface area.

**Figure 6.22. Digestive system of Planaria**

### 2. Alimentary canal of earthworm




The alimentary canal of earthworm consists of mouth, buccal cavity, pharynx, oesophagus, crop, gizzard, intestine and anus. Digestion here is mostly extracellular, that is, digestion is outside the cells.

### Mouth and buccal cavity

The mouth is in the first segment and is overhung by a fleshy, lip-like structure called **prostomium**. The mouth leads into a **buccal cavity**. Food is sucked into the mouth by the muscular pharynx. The prostomium helps by arranging the food substance in position for ingestion.

### Pharynx

The muscular pharynx leads from the buccal cavity to the oesophagus. Glandular cells present secrete

mucus and protein digesting enzyme into the pharyngeal cavity thus starting the digestion of protein.

## Oesophagus

The oesophagus is long and connects pharynx with the crop. It contains three pairs of calciferous glands which secrete calcium tri-oxocarbon (IV) oxide that removes excess calcium taken in with food.

## Crop

The crop connects oesophagus with the gizzard. It is relatively thin-walled and enlarged. It functions as a temporary storage chamber.

## Gizzard

The gizzard connects the crop with the intestine. The gizzard is a large, thick-walled muscular chamber. Food is ground into small particles by the churning action of the gizzard. Grinding is aided b small stones present in the gizzard.

## Intestine

The intestine is the longest part of the alimentar canal and terminates as an anus. Digestive enzyme (pepsin, amylase and lipase) are secreted to dige various types of food. The blood circulating throug the intestine absorbs the digested food and distribute it to all parts of the body.

The rear portion of the intestine absorbs some of th water involved in the digestion. The indigestibl materials are removed from the body through the anu as **casts.**

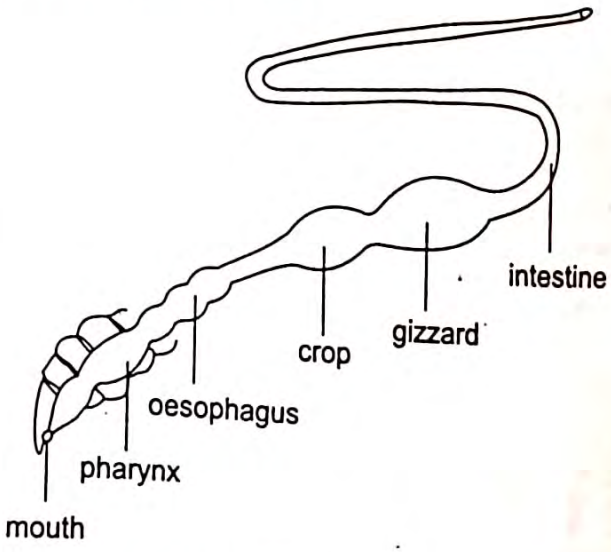



**Figure 6.23. Digestive system an earthworm.**

## Advancements of the alimentary canal of earthworm over that of planaria.

1. Oesophagus and crop for temporary storage of food are present in earthworm but absent in planaria.
2. A muscular thick-walled gizzard for grinding large particles to smaller bits is present in earthworm but absent in planaria.
3. Earthworm has a long and straight single intestine for efficient digestion and absorption of food while planaria has diffused diverticular (intestinal branches).
4. Aborption of food is by blood and not by diffusion as in planaria.
5. Earthworm has two openings, the mouth and anus while planaria has only one opening, the mouth.

## Alimentary canal of a cockroach

Cockroach is an omnivorous animal eating anything ranging from starchy and sweet things to papers, clothes etc. Its alimentary canal is therefore adapted to

suit its type of diet. The alimentary canal consists of **foregut, midgut** and **hindgut**.

## Foregut

Foregut consists of mouth, oesophagus, crop and gizzard.

## Mouth

The mouth is modified for cutting and chewing. It consists of the following: Labrum, hypopharynx, mandibles, first maxillae, labium and second maxillae.

## Labrum

Labrum is a flap-like structure regarded as the upper lip of the mouth. It is sensitive to various chemical substances and thus acts as taste buds.

## Hypopharynx

This is a membranous tongue-like structure located on the back of the mouth. It helps in swallowing of food.

## Mandibles

Two mandibles, one on each side, are the jaws of the mouth. They are heavily built and toothed for biting, cutting and chewing.

## First maxillae

Under each mandible lies a first maxilla. Each maxilla is toothed and assists the mandible in cutting food. It also helps in directing food into the mouth. The maxillary palp is sensitive to chemicals and touch and therefore helps in locating food substances.

## Labium and second maxillae

Two maxillae are fused at the base to form the labium or lower lip. They also, assist in food cutting and direct the cut food into the mouth.

## Salivary glands

Salivary glands open into the mouth via salivary ducts. The salivary glands secrete digestive enzyme (amylase) which starts the digestion of starchy food.

## Oesophagus

The oesophagus is short, narrow and tubular and connects the mouth with the thin-walled crop. The oesophagus functions as a passage through which food passes from the mouth to the stomach.

## Crop

The crop is thin-walled and large. It acts as a temporary storage chamber and most digestion occurs here. (Note: Cockroach has no stomach).

## Gizzard (proventriculus)

The gizzard is a highly muscular bag where hard food substances are ground into smaller particles before digestion.

## Midgut

The midgut consists of six mesenteric (hepatic or digestive) caeca. The caeca open into the midgut and secrete digestive juice which contains the three kinds of enzymes that complete the digestion of carbohydrates, proteins and fats. Digestion and absorption take place in the midgut.

## Hindgut

The hindgut consists of small intestine, rectum and anus. Between the midgut and hindgut are many fine structures called **Malpighian tabules**. They excrete nitrogenous wastes. The rectum absorbs water from the faeces and let the dry faeces pass out through the anus.

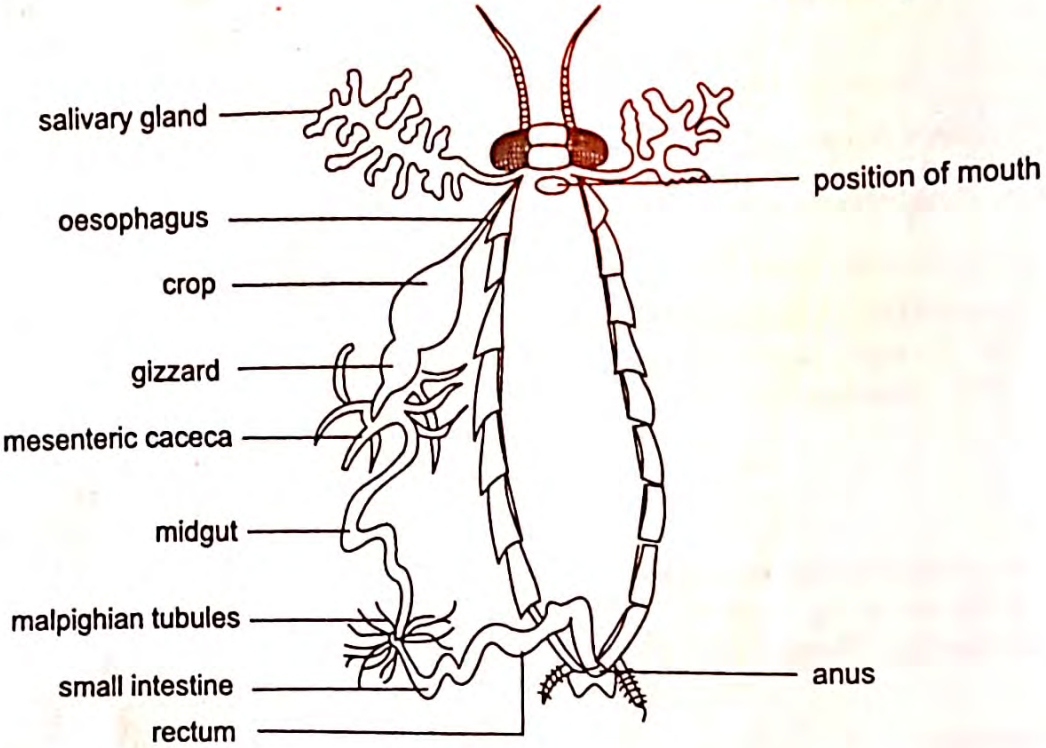



**Figure 6.24. Digestive system of a cockroach**

# Alimentary canal of birds

## Mouth

The mouth has a horny covered tongue to facilitate swallowing of food substances to the oesophagus. There are no teeth. The lower and upper lips have been modified into sharp strong beaks for picking of food substances such as grains, fruits, worms and foliage. Salivary glands are poorly developed since they rarely secrete enzymes rather they secrete mucus for lubricating the horny covered tongue. Only few taste buds are present.

## Pharynx and oesophagus

The pharynx is short and is connected to the long and narrow oesophagus posteriorly.

The oesophagus extends to the crop. The oesophagus directs food and water to the crop.

## Crop

The crop is large and functions as a chamber where food is temporarily stored. In some birds such as pigeons and parrots, the epithelial cells lining the walls are broken down to produce" bird milk" which is regurgitated by both parents to the mouth of the young ones.

## Stomach

The stomach consists of **proventriculus** (true stomach) and strong **muscular gizzard**. The proventriculus secretes gastric juice (which contains protein digesting enzyme) and dilute hydrochloric acid. The muscular gizzard by its churning action grinds large food substances into smaller ones for easy digestion.To aid in the grinding process, the birds swallow some coarse sand and pebbles which are stored in the gizzard.

## Duodenum

Connecting the gizzard posteriorly is the U-shaped duodenum. The duodenum is the upper part of the small intestine. The liver and pancreas are connected to the duodenum by the bile and pancreatic ducts respectively. Bile is secreted into the duodenum by two bile ducts while pancreatic juice is secreted into the duodenum by two or three pancreatic ducts. The bile emulsifies fats and oils. The pancreatic juice contains amylase, trypsin and lipase which digest carbohydrates, proteins and fats respectively.

The duodenum (upper intestine) is connected to the remaining intestine (lower intestine). The intestine is slender and coiled.

The entrance from the duodenum to the lower intestine is muscular and ring-like called **pyloric sphincter.**

The pyloric sphincter regulates the quantity of food that goes to the lower intestine. Digestion of all classes of food is completed in the lower intestine by intestinal enzymes. The long and coiled intestine affords a large surface area for absorption. At the posterior end of the intestine, it joins a short rectum. The blind caeca branch off from the junction of the intestine and rectum. The rectum leads to a **cloaca** which discharges faeces and urine.

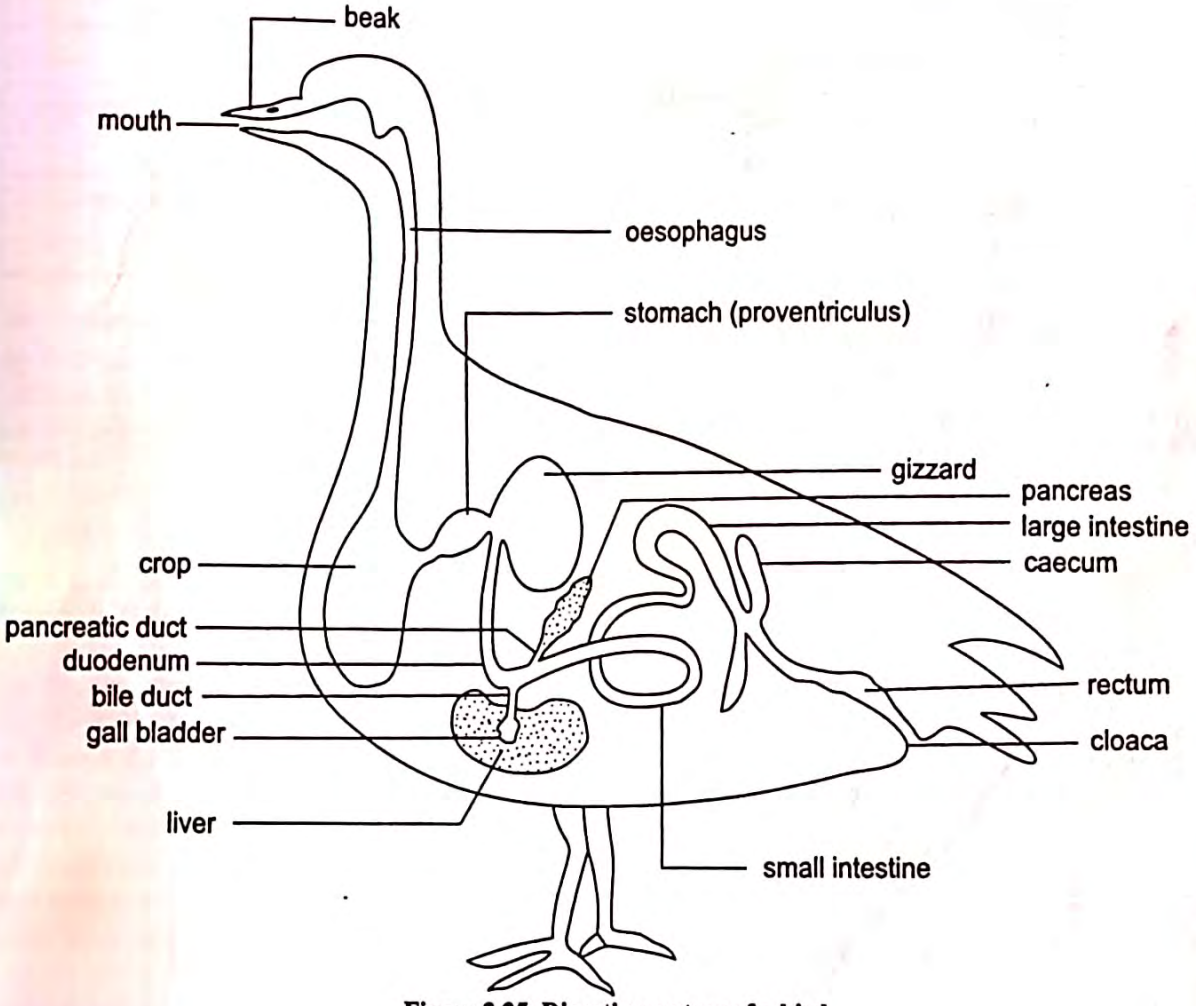



**Figure 2.25. Digestive system of a bird**

**Note:** Ducts from the kidneys and genital organs also open into the cloaca.

## Similarities and differences between the alimentary canals of a bird and that of a cockroach.

**Similarities**

1. Both have narrow oesophagus.
2. Both have crop.
3. Muscular gizzard is present in both.
4. Midgut is present in both.
5. Both have caecum.

**Table 23: Differences between alimentary canals of bird and cockroach**

| Bird | Cockroach |
|---|---|
| 1. Mouth is modified into a beak | Mouth is modified into labrum, hypopharynx mandibles, first maxillae, labium and second maxillae. |
| 2. Tongue is present in the mouth | Tongue is absent in the mouth. |
| 3. Duodenum is present | Duodenum is absent. |
| 4. Alimentary canal is long | Alimentary canal is relatively short. |
| 5. Hindgut terminates in cloaca | Hindgut terminates in anus. |
| 6. Malpighian tubules are not attached to the alimentary canal | Malpighian tubules are attached to the alimentary canal. |
| 7. Liver and pancreas are connected to the alimentary canal | No liver and pancreas are connected to the alimentary canal. |

## Feeding habits

If all animals were to feed on one type of food, the competition for that food would be too keen and many animals especially the weak ones would be eliminated. To avoid this,animals have evolved different ways of feeding and are categorized as follows:

1. **Herbivores**
2. **Carnivores**
3. **Omnivores**
4. **Scavengers.**

### Herbivores (plant eaters)

These are animals which feed on grass and vegetable. This is a large group of animals which include goats, sheep, rabbits, antelopes,deer, squirrels and elephants. *Tilapia* and carps are examples of fish that feed on plants.

### Carnivores

These are animals that feed on the flesh and bones of other animals. Examples are lions, cats, dogs, foxes, tiger fish (*Hydrocynus*), *Gymnarchus, niloticus* and *Lates niloticus* (Niger perch).

Carnivores can be classified into **insectivorous** and **piscivorous animals. Insectivorous animals** are those that feed on insects.

Animals having this type of feeding habits are bats, pangolin, mice, moles, shrews, wallgeckos etc. **Piscivorous** animals feed on fish. Crocodiles, *Hydrocynus forkali* (tiger fish) *Gymnarchus niloticus, Lates niloticus,* herons, kingfishers are examples of piscivores.

### Omnivores

Omnivores feed on both plants and animals. Man, pigs, rats, catfishes, (*Clarias spp*) and domestic fowls are examples.

### Scavengers

These organisms feed on dead organisms or decaying plants or animal matter. Examples are **vultures, earthworms, African river prawns** (*Palaemon*) and **snails.** Vulture eats dead animals, earthworm eats dead plant remains, *Palaemon* eats dead animals in the river and snail eats dead plant remains.

Scavengers are important because they help to remove wastes hence they are also called "garbage **collectors".**

### Modifications and mechanisms associated with the following feeding habits

1. **Filter feeding**
2. **Fluid feeding**

3. **Saprophytic feeding and**
4. **Parasitic feeding.**

## 1. Filter feeding habit:

Some aquatic animals feed on microscopic organisms surrounding them. The microscopic organisms are phytoplankton (microscopic plants) and zooplankton (microscopic animals). These two groups of micro-organisms are referred to as **plankton.** Filter feeders feed on plankton. Examples of filter feeders are mosquito larvae and *Tilapia galilaea*.

### Filter feeding in mosquito larva

### Feeding modifications

The mouth parts of a mosquito larva have jaws and two ciliated mouth brushes.

### Feeding mechanism

The larva uses the mouth brushes to create current of water. From the current of water, the mouth brushes filter off plankton and colloidal particles from the water and sweep them into the mouth. From the mouth the food is sent to the oesophagus and other parts of the alimentary canal for digestion and absorption into the body.

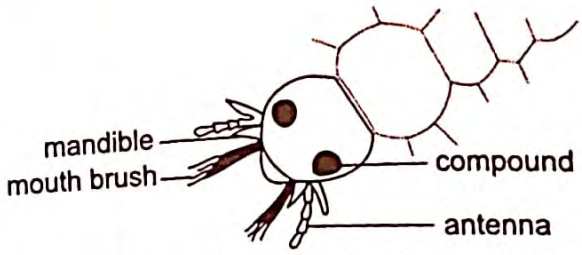



**Figure 6.26. Mouth parts of a female *Anopheles* mosquito larva.**

### Filter feeding in *Tilapia galilaea*

*Tilapia galilaea* feeds by filtering its food (plankton) through the gill rakers. There are 21-26 gill rakers arranged closely on the first gill arch. When the floor of the mouth is lowered, water containing plankton is drawn into the mouth and at the same time the opercula are closed. When the mouth is closed and the floor of the mouth is raised, the gill rakers filter off the plankton and direct them to the oesophagus. From the oesophagus the food goes to the stomach and small intestine where digestive enzymes are secreted. The digested food is then absorbed.

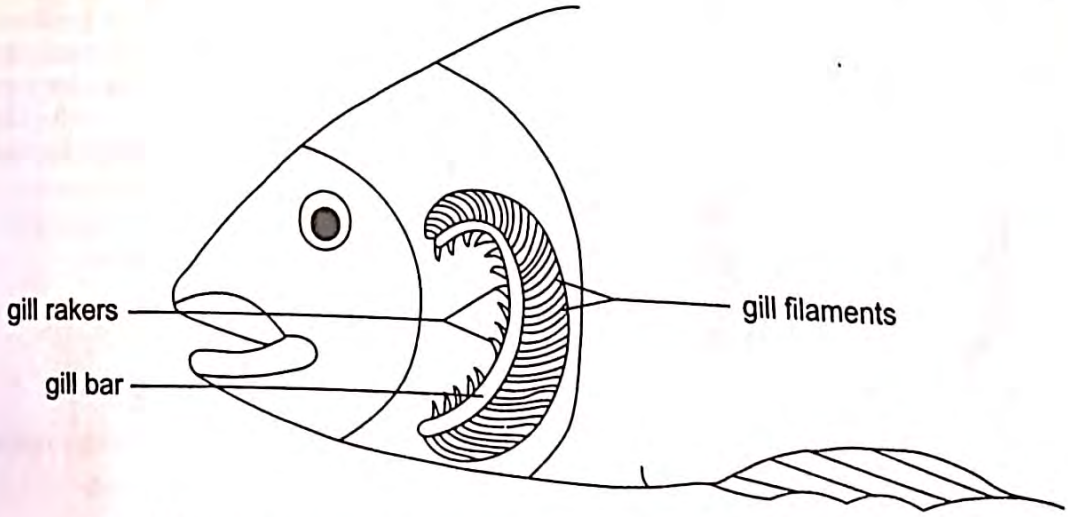



**Figure 6.27. Structure of the first gills to show the gill rakers, gill bar and gill filament (the operculum has been removed to show detailed structures).**

## Fluid feeding

Some animals feed on fluid substances derived from either animals or plants. If the food is solid, it has to be converted into liquid form before it is sucked into the gut. Example of animals that feed on fluid food substances are housefly (*Musca domestica*), adult female *Anopheles* mosquito and adult butterfly.

Fluid Feeding in housefly *(Musca domestica)*.

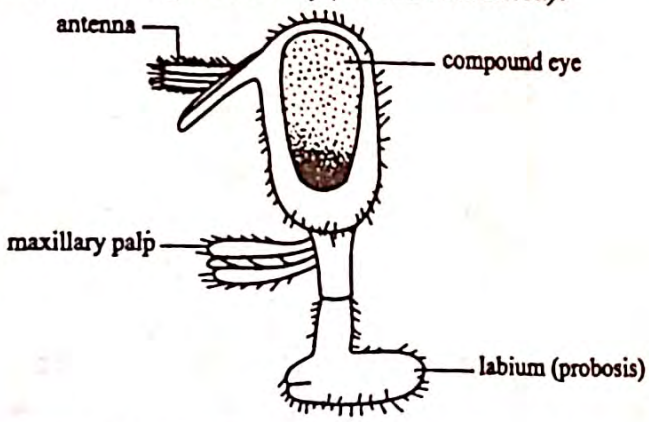



**Figure 2.28. Mouth parts of a Housefly.**

## Fluid feeding mechanism in housefly

The labella assume different position depending upon the type of food. If the food substance is a moderately **thick liquid** such as **pus** or **syrup**, the head of the labella is raised off the food so that the **pseudotracheal** surface can rest on the pus or syrup. The food is them sucked into the pseudotrachea and then to the food canal by capillary action.

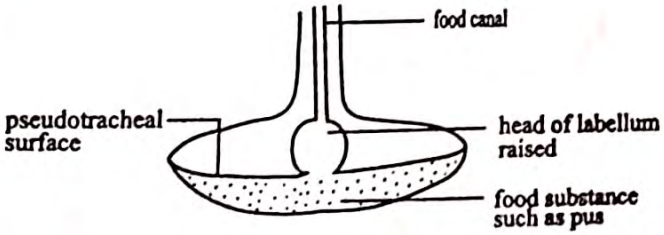



**Figure 6.29. Head of labellum raised.**

## Pseudotracheal surface food substance such as pus

If the food substance is **thin liquid**, such as mil the labella are closely attached to the food. The fo is sucked by the pseudotracheae and taken into th food canal by capillary action.

If the food is **solid**, such as sugar cube, the label are inverted and saliva from salivary gland secreted into it through the opening of the mou The saliva with the enzymes contained in it make th food soluble and is then sucked by th **pseudotracheae** to the food canal through capilla action.

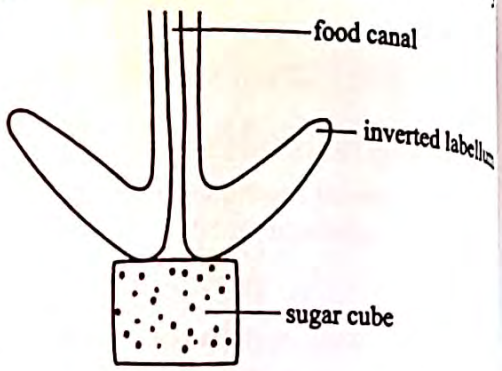



**Figure 6.30. Inverted labellum on sugar cube.**

## Fluid feeding in adult female *Anopheles* (mosquito).

### Feeding modifications

The labrum, mandibles, maxillae are serrated at th tips. A **proboscis sheath** is formed from great elongated labium. The labrum is **deeply groove** The proboscis sheath therefore contains th **mandibles, maxillae, labrum** and **hypopharyn** The hypopharynx contains a salivary duct. Th **pressing of hypopharynx against the labrum forms** **food canal.**

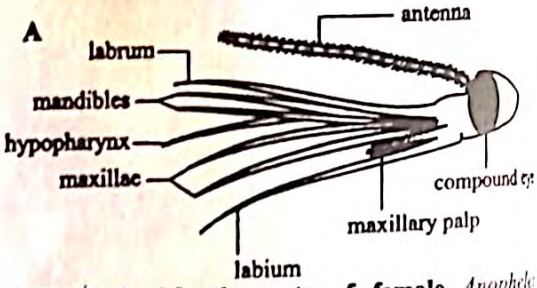



**Figure 6.31A. Mouth parts of female** *Anophele* **mosquito.**

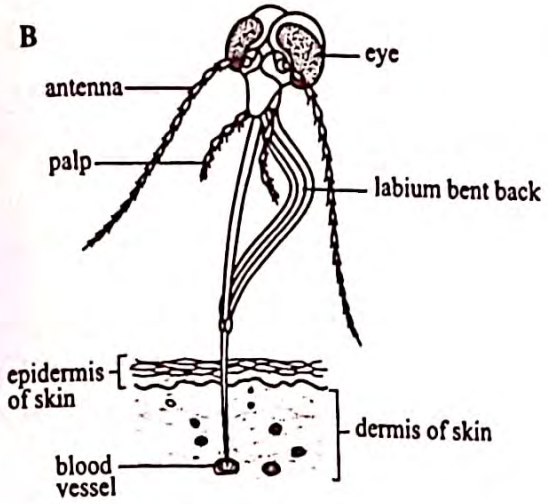



**Figure 6.31B. Feeding mechanism: the stylets injected into the blood vessels of the host.**

## Fluid feeding mechanism in female *Anopheles*

The mosquito (such as *Anopheles)* alights on the skin of a man or any other mammal. It applies its **labella** on the various points on the skin. The **mandibles** and **maxillae** then cut the skin and make a tunnel through the tissues to the blood vessels. The **labrum** and **hypopharynx** pass into the blood vessels while the **labium** stays on the skin. **Saliva** is injected into the blood through the hypopharynx to prevent the blood from clotting. The blood is then sucked through the labrum into the food canal (pharynx).

## Fluid feeding in adult butterfly

### Feeding modifications

Mandibles are absent. The maxillary palps are also absent but if present, are poorly developed. A long **proboscis** is formed from the two **maxillae**. Each maxilla is grooved along its inner surface and a **proboscis tube** is formed by the two maxillae when fitted together by interlocking spines.

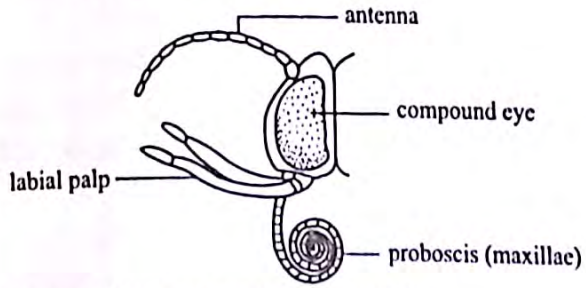



**Figure 6.32. Mouth parts of a butterfly.**

### Feeding mechanism

When the butterfly is at rest, the long proboscis is coiled and held under the head. During feeding the proboscis uncoils and is extended into the petal (**corolla**) of a flower and its tip is placed directly on the nectar. The muscles in the pharynx contract causing the nectar to be sucked into the mouth.

## 3. Saprophytic feeding

This is a type of feeding carried out by plants lacking chlorophyll.

These chlorophyll-free plants feed on dead decaying organic matter. Examples of saprophytic feeders are *Rhizopus* and mushroom. The **rhizoids** (false roots) of these fungal plants secrete digestive enzymes from their cells to the dead organic matter. The digestion of dead organic matter takes place outside the cells of the saprophytic plant. The digested and soluble food substances are absorbed by the cells by **diffusion.** Digestion is therefore extra-cellular.

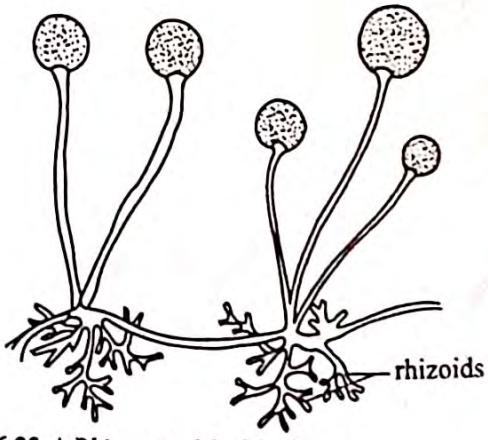



**Figure 6.33. A *Rhizopus* with rhizoids.**

## 4. Parasitic feeding

This feeding habit is carried out by both plant and animal parasites. **A parasite** is a small organism that lives in or on another large organism (the host), from which the parasite obtains food without contributing anything in return. During its feeding process, the host is harmed.

Examples of parasites are ticks, mites, lice, fleas (these are ectoparasites); tapeworm, roundworm (*Ascaris lumbricoides*) are endoparasites.

## Feeding modification of a tapeworm

The head has hooks and suckers for firm attachment to its host (man).

The body is covered with a thick cuticle which prevents it from being digested by the enzymes in the intestines of the host. The body is long and tape-like thus providing a large surface area for absorption of digested food.

## Feeding mechanism

The tapeworm lies within the digested and soluble food of its host. It therefore absorbs the digested food into its body by **diffusion**.

## Feeding in Protozoa

Protozoans (unicellular organisms) feed in different ways. Some feed holozoically while other are parasitic and yet others feed both holophytically and holozoically.

## Holozoic nutrition in Protozoa

***Amoeba proteus*** is an example of a protozoan that feeds holozoically. *Amoeba* feeds on algae like diatoms and *Chlamydomonas*. Feeding is therefore holozoic. When an *Amoeba* comes in contact with food, it thrusts out pseudopodia rapidly and surrounds the food-particle with a drop of water. The food particle and the drop of water form a food vacuole. The food vacuole is carried around through the streaming of the protoplasm.

Digestive enzymes which are secreted from the cytoplasm help to digest the food. The food vacuole is at first acidic but later changes to alkaline. The digested food is absorbed and the undigested material is left behind as *Amoeba* continues to flow on. Ingestion and egestion can take place at any point on the surface of the body.

**Figure 6.34. Ingestion of prey by *Amoeba*.**

## Holozoic Feeding in *Paramecium*

***Paramecium*** feeds mainly on bacteria. The movement of the cilia of the oral groove and the forward movement of the animal force water and bacteria and other food particles into the mouth pore and from there into the gullet. From the gullet, a food vacuole is formed. The food vacuole moves slowly round the cytoplasm. During the movement of the food vacuole, digestive enzymes are secreted. The digested food is absorbed from the food vacuole by **diffusion** and **cyclosis**. The undigested food is passed away through a special opening called **anal pore**. See figure 2.29 page 37.

## Parasitic feeding in protozoans

Some protozoans are parasites and feed parasitically. Examples are *Plasmodium*, *Trypanosome* and *Entamoeba histolytica*

*Plasmodium* enters the red blood cell and feeds on it. During this feeding process the red blood cell is destroyed. *Plasmodium* is a malaria parasite.

Trypanosomes are also blood parasites belonging to flagellate protozoans. They live in the blood and also feed on the red blood cells causing sickness such as **sleeping sickness.**

*Entamoeba histolytica* is a protozoan parasite that lives in the large intestine of man. It feeds on the cells of the intestinal wall and blood cells causing bleeding.

## Autotrophic or Heterotrophic feeding in Protozoa

*Euglena* is an example of a protozoan that feeds autotrophically. It has chloroplasts for photosynthesising its food. When conditions are not favourable, such as when light is absent for a long time, *Euglena* reverts to heterotrophic way of nutrition. Dissolved organic matter passes through the cell membrane into the cell. The food is then digested in the cytoplasm of the cell. The digested food is then absorbed from the cytoplasm to other parts by **diffusion** and **cyclosis**. See figure 2.30 page 37.

## Feeding in *Hydra*

Hydra is a carnivorous animal. It feeds on small aquatic animals such as *Daphnia*, water-fleas and insect larvae. *Hydra* feeds with the aid of **nematocysts** present in the tentacles. A nematocyst has a **stinging thread** which contains a poisonous substance. When *Hydra* is hungry, it stretches its body and tentacles. The tentacles are waved about. When a prey comes in contact with a tentacle, the nematocysts immediately discharge their stinging threads which pierce the body of the prey and inject a poisonous substance. The poison paralyses the prey. Other nematocysts are also discharged and coil around the prey to hold it temporarily until it is ready to be taken into the mouth.

The tentacle holding the prey shortens and bends towards the mouth. Other tentacles then bend over the tentacle holding the prey. Finally, all the tentacles shorten and the prey is pushed into the mouth and engulfed. Once the food (prey) is in the enteron, digestive enzymes are secreted by the endodermal cells to digest it. Digested food is absorbed and undigested food is passed out through the mouth by a sudden contraction of the body muscles while the mouth is open. See figure 2.32 page 39.

# Feeding in mammals

Mammals have different methods of feeding based on their dentition. Their alimentary tracts are also modified to suit their diet. Mammals that feed on the flesh and bones of other animals are called **carnivores**. Those that feed on plants are called **herbivores** while those that feed on both plants and animals are called **omnivores**.

## The digestive tracts of mammals

Typically the digestive tracts of a mammal consist of the following: **mouth, pharynx, oesophagus (gullet), stomach, small intestine, large intestine, rectum and anus**. Liver and pancreas are associated glands with the alimentary system. There are modifications within the tract depending upon the diet of the mammal under investigation.

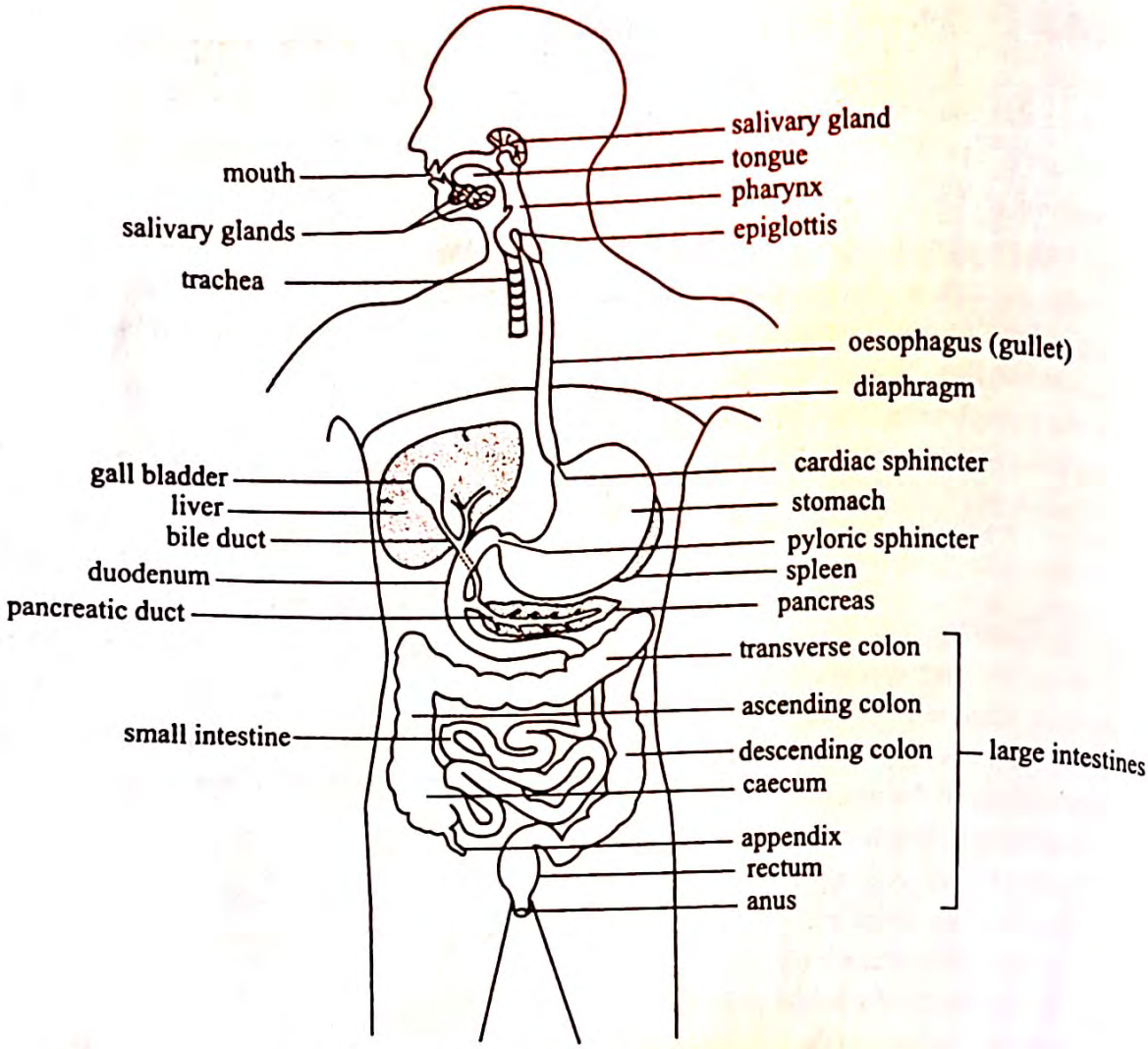



**Figure 6.35. The digestive system of a man**

## Mouth

The mouth is surrounded by cheeks, hard palate, soft palate, tongue and jaws with teeth. The mouth is always kept wet with saliva which is supplied from salivary glands via salivary ducts.

## Hard and soft palates

The hard palate is the upper floor of the mouth covering the chewing area. It is made of a bony structure covered with several membranes. The soft **palate** forms the posterior part of the hard palate. It is made of fleshy and folded membranes. The soft palate has a projection called uvula.

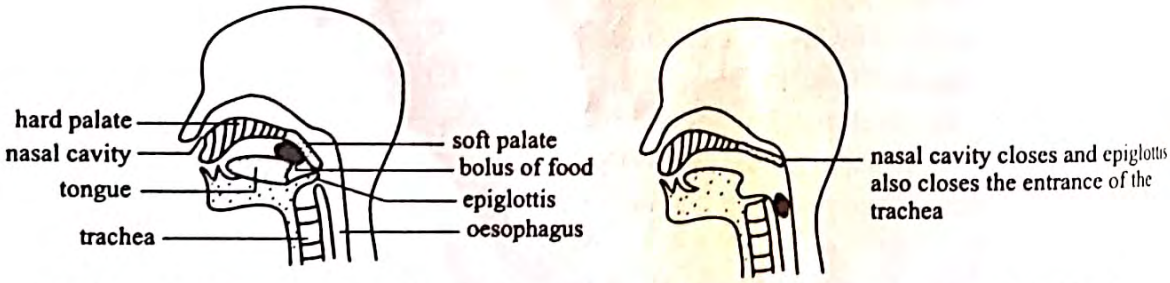



**Figure 6.36. The structure of the hard and soft palates and the swallowing machanism of food bolus.**

## Functions

1. The food is rolled against the roof of the hard palate by the tongue during the mechanical breakdown of large particles to smaller particles.
2. The hard palate aids in easy swallowing of food.
3. The soft palate helps in preventing food from going into the nasal cavity and thereby directing food into the pharynx.

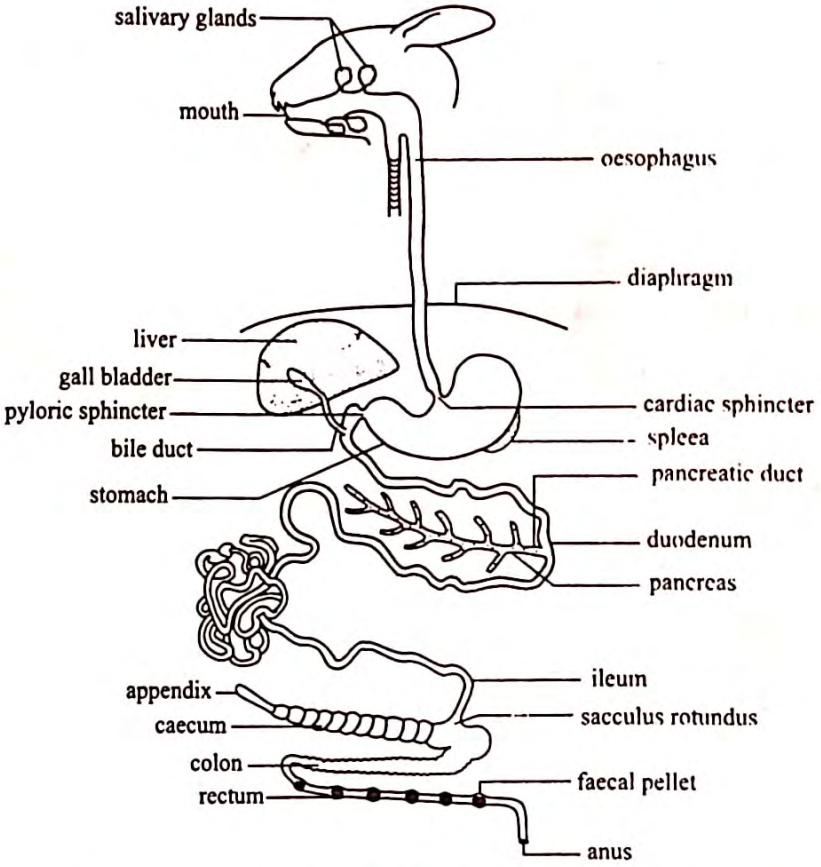



**Figure 6.36. The digestive system of a rabbit.**

## Tongue

The tongue is a strong muscular organ which lies in the floor of the mouth. It has several taste buds which are sensitive to substances dissolved in saliva. There are four kinds of taste buds namely: **sour, salty, sweet and bitter.** The taste buds are arranged on the tongue as follows:

1. **Sour and salty taste buds** are mainly located on the sides of the tongue;
2. **Sweet taste buds** are located mainly at the tip of the tongue.
3. **Bitter taste buds** are located at the back of the tongue.

## Functions

1. It function as an organ of taste.
2. The tongue helps during chewing of food between the teeth and forms the chewed food into a bolus.
3. It keeps the inner and the outer surface of the teeth and hard palate clean by constant rolling of the tongue.
4. The tongue helps in swallowing of food.
5. It prevents food from passing into the trachea by moving the epiglottis to block the trachea passage temporarily during swallowing.
6. The tongue is essential in speech. Together with saliva, teeth, lips and hard palate clear words are formed.

## Salivary glands

Three pairs of salivary glands exist in man while in rabbit they are four pairs. In man, the three pairs are **parotid, submaxillary** and **sublingual glands.** They all have ducts leading to the mouth cavity. They secrete digestive juice called **saliva**. Saliva contains an enzyme called **ptyalin, mucin** and **water.** The smell, sight and taste of food stimulate the secretion of saliva.

### Functions

1. Saliva protects the soft lining of the mouth from drying up.
2. The watery parts of the saliva help to dissolve dry food substances.
3. The mucin lubricates the chewed food and makes the food particles stick together to form **bolus** for easy swallowing.
4. It helps in cleaning the mouth.
5. It helps in speech by wetting the tongue, hard palate and lips so that the tongue does not stick to the roof of the mouth.
6. Saliva being alkaline helps to neutralise the acids produced by bacteria during the fermentation of food particles left over between the teeth.

# Dentition

## Types of teeth

There are four types of teeth. They are
(1) **incisors** (2) **canines** (3) **premolars** and
(4) **molars**.

During the existence of man on earth, two sets of teeth are formed. These are **temporary** (milk) and **permanent sets**. The **temporary** teeth consist of **four incisors, two canines, four premolars** on each jaw totalling 20 teeth on the two jaws while the **permanent teeth** have four incisors, two canines, four premolars and six molars on each jaw totalling 32 teeth on both jaws. Temporary set of teeth comes up during childhood while the permanent set comes up as one grows up. When a baby is about seven to eight months old, the incisors appear and gradually, the canines and premolars appear at about the age of two years. At the age of 6 -7 years, permanent teeth start replacing the temporary teeth. By the age of 15 years all the premolars and the first and second molars have been replaced leaving the third molars (called **wisdom teeth**). The wisdom teeth are replaced at about the ages of eighteen to twenty years. From this age, the permanent set when lost due to disease or accident can no longer be replaced.

## Structure of a tooth

A tooth consists of three main portions namely: the **crown, neck** and **root.**

## Crown

The crown is the portion above the gum. It is covered with a white hard substance called **enamel**. The enamel is mainly made of calcium salt.

It protects the **dentine**. Below the enamel is the dentine. The dentine produces the enamel. Inside the dentine is the pulp cavity containing blood vessels (supply food substances) and nerves. The dentine is the hardest substance in the body of the mammal. When the pulp cavity is exposed to air due to the decay of the tooth or teeth, pains and headache set in. The root is fastened firmly to the jaw bone by substance called **cement**. A **periodontal membrane** attaches the cement into the jaw bone. The short neck is covered with **gum**. The **root** is embedded in the jaw bone.

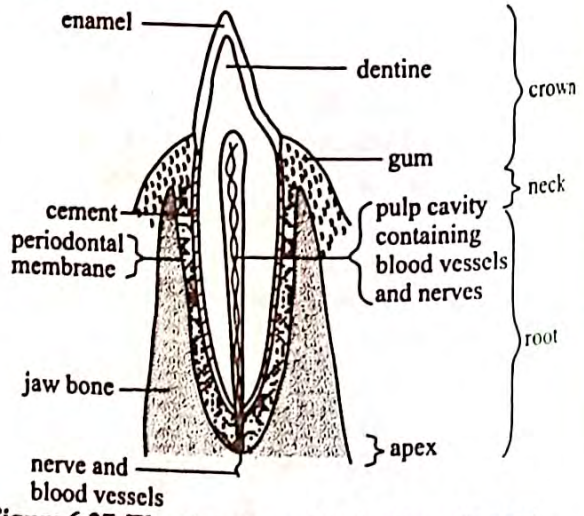



**Figure 6.37. The structure of the incisor of a man.**

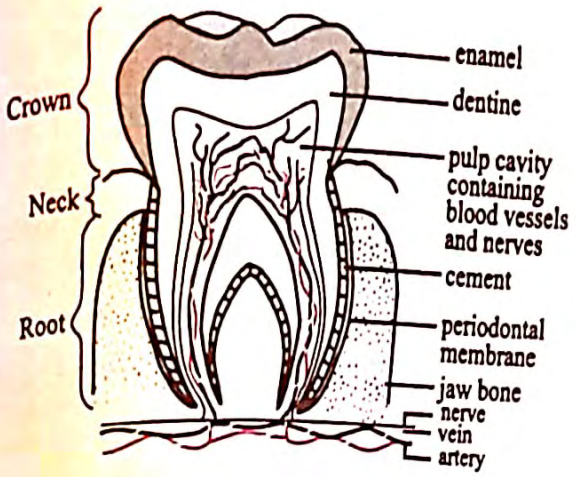



**Figure 6.38. The structure of the premolar of a man**

## Dentition and adaptation of teeth in mammals

It has been earlier stated in this chapter that mammals are classified as carnivores, herbivores and omnivores based on the types, number, shapes and arrangement of their teeth in the jaw bones.

## Dentition and adaptation of carnivore e.g dog.

**Incisors**: They are small, pointed and chisel-like, used for cutting flesh from bones, holding pieces of food or prey and also used for defence.

## Canines

Are long, strong, curved, sharp and pointed. They are used for killing prey and tearing flesh from bones. They are weapons of offence and defence. They are used for holding the prey from escaping.

## Premolars

Have flat surfaces with pointed and sharp cusps on the edges. The last upper premolar and the first lower molar are enlarged and are called carnassial teeth.

## Carnassial teeth.

They work like scissors by sliding pass each other. They are used for cutting large pieces of meat, breaking, grinding and chewing of bones and tendons.

## Molars

Molars are cusped and are used for crushing and breaking of food.

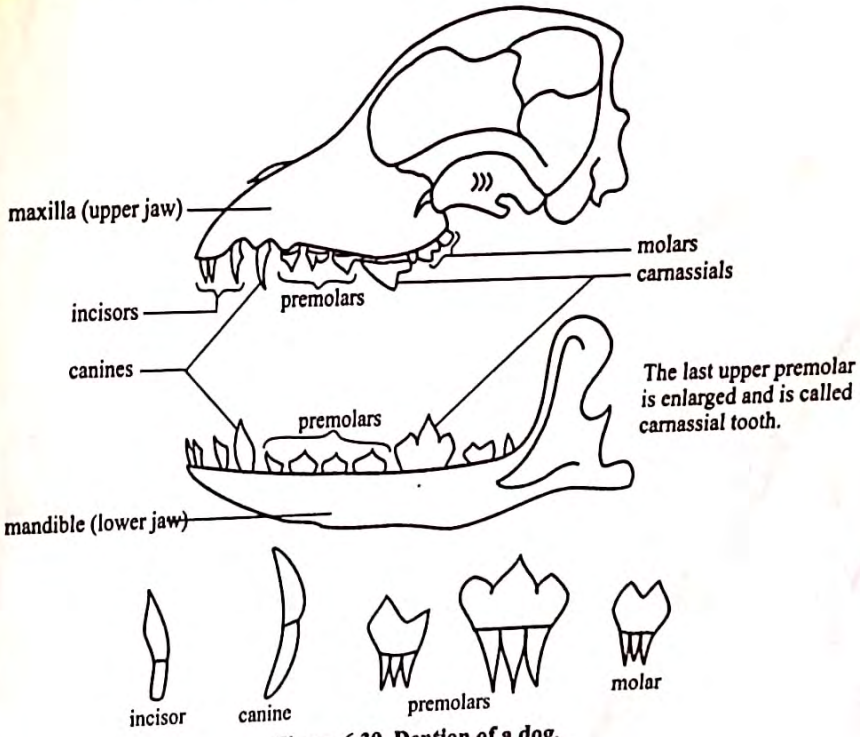



**Figure 6.39. Dention of a dog.**

*Dental formula*: I $\frac{3}{3}$ C $\frac{1}{1}$ PM $\frac{4}{4}$ M $\frac{2}{3}$ =42

## Dentition of herbivore e.g rabbit

### Incisors

Incisors are long, curved and chisel-like. The incisors of the upper jaw are more curved than those of the lower jaw. Enamel is present only on the outer surface of the incisors. As the inner surface of the incisors wears away, a chisel-like structure is created. The incisor has an open pulp cavity hence growth is throughout life. A loss of any incisor will allow the opposite incisor to grow unchecked and in due course will prevent the opening of the mouth. The animal will eventually die of hunger.

There are four incisors in the upper jaw. Incisor used for cutting leaves, shoots and gnawing.

### Canines

Canines are absent instead there is a wide sp called **diastema** which separates the incisors f the premolars.

### Premolars

Premolars are broad and ridged and they are u for grinding.

*Dental formula* I $\frac{2}{1}$ C $\frac{0}{0}$ PM $\frac{3}{2}$ M $\frac{3}{3}$ =28

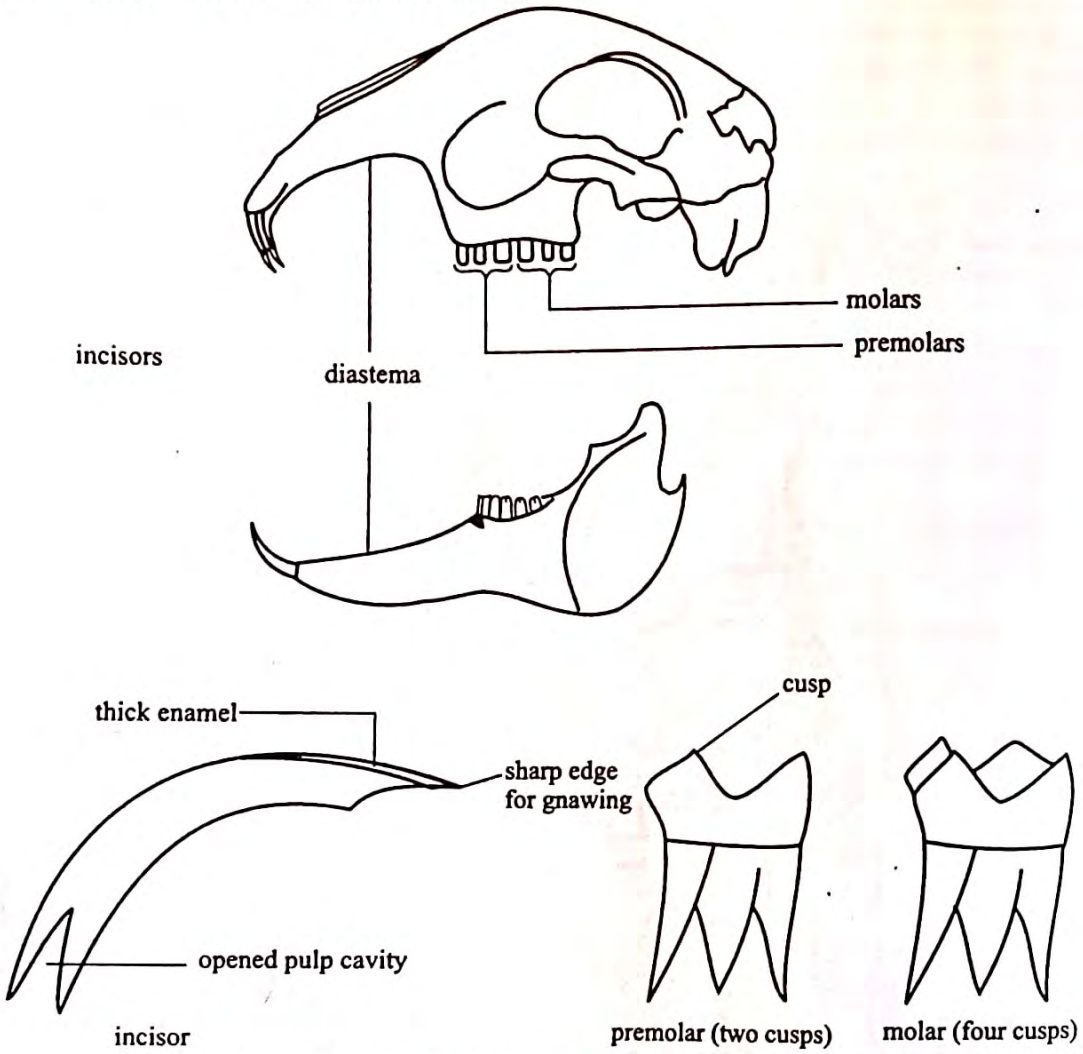



**Figure 6.40. Dentition of a rabbit.**

## Incisors

Incisors are rectangular, flat, chisel-like. They are used for cutting.

## Canines

Canines are sharp and pointed, and are used together with incisors for cutting, biting and tearing.

## Premolars

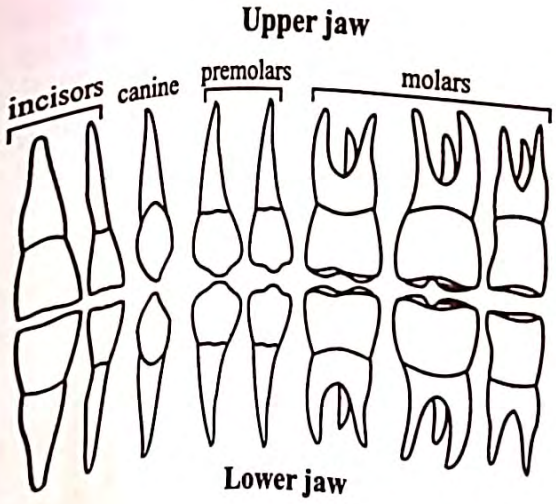
Premolars are broad with two cusps used for grinding and chewing.

## Molars

Molars are broad with four or five cusps. They are used for grinding and chewing.

Dental formula of man:

$$I\ \frac{2}{2}\ C\ \frac{1}{1}\ PM\ \frac{2}{2}\ M\ \frac{3}{3} = 32$$



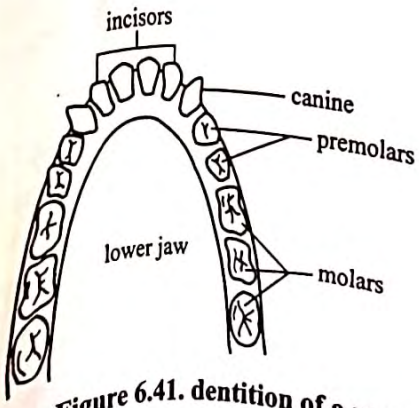
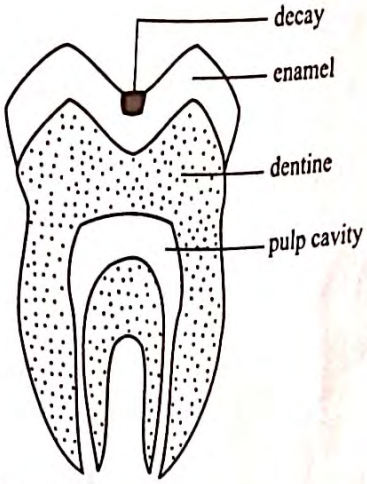



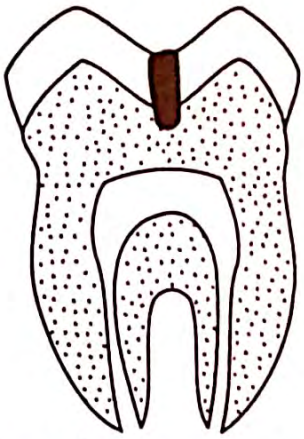

**Figure 6.41. dentition of a man.**

When the enamel wears away or is cracked, small holes are formed. Small food particles now enter the holes and start fermenting. The fermentation of the food produces acids. The acids eat through the enamel into the dentine. The attack of the acid widens the holes. Food particles also collect between the base of the teeth. Eventually the hole gets to the pulp cavity thereby exposing the sensory nerves. Bacteria now infect the pulp cavity. The exposure of the sensory nerves of pulp cavity and consequent infection result in **toothache**. In serious infection, the pulp may be destroyed when the infection spreads to the base of the tooth causing abscess and serious pains.

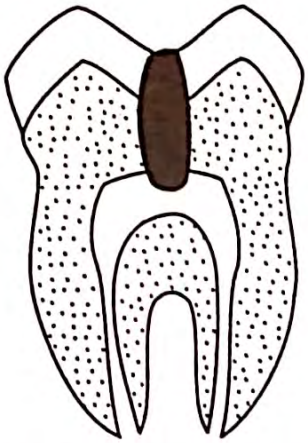
The gum may also be infected by bacteria which may find their way into the blood stream causing disease such as tonsilitis and rheumatism. Eating sugary foods such as **ice cream, cake, sweets** and also by drinking sugary drinks promote the growth of bacteria around the teeth. They should not be consumed as the last thing before going to bed. It leads to tooth decay. Also picking of food particles from the teeth with hard object like pins damage the enamel and initiate tooth decay.



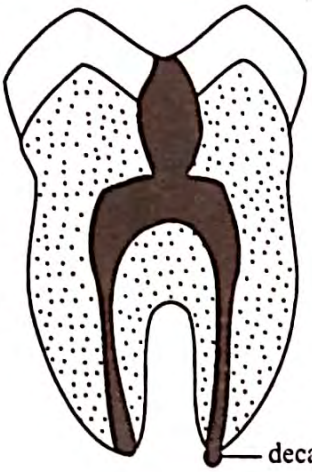

1. Decay in the enamel
   No toothache



2. Decay has spread to the dentine
**Slight toothache**



3. Decay has spread to the root of the tooth and forming an abscess.
**Agonising pains**




4. Decay has reached the pulp cavity.
**Severe toothache**

**Figure 6.42. The process of decay in the premolar.**

## Care of the human teeth

### 1. Teeth cleaning

Clean the teeth regularly particularly after breakfast and dinner with soft brush and tooth paste. Brushing up- and-down motion is recommended. Chewing stick is equally good as chewing the stick will help to exercise the teeth. Bacteria are very active after dinner and before breakfast. If the teeth are not brushed at these periods, bacteria will multiply and ferment the food particles between the teeth forming acids which attack and dissolve the enamel.

### 2. Constant use of teeth

Constant use of the teeth keeps them healthy. Chewing of moderately hard food stuffs such as raw carrots, soft bones, hard biscuits, groundnuts and sugar cane helps to exercise the teeth and also increases the flow of blood supply to the teeth. During chewing, the flow of saliva is increased. Saliva helps to clean and wash away food particles. Being alkaline, saliva neutralises the acids produced by bacteria in the mouth.

### 3. Sweet or sugary drinks

Do not eat or drink sugary drinks between meals and most importantly do not hold sweets in the mouth or suck sugary drinks for a long time. Sweet and sugary drinks help in increasing bacteria activities.

### 4. Right diet

During pregnancy and after delivery, the mother should eat a balanced diet with right amount of food containing calcium, phosphorus fluoride and **vitamin D**. These minerals and vitamins will help the baby to grow healthy set of teeth. Children should be given milk and food containing the above minerals and vitamin D.

### 5. Well spaced teeth

Unevenly spaced teeth are likely to cause dental decay. Food particles easily deposit between them. Modern mothers give their babies "rubber **comforters**" to suck. Many babies are allowed to **suck fingers**. These practices tend to displace the right position of the growing teeth and therefore should be discouraged. **Temporary teeth** should not be allowed to remain too long in the jaws as they

would cause obstruction to the normal growth of the **permanent teeth. Dental surgeon** should be consulted to remove the temporary teeth to pave way for normal growth of the premanent sets.

## Dental inspection

Teeth should be inspected by a dental surgeon **every six months**. Decay can start without your knowing. Toothache will not start until the pulp cavity is attacked. When dentists discover early stages of decay, the tooth or teeth can be filled. School authorities should regularly invite dentists to inspect the teeth of their pupils.

## Pharynx

This is a short muscular tube connecting the mouth with the oesophagus. Bolus of food is swallowed through the pharynx to the oesophagus.

## Oesophagus

The oesophagus is about 30cm long muscular tube that connects the pharynx to the stomach. Movement of food in the oesophagus is by **peristalsis**. This is a wave-like muscular contraction and relaxation of the longitudinal and circular muscles. The circular muscles behind the bolus contract, pushing the bolus forward.

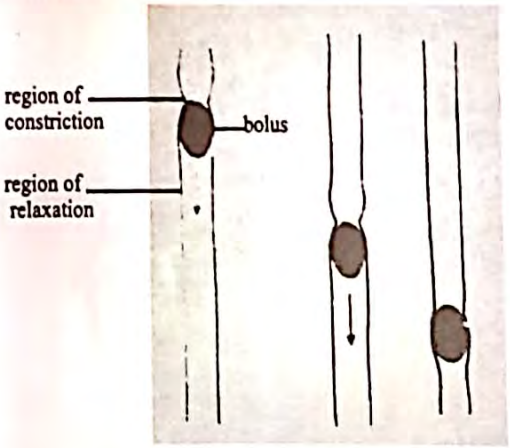



**Figure 6.43. Peristalsis**

## Stomach

The stomach is a thick-walled large muscular sac which lies in the left portion of the abdominal cavity below the diaphragm. It is made of three layers of muscles arranged longitudinally, circularly and obliquely. The contractions of these muscles in different directions bring about twisting, squeezing and churning of the stomach. Thus large food particles are further broken down into smaller particles for easy digestion by enzymes. The entrance and exit of the stomach is guided by cardiac and pyloric sphincters respectively.

The stomach has a thick and delicate inner folded membrane called gastric **mucosa** in which gastric glands are embedded. Three types of glands are present in the gastric mucosa. One type of gland secretes the enzymes **pepsinogen** and **renin**. Pepsinogen is coverted to pepsin on contact with dilute hydrochloric acid. Pepsin converts proteins to peptones while renin coagulates **milk protein (caesin)** before it is acted upon by pepsin. The digestion of carbohydrates, fats and oils does not start in the stomach. The second type of gland secretes mucus while the third type of gland secretes dilute hydrochloric acid. Hydrochloric acid also helps to kill germs such as bacteria in the stomach.

The mucus which forms a layer over the stomach prevents it from the attack of the dilute hydrochloric acid. If the mucus is not available, the acid attacks the stomach wall causing gastric ulcer. These three secretions form what is called **gastric juice**. When the stomach is empty, muscular contraction still goes on causing **hunger sensation**.

## Functions of stomach

1. Food is temporarily stored in the stomach for about one to four hours allowing time for digestion of protein to start.
2. The warmth of the stomach helps to melt fats.
3. The secretion of dilute hydrochloric acid from the stomach wall helps to destroy bacteria and converts pepsinogen to pepsin for digestion of proteins.
4. The contraction of the stomach muscles brings about churning of the food and breaking of large food particles to small particles for easy digestion.

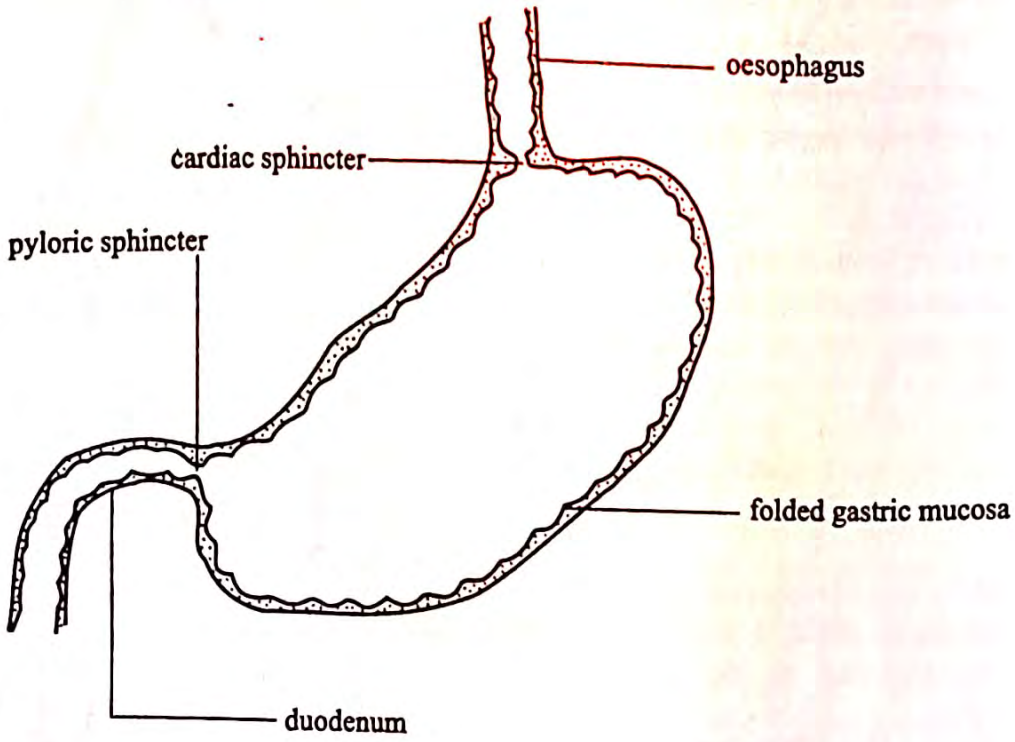



**Figure 6.44. Human stomach**

## Stomach of ruminants

**A ruminant is a herbivorous animal which has a four-chambered stomach for effective digestion of plant materials.** The four chambers are **rumen, reticulum, omasum** and **abomasum.** The rumen is the largest portion and it is here that the vegetables (mainly grasses) taken in are stored temporarily. A huge population of bacteria and protozoans live in the rumen and start the digestion and fermentation of cellulose present in the vegetable. The contents of the rumen are passed into the reticulum where further fermentation takes place. The reticulum also supplies fluid to the rumen and stores sand and stones picked up with vegetables. When the animal is at rest, the **partially digested food** is brought back **(regurgitated)** to the mouth for thorough chewing before it is swallowed back. This rechewing is referred to as **"chewing the cud".**

On reswallowing the semi-liquid cud, it is directed to another chamber called **omasum.** The towel-like omasum further breaks down the food and water is passed out of the cud and absorbed into the body. The solid material is passed into another chamber called **abomasum** (a true stomach). Glands in the walls of the abomasum secrete protein-digesting enzymes and dilute hydrochloric acid for the digestion of protein. Some bacteria and protozoans entering the abomasum with the cud are killed and digested.

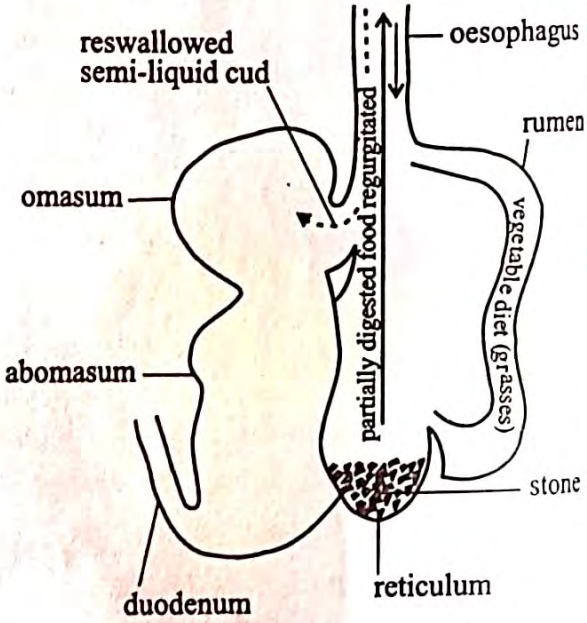



**Figure 6.45. Ruminant stomach.**

## Small intestine

In man, the small intestine is about 7 metres long and 2½cm in diametre.

The small intestine is divided into **duodenum, ileum, and jejunum.**

The duodenum is the upper part of the small intestine; it is about 25cm in length and U-shaped. The entrance from the stomach to the duodenum is guided by a ring-like pyloric sphincter muscle. Occasional relaxation of the pyloric sphincter muscle allows the stomach contents (**chyme**) to enter the duodenum a little at a time. Bile duct and pancreatic duct open into the duodenum through a common duct. Duodenum is the major site for the digestion of all food substances.

In rabbit, the bile duct and pancreatic duct enter the duodenum separately.

## Pancreas

The pancreas is a whitish gland consisting of many diffuse lobes lying between the lower part of the stomach and duodenum. An average person secretes about 1 to 1.5 litres of pancreatic juice a day.

It secretes pancreatic juice which contains three important digestive enzymes namely **amylase (amylopsin), trypsin** and **lipase**. The pancreatic juice is secreted to the duodenum through a pancreatic duct.

Amylase converts starch to **maltose sugar, trypsin** converts proteins to **peptones and amino acids** while **lipase** acts on emusified fats and oil changing them into **fatty acids** and **glycerol**. Also found in the pancreas are the ***islets of Langerhans*** which secrete two hormones namely **insulin** and **glucagon.** These two hormones are secreted by islet of Langerhans located in pancreas. Insulin is secreted when there is surplus glucose in the blood. Insulin helps in the conversion of excess glucose to glycogen for storage in the liver. When the blood glucose falls below normal, glucagon is secreted when helps to convert glycogen to glucose. These two hormones (insulin and glucagon) help to keep the blood sugar constant.

$$\text{Glucose} \xrightarrow[\text{insulin}]{\text{surplus blood glucose}} \text{Glycogen}$$

$$\text{Glucose} \xleftarrow[\text{glucagon}]{\text{low blood glucose}} \text{Glycogen}$$

A person short of insulin is unable to convert excess blood glucose to glycogen. Glucose, therefore collects in the blood and as glucose in the blood increases, some of the glucose is excreted in the urine leading to a disease called **diabetes mellitus.**

### Effects of malfunctioning of pancreas

1. May not be able to produce pancreatic juice which contains trypsin, amylase and lipase. Therefore proteins, carbohydrates, fats and oil will be difficult to digest.
2. There will be insuffient production of insulin and this will lead to diabetes.

## Bile

Bile is an alkaline greenish fluid with a pH of 7 to 8 secreted by the cells of the liver and stored in the gall bladder. It is passed to the duodenum through a bile duct. Bile has no digestive enzyme but performs the following functions:

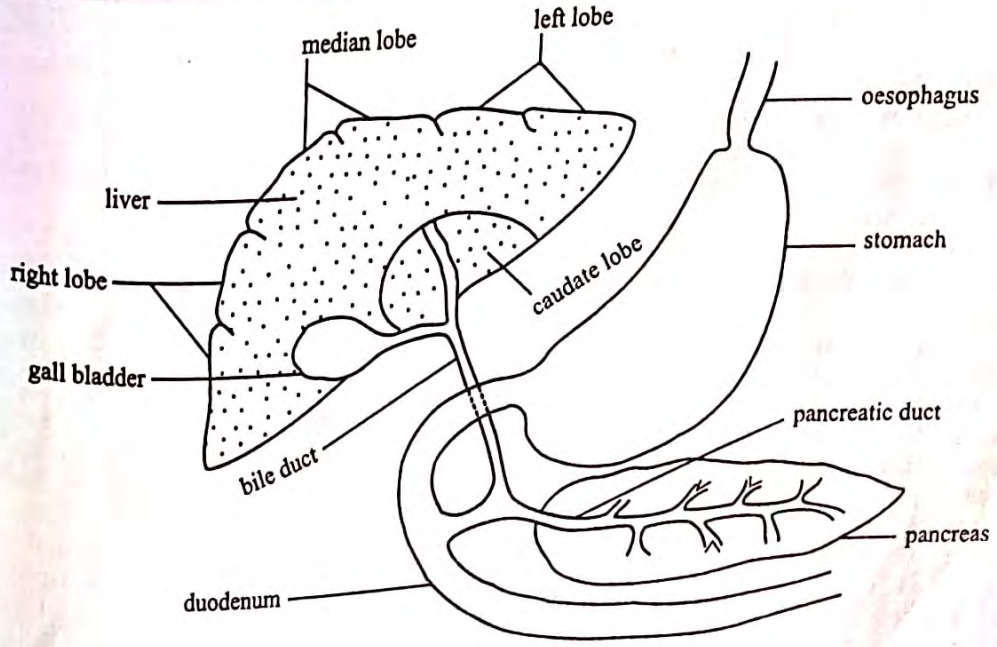



**Figure 6.46. Relationship between duodenum, pancreas, liver, gall bladder and stomach.**

1. It neutralises the acid chyme (food leaving the stomach) from the stomach. Bile has a pH of between 7 to 8. This is the best medium for the pancreatic enzymes to work.
2. Bile emulsifies fats and oils causing them to break into tiny droplets. Lipase can then act on the oil and fat droplets changing then into **fatty acids** and **glycerol**.
3. It prevents putrefaction (decay) of the food in the small intestine.

## Liver

### Structure and functions

The structure of liver has been described (See figure 6.46 on page 127 and page 198).

### Functions of the liver

### Blood sugar constant

1. Glucose in the blood stream is maintained at a constant level called **blood sugar constant** as low levels of glucose would be injurious to tissues of certain organs such as the brain that cannot store glucose. Surplus glucose is converted by the liver cells into glycogen for storage under the control of insulin. When blood sugar level is low, the glycogen is converted to glucose in order to maintain a constant blood sugar level. The liver also converts fructose and galactose to glucose for use by the body.

Glucose in the blood ⟶ Glycogen in the liver

2. **Deamination of proteins**

Surplus amino acids (those not needed for growth and repairs) are deaminated in the liver. The nitrogenous part, together with the nitrogenous wastes from the breakdown of protoplasm is formed into urea which passes into the blood stream for transport to the kidneys.

3. **Manufacture of bile**

The liver makes and secretes bile. This is not a digestive juice and also contains excretory pigments, formed from the haemoglobin of dead red blood corpuscles. Bile is stored in the gall bladder in man. *Rat* has no gall bladder.

4. It manufactures fibrinogen from amino acids for clotting of blood.
5. It produces heat which is distributed to all parts of the body by blood circulation thus regulating the body temperature.
6. **Removal of cholesterol from the blood.**

The liver removes cholesterol from the blood. Excess cholesterol if not removed from the blood may be deposited in the blood vessels leading to heart attacks. Excess cholesterol may also be excreted into the bile and precipitates and forms stones in the bile duct or bladder.7. It prepares fats for utilization as a source of energy.

8. Stores vitamin $B_{12}$
9. Stores iron, resulting from the decomposition of haemoglobin of dead red blood cells.
10. It converts other sugars to glucose. Fructose and galactose are converted by liver cells to glucose since glucose is the most suitable to the tissues generally.
11. **Detoxification**

Organic toxins produced by bacteria in the large intestine are absorbed into the **portal blood**. The liver prevents these compounds from reaching toxic levels in the body. Some enzymes present in the liver cells convert the toxic products into non-toxic compounds which are later excreted by the kidneys. For example, hydrogen peroxide which is a by-product of many metabolic processes, is split into water and oxygen by an enzyme called catalase in the liver.

12. **Manufacture of foetal red blood.** The liver of the embryo manufacture his or her red blood cells.

**The effects of malfunctioning of the liver**

1. Bile may not be produced. Therefore fats and oils will not be emulsified for digestion by lipase.
2. Excess sugar may not be converted into glycogen for storage. Therefore excess sugar will be in the blood than necessary.
3. Iron and vitamin $B_{12}$ may not be stored.
4. Fibrinogen may not be manufactured for blood clotting.
5. The liver may fail to deaminate amino acids, therefore nitrogenous wastes may accumulate in the body causing harm.
6. The body temperature may fall as the liver may fail to produce heat for the body.

7. The toxic products produced by bacteria in the body may not be converted into non-toxic compounds. Therefore the toxic products will be harmful to the body.
8. In pregnant mammals, the embryos will be anaemic as the liver may not be able to form red blood cells for the embryos.

## Jejunum

The *jejunm* is the second portion of the small intestine. It is about 2 metres in length.

## Ileum

The third portion of the small intestine is called **ileum**. It is about 4 metres long. It coils round the abdominal cavity before joining the large intestine.

The **jejunum** and **ileum** have numerous intestinal glands which secrete intestinal juice, called **succus entericus**, which is alkaline.

Succus entericus contains the following enzymes:

1. **Erepsin** which converts peptones to amino acids.
2. **Maltase** which converts maltose sugar to glucose.
3. **Lipase** which converts droplets of fats and oils to fatty acids and glycerol.
4. **Sucrase** which converts sucrose into glucose and fructose.
5. **Lactase** which converts lactose (milk sugar) to glucose and galactose.
6. Digestion of food substances is completed in ileum. Absorption of digested food is absorbed.

## Absorption of digested food in the small intestine

The linings of the small intestine are thrown into finger-like folds, called **villi**. Each villus has a mass of **blood capillaries** and a **lacteal**.

**Absorption** is the diffusion of digested food through the walls of the small intestine (villi) into the blood stream. The soluble and diffusible molecules of amino acids, glucose, frustose and galactose are absorbed by diffusion into the blood capillaries and epithelial cells. They enter the blood stream and are carried to the liver via the hepatic portal vein.

The fatty acids and glycerol diffuse into the lacteal of the villi where they recombine to form droplets of fats and are carried to the thoracic lymphatic duct, then to the blood stream. Absorption takes place mainly in the **duodenum** and **Ileum**.

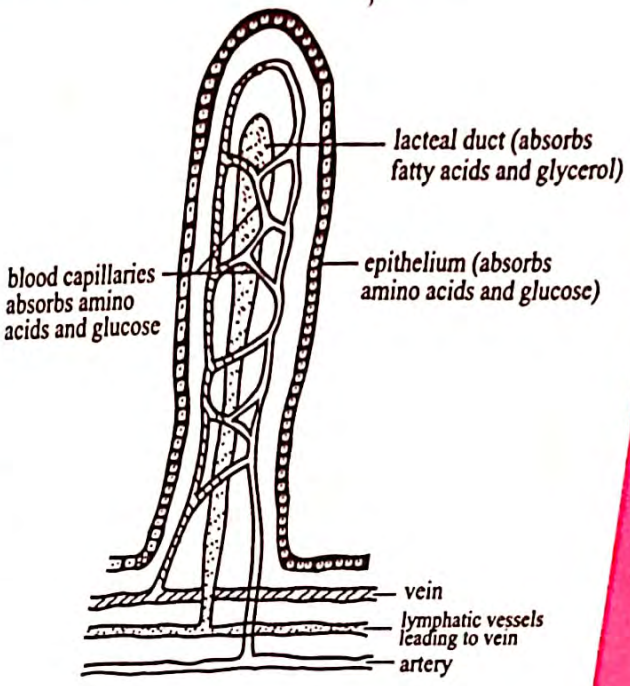



**Figure 6.47. The structure of villus**

## Adaptation of small intestine to absorption of digested food

1. The small intestine is long and coiled round the abdominal cavity, thus giving it a large surface area for absoption of digested food.
2. The walls of the small intestine are thrown into finger-like folds called villi. These villi are numerous and afford a large surface area for absorption of food.
3. The villi sway constantly over the intestinal content. This action makes them to be in touch with digested food.
4. The epithelial cells of the villi have brush-like structures called **micro villi** for absorption of digested food.

## Large intestine (Colon)

The large intestine is connected to the posterior end of the jejunum of small intestine. The large intestine is about 1.9 metres long and 7.5cm wide. It is divided into **ascending, transverse** and **descending** colons.

2. High concentration of bilirubin in blood, tissues and bile.
3. Over weight.

### Effects

1. Adbominal pains, chills and fever.
2. Skin and eyes turn yellow due to the concentration of bilirubin in the blood and tissues.
3. May lead to cancer of the liver.

### Remedies

1. Drink sufficient water or fruit juices.
2. Reduce consumption of food containing cholesterol.
3. Avoid over weight.
4. See a medical doctor

## Cancer of the liver

### Causes

1. Dietary deficiencies.
2. Gall stones.
3. Cancer cells from elsewhere in the body may come to affect the liver cells.

### Effects

1. Indigestion or change in bowel habits.
2. Loss of weight, weakness, anaemia, jaundice, fluid in abdomen.
3. Pains, frequent chills and fever.

### Remedies

1. Sufficient rest and care are essential to reduce the progress of the cancer.
2. Eat balanced diet.
3. Carry out regular medical check up at least once a year.
4. See a medical doctor.

## Diarrhoea

Diarrhoea is the frequent passing out of watery faeces.

### Causes

1. It may be caused by the infection of the large intestine by germs and roundworms causing rapid movement of the contents of the large intestine. This rapid movement does not allow sufficient time to absorb water from the undigested materials. Therefore liquid faeces are passed to the rectum and passed out as watery faeces through the anus.
2. **Food poisoning.** The toxins produced by bacteria weaken the large intestine and rectum.

### Effects

1. Dehydration of the body due to loss of fluid.
2. Weakness and possible collapse.

### Remedies

1. Strict sanitation must be observed.
2. Boil and filter drinking water.
3. Flies must be kept away from food stuffs.

## Constipation

### Causes

1. Very slow movement of waste materials through the large intestine resulting in large amount of water being removed from the waste. Dry and hard faeces are difficult to pass from the rectum.
2. Lack of muscular exercise.
3. Lack of roughage and fresh fruits in diet.
4. Eating in between meals.
5. Drinking insufficient water.
6. Sedentary life.

### Effects

Weakness, headache, fever and loss of appetite, belching, flatulence and stomach discomfort.

### Remedies

1. Diet should contain plenty of vegetables and fruits to supply sufficient roughage (2g per day).
2. Drink plenty of water between meals.
3. Take regular muscular exercise.
4. Form the habit of emptying the bowel at a particular time of day preferably morning.

## Indigestion

### Causes

1. Eating a large meal hurriedly without thorough chewing. The stomach then produces a large amount of juice containing a lot of dilute hydrochloric acid.
2. Over eating.
3. Eating food containing too much fats.
4. Lack of rest after a meal.

Scanned with CamScanner

The lower end of the ascending colon is the **caecum**. There is a finger-like outgrowth of the caecum called **appendix** which has no function in man but it is a notorious seat of the disease called *appendicitis*. An infected appendix is surgically removed.

The tranverse colon runs across the upper part of the abdominal cavity and descends to form the **descending colon**. The lower end of the descen-ding colon is the **muscular rectum**.

The rectum ends up as **anus**. The anus is guided by a ring-like sphincter muscle.

The **caecum** and appendix of herbivores such as rabbit, are long and enlarged and harbour large populations of bacteria and protozoa that digest cellulose present in the vegetable diet. In man, the caecum and appendix are small because the digestion of cellulose does not take place there. The large intestine receives large quantities of undigestable materials from the small intestine. As the undigestable watery materials pass through the large intestine by slow churning and peristaltic movements, about 90% of water and mineral salts are absorbed and returned into the body. Excess calcium and iron not needed in the body are excreted as salts in the large intestine. The epithelial cells of the large intestine excrete mucus which helps to lubricate faeces for an easy passage through the anus. Some symbiotic bacteria in the large intestine produce amino acids and vitamins such as vitamin K which are absorbed into the body. The remaining semi solid undigested materials are passed to the rectum as faeces where they stay temporarily before passing to the anus for evacuation from the body.

The rectum terminates as anus. The anus is guided by a ring-like **sphincter muscle**. The contraction of the large intestine and rectum muscles and relaxation of the sphincter muscles of the anus force the faeces out through the anus. This is called **defaecation**.

## Food storage in human body.

Excess glucose is converted to glycogen in the liver and stored as glycogen in the liver. When the body needs glucose, glycogen is reconverted to glucose in the liver and circulated to all over the body again. For example, a sick person who does not eat relies on the stored glycogen which is converted to glucose (with the help of hormone called glucagon secreted in the pancreas) for the supply of energy to the body.

$$\text{Glycogen} \xrightarrow{\text{glucagon}} \text{Glucose}$$

### Excess fats

The end product of digested fats is **fatty acids** and **glycerol.** Fatty acids and glycerol are conveyed to liver by lacteal. From the liver, they are distributed to all cells of the body for oxidation producing energy.

Excess fatty acids and glycerol are used to form cell membranes while the remaining excess is stored under **the skin, around the muscles of thighs, buttocks, abdomen and kidneys.**

### Excess Proteins

Excess proteins are destroyed by the cell of the liver and excreted as urea and passed out as urine.

## Disorders of the digestive system.

## Infectious hepatitis (Caterrhal jaundice)

### Causes

It is caused by contamination of food and water by **virus**. Faeces of infected person may be carried to our drinking water or food. It is also transmitted by transfusion of blood of an infected person to an uninfected person.

### Effects

1. Loss of appetite, nausea, weakness, fever, headache, diarrhoea, abdominal discomfort, pains, yellow eyes and skin.

### Remedies

1. Fruits and vegetables must be properly washed with clean water.
2. Drinking water must be boiled and filtered.
3. Faeces of an infected person must be buried deeply or burnt.
4. Flies should not be allowed to perch on our food.
5. An infected person should have a complete bed rest.
6. An infected person must avoid protein foods such as meat, eggs, fish and groundnuts.
7. Constant consumption of sugary foods such as glucose, sugar cane, pineapple and bread must be avoided.
8. Drink plenty of water.
9. See a medical doctor.

## Hepatitis

### Causes

1. Over concentration of bile thus preventing its normal flow. This leads to crystalization of cholesterol in the bile to form stones. The stones may block the bile duct, thus stopping the flow of bile.

2. High concentration of bilirubin in blood, tissues and bile.
3. Over weight.

## Effects

1. Adbominal pains, chills and fever.
2. Skin and eyes turn yellow due to the concentration of bilirubin in the blood and tissues.
3. May lead to cancer of the liver.

## Remedies

1. Drink sufficient water or fruit juices.
2. Reduce consumption of food containing cholesterol.
3. Avoid over weight.
4. See a medical doctor

## Cancer of the liver

## Causes

1. Dietary deficiencies.
2. Gall stones.
3. Cancer cells from elsewhere in the body may come to affect the liver cells.

## Effects

1. Indigestion or change in bowel habits.
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1. Sufficient rest and care are essential to reduce the progress of the cancer.
2. Eat balanced diet.
3. Carry out regular medical check up at least once a year.
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Diarrhoea is the frequent passing out of watery faeces.

## Causes

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2. **Food poisoning.** The toxins produced by bacteria weaken the large intestine and rectum.

## Effects

1. Dehydration of the body due to loss of fluid.
2. Weakness and possible collapse.

## Remedies

1. Strict sanitation must be observed.
2. Boil and filter drinking water.
3. Flies must be kept away from food stuffs.

## Constipation

## Causes

1. Very slow movement of waste materials through the large intestine resulting in large amount of water being removed from the waste. Dry and hard faeces are difficult to pass from the rectum.
2. Lack of muscular exercise.
3. Lack of roughage and fresh fruits in diet.
4. Eating in between meals.
5. Drinking insufficient water.
6. Sedentary life.

## Effects

Weakness, headache, fever and loss of appetite, belching, flatulence and stomach discomfort.

## Remedies

1. Diet should contain plenty of vegetables and fruits to supply sufficient roughage (2g per day).
2. Drink plenty of water between meals.
3. Take regular muscular exercise.
4. Form the habit of emptying the bowel at a particular time of day preferably morning.

## Indigestion

## Causes

1. Eating a large meal hurriedly without thorough chewing. The stomach then produces a large amount of juice containing a lot of dilute hydrochloric acid.
2. Over eating.
3. Eating food containing too much fats.
4. Lack of rest after a meal.

## Effects

1. **Burning sensation or "heart burn".** If a person suffering from indigestion belches some acid come up to the oesophagus giving burning sensations.
2. **Stomach ulcer.** The acid may eat up the linings of the stomach forming *stomach sores* which are very painful.
3. General weakness.

1. **Remedies**

1. Food must be thoroughly chewed if solid before swallowing.
2. Avoid over eating.
3. Eat food containing less fats.
4. After meal, rest sufficiently.

## *Questions*

*1. (a) What is photosynthesis?*
*(b) Outline the processes involved in the light and dark reactions in photosynthesis.*
*(c) State briefly what happens to the carbohydrates formed in a leaf.*
*(d) State the external factors which affect the rate of photosynthesis.*

*2. (a) Describe an experiment to demonstrate the importance (i) sunlight (ii) carbon (IV) oxide [carbon dioxide] (iii) chlorophyll in photosynthesis.*
*(b) What is the importance of photosynthesis in nature?*

*3. (a) What classes of food do green plants manufacture?*
*(b) How would you test for any three foods belonging to the different classes?*
*(c) How would you demonstrate that oxygen is released during photosynthesis?*

*4. (a) Draw up a table to show ways in which photosynthesis differs from respiration.*
*(b) List similarities between photosynthesis and aerobic respiration.*
*(c) Describe a simple experiment by which you could show the effect of darkness on photosynthesis.*

*5. (a) In a tabular form, state the source, importance and deficiency, if any, of five elements to healthy growth in flowering plants and mammals.*
*(b) Name the deficiency or disorder and the symptoms shown in mammals, which result from an inadequate supply of: (i) protein (ii) roughage.*
*(c) What is a balanced diet? Draw a table of balanced diet for one week.*
*(d) What are deficiency diseases? Name four of them.*
*(e) Demonstrate experimentally with necessary precautions the effects of deficiencies of the following elements to flowering plants; nitrogen, phosphorus, sulphur, potassium, magnesium, calcium and iron.*

*6. (a) For a leaf to be tested for starch, it is first boiled in water for 5 minutes and transferred to hot ethyl alcohol. From alcohol, it is rinsed in water and finally dipped in iodine solution.*
*(i) Give one reason for boiling the leaf.*
*(ii) Give one reason for transferring the boiled leaf into hot ethyl alcohol.*
*(iii) What change is brought about in the leaf by the hot ethyl alcohol?*

(iv) *State one reason for rinsing the leaf in water.*
(v) *What is the importance of iodine solution?*

(b) *Name the conditions necessary for the formation of sugar in a leaf.*

7. *Give the names of the different kinds of teeth in an adult mammal and draw and label a vertical section of one tooth to show its structure. In what ways are the teeth of (a) man (b) a herbivore (c) a carnivore related to their respective diets.*

8. (a) *State two differences between oils and fats.*
(b) *List common foods which are rich in carbohydrates.*
(c) *Describe the process of digestion of carbohydrates in man and explain fully how they are absorbed and used in the body.*

9. *Make a large fully labelled drawing to show the structure of the alimentary canal and associated glands in a named mammal. What are the functions of the (a) Salivary glands (b) Pancreas (c) Stomach (d) Small intestine.*

10. *List the common foods which are rich in fats and proteins. Give an account of the digestion of proteins and fats in man. Describe how the products of fats and proteins digestion are absorbed from the alimentary canal. How are these products used by the body?*

11. (a) *Describe the external appearance and the position of the liver within the body of a named mammal. Diagram is essential and must show the relationship between duodenun, stomach, gall bladder and pancreas.*
(b) *What part does the liver play in the life of this animal?*
(c) *How is the small intestine of this animal adapted to the absorption of digested food.*

12. (a) *What are the properties of enzymes?*
(b) *Give an example of one animal enzyme, say where it occurs and describe an experiment on how you would show the action of the enzyme that you have selected.*
(c) *What are the problems associated with the malfunctioning of:*
(i) *Liver,*
(ii) *Pancreas?*

13. (a) *What is digestion?*
(b) *How are carbohydrates digested in the alimentary canal?*
(c) *State the functions of pancreas.*

14. (a) *State six functions of a mammalian liver.*
(b) *In a tabular form, state the causes, effects and remedies of the following liver diseases: infectious hepatitis, gall stones and cancer of the liver.*

15. (a) *Describe briefly the modifications and mechanisms associated with the following feeding habits:*
(i) *fluid feeding in a housefly or female adult mosquito or butterfly.*
(ii) *filter feeding in mosquito larva.*
(iii) *parasitic feeding in tapeworm.*
(iv) *saprophytic feeding in mucor*
(b) *State either how Amoeba or Hydra feeds.*

16. (a) *Describe with examples (i) chemosynthetic nutrition in bacteria (ii) parasitic nutrition in a named flowering plant. (iii) carnivorous nutrition in a named flowering plant.*

(b) *Draw a labelled diagram of (i) the digestive system of a planaria (ii) the stomach of a named ruminant.*

(c) *State five reasons why the alimentary canal of earthworm is more advanced than that of planaria.*

17. (a) *What are vitamins?*

*Discuss vitamins A, B, C and D under the following headings:*

*Main sources*

*Functions*

*Deficiency*

(b) *Give the elements which make up:*

(i) *Fats*

(ii) *Carbohydrates*

(iii) *Proteins*

(c). *State the functions of terms (i), (ii) and (iii). How do such plants as yam or cassava make use of their main stored food substance?*

18. (i) *Name two elements apart from oxygen, hydrogen, carbon and nitrogen which are needed by both plants and mammals.*

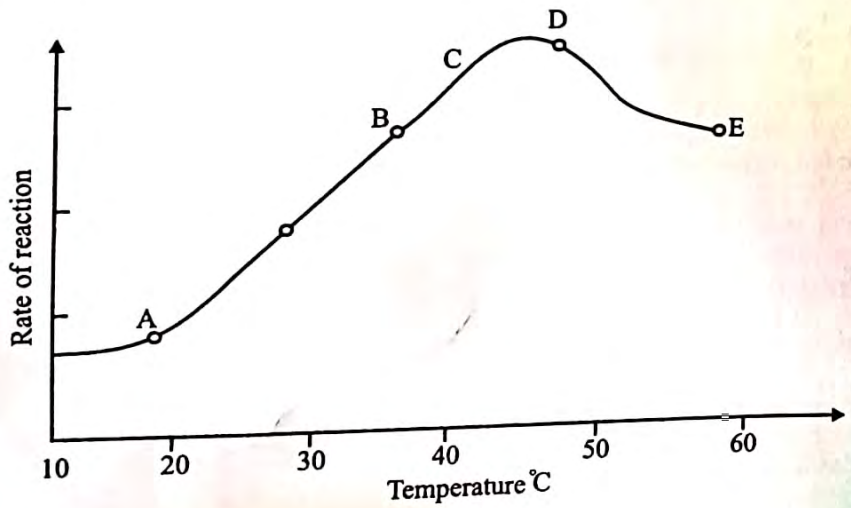
(ii) *State one reason why each of the elements chosen in (i) is needed by green plants and mammals.*

(iii) *Describe an experiment to show how one of the elements is important for the healthy growth of a green plant.*

(iv) *In what form is oxygen, nitrogen and phosphorus are absorbed by the roots of plants.*

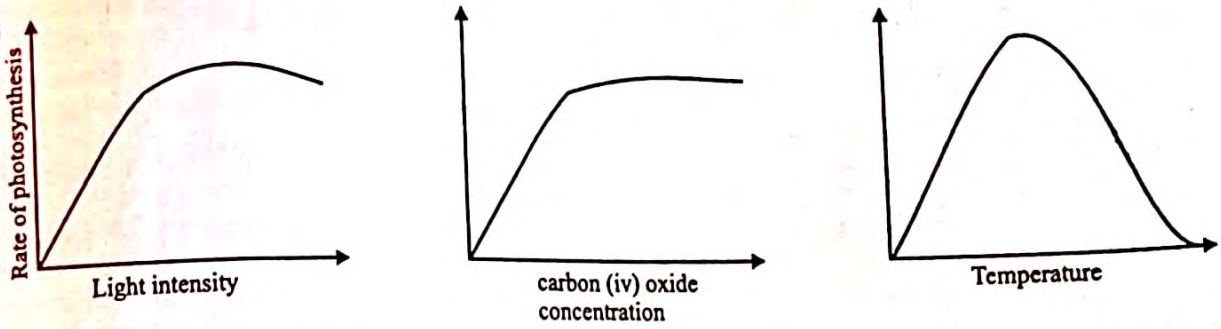
(v) *Describe how the nitrogen of an animal protein is made available for plant use after the death of an animal.*

19.(a) *Carefully study the graph below which shows the effect of temperature on the rate of enzyme reaction.*



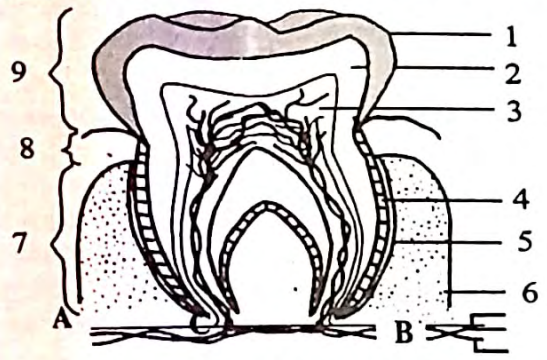
(i) *Explain the slope of curve (i) between A and B. (ii) at C; (iii) between D and E.*
(ii) *From the results of this experiment, give your general conclusion.*
(iii) *Give two more factors, other than the one above, that affects the rate of enzymes reaction.*
(iv) (a) *Name one gland which produces an enzyme.*
(b) *Name the type of food which the named enzyme acts upon and the medium which it acts.*

19.(b)




*Study the graphs above and briefly explain how light intensity, carbon (iv) oxide concentration and temperature affect the rate of photosynthesis.*

20. *(a)State six functions of water to living organisms.*
*(b) (i) Define roughage (ii) List three symptoms due to the absence of roughage in diet of a man.*
*(c).*




(i) *Name the parts labelled 1- 9 in the diagram above of the vertical section of a tooth.*

(ii) *State two reasons to show that it is a molar tooth.*
(iii) *Name an organism responsible for the decay of teeth.*
(iv) *State four ways of caring for teeth.*

# 7

# TRANSPORT (CIRCULATORY) SYSTEM

The transport system carries food and oxygen to all tissues and removes waste materials of metabolism, convenes hormones from ductless glands to their target organs and the body temperatures are equalized.

## Needs for transportation

In *Amoeba* and many simple multicellular organisms food products and oxygen are taken into cells and distributed and the waste materials are eliminated by diffusion. In many other complicated plants and animals, many of their cells are too far away to be in direct contact with food and oxygen and some means had to be provided to carry these substances to them and to remove their metabolic wastes.

The primary purpose of the transport system is to transport materials throughout the plant and animal bodies. Other functions of transport system include:

1. Regulation of body temperature in the vertebra by transporting and distributing heat.
2. Regulation of water balance in the animals.
3. Auxins in plants and animal hormones (secreted by ductless glands) are carried from the site of production to the **target tissues** by the transport system.
4. Regions of active cell division need substances to enable them build new protoplasm for the purpose of forming new cells. The transport system serves these needs.
5. Excess useful substances that can be stored are transported to tissues specialized to store them.
6. Substances required by reproductive cells for development are moved to them by the trans port system.

## Surface area/volume ratio

Numerous micro-organisms, unicellular organisms and simple multicellular organisms are found in aquatic habitat of various types. They are bathed by water all the time. Essential materials move from water directly into their bodies with minimum difficulty. On the reverse route metabolic wastes leave their bodies into the surrounding water by simple diffusion following diffusion gradient. In the larger and more complex organisms simple diffusion can no longer satisfy these needs. We now talk of short distance to cover in the less complex organisms and long distance to cover in the more complex organisms. In the simple organisms surface area is comparatively larger than the volume of the cell. This means that the surface area to volume ratio is high and therefore the distance from the environment into the cell and from the cell to the environment is short. Simple diffusion can transport materials from the environment into the cells and eliminate waste from the cells to the exterior. Consequently there is no need for a transport system.

In the large and more complex organisms, the surface area is comparatively far smaller than the volume. This means that the surface area to volume ratio is low and therefore the distance from the environment into the body is very great or long. The organisms therefore, have to develop an effi-cient transport system to cope with these problems.

## Substances have to move greater distances in complex organisms.

As the organisms become larger the body becomes more complex in structure, specialization of parts for specific function leads to a division of labour among different parts. All the living cells

in the body of complex organisms need materials to release energy needed for carrying out their assigned function to the well being of the organisms. The cells are numerous and far from the source of these long distances has to be met by special transport system. The distances to cover in complex organisms are greater than those to cover in the smaller, simple or less complex organisms whose bodies are bathed by water. You can now appreciate the great distances that have to be covered in transporting digested food absorbed into the villi in the small intestine of vertebrates to the cells of the brain, the skin etc or soil nutrients in the root-hairs through the tall stem to the branches, leaves, flowers and fruits in higher plants.

## Materials for transportation

In the living things, there is a life long process of continuous exchange of materials within the cells in the body and between the entire organism and the environment. As a host of essential materials enter the organisms body for their vital functioning so also waste products and unwanted substances leave the body to the environment. Materials for transportation include: water, gases, digested food and other nutrients and various secretions such as enzymes, hormones, excretory products and excess materials for elimination and or storage.

## Media of transportation

The media of transportation in the living things are:

1. Cytoplasm
2. Water
3. Body fluid
4. Blood and lymph
5. Cell sap
6. Latex

1. Cytoplasm in cell: The unicellular plants and animals live in aquatic habitat of all types (freshwater, brackishwater and marine or salt water). Their bodies are surrounded and bathed by water. Nutrients and air dissolved in the surrounding water diffuse into the bodies of these organisms for the purpose of building their bodies and releasing energy.

Similarly metabolic wastes such as ammonia and carbon (IV) oxide leave their bodies into the surrounding water by simple diffusion.The nutrients and oxygen on entering the cells are distributed or circulated to all parts of the cell by streaming of the cytoplasm in the cell. The Golgi bodies ribosomes and mitochondria concerned with carbohydrate, protein synthesis adn final internal respiration are found scattered through out teh cytoplasm makes it possible for the Golgi bodies, ribosome and mitochondria to receive their share of food and oxygen. The streaming of cytoplasm in cell serves as the medium of transportation in the unicellular forms such as *Amoeba, Paramecium* and *Euglena,* simple multicellular forms like Spirogyra and fungi, the non-vascular plants (Pteriodophyta) and the roundworms special media of transportation of food and oxygen to the more bulky and complex body had to be developed to assist cytoplasmic streaming. Similar media for the removal of metabolic waste were also developed. Whereas the same cytoplasmic streaming brings metabolic waste such as ammonium compound to the periphery of the cell for diffusion to the exterior.

## Body fluid in the invertebrates

In the invertebrate phyla from the Platyhelminthes through the Nematoda, Annelida to the Arthropoda large volume of body fluid flowing and bathing numerous cells serve as the transport medium for animals. The food and oxygen needed for the body well being is distributed in the body fluid to reach all living cells. The waste products of cellular metabolism are carried in the body fluid to the excretory organs for excretion. For this plan excretory organs lie free in the space called **coelom** where it is bathed by body fluid called **coelomic fluid**. Under this arrangement these excretory organs of the following animals are not supplied by blood vessels as seen in the vertebrates.

**Table 24: Excretory organs of some invertebrates**

| Animals | Excretory organs | Location |
|---|---|---|
| Flatworm (*Fasciola*) | Flame cells | Coelomic fluid |
| Round worm | Excretory duct | Coelomic fluid |
| Earthworm | Nephridia | Coelomic fluid |
| Shrimps | Green glands | Coelomic fluid |
| Insects | Malpighian tubules | Haemocoel. |

Although the earthworm has a blood vascular system the body fluid in the coelom still serves as transport medium for distribution of food and the carrying of wastes to the nephridia which lie free in it. Many other invertebrates have no vascular system and so the body fluid serves the needs of transportation for the animals.

## Blood and lymph in the vertebrates

The fish, toad and frog, lizards, birds and mammals have large bodies with complex internal structures which cannot be served or reached by body fluid alone. As a result special vascular systems with special fluid tissues have been developed to meet the needs of carrying food, oxygen, various secretions and water to all living cells of the body and to remove from them waste products of cellular metabolism to excretory organs (kidneys) for excretion. The special fluid tissues are: (1) Blood in the blood circulatory system and (2) lymph in the lymphastic circulatory system.

**Advantages of the blood and lymph over the cytoplasm and body fluid as transport media in the lower animals.**

1. The development of special respiratory pigment haemoglobin for transporting oxygen and plasma for carbon IV oxide during the process of gaseous exchange is faster and more efficient for active animals.
2. The plasma of blood transports digested food, mineral salts, other organic compounds such as hormones, drugs and water to all cells and urea, ammonium compound and other surplus substances such as water plus dissolved salts to excretory organs for excretion.
3. The lymph carries fatty acids and later hands them over to the blood for onward transportation to the liver for final distribution.
4. The lymph fills the gap created by the blood circulation by reaching all the cells that cannot be reached by the blood.
5. The lymph returns body fluid to the blood and when this is disturbed by certain monotonous activity of the body disease called dropsy is developed. This is characterized by the swelling of the legs with the accumulated unreturned body fluid.

The blood being pumped by the heart and the lymph propelled by muscular contraction are in **constant circulation** round the body supplying food, oxygen, water, hormones, drugs and heat to all the cells and removing from them urea ammonium compounds, carbon **(IV)** oxide, surplus heat, water mineral salts to excretory organs (kidneys skin) for excretion. This meets the physiological requirements to sustain the life of large complex and active animals in teh vertebrate group.

## Cell sap and latex in most plants

The flowering plants form the major vegetation of the whole world, cell sap like body fluid in animals is widely spread in them. But latex which is an excretory product stored away in the dead cells of the cortical tissue occurs in some families of plants like Euphorbiaceae such as *Euphorbia*

*hirta, Poinsettia, Pedilanthus, Jatropha, Rubber, Allamanda, Thivetia, Ficus* and *Rawolfia.*

Both cell sap and latex are fluid tissues as water is their basic component. The flowering plants are large and have complex tissues with many of them attaining great heights. The movement of absorbed soil water and manufactured food is greatly polarized. That is from the roots to the shoot tips and from the shoot to roots below. The sideways distribution of water, food, oxygen and carbon (IV) oxide is by the cell sap and latex.

## Transport in animals (man)

The transport system in man and most other vertebrates comprises:

1. A circulatory fluid **(blood).**
2. A pumping organ **(the heart).**
3. A system of closed vessles **(arteries, veins** and **capillaries).**

**Blood** is a fluid tissue made up of about 55% fluid called **plasma** and 45% cells.

## Plasma

The fluid portion of the blood is called plasma. It is amber or straw coloured fluid made up of water (90%) and dissolved substances (10%). The substances dissolved in the plasma include:

(a) Mineral salts such as bicarbonates, phosphates, chlorides, sulphates, sodium, Calcium and potassium..
(b) Food substances - mainly glucose, fats and amino acids.
(C) Blood proteins - albumin, prothrombin, globulin, fibrinogen..
(D) Excretory substances, mainly urea.
(E) Hormones.
(F) Antibodies.

## Functions

(1) Forms the medium in which all the other blood components such as the red blood cells, white blood cells and the blood platelets are suspended and transported round the body.
(2) The plasma picks carbon (IV) oxide from all living cells where oxidation takes place, to the lungs for excretion.
(3) The plasma transports urea from the site of formation in all living cells to the kidneys that excrete it.
(4) The plasma transports surplus heat, mineral salts and water to the skin that excretes them to regulate the body temperature and maintain the salt and water balance in the body.
(5) The plasma transports the followings:
   (a). Digested food from the small intestine to all living cells for assimilation.
   (b). Surplus glucose in the blood to the liver for conversion to glycogen for storage.
   (c) Surplus amino acids to the liver for deamination.
   (d) Old and non-functional red blood cells to the liver for destruction.
   (e) Hormones from ductless glands to tissues that use them to regulate the body activities.

### Blood cells

The cells that are found floating in the blood are referred to as blood cells and they are:- red blood cells (erythrocytes), white blood cells (leucocytes) and platelets (thrombocytes).

## Red blood cells (Erythrocytes)

Which makes them ideal for transporting enough oxygen to the cells. They contain haemoglobin which carries oxygen from the lungs to the living cells. Red blood cells have no nucleus hence they live for a short time. They live for about three months and when they become old and non-functional they are gathered and destroyed from the cells of liver spleen and replaced from the cells in the marrow of the long bones. Red blood cells are reproduced by the cells of the bone marrow. The red blood cells are the most numerous of the blood cells.

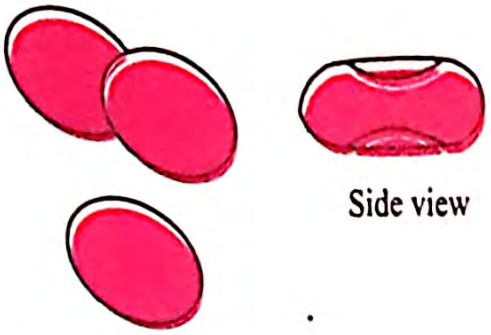



**Figure 7.1. Red blood cells**

## Functions

(a) The red blood cells transport oxygen from the lungs to all living cells of the body for cellular respiration.

(b) The red blood cells contribute to the formation of a clot over the wound by blocking the fine mesh formed by the fibrins.

## White blood cells (leucocytes)

Each white blood cell has a nucleus and lacks haemoglobin. White blood cells are larger and more active than the red blood cells. They are capable of **amoeboid movement** and can squeeze through narrow spaces from the blood vessels into the body tissues. They are fewer than the red blood cells. White blood cells move into the site of infection, engulf bacteria and destroy them. The remains of the dead bacteria, body cells and white blood cells constitute the pus that comes out from a damaged tissue. The white blood cells are of various types, the ones which have **nongranular cytoplasm** are the **lymphocytes** and **monocytes,** while those that have **granular cytoplasm** are the known as the granulocytes. **Lymphocytes** are formed in the lymph nodes. **Monocytes** and **granulocytes** are formed in the **bone marrow.** The **nucleus** of lymphocyte is **round,** that of monocyte is **been or kidney-shaped** while that of granulocyte is lobed.

## Functions

### 1. Engulfing

**Granulocytes and monocytes (phagocytes)** engulf (ingest) bacteria and viruses that infect the body and digest them.

### Neutralization

2. The **lymphocytes** produce **antitoxins** which neutralize the toxins (poisons) produced by disease-producing organisms that infect the body.

### 3. Clumping

Lymphocytes produce chemical substances (antibodies) which react with the cell or antigens of bacteria causing the bacteria antigens to clump (clot) with antibody rendering bacteria antigens harmless.

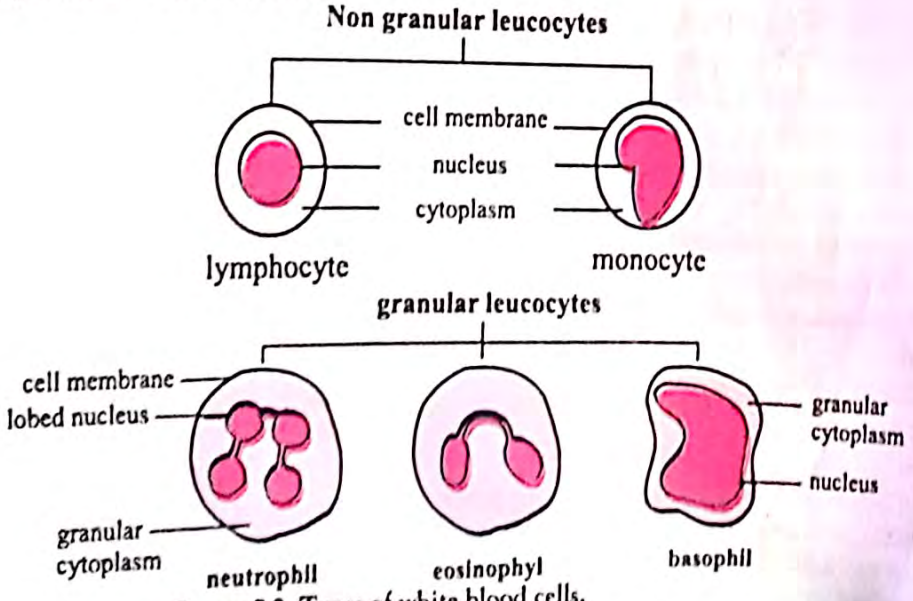



Figure 7.2. Types of white blood cells.

## Platelets (Thrombocytes):

Platelets are tiny fragments of cells, non nucleated, colourless. They are formed in the bone marrow. They are the source of thromboplastin which initiates blood clotting.

Figure 7.3. Blood platelets

## Functions

The blood platelets also help in the formation of a blood clot over the wound by getting entangled in the meshwork formed by the fibrin over the wound and this helps to control bleeding.

Table 25: Table of white blood cells.

| Types of white blood cells | Where formed | Nature of nucleus | Nature of cytoplasm | Function |
|---|---|---|---|---|
| Non-granular<br>(a) Lymphocytes | Lymph nodes, spleen and tonsit. | Rounded | No granules | Release of antibodies |
| (b) Monocytes | Spleen and connective tissues | Bean or kidney shaped | No granules | Release of antibodies |
| Granulocytes<br>Neutrophils<br>Eosinophils<br>Basophils | Bone marrow | Lobed | Contain granules | They are all phagocytic. |

Table 26: Differences between red blood cells and white blood cells.

| Red Blood Cells (Erythrocytes) | White Blood Cells (Leucocytes) |
|---|---|
| 1. Very numrous | Very few |
| 2. Coloured red due to pigment Haemoglobin | No pigment hence white |
| 3. Carry oxygen | Do not carry oxygen |
| 4. Very small | Much larger |
| 5. Round disc with thickened edge. Fixed shape. | Amoeboid constantly changing shape. |
| 6. Not nucleated | Nucleated |
| 7. Elastic in nature | Non-elastic |
| 8. No defence against infection | Engulf bacteria.<br>Produce antitoxin |

## Process of blood clotting in mammals

When a blood vessel is damaged and exposed to air, platelets in the blood stream release an enzyme thrombokinase. The thrombokinase then converts prothrombin (inactive blood protein) to an enzyme called **thrombin.** The thrombin then converts the soluble fibrinogen in the plasma to insoluble fibrin in the presence of calcium ions. The threadlike fibrin then forms a network or mesh on the surface of the wound and blood cells are trapped within the network or mesh to form a clot. The clot dries to scab over the wound.

## Importance of blood clotting

1. It prevents the loss of more blood from the body.
2. It prevents harmful micro-organisms from entering the body.
3. Blood clotting ensures healing of wounds. The clot becomes hardened forming a scab protect the tissues beneath while grad healing of the wound goes on.

## Haemophilia

The inability of the blood to clot easily in som persons is called **Haemophilia.** By the time th blood finally clots the victim might have lost a larg volume of blood even from a small wound **Haemophilia is a hereditary** disease which is sex **linked.** The individuals lack the enzyme responsible for the promotion of clotting of the blood. The enzyme is called **thrombokinase.** The disease shows in the males while the females are the carriers.

**Table 27:** **How blood serves as transport medium.**

| Substances transported | From | To | Purpose |
|---|---|---|---|
| Disgested food | Digestive organs and liver | Tissues | Growth and repair of damaged cells.<br>Release of energy and regulating life processes. |
| Cell wastes | Active tissues | Lungs, kidneys and skin | Excretion |
| Water | Digestive organs | Kidneys, skin and lungs | Excretion and regulation of body fluids. |
| Carbon (IV) oxi de<br>Oxygen | Tissues<br>Lungs | Lungs<br>Tissues | Excretion<br>Oxidation |
| Heat | Tissues | Skin and lungs | Equalization of the body temperature. |
| Secretions such as hormones | Ductless glands | Various organs and glands. | Regulation of body activities. |

## General functions of blood

1. **The blood serves as a transport medium:**
2. **Homeostasis:** The maintenance of a constant internal environment, such as water, tempera-ture and ions.
3. **Regulation of body temperature:**
   The blood distributes heat from active organs which release much heat (liver, muscles) to the rest part of the body.
4. The blood defends the body against diseases through the phagocytic action of the white blood cells, production of antibodies by the lymphocytes and clotting of blood over wounds to control bleeding by the blood platelets.

### Blood groups

Man's desire to assist nature in the effort to solve several severe health problems such as haemorrhage (severe bleeding), wound shock, severe burns led to the discovering and the use of blood transfusions. Blood transfusions did not however produce tangible success, for many recipients were found to have died from respiratory inhibition due to **clumping** or **agglutination** of their red blood cells. The effort of **Dr. Landsteiner (England 1902)** in discovering and working out the **ABO blood groups** brightened the hope of the medical world and mankind. This led to a higher level of success in the blood transfusions. Few fatal consequences were still recorded, until in the **1940s** when **Dr. Landsteiner** and **Levine** discovered the **rhesus factor** in the human blood. Blood groups and the rhesus factor are used in the blood transfusions to achieve higher success.

According to the blood groups, human blood can be any one of the four types A, B, AB, and O depending on the presence or absence of two substances A and B on the membrane of the red blood cell.

**Table 28:** **Blood groups in man**

| Blood group | Substance on cell | Substance in plasma |
|---|---|---|
| A | Antigen A | O |
| B | Antigen B | O,A |
| AB | Antigen A and B | O.B |
| O | No Antigen | O,A,B,AB |

The effect of the recipient's plasma on the donor's erythrocyte is considered. The plasma of the donor is usually too small to have any effect on the recipient's erythrocytes.

**Table 29:** **Transfusion compatibility of A, B, O Blood groups**

| Blood group | Recipients | Donors |
|---|---|---|
| O | O, A, B, AB | O |
| A | A, AB | O.A |
| B | B, AB | O,B |
| AB | AB | O,A,B, AB |

Table 30: **Blood group compatibility**

| Recipients blood group | Antibodies present in plasma | Donor's blood group | | | |
|---|---|---|---|---|---|
| | | A | B | AB | O |
| A | b | √ | X | X | √ |
| B | a | X | √ | X | √ |
| AB | None | √ | √ | √ | √ |
| O | ab | X | X | X | √ |

√ = Compatible
X = Not Compatible

From the chart blood O persons can donate their blood to any person. They are called universal donors. AB persons can receive blood from any group. They are called universal recipients.

## Rhesus factor

**Rhesus factor** in some red blood cells in some human beings was named after the rhesus monkey in which it was first discovered. Rhesus factor is an antigen present on the cell membrane of some red blood cells. The people that have it are rhesus positive ($Rh^+$) and those that lack it are rhesus negative ($Rh^-$)

**Rhesus factor (Rh):** If a person with a Rh negative (a person without Rh antigen) is by mistake given a transfusion of **Rh** positive blood, his blood cells are stimulated by the presence of the **Rh** antigen to produce antibodies. The first transfusion does not cause any harm to the patient. But if the same patient is later given a second blood transfusion of Rh-positive, the antibodies already present in the blood of the patient will react with the Rh-antigen of the donated blood and may lead to the death of the patient.

### Implications of a marriage between a girl with a negative Rhesus factor and a boy with a positive Rhesus factor.

This marriage may cause complications in childbirth. A Rhesus factor is inheritable. When the girl is Rhesus negative and the boy is Rhesus positive a child resulting from the marriage may inherit the Rhesus positive factor from the father. During pregnancy, labour or miscarriage, if rup-tures occur in the placenta, separating the mother=s circulation from that of the foetus, the foetus blood containing positive Rhesus factor seeps into the mother=s blood circulation. The mother=s blood (serum) containing no Rhesus factor forms antibodies. These antibodies seep into the foetal blood circulation and causes the destruction of the red blood cells of the foetus leading to anaemia and jaundice. In most cases the baby may die before birth or immediately after birth. This situation may happen during subsequent pregnancies.

## Remedies

1. Blood transfusion: The baby=s entire blood is removed and a negative Rhesus blood is transfused into the baby.
2. Immunisation of a negative Rhesus mother with Rhesus antibodies immediately after childbirth. This prevents her blood from forming antibo-dies which would otherwise destroy the red blood cell of the baby.

## Heart

The heart is an muscular organ that pumps blood to all parts of the body. It lies at the centre of the thoracic cavity in the pericardial cavity and being flanked on either side by and left lungs.

It is connected to the lungs by the pulmonary arteries which convey de-oxygenated blood into the lungs and

the pulmonary veins, which convey oxygenated blood into the heart. The heart is a little bit notched or inclined to the left side of the body in the thoracic cavity.

## The Structure and function of the heart

The heart of human being is cone-shaped and divided into four chambers. The four chambers of the heart are two **atria (auricles)** on the top and **two ventricles** below. A thick **interventricular septum** divides the heart longitudinally into two sides; right and left. The **right atrium** (auricle) communicates with the **right ventricle** below it by an opening guarded by the **tricuspid valve.** The arrangement is the same on the left side and the valve is called **mitral or bicuspid valve.** These valves ensure that blood flows only in one direction thus preventing wrong or reverse flow.

There is no communication between the right and left sides of the heart, for this reason the heart functions as a **double pump**. The right side pumps **deoxygenated blood** to the lungs in the **pulmonarycirculation for oxygenation.** The left side pumps **oxygenated blood** through the **aorta** to all parts of the body in the **systemic circulation.**

The heart is made up of **cardiac muscles.** It is the only involuntary muscle that is striped or striated. The heart is made up of a complex network of these cardiac muscle fibres that branch and fuse in most directions and planes. The muscles of the heart are not attached to bone or any hard structures. The **ventricles** are thicker and firmer than the auricles. The atria contract against the thick ventricles without loss of rhythm. The **atrio-ventricular** valves are attached to ventricles below by the fully stretched **Chordae tendinae.**

The function of the heart muscles is not under the control of the will and so the function of the heart is **involuntary.** The beat of the mammalian heart is initiated by the **sino-atrial node**. The rate of the beat is controlled by the nervous system, (medulla). The sinu-auricular node receives fibres from the **vagus nerve (parasympathetic nerve)** and the **sympathetic nerve** of the **autonomic nervous system**. The **vagus** of the parasympathetic nerve slows the rate of heart beat while the sympathetic fibres accelerate it. The rate of heart beat is always adjusted to suit the needs of the body under various conditions. The rate is therefore dependent on such factors as the state of the body, fear or calm, active or at rest, healthy or in sickness, age, size of the person, temperature of the body and surrounding. In the vertebrates and molluscs, the contraction of the heart is inde-pendent of nervous control as it is initiated in the heart itself. Such hearts are called **myogenic** hearts (myo=muscle; genic=giving rise to). They continue to beat when all nervous connections with the rest of the body are severed. Myogenic hearts are inhibited by **acetylcholine.** Contraction of the heart or of any chamber is called **systole** and relaxation is called **diastole.** The two atria contract together and then the two ventricles. The heart contracts and relaxes all the time throughout the life of the organism. It is not easily fatigued. The contractions are successive atria and ventricles and then a pause.

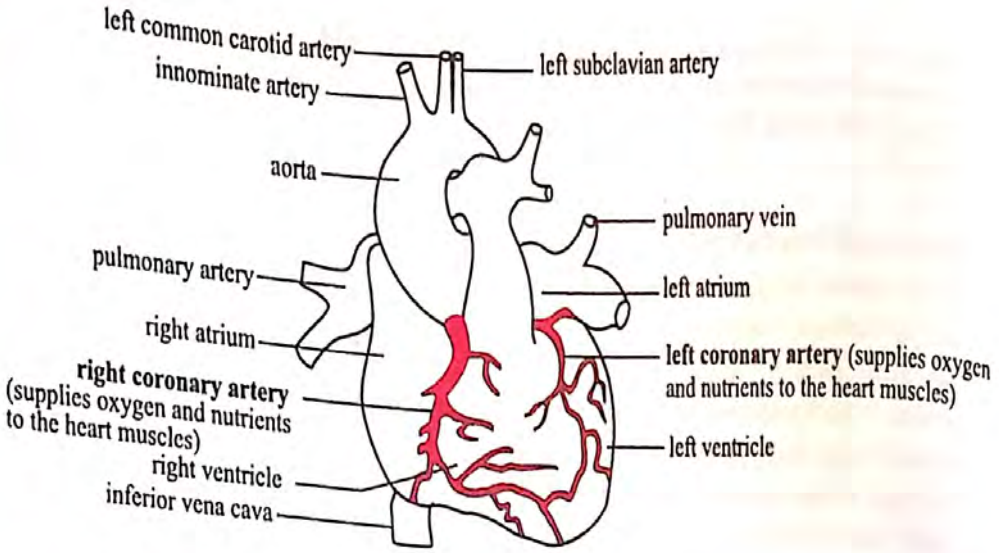



**Figure 7.4A. The side view of the human heart showing coronary arteries**

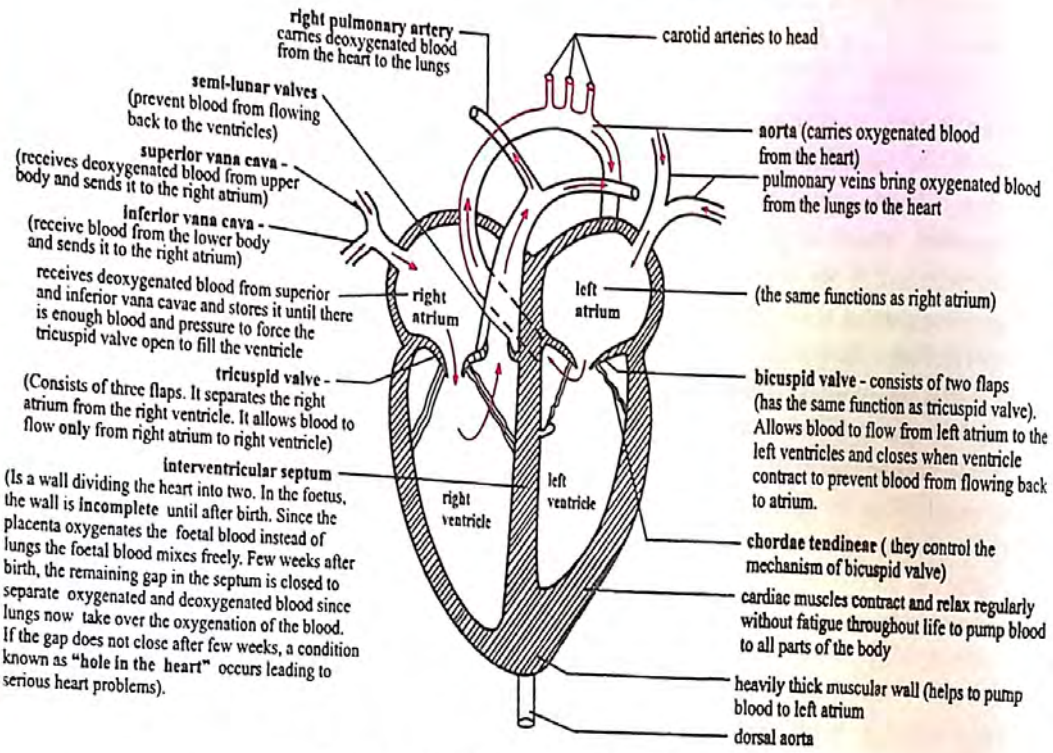



**Figure 7.4B. The vertical section of the heart**

## How the heart works

One heart beat consists of **contractions, relaxation** and a **pulse**. The **beating** of the heart itself and it can only be controlled by the nervous system. The heart beat or cardiac cycle starts with the contraction of the atrium (atrial contraction).

The stimulus for the rhythmic beat of the heart comes from a small part of the right atrium called the **sino-atrial** node otherwise known as the **pacemaker**. The action is wavelike and so it spreads to the left atrium (auricle). The blood is pumped to all parts of the body and again returns to the heart. The deoxygenated blood enters the **right atrium** from the superior and inferior venae cavae while oxygenated blood enters the left atrium from the lungs through the **pulmonary veins.** When the two atria contract, the blood presses open the **tricuspid** and **bicupsid valves** leading into the ventricles and fills the ventricles.

When the ventricles contract, the tricupid and **biscuspid valves** are closed in such a way that no blood flows back into the atria. The blood from the right ventricle is forced into the **pulmonary artery** which supplies the lungs. The blood from left ventricle enters the **aorta** which supplies all parts of the body. The entrance of the pulmonary artery is guarded by **semi-lunar** valves which prevent the blood from flowing into the ventricles.

All these constitute one cardiac cycle. The cardiac output is the total volume of blood pumped out by one ventricle in minute.

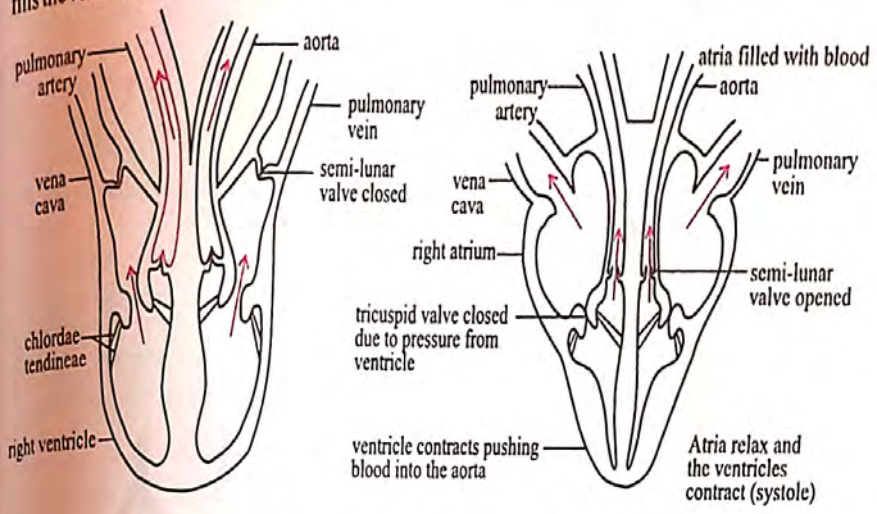



**Figure 7.5. The pumping action of the heart.**

## Rest period

With this there is an endless rhythm of auricular contraction, ventricular contraction and rest. The rest period is as long as both contractions put together. The rate of heart beat that is the number of beats per unit time can be measured. In an adult human being the rate is 72 beats per minute with considerable fluctuation among individuals of different ages and under different conditions.

## The blood vessels

The tubes in which blood leaves the heart flows round the body and returns to the heart are called **blood vessels.** The system of tubes or the blood vessels start as the **artery** leaving the left ventricle of the heart as the **main artery** or **aorta**. On leaving the heart, the aorta makes a **U-turn** and gives out branches to the head and fore limbs and continues downwards to the trunk and hind limbs. The **U-turn** is called the **aortic arch.** These major branches divide and further divide into smaller **branches called arterioles.** The arterioles further divide and subdivide into much tiny branches known as **capillaries.** Capillaries are small blood vessels that connect the arteries to the vein so as to reach individual cells for the purpose of exchange of matrials. Blood flow in the capillaries is slow. After making the desired contact with the cells the **capillaries** start to unite and reunite into tangible blood vessels known as **venules.** The venules again unite into veins that return blood to the right atrium of the heart.

These major veins are the superior vena cava draining blood from the head and forelimbs and inferior vena cava draining blood from the hindlimbs and trunk. Arteries and veins are similar in that their walls are made of three layers but differ in some other features.

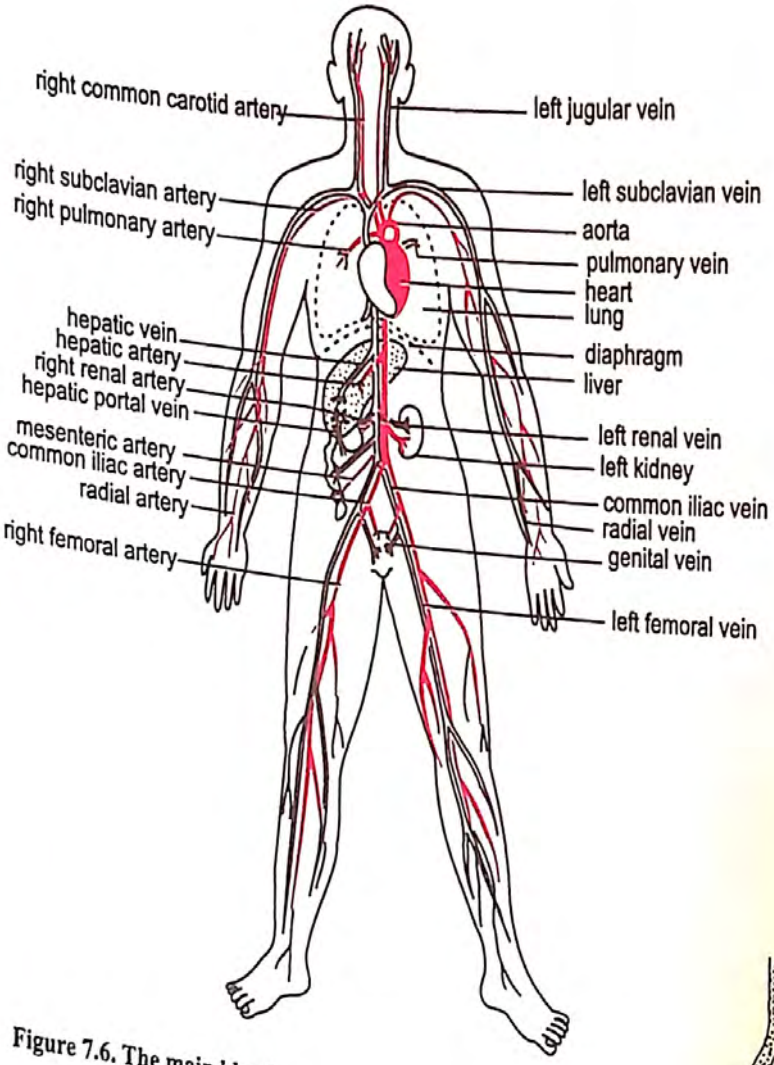



Figure 7.6. The main blood vessels (arteries and veins) of a man.

Figure 7.8. Capillary network.

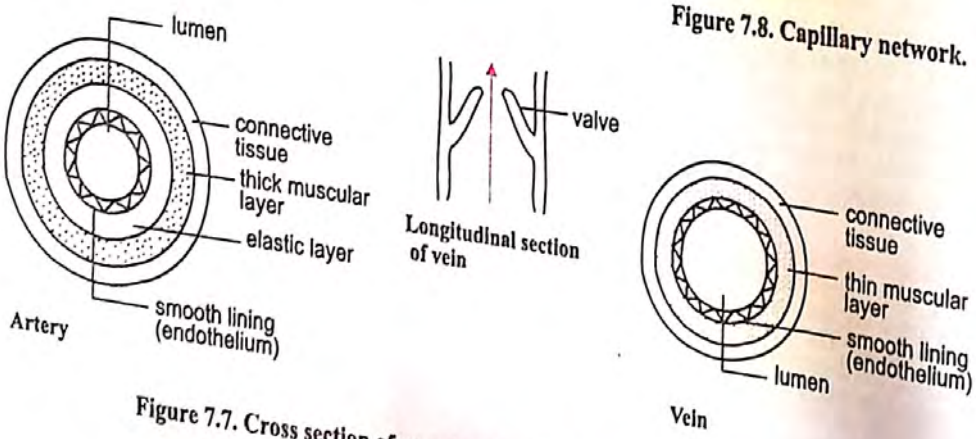



Figure 7.7. Cross section of an artery, a vein and section of a capillary.

**Table 31: Differences between arteries, veins and capillaries**

| Arteries | Veins | Capillaries |
|---|---|---|
| 1. Carry oxygenated blood away from the heart. | Return de-oxygenated blood to the heart. | Carry mixed oxygenated and deoxygenated blood. |
| 2. Pulmonary artery carries deoxygenated blood away from the heart to the lungs. | Pulmonary veins bring oxygenated blood from the lungs into the left auricle of the heart. | Carry deoxygenated blood from pulmonary artery and oxygenated blood from the pulmonary vein. |
| 3. Blood flows rapidly under high pressure, hence small lumen. | Blood flows gently under low pressure, hence large lumen. | Blood flow is slow and falling pressure. |
| 4. Walls have thick layer of muscle. | Walls have th in layer of muscle. | One cell layer thick. |
| 5. Walls have an elastic layer. | Walls have no elastic layer. | No elastic layer. |
| 6. Valves are not present except the aorta with semi -lunar valves. | Valves are present. | No valves present |
| 7. Start as large vessels from the heart and sub divide. | Start as tiny vessels in the tissues. Unite and reunite into large ones. | Start as arterioles and divide into venules. |
| 8. Deep seated in the body. | Superificially seated in the body. | Intermediat ely seated. |
| 9. Blood flows in arteries under the pressure from the heart beats. | Blood flows in the veins with assistance from contracting muscles and gravity. | Blood flows in capillaries under the pressure of blood from arteries. |
| 10. Low bloodvolume. | Increased blood volume. | High blood volume. |
| 11. Blood flows in pulse . | No pulse in blood flow. | No pulse in blood flow. |

## The circulation of blood

There are three plans or types of blood circulation in human beings, other mammals and birds. They are the **pulmonary circulation**, **systemic circulation** and the **coronary circulation**.

### The pulmonary circulation (Heart→lung→heart)

The pulmonary circulation transports blood between the heart and the lungs. The **superior vena cava** returns blood from the head and upper limbs into the **right artrium.** Blood from the lower limbs and the abdomen is brought to the right atrium by the **inferior vena cava**. The right artrium contracts and the blood is forced through the **tricuspid valves** into the **right ventricle**. The right ventricle contracts forcing the blood up into the **pulmonary artery**. The pulmonary artery divides into right and pulmonary arteries each leading to right and left lungs respectively. When the right ventricle relaxes the semi-lunar valves close up to prevent the blood from rushing back into the ventricle.The pulmonary arteries divide and sub-divide

Into numerous arterioles which in turn subdivide into microscopic capillaries in the lungs. With the thin walls of the capillaries and the moist individual cells of the lungs exchange of gases, nutrients and wastes takes place between the blood and the cells of the lungs. The capillaries unite and reunite to form venules. The venules in turn form t pulmonary vein that brings back the oxygenat blood into the left atrium of the heart. When the le atrium contracts the blood is forced through th bicuspid (mitral) valves into the left ventricle.

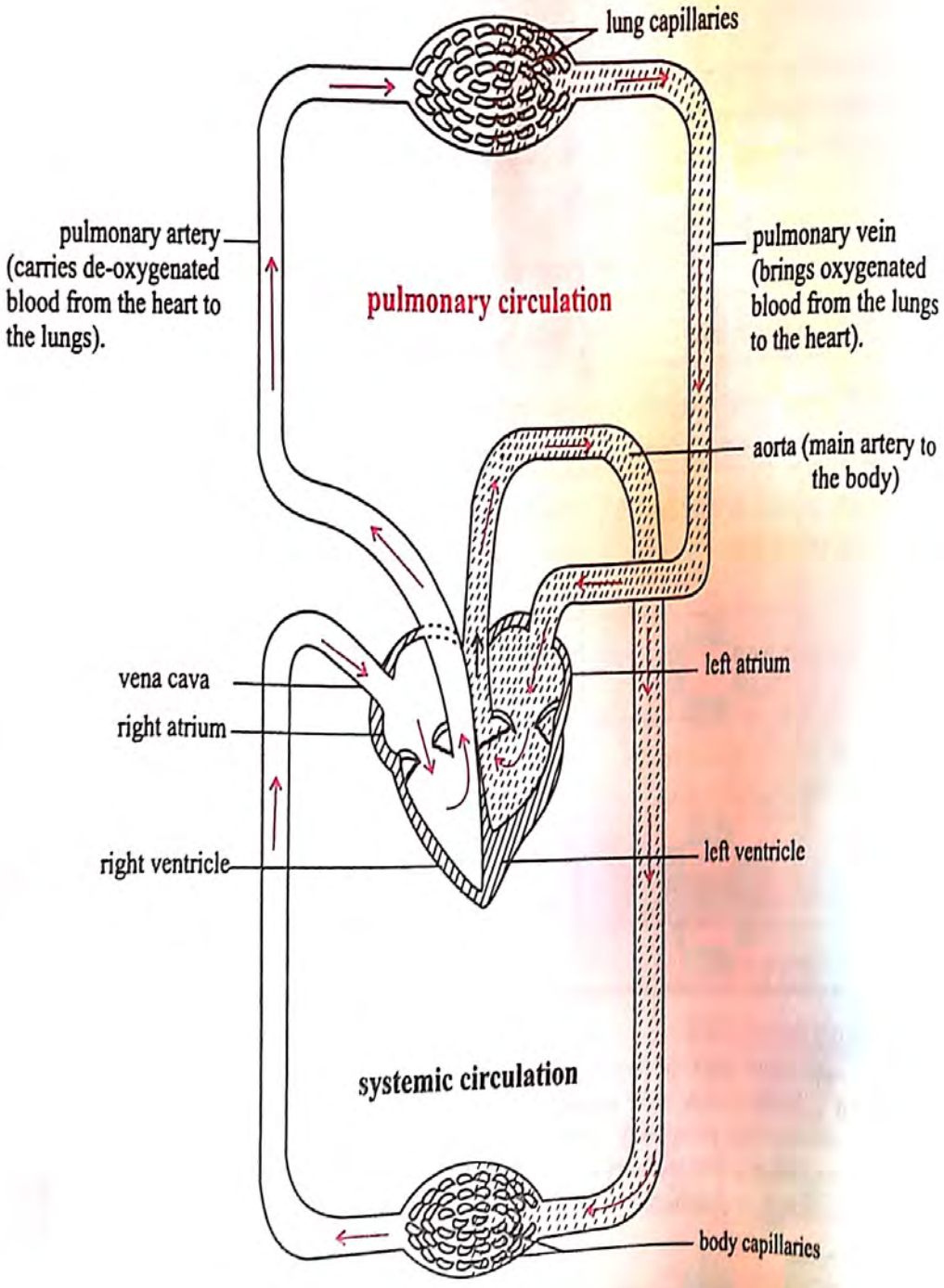



Figure 7.9. Pulmonary and systemic blood circulations. (Double circulation)

## The importance of pulmonary circulation

1. Pulmonary circulation in the first place prevents the mixing of **deoxygenated blood with oxygenated blood.** This is found only in the birds and mammals which account for their being very active animals and also being warm-blooded (homeothermic). The mixing of de-oxygenated blood with oxygenated blood in the three-chambered hearts of the Amphibians and Reptiles makes them sluggish and poiki-lothermic.
2. Pulmonary circulation makes oxygenated blood available in the left ventricle for systemic ciculartion. Deoxygenated blood gives out carbon (IV) oxide, urea and other wastes and picks oxygen and other nutrients to enter the **systemic circulation.**
3. It checks accumulation of wastes and enhances renewal of the blood.
4. It prevents deoxygenated blood from entering the systemic and coronary circulation and ensures that only oxygenated blood does.

## Systemic circulation (Heart ⟶ rest of body⟶ heart)

Systemic circulation transports blood between the heart and all parts of the body. The oxygenated blood arrives the left ventricle. The left atrium relaxes and the left ventricle contracts. Blood is forced up the aorta to all parts of the body. Blood rich in oxygen and other nutrients is taken to all living cells in the body. Exchange of materials takes place and the living cells are provided with means for releasing energy for use. By this all energy-dependent vital processes of living organism is maintained. The aorta is the main artery and on leaving the heart, it forms and aortic arch where it gives out three branches before running down the trunk. The arterial supplies in the systemic circulation are as follows:

1. At the curve or bend, the first two branches the **right** and **left carotid arteries** pass through the neck into the head to supply the head, brain and face.
2. The first branch which is the **right carotid artery** gives a branch to the right arm as the **right subclavian artery.**
3. The third branch is the **left subclavian artery** which supplies the left arm.
4. The main artery continues down the trunk as the **aorta** and in the thorax gives out a pair of small branches to a pair of ribs as the **phrenic arteries.**
5. A major branch, the **hepatic artery** supplies the liver.
6. Next is the **mesenteric artery** which branches into the stomach as **gastric artery,** the spleen as **splenic artery** and the intestine as the **intestinal artery.**
7. The right and left **renal arteries** supplying the respective kidneys.
8. The testicular and ovarian arteries are the **genital arteries** that supply the testes and ovaries in the male and female respectively.
9. The **abdominal artery** now gives rise to two major branches which go into the lower or hind limbs as common **iliac arteries** and later the **femural arteries** into the legs.

The **major veins** that return the blood back to the heart in the systemic circulation are as follows:

1. The **right** and **left jugular veins** from the head, brain and face join the right and left subclavian vein and enter the right auricle as the superior **vena cava.**
2. The **inferior vena cava** drains the blood from the rest parts of the body into the same right atrium after receiving blood from:

(a) **Phrenic veins** from the ribs and intercoastal muscles.

(b) **Hepatic vein** from the liver.

(c) **Hepatic portal** vein from the gut.

(d) **Renal veins** from kidneys.

(e) **Genital veins** from the ovaries and testes.

(f) **Common iliac veins** and **femural veins** from the thigh and legs.

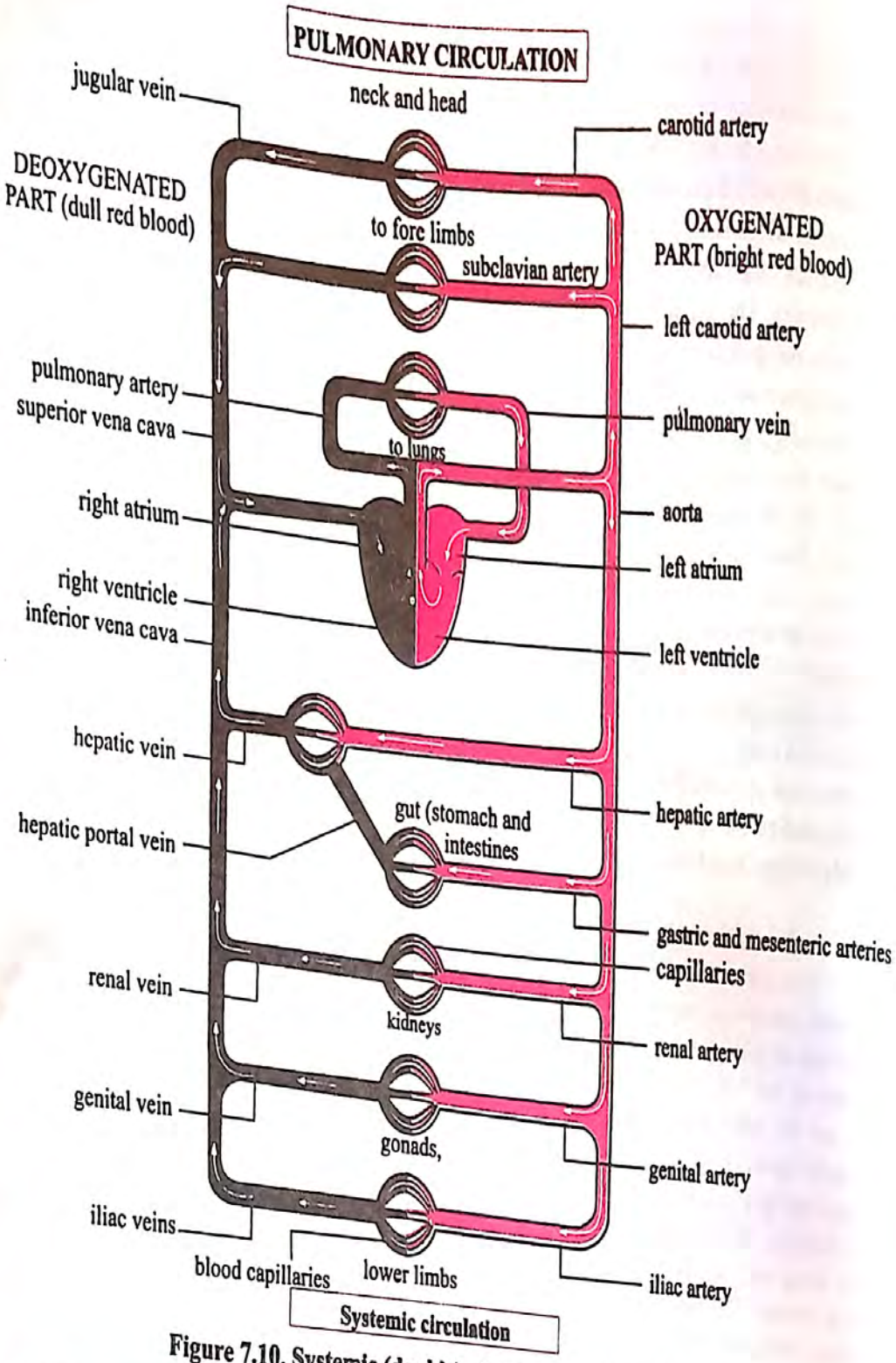



**Figure 7.10. Systemic (double) circulatory system of a man.**

## Coronary circulation

The coronary circulation supplies the heart. It starts at the aorta where a branch of the coronary artery takes oxygenated blood to all the contractile cells of the heart through a complex network of capillaries. The coronary vein drains the spent blood into the right atrium of the heart. It is a very short circulation but very vital. The heart muscles are very strong and they beat rhythmically without stop throughout the life of the organism. They are not easily fatigued. There is a high and continuous energy demand and utilization in the heart hence its own special circulation.

## Open and closed blood circulatory systems

There are two systems of blood circulation throughout the animal world. These are **open** and **closed blood circulatory systems.**

## Open blood circulatory system.

This is found in most invertebrates. The heart which is dorsally placed is tubular in structure.

This tubular heart extends most of the body's length and ends up in a single **dorsal blood vessel** called **aorta**. The heart is provided with paired holes called ostia. The heart pumps blood forward through the single dorsal blood vessel (aorta) into the **haemocoel** (body cavity). Blood is collected from the haemocoel through the paired ostia and returned to the heart.

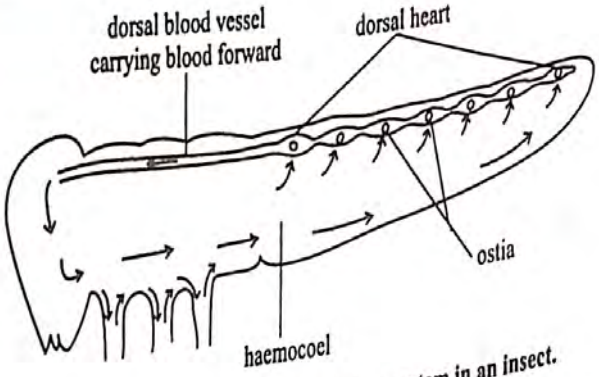



**Figure 7.11. Open blood circulatory system in an insect. (arrows indicate the direction of blood flow).**

## Closed blood circulatory system:

In this system, blood leaves the heart in **closed pipes** (blood vessels and capillaries) and circulates round the body and returns to the heart (a closed pumping organ) without being exposed. This is the system in the earthworms and the vertebrates. A **closed system** is more efficient and better for a large and complex body. The blood is always on the move and moves rapidly through the various vessels all the time. It only requires the assistance of a **lymphatic** system for a more effective exchange of materials between the cells and the body fluid. In the lymphatic system, fluid flow is slow but bathes the cells directly with nutritive fluid. A closed system is better for very active animals as a complete circulation of blood occurs in a short time. Fishes, amphibians (toads and frogs), reptiles (e.g lizards, snakes, tortoises, crocodiles) birds and mammals (e.g goats, dogs, cats, cows and human beings) are organism with closed circulatory system.

## Lymphatic system

The part of plasma which filters into the spaces among the tissues and flows in vessels similar to arteries and veins constitute the **lymphatic** system.

The lymph is clear colourless tissue fluid. The vessels that convey lymph are called **lymphatic vessels.** Lymph is very much like the plasma of the blood but it lacks the plasma **protein** whose molecules are too large to pass through the capillary walls. The **lymph** is different from the blood by the **absence of the red blood cells** that are also too large and are not amoeboid to be able to squeeze themselves through the capillary walls. **The lymph is fluid plasma with dissolved mineral salts, nutrients and white blood cells.** The lymph can also coagulate but very slowly. The vessels in which the lymph flows are called lymphatic vessels. The lymphatic vessels also divided and subdivided to form lymphatic capillaries like those of the blood vessels. The lymph is rich in oxygen, nutrients and other useful substances. It fills all the spaces between the cells as tissue fluid. When cells have removed all the oxygen and food substances and discharge carbon (IV) oxide and nirogenous waste into it, it now moves toward the heart through lymphatic capillaries to the major lymphatic vessels.

The lymphtic vessels contain valves like those of the blood vessels. The lymphatic vessels have some swellings along their courses which are called **lymph nodes** or **lymph glands.** They produce lymphocytes (white blood cells) which are phagocytes. During infection, lymph nodes filter out bacteria from tissue fluid and pass them on to the lymphocytes which engulf and digest them. The lymph which contains plasam plus waste, lymphocytes and fats picked up from the villi of the small intestine flows into the large lymphatic vessels towards the heart. The lymph flows very slowly and is assisted by muscular contraction and the valves which prevent backward flow. These major lymphatic vessels empty into the **left** and **right subclavian veins** which finally take blood into the right atrium.

## Return of lymph to the blood circulation

The lymph of the head, neck and right arm drain into a large vessel called **right lymphatic duct** which opens into a large blood called right **subclavian vein.** The lymph from the right lymphatic duct is therefore emptied into right **subclavian vein.** The lymphatic vessels (lymphatics) from other parts of the body empty their lymph into the **thoracic duct**. The thoracic duct in turn empties its lymph into the left subclavian.

The right and left subclavian veins return blood to the right atrium.

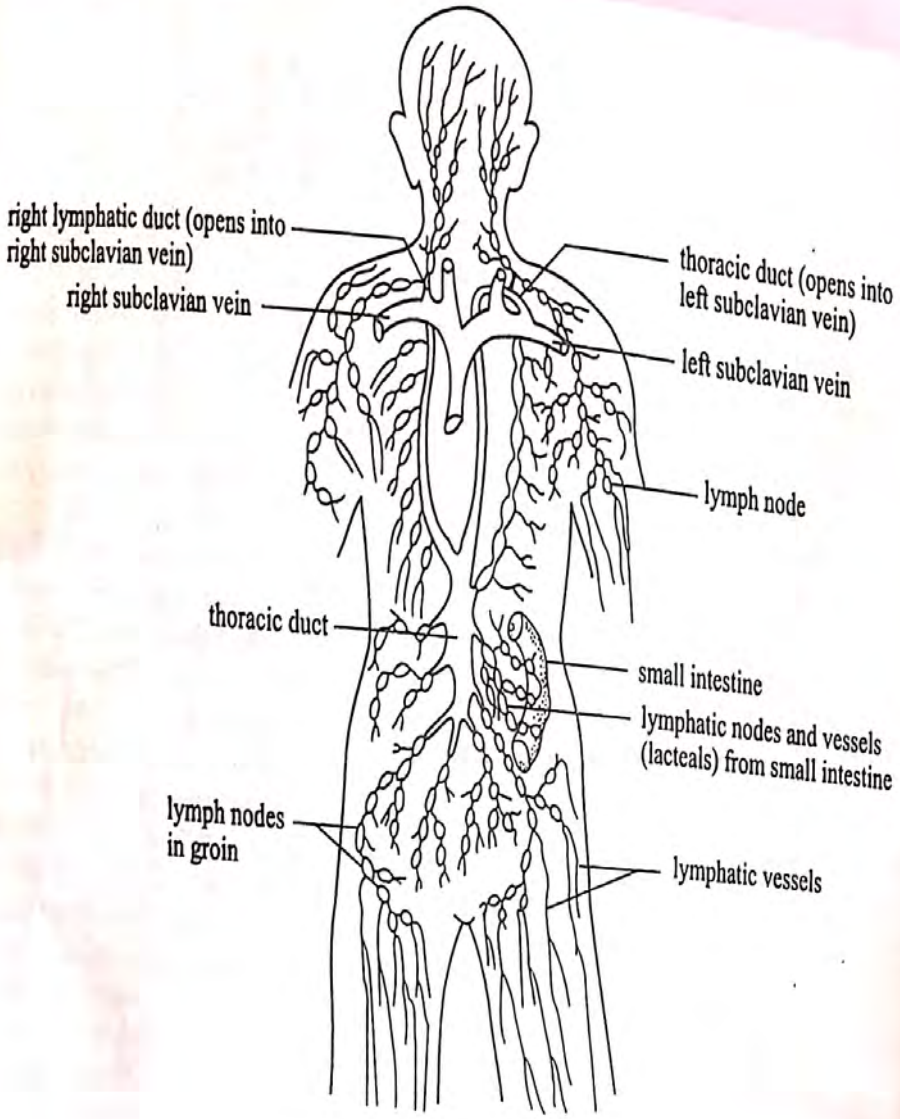



**Figure 7.12. Lymphatic system in man.**

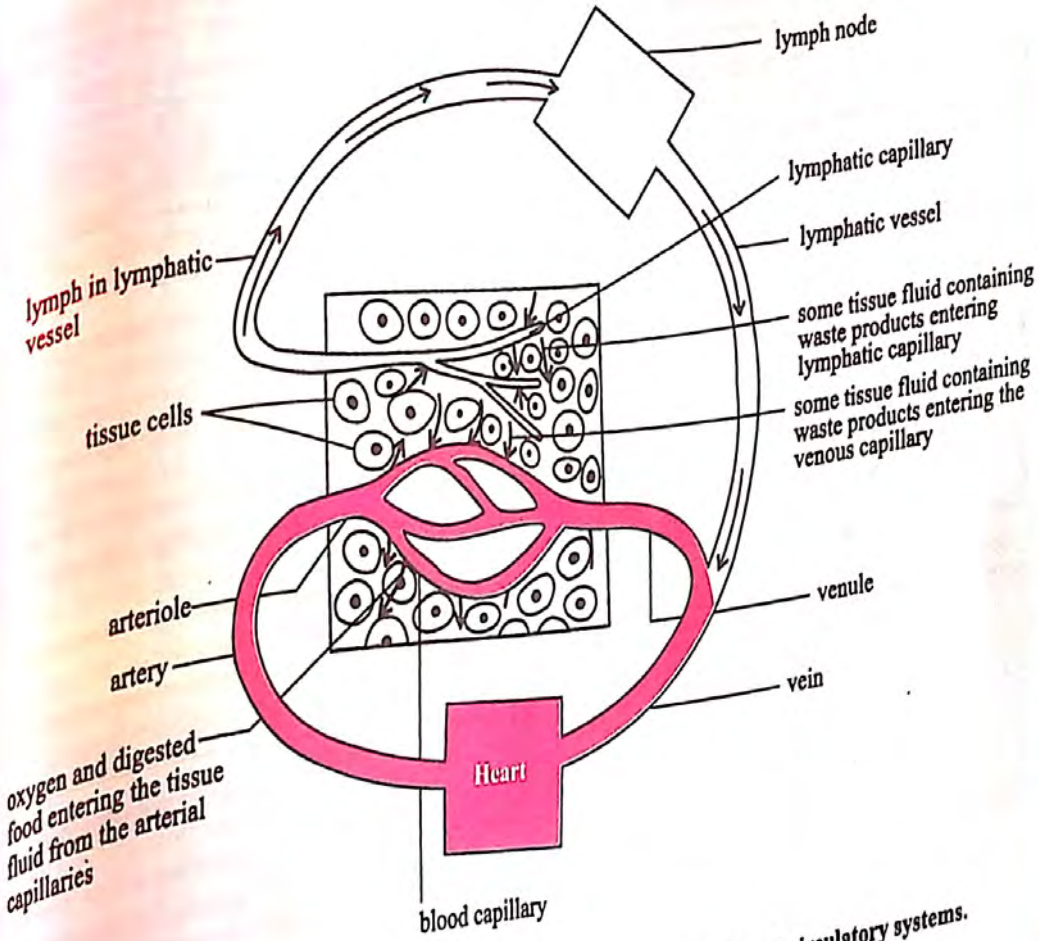



**Figure 7.13. Diagramatic relationship between the lymphatic and the blood circulatory systems.**

## Functions of the lymphatic system

1.The lymphatic system collects the fluid which has diffused out from blood capillaries and returns it to the blood stream.

2.It removes excretory products from the cells. If the lymph vessels are unable to drain the body fluid efficiently, water is retained in the body causing swelling of the body (**dropsy**). Standing on one spot for a long time without movement may result in swollen ankles due to collection of lymph.

3.It removes foreign bodies from the cells.

4.It collects fatty acids from the lacteals in the villi of the small intestine and passes them into the blood.

5.It produces white blood cells which help to fight pathogenic organisms invading the body.

6.The lymph glands filter out bacteria from body fluid thereby stopping the spread of such infection.

**Table 32: 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 transports oxygen. |
| 4. Lymph flow is assisted by muscular activities. | Blood flow is facilitated by pressure from heart beat. |
| 5. Collects tissue fluid and returns it into the blood stream. | Circulates blood round the body and back to the heart. |

**Table 33: Differences between blood plasma, tissue fluid and lymph.**

| | Blood plasma | Tissue fluid | Lymph |
|---|---|---|---|
| 1. | Contain blood proteins (e.g. albumen) | Does not contain blood proteins | Contain some proteins |
| 2. | Contain far drops | Does not contain far droplets | Contains far droplets. |

## Tissue fluid

Tissue fluid is produced at the arterial end of the capillaries. The high blood of the artery forces fluid out of thin walls of the capillaries into the spaces between the tissue cells is known as **tissue fluid**.

This issue fluid contains glucose, amino acids, oxygen and waste products but no fat droplets and protein molecules. Since their molecules are too large to pass through the thin capillary walls. The tissue cells absorb oxygen, glucose and amino acids by diffusion and use them for metabolic activities. Waste products resulting from metabolic activities are passed into the tissue fluid

At the venous and of the capillaries, some fluid containing carbon (IV) oxide and waste products enter the venous capillaries and are taken into the main blood stream.

The **remaining fluid** filters into lymph capillaries to become **lymph**.

## Pulse

The heart contracts to pump blood into arteries for circulation to all parts of the body. The force with which the blood is pushed into arteries causes the arteries to expand in order to accommodate the volume of the blood rushing through. This expansion of the arteries is called the **pulse**. The pulse can be felt by feeling the artery over a bone in the wrist. The pulse corresponds with the contraction of the heart. The pulse is felt in succesions and the rate at which one follows the other is measured and expressed as pulse rate. Pulse rate can be normal, rapid or slow. Pulse rate varies among individuals of different ages, sizes of the body and state of health.

## Different pulse rates

### Fast pulse rate

A very rapid pulse rate may be caused by:

1. Fear
2. Rigorous muscular activities.
3. Fever.
4. Heart disease.

5. Over secretion from the thyroid gland.
6. Over weight in very fat individuals.

## Low pulse rate.

## A very low pulse rate may be caused by:

Heart disease.
Injuries or diseases of the brain.
Old age

## Blood pressure

The heart contracts to force blood into the arteries. The force is considerably high enough to make the walls of the arteries fully stretched all the time. This force exerted by the blood against the arterial wall is called **blood pressure.** The resistance put on by the arterial walls by exerting a similar pressure on the blood propels the blood forwards towards the capillaries. The pressure however gets reduced proportionately with distance from the heart and so considerably less or low in the venules and veins.

Blood pressure is maintained by the force of the heart's contraction and the elasticity of the arterial walls. It is this pressure that makes blood to flow in jets or spurts when an artery is cut in a wound. The diminished pressure in the capillaries and veins makes blood to ooze or flow gently when a vein is cut in a wound.

## High blood pressure

Blood pressure is measured by an instrument called **sphygmomanometer.** Average values have been worked out by medical scientists. A persistent deviation from the average value to the high side is diagnosed as high blood pressure, popularly called high BP.

### Causes

1. Diseases of the kidneys
2. Nervous trouble. and
3. Disease of the walls of the blood vessels

## Anaemia

Anaemia is not shortage of blood or lack of blood as it is commonly believed. It is the shortage of red blood cells or in some forms lack of haemoglobin in the red blood cells so that the red blood cells are not able to carry sufficient oxygen to the cells for respiration.

### Causes

1. Severe bleeding leading to loss of large volume of blood (involving numerous red blood cells).
2. Infection by malaria parasites *(Plasmodium)* blood fluke *(Schistosoma)* and *Trypanosoma* resulting in the attacking and destroying of large number of red blood cells.
3. Malnutrition - low intake of food containing essential nutrients such as iron and proteins leading to poor quality of protoplasm and haemoglobin.
4. Injuries or damages done to the bone marrow where red blood cells are manufactured reduce the number of the red blood cells in the blood.

### Remedies

1. Give balanced diet which will supply enough proteins for normal growth and iron for the formation of haemoglobin.
2. Include green leafy vegetables in most meals.
3. Give a lot of fruit juices which supply mineral salts and vitamins for healthy growth and rich blood.
4. Treat all diseases causing loss of blood.

## First aid in haemorhage (bleeding)

**Haemorhage (bleeding)** is the coming out of blood from the blood vessels which have been damaged.

When the loss of blood is to the outside, it is called **external haemorhage** and when it is to the tissues, it is called **internal haemorhage (internal bleeding).**

First aid to a patient of internal bleeding is not advisable. The suspected patient should be rushed to a nearby hospital when where he/she will be treated by a medical doctor.

### Mouth bleeding

1. The mouth should be rinsed with cold water many times.
2. Put ice block if available into the mouth and let it remain there for sometime to reduce bleeding.

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## First aid for bleeding limbs

1. Let the patient lie down or sit and raise the bleeding limb above the heart so that less blood flows to the wounded area thereby reducing loss of blood and promoting clotting except in case of a fractured limb.
2. **Direct pressure**
   (a) If the wound is small, use finger to apply **direct pressure** on the surface of the wound area.
   (b) If the wound is large and bleeding is serious, you may have to use your bare hand to apply pressure evenly on the wound area for someone to bring dressing materials. Pressure squeezes the damaged blood vessels closer together and promotes clotting of blood to prevent more loss of blood. If the pressure is not evenly applied, the unpressed area may continue to bleed.
3. Clean the surrounding skin (not the wound itself) with iodine or methylated spirit or hydrogen peroxide.
4. Cover the bleeding spot with clean soft material (e.g. handkerchief, shirt, sanitary napkin) or wool and apply pressure until the bleeding has stopped or slowed to the point that a bandage can be applied. (Don=t be in hurry to stop the pressure).
   The cleaner the soft material the better in preventing disease infection.
5. Apply the bandage firmly over the pad and continue the pressure. *(Note:* The bandage must be checked after the knot has been tied to be sure that it is not too tight to stop blood circulation to the area).
6. **Pressure points**:- A pressure point is a point where an artery is pressed against a bone externally to stop bleeding. For example, to stop bleeding from the elbow or fore-arm, the brachial artery is pressed against the humerus.
   To stop bleeding from the thigh, knee or foot, press femoral artery against the femur (thigh bone).
7. **Application of tourniquet**: Refer to chapter 3 (First Aid).

### Nose bleeding

When there is bleeding from the nose (nostril), the following steps are to be followed:-

1. Let the victim sit on a comfortable place such as chair.
2. Let him receive fresh air.
3. The victim's head should be bent backwards slightly so as to reduce or prevent further loss of blood.
4. The victim should be encouraged to breathe through the mouth and not through the nose to reduce or prevent loss of blood and also to promote clotting. The nose is pinched for 10 minutes.
5. Use cotton wool or tissue paper to remove blood from the nostrils and push in some of the cotton wool or tissue paper into the nostrils to absorb blood. The blood soaked cotton wool is removed at interval and new cotton wool is pushed in until bleeding stops.
6. The nose must not be blown, as doing so will promote bleeding.
7. Apply pressure point. Press the carotid artery against the jaw bone to reduce bleeding.
8. Send the victim to hospital for medical treatment.

**Table 34: Bleeding parts and pressure points.**

| Bleeding parts | Pressure points |
|---|---|
| 1. Back part pf tje scalp or head. | Occipital artery against the skull at the back of the head. |
| 2. Middle or front part of scalp. | Temporal artery against the skull near the ear. |
| 3. The cheek, mouth or nose regions. | Facial artery against the low jaw. |
| 4. Shoulder and armpit. | Subclavian artery against the first rib. |
| 5. Elbow and forearm. | Branchial artery against the humerus. |
| 6. The hand. | Radial and ulnar arteries against radius and ulna. |
| 7. The thigh, knee or leg. | Femural artery against the hip bone and femur. |

## The lower plants

All the plants from the single-celled *Chlamydomonas,* bacterium, *Phacus* to the simple muticellular *Spirogyra, Funaria* (Bryophyta) that lack conducting vessels use their cytoplasm for the movement and distribution of materials. Most of these lower plants live in water, moist places and the shade of larger higher plants. There is water to hydrate their cytoplasm if not completely surrounded by it. Digested food, dissolved gases and manufactured food are moved around the cell and from cell to cell by the streaming of cytoplasm. **Carbon (IV) oxide diffuses out of the cells as the cytoplasm streams around.** Other metabolic wastes diffuse out or diffuse into cell wall where they are converted into insoluble forms, stored and kept away from contact with cytoplasm.

Reserved carbohydrate in the form of simple sugar gets moved in similar manner to the pyrenoids where it is stored in the form of starch.

## Transportation in the vascular plants

Some vascular plants are the ferns (Pteridophyta) pinus (Gymnospermae) sunflower and maize (Angiospermae). These plants develop channels through which water flows in their body. The materials for transportation (gases, soil water, solutes, manufactured food, hormones and metabolic wastes) are carried in water that flows in these channels. The structures that serve as transport channels are called **vascular bundles** (tissues) comparable to the blood vessels and lymphatic vessels of animals.

The **Vascular bundles** are the **conducting elements** of the plants. Each vascular bundle consists of the **phloem** on the outside and the **xylem** inside.

The phloem is a complex tissue made up of **sieve tube cells, phloem parenchyma** and **phloem fibres.** Of these four types of phloem cells only the **sieve tube cells** translocate **manufactured food** from the **leaves** down to all living cells and storage organs of the plant.

The **xylem** is also a complex tissue made up of **vessels, xylem, tracheids, wood parenchyma** and **wood fibres.** Of these four types of xylem cells only the **xylem vessels** and **tracheids** are responsible for the upward conduction of soil solution containing dissolved mineral substances from the roots to the leaves.

## Mechanism of transportation of water in higher plants (root pressure)

The soil water which has entered the cell sap of the root hairs through osmosis and by capillarity passes to the cortical cells of the root. From the cortical cells, the soil water enters the endodermis then to the pericycle and finally to the xylem vessels of the root. From the xylem vessels of the root, the soil water is passed to the xylem of the stem under root pressure.

## Experiment to demonstrate root pres-sure in a young potted plant

Method:

The shoot of a young potted plant is cut off sharply a few centimetres above the level of soil thus leaving a stump. Within a short time water (xylem sap) exudes from the cut end of the stump. A glass tube is fixed tightly to the stump with a short rubber band. Water is introduced into the glass tube with a pipette to level marked "A".

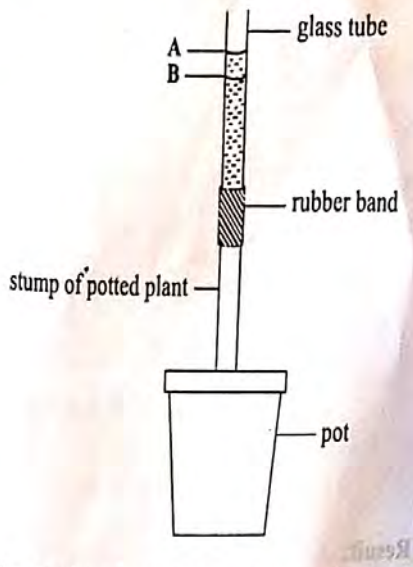



**Figure 7.14. To demonstrate root pressure in a potted plant.**

**Result**: After a short time water is seen rising from **A** to **B** in the glass tube due to root pressure. The force responsible for pushing the sap up the tube is called **root pressure**. The pushing effect of root pressure is sufficiently strong to account for ascent of water in low growing plants. The root pressure is not enough to raise water up to heights of trees over 34 metres tall.

## TRANSPIRATION

**Transpiration** is the loss of water vapour from different parts of the plant shoot. These parts include the **stomata** of leaves, the **cuticle** of both leaves and young stems, and the lenticels on tree trunks. Transpiration is described according to the venue through which the water vapour is lost. Hence water loss through the stomata is called **stomatal transpiration.** Water loss through the cuticle and lenticels are called **cuticular** and **lenticular transpiration,** respectively.

The greatest amount of transpiration occurs through the stomata. The water that is lost through the leaves is originally absorbed by the root hairs from the soil into the root cortex. The water is passed into the **root xylem** from where it is translocated to the **stem xylem,** to the veins and mesophylls of the leaf and finally to the stomatal surfaces from where the water evaporates into the atmosphere. This unbroken chain of water existing between the **soil** and the leaves constitutes the **transpiration stream.**

### Experiment to demonstrate transpira-tion in a young shoot

**Aim:** To show that a potted plant loses water vapour from its leaves.

**Method:** A rubber sheet is used to cover the pot and part of the stem of the potted plant. This prevents water evaporating from the soil and the stem. The potted plant is placed on a vaselined glass plate. The potted plant is then covered with a dried bell jar 'A' and placed on a sunny place. The **control experiment** B is set in the same manner but with the leaves of the potted plant removed.

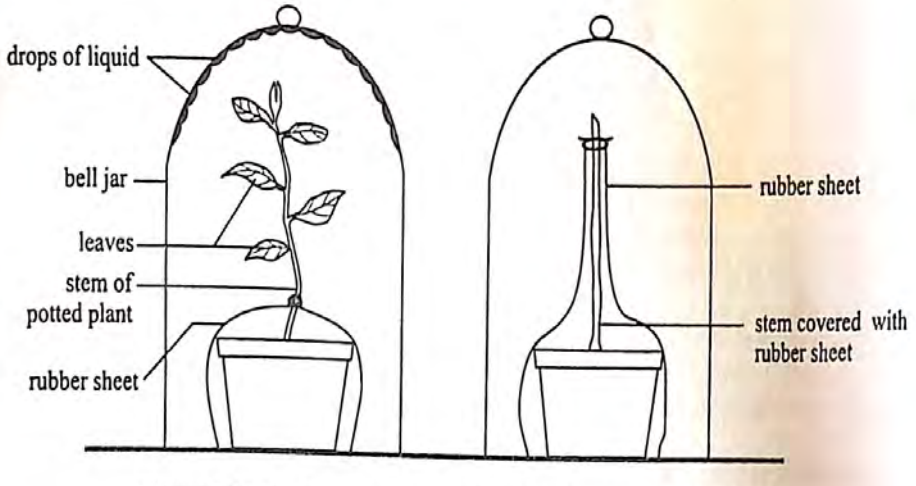



**Figure 7.15. To demonstrate transpiration in young potted shoot.**

**Result:** After two hours, drops of colourless liquid collect on the inside of the bell jar **A**. No such drops of colourless liquid collect on the inside of the bell jar **B**.

**Conclusion:** Since the pot and soil are covered, the presence of water in the experiment shows that plant loses water through the leaves. Since the bell jar was not in contact with leaves, the loss of water is by vapour.

**Precaution:** It is important to invert the bell-jar over a flat vaselined glass-sheet on which the potted plant is placed. This is to prevent the leakage of air into and out of the bell-jar as this is likely to lead to loss of vapour from the bell-jar into the atmosphere. Air contains some amount of water vapour which can, also leak into the apparatus if unprevented.

## Forces of transpiration

The role of the root hairs in the absorption of water and mineral salts has earlier been discussed. The continuous absorption of water from the soil into the plant is believed to be under the influence of two main forces. These are the **root pressure** which is known to be most active at night or the **suction pressure** set up on the leaves during the day in the presence of light.

## Suction pressure on the leaves

It has earlier been mentioned that the root pressure is most active under conditions of **high humidity** and **low temperature** and cannot account for the rise of water to the top of very tall trees. It has also been established that there is an unbroken column of water existing between the water in the soil and the water in the leaves (**the transpiration stream**). As water evaporates through the stomata, the cells of the spongy tissue become more concentrated in **sap** than the cells of the **inner tissues**. A **suction pressure** is set up which draws up water from the cells of the inner tissues into the intercellular spaces. Water absorption is by osmosis. After losing water to the outer cells, the inner cells become concentrated and draw up water from the veins of the leaves. Water drawn from the veins is replaced by water in the xylem vessels of the stem and branches. The whole process sets up a tension which is transmitted to the root system, causing more water to be absorbed from the soil.

The xylem vessels are **capillary tubes** and the water moving up through them moves with a **capillary force** which ensures that the water column remains unbroken. It has been accepted that the actual force which causes the rise of water from the soil to the top of very tall trees is generated on the leaves as a result of the continuous evaporation of water through the stomata during the day in the presence of light. This force is called the **Atranspiration pull@**.

## Experiment to demonstrate the pathway of water to the leaves

**Aim:** To show the path through which water passes up the stem to the leaves of a flowering plant.

**Method:** A young sunflower plant is carefully dug to avoid damage to the roots. The soil is rinsed from roots with water. The roots are placed in a beaker of water coloured with eosin or **red ink**. The experiment is left for about 3 - 48 hours. When red colour appears in the veins of the leaves, a thin section of the stem is cut above the solution level, and examined under the microscope or hand lens.

**Results:** The colour was found to concentrate inside xylem. The red colour was not found in the phloem or other parts of the stem.

**Conclusion:** Water passes up through the xylem of the stem only.

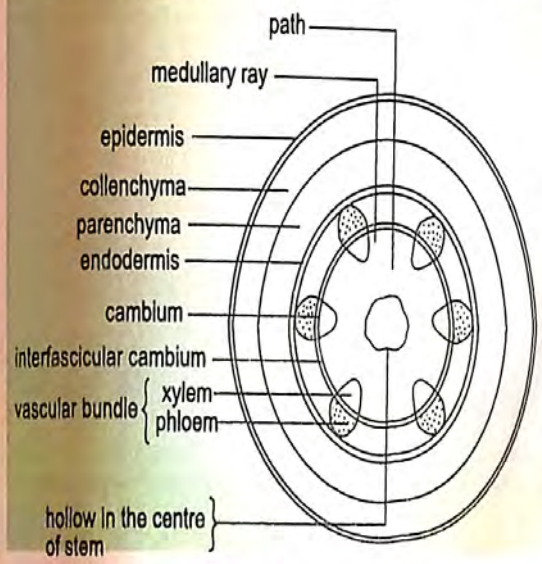



Figure 7.16. A section of the stem to show that water passes upward through the xylem.

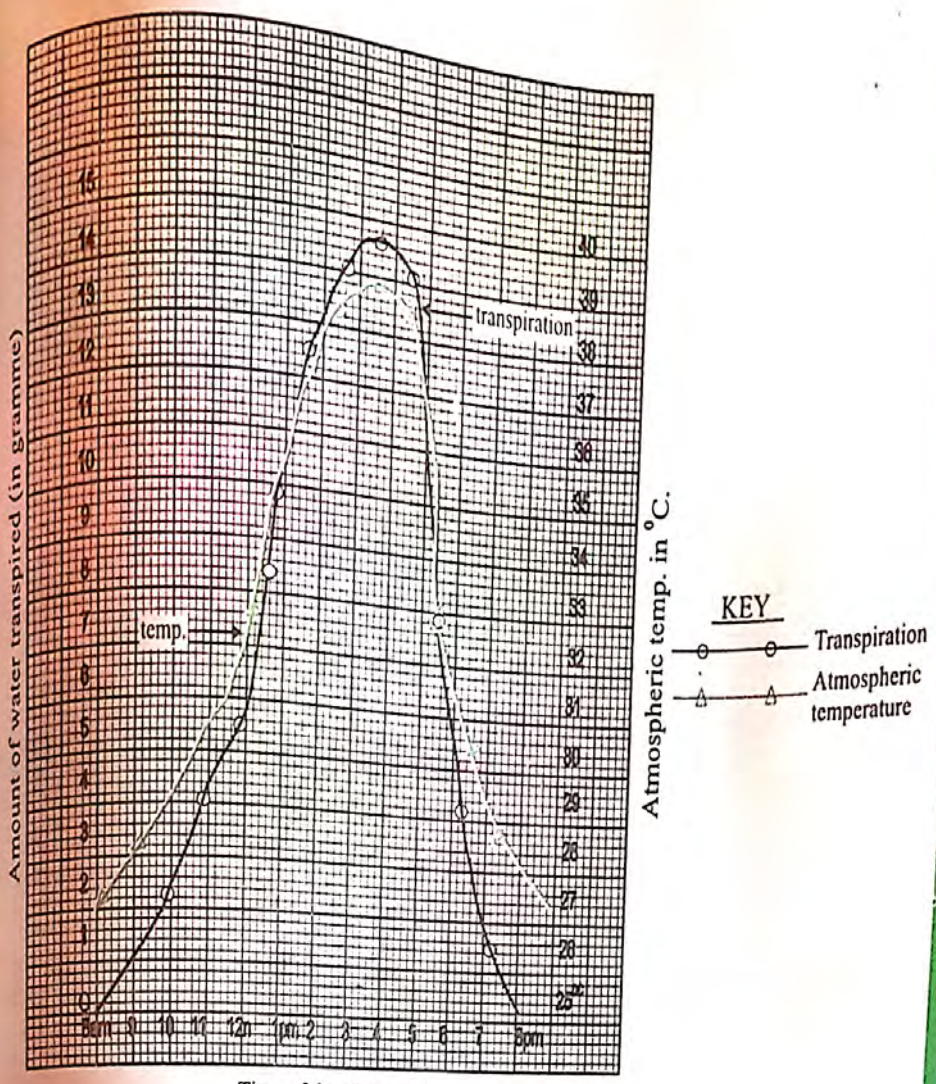



**Figure 7.18. A graph showing transpiration and temperature curves on a sunny day.**

The graph in figure 7.18. indicates that:

1. The rate of transpiration increases as the atmospheric temperature increases.
2. The rate of transpiration is highest in the afternoon of a sunny day between 2 and 4pm.
3. Transpiration begins at a lower rate in the mornings becoming faster as the temperature increases and after reaching a peak in the afternoon it becomes lower in the evenings and is likely to cease at night after 8pm.

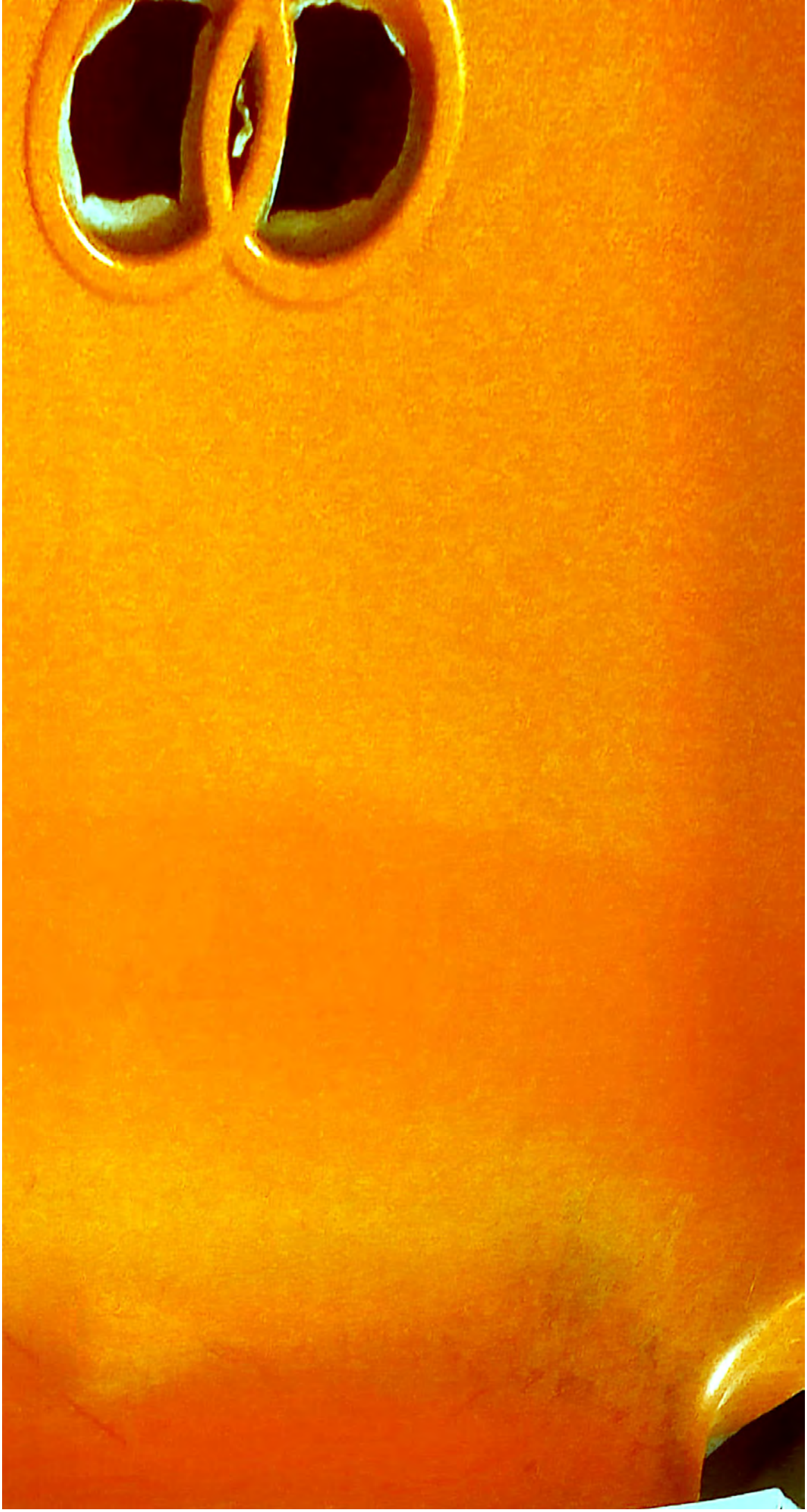
## The potometer method

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. It can be used in the laboratory where the condition is humid. It can be placed under fan to determine the effect of wind, or used in an open ground where there is bright sunlight.

The setting up of a potometer (Figure 7.19) is done with some degree of **precautions**.

1. The shoot to be used is cut **under water** to prevent the **entry of air** which will likely block up the xylem vessels in the stem and disturb the movement of water through them.
2. The whole apparatus is carefully filled with water. There should be no air space in it.
3. When the shoot is quickly introduced through the rubber cork, it is immediately greased with vaseline to keep the apparatus air-tight.

With all these precautions taken, transpiration occurs and as water is being lost an equivalent amount of water is absorbed into the shoot.



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## Measurements of transpiration

There are various ways by which the rate of transpiration can be measured.

1. By the weighing method
2. By the use of a potometer
3. By the use of cobalt chloride paper

Which-ever method is used, the rate of transpiration depends on a number of factors which will be discussed later in this chapter.

## The weighing method

This is about the most reliable method of measuring the rate of transpiration. It involves the use of an **intact living potted plant.** The plant is well watered in the morning. The body of the pot together with the soil surface is covered with an aluminum foil to prevent the evaporation of water from the soil. This is an important precaution. The initial weight of the potted plant is taken with a sensitive balance at about 8.00am. The pot is kept in an open place where the plant can receive maximum sunlight. Weighing is repeated at one hour interval until about 7.00pm. It may be necessary to record the atmospheric temperature at each time of weighing and relate it to the amount of water loss.

The amount of water transpired at the various time intervals is calculated from the differences in weights. The results of an experiment carried out in Benin City on a sunny day in April, 1979 are expressed in table and in fig. 7.18 (graph).

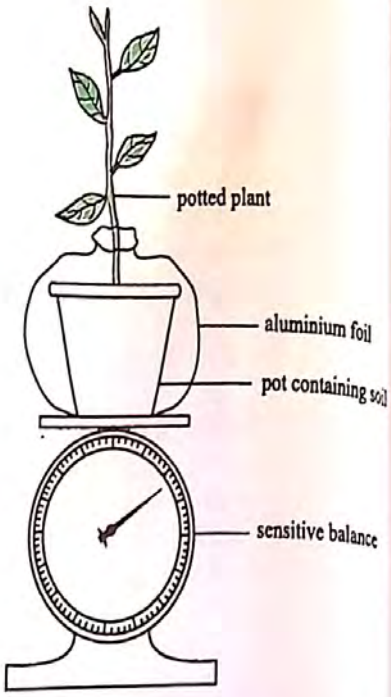
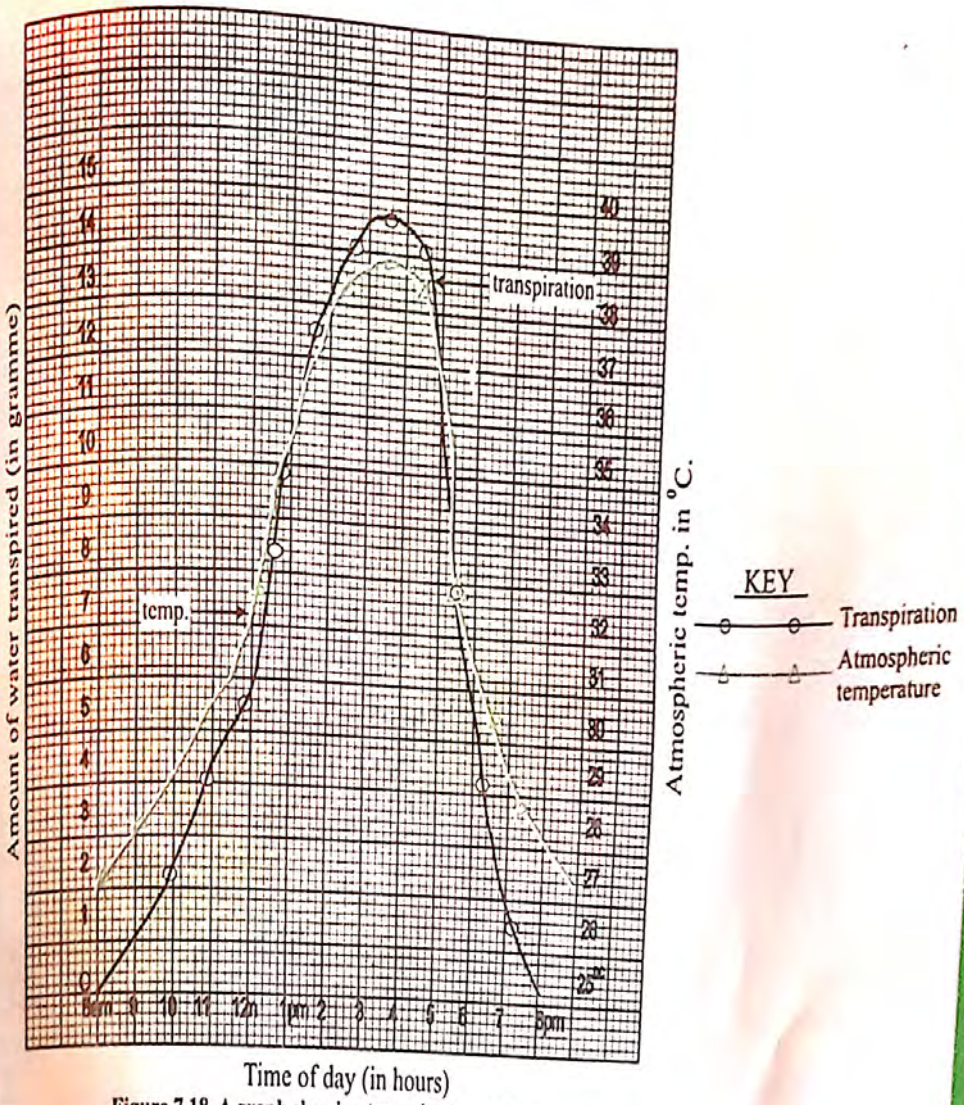



**Figure 7.17. Transpiration by weighing method**

**Table 35:** **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 gramme) |
|---|---|---|---|
| 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 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 |

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The setting up of a potometer (Figure 7.19) is done with some degree of **precautions**.

1. The shoot to be used is cut **under water** to prevent the **entry of air** which will likely block up the xylem vessels in the stem and disturb the movement of water through them.
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3. When the shoot is quickly introduced through the rubber cork, it is immediately greased with vaseline to keep the apparatus air-tight.

With all these precautions taken, transpiration occurs and as water is being lost an equivalent amount of water is absorbed into the shoot.

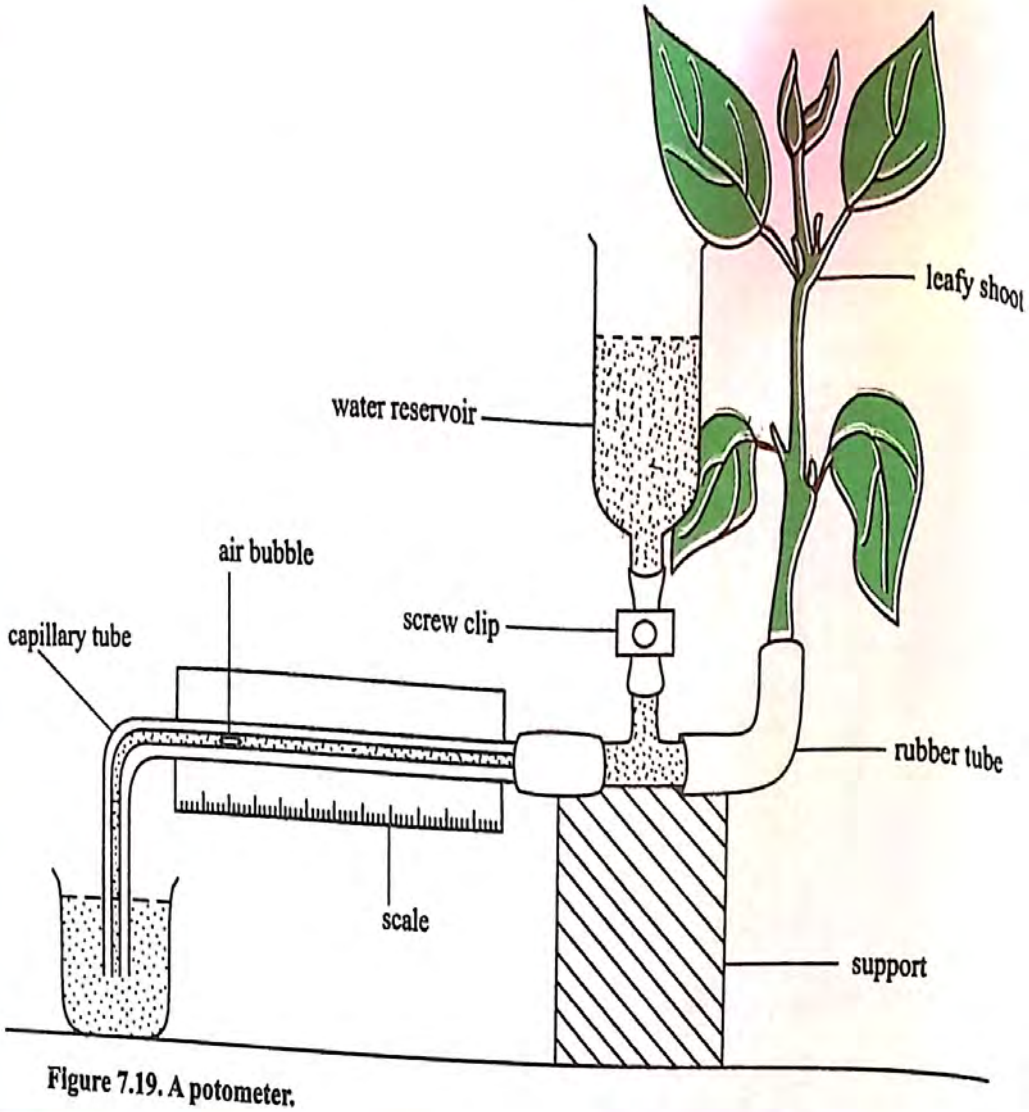



**Figure 7.19. A potometer.**

The rate of water absorption into the shoot can be measured as the **water meniscus** moves through the graduated capillary tube. The average distance covered per minute can be measured with a stop clock. If the diameter of the capillary tube is known, the volume of water absorbed per minute or hour over a given distance can be calculated. The **meniscus** can be driven back to the zero mark by opening the reservoir tap for repeat recordings.

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.

## The cobalt chloride paper method

This 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 time it takes the dry blue paper to change to pink when brought in contact with a transpiring leaf. This method does not however give a very accurate result, as two individuals may disagree on the exact time the pink colour is obtained. To minimise the errors in judgement, the cobalt chloride paper is sand-wiched between standard blue and pink papers (Figure 7.20). The cobalt chloride paper when dry has the same colour with the standard blue paper. They are fastened to the surface of a transpiring leaf with a cellotape and the time taken to change to exact colour of the standard pink paper is noted.

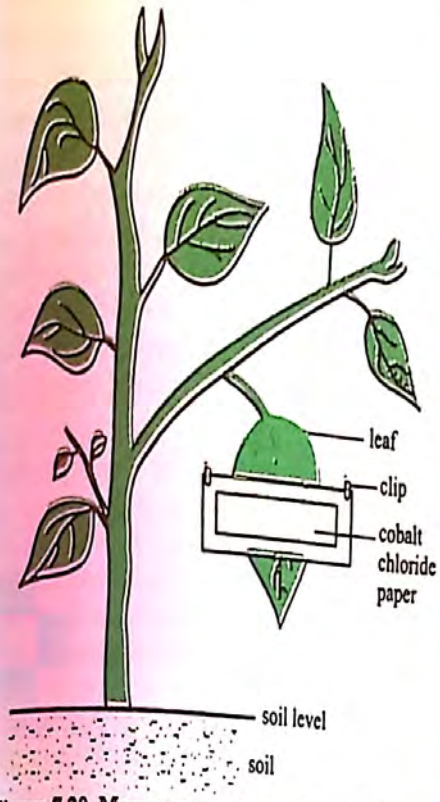



**Figure 7.20. Measurement of transpiration with cobalt chloride paper.**

The change in colour is brought about by the **condensation** of the water which would have been lost into the atmosphere either through the stomata or through the leaf cuticle as vapour. The water vapour on condensing, wets the cobalt chloride paper.

## Factors affecting the rate of transpiration

There are three groups of factors which affect the rate of transpiration. These are:
Plant factors
Atmospheric factors
Soil factors.

## PLANT FACTORS

(a) Leaf area: Experiments on transpiration have shown that the larger the leaf area, the greater the amount of water loss. This is because larger leaf areas occupy greater number of stomata through which water is lost. Using two plants of the same species, the one with greater number of leaves of approximately the same size will have more water transpired, than the other with reduced number of leaves. In determining the rate of transpiration of any plant, it is important to note the total leaf area. The rate of transpiration is therefore the amount of water loss per unit area of leaf per unit time. For example, the rate of transpiration of maize can be expressed as X gramme of water per $cm^2$ per hour.

(b) **Leaf structure:** The leaves of certain plants are specially adapted to live under dry habitats. These plants are known as **xerophytes**. Generally they posses **thick cuticles, thick cells walls, compact mesophylls** and **sunken** (or hidden) stomata. Sometimes the leaves possess a covering of dead epidermal hairs. Plants like the **whistling pines** have their leaves reduced to very tiny needle-like structure while in **cactus** there are no leaves at all. These are various adaptations of the plants to maintain a low rate of transpiration as excessive loss of water will lead to the death of the plant.

(c) **Root system:** The major function of the root is for the absorption of water and mineral salts. The degree of water absorption depends largely on the extent of the roots, the number of root hairs, the osmotic value of the cell sap and the permeability of the cell membranes. There is a very close relationship between the rate of water absorption and transpiration. Under all other conditions which favour transpiration, the rate of transpiration increases as the rate of water absorption becomes increased. But whereas both events occur during the day, transpiration stops at night when the stomata are closed, water absorption continues at night, although at a much reduced rate.

## Atmosphere factors

(a) **Sunlight:** Sunlight is about the most important factor which influences transpiration. Sunlight is responsible for the opening of stomate. This is why transpiration occurs during the day when the stomata are open and ceases at night when the stomata become closed.(b)

**Humidity:** Generally the higher the relative humidity of the atmosphere the lower the rate of transpiration. This is because at high relative humidity, the atmosphere is getting nearer the point at which it becomes saturated with water vapour. Such a

condition does not favour the evaporation of water. At high relative humidity, the layer of air immediately above the leaf surface is easily saturated with water vapour which evaporates at a very slow rate.

(c) **Temperature:** An increase in temperature increase the rate of transpiration, provided that the increase does not disturb the functioning of the plant. Temperature influences the opening of stomata. Furthermore, an increase in temperature increases the kinetic energy which changes the liquid water to vapour, thus increasing the rate of transpiration. The effect of temperature changes in transpiration is shown in figure 7.18.

(d) **Wind:** Wind has two effects on transpiration. A gentle wind increases the rate of transpiration. Wind helps to sweep away the water vapour over the surface of the leaf thereby preventing the surface from being saturated. The water becomes replaced as fast as it evaporates. However, when the wind is too strong and persistent, like in the harmattan, it not only acts against evaporation of water, it also increases dust particles on the leaves which are likely to block up the stomata and reduce the rate of transpiration.

## Soil factors

(a) **Availability of soil water:** For transpiration to be effective, water must be available in the soil in adequate amount. The soil water must remain at a lower osmotic value than the osmotic values of the cell sap of the plant root hairs.

(b) **Temperature:** The rate of water absorption increases with an increase in the temperature of the soil. Generally at lower temperatures, water becomes more viscous and the cell membranes become less permeable to the water molecules, thus reducing the rate of water absorption. For transpiration to progress, the rate of absorption of soil water must **at least** be equal to the rate of transpiration. If the rate of transpiration by far exceeds the rate of water absorption, the plant will wilt. This is the case when the soil is in short supply of absorbable water or when the osmotic value of soil water is higher than that of the cell sap of the root hairs.

## Importance of transpiration

1. **Cooling effect:** Transpiration involves the evaporation of water which is a cooling process. It is believed that this cooling effect is likely to prevent the plant from overheating on a very hot day.

2. **Translocation of mineral salts:** Water absorption by the plant roots is a passive process which does not involve the use of metabolic energy. Salt absorption is an active process which involves the use of energy and is independent of water absorption. However, once the salt reaches the xylem vessels in the root, it is translocated to the other parts of the plant under the influence of transpiration pull.

3. **Good growth of the plant:** Most plants do not grow well when they are maintained under conditions of high humidity conditions which do not favour transpiration. Often there is a great reduction in the size of the plant. In some cases the buds fail to grow and no flower is produced. It can be argued that under conditions of high humidity, the rates of water absorption and transpiration are greatly reduced and the plant lacks the required amount of water to carry out the vital metabolic processes. Transpiration is a process which ensures the continuous availability of water in the plant body.

## GUTTATION

This is a loss of water in a **liquid form** through the margins of leaves of plants growing in a warm and moist soil in a humid atmosphere. **Guttation** is usually experienced at the early hours of the morning and is common among grasses. Such plants possess specialized ducts at the tip of the veins in the leaves. These specialized ducts are known as **hydathodes**.

A condition in which a plant is growing in a warm and moist soil with a humid atmosphere favours the absorption of water with low rate of transpiration. The rate of water absorption soon exceeds the rate of transpiration and since the excess water must be removed, it is removed not as water vapour through the stomata, but as liquid through the hydathodes.

**Guttation** water may not be pure water. It contains some dissolved organic and inoraganic substances. Palm wine which is tapped from palm trees, is brought to the top of the tree under the influence of guttation initiated by root pressure.

## TRANSLOCATION

Translocation is the transport of manufactured food substances from the leaves to all parts of the plant. The movement is usually described as **downwards** from the leaves to the roots but it is also known to occur on the reverse direction especially in the non-growing season. While the **downward movement** will take food and mineral salts to growing branches, root tips and storage organs such as roots and stem tubers, corms, bulbs and rhizomes, upwards and side ways movements of manufactured food substances are necessary to serve the growing shoot tips, flowers and storage organs such as seeds and fruits. Photosynthesis takes place in the leaves and the manufactured food substances such as **sucrose** is traced to the **sieve tubes** of the **phloem tissue** in the veins of the leaves and stems of plants.

### Substances translocated in plants

Substances translocated in plants are sugar, fatty acids, amino acids, oil, hormones (auxins) and alkaloids (steroids).

### Experiment to show that translo-cation takes place through the phloem.

### Ringing or girdling experiment

**Aim:** To demonstrate evidence of translocation of manufactured food substances from the leaves to other parts of the plant through the phloem.

**Method:** A medium sized, healthy growing young plant such as *Delonix regia,* **mango, orange,** etc. is selected on the school compound or garden. Rings of bark including **phloem tissues** are removed from the stem at a point far above the ground level and below the first branches and leaves. A control experiment in which the ringing allows some leaves below is made.

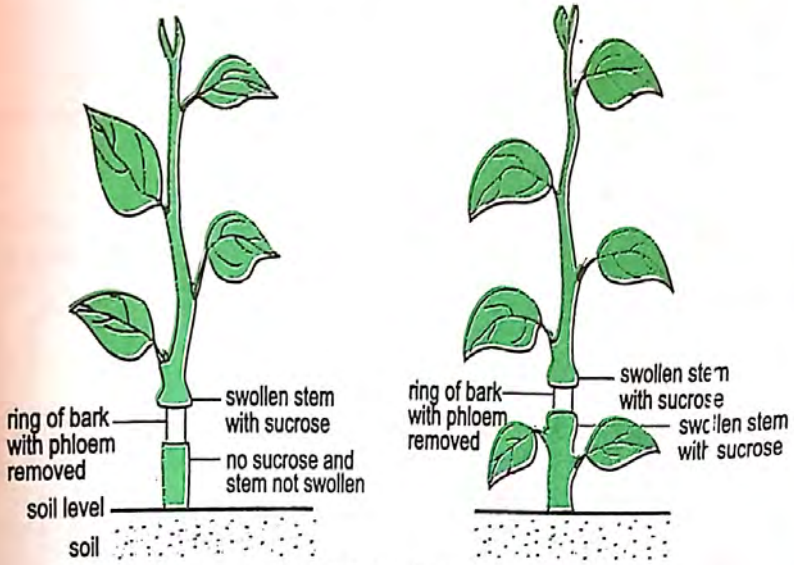



**Figure 7.21. A ringing experiment.**

**Result:** After two weeks, the portion of the stem above the ringed region becomes swollen. On testing the plant juice above and below the ringed ar-eas for sucrose (using dilute hydrochloric acid and later Fehlings solutions **A** and **B**), it is found that the juice above the ringed area contains sucrose while the juice below ringed area contains no sucrose.

In the **control** in which some leaves are left below the ring, sucrose is found above and below the ringed areas.

**Conclusion:** Manufactured food substances in the leaves are translocated through the **phloem** to all parts of the plant.

## Similarities and differences between transport in vascular plants and vertebrates.

### Similarities

1. Both transport materials in tubular vessels.
2. Both transport in liquid medium.
3. Food and hormones are transported in dissolved form.
4. Both transport some materials by diffusion.

**Table 36: Differences between transport in vascular plants and vertebrates.**

| Flowering Plants | Vertebrates |
|---|---|
| 1. Cell sap is the medium of transportation. | Blood is the medium of transportation. |
| 2. Water p lus dissolved mineral salts and manufactured food are transported through different vessels (phloem and xylem). | Water and dissolved mineral salts and food are transported through the same vessels (veins and arteries). |
| 3. Transpiration pull or root pressure produces force for transportation of materials. | Heart produces force for transport of materials. |

### *Questions*

1. (a) List the constituents of the blood of a mammal and state the functions of each of them.
   (b) Make a large labelled drawing to show the structure of the heart of a mammal and describe its method of working.

2. Mention the changes that take place in the composition of blood as it starts its journey from The right atrium to the lungs, small intestines, kidneys and liver and back to its starting point (right atrium).

3. (a) State: (i) three similarities (ii) three differences in the function of the lymphatic system and the blood circulatory system in mammals.
   (b) (i) Describe briefly the process of blood clotting in mammals. (ii) What is the importance of blood clotting to mammals?.

4. (a) List three ways why you consider transport system to be important in complex plants and animals.
   (b) Name four media of transportation in living organisms.
   (c) State why the pulmonary circulation is important to mammals.

5. (a) *Briefly describe with examples the terms open and closed circulatory system in animals.*
(b) *List three similarities and two differences between transport in flowering plants and vertebrates.*
(c) *State four functions of the lymphatic system in vertebrates.*

6. *Discuss the importance of transport system in lives of the vertebrates.*

7. *Write short descriptive notes on each of the following structures:*
   (i) Collenchyma
   (ii) Sclerenchyma
   (iii) Tracheids
   (iv) Xylem vessels
   (v) Sieve tubes of phloem

8. *The cut end of a herbaceous stem was placed in a solution of eosin. A short time later, a cross section of the upper part of the stem showed distinct red areas.*
   (a) Name the tissue which could have been stained.
   (b) Briefly describe what had happened to cause this staining. (WASC)

9. Explain the term transpiration.
   (a) Describe exactly how you would show that a living plant loses water vapour from its leaves.
   (b) What are the factors that can affect the rate at which a plant lose water?

10. (a) In a tabular form distinguish between transpiration and excretion.
   (b) Describe an experiment to demonstrate root pressure in a young potted plant.
   (c) Why is transpiration important to plant?

11. Describe exactly how you would find out experimentally:
   (a) if a potted plant loses water vapour from its leaves, (include in your accounts a reasoned conclusion).
   (b) the path through which water passes up the stem to the leaves of a flowering plant (W.A.S.C.).

12. (a) What do you understand by open and closed blood circulatory system? Give examples of animals in each type to illustrate your answer.
   (b) Why is the closed system considered more efficient?

13. (a) Draw a labelled diagram of the circulation of the blood of a mammal, using arrow-head to show the direction of the flow of the blood.
   (b) What are the functions of the blood?
   (c) In a tabular form, list five ways in which capillaries and arteries differ from each other. Which structures in flowering plants perform similar functions and what substances are transported (WASC).

# 8

# RESPIRATORY (GAS EXCHANGE) SYSTEM

As earlier stated, all living organisms respire in order to liberate energy for life activities such as contraction of muscles for movement (in animals), transmission of nerve impulses, growth of cells, division of cells, synthesis of food substances, transport of substances in and out of the cells, control of constant body temperature in birds and mammals etc..

## Respiration

*This is the oxidation of food substances in the cell, (particularly in the mitochondria) with the release of chemical energy (ATP), carbon (IV) oxide,(carbon dioxide) and water* ***(aerobic)*** *or chemical energy, alcohol and water* ***(anaerobic)****.*

## Gaseous exchange (external Respiration)

All organisms that respire aerobically, take in oxygen and give out carbon (IV) oxide as a waste product.

These two gases have to be exchanged constantly the organism is to survive. The oxygen taken in is use to oxidize food. In the process of oxidizing food in th cell, carbon (IV) oxide is produced. The carbon (IV oxide has to leave the cell before another atmospheri oxygen can be taken into the cell. This exchange of th two gases between the atmospheric oxygen and ce environment is called **external respiration**. Th exchange of the two gases is by **diffusion**. When th concentration of oxygen is higher in the alveoli (ai sacs) than in the cells, oxygen diffuses into the cells. In the same way, if the concentration of carbon (IV oxide is higher in the cell than in the alveoli, carbo (IV) oxide diffuses to the atmosphere through th alveoli and tracheae.

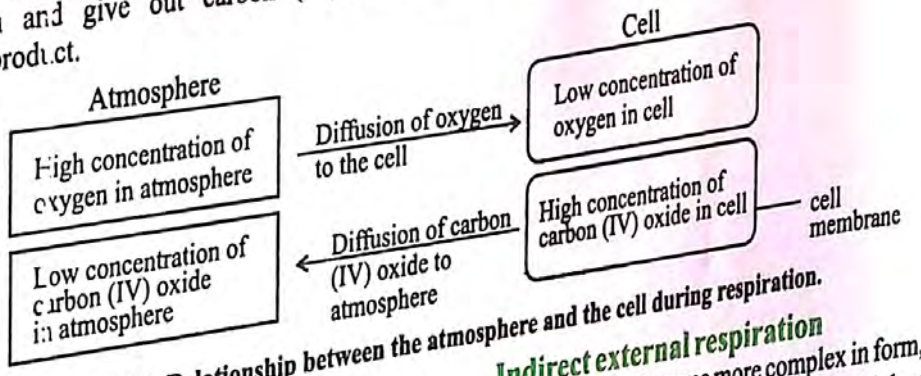



**Figure 8.1. Relationship between the atmosphere and the cell during respiration.**

## Direct (external) respiration

This is a type of respiration in which dissolved oxygen from the surrounding environment diffuses directly into the cell or cells and carbon (IV) oxide diffuses out directly from the cell into the surrounding environment. The environment is mostly water or wet surfaces. No special respiratory system is required. Simple organisms such as *Spirogyra, Amoeba,* and *Hydra,* carry out direct **respiration**.

## Indirect external respiration

As organisms become more complex in form, direct **respiration** cannot cope with their high oxygen **demand.** Some specialized structures for an efficient indirect respiration are required. These specialized structures are within the animal's body. For example, **lungs** in reptiles,

Birds and mammals; **tracheal tubes** in insects; **gills** in fish and crabs; **moist skin** in earthworms, toads and frogs. In the **indirect respiration**, not all cells are in direct contact with the environment (air or water). Blood acts as a **circulatory medium** which receives the oxygen from the environment and carries it to the cells. In the same way, carbon (IV) oxide and water are removed from the cells as wastes and expelled from the body through specialized structures.

## Characteristics of respiratory surfaces

1. **Large surface area:** This facilitates high rate of exchange of gases.
2. **Thin respiratory surface:** This helps to shorten the diffusion distance. Diffusion is relatively slow, so a thin surface will increase diffusion rate.
3. **Moist surface:** This enables the oxygen to dissolve before entering the blood or body fluid.
4. **Permeability:** The respiratory surface must be permeable so that oxygen and carbon (IV) oxide can pass freely.
5. **Well ventilated surface:** Respiratory surfaces are well ventilated so that supply of oxygen to the surface and carbon (IV) oxide from the surface are efficient.
6. **Efficient transport system:** This facilitates oxygen supply to the tissues. For example, blood supply facilitates delivery of oxygen to and carbon (IV) oxide from tissues.

**Table 37: Types of respiratory surfaces, examples and the environment in which each functions.**

| Respiratory surface | Example | Functioning environment |
|---|---|---|
| 1. Cell membrane | *Amoeba and Paramecium* | Aquatic |
| 2. Gills | Bivalve molluscs, fish, tadpoles, crustacea | Aquatic |
| 3. Skin | Frogs, toads and earthworms | 1. Aquatic or terrestrial<br>2. Moist burrow (for earthworm) |
| 4. Tracheae | Insects | Terrestrial |
| 5. Lungs | Reptiles, birds and mammals | Terrestrial |
| 6. Mouth | Frog and toad | Terrestrial |
| 7. Stomata | Leaves | Terrestrial |
| 8. Lenticels | Stems | Terrestrial |

## Types of respiratory structures

### 1. Body surface

Gaseous exchange through the body surface is carried out by aquatic microscopic organisms using cell membrane. Some multicellular organisms such as earthworms, toads and frogs carry out gaseous exchange through the skin (**cutaneuos respiration**).

### 2. Cell membrane

Microscopic aquatic organisms such as *Amoeba* and *Paramecium* have no specialized organs for respiration. Oxygen intake and expulsion of carbon (IV) oxide is by **diffusion** through the entire body surface (**cell membrane**). Oxygen needed for respiration is dissolved in water. Based on the principle that molecular gases will diffuse from a region of higher concentration to a region of lower concentration, dissolved oxygen which is of higher concentration in water than in the cell will diffuse into

the cell. After gaseous exchange, carbon (IV) oxide which is now higher in concentration in the cell than in water will diffuse out of the cell into the water.

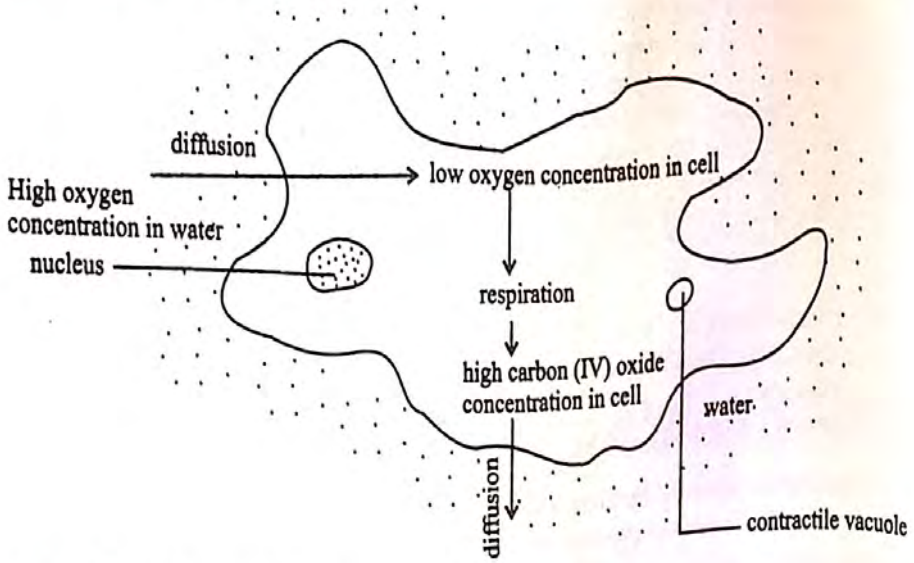



**Figure 8.2. Gas exchange (direct respiration) through cell membrane in *Amoeba***

## Gaseous exchange (direct respiration)

Earthworm, toad and frog use the skin for gaseous exchange.

## Gaseous exchange in an earthworm

The skin of an earthworm is thin and protected by a thin cuticle secreted by epidermal cells. The skin is always kept moist by a slimy mucus substance also secreted by the epidermal cells.

Oxygen for respiration easily diffuses through the **moist skin** and dissolves in the blood. The dissolved oxygen combines with **haemoglobin** of the blood to form **oxy-haemoglobin** and circulated to all the cells of the body. After **internal respiration,** the carbon (IV) oxide produced diffuses out of the cells into the blood. The carbon (IV) oxide then diffuses from the blood through the skin to the environment.

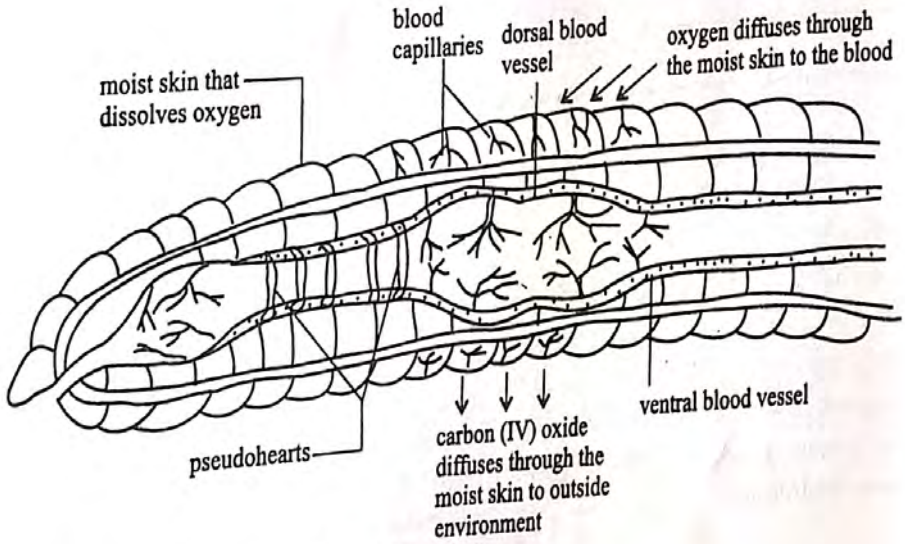



**Figure 8.3. The respiratory system of an earthworm.**

## Cutaneous (skin) respiration

### Frog and toad

The skin is thin and well supplied with blood capillaries. The skin is always kept moist by the slimy mucus secreted by the mucus glands. Oxygen for respiration diffuses through the moist skin into the blood vessels and combines with haemoglobin forming **oxy-haemoglobin** which is transported to all the cells of the body. After internal respiration, the carbon (IV) oxide produced diffuses from the cells to the blood and from the blood to its environment by **diffusion.**

**Cutaneous (skin) respiration** is carried out mostly when the animal is in water. The dissolved oxygen in water easily diffuses into the blood capillaries and carbon (IV) oxide diffuses into water. However, cutaneous respiration can take place on land as long as the skin is moist.

### Respiration by lungs in frog and toad

During lungs respiration, the nostrils are opened while the mouth is closed. The floor of the mouth is lowered and atmospheric air is drawn in. When the floor of the mouth is raised, the nostrils and the mouth are closed and the glottis is opened, air is forced through the glottis into the lungs. Oxygen diffuses into the capillaries of lungs and then to the general circulation. At the same time, carbon (IV) oxide and water vapour diffuse from the blood to the lungs and out through the nostrils to atmosphere.

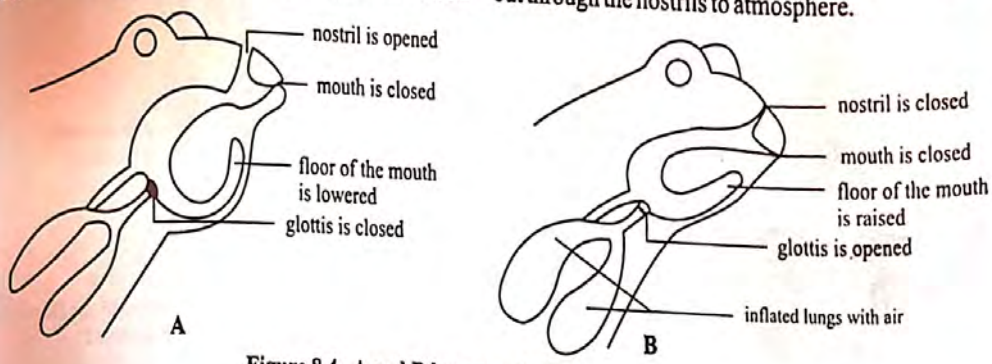



**Figure 8.4. A and B lung respiration.**

## Buccal (mouth) respiration in frog or toad

Frog or toad carries out **buccal respiration** especially when the animal is on land. The buccal cavity is lined with thin membrane which is abundantly supplied with blood capillaries.

When the mouth is closed, the nostrils are opened and the floor of the mouth is lowered. The lowering of the floor of the mouth, creates a depression and low pressure. Atmospheric air is drawn in through the nostrils to occupy the depression. The nostrils are then closed while the mouth remains closed. Oxygen the diffuses into the blood capillaries of the mouth and is carried to all parts of the body. At the same time, carbon (IV) oxide and water vapour diffuse into the buccal cavity. When the floor of the mouth is raised and the mouth is still closed, a high pressure is created. Then the nostrils are opened, carbon (IV) oxide and water vapour pass out to the atmosphere.

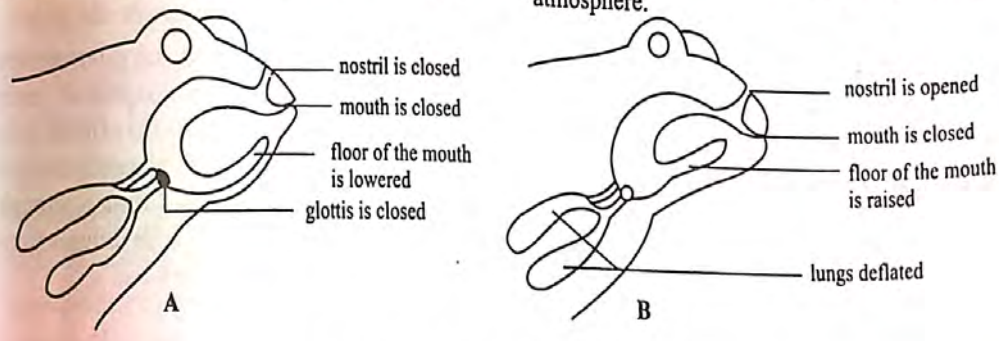



**Figure 8.5. A and B Buccal respiration in frog.**

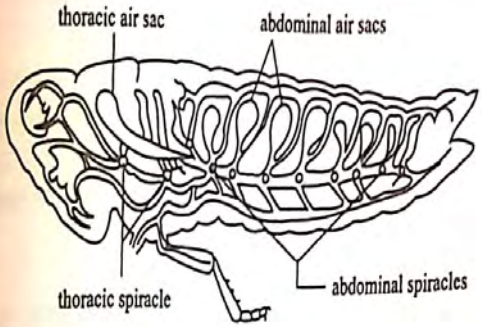
## Gaseous exchange through tracheal system

Exchange of gases (oxygen and carbon (IV) oxide) is through tracheal system. The **tracheal system** comprises **spiracles, tracheae** (air tubes) and **tracheoles**. Spiracles have valves which only open when the need arises.

In an insect such as **grasshopper** or **cockroach**, there are ten pairs of spiracles (openings) located on the eight abdominal segments and two thoracic (second and third) segments, with each segment having two spiracles (one spiracle on each side).

**Figure 8.8. The external gills of a tadpole of a frog.**

Spiracles lead to air called **tracheae** (singular trachea) which are lined with thin cuticles to prevent them from collapsing. The tracheae divide into smaller branches called **tracheoles.** Each tracheole ends in **body fluid** that is in contact with the body tissue. In the abdomen, there are many air **sacs** which help to pump **air** into the **tissues.**



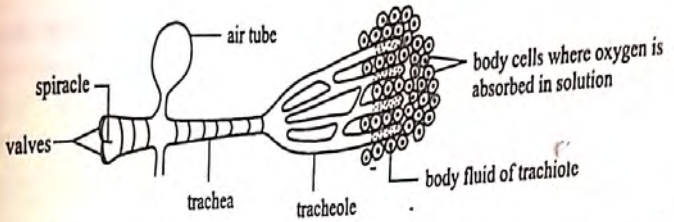




**Figure 8.9. The tracheal system of a grasshopper.**

## Breathing mechanism in grasshopper

Oxygen for respiration is supplied from the surrounding atmosphere. The abdomen and thoracic segments expand and contract. The expansion of the abdomen causes the volume of the abdomen to increase thereby drawing air by diffusion into the body through the spiracles, tracheae, air sacs and tracheoles.

When the atmospheric oxygen reaches the fluid of the tracheoles, it dissolves. The dissolved oxygen then diffuses into the tissues where cellular or tissue respiration takes place.

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

During cellular respiration, carbon (IV) oxide

## Gills

Fish and tadpoles are aquatic vertebrates. They possess gills for gaseous exchange.

**Gills of fish:**

Fish has four gills on each side of the head. Each gill has two rows of soft **gill filaments.** The filaments are tiny, long and numerous structures which are well supplied with blood vessels. In bony fish such as *Tilapia*, the four gills of each side are covered with a bony plate called **operculum.** The filaments are attached to a curved bony structure called **gill arch.** The inner sides of the gill arch are short bony structures called **gill rakers,** which are used for feeding rather than gaseous exchange. They also prevent food substances from entering the gills from the pharynx.

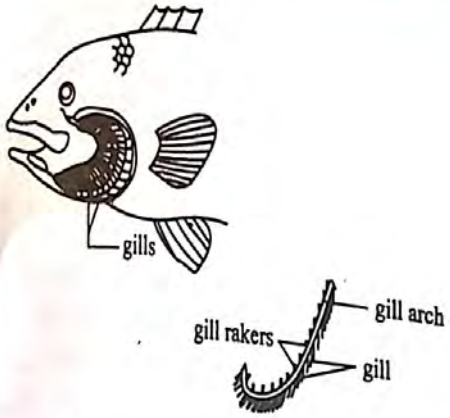



**Figure 8.6. Structure of gills (the operculum has been removed to expose the gills).**

## Breathing mechanism in *Tilapia*

When the mouth is opened, the floor of the mouth is lowered and at the same time the two opercula are closed, water is drawn into the mouth to occupy the depression created by the lowering of the floor of the mouth. When the mouth is closed, the floor of the mouth is raised and at the same time the two opercula are opened, water containing dissolved oxygen passes through the gills. The dissolved oxygen is then absorbed by the blood capillaries and carried into the general blood circulation. During **cellular respiration,** the carbon (IV) oxide produced is carried by blood vessels to the gills where it diffuses into the water.

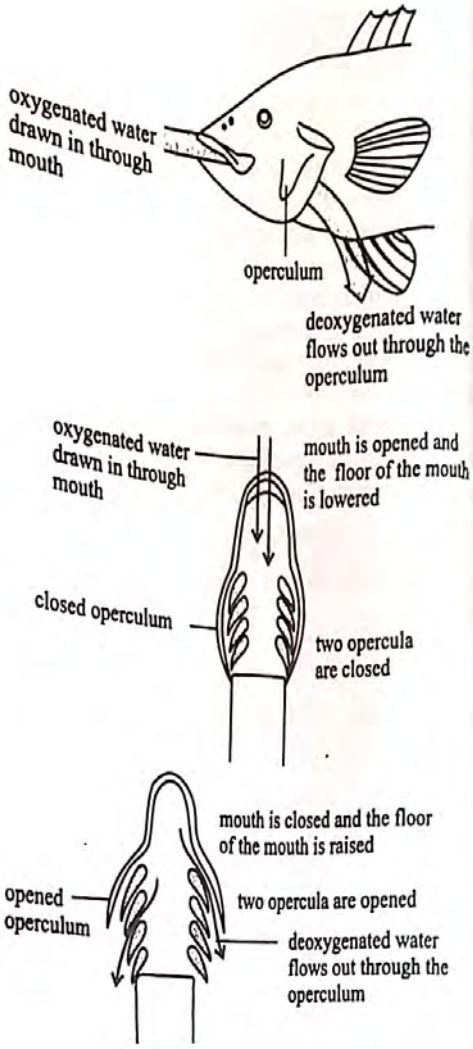



**Figure 8.7. The breathing mechanism in *Tilapia*.**

Note that in the fish, the **nostrils** are not used for breathing **in** and **out** as in other vertebrates.

## Gaseous exchange through external gills

**Tadpoles** (of frogs and toads) and **salamanders** (all belonging to the phylum **Amphibia**) have external gills for gaseous exchange. The external gills are well supplied with blood vessels. Oxygen dissolved in water is absorbed by diffusion through the external gills and carbon (IV) oxide diffuses from the blood vessels of the gills into the water.

## Gaseous exchange through tracheal system

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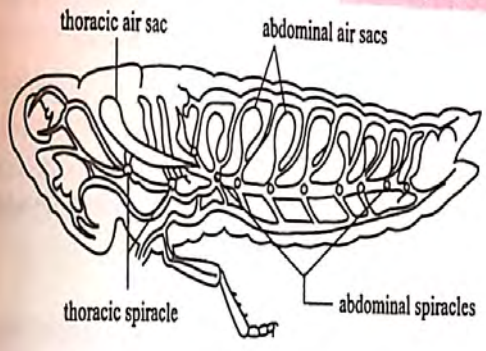
Spiracles lead to air called **tracheae** (singular trachea) which are lined with thin cuticles to prevent them from collapsing. The tracheae divide into smaller branches called **tracheoles.** Each tracheole ends in **body fluid** that is in contact with the body tissue. In the abdomen, there are many air **sacs** which help to pump **air** into the **tissues.**



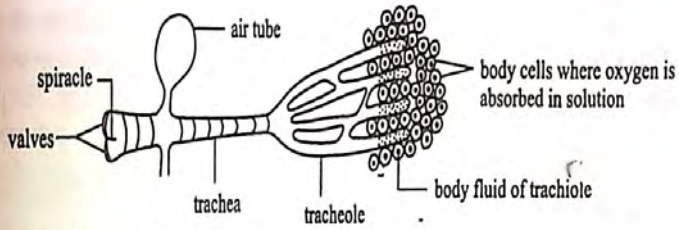




**Figure 8.9. The tracheal system of a grasshopper.**

## Breathing mechanism in grasshopper

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When the atmospheric oxygen reaches the fluid of the tracheoles, it dissolves. The dissolved oxygen then diffuses into the tissues where cellular or tissue respiration takes place.

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

During cellular respiration, carbon (IV) oxide

and water vapour are formed. When the thoracic segments and abdomen contract, carbon (IV) oxide and water vapour diffuse from the tissues to the tracheoles and from the tracheoles to the spiracles where they finally diffuse from the body into the atmosphere. Some carbon (IV) oxide and water vapour diffuse out through the cuticle.

## Cellular (internal or tissue) respiration.

All living organisms require energy to do work. Energy is bound in food molecules. The energy in the food molecules is called **potential energy** (energy at rest). This potential energy can only be used for work when it has been converted into **kinetic energy** (energy for work).

**Cellular respiration** is therefore, **the oxidation of food substance in the cells (paticularly in the mitochondria), to release energy (ATP) for work.**

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38ATP$$

Glucose oxygen carbon (IV) oxide water Energy

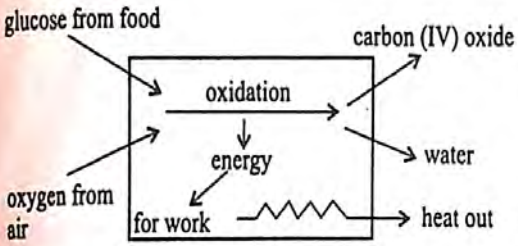



**Figure 8.10. The oxidation of glucose in the cell.**

## Types of cellular respiration

There are two types of cellular respiration: **aerobic** and **anaerobic**.

### Aerobic respiration:

**Aerobic respiration** is a type of respiration in which oxygen is used to oxidize a sugar molecule (usually glucose) inside the cell with the release of chemical energy, carbon (IV) oxide and water.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38ATP$$

This type of respiration is commonly carried out by **most living things.**

### Anaerobic respiration:

Anaerobic respiration is a type of respiration in which the glucose is broken down inside the cells without oxygen. **Alcohol, carbon (IV) oxide** and **2ATP** are the products.

$$C_6H_{12}O_6 \longrightarrow C_2H5OH + 2CO2 + energy\ (2ATP)$$

Glucose Ethyl alcohol Carbon (IV) oxide

Some micro-organisms such as **yeasts, bacteria, fungi,** and **endoparasites** such as **tapeworms** and **roundworms** respire **anaerobically.** Anaerobic respiration of yeast is referred to as **alcoholic fermentation.** In this respiration, the glucose is first converted to **pyruvic acid.** The pyruvic acid is then reduced to **ethanol** by accepting the hydrogen of **NADH.**

**1st step:**

$$C_6H_{12}O_6 \xrightarrow[NAD]{Glycolysis} 2CH_3COCOOH + 2H_2 + 2ATP$$

Pyruvic acid

**2nd Step:**

$$CH_3COCOOH \xrightarrow{NADH} C_2H_5OH + CO_2 + 2ATP + NAD$$

pyruvic acid ethanol

Terrestrial trees growing in waterlogged soil respire anaerobically and are able to stay alive while the water lasts.

Another type of anaerobic respiration is **lactic acid fermentation.** In this type of respiration, the glucose is broken down to **pyruvic acid.** The **pyruvic** acid is then reduced to **lactic acid** by **NADH** without the production of carbon (IV) oxide.

$$2CH_3COCOOH \longrightarrow CH_3CHOHCOOH + 2NAD + 2ATP$$

pyruvic acid Lactic acid

**Lactic acid fermentation** often occurs in the muscles of animals after a very fast race or strenuous exercise. For example, when an athlete has just finished a fast race, the glucose in the muscle cells is broken down to pyruvic acid at a very fast rate. In the absence of oxygen reaching the muscle cells, the **pyruvic acid** is reduced to **lactic acid.** The accumulation of lactic acid in the muscle cells causes

temporary **muscle fatigue and aches**. The athlete recovers when oxygen is carried to the muscle cells later to oxidise the **lactic acid** to **pyruvic acid** and the **pyruvic acid** is oxidized by the supplied oxygen to give **carbon (IV) oxide, water** and energy. The muscle cells then recover. This is the reason why athletes have to breathe in and out deeply or pant heavily immediately after a race.

## Oxygen Debt

The oxygen needed to oxidize lactic acid to pyruvic acid and from pyruvic acid to carbon oxide, water and chemical energy is called **Oxygen debt.**

## Uses of anaerobic respiration in Industries

1. Cassava, guinea corn and locust beans are fermented by anaerobic bacteria.
2. Yeasts which bakers use respire anaerobically during the baking of bread. The **carbon (IV) oxide** produced makes the dough to rise.
3. During production of wine, beer and alcohol, yeasts are used to ferment sugar to alcohol.
4. Bacteria used in the **retting of jute** respire anaerobically. The bacteria decompose the protein that holds the fibres together thus freeing the fibres which are processed into linen.

## Comparison between aerobic and anaerobic respiration

### Similarities

1. Both occur in the mitochondria of plant and animal cells.
2. Both involve the break down of simple sugar(**glycolysis**) to pyruvic acid.
3. Both convert pyruvic acid to energy called ATP.
4. Respiratory enzymes and co-enzymes are involved in both cases.
5. Carbon (IV) oxide is the by-product of both, except lactic acid fermentation which does not produce carbon (IV) oxide.
6. Both reactions produce by-products.

**Table 38: Differences between aerobic and anaerobic respiration**

| Aerobic respiration | Anaerobic respiration |
|---|---|
| 1. Occurs in most animals and plant cells. | Occurs in some bacterial, fungi and cells of the muscles of animal |
| 2. Oxygen is needed. | Oxygen is not needed |
| 3. Produce greater energy (38ATP) per molecule of glucose | Produces lesser energy (2ATP) per molecule of glucose. |
| 4. Carbon (IV) oxide and water are the by products. | Carbon (IV) oxide and alcohol or lactic acid are the by-products. |
| 5. Sugar is completely oxidized.<br>**Aerobic**<br>Glucose<br>↓ Glycolysis<br>Pyruvic acid<br>↓ Oxygen<br>Carbon(IV) oxide + Water + 38ATP | Sugar is incompletely broken down.<br>**Anaerobic**<br>**Alcohol fermentation**: Glucose ↓ Glycolysis ↓ Pyruvic acid ↓ Carbon (IV) oxide + Water + 2ATP<br>**Lactic acid fermentation**: Glucose ↓ Glycolysis ↓ Pyruvic acid ↓ Lactic acid + 2ATP |
| 6. Takes place in cytoplasm and mitochondria | Takes place in the cytoplasm |

## Chemical processes of cellular respiration

**Cellular respiration** occurs in two main stages involving series of chemical reactions and respiratory enzymes.

**First stage:**

**Glycolysis** (sugar breaking process) **in the cytoplasm (Anaerobic)**

The glucose molecule is phosphorylated by an addition of **phosphate group** to the glucose to become **glucose phosphate.** Through series of *oxidative* enzymes, the glucose phosphate is converted to two molecules of **triose** sugar (a 3 carbon sugar). The triose sugar is converted to pyruvic acid by the removal of four atoms of hydrogen by a *co-enzyme* called NAD (Nicotinamide adenine dinucleotide) with the formation of 2ATP.

$$C_6H_{12}O_6 \xrightarrow[\text{NAD}]{\text{Glycolysis}} \underset{\text{Pyruvic acid}}{2C_3H_4O_3} + 2H_2 + 2ATP$$

**Second stage:**

**Aerobic respiration in mitochondria**

If sufficient oxygen is available, each molecule of **pyruvic acid** is oxidized to remove one molecule of carbon (IV) oxide (**decarboxylation**) and two atoms of hydrogen (**dehydrogenation**) forming one molecule of **acetic acid** a 2-carbon acid. Carbon (IV) oxide is released.

**Krebs' cycle or citric acid cycle**

The acetic acid enters into a **Krebs= cycle** where it is joined to a **4-carbon acid** (*oxaloacetic acid*) present in the mitochondrion to form **citric acid** (*a 6-carbon acid*).

One molecule of carbon atom in form of carbon (IV) oxide (carbon dioxide) and one atom of hydrogen is removed by **oxidative decarboxylation and NAD** respectively to form a **5-carbon** *ketoglutaric acid.* Another molecule of carbon (IV) oxide and one atom of hydrogen are further removed from *ketoglutaric acid* to form a 4-carbon *succinic acid.* One atom of hydrogen is removed from succinic acid to form a **4-carbon** *malic acid.* Again, another hydrogen atom is removed from malic acid to form a **4-carbon** *oxaloacetic acid.* The oxaloacetic acid then combines with *acetic acid* again and the cycle is repeated.

The hydrogen atoms removed in successive stages combine with molecular oxygen to form water.

The overall reactions of glycolysis and **Kreb's cycle** is represented by an equation:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy (38 ATP)}$$

**ATP**

1. ATP (Adenosine triphosphate) is a water soluble electrical energy carrying small molecule that is transported around cells.
2. It is manufactured from nuclear tide base adenine combining ribose sugar and three phosphate groups making ATP a phosphorylated nucleotide.
3. ATP carries energy to any part of the cell that needs energy.
4. On reaching the cell, ATP is broken down by an enzyme called ATPase to ADP (Adenosine diphosphate) to release chemical energy for metabolic activities.

**Manufactured of ATP**

As earlier stated, ATP has 3 phosphate groups. Having lost one phosphate group during metabolic activities in the cell to release energy, it has to get back the lost phosphate group. The process of getting back the phosphate group is called **Phosphorylation.**

Inorganic phosphate is added to the ADP to make ATP with the help of an enzyme called **ATPsythase** using the energy released during cellular respiration.

$$C_6H_{12}O_2(\text{glucose}) + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy.}$$

**Importance of ATP (chemical energy)**

**ATP** is the standard unit in which all energy released during respiration is stored.

**ATP** is important to living organisms in the following ways:

**Work**

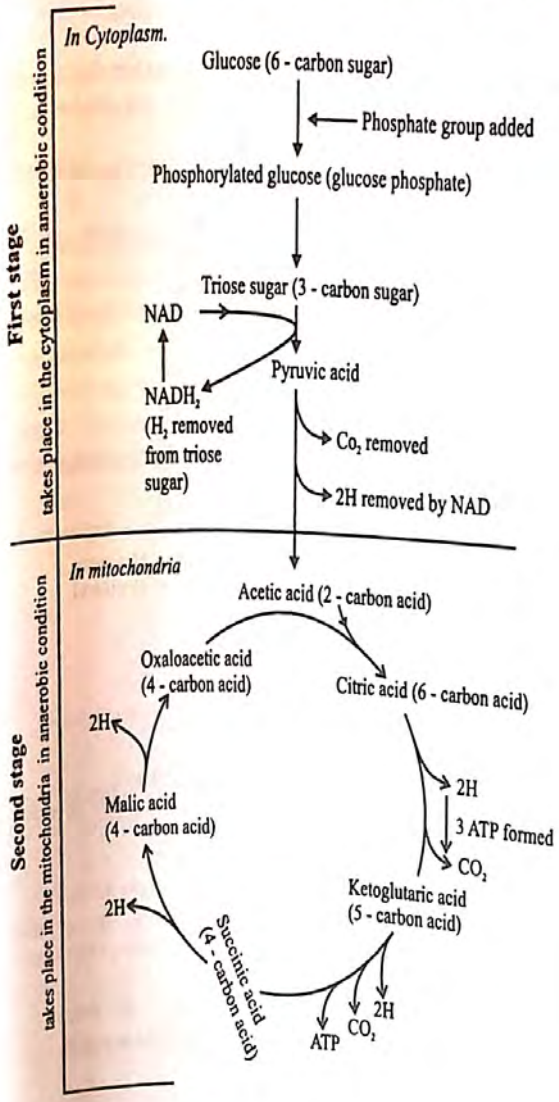
All living organisms (especially animals) need energy to do work. Movements in animals such as swimming, walking, running, flying, respiration, heart beat, blood pressure, talking require energy. This energy is supplied by ATP.

**2. Electric organs**

The electric organs of fish such as those of electric eel and *Malapterurus electricus* (Electric fish) convert ATP into electrical

energy which forms electric current used for capturing prey and also acts as a weapon of defence. An electric eel can generate up to 400 volts, high enough to kill another fish.

3. The transmission of nerve impulses requires ATP.
4. **Production of heat**
   Warm blooded animals need heat produced internally to keep their bodies warm. These animals (mammals and birds) have constant body temperatures. The heat needed by the above animals is produced by **ATP**.
5. **Active transport**
   The active transport of *ions* from a region of lower concentration to high concentration requires the energy of ATP. The working of contractile vacuoles in animals such as *Amoeba* and *Para mecium* is through the energy provided by **ATP**.
6. **Production of light**
   Some animals such as **fire flies** produce lights. The energy needed for the production of light comes from **ATP.** Animals producing light have two substances in them - *Lucifern* and *luciferase* (enzyme). When oxygen and **ATP** are added to the two substances, light is produced.
7. **Synthesis of proteins, starch, cellulose, fats and oils:** The synthesis of the above products require energy provided by **ATP**.
8. **Cell division**
   **ATP** provides energy required by cell to divide.




**Step by step break down of glucose**

*The step by step breakdown of glucose enables maximum use of energy at each step by the cell for work.*

*It also prevents too much heat from being released at once. If the heat is released at once, the cell can be destroyed.*

***Difference between photosynthetic phosphorylation and mitochondrial oxidative phosphorylation***

**Photosynthetic phosphorylation** takes place in the chloroplasts of green plants only without oxygen while the **mitochondrial oxidative phosphorylation** takes place in the cells of both plants and animals in the presence of oxygen.

## Respiratory system in mammals

The respiratory system of mammals consists of the following organs:

1. **Nose and mouth**

   They warm and moisten the in-coming air. The air entering through the mouth is not filtered

   The nose also filters dust from the in-coming air through the hairs and mucus.

2. **Pharynx**

   Leading from the mouth and nose is the pharynx. (Note: pharynx leads to the gullet (oesophagus) and larynx (voice box). Food goes into the gullet and air into the trachea. There is a regulatory structure called **epiglottis** that directs food to the gullet. When food is being swallowed, the epiglottis quickly closes the glottis (upper parts of trachea) so that food does not go into the trachea. At this time breathing is stopped. If the epiglottis fails to quickly close the glottis, some particles of food may go to the trachea causing an irritation which leads to coughing so as to throw out the food particles.

3. **Larynx (voice box)**

   The larynx is short and made of strong cartilage. Air enters the trachea through the larynx.

4. **Trachea**

   The trachea is about **10cm** long in man. The trachea is made of C-shaped cartilage which prevents it from collapsing. It runs from the larynx and divides into right and left bronchi.

5. **Bronchi**

   The bronchi are made of rings and cartilage. The right and left bronchi lead to right and left lungs respectively. The bronchi branch into **bronchioles.** The **bronchioles** in turn lead into air sacs. An air sac is made up of a cluster of **alveoli.**

**Adaptive features of alveoli for gaseous exchange.**

1. The walls of the airsacs are very thin (one cell thick) and elastic. Through this thin walls, exchange of gases takes place between the air sacs and capillaries.
2. moist inner surface in which oxygen can easily be dissolve.
3. Alveoli are abundantly surrounded by blood capillaries, that is, they receive oxygenated blood all the time and easily excretion of carbon(iv)oxide.
4. Large surface area.

**6. Lungs**

The lungs are spongy consisting mainly of **bronchioles, air sacs, network of blood vessels and capillaries** bound together by connective tissue. The lungs occupy the thoracic cavity from the shoulders to the diaphragm except the area occupied by the trachea, gullet, blood vessels and heart. This deep position of the lungs in the chest cavity reduces water from the alveoli surface.Each lung is surrounded by an **elastic membrane (pleural membrane)** and so it can stretch.

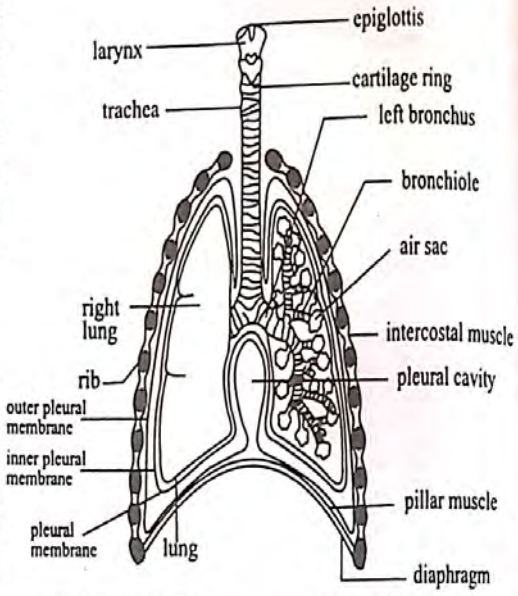



**Figure 8.12. The respiratory organs of a man. (Left lung in section to show internal structure)**

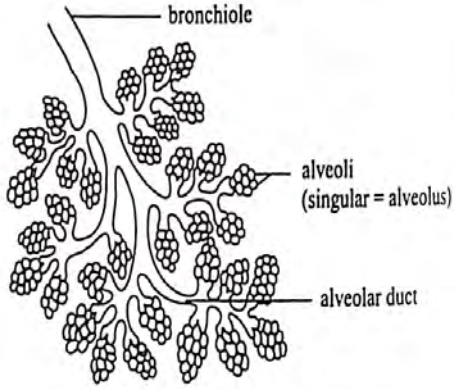



**Figure 8.13. A small portion of the lungs highly magnified to show air sacs at the end of the alveolar ducts.**

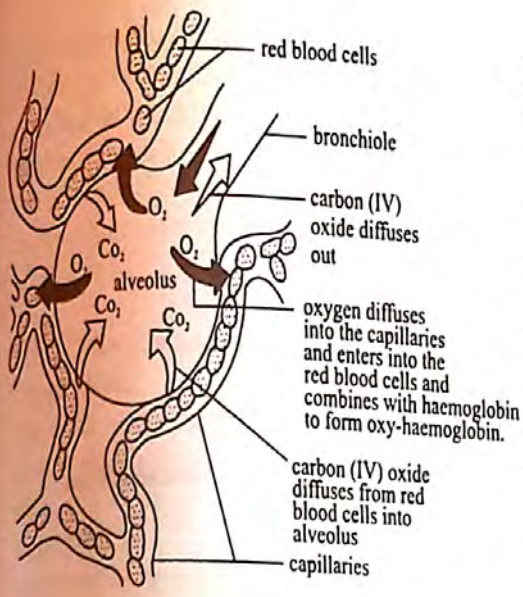



**Figure 8.14. Gaseous exchange between alveolus and blood capillaries.**

## Breathing mechanism in mammal

***Breathing occurs due to the movements of the ribs, diaphragm and the intercoastal muscles resulting in the increase and decrease in volume of the lungs.***

Each lung is surrounded by an air tight **pleural cavity.** The lung membrane is elastic and so it can stretch. Two sets of muscles of the ribs (inspiratory and expiratory intercoastal muscles) work in opposite directions (antagonistic).

**Inspiration:**

When we breathe in, the **pillar muscles** of the diaphragm contract thereby flattening the **diaphragm.** At the same time the inspiratory intercoastal muscles contract while expiratory intercoastal muscles relax thus pulling the ribs **upward** and **forward.** This enlarges the thoracic cavity thus creating low air pressure in the lungs. The elastic walls of the lungs are pulled out and air is drawn in through the **trachea, bronchi** and **bronchioles.** The concentration of oxygen in the lungs is now higher than in the blood. Oxygen then diffuses from the lungs into the blood. At the same time the concentration of carbon (IV) oxide in the blood is higher than in the lungs and therefore diffuses from the blood into the lungs and expelled during expiration.

**Expiration**

When we breathe out, the pillar muscles of the diaphragm relax thus the diaphragm returns to its curved position. At the same time, the expiratory intercoastal muscles contract, the inspiratory intercoastal muscles relax. This reduces the volume of the thoracic cavity and increases its air pressure. Therefore air is forced out through the trachea.

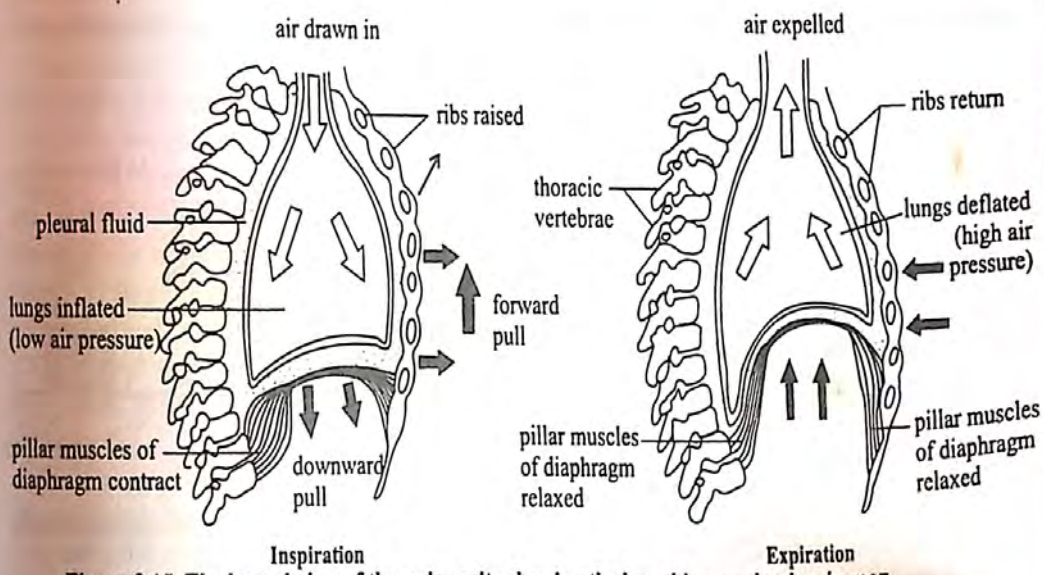



**Figure 8.15. The lateral view of thoracic cavity showing the breathing mechanism in man.**

## Working models for breathing mechanism in mammals

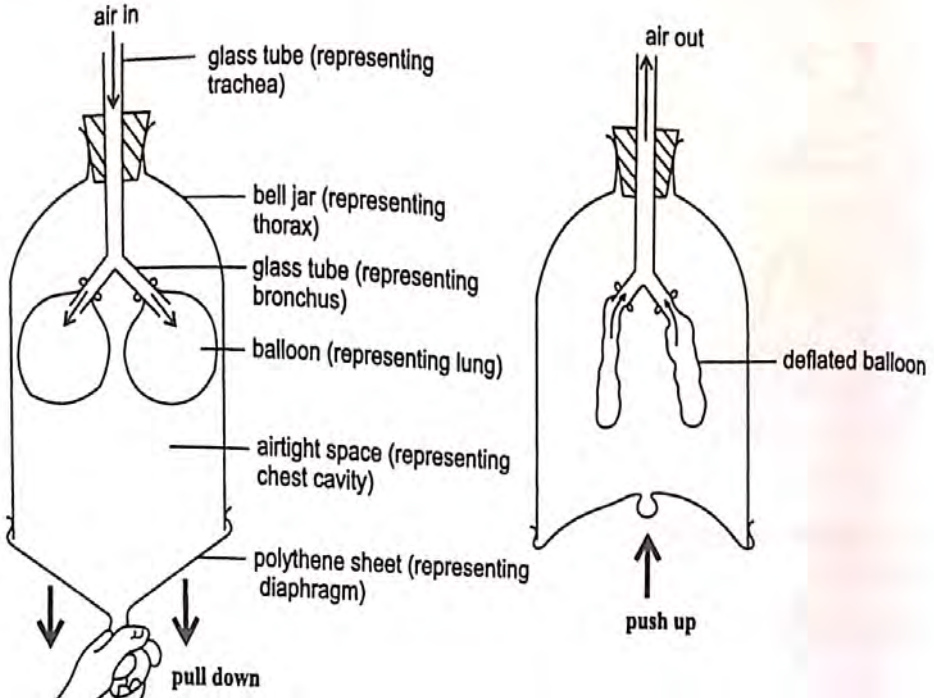



**Figure 8.16. A working model for breathing mechanism.**

When the polythene sheet is pulled downward, the air pressure in the bell jar **decreases**. Air then enters through the glass tube and the balloons are inflated. When the polythene sheet is left to return to its original domed shape, the air pressure **increases** and air is expelled through the glass tube and the balloons are deflated.

Experiment to demonstrate respiration in a small mammal.

### Experiment

**Aim:** To demonstrate respiration in a small mammal using a rat (*Rattus rattus*).

**Method:** The apparatus is arranged as in the diagram. It is attached to a filter pump and air is drawn in. A current of air is drawn gently through the apparatus by means of the filter pump. As the air enters '**A**' the caustic soda (Lime water) solution absorbs the carbon (IV) oxide. The lime water remains clear in '**B**'. This shows that there is no carbon (IV) oxide entering '**C**'. The experiment is left for two to three hours.

A control experiment is set up in the same way but without a rat as in '**C**'.

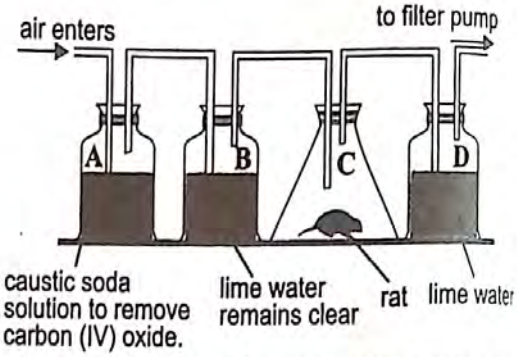



**Figure 8.17. Experiment to demonstrate respiration in a small mammal (rat).**

**Result:** The lime water in **D** turns milky showing

the liberation of carbon (IV) oxide. The lime water in **D** of the control experiment remains clear.

**Conclusion:** Since the lime water turns milky and the lime water in **B** remains clear, the air entering **C** is free of carbon (IV) oxide. The carbon (IV) oxide that turns the lime water in **D** comes from the respiration of the rat in **C**.

**Note:** Insects or toad can also be used instead of rat.

**Oxygen Debt**

The quick heavy breathing to take in oxygen to the muscle cells lacking oxygen in other to oxidize the lactic acid built up in the muscle cells called **Oxygen Debt (OD).**

**Causes of Oxygen Debt**

1. Vigorous exercise, leading to shortage of oxygen in muscle cells.
2. Lungs unable to meet the demand of oxygen in the cells of the muscles.
3. The cells of the muscles have to respire Aerobically producing lactic acid and little energy.
4. Lactic acid accumulates in the muscle cells.
5. After vigorous exercise, the lactic acid remains in the muscle cells resulting in muscle fatigue and aches.
6. More oxygen is then required to repay the debt of oxygen in the muscle cells.
7. As sufficient oxygen is breathed in to oxidize the Lactic acids, the debt of oxygen has been paid.

**Respiration in plants.**

All plants respire at all times, like any other living thing. 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 carbon (IV) oxide and water. The green plants use the carbon (IV) oxide from respiration for photosynthesis during the day.

In a simple aquatic plants such as *Spirogyra*, dissolved air in water diffuses into the cells through the general body surface while in the vascular plants atmospheric air enters through the **stomata** and lenticels which occur more abundantly on the lower surface in most leaves and the stem respectively. Stomata are pores or holes inbetween guard cells which move to open and close them. When stomata open, air enters the mesophyll layer of the leaf. Here the oxygen of the air diffuses into the **mesophyll** cells and other cells for respiration. Suitable respiratory substrates such as glucose are oxidized and broken down into energy, carbon (IV) oxide and water. The energy released is used for vital functions in all living cells while the carbon (IV) oxide diffuses into the intercellular spaces and from thence into the surrounding through the stomata. Much of the water is retained in the tissues while some is lost in the form of water vapour during transpiration.

The structure of stomata and its mechanism of opening and closing are discussed in chapter 9.

**Experiment**

**Aim:** To demonstrate respiration in a small potted plant.

**Method:** The apparatus is arranged as in the diagram. It is attached to a filter pump and air is drawn in. The experiment is carried out in darkness to prevent photosynthesis occurring because carbon (IV) oxide would be used up.

The pot is covered with plastic rubber to avoid respiration of organisms in the soil from affecting the lime water in **D**.

A current of air is drawn gently through the apparatus by means of the filter pump.

As the air enters 'A' the caustic soda (lime water) solution absorbs the carbon (IV) oxide. The lime water remains clear in 'B'. This shows that there is no carbon (IV) oxide entering 'C'. The experiment is left for two to three hours.

A control experiment is set in the same way but without a potted plant as in **'C'**.

**Result:** The lime water in **'D'** turned milky, showing liberation of carbon (IV) oxide. The lime water in **'C'** of the control experiment remains clear.

**Conclusion:** Since the experiment was carried out in darkness and the pot was covered with rubber, the carbon (IV) oxide given off, came from the plant during respiration.

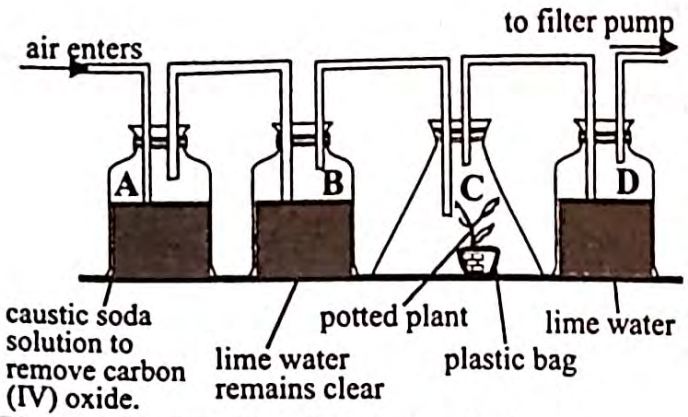



**Figure 8.18. Experiment to demonstrate respiration in a small potted plant.**

Respiratory Quotient (RQ)

During aerobic respiration, oxygen is used up and carbon (IV) is produced as a bye-product. Respiratory Quotient (RQ) is the amount of carbon(IV)oxide produced divided by the amount of oxygen consumed of a particular food at a particular time.

RQ reveals what type of food is being oxidized and the type of metabolism that is going on in the organism.

$$RQ = \frac{\text{Molecules of } Co_2 \text{ produced in respiration.}}{\text{Molecules of } O_2 \text{ used.}}$$

For example, respiration of glucose is

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

$$RQ = \frac{6}{6} = 1.0$$

The RQ in human beings ranges from 0.70- 1.0. This indicates that fats/oils, proteins are also used for respiration.

| Respiratory foods | RQ |
|---|---|
| Fats/Oils | 0.7 |
| Amino acids | 0.9 |
| Glucose | 1 |
| Anaerobic respiration of glucose | Greater than 1 |

**Notes**

1. RQ greater than 1.0 indicates that the organism is short of oxygen and is respiring both aerobically and anaerobically. For example, sprinters of 100, or 200 metres run out of oxygen in their muscles and have to complete the race respiring anaerobically.
2. If the organism is respiring oil or fats, RQ is less than 1 because more oxygen is needed.
3. Plants usually have RQ less than 1 because part of Co2 produced during respiration is used up again for photosynthesis.

**Table 39: Differences between inspired and expired air.**

| | Inspired air | Expired air |
|---|---|---|
| 1. Oxygen | 21% | 16% |
| 2. Carbon (IV) oxide | 0.03% | 4% |
| 3. Nitrogen | 79% | 79% |
| 4. Temperature | Atmospheric temperature | Body temperature |
| 5. Humidity | Humidity of atmosphere | Humidity increased by moisture in lungs |
| 6. Air | Cold and dry | Warm and moist. |

***Questions***

1. (A) Define (i) cellular (tissue or internal) respiration (ii) external respiration (iii) breathing.
   (b) What is:
   (i) aerobic respiration
   (ii) anaerobic respiration?
   Give examples where possible.

(c) Briefly describe the simplified chemical process of cellular respiration.
(d) What is the importance of ATP?
(e) In a tabular form state the differences between aerobic and anaerobic respiration.

2. Define the terms:
(a) internal respiration and
(b) external respiration
(c) How does a mammal obtain its oxygen and give out carbon (IV) oxide?
(d) What are the differences between inspired and expired air?
(e) What part do the following play in respiration: (i) lenticels (ii) guard cells (iii) spiracles (iv) glucose (v) water?

3. (a) What is respiration? Give an illustrated account of how you could demonstrate respiration in a small plant growing in a pot.
(b) (i) State the structural features which are common to the gills of a fish and the lungs of a mammal.
(ii) How do these features contribute to their efficient functioning?
(iii) State how the inadequate supply of oxygen affects tissue respiration.

4. (a) List three uses of anaerobic respiration in industry.
(b) State under what conditions can glycogen be converted to glucose to produce ATP (energy).
(c) How does oxygen: (i) reach the lungs (ii) enter the blood stream (iii) enter the liver of a mammal?
(d) Describe the breathing mechanism in a named bony fish (diagram essential).

5. When living organisms respire they release and use chemical energy within a sugar molecule.
(a) Write an equation to indicate the beginning and final products of respiration where oxygen is plentiful.
(b) Write an equation to indicate the beginning and final products of respiration in some organisms where oxygen is absent.
(c) State what happens when oxygen is not sufficient in an active muscle?
(d) Briefly state the importance of respiration in plants and animals.

6. (a) What roles do the following play in respiration:
(i) lung (ii) stomata (iii) lenticels (iv) blood (v) glucose and (vi) water?
(b) Name where gaseous exchange takes place in the following organisms:
(i) Amoeba (ii) mammal (iii) fish (iv) toad
(c) Name four features which make respiratory surfaces efficient for gaseous exchange.

7. (a) Describe how oxygen is absorbed from the surrounding into the cells of
(i) earthworm (ii) a terrestrial insect (iii) a bony fish and (iv) a mammal.
(b) Describe an experiment to show that respiration takes place in a: (i) small potted plant and (ii) a small mammal.

8. (a) Name the structure in a cell in which ATP (adenosine triphosphate) is formed.
(b) State how ATP and ADP (adenosine diphosphate) are stored and how energy is used in a cell.
(c) Name the substance that accumulates in the muscles of athletes after a keenly contested 400metre race.
(d) Give reasons why the breathing rate remains high for a while after the race.

9. (a) Describe the process of inhalation in man
(b) Describe briefly the process of gaseous exchange in the shoot system of flowering plants
(c) Describe an experiment to demonstrate the effect of distilled water on mammalian red blood cell (S.S.C.E. 1993).

10. (a) List the main features of efficient respiratory systems.
(b) Explain why there are no active respiratory systems in plants.
(C) Draw an annotated diagram of the respiratory system of human being.

11. (a)(i) Explain the term respiration
(ii) Describe the process common to both aerobic and anaerobic respiration.
(b) (i) State five ways in which respiration is importan to animals.
(ii) List four industrial applications of anaerobic respiration.
(Iii) Explain briefly the term muscle fatigue. (WAEC).

# 9

# EXCRETION

## Excretory systems and mechanism

Living organisms produce many excretory waste products during their metabolic activities. Some of these waste products are harmful if left to remain in the bodies of living organisms.

*The removal of waste products of metabolism which are harmful or would in time interfere with normal functions of organisms is known as excretion.*

## Excretory waste products in animals

Carbon (IV) oxide, (carbon dioxide), nitrogenous compounds and water are the main waste products.

Carbon (IV) oxide and water are formed during tissue (internal) respiration.

$$\underset{\text{(Glucose)}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \longrightarrow \underset{\text{Carbon (IV) oxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{ATP}}{\text{Energy}}$$

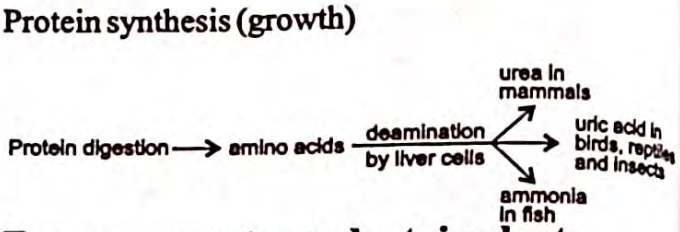
Nitrogenous waste compounds are **urea, uric acid** and **ammonia**. Each of the nitrogenous compounds is excreted by different animals depending upon the habitat and water needs.

**Urea** is soluble in water. It is excreted by mammals and dogfish.

**Uric acid** is relatively insoluble in water. Animals living on land that have needs to conserve water excrete uric acid as white semi-solid. Birds, reptiles and insects excrete uric acid.

**Ammonia** is very toxic and highly soluble in water. It is excreted by most aquatic animals such as *Amoeba* and bony-fish.

**Urea, uric acid** and **ammonia** are by-products of protein breakdown. The end-product of protein digestion is **amino acid.** Excess amino acid is deaminated by the cells of the liver into urea, uric acid or ammonia and organic compounds.




## Excretory waste products in plants

Carbon (IV) oxide, water and oxygen are the main excretory wastes in plants. Carbon (IV) oxide and water are produced as wastes during **internal respiration.**

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \longrightarrow \underset{\text{Carbon (IV) oxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{ATP}}{\text{Energy}}$$

Oxygen is given out as a by-product during photosynthesis.

$$\underset{\text{Chlorophyll}}{6CO_2 + 6H_2O \xrightarrow{\text{Radiant energy}}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

It must be noted, however, that carbon (IV) oxide and water produced during respiration are used by plants during photosynthesis in the day light, while the oxygen released as a by-product during photosynthesis is used for respiration. Excess oxygen, not used for respiration is released into the atmosphere.

Some other waste products from plants include **quinine, cocaine, gums, latex, resins, turpen-tine, morphine** and **tannin.**

## Excretory structures in animals and plants

Contractile vacuole, flame cell, nephridia, Malpighian tubules and kidneys are the excretory structures in animals while stomata and lenticels are excretory structures in plants.

**Table 40. Excretory structure or organ and living thing (organism) in which it is found.**

| (a) Excretory structure or organ | Living thingin which it is found |
|---|---|
| 1. Kidneys | *Mammal* |
| 2. Skin | *Mammal*, e.g. man |
| 3. Lungs | *Mammal* |
| 4. Liver | *Mammal* |
| 5. Gills | Fish e.g *Tilapia.* |
| 6. Nephridia | Earthworm. |
| 7. Malphian tubules | Insects e.g. cockroach. |
| 8. Flame cell | Flatworm e.g. Planarian. |
| 9. Lung book | Spider. |
| 10. Green gland | Crustaceans e.g. Shrimp |
| 11. Contra ctile vacu ole | Protozoa e.g. *Amoeba* |
| 12. Lenticel | Woody plant e.g. Orange tree |
| 13. Stomata | Vascular plant e.g. Hibiscus plant |
| 14. Leaves | Plant. |

## Excretion in Protozoa

Excretion in most protozoans is by contractile vacuole. This is a simple cavity found in the cell of freshwater protozoans that helps to eliminate water from the cell. Some contractile vacuoles are spherical while others are stellate or star-shaped.

The cell membrane of protozoans such as *Amoeba* is semi-permeable. The osmotic pressure inside the cytoplasm is greater than that of the water surrounding it. Water therefore passes from the environment into the cytoplasm. As water enters into the cytoplasm, a contractile vacuole is formed and water flows into it. When it reaches the maximum size it contracts and discharges the excess water through a temporary break in the cell membrane at a regular interval. As the water is discharged, the membrane of the vacuole reunites with the cell membrane.

Excretion of waste products (carbon (IV) oxide and ammonia) is by **diffusion** through the cell membrane.

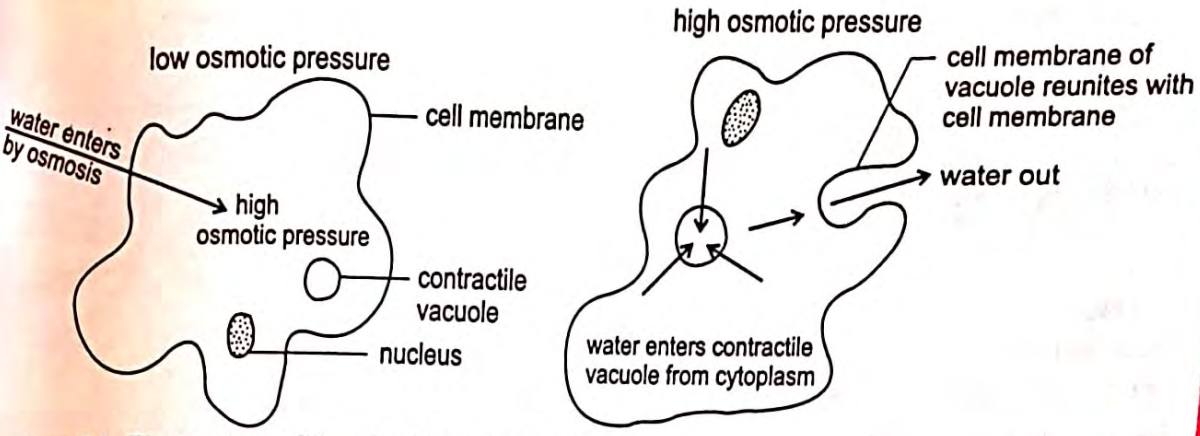



**Figure 9.1. The structure of *Amoeba* with contractile vacuole.**

## Excretory system in flatworms (flame cells)

The excretory system consists of two longitudinal canals with network of ducts (tubules).

The ducts branch to all parts of the body and end up in flame cells.

The two main canals open on the dorsal surface of the body by excretory pores. Each flame cell is a bulb cavity and funnel-shaped. Projecting down from the cell lumen is a brush of **long cilia**. The cell lumen ends up as a narrow tube called **duct**. The beating of the cilia resembles a flame. This gives the entire structure the name **flame cell**.

## Excretory system in planaria

Liquid waste containing ammonia and carbon (IV) oxide diffuse into cell lumen. The continous beating of the cilia drives the wastes into excretory ducts and from there to the excretory pores on the surface of the body where they are eventually removed.

Flame cells are found in flatworms such as **Schistosoma** and **tapeworms.**

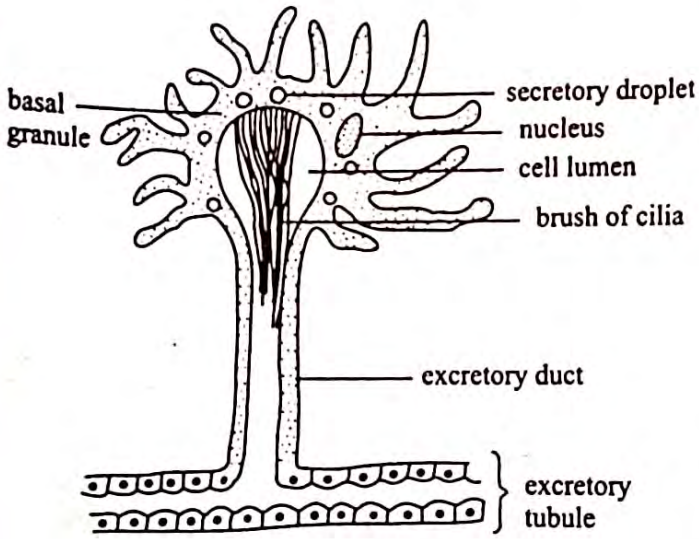



**Figure 9.2. The structure of the flame cell of the planaria.**

## Excretory system in earthworm (Nephridia)

**Nephridia** are organs of excretion in earthworms. A pair of nephridia is located in each segment except the **first three** and the last segments. All nephridia have the **same plan.**

Each nephridium consists of five portions namely **nephrostome, narrow tube, middle tube, wide tube and muscular tube.** The **nephrostome** is ciliated and funnel-shaped with its upper wall (upper lip) larger than the lower wall (lower lip). The nephrostome leads into a **narrow coiled** and **ciliated tube** and the narrow tube leads into a **middle ciliated** tube. The middle ciliated tube finally leads into the **muscular bladder-like tube** with an opening to the exterior by the **nephridiopore.**

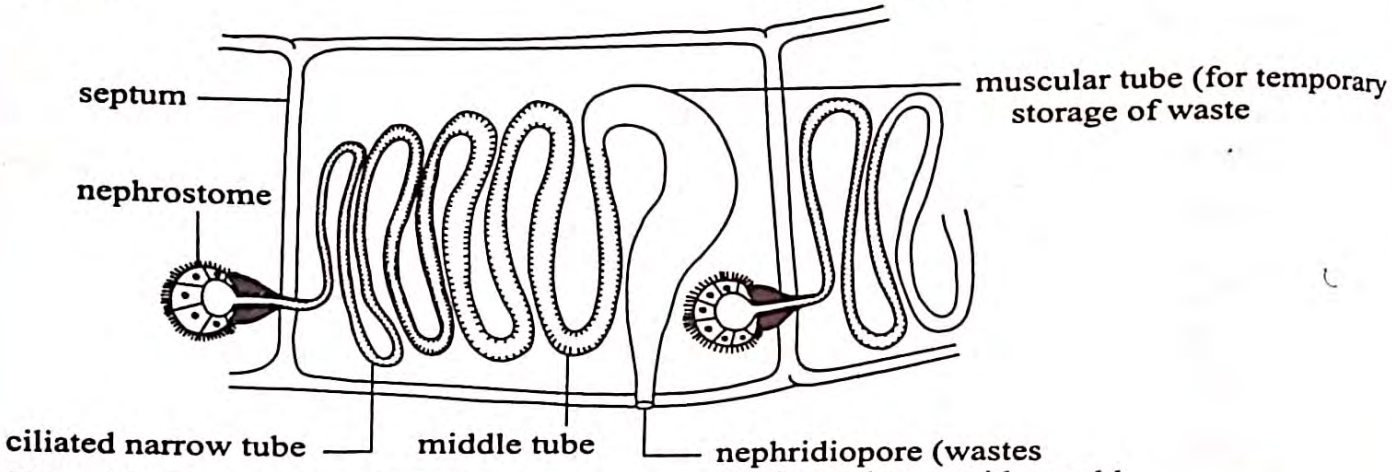



**Figure 9.3. The structure of a nephridium**

## Mechanism of excretion

Each nephrostome is located in the body cavity (coelom) of one segment while the rest coiled parts of the nephridium are embedded in the body cavity of the segment behind it.

The gut muscles in the body cavity (coelomic cavity) is lined with **chloragogenous cells** which deaminate unwanted amino acids into **urea, guanin** and other organic compounds. These waste nitrogenous compounds are secreted into the fluid of the body cavity. The coelomic fluid therefore contains both useful materials (e.g. glucose) and waste materials (e.g. urea). The beating of the cilia of the nephrostome draws coelomic fluid which is pushed along the tube by the cilia and muscular contraction. As the fluid passes along the tube, useful materials such as glucose is reabsorbed into the blood circulation as the tube is well supplied with blood capillaries. Also some nitrogenous wastes in the blood are absorbed by the secretory cells of the tubule. The waste fluid is finally pushed into the muscular bladder where it is temporarily stored before being discharged to the outside through the nephridiopore.

Carbon (IV) oxide is excreted from the body by **diffusion** through the **moist skin.**

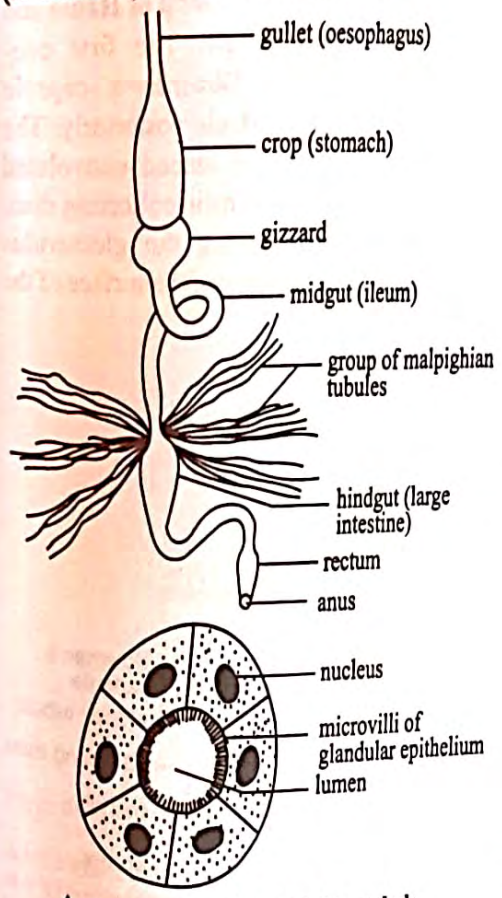
## Excretory system in insects

### Malpighian tubules of cockroach

The excretory system of insects is made up of **Malpighian tubules**. They arise from the junction between the midgut (small intestine or ileum) and hindgut (large intestine). Each tubule consists of two parts: the **distal end** and the **proximal end**. The distal end is free and closed. Malpighian tubules are thin-walled, long, and slender with lumen.

Internally, Malpighian a tubule is lined by glandular epithelium with a layer of **microvilli**. They are arranged in group of six and vary in number depending upon species and sex. For example *Blatta orientalis* has 148 in male and 186 in female.

Malpighian tubules lie in the body cavity (haemocoel) and are bathed by blood.




A cross section of a malpighian tubule

**Figure 9.4. The malpighian tubules of cockroach.**

### Mechanism of excretion

Malpighian tubules as already stated lie in the body cavity (haemocoel) of the insect and are bathed by blood. Soluble nitrogenous waste (**potassium urates**) are produced by the tissues of insects and sent to the blood. The distal ends of the Malpighian tubules absorb the potassium urates from the blood. Inside the tubules, the potassium combines with carbon (IV) oxide and water to produce **potassium** and **sodium bicarbonates and uric acid**. These wastes move along the proximal ends of the tubules, where the bicarbonates and water are reabsorbed leaving the concentrated crystalline uric acid which is passed to the hindgut to mix with faeces.

The uric acid and faeces are then passed into the rectum where water is reabsorbed again. The dry faeces and uric acid are passed out through the anus.

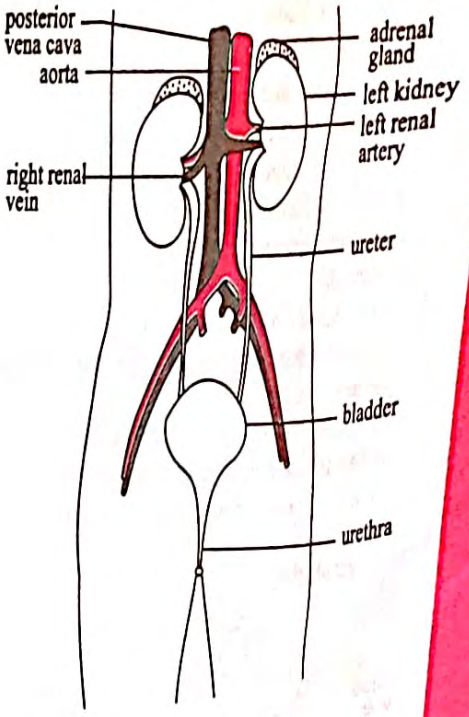



**Figure 9.5. The human excretory system.**

## Excretory system in mammals

Kidneys are the organs responsible for the excretion of all nitrogenous wastes from the body and also responsible for the osmoregulation of the blood and body fluid.

## Structure of kidney

There are two kidneys which lie in the abdominal wall. The left kidney is slightly higher in position than the right one. Each kidney is bean-shaped and dark red in colour and is surrounded by fibrous capsule and fats which keep it in position. At the top of each kidney lies the **adrenal gland.**

**Renal artery, renal vein** and **ureter** join each kidney. Renal artery carries **oxygenated blood** to the kidney while renal vein carries away **deoxygenated blood**. Ureter carries **urine** to the urinary bladder.

When a kidney is cut vertically, it consists of three portions: **cortex, medulla** and **pelvis.**

1. **Cortex** is the outer layer consisting of **Malpighian bodies** and **tubules**. In the Malpighian capsule, there are capillaries formed from the renal artery and renal vein.
2. **Medulla** is the inner layer consisting of uriniferous tubules. The medulla projects inwards to form 15 to 16 pyramids. The uriniferous tubules open into the **pelvis** through these pyramids.
3. **Pelvis** leads into the ureter. Ureter leads into the urinary bladder and the urinary bladder leads into the **urethra.**

The structure responsible for the formation of **urine is the nephron (kidney tubule).** *Each kidney in man consists of about one million nephrons.*

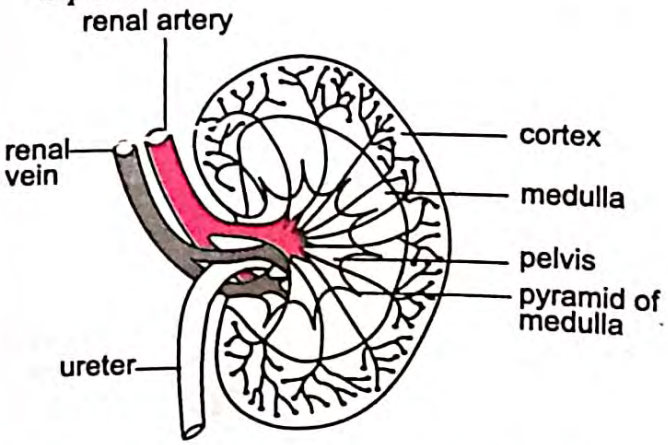
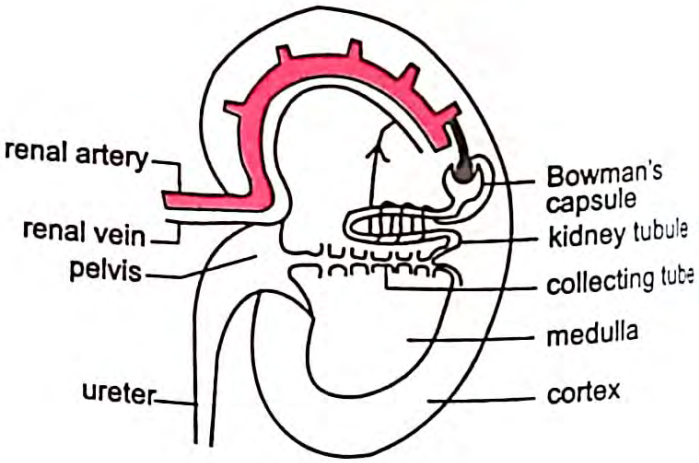


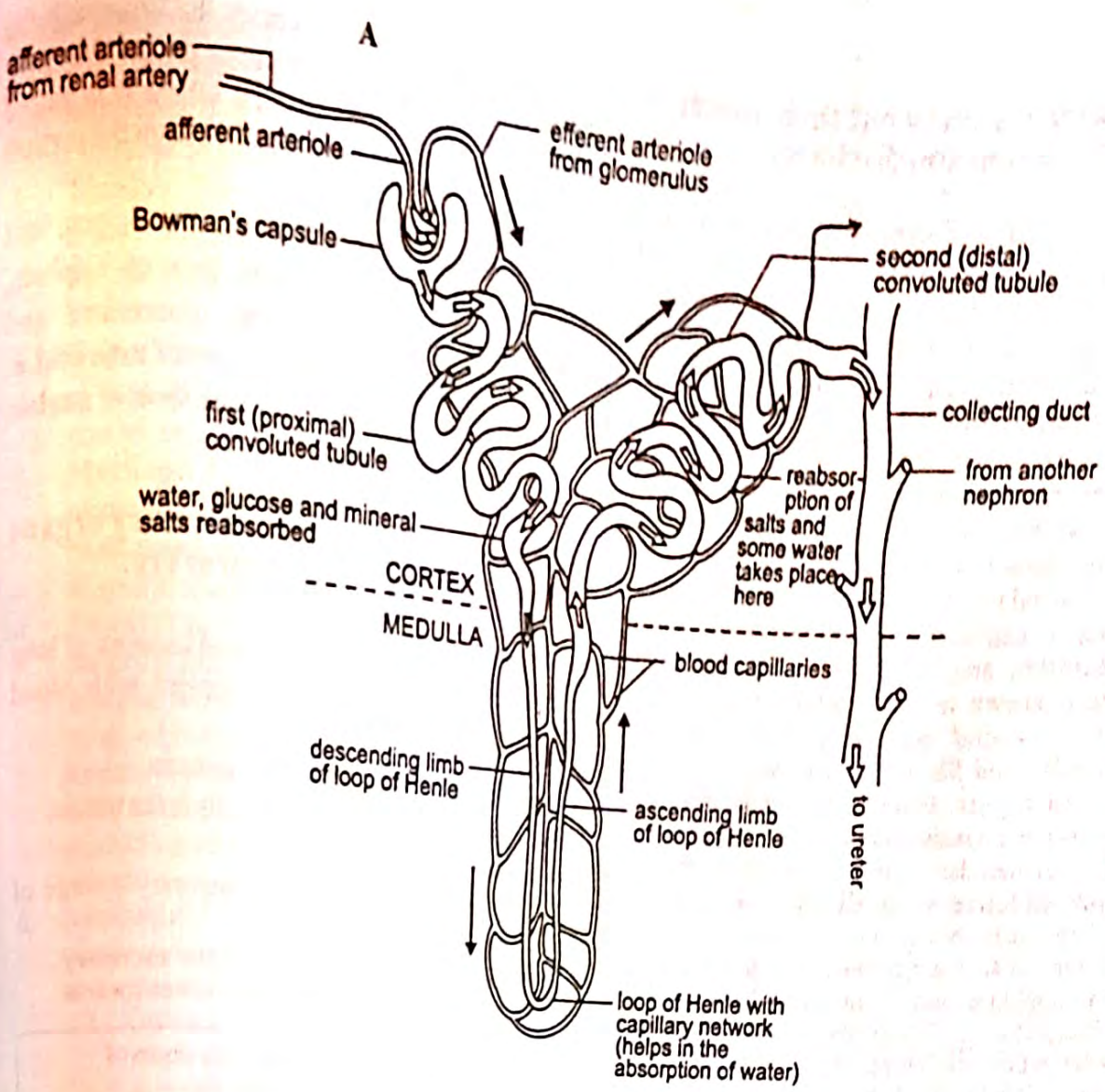

**Figure 9.6. Vertical sections of the left kidney**

## The structure of a nephron (kidney tubule/uriniferous tubule)

Each nephron is made up of a cup-shaped and hollow structure called **Bowman=s capsule** and a narrow, coiled and long tube called **uriniferous tubule (kidney tubule).** Each Bowman=s capsule is supplied with an afferent arteriole (a branch of renal artery) which divides several times forming tiny branches called **capillaries.** These capillaries unite at one end to form **efferent arteriole.** The network of capillaries is known as **glomerulus.** The walls of the glomerulus and Bowman=s capsule have tiny pores which only allow small molecules to pass through.

The nephron consists of three portions namely (a) **First convoluted tubule,** (b) **loop of Henle** and (c) **second convoluted tubule.** The first convoluted tubule joins the Bowman=s capsule anteriorly and the loop of Henle posteriorly. The loop of Henle leads into the second convoluted tubule which in turn joins the main collecting duct. The **efferent arteriole** leaving the glomerulus forms a network of capillaries over the surface of the uriniferous tubule.





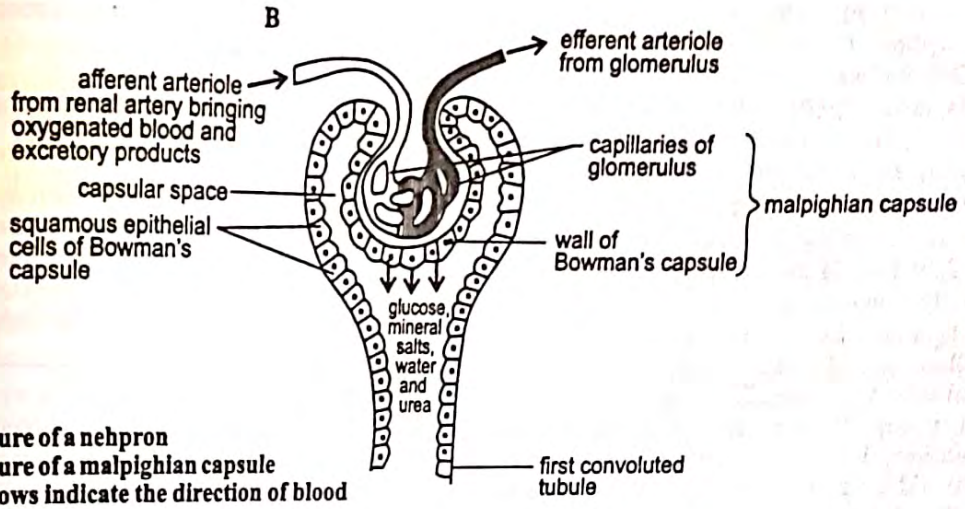




**Figure 9.7**

**A = The structure of a nehpron**
**B = The structure of a malpighian capsule**
**The black arrows indicate the direction of blood flow.**
**The open arrows indicate the direction of urine flow.**

## How the kidneys carry out their function of urine formation and discharge

All waste nitrogenous matter is changed into urea by the cells of the liver. Urea is soluble in water and is carried in solution in the plasma to the kidneys by the renal artery. Blood under high pressure flows into the Bowman=s capsule through the afferent arteriole (a branch of renal artery). Under this high blood pressure in the Bowman=s capsule, substances of small molecular size such as urea, glucose, water, mineral salts, vitamins, hormones and amino acids pass through the tiny pores of the glomerulus and Bowman's capsule into the cavity of Bowman's capsule. The process is called **ultrafiltration** and the fluid in the Bowman's capsule is known as **glomerular filtrate**. (*Note: Blood cells and plasma proteins such as prothrombin and fibrinogen with large molecular size cannot pass through the glomerulus and therefore remain in the blood*).

The glomerular filtrate passes into the first convoluted tubule where all amino acids, glucose and large quantities of hormones, vitamins, water and mineral salts are reabsorbed into the body by blood capillaries surrounding the tubule. After this reabsorption, the filtrate passes into the **loop of Henle** where exchange of ions occurs, thereby maintaining the pH of the blood at 7.3 to 7.4. (*Note that the **loop of Henle** is the seat of final water reabsorption to the body hence the osmotic regulation of the body fluid).* The longer the **loop of Henle,** the more efficient the reabsorption of water. Desert animals that have no access to water have very long **loop of Henle** in their nephrons. This helps to reabsorb a lot of water from their urine. They therefore excrete scanty concentrated urine.

They recycle the metabolic water in their body for their water needs. The filtrate continues its journey to the second convoluted tubule and collecting duct where further reabsorption of water and salts takes place. The process of selecting what to return to the body is called **selective reabsorption**. After this reabsorption, the fluid in the kidney tubule (nephron) is called **urine.** The efferent arteriole then joins the renal vein which carries blood away from the kidney.

Different tubules join up to form several main collecting ducts which empty the urine into pelvis. From the pelvis, the ureter passes the u into a muscular urinary bladder where it is sto temporarily and later discharged through the ure to the outside.

**Urine** is composed of water (96%), urea a traces of uric acid (2%) and ions of sulpha phosphate, sodium, calcium, potassium a chloride (2%). (Note: The presence of **uric acid** the urine of man is due to the breakdown of nucle **acid** and not proteins).

## Similarities between the excretory organ of a mammal and earthworm are:

1. Both are made of complicated network of lo coiled tubule and well supplied with blo vessels.
2. Both filter their excretory products.
3. Both reabsorb useful materials in the tubule.
4. Both excrete urea.
5. Both have bladders for temporary storage o excretory products.

**Table 41. Differences between the excretory organs of a mammal and earthworm**

| Excretory organ of earthworm | Excretory organ of mammals. |
|---|---|
| 1. There is a ciliated funnel called nephrost ome. | There is no ciliated funnel |
| 2. A pair of nephridia is arranged in each seg ment. | Nephrons are not arranged in segment. |
| 3. Each segment has its own pair of excretory organ called nephridia which discharge waste products out side the body. | All nephrons unite to form a main collecting tubule which e mpties into the renal pelvis and is disch arged a single opening. |

## Excretion in plants

There are no special excretory organs o systems in plants. The plants as living things do carry out excretion. Elimination of certain waste takes place through the stomata and lenticels. The main waste products of plants are water from transpiration and guttation, carbon (IV)

oxide from respiration at night when photosynthesis is not taking place and oxygen from photosynthesis during the day.

Other waste products of certain plants are

1. **Tannins:** These are stored in the leaves, bark of many trees and unripe fruits found in *Acacia* and red mangrove. Tannin is used for tanning of leather.
2. **Gums:** Gums are produced by certain species of *Acacia*. They are used in production of emulsions.
3. **Mucilage:** This is produced by certain **algae, okro** and other members of the family of **Malvaceae.** Mucilage is used in the production of emulsion and gum.
4. **Latex:** This is a milky exudate found in the bark of plants such as **rubber trees,** *Allamanda* and *Euphorbia*. Latex is used in the making of tyres, tubes and balls.
5. **Resins:** These are produced by conifers and other trees. It is the main raw material for the production of **shellac** and **turpentine** used as solvents.
6. **Alkaloids:** These are complex nitrogenous compounds found in the barks and leaves of some plants. Alkaloids include the following:
   (i) **Quinine:** This is found in the bark of **cinchona** and **nim trees.** Quinine is used in making anti-malaria drugs.
   (ii) **Nicotine:** Nicotine is found in the leaves of tobacco plants.
   (iii) **Morphine:** It is found in the immature fruits of opium poppy.
   (iv) **Cocaine:** This is found in the leaves of *Erythroxylon coca.*

## Stomata

Stomata are openings in the epidermal layer of leaves of plants. Two guard cells surround each stoma. The guard cells are bean-shaped. The inner cell walls of the guard cells are elastic and thicker than the outer cell walls. This enables the guard cells to change in shape thus allowing opening and closing of the stoma. Stomata are frequently found on leaves and aerial parts of stems and branches in herbaceous plants. Guard cells contain chloroplasts and carry out photosynthesis for the plants.

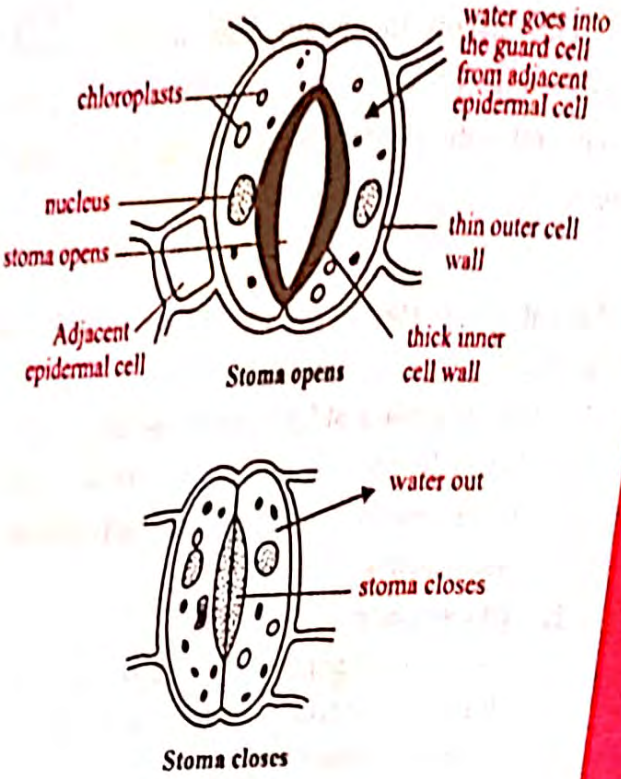



**Figure 9.8. The structure of stomata**

## 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. Variations in turgor pressure change the shapes of the guard cells.

### 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 the adjacent epidermal cells into the guard cells by osmosis. The guard cells become turgid. The pressure resulting from the turgidity causes the bulging of the thinner cell walls to press into the adjacent epidermal cells. This causes the thicker inner cell walls to assume crescent shape and thus opening the stomatal pore.

### 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 the adjacent epidermal cells.

This makes the guard cells to shrink and becomes flaccid due to loss of water causing the inner cell walls to straighten and close the stomatal pore.

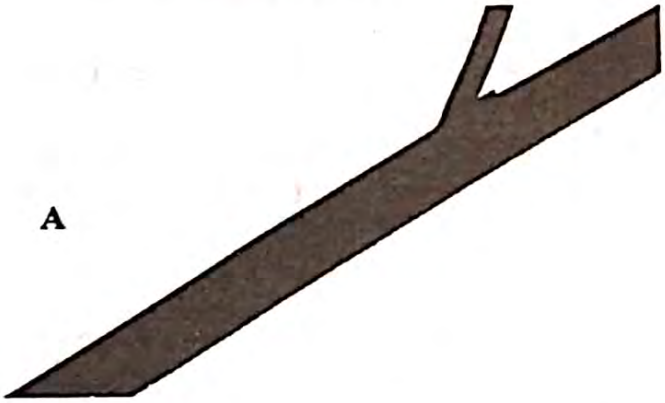
**Factors that lead to the opening and closing of stomata**

1. **Concentration of Carbon (IV) oxide ($CO_2$)**
   When the concentration of carbon (IV) oxide 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 prevents inhibits the action of enzymes that digest starch to sugar. However, starch in the guard cells makes 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.

## Lenticels (breathing pores)

Lenticels are small openings found in the epidermis or bark of woody stem through which gases are exchanged between the internal tissues and the atmosphere. Under each lenticel, are cork cells that are loosely arranged with many intercellular air spaces betweenm them.

Cork cambium gives rise to cork cells. The cork cells are dead and lined with a waxy material called **suberin** so that the loss of water from the plant is greatly reduced. Lenticels remain open throughout the life of the plant.



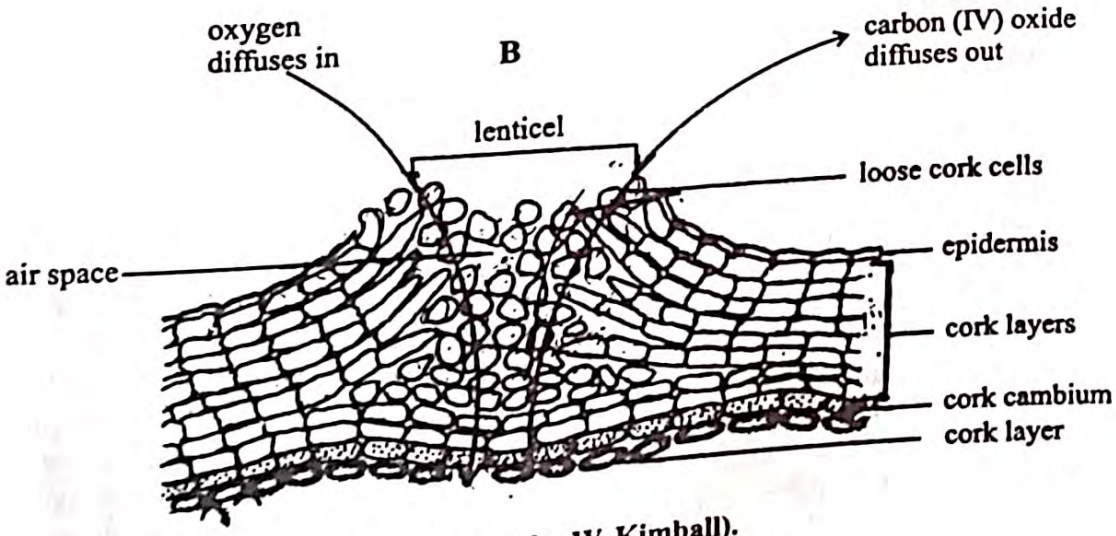




**Figure 9.9. (After John W. Kimball).**
**A = Lenticels in the bark of a young stem**
**B = The structure of lenticels.**

**Table 42: Differences between transpiration and excretion.**

| | Transpiration | Excretion |
|---|---|---|
| 1. | Occurs in plants only. | Occurs in both plants and animals. |
| 2. | Water in form of vapour is lost. | Water, urea, carbon (IV) oxide, salts and dyes are lost. |
| 3. | The rate of transpiration is faster in a sunny day. | The production of urine is faster in a cold day but sweat production is faster in sunny day. |
| 4. | Occurs only in the day. | Occurs both day and night. |
| 5. | Wind and light affect its rate. | Wind and light do not affect its rate. |
| 6. | It is responsible for the uptake of water and mineral salts to the leaves. | Does not affect water and salt absorption. |
| 7. | Brings cooling effect on the leaves or plants. | Does not cool the body except the evaporation of sweat from skin of mammals which brings cooling effect. |
| 8. | Takes place through the stomata or lenticels or epidermais. | Takes place through the skin, kidneys, lungs or stored in plants. |

## REGULATION OF INTERNAL ENVIRONMENT (HOMEOSTASIS)

**Homeostasis** is the regulation of the internal environment of the body so as to maintain a steady state by self-regulating adjustments. This self-regulating adjustment provides optimum conditions for normal and efficient functioning of the body cells, thereby preventing the damage of cells. Homeostasis takes place at all levels of living organisms. In one celled-organisms such as *Amoeba* the adjustment involves the whole body using contractile vacuole to collect and expel excess water while in higher animals such as mammals, the adjustments are at the tissue, organ and system levels. Survival of all organisms depends upon these self-regulating adjustments.

Some homeostatic mechanisms which the mammalian body (e.g. human body) carry out include: **osmoregulation (control of water balance), excretion (control of waste nitrogenous product), acid-base balance (pH)** and **thermoregulation (control of body temperature).**

Structures that carry out these homeostatic mechanisms mentioned above are **kidneys, liver** and **skin.**

### Kidney

Detailed structure of mammalian kidney has been discussed in **page 190.**

### Functions of kidney

**Osmoregulation (water balance in the body)**

Our bodies get water from the different liquids (e.g. Water) food and water produced during respiration.

***Osmoregulation is the process by which a living organism balances the amount of water to mineral salts in its body fluids.*** If a person drinks small quantity of water and at the same time is losing

water through sweating, the body starts conserving water.

***Little water in the body (Dehydrated body)***

If a persons drinks small quantity of water and at the same time losing water through sweating such as during exercise, the body starts conserving water to prevent damaging the body cells due to loss water from them. The osmotic pressure of the blood changes. Osmoreceptors (special receptors in the hypothalamus in the brain) detect changes in the osmotic pressure in the blood as the water content of the blood drops. The pituitary gland is stimulated to release more ADH ( anti-diuretic hormone) into the blood, thus making the walls of the kidney tubules more permeable to water and so more water is reabsorbed into the blood by osmosis. Less water is then lost from the body as concentrated urine through the bladder.

***To much water in the body (Hydrated body)***

When there is too much water in the body, the osmoreceptors in the hypothalamus in the brain are stimulated to release less ADH into the blood making the walls of kidney less permeable to water and so less water is reabsorbed into the body by osmosis. Large quantity of water is then present in the urine which is frequently passed out from the bladder as dilute urine. People frequently pass urine in a cold weather and rainy day because the body loss very little or no water through the skin by sweating.

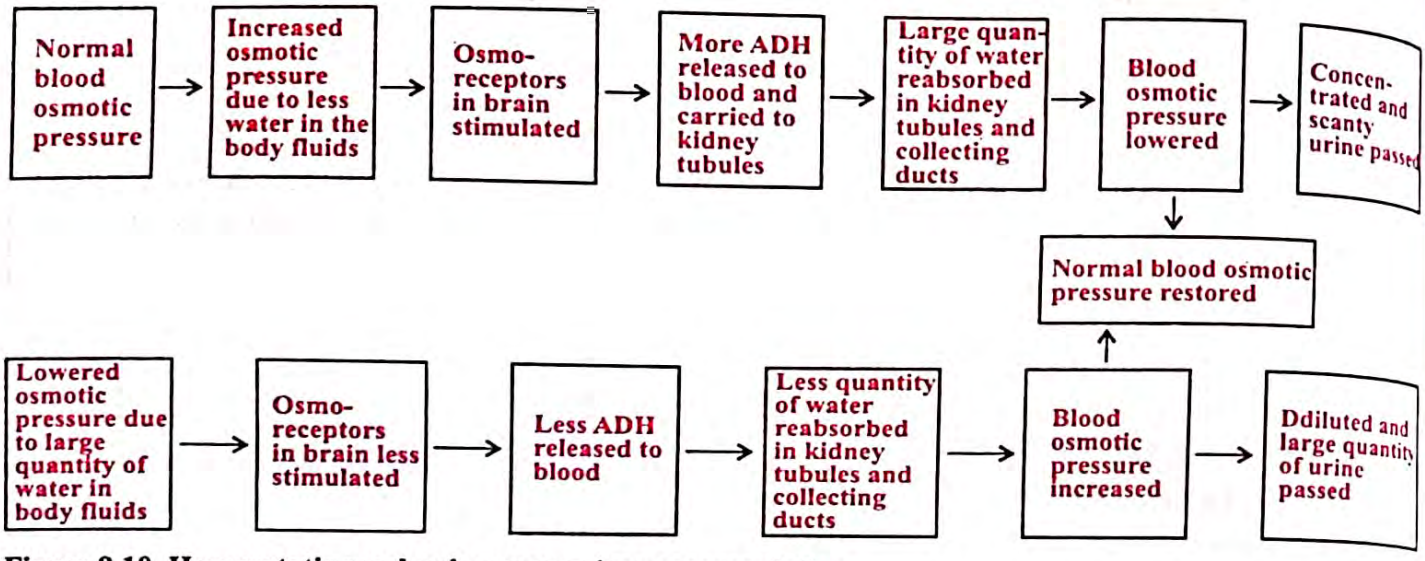



**Figure 9.10. Homeostatic mechanism governing osmoregulation.**

2. **Excretion** is the removal of waste products of metabolism from the body. Excretion has been discussed.
3. **Acid-base balance (pH).** The acid-base balance of the body fluids is maintained by the kidneys. The pH of human blood is between 7.35 and 7.45. Anything below or above this range is dangerous to the body.

The body fluids contain some little amount of acids. These acids mostly come from the food we eat and carbonic acids produced by the cells during respiration. The carbon (IV) oxide from respiration combines with water in the cell to form carbonic acid [tri-oxo-carbon (IV) acid].

$$2CO_2 + 2H_2O \longrightarrow 2H_2CO_3$$

Carbonic acid

If the acid content of the blood gets higher, the cells of the second convoluted tubules reabsorb more hydroxyl ions ($OH^-$) from the urine and more hydrogen ions ($H^+$) are therefore excreted with the urine. On the other hand, if the hydroxyl content of the blood gets higher, less hydrogen ions are produced by the cells of the second convoluted tubules while more hydroxyl ions are produced and excreted with the urine. In this way, the **acid-base balance** of the body is maintained.

4. Kidneys eliminate undesirable substances such

as drugs, alcohol and toxins.

They help to maintain the osmotic pressure of the blood.

## Diseases of the kidney

### Nephritis

### Causes

1. **Streptococcus** infection in the throat, ears, nose or elsewhere. The poison produced by the germs when carried by blood to the kidneys damage the glomeruli.

### Effects

1. Glomeruli become inflamed causing them to be more permeable than normal.
2. Puffiness in the face.
3. Watery swellings in the feet and ankles. This condition is known as **oedema.**
4. Kidney becomes swollen.
5. Dizziness, fatigue, high blood pressure convulsion, back pains, headache, fever and vomiting may result.
6. Proteins and blood cells pass into the urine.

### Remedy

1. All food items must be properly washed or well cooked.
2. Drinking water must be properly boiled an filtered.
3. Dialysis machine (artificial kidney) for filtering out waste from patients blood and body fluid.

### Dialysis machine (artificial kidney)

The patient's blood is passed through a dialysis machine by tubes which convey his blood through the machine and back to his body. As the blood passes through the machine, waste products pass into fluid of the machine. Patient needs to go through this procedure several times a week in order to purify his blood. It must be noted that dialysis machines are expensive and few in Nigeria.

4. **Kidney transplant**

This is a surgical process of replacing a damaged or non-functioning kidney with a healthy kidney. Healthy kidneys are got from donors. In most cases, the recipient=s body (patient) may reject the transplanted kidney as the recipient immune system recognises the transplanted kidney as a foreign body and starts destroying it.

However, there are good drugs which help in suppressing the patient=s immune system from rejecting the transplanted kidney. It is interesting to note that a transplant between identical twins has no problem.

## Kidney stones

### Causes

Some of the tiny solids (e.g. calcium phosphate) present in urine are not very soluble. These tiny solids under certain conditions are precipitated in the nephrons into **kidney stones.** When the **kidney stones** become too large, they block the nephrons thereby disturbing the free flow of urine.

### Effects

1. Passing urine is with great difficulty.
2. Severe abdominal pains.
3. High blood pressure may be experienced.

### Remedy

1. Drink sufficient water and other fluids such as fruit juices specially during hot weather so as to prevent the urine from becoming over concentrated. Over concentrated urine may lead to precipitation of kidney stones. Sufficient water in the body helps to flush out unwanted waste products and salts.
2. Avoid food items that are hard to digest.
3. Avoid excessive intake of food containing calcium.

4. **Drugs:** Some drugs are capable of dissolving kidney stones. The drugs have to be recommended by a qualified medical doctor.
5. **Surgery:** If drugs fail, surgery is performed to remove the stones.

## Diuresis

**Diuresis** is the removal of excess watery urine from the body through the kidneys. The situation occurs when the kidney tubules fail to reabsorb water from the glomerular filtrate back to the blood.

## Causes

1. Diseases such as diabetes insipidus and pituitary disease.
2. Lack of a hormone called aldosterone causing excess sodium ions to be excreted.
3. Drinking of excessive alcohol.
4. Drugs such as lasix when given to patients suffering from oedema causes diuresis.
5. Heart failure, renal failure and kwashiokor cause diuresis.

## Effects

1. Thirst and dehydration occur due to excess removal of body fluids.
2. High blood pressure may occur.
3. It can lead to loss of serum electrolytes from the body.
4. Loss of appetite, weakness, fatigue and nausea. Death eventually occurs if not treated.

## Remedy

1. Do not use fans and air conditioners in cold weather.
2. Avoid excessive drinking of alcohol.
3. Diabetic patients should be treated with insulin.
4. People lacking ADH and aldosterone should be treated.
5. Kidney transplant.

## Liver

The liver is the largest gland in the body. It is dark-red, spongy and lobed.

The lobes are: **caudate lobe, left lobe, right lobe** and **median lobe**. It is hung from the posterior surface of the diaphragm by a ligament and partly overlaps the stomach. Underside of the right lobe is a gall bladder containing liquid called **bile**. Attached to the gall bladder is a **bile duct** which leads from the liver to the **duodenum**. Blood is supplied to the liver by the **hepatic artery** and **hepatic portal vein**. Hepatic vein carries blood away from the liver. See figure 6.46 on page 127. The role of liver in homeostasis has been stated in its functions on page 128.

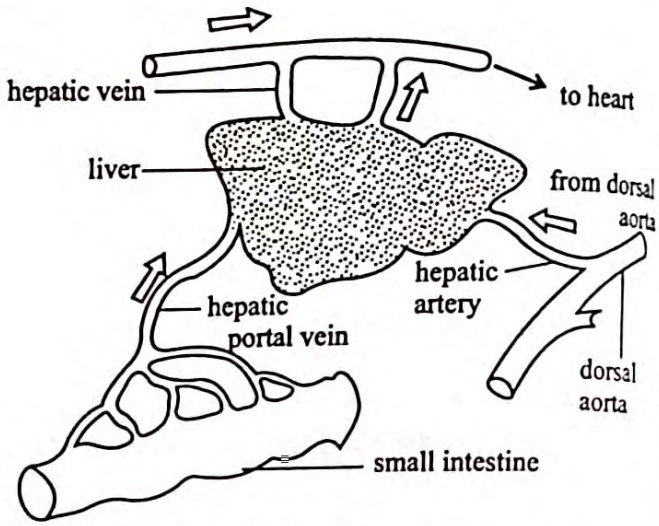



**Figure 9.11. The blood vessels serving the liver.**

## Functions of liver (refer to page 126)

## Table 43: Diseases, their effects and remedies

| Disease | Causes | Effects | Remedies |
|---|---|---|---|
| **Infectious hepatitis (catarrhal jaundice)** | 1. Filtrable virus.<br>2. Contamination of food and water by the virus.<br>3. Faeces of infected person may be carried to our drinking water or food by flies or other agents. | Loss of appetite, nausea, weakness, fever, headache, diarrhoea, abdominal discomfort, pains, eyes and skin turns yellow. | 1. Fruits and vegetables must be properly washed with clean water.<br>2. Drinking water must be boiled and filtered.<br>3. Faeces of infected person must be buried.<br>4. Flies should be kept<br>5. Away from our food. Bed rest. See a medical doctor. |
| **Gall stones** | 1. Over concentration of the bile leading to solidification of substances and consequently blocking the bile duct and preventing bile from reaching small intestine. Also cholesterol in the bile crystallises to form stones.<br>2. Over weight.<br>3. High concentration of bilirubin in the bile. | 1. Abdominal pains, chills and fever, signs of jaundice (skin and eyes yellow).<br>2. May lead to cancer of the liver. | 1. Drinking sufficient water or fruit juices.<br>2. Reduction of cholesterol intake.<br>3. Over weight must be avoided. |
| **Cancer of liver** | 1. Dietary deficiencies.<br>2. Cancer cells from elsewhere in the body come to affect the liver cells. | 1. Indigestion or change in bowel habits.<br>2. Loss of weight, weakness and anaemia, jaundice, fluid in abdomen, and frequent chills, fever and pains. | 1. Sufficient rest and care are essential to reduce the progress of the disease. Eating balanced diet.<br>2. See medical doctor.<br>3. Regular medical examination at least once a year. |

### Skin

The entire surface of the body is covered with skin. In man, the skin is about 1 to 2mm thick except the skin of the palm and soles with thickness of about 6mm. The skin is the most extensive organ in the body.

The mammalian skin consists of two major layers: the **outer epidermis** and **inner dermis**.

### Epidermis

This is further divided into three layers known as **cornified, granular** and **malpighian layers**.

### Cornified layer

This is the upper-most layer of the skin and consists of flat dead cells. Cornified layer protects the body against loss of water and entering of foreign bodies. It protects the under lying layers from excessive harmful radiation of the sun.

### Granular layer

Contains living cells. It lies just beneath the cornified layer. The cells become gradually thickened and longer until they are given up to the cornified cells.

## Malpighian layer

This is a layer of living cells and where active cell division takes place. This layer contains **dark melanin pigments** which give the skin its colour. Black people have more melanin pigments than white people. Oriental people have an additional pigment, carotene making their skin yellowish. Melanin pigments are absent in albinos.

As the cells of the malpighian layer divide, they are pushed up. As they move up, they become filled with a substance called **keratin** and become flat and dead, thus forming the cornified layer.

## Dermis

The dermis lies below the epidermis. It is a thick layer of connective tissues. This layer consists of blood vessels, sweat glands, sebaceous glands, hair follicles, erector muscles and sensory cells.

## Blood vessels

Blood vessels supply food and oxygen to the tissues of the skin. The flowing of blood in the capillaries helps to determine the amount of heat that is lost from the skin surface by radiation and convention.

**Sweat gland** is a coiled tube becoming straight as it passes through the dermis and slightly drawn into folds as it goes through the epidermis. It opens onto the surface as a pore. The sweat gland is well supplied with blood capillaries. As blood flows through the blood capillaries, waste products such as water, sodium chloride, small amount of urea are absorbed by the sweat gland. From the sweat gland, the wastes are secreted to the sweat duct and finally to the sweat pore. It secretes waste products in form of sweat from the body. When sweat evaporates from the skin, it has a cooling effect on the body. It is also greatly concerned with temperature regulation.

## Sebaceous gland

Each hair follicle is supplied with at least two sebaceous glands.

Sebaceous glands secrete oily substance (sebum) which lubricates the hair and keeps it flexible. The sebum contains **lysozyme** which kills bacteria and viruses.

## Hair follicle

Each hair lies in a deep pit called hair follicle. The part of the hair that projects out of the skin is called **hair shaft**. Erected hair shafts trap a layer of air between them to prevent heat loss by convention. A hair is made up of **keratin**. Hair takes part in temperature regulation. The root of each hair is situated deep in the dermis, but the hair is an epidermal structure. The cells of the hair follicle produce the hair. Hair is produced by follicle.

## Sweat pore

Sweat pore is an opening through the skin by which sweat reaches the skin surface from the sweat gland.

## Hair erector muscle

This is a slender muscle which runs from each side of the hair to the base of the Malpighian layer. The contraction of muscle makes the hair to stand up-right and its relaxation flattens the hair. It is concerned with temperature regulation.

## Hair shaft

Hair helps to trap still air to prevent lose of heat by convention.

## Fatty (subcutaneous) layer

The fatty (subcutaneous) layer lies below the dermis and mainly made of fatty cells.

## Fatty cells (adipose tissue)

These cells are formed below the dermis. They are round in shape. Fatty cells act as insulating layers against heat loss. They also act as energy reserve and protect the skin from mechanical damage.

## Sense receptors

There are five sense receptors in the skin namely: **touch, pressure, pain, heat** and **cold receptors**. Each receptor is sensitive to a particular type of stimulus.

## Connective tissue

Between the Malpighian layer and fatty cells is the **connective tissue**. The connective tissue holds the different component of the skin together.

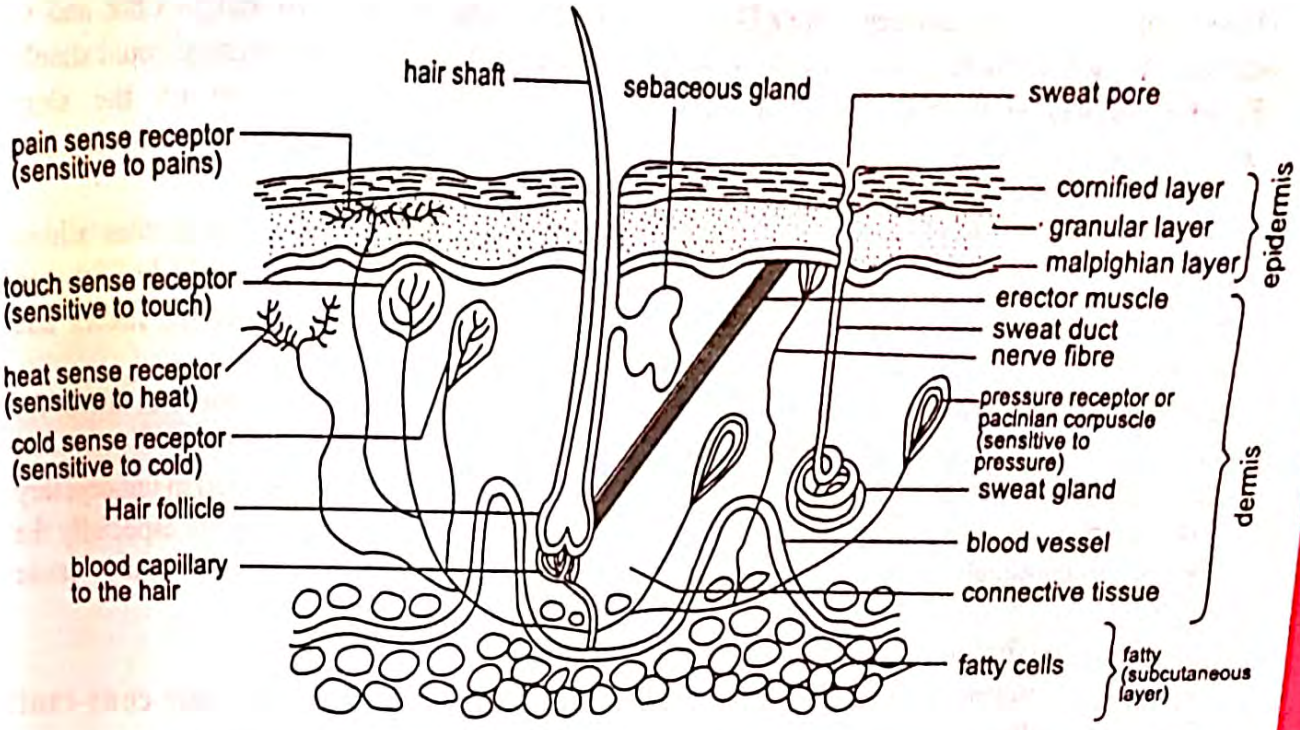



**Figure 9.12. Vertical section of a human skin.**

## Functions of the skin

1. **Protection:** The skin protects the body in the following ways:

(a) The skin covers and holds the body together.

(b) It forms barrier between external environment and the tissues below.

(c) Prevents harmful bacteria from invading the tissues. The sweat and sebaceous glands have certain constituents e.g. (Iysozyme) in them that are antagonistic to invading bacteria.

(d) Protects the body to some extent from physical injuries.

(e) It prevents the tissues from drying up.

(f) Melanin pigments prevent the ultra-violet rays from damaging the under-lying tissues.

(g) In some mammals such as porcupine, the hairs are modified into thick sharp spines that protect the animal from attack by predators.

(i) The hairs of many mammals have different colours and patterns, that camouflage the animals in their surrounding, making them difficult to be seen by their predators.

2. **Sensitivity**

The skin contains different sense receptors which are sensitive to different environmental stimuli. The body can therefore react to changes in the environment. For example, on touching a hot object you quickly withdraw your hand to avoid burning injury.

3. **Excretion and osmoregulation**

The sweat glands excrete surplus water containing salts and some little amount of waste nitrogenous substance (mainly urea).

4. **Maintenance of a suitable constant body temperature**

Maintenance of a suitable constant body temperature is very important to mammals and birds, since their metabolic activities are tied to a constant temperature. These animals are known as **warn blooded animals** or **homoio-thermic animals.**

No matter the external changes in tempera-ture, the body temperatures of mammals and birds remain the same. The constant body temperature in man is 98.4°F (37°C). This is the temperature at which our body enzymes work best. Above this temperature may destroy enzymes while below enzymes may be inactive.

The heat gained must be equal to heat lost. Other animals such as fish, amphibians and reptiles are **cold blooded** or **poikilothermic** since their body temperature changes with external temperatures.

5. The skin manufactures and stores vitamin D.
6. **Storage of reserved food**
   Fats are stored under the dermis. The fats form an insulating layer.
7. Nails, claws, hoofs, horns and scales are outgrowths of skin.
   **Nails** give extra support to the fingers so that they can hold or grasp things well. Nails are also used in scratching the skin.
   **Claws** are mostly used by carnivores such as cats and lions as weapons of defence, offence and for catching their prey.
   **Horns** are used as weapons of offence and defence in mammals such as cows, deer, goats and rams.
   **Scales** protect the body of some mammals (e.g. pangolin) from losing water. They also protect the inner organs.
8. The mammary glands in mammals are modification of the skin. They help to produce milk for feeding the young.
9. **Flight:** The forelimbs of bats is made of a leathery skin and muscle stretched over the bones of four fingers for an efficient flight. Bats are only mammals that fly.

## The care of the human's skin

1. Bathe regularly with soap to remove dirts, sweat and natural oils from the skin. This prevents bacteria, fungi, mites and dust from sticking to the skin and blocking the sweat pores. Dirty skin causes diseases such as yaws, tinea and scabies. Do not bathe with harsh soap.
2. Dry the washed body with clean towel.
3. The feet must be washed frequently and cleaned with towel. Wearing clean stockings helps to absorb sweat from the clefts of the toes. Sweat staying in between toes inhabits fungus which causes tinea.
4. Wearing of shoes prevents hookworms and jiggers from infecting the skin and its underlying tissues.
5. The skin must be kept moist always by using good creams especially during the harmattan period to keep the skin soft and flexible and to protect it from cracking. On no account should bleaching creams be used on the skin. Bleached skin is proned to skin infection and cancer.
6. Wearing clean light and loose clothes allows free circulation of air round the body. Dirty and heavy clothes cause discomfort, rashes and fungal infections of the skin.
7. Report any skin disease to a medical doctor for treatment.
8. The skin should not be exposed to unnecessary direct radiation of the sun more especially the albinos. Direct hot sunlight may cause sunburns.

## How mammals maintain their cons-tant body temperature

1. **In hot weather**
   In a hot weather, the body temperature goes up. The following happens to maintain a constant body temperature.

(a) **More blood flows to the surface of the skin:** The blood vessels in the skin dilate. More blood flows to the surface of the skin. The flow of blood stimulates the sweat glands to produce more sweat which is poured to the surface of the skin. The sweat evaporates thus producing cooling effect since the latent heat of vaporisation required to evaporate the sweat comes from the body. Failure of the skin to keep the body at constant normal temperature during hot weather leads to **hyperthermia**, heat stroke and death occurs.

(b) **The hairs are lowered:** The erector muscles of the hairs relax thus lowering the hairs and therefore the layer of air between the hairs and the skin is thin. This thinness of air allows more heat to be lost from the body (Note, air is a poor conductor of heat and if a thick layer of air is trapped more heat will be retained in the body).

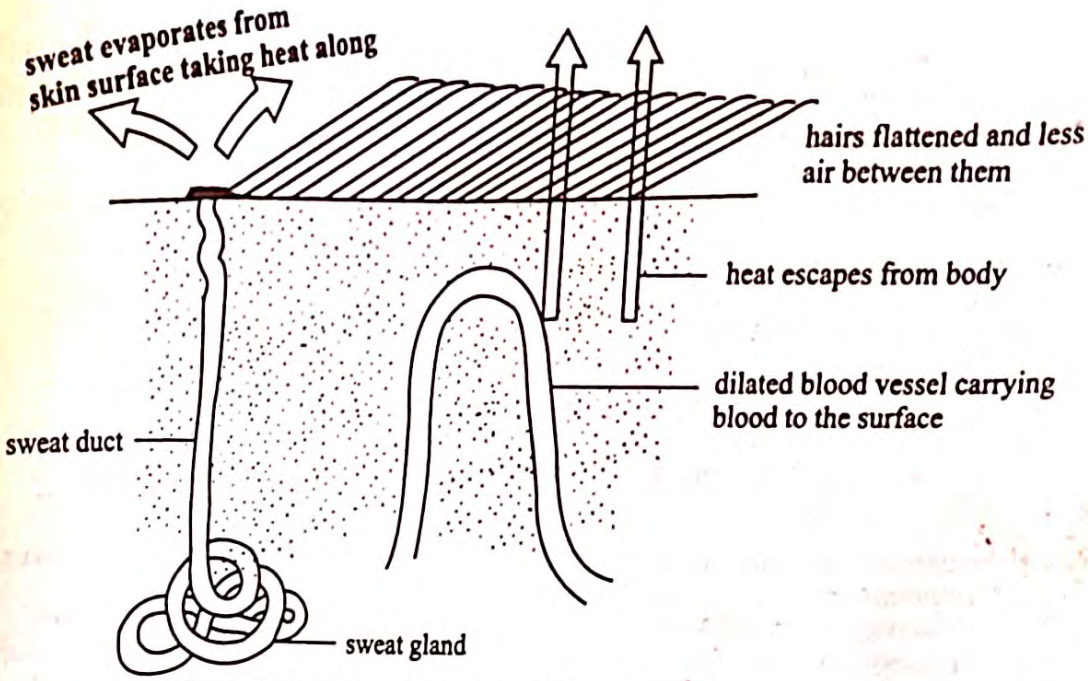



**Figure 9.13. The effect of hot weather on the skin**

**2. In cold weather**

In a cold weather, the body temperature is lowered and the following happens to maintain a constant body temperature of 98.4°F (37°C).

(a) **Less blood flows to the surface:** In a cold weather, the blood vessels constrict, therefore, less blood flows to the surface of the skin; less sweat is produced by sweat glands. Little latent heat is lost from the body and therefore less heat is lost from the body. That is why people are pale in cold weather.

(b) **The hairs stand erect:** The erector muscles of the hairs contract making the hairs to stand erect. A layer of thick air is trapped between them. Air being a poor conductor of heat insulates the body and less heat is lost by conduction, convection and radiation. Failure of the skin to keep the body at constant normal temperature during cold lead to **hypothermia.** Death occurs by frost bite.

(c) **Shivering:** When the body temperature is low, some involuntary muscles contract and relax continuously, thus producing heat. This is circulated to all parts of the body by the blood stream and helps to raise the body temperature.

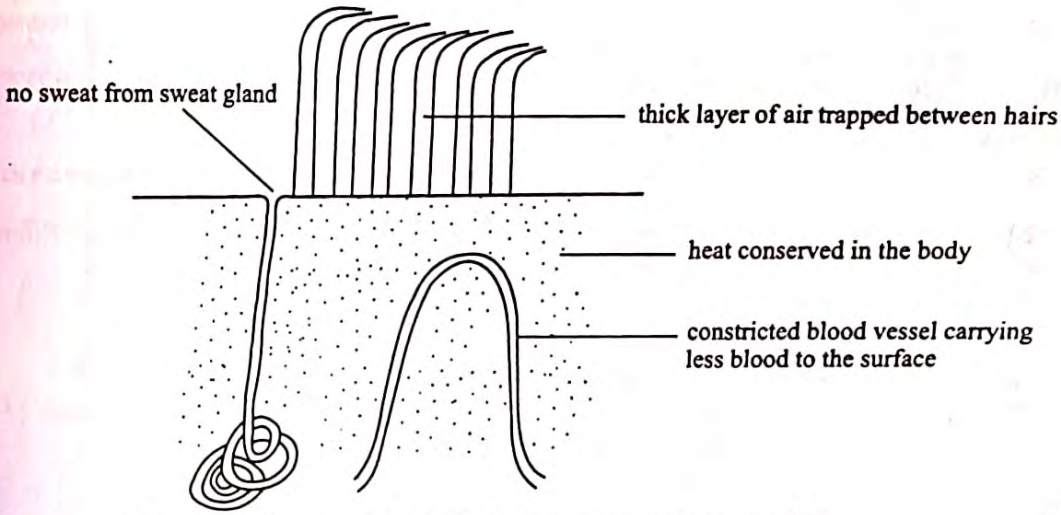
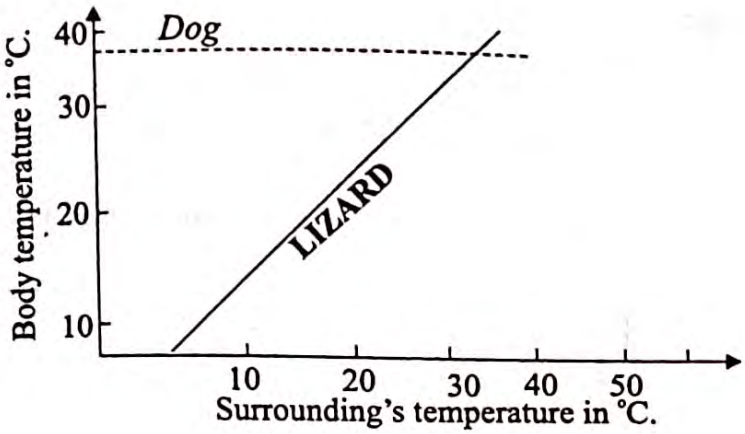



**Figure 9.14. Diagram showing the effect of cold weather on the skin**

## Questions




1. *Study the above graph carefully and answer the questions that follows: The graph shows the effect of habitat temperature on the body temperature of animals.*
   - (a) *What explanation can you give in the graph about the body temperature of: (i) Dog (ii) Lizard?*
   - (b) *Activity of the body depends on the chemical changes taking place in it. These changes often slow down when the temperature is low in the case of a lizard. When do you think a lizard would be difficult to catch, 6 a.m or 1p.m? Give reasons.*
   - (c) *Which of the two animals is: (i) Poikilothermic: (ii) Homoithermic: (iii) Name one other group of animals belonging to (i) and (ii). The groups of dog and lizards are excluded.*
   - (d) *Is it correct to say that lizard is a Aslave@ to its environment? Give reasons.*
     *(iii) What type of blood is carried by structures 1 and 2?*
     *(iv) Name the solution which collects in structure 8 and name three substances found in the solution.*
   - (e) *In a tabular form, what are the causes, effects and remedies of the following kidney diseases:*
     *(ii Nephritis.*
     *(ii Kidney stones?*

2. (a) *(i) Why is it necessary for a mammal to dispose of waste materials?*
   *(ii) Give examples of the processes and products involved in the disposal of these waste products.*
   - (b) *With the aid of annotated diagrams, describe the micro-anatomy of a mammalian nephron (uriniferous tubule) and its blood supply.*
   - (c) *Explain carefully how the nephron carries out its various functions (OXF) with malfunctioning of liver?*

3. (a) *Name eight excretory structures or organs that exist in living things and give an example of the living thing in which the excretory structure or organ is found.*
   - (b) *State how the excretory organs of a mammal and earthworm are similar and different.*
   - (c) *(i) Describe the mechanism of the opening and closing of stomata.*
     *(ii) State three factors that lead to the opening and closing of stomata.*

4. (a) *Define diuresis.*
   - (b) *State the causes, effects and remedy of diuresis.*
   - (c) *State three ways in which animals and five ways in which plants are adapted to dry condition. Give one example in each case.*

5. (a) How are excretory products removed in (i) Amoeba and (ii) earthworm.
(b) The main excretory products of freshwater fish is ammonia and that of a terrestrial mammals is urea. How does the difference in excretory products relate to their environments?

6. Explain the following phenomena shown by the human body.
(a) Violent exercise results in a rise in body temperature accompanied by noticeable sweating.
(b) Shivering when we are cold.
(c) Keeping cool in hot countries by wearing loose-fitting, light coloured clothing.
(d) The formation of >goose pimples= on the skin when cold. (Oxf)

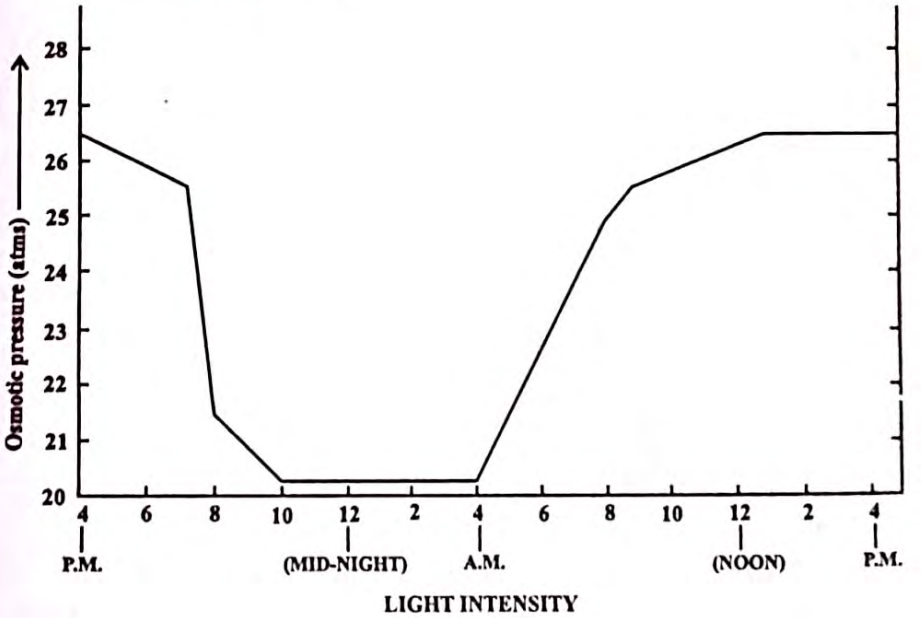
7. (a) Briefly explain the term homeostasis.
(B) Describe the structure of the mammalian skin and state its functions.
(C) How do you take care of your skin?

8. (a) Name five areas of the mammalian skin in which sweat glands and hairs are absent.
(b) What are the differences and similarities between the mammalian skin and the epidermis of the leaf of a flowering plant?
(c) Describe how the skin of a toad or frog is adapted for respiration.

9. (a) Describe the external appearance and the position of the liver within the body of a named mammal. Diagram essential and must show the relationship between duodenum, stomach, gall bladder and pancreas.
(b) What part does the liver play in the life of this animal?
(c) In a tabular form, state the causes, effects and remedies of the following liver disease: infectious hepatitis, cancer and gall stones.

10. (a) Describe the process of osmoregulation in
(i) a named unicellualr organism.
(ii) man
(b) Describe how the mammalian skin can react to regulate the body temperature in a hot room. (S.S.C.E. 1996).

11.



*The graph above shows the daily variation in the osmotic pressure of the leaves of a green flowe plant. Study the graph carefully and answer the questions below:*

(a) *Explain curves (i) A and B (ii) C and D and (iii) D and E.*

(b) *What general conclusion would you make from the result of above graphs.*

(c) *How does the variation in the osmotic pressure of the leaves affect (i) the stomata? the rate of transpiration?*

(d) *Give two more factors, other than that shown in the graph, which affect the opening closing of the stomata.*

# 10

# NERVOUS COORDINATION (NERVOUS SYSTEM)

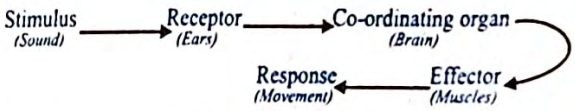
All the systems in the multicellular organisms work together as a team. No system should be independent if the body is to function properly. Therefore, a part or some parts must act as coordinator of the activities of the systems. Multicellular organisms will not be able to exist if all the parts are not coordinated. **Information** (messages) must pass to the coordinator from various parts of the organisms and from the external environment which continues to change. Information received must be sent from the **coordinator** to other parts of the organisms for **response**.

For example, athletes are getting ready to run a 400 metre race. The starter commands them to get set.

The gun is fired and the race starts. The ears pick the sound and transmit the impulse to the brain.

The brain interprets the impulse and relays the response to the **muscular system**. The muscular system is set at work, contracting and relaxing to give the body the desired speed. Muscular activities require energy. Therefore, breathing is increased to take in more oxygen for respiration and consequent release of energy. At the same time more carbon (IV) oxide is released. The heart beats faster to send more blood containing glucose and oxygen to the muscles for faster contraction.

More glycogen is converted to glucose to meet the energy requirement of the body. The athlete sweats profusely in order to cool the body from the heat generated by muscular activities. At the end of the race, the body starts recovering gradually, and eventually breathing and heart rates return to normal. The order of events is as follows:




Respiratory, circulatory, muscular, skeletal and excretory systems work together as a team under the control and coordination of nervous and endocrine systems.

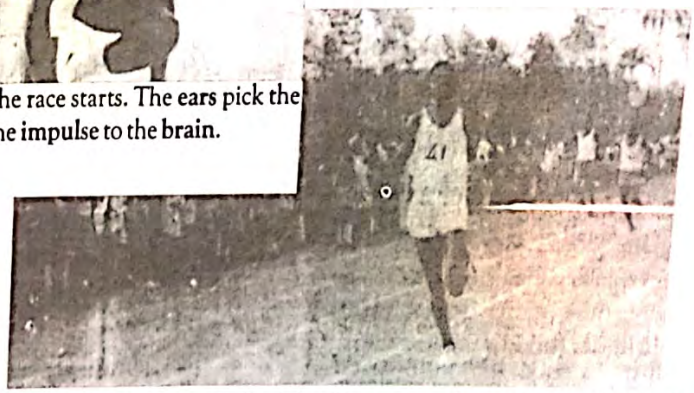


**Figure 10.1.** The author (representing Hussey College) finishing 440 yards during Zone F Grier Cup athletic competitions at Hussey College ground, Warri, 1966.

## Nervous system

The nervous system consists of brain, spinal cord and nerves. It receives stimuli, process, responds, and co-ordinates the activities of the body.

The nervous system is divided into two parts namely: **Central nervous system, and peripheral nervous system.**

### The central nervous system

This consists of the **brain** enclosed in the **cranium** (brain box) and **spinal cord** which runs down the centre of the vertebral column (**back bone**).

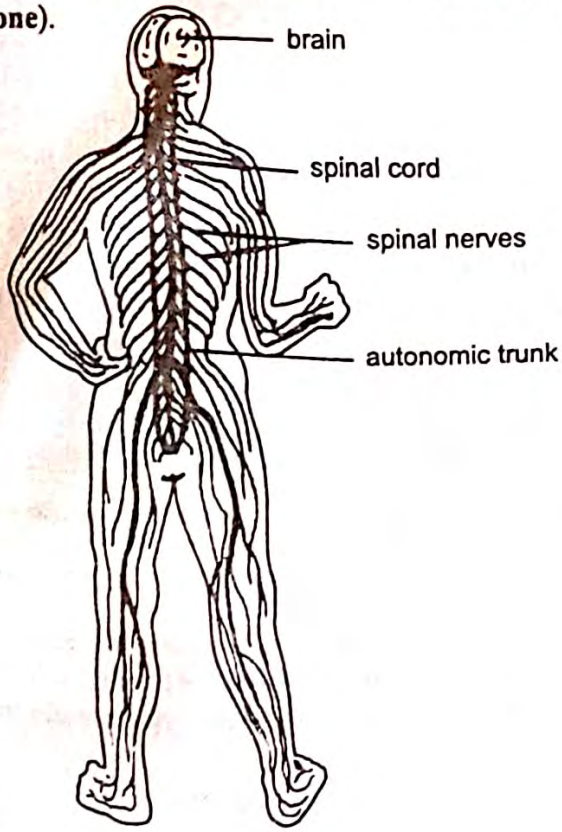
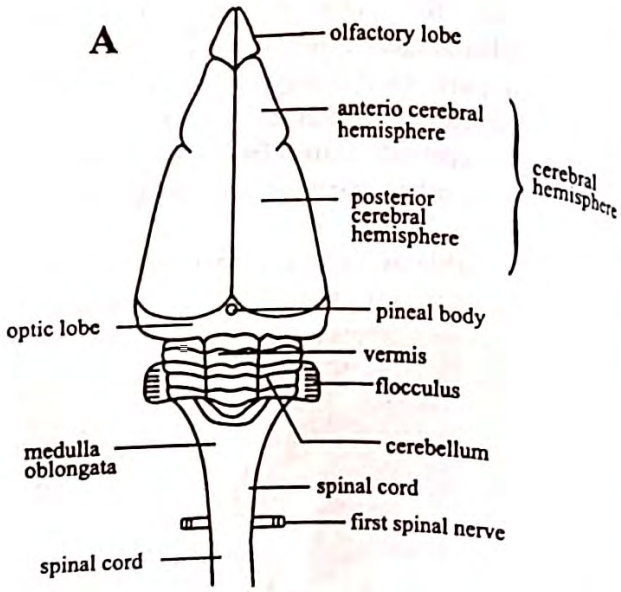


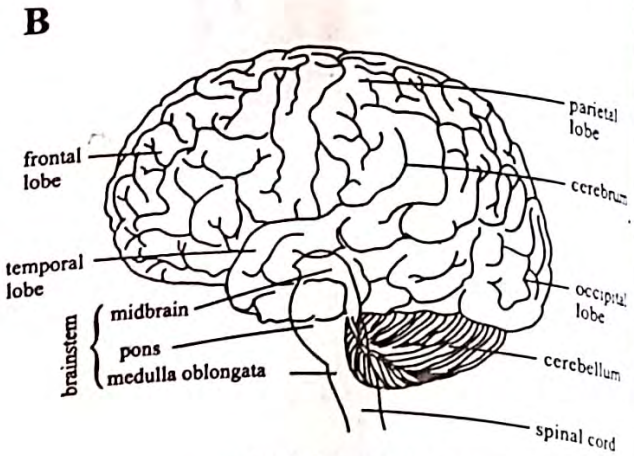

**Figure 10.2. The central nervous system of a man.**

### Brain.

The brain is the most specialized organ of the human body weighing about 1.4kg. It is composed of millions of nerve cells called **neurons.** Three membranes namely: **dura mater, (outer membrane), arachnoid mater (middle membrane)** and **pia mater (inner membrane)** cover the brain. These three membranes are collectively called **meninges.** The **dura mater** is strong and thick and protective in function. The **arachnoid mater** is made up of elastic and fibrous tissue. The **pia mater** is a delicate membrane, well supplied with blood vessels that carry food and oxygen to the cells of the brain. Between the pai mater and arachnoid mater is a space filled with **cerebrospinal fluid.**

The brain is divided into three portions namely, **forebrain, midbrain and hindbrain.**




**Major divisions of the brain**

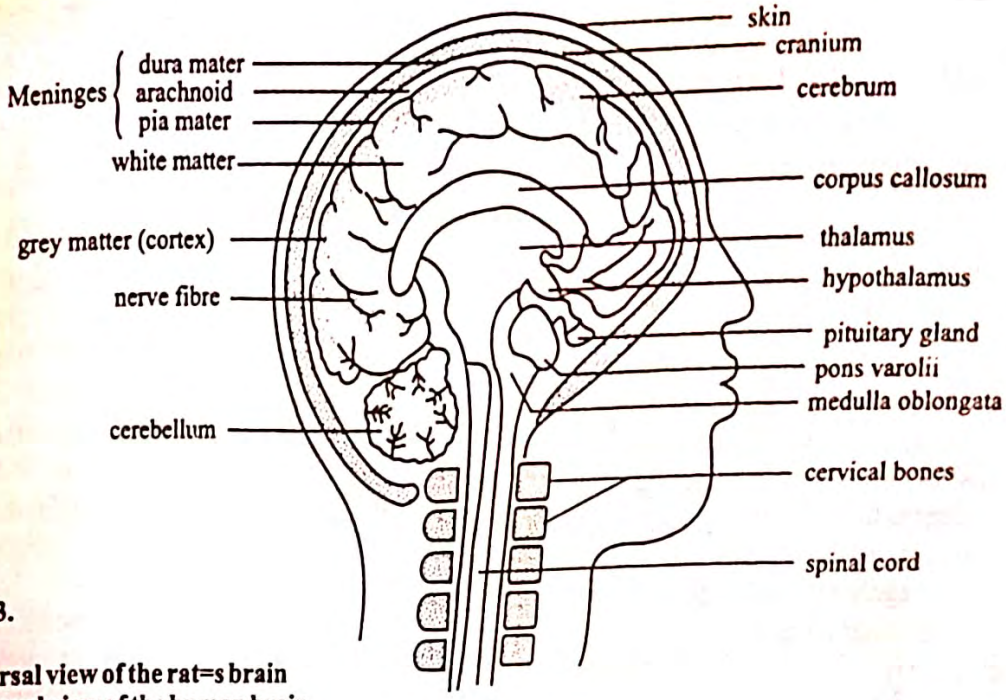



**Figure 10.3.**

**A = The dorsal view of the rat=s brain**
**B = The lateral view of the human brain**
**C = The vertical section of the human brain**

## Forebrain

Forebrain consists of the olfactory lobes, cerebrum (cerebral hemisphere), thalamus and hypothalamus.

## Olfactory lobes

These are two small structures placed anteriorly on the cerebrum.

### Function

(1) They receive sensory impulses from the olfactory organ.
(2) They are concerned with smell, thus making the animal aware of odour in its environment.

## Cerebrum

This is the largest and most dominant part of the brain. It occupies the upper portion in the brain box (cranium). It is divided into two halves or hemispheres by a **median fissure**. The two halves are connected by a band of fibres and nerves called **corpus callosum**. The outer surface of the cerebrum is called **cerebral cortex** and is deeply folded in irregular pattern or convoluted thus increasing the surface area of the cerebrum. The **cortex** consists of **grey matter** because it is made up of the grey cell bodies of neurones. The inner part of the cerebrum is made up of mass of **nerve fibres** (axons) known as **white matter**.

### Functions

1. It is the seat of consciousness, intelligence, memory, judgement, learning, interpreter of sensation and imagination.
2. It is the seat of voluntary actions.
3. It collects information from sense organs and store such information (e.g. learning and behaviour) for later use.

## Thalamus

It is located above the midbrain and contains masses of grey matter.

### Functions

1. It is the centre for sensation of pains, touch and anger.
2. Directs sensory impulses from the lower parts of the brain and spinal cord to the appropriate parts of the cerebrum.
3. It relays motor impulses to the spinal cord from the cerebrum.

## Hypothalamus

It lies below the **thalamus** and is connected to the pituitary gland. It contains reflex centres linked to the **autonomic nervous system**.

### Functions

1. It regulates the body temperature, water balance, sleep and blood pressure.
2. It is the centre of appetite. When the stomach is empty, hypothalamus is stimulated and the sensation of hunger is felt. When the stomach is full, the **satiety centre** is stimulated to stop further feeding (satiety means to satisfying one's appetite fully).
3. It is the seat of aggression and anger.
4. It controls the pituitary gland.
5. It controls speech.

## Midbrain

The **midbrain** is narrow and short (less than a centimetre) with thick walls portion which connects the hindbrain and forebrain together. It consists of the optic lobes.

### Function

The optic lobes are the seat of sight.

## Hindbrain

The **hind brain** consists of three parts namely **cerebellum, medulla oblongata** and **pons varolli.**

## Cerebellum

**Cerebellum** is sometimes called **little brain.** It lies below the back of the cerebrum, oval in shape and consists of **two hemispheres.** It is less convoluted than cerebrum and are shallower and less irregular (more or less parallel) than those of cerebrum. The surface is covered with **grey matter** while the inner side is composed of **white matter.** It is connected to the **semi-circular canals** of the ears.

### Functions

1. It is concerned with the balance and positi- ning of the body, it receives impulses from semi-circular canals of the ears, through the vestibular nerve fibre.
2. It is the coordinator of various actions of mus-cles in voluntary responses such as walking, talking and sitting.

## Medulla oblongata

The medulla oblongata connects the cerebellum to the spinal cord. It is the posterior portion of the brain. In medulla oblongata, the white matter surrounds the grey matter. It is interesting to know that it is *the medulla oblongata* that the right and left motor fibres from the brain cross over each other, so that the left hemisphere controls the right side and the right hemisphere controls the left side of the body.

### Functions

It controls respiration, heart-beat, digestive movement, size of blood vessels or supply of blood to different parts of the body, secretion of saliva, laughing, coughing, yawning and blinking of eyes. These are all **involuntary actions.**

## Pons varolli

It connects the two halves of the cerebellum and the cerebrum to the medulla oblongata. It is made up of thick bundles of nerve fibres.

### Functions

It carries impulses from one hemisphere of the cerebellum to the other thereby co-ordinating muscular movement in the two sides of the body.

## Spinal cord

The spinal cord extends from the medulla oblongata and passes through the neural canal of the back bone (vertebral column) which protects it and ends in the **sacrum.** The spinal cord is protected by three layers of meninges namely **dura mater** (outer layer), **arachnoid mater** (middle layer) and **pia mater** (inner layer). The spaces between these layers are occupied by **cerebrospinal** fluid which acts as a protective cushion. In cross section, it is divided into two portions, the **outer** and **inner portions.** The outer portion contains **white matter** consisting of bundles of axons and dentrites. The inner portion, H-shaped, contains **grey matter** is made up of intermediate neurones and cell bodies of motor

neurones. The grey matter is divided into **anterior horn** and **posterior horn.** At the centre of the grey matter is a central canal containing fluid which helps to transport food to the nerve cells.

Each spinal nerve before attaching to the spinal cord divides into **dorsal root** and **ventral root.** The dorsal root contains sensory neurones (nerve cells) and before it enters the spinal cord it forms a **ganglion** containing cell bodies of sensory neurones. The dorsal root carries impulses (messages) from the body to the spinal cord.

The **ventral root** contains **motor neurones** (nerve cells) and carries impulses away from the spinal cord to the body.

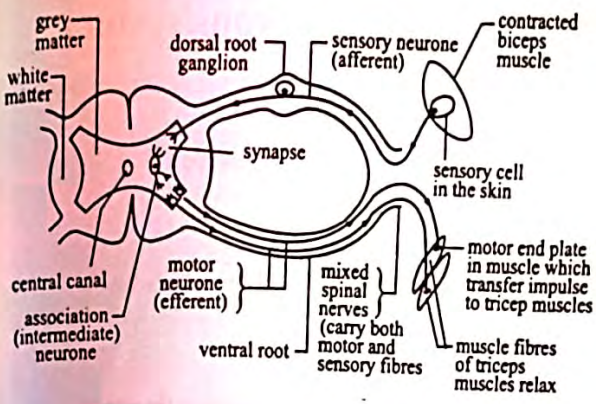



**Figure 10.4. The cross section of the spinal cord to illustrate a reflex arch of the forelimb**

## Functions of the spinal cord

1. It is the seat of reflex (involuntary) actions.
2. It sends impulses (messages) to the brain and carries responses from the brain to the muscles.

### Peripheral nervous system

The communication between the brain, spinal cord and the entire body is provided by the peripheral nervous system. It consists of twelve (12) **pairs of cranial and thirty one (31) pairs of spinal nerves.** The cranial nerves arise from the brain while the spinal nerves arise from the spinal cord.

The peripheral nervous system consist of **somatic nervous system** and **autonomic nervous system.**

## Somatic nervous system

In the **somatic nervous system,** nerves without synapses lead from the brain through the spinal cord to skeletal muscles. The nerves transmit **impulses** (messages) from **external stimuli** to the central **nervous system** and relay responses from the **central nervous system** to the **skeletal muscles** of the body thus causing body movement. The gap between muscle fibres and the terminal end (motor end plate) of the motor neurone is called **neuro-muscular junction.** The conscious awareness of the external environment by the body is the main function of **somatic system.**

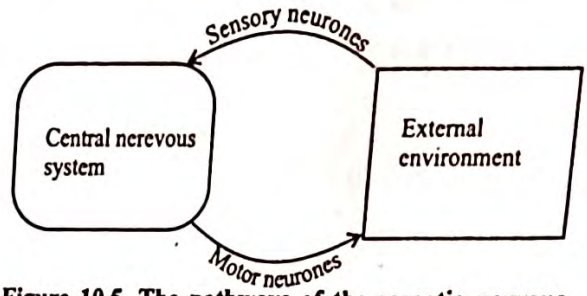



**Figure 10.5. The pathways of the somatic nervous system.**

## Autonomic nervous system (*autos = self; nomous = governing*)

*Autonomous nervous system is the part of the peripheral nervous system which controls the involuntary actions inside the body such as the rate of heart beat, sweating, peristaltic contractions of the intestines.* The neurones of autonomic nervous system are connected to the involuntary muscles of the internal organs. The activities of the autonomic nervous system are under the control of spinal cord or brain by reflexes called **visceral reflexes** which are not under the control of the brain.

The autonomic nervous system comprises **sensory** and **motor neurones.** It arises from the central nervous system and is connected to different internal organs.

The autonomic nervous system consists of two parts namely: **sympathetic** and **parasympathetic nervous systems.** It is made up of two rows of nerve tissues or ganglia that line on other side the spinal column. These two systems help to regulate the vital internal organs such as heart, eye, lung, kidney and penis thus maintaining a system of **"checks and balances".**

**Table 44: The functional differences between sympathetic and parasympathetic nervous systems.**

| Area in the body | Sympathetic nervous system | Parasympathetic nervous system |
|---|---|---|
| Eye | 1. Dilates the pupils<br>2. Does not stimulate the secretion of tears. | 1. Constricts the pupils.<br>2. Stimulates the secretion of tears |
| Mouth | Inhibits the secretion of saliva. | Stimulates the secretion of saliva. |
| Gut | Inhibits peristalic movement. | Stimulates peristaltic movement. |
| Lungs | 1. Stimulates the dilation of bronchi and bronchioles.<br>2. It increases ventilation rate. | 1. Causes the constriction of bronchi and bronchioles.<br>2. Decreases ventilation rate. |
| Heart | Causes the increase in the rate of heart beat. | Decreases the rate of heart beat. |
| Skin | 1. Causes the contraction of erector (hair stands on end) muscles of the hair.<br>2. Increases secretion of sweat.<br>3. Arterioles in the skin of limbs are constricted making skin to be come white. | Does not cause the contraction of erector muscles of the hair.<br>Does not increase secretion of sweat.<br>Arterioles in the skin of the face are dilated making the facial skin red. |
| Kidney | 1. Reduces urine output.<br>2. Causes contraction of the sphincter muscle of the urinary bladder. | 1. Does not reduce urine out put.<br>2. It inhibits the sphincter muscles. |
| Penis | Stimulates ejaculation. | Stimulates erection. |
| Adrenal gland | In emergency, it releases adrenaline from adrenal gland | Does not release adrenaline from adrenal gland. |
| Blood | Causes the increase in blood pressure. | Reduces blood pressure. |

## Structure and function of neurone (nerve cell)

Neurones are specialized cells that transmit impulses (messages) around the body in form of electrical charges. The nervous system consists of millions of neurones (nerve cell). Three main types exist in the body namely: **sensory, association (intermediate)** and **motor neurones.** Each neurone contains a **cell body** (soma), **dendrites** (afferent nerve fibres) and **axon.**

### Cell body (soma)

This is made up of a muscle with nucleolus, and Cytoplasm. The cytoplasm is stellate in shape and contains **Nissl's granules** which are rich in RNA and manufacture protein.

### Dendrite (afferent nerve fibres)

These are short hair-like structures originating from the periphery of the cytoplasm. Dendrites are either in close contact with other neurones or the stimulus receptor cells. They conduct **impulses (messages)** to the cell body.

## Sympathetic nervous system

In the autonomic nervous system, the nerve cell bodies are located in the thoracic and upper lumber area of the spinal cord. The ganglia lie close to the vertebral and spinal cord resulting in short **pre-ganglionic fibres** while its **post-ganglionic fibres** are long. There is a chain of ganglia on each side of the spinal cord. The ganglia receive nerves from the spinal cord and send nerves to the internal organs and blood vessels. The sympathetic nervous system prepares the body for emergencies.

## Parasympathetic nervous system

In the parasympathetic nervous system, the ganglia are in the organs themselves resulting in long preganglionic and short post ganglionic nerve fibres. The nerve fibres leave the central nervous system in the cranial and sacral areas of the body. The parasympathetic nervous system reverses the actions of **sympathetic nervous system**. Parasympathetic system stands for a quiet and easy life such as maintaining normal heart beat, respiration, good digestion and conservation of energy.

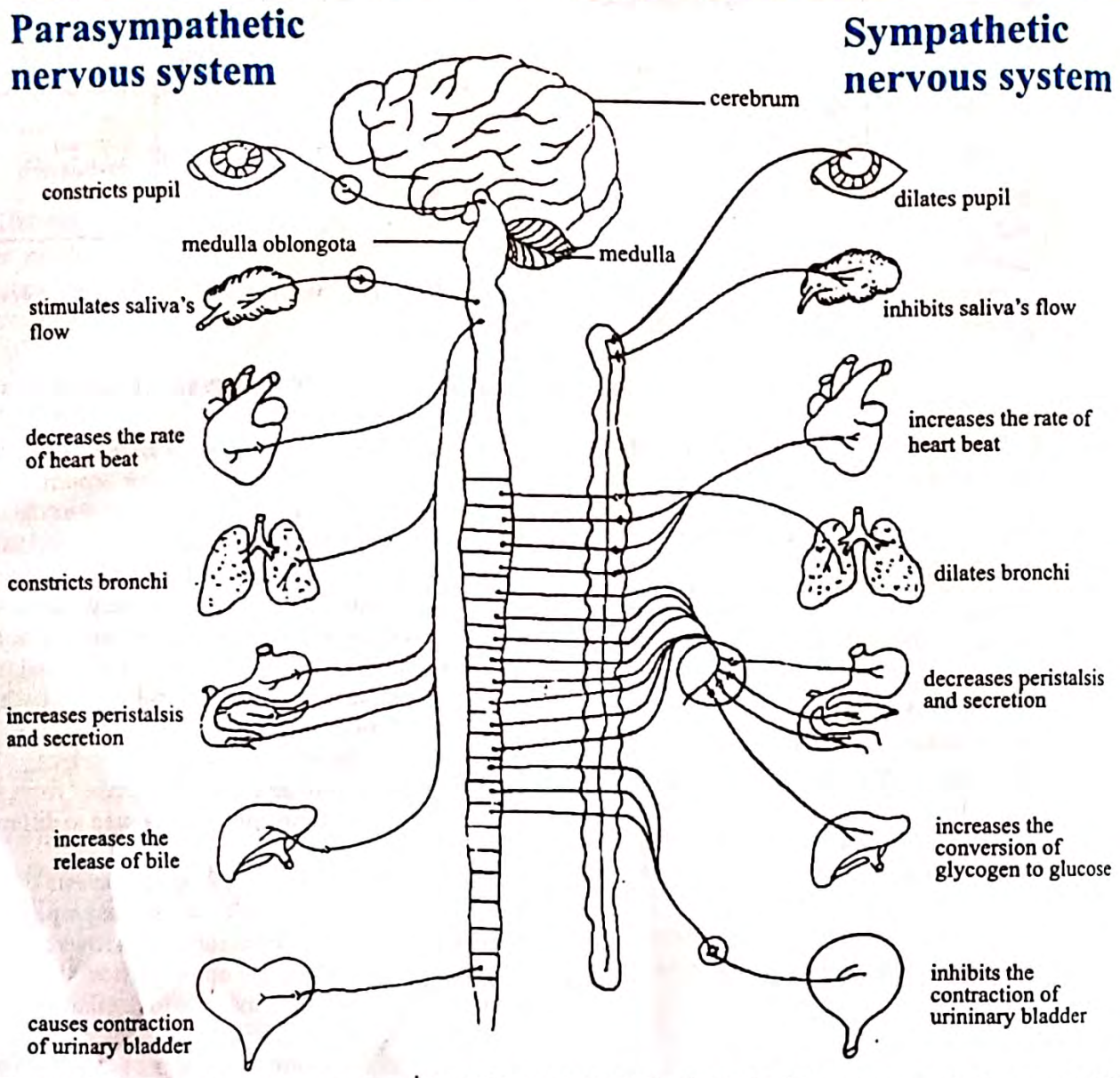



**Figure 10.6. The autonomic nervous system, the parasympathetic on the left and sympathetic on the right.**

**Table 44: The functional differences between sympathetic and parasympathetic nervous systems.**

| Area in the body | Sympathetic nervous system | Parasympathetic nervous system |
|---|---|---|
| Eye | 1. Dilates the pupils<br>2. Does not stimulate the secretion of tears. | 1. Constricts the pupils.<br>2. Stimulates the secretion of tears. |
| Mouth | Inhibits the secretion of saliva. | Stimulates the secretion of saliva. |
| Gut | Inhibits peristalic movement. | Stimulates peristaltic movement. |
| Lungs | 1. Stimulates the dilation of bronchi and bronchioles.<br>2. It increases ventilation rate. | 1. Causes the constriction of bronchi and bronchioles.<br>2. Decreases ventilation rate. |
| Heart | Causes the increase in the rate of heart beat. | Decreases the rate of heart beat. |
| Skin | 1. Causes the contraction of erector (hair stands on end) muscles of the hair.<br>2. Increases secretion of sweat.<br>3. Arterioles in the skin of limbs are constricted making skin to be come white. | Does not cause the contraction of erector muscles of the hair.<br>Does not increase secretion of sweat.<br>Arterioles in the skin of the face are dilated making the facial skin red. |
| Kidney | 1. Reduces urine output.<br>2. Causes contraction of the sphincter muscle of the urinary bladder. | 1. Does not reduce urine out put.<br>2. It inhibits the sphincter muscles. |
| Penis | Stimulates ejaculation. | Stimulates erection. |
| Adrenal gland | In emergency, it releases adrenaline from adrenal gland | Does not release adrenaline from adrenal gland. |
| Blood | Causes the increase in blood pressure. | Reduces blood pressure. |

## Structure and function of neurone (nerve cell)

Neurones are specialized cells that transmit impulses (messages) around the body in form of electrical charges. The nervous system consists of millions of neurones (nerve cell). Three main types exist in the body namely: **sensory, association (intermediate)** and **motor neurones.** Each neurone contains a **cell body** (soma), **dendrites** (afferent nerve fibres) and **axon.**

### Cell body (soma)

This is made up of a muscle with nucleolus, and Cytoplasm. The cytoplasm is stellate in shape and contains **Nissl's granules** which are rich in RNA and manufacture protein.

### Dendrite (afferent nerve fibres)

These are short hair-like structures originating from the periphery of the cytoplasm. Dendrites are either in close contact with other neurones or the stimulus receptor cells. They conduct **impulses (messages)** to the cell body.

Differences between sympathetic and parasympathetic nervous systems.

| Area in the body | Sympathetic nervous system | Parasympathetic nervous system |
|---|---|---|
| Eye | 1. Dilates the pupils<br>2. Does not stimulate the secretion of tears. | 1. Constricts the pupils.<br>2. Stimulates the secretion of tears. |
| Mouth | Inhibits the secretion of saliva. | Stimulates the secretion of saliva. |
| Gut | Inhibits peristalic movement. | Stimulates peristaltic movement. |
| Lungs | 1. Stimulates the dilation of bronchi and bronchioles.<br>2. It increases ventilation rate. | 1. Causes the constriction of bronchi and bronchioles.<br>2. Decreases ventilation rate. |
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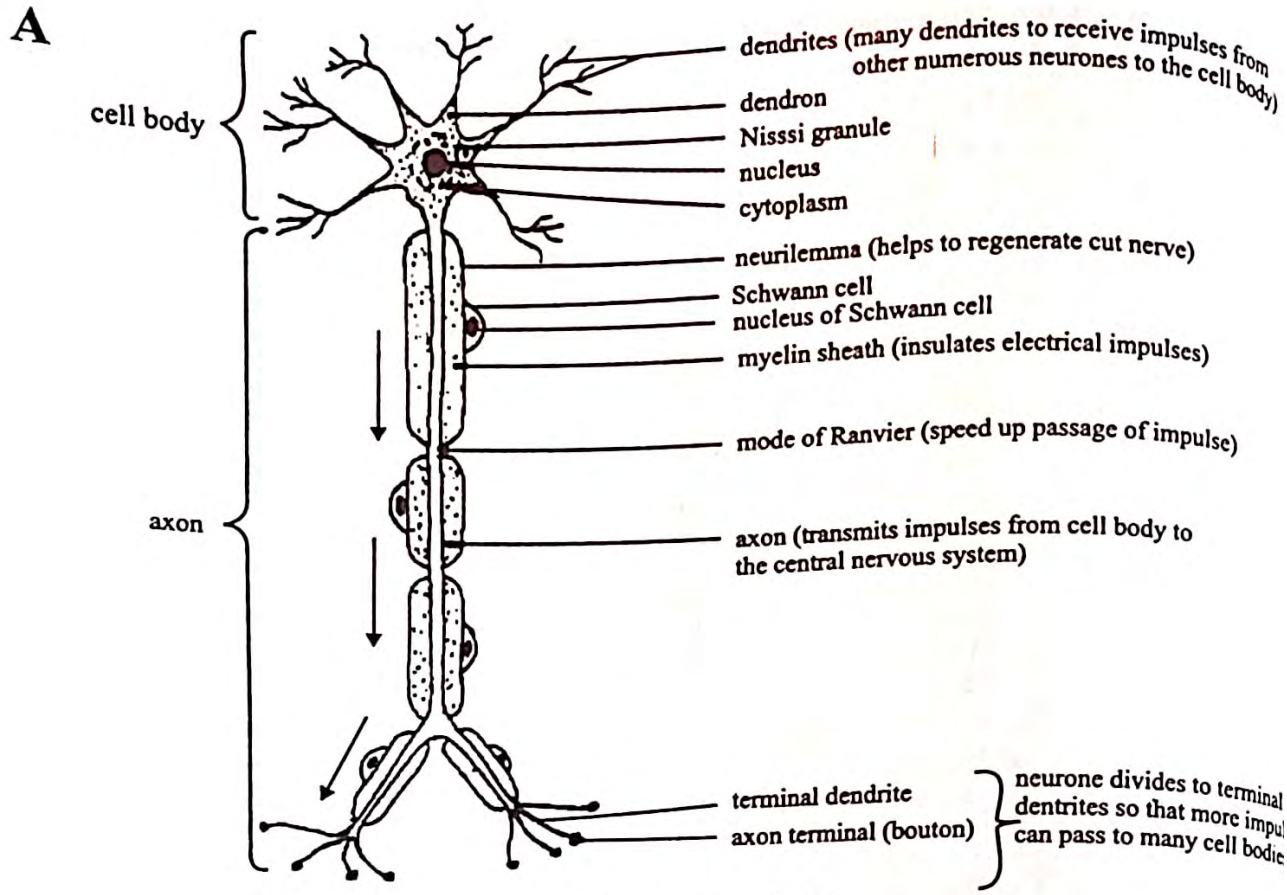
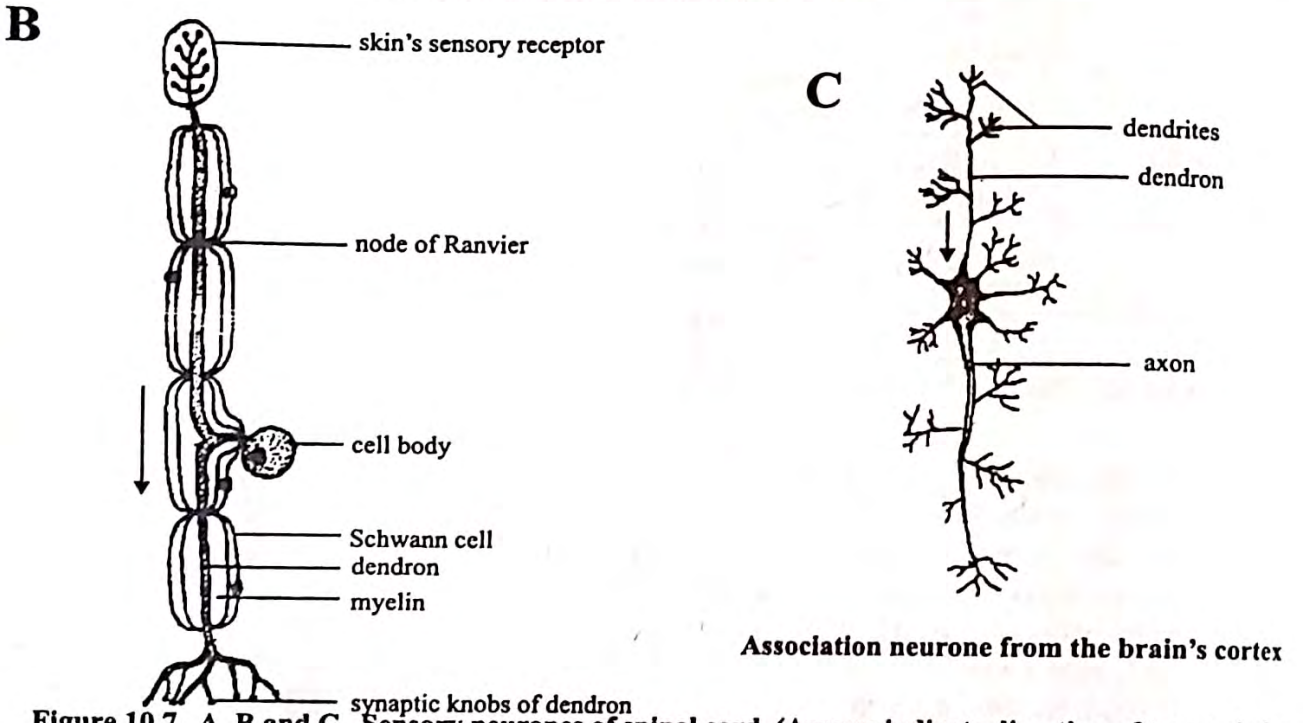



**A motor neurone from the spinal cord.**




**Association neurone from the brain's cortex**

**Figure 10.7. A, B and C. Sensory neurones of spinal cord. (Arrows indicate direction of transmission c impulses).**

## Axon (efferent nerve fibre)

This is a single long fibre arising from the cell body and ending with many branches (**terminal dendrites**) which almost touch the dendrites of adjacent neurones. Each branch of the axon ends in **synaptic knobs**. Axon can be up to a metre long as in the **sciatic nerve** of the leg. Axon is covered with a **fatty myelin sheath** and the myelin sheath is covered with **neurilemma**. In fact, neurilema is a membrane of another cell called **Schwann cell** and not a part of neurone. The myelin sheath insulates and protects the axon and helps to prevent impulses from spreading from one neurone to another. At interval (about one metre), the myelin sheath is interrupted by constriction called **nodes of Ranvier**. The nodes of Ranvier assist in the transmission of impulses. Axons with myelin sheath are called **myelinated** axons while those without are called **unmyelinated** axons.

Each **synaptic knob** at the terminal end of the dendrite contains many **synaptic vesicles** which possess substances that transmit impulses. When the substances are released by the synaptic vesicles into the **synaptic cleft**, the substance diffuses across the synaptic cleft thus altering the polarisation of the postsynaptic membrane of the dendrite or the cell body of the next neurone.

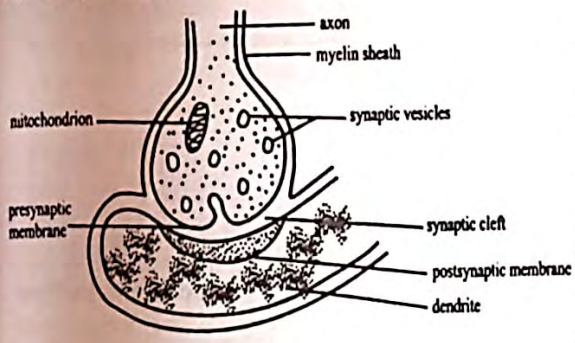



Figure 10.8. Synaptic knob

## Sensory neurones (afferent neurones)

These types of neurones receive stimuli and convert the stimuli into impulses which are carried from stimulus receptors (e.g. sense organs) to the central nervous system. Any nerve composed only of sensory fibres is called **sensory nerve**. A sensory neurone has two long fibres namely: **dendron** which conducts impulses from a **sensory organ** to the cell body (soma) and **axon** which conducts impulses from the cell body to the central nervous system.

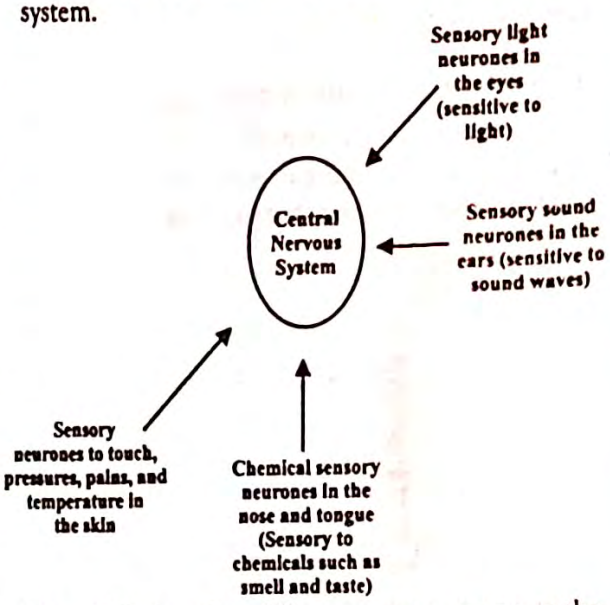



Figure 10.8b shows how different sensory neurones in the human body and how they respond to different stimuli

## Association neurones (intermediate neurones)

These neurones are located only in the central nervous system. They connect sensory and motor neurones with each other and with other nerve cells in the central nervous system. They have no myelin sheath.

They transmit impulses from sensory neurones to motor neurones which enter and leave the brain.

## Motor neurones (efferent neurones)

They transmit impulses from the central nervous system to the effectors (e.g. muscles and glands). Only one long axon is present. Any nerve composed of only fibres of motor neurones is called **motor nerves**.

## Mixed nerves

Any nerve composed of sensory and motor fibres is called **mixed nerve**. All the nerves connected to the spinal cord are mixed nerves. They are 31 in man.

## Process by which neurones transmit impulses

**Impulses** are transmitted along a neurone by **electro-chemical** means (that is by electrical and chemical transmissions).

## Electrical transmission of impulses

An unmyelinated neurone at rest, that is, a neurone not transmitting impulses, has a **positive charge** outside and a **negative charge** inside the cell membrane. At this **resting condition,** neurone is said to be **polarized** and is referred to **resting potential.** The **positive** and negat **charges** are equal. As an impulse passes alon particular point of a neurone, the **polarity** changes **(depolarized),** the outer **surface** of the c membrane becomes **negatively charged** while inner side surface of cell membrane becom **positively charged.** This sudden change in polar is called **action potential.** The resting potential obtained when the original polarity is restored.

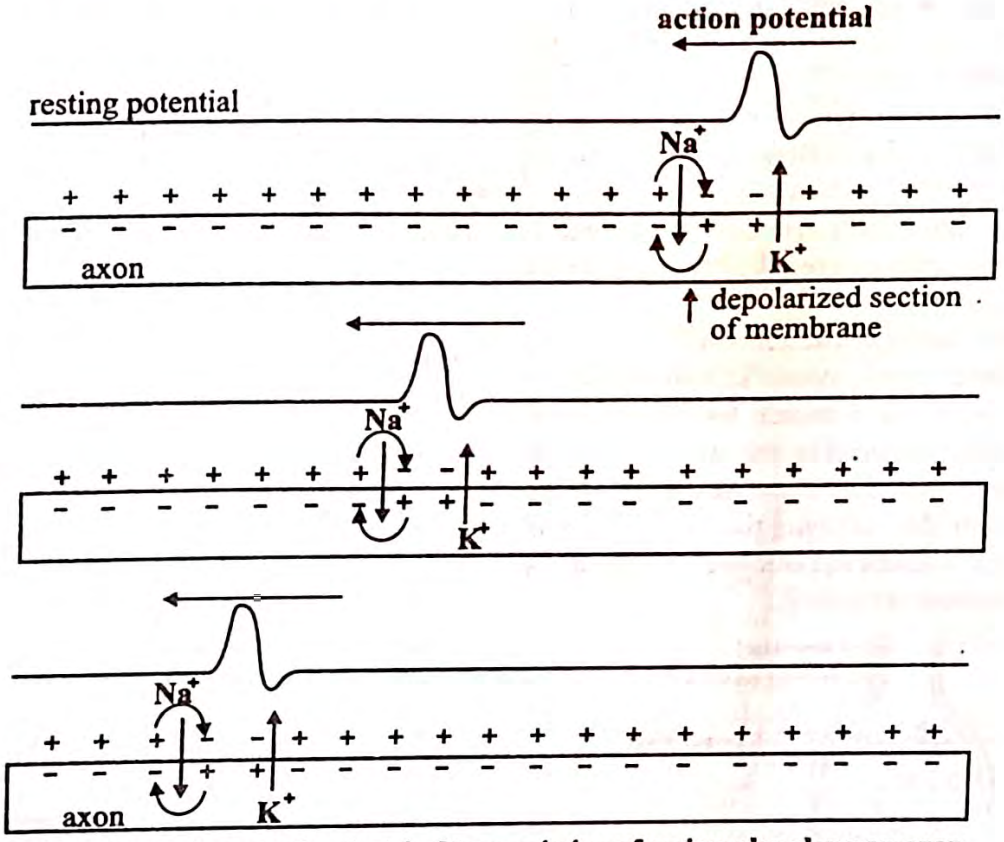



**Figure 10.9. Three stages in the electrical transmission of an impulse along an axon.**

## Ionic transmission

When a neuron is at rest **(polarized neuron)** both **inside and outside** cell membrane have different concentrations of **potassium** and **sodium** ions, that is, excess **sodium ions** are outside the cell membrane. This condition makes the cell membrane inside negatively charged and outside positively charged.

When an impulse is transmitted along a neuron, the cell membrane becomes **permeable** to sodium **ions,** (depolarized), thus sodium ions are pumped inside the cell membrane and potassium ions outside. The cell membrane is now **depolarized** with **inside** the cell membrane positively chargedand outside negatively charged. A **sodium-potassium pump** located in the cell membrane moves **excess sodium ions** outside and potassium ions inside the cell membrane, thereby restoring the original resting stage of the neurone. When an

impulse reaches the **motor end plate** or **synapse** the impulse causes the release of a small amount of a chemical substance called **acetylocholine** which then transmits the impulse to the muscle fibres to contract. After contraction, another chemical substance called **cholinesterase** is released to neutralise acetycholine thus causing the muscle fibres to relax.

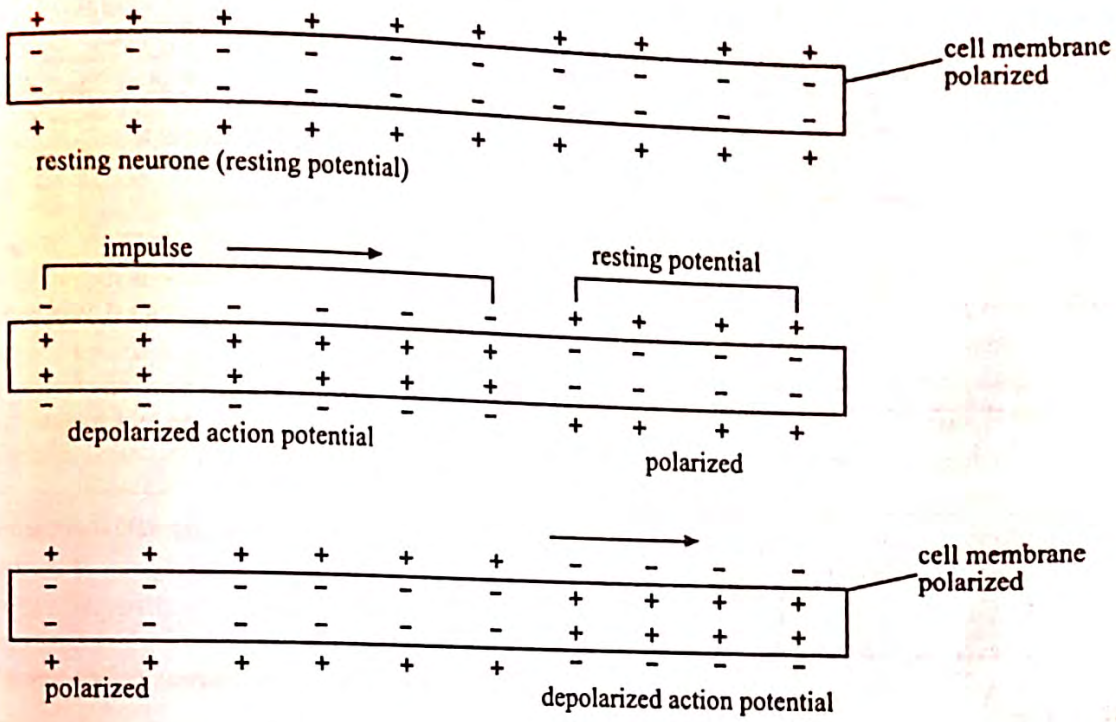



**Figure 10.10. Ionic transmission of an impulse along an axon.**

## Reflex action (involuntary action)

**A reflex action is an involuntary or automatic response of the body to a stimulus involving the spinal cord or the brain.** After the reflex action is completed, the impulse reaches the brain. Pulling off your hand immediately from a hot object when you accidentally touch it is an example of a **reflex action.**

When you pick up a hot object accidentally, the sensory cells (pain receptors) in the skin are stimulated by the hot pain. The stimulus (hot pain) then initiates nerve impulses which are sent through the sensory neurone (afferent) in the spinal cord. The impulses are then transmitted through **synapse** into the **intermediate neurone** in the spinal cord. From the intermediate neurone, the impulses are transmitted into motor neurones which then tranmit the impulses to the **muscles.** The impulses cause the stimulation of the **biceps** muscles (flexor) to contract and the **triceps** muscles to relax. The hot object is immediately dropped.

This action takes a fraction of a second to **complete** thus showing how fast an impulse can pass through the nervous system. It is after the reflex action has been completed, that the impulses reach the brain, and the pain is registered. Examples of other reflex actions are **knee jerk, sneezing, coughing, laughing when tickled, jumping when frightened, blinking when the cornea is touched by a foreign body, heart beat,** and **gut movement.** The brain does not initiate a reflex action. We cannot initiate or control some of these actions such as heart

**Table 45: Some reflex actions, source of stimulus and response**

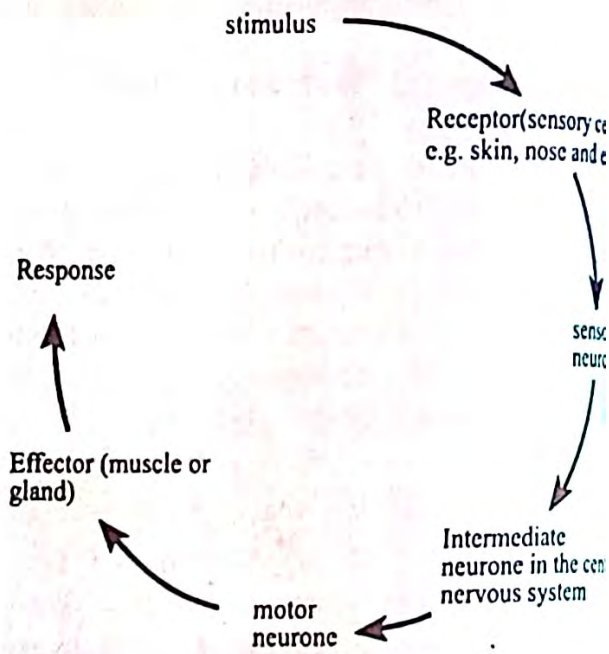
| Reflex action | Source of stimulus | Response |
|---|---|---|
| 1. Sneezing | Irritation of nasal mucous membrane | Quick and violent contraction of tl abdominal muscles. |
| 2. Contraction of iris muscles | Variation in light intensity | Increase or decrease in diameter o the pupil of the eye. |
| 3. Salivation | Smell of food | Flow of saliva. |
| 4. Withdrawal reflex | Hot or sharp object | Contraction of muscles resulting in immediate withdrawal from the object. |
| 5. Knee jerk | Tap on the tendon which causes the muscle to stretch. | Muscle flexes and the lower leg is raised. |
| 6. Coughing | Irritation of the throat by a foreign body. | Contraction of the abdominal muscl resulting in the closure of the epiglottis. |

## Reflex arc

**A reflex arc is the route which impulses have to pass through in order to bring about a reflex action. A reflex arc consists of the following:**

1. ***A receptor organ:*** This receives the stimulus.
2. ***Sensory nerve:*** This carries the impulses from the sensory ending to the spinal cord.
3. ***The spinal cord:*** This receives the impulses and passes the impulses to the intermediate neurone.
4. ***Motor nerve:*** This receives the impulses from intermediate neurone and passes the impulses to the muscles (effector organ) which brings about contraction and relaxation of muscles. Refer to figure 10.4.

**The pathway of a generalised reflex arc is th**



## Inhibition of reflex action

In human beings, some reflex actions are subordinate to the actions of the brain. For example, **the effort of the will,** from the brain stops the jerking of the foot when tickled. Another example is when you accidentally pick a very hot breakable plate. Under reflex action, you would drop the plate but when you realise that dropping would break the plate, an effort under the **will** (voluntary action) from the brain makes a person to bear the pains until the plate is kept safely somewhere gently. Here, the hot pain from the receptor (skin) has left the spinal cord to the brain where the response is modified. This overriding power of the reflex action by the will of the brain is called **inhibition.** It is interesting to note that only human being has **power of inhibition.** All other **animals** have no inhibition power.

## The importance of simple reflexes to animals

Simple reflex arc enables the body to involuntarily (autonomically) adjust to changes both in external and internal environments. Accommodation of the eyes, body balance during movement, withdrawal of hand or leg when it is hit against sharp objects are examples of adjustment to external environment while breathing rate, blood pressure and heart beat are examples of internal adjustment. Without these adjustments the body will be damaged.

## Voluntary action

A voluntary action is an action initiated and controlled by the conscious part of the brain. We think and reason before voluntary actions are carried out. Examples of voluntary actions are **writing, walking, running, reading, talking, driving, swimming, typing, dancing and climbing.** In voluntary action, sensory neurones send impulses to the spinal cord and from the spinal cord to the brain for interpretation. The interpretation is sent through the motor neurones to the effector.

**Table 46: Reflex actions contrasted with voluntary actions**

| Reflex actions | Voluntary actions |
|---|---|
| 1. Have their actions in the spinal cord or hind brain. | Have their actions in the forebrain. |
| 2. Response to stimuli is unconscious and not under the control of the will. | It is under the control of the will. |
| 3. Most reflex actions are not learnt, they are inborn. | They are mostly learnt. |
| 4. Response to stimulus is quick and automatic. | Response to stimuli is not automatic. It is little delayed. |
| 5. In the part of nervous impulses, few neurones are involved hence the path is shorter. | Many neurones are involved hence a longer path. |
| 6. Some reflex actions can be converted to voluntary actions. | Voluntary actions cannot be concerted to reflex actions. |

## Conditioned reflex as a learned behaviour

**Conditioned reflexes** are those behaviours we acquired through **learning**, such as walking, running, swimming, awareness of danger, salivation on sight and smell of food, typing, toileting at a particular time, driving a car, riding a bicycle, pushing levers and opening doors.

Each behaviour takes a long time to learn through dedicated practice but once mastered, it is performed with perfection without thinking before doing it. For example, you don=t think about walking before doing so neither do you think of running before running away from danger.

A Russian biologist, **Ivan Pavlov** in 1902 carried out an experiment on dog. Naturally when food is placed before a hungry dog, the sight and smell of the food cause saliva to flow in the mouth of the dog.

In his experiment, **Pavlov** rang a bell each time food was ready for the dog. After a long time of giving food with the ringing of the bell, the dog became **conditioned** to the **sound of the** bell. After sometime, he observed that when the bell was rung the dog still salivated. The dog has been conditioned to the **sight** and **smell of food** and **sound of the bell**. Any of the stimulus (either sight, smell or sound of the bell) could stimulate salivation. Training of domestic animals such as dogs, cats, horses is based on conditioning. The animals learn to associate spoken command or sound of whistles. Majority of our likes and dislikes, prejudices, interests and habits result from conditioned reflexes.

## Unconditioned or inherited reflexes

Unconditioned reflexes are reflex actions a person is born with such as withdrawing hand or leg from a sharp object.

**Differences between reflex actions and tropisms**

| | Tropisms | Reflex actions |
|---|---|---|
| 1. | Growth movements occurring in plant. | Mostly muscular movements occurring in animals. |
| 2. | There is an unequal slow movement resulting in permanent bending | Movements are fast resulting from contraction of muscles which are easily reversed by other muscles. |
| 3. | Response to stimulus is slow. | Response to a stimulus very fast. |
| 4. | No nerve cells are involved in stimulus. | Stimulus is conducted along nerve fibres |
| 5. | Tropic movements are limited to the growth regions. | All part of the body responds to stimuli. |
| 6. | Only the growing parts are sensitive to stimuli | Any part of the body is sensitive to stimuli. |
| 7. | Hormones (auxins) transmit stimulus to the affected area. | A stimulus is carried by nerve fibres to affected area in most cases. |

*Questions*

1. (a) *Give an illustrated account of the parts of the brain of a named mammal as seen from the dorsal side.*
   (b) *What are the functions of the parts described?*

organ each nerve connects to the brain.

2. (a) Make a large labelled drawing of a vertical section of a mammalian eye. Give the functions of the parts you have labelled.

(b) What do you understand by the terms (a) short sight and (b) long sight, and how are they corrected? (W.A.S.C.)

3. (a) Define autonomic nervous system.

(b) In a tabular form, state the differences between sympathetic and parasympathetic nervous systems in the body of the mammal.

(c) Define a sense organ.

(d) Name four sense organs in mammals.

Draw a mammalian tongue and show the areas associated with the following:

(i) sweetness (ii) bitterness (iii) sourness (iv) saltiness. Give the name of the cells responsible for the detection of the different chemicals.

4. (a) What is a reflex action?

(b) What is the importance of reflex action to animal?

(c) In a tabular form distinguish between a reflex action and a voluntary action.

5. (a) Briefly explain what are conditioned reflexes.

(b) The smell of appetizing food may cause a person=s mouth to salivate. Briefly explain.

(c) Describe with diagrams how impulses are transmitted through a nerve fibre.

6. (a) Make a large labelled diagram of a simple reflex arc including a transverse section of the mammalian spinal cord. Use arrow-heads to indicate the directions of impulses.

(b) Describe what happens when you accidentally pick up a hot object.

(c) Name four reflex actions.

(d) If the left eye is closed and the right one is focussed on the left cross below, the circle on the right seems to disappear when the question paper is held about 26cm away from the face. Give reasons for the disappearance of the circle.

7. (i) What do you understand by central nervous system?

(ii) Draw a mammalian brain and state the functions of each of the following

(a) Medulla oblongata

(b) cerebral hemisphere and

(c) thalamus

(iii) State the survival value of reflex actions.

# 11

# SENSE ORGANS

Higher animals have developed sense organs due to their complex nature of existence. The activities of searching for food, escaping from enemies and attracting mates are complex and hazardous. The environment is constantly changing. Therefore, the need to have specialized sense organs to help higher animals in their struggle for life have become necessary. A sense organ is specialized for one or a few types of stimuli.

Human beings have five major sense organs and these are listed in the table below.

**Table 47: Major sense organs and their functions**

| Sense organ | Stimulus | Function |
|---|---|---|
| 1. Skin | Temperature (heat or cold) pains, touch and pressure | Detects temperature and pressure changes, pains and touch. |
| 2. Eye | Light | Vision |
| 3. Ear | Sound and gravity | Hearing and balance. |
| 4. Tongue | Chemicals | Tasting. |
| 5. Nose | Chemicals | Smelling |

The sensory nerves of each organ receive stimuli and transmit the impulses to the central nervous system for the appropriate responses.

## Skin as a sense organ

In the skin, there are five sense receptors namely touch, pressure, pain, heat and cold. Their sensory nerve endings are unevenly distributed in the skin. (See figure 9.12).

## Touch

If you prick your skin with a needle, you will feel touch sensation. If you wear a hairy dress, at first it tickles you and gradually the tickling sensation stops.

The explanation is that, at first tickling impulses are sent to the brain but later touch receptors stop sending impulses to the brain therefore tickling sensation is no longer felt. This adaptation is called sensory adaptation. Sense of touch is greatly developed in the finger tips of blind people which help them to identify objects and for reading braille.

## Temperature:

There are two temperature receptors in the skin. These are heat and cold receptors. The heat receptor detects heat while the cold receptor detects cold. These two receptors make us aware of temperature changes. If the temperature is low, we keep our bodies warm either by wearing thick clothes or sit near fire. If we feel hot, we wear light clothes or have a cold bath or move to cold shady place. The heat and cold receptors enable us to detect hot and cold food.

## Pain

Pain receptors when stimulated give rise to the sensation of pain.

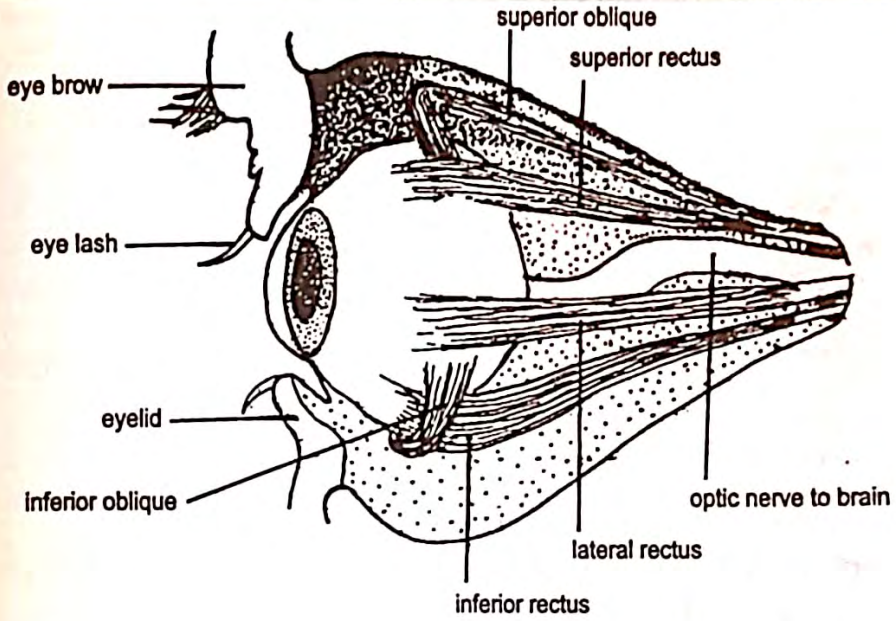
## Pressure

Receptors that respond to pressure are located deep in the skin. They respond to very heavy touch. If you press a ruler against your skin, you feel the pressure and the touch. Since the nerves are located deep, a pressure stimulus must be stronger than touch stimulus.

## Organs of sight (eyes)

The eyes are the organs of sight in the higher invertebrates and all vertebrates. They (eyes) are equipped with photo receptors (rods and cones) to detect light. Most of these animals have two eyes. In man, the eyes are more or less spherical in shape, about 1.5cm in diameter.

Each eye is located in a bony socket (occipital).



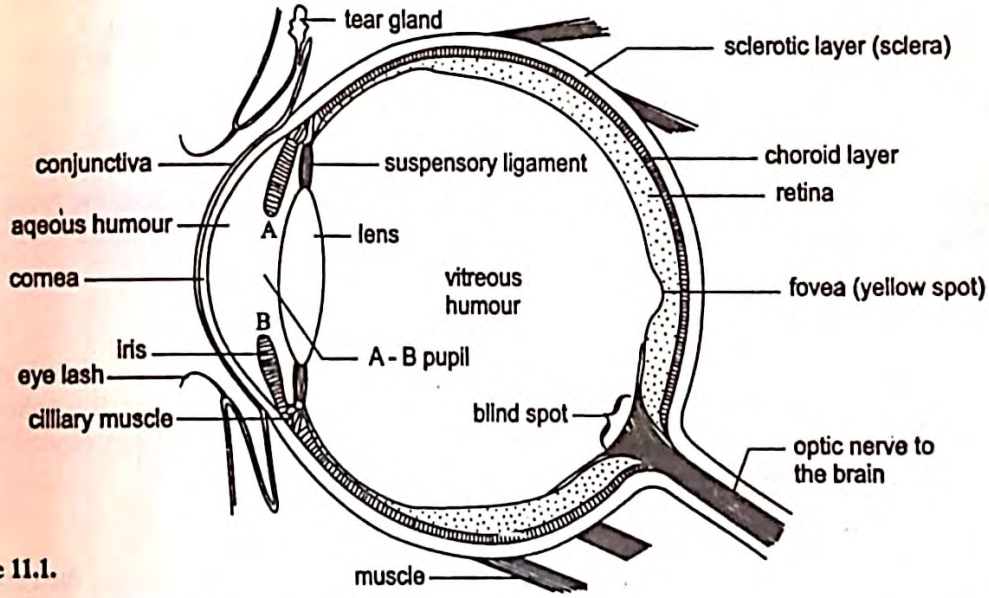




**Figure 11.1.**

**A = The eyeball in its socket. Five of the six muscles are shown. The remaining one is on the other side**
**B = The vertical section of the eye.**

orbit) in the skull from which a little portion projects out.

## Protection of the eyes

1. The bony socket protects the eye from damage. The eyes are also protected in front by eyebrows, eye lashes and eyelids.
2. **The eyebrows** prevent bright light and sweat from dropping to the eyes.
3. **Eye lashes** prevent dust, bright light and insects from the eyes.
4. **Eyelids** help to moisten and clear the conjunctiva. They also prevent bright light from damaging the eyes.
5. **Tear glands (lacrimal glands)** produce tears which help to wash away dust particles thus preventing abrasion of the eye's surface by dust particles. They help to keep the surface of the eye moist. The **tears** also help to destroy bacteria because they contain a substance called **lysozyme** which is harmful to bacteria.
6. **Fats** surround the eyes except the exposed little part. Fats help to cushion the eyes from shock. ***When fats of the eyes are used up during illness or as a result of old age, the eyes show sunken appearance.***

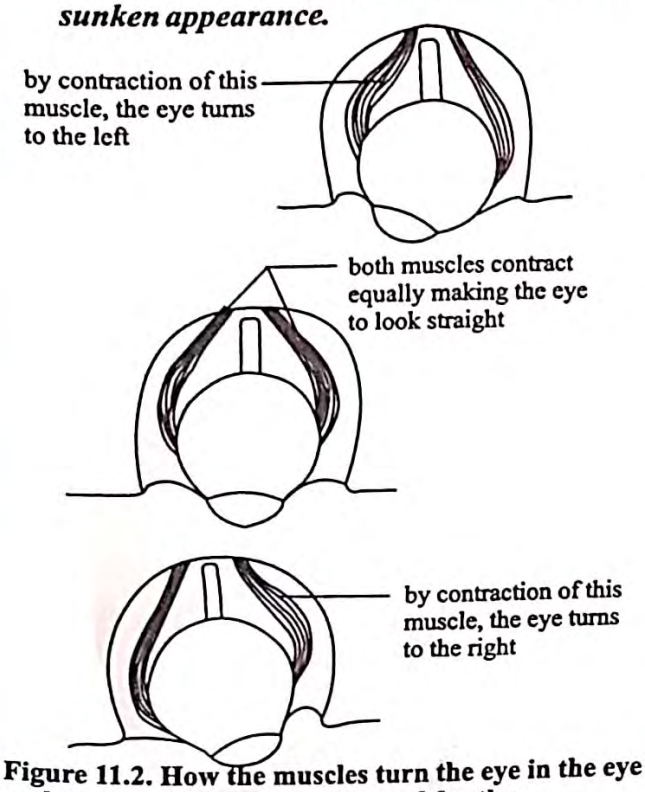



**Figure 11.2. How the muscles turn the eye in the eye socket. Only two muscles are used for the illustration.**

## Structures of the eye

### Muscles

Each eye has six muscles which attach it to the sk The muscles are **superior** and **inferior** recti (singular = rectus) and **superior** and **inferior obliques** and two **lateral recti**. These muscles hel to move the eyeball to different directions. In hum beings, the eyes are moved together but some reptiles e.g chameleon, each eye can move independently of the other. The eyeball is covered front by a fine transparent membrane called **conjunctiva**. It helps to protect the eyeball in front

### Layers of the eye

The eyeball is made up of three layers name **sclerotic, choroid and retina.**

### Sclerotic layer

The sclerotic layer is the white part of the eye. It made up of tough and inelastic tissues. Light cann penetrate it. It covers the entire eyeball except th cornea.

### Functions

It protects the eye and maintains the shape of th eyeball. The sclerotic layer bulges out in front to form a transparent and convex tissue called **cornea**

### Functions of cornea

1. Protects the eye in front.
2. Allows light rays to enter the eyeball.
3. It helps the lens to bend light rays to form an image on the retina.

### Choroid layer

This layer is dark in colour due to the presence of black pigments. It is well supplied with blood vessels (vascularized).

### Functions

The black pigments help to absorb light rays thus preventing internal reflection of light. It supplies food and oxygen to other parts of the eye especially the retina.

### Iris

The choroid forms the iris in front of the lens. It is sometimes referred to as the muscular diaphragm of the eye. It covers the lens except the pupil thus restricting the amount of light rays

entering the eye so that a clear image is formed on the retina. The iris is pigmented. The pigments may be blue, brown or green hence some people have *blue, brown or green eyes*. The iris is swollen behind.

## Ciliary muscles

Behind the iris there is a swollen body called ciliary muscle. The ciliary muscles consist of circular and radial muscles. The contraction and relaxation of the ciliary muscles alter the shape of the eye to focus light properly from near and far objects.

## Pupil

The pupil is a small hole in the iris which helps to regulate the amount of light rays entering the eye. Its size is regulated as described above.

## Lens

The lens focuses light unto the retina. It is crystalline and convex in shape, and is attached to the ciliary muscles by suspensory ligaments. The lens and suspensory ligaments thus divide the eye chamber into two parts, each chamber is filled with liquid of different density.

## Retina

The retina is the sensory part of the eye. It is a thin, delicate, and vascularized layer consisting of light sensitive cells (photo receptors) called rods and cones.

## Rods

Rods are sensitive to dim light and colourless vision (since they are unable to detect colours). Rods contain a sensitive pigment called visual purple (rhodopsin). The visual purple contains vitamin A and protein. When light falls on the visual purple, chemical reaction (bleaching) takes place in the visual purple that releases yellow pigment called retinene and energy that stimulates the optic nerve which then carries light rays to the brain. The brain interpretes the light rays as light. When the eyes are closed, the purple colour is regenerated with the help of vitamin A. This is the reason why the deficiency of vitamin A causes night blindness.

**Why is that a person in a dark room is dazzled for some seconds when suddenly exposed to bright sunlight?**

When a person is in a dark room, his iris contracts, then the pupil dilates to allow in more light. On sudden exposure to bright sunlight, the pupil is still wide open leading to much light entering the eye. As a result of too much light in the eye, the visual purple (rhodopsin) is bleached leading to dazzling sensation experienced for some seconds.

## Cones

Cones are sensitive to bright light and are able to detect colours. They contain a photochemical substance called iodopsin which is not easily bleached by high light intensity. The yellow spot (fovea) contains only cones hence the yellow spot gives the best vision.

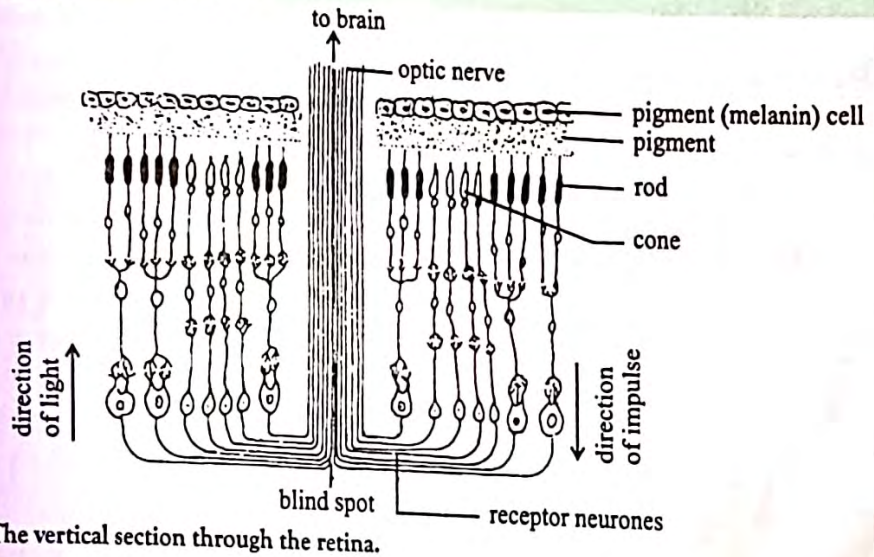



**Figure 11.3. The vertical section through the retina.**

The differences between rods and cones form the basis of nocturnal and diurnal habits of ani-mals.

Man has both rods and cones, and therefore has both day and night visions. Many animals have only one vision. Chickens have only cones hence they are active in the day. That is the reason why they go to roost very early. Owls have only rods hence they are active at night during which they see better. Cat and deer see very well at night because they have far more rods than cones.

## Blind spot

Blind spot is a point where nerve fibres leave the eyeball to form the optic nerve. There are no rods and cones. It is not sensitive to light, therefore not used for seeing.

If the left eye is closed and the right eye is focused on the cross (+) above, the circle on the right seems to disappear when the paper is held about 26cm away from the face. This is because the image of the circle has fallen on the blind spot which has no sensitive cells (rods and cones) hence no impulses are registered in the brain.

## Optic nerves

Optic nerve carries impulses from the retina of the eye to the optic lobe of the brain.

## Aqueous humour

The space between the cornea and lens is filled with thin and watery fluid called aqueous humour. The fluid helps to hold out the cornea and helps also to bend light rays. It provides food, (sugar, protein and salts) and oxygen to the adjacent parts of the eye.

## Vitreous humour

This is a jelly-like transparent substance that fills the interior part of the eyeball . It helps to keeps the shape of the eyeball and assists in bending light rays. It provides food (sugar, protein and salts) and oxygen to adjacent parts of the eye.

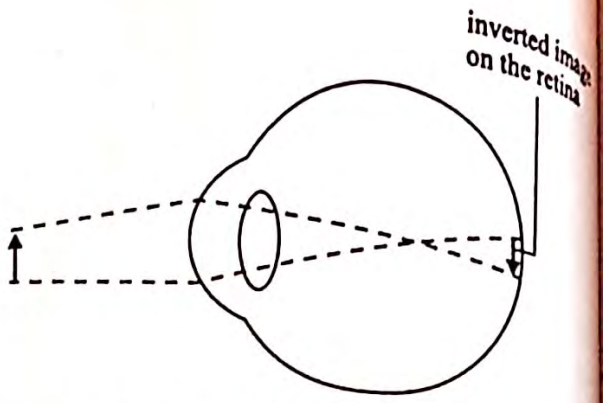


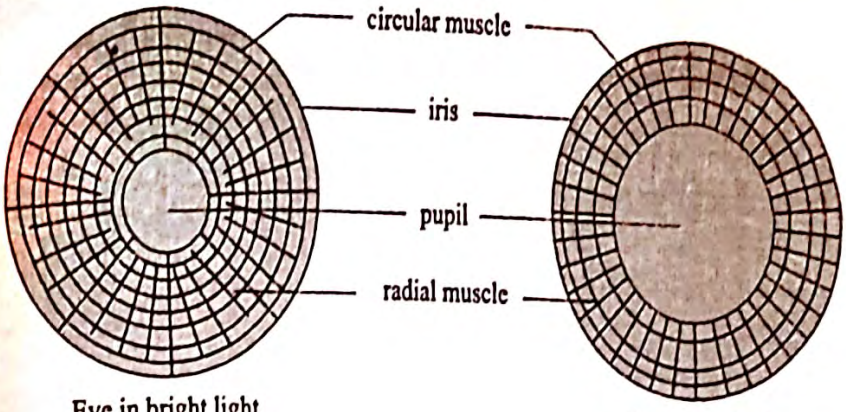

**Figure 11.4. Formation of an image on the retina.**

## Mechanism of seeing

Light rays from an object enter the eye through the cornea. The light rays are **refracted** (bent) by he convex cornea and passed through the aqueous humour which further bends the light rays before entering the lens through the pupil. The lens further bends the light rays and focuses them on the retina, especially on the yellow spot. As the light rays pass through the vitreous humour, bending of light rays occurs again. The light rays from the object are converted into electrical impulses on reaching the retina stimulate the **rods** and **cones** to form an **inverted image on the retina. The inverted** image on the retina is smaller than the actual size of the object. The electrical impulses are sent through the optic nerve to the optic lobes of the brain. From the optic lobes, the image is sent to the **visual centre** of the **cerebral hemisphere** where the actual size and colour of the image are interpreted correctly.

## Accommodation of the lens

**Accommodation is the ability of the human eyes to focus far and near objects on the retina.** It is brought about by the contraction and relaxation of the ciliary muscles. The ciliary muscles contain **circular** and **radial muscles.**




Eye in bright light

a. Circular muscles contract
b. Radial muscles relax
c. Pupil constricts
d. Less light goes into the eye

Eye in dim light

a. Circular muscles relax
b. Radial muscles contract
c. Pupil dilates
d. More light goes into the eye

## Near object

When the eyes are looking at a near object, the ciliary muscles contract and become thicker and fat. The suspensory ligaments slacken. The lens becomes fat and more convex. This shape greatly bends the diverging rays which fall on the retina and near object is seen clearly.

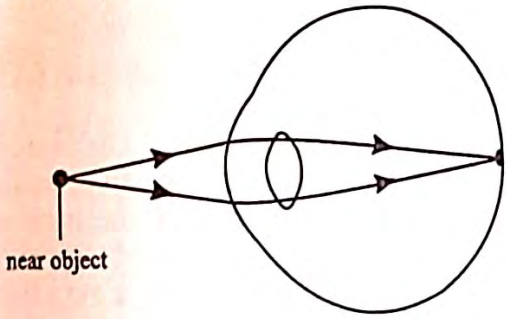



**Figure 11.5 Near object. Light from near object is focused by thick and fat lens.**

## Far object

When the eyes are looking at a far object, the *ciliary* muscles relax, the suspensory ligaments are pulled tight thus stretching the lens to be thin, flat and less convex. This flat and thin shape of the lens slightly bends (refracts) parallel light rays before falling on the retina and far object is seen clearly.

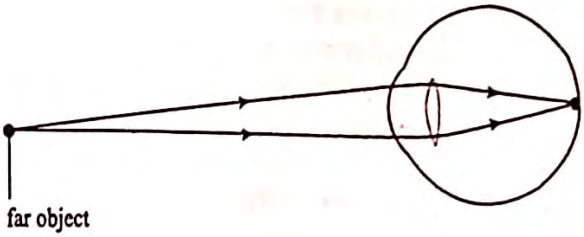



**Figure 11.6. Light from far object is focused on the retina by thin and flat lens.**

## Eye defects

### 1. Shortsightedness (Myopia)

In short sight, the eye ball is too long or the cornea is too curved. Parallel rays of light from a distant object are brought to focus by cornea and lens at a point in front of retina. A shortsighted person can only see object near him but cannot see distant object clearly.

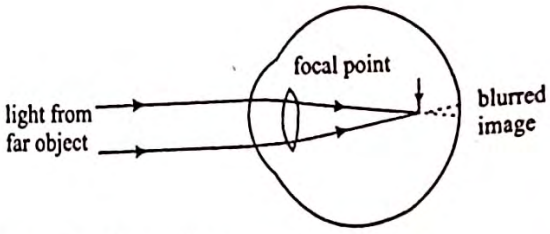



**Figure 11.7. Shortsightedness.**

## Correction

This defect can be corrected by using concave lens eye-glasses which diverge (bend light rays outwards) parallel light rays from distant objects before falling on the eyeball, and thus focusing them on the retina.

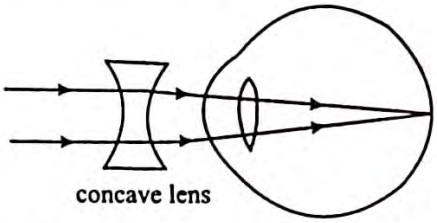



**Figure 11.8. Correction of shortsightedness.**

## 2. Longsightedness (Hypermetropia)

In long sight, the eyeball is **too short or the cornea is not sufficiently curved.** Parallel rays or light from a near object are brought to focus at a point behind the retina. A longsighted person cannot see near objects clearly but can see distant object clearly.

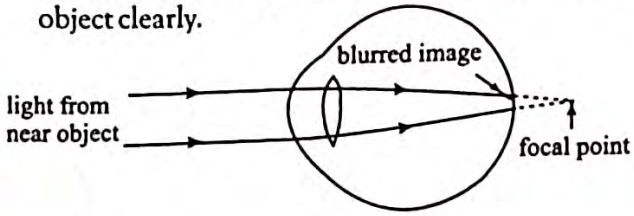



**Figure 11.9. Longsightedness**

## Correction

This defect can be corrected by using convex lens eye-glasses which coverage (bend light rays inwards) light rays before falling on the eyeball and thus focusing them on the retina.

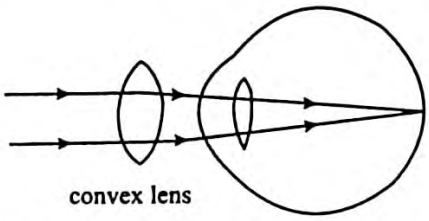



**Figure 11.10. Correction of longsightedness.**

## 3. Presbyopia

This is a defect which usually comes with old age. The power of the lens to accommodate is reduced due to less elasticity of the lens or hardened ciliary muscles.

## Correction

Wearing bifocal glasses with one part for **near vision** and another part for **distant vision.**

## 4. Astigmatism

This eye defect is caused by **uneven curvature** of the cornea or lens or both. Light rays are not focused on the retina evenly and therefore the person is unable to focus objects horizontally and vertically.

## Correction

Wearing glasses with **uneven curvatures.**

## 5. Colour blindness

When one type of colour receptive cone is missing from the retina, that person will not be able to distinguish this colour from some others. For example if the red sensitive cone is lacking, the person will not be able to identify a red colour. He will perceive red colour as green. He is said to be red-colour blind. Colour blindness is an inherited sex-linked characteristic showing up in males.

## Care of the eye

1. Avoid rubbing the eye or removing foreign bodies with dirty hands or materials such as towel and handkerchief.
2. Read in well lighted places. The source of light should come from the front and not from the back. Light from the back will form a shade in the front thereby providing poor light. Avoid looking at a very bright light.
3. Book should be placed at a good reading distance of about 30cm to 50cm.
4. Do not read while lying on bed. This strains the eyes.
5. Read books with bold and clear prints. Tiny prints strain the eyes.
6. Bathe or wash the face with clean water. Dirty water may infect the eyes.
7. Eat food containing **Vitamin A** for clear vision.
8. Avoid playing with sharp objects such as arrows, knives, pins, etc. near the eyes.
9. Avoid swimming or bathing in fast flowing streams or rivers so as to prevent infected

black-flies from biting you. Blackflies lay their eggs in fast flowing streams or rivers and if you are bitten by them during bathing or swimming, they transmit **microfilaria worms** into your blood. These microfilaria worms *(Onchocerca)* attack the eyes causing river blindness.

10. Any eye problem should be reported to the doctor for medical attention.

## Advantages of having two eyes

## (Binocular or stereo vision)

1. Two eyes give better and accurate judgement of size, distance, depth, colour and form of objects than one eye. In primates, two eyes are placed on the front of the face to produce overlapping binocular vision that makes the brain to judge distance accurately very important especially for jumping animals such as monkeys
2. If one eye is faulty, the other one can carry out the function of vision to a reasonable degree. (Note: the loss of one eye can reduce the field of vision by about one-third because the nose acts as a barrier to the vision of the remaining eye).
3. Two eyes give increased range of vision than one eye.

## Eyes of arthropods

The eyes of arthropods are simple. They consist of a few cells sensitive to light. They are sensitive to dark and light but incapable of producing images. Majority or insects and crustaceans have compound eyes. A compound eye is composed of a separate unit called **ommatidium (plural ommatidia)**. One ommatidium c onsists of a lens, pigmented cells that prevent internal reflection and light sensitive cells which transmit nerve impulses to the brain. An ommatidium sends separate image to the brain. When all the ommatidia send images to the brain, a mosaic image is formed.

## Vertebrate visual characteristics

The vertebrates eyes are the same in structure and in number. All vertebrates have two eyes each. They are different in size. They are large in owl, bulging in the toad, frog and mudskipper, tiny in the snake and small in the elephant. The eyes show many adaptations according to the condition under which their possessors live.

Animals that are chiefly active day are called **diurnal animals.** Their eyes are stimulated by **high or bright light** intensity. For this reason their eyes have more cones than rods in the retina. More cones increase sensitivity to the high light intensities of day.

Animals that are chiefly active by night are called **nocturnal animals.** Their eyes are stimulated by **dim light.** For this reason they have more rods than **cones** in the retina. Their eyes have **slit pupils** instead of the **round pupils** of the diurnal animals. The advantages of **slit pupils** of nocturnal animals over the **round pupil** of diurnal animals is that it (slit pupil) closes more tightly than **round pupil** (thereby preventing bright light from destroying the sensitive cells (rods) of the retina. The **slit pupil** can also extend more widely in dim light to admit more light to the retina.

*Why is it that the eye of many nocturnal animals shine in unidirectional light at night.*

Many nocturnal animals have a **reflecting layer** in the choroid of their eyes. Their eyes are stimulated by dim light and so in the bright light from hunter=s carbide lamp, touch light and vehicle lamps, the surplus light not absorbed by the retina is **reflected** back through the **reflecting layer of the choroid.** Some of the reflected light passing out through the pupil makes the eyes of the nocturnal animals to shine. The hunters use this to their advantages by hunting at night when the moon is not shining. Very good hunters accurately identify the animals with their shining eyes while the less experienced ones shoot at the frogs and other shining objects mistaking them for the desired animals. These eyes do not shine in diffuse light from the moon or in the sun during the day.

## Organ of hearing (ear)

The ear is a sense organ responsible for hearing and balancing. The mammalian ear consists of three parts called **external ear** (outer ear), **middle ear** (tympanum) and **inner ear** (labyrinth).

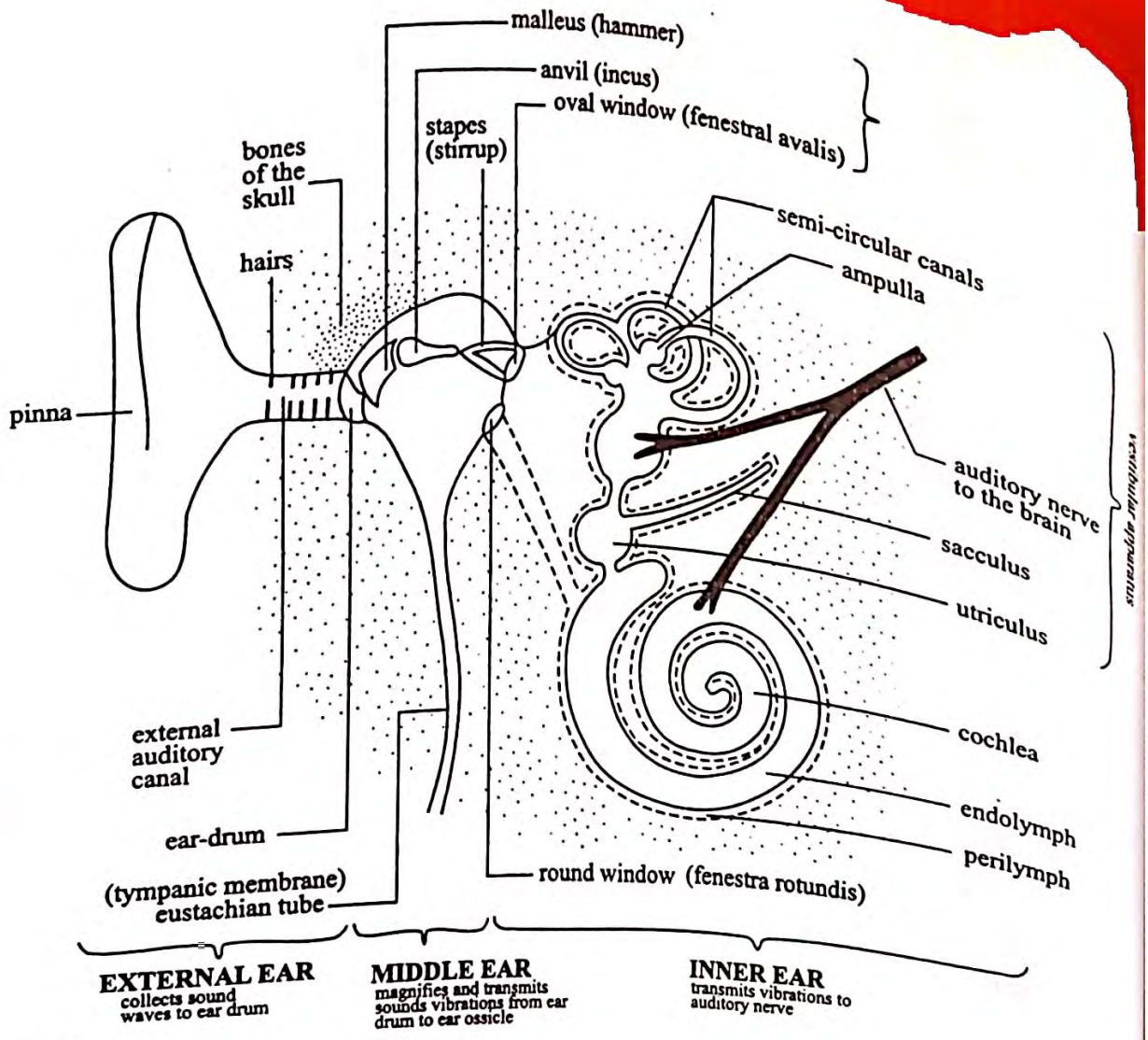



**Figure 11.11. The vertical section through the human ear.**

## The structure of the ear

### The external ear (outer ear)

The external ear is made up to two parts: the **pinna and auditory canal.**

### Pinna (external ear)

Is composed of irregular elastic plate of cartilage and muscles covered by skin. It is well supplied with blood vessels to keep it warm. Pinna collects sound waves and directs them into the auditory canal. In most mammals, the pinnae are moved about by the ear muscles to detect accurately the direction of in which sound is coming from without necessarily moving the head about. The pinnae of man are immovable hence he turns his head to detect the direction of sound. It also protects the internal structures.

### Auditory canal (accoustic meatus)

The auditory canal extends inward in an oblique direction so as to prevent hard objects from hitting the tiny sheet of skin called the **eardrum** (tympanic membrane). It is lined with hairs and contains glands that produce wax which helps to trap dirts and thus preventing them from entering the middle and inner ear to avoid causing damage to them. The auditory canal connects the external ear and the middle ear.

### Middle ear (tympanum)

The middle ear is separated from the external ear by **eardrum (tympanic membrane)** and from the inner ear by oval window (fenestra ovalis) and round windows (fenestra rotundis). It is an air-filled cavity in the temporal bone of the skull.

The eardrum picks sound waves from the external auditory canal and vibrates them. Below the middle ear is a tube called **eustachian or pharyngial** tube that connects the throat. The **eustachian** tube

allows air into the middle ear so as to keep the air pressures between the inside and outside ear of the eardrum equal thus preventing the bursting of the eardrum. Within the cavity of the middle ear is a chain of three tiny bones called **malleus** (hammer), **incus (anvil)** and stapes (stirrup). The three bones are so arranged that the malleus is in contact with the eardrum while the stapes is in contact with oval window which opens to the inner ear. These three tiny bones magnify and transmit sound vibrations from the eardrum to the oval window (fenestra ovalis). The three bones of the middle ear are called **ear ossicles.** They are the smallest, softest and lightest bones in the mammalian skeleton.

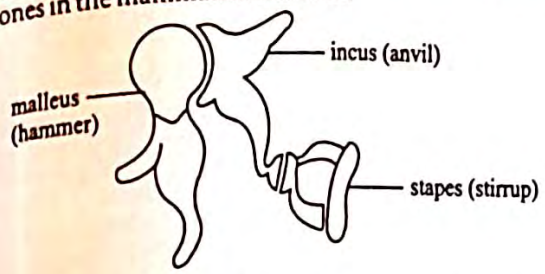



**Figure 11.12. An enlarged view of the three ossicles of the middle ear.**

## Inner ear (membraneous labyrinth)

The inner ear is made up of complicated and interconnected canals and sacs.

The inner ear is made up of two major parts namely: the vestibular apparatus and cochlear. The vestibular apparatus comprises three semi circular canals, utricullis and sacculus. Inside the inner ear is a fluid called **endolymph** which fills the semicircular canals, utriculus, sacculus and cochlea. The inner ear is surrounded by a bony frame work called bony **labyrinth.** Between the inner ear and bony labyrinth is a space filled with a fluid called **perilymph** which bathes the inner ear.

## Semicircular canals

The semicircular canals are attached to the **utriculus.** The three canals are loop-shaped (hence called *semicircular canals*) and lie at right angles to one another in different planes. The ending of each semicircular canal is enlarged and thickened and is called **ampulla.** The ampulla contains sensory cells.

The semicircular canals have sensory **hair cells** and **otoliths** which are concerned with balance and maintaining the posture of the body.

## Utriculus and sacculus

Semicircular canals and cochlea and attached to the **utriculus** and **sacculus** respectively. They also function in body balance.

## Cochlea

The cochlea is a coiled fluid -filled tube in the inner ear lined with sensitive nerve endings and filled with fluid. It is coiled like a snail=s shell. It contains nerve cells sensitive to sound vibrations and therefore concerned with hearing

# The mechanism of hearing and balance

## Hearing

The pinna detects, collects and directs sound waves down the **auditory canal.** The sound waves strike the eardrum and cause the **vibrations** of the membrane. The vibrations are amplified and carried across the ear ossicles (*hammer, anvil and stirrup*) to the *oval window.* The vibrations are further amplified by the ear ossicles. In the oval window, the vibrations are magnified. The vibrations of the oval window are transferred to the **perilymph** that surrounds the **membraneous labyrinth.** The vibrated perilymph in turn excites the **endolymph** through the membrane separating them. The excited endolymph stimulates a group of sensory cells called the **organ of Corti** present in the cochlea. The stimulation of these sensory cells converts the sound vibrations into **electrical impulses** which in turn stimulate the nerve endings of the accoustic branch of the auditory nerves which are in contact with the auditory lobes of the brain where they are interpreted into different sounds you hear.

## Balance

The **semi-circular canals, utriculus** and **sacculus** contain **endolymph fluid.** The semi-circular canals contain *sensory cells* while the ampullae, utriculus and sacculus contain small granules called **otoliths** (ear stones). These otoliths rest on sensory hairs which are in abundance in the ampullae, utriculus and sacculus. When the head moves or changes position, the endolymph fluid moves in the canals and stimulates the sensory hairs which in turn stimulate the nerve endings. The movement of the otoliths (ear stones) also stimulates the sensory hairs. The nerve

endings then transmit the impulses through the vestibula (a branch of the auditory nerve) to the cerebellum of the brain where the new position of the head is interpreted and the appro-priate responses sent to the muscular system to maintain the body balance. (*Note the auditory nerve transmits two kinds of stimuli to the brain:*
*sound and balance through the accoustic and vestibular nerve fibres* respectively).

If you spin around rapidly, the endolymph is forced to move to one end and impulses are quickly sent to the brain. On stopping the endolymph still moves back and forth making you to feel that all things including the ground are turning round. The eyes that see things also inform the brain that the surrounding things are motionless. This confused information to the brain makes you *feel dizzy*. When the head moves in an unfamiliar manner as usually occurs in an air craft or a boat during a rough and stormy weather, the sensory hair cells are equally stimulated in unfamiliar manner resulting in sensations called **motion sickness.** Disease of the semicircular canals results in temporary or permanent dizziness and loss of balance.

## Advantages of having two ears

1. Two ears increase range of sound waves.
2. It enables us to detect faster the direction of sound, the magnitude or pitch of sound since the ear nearer the source will be more stimulated.

## Diseases of the ear

The diseases of the ear are mainly defects of the tympanum, middle ear and inner ear. These defects lead to deafness which could be partial or permanent.

Two main types of deafness are:

1. **Conduction deafness**
   Conduction deafness is the inability of the ear ossicles (ear bones) to conduct sound vibrations to the inner ear.
2. **Nerve deafness**
   Nerve deafness is the inability of the auditory nerve to transmit sound vibrations from the ear ossicles to the auditory part of the brain.

## Causes of deafness

1. **Wax in the ears**
   When large quantities of wax are produced by the wax glands partial deafness may result due to complete blockage of the canals. This can be corrected by seeing an experienced ear, nose and throat (ENT) doctor.
2. **Deafness from otosclerosis**
   This deafness is due to replacement of the oval window by a spongy bone thereby blocking the movement of the stapes. This disturbs the transmission of vibrations from the ear ossicles to the inner ear. This deafness can be corrected by an ear specialist doctor.
3. **Noise deafness**
   A loud noise such as explosion, high disco noise and gun shots may damage the eardrum and cochlea and may cause noise **deafness.** This deafness can be prevented by avoiding areas of loud noise or by wearing suitable **earplugs** to protect the ears.
4. **Deafness from arteriosclerosis**
   This type of deafness is due to old age. It is caused by the hardening of the arteries. The patient is unable to hear the ringing of a telephone and doorbell. There is no preventive measure. Hearing aid may help.
5. **Deafness due to viral and bacterial infection** Diseases such as measles, influenza, polio, diphtheria, and meningitis cause deafness. Prevention: vaccination (especially in children) against such diseases help to prevent their attack. In case of attack by such diseases, see a medical doctor immediately.
6. **Deafness from syphilis**
   A mother infected with syphilis during pregnancy may infect her baby. The **syphilis** may affect the auditory nerve, and cause deafness . Syphilis contacted later in life may also cause deafness if not treated in time.
7. **Deafness from head injuries**
   Any head injury such as bad fall, hitting the

head with stick or traffic accident may cause the fracture of the skull and affect the hearing organs due to internal bleeding and pressure.

**Prevention** Avoid rough plays which may lead to injuries of the head. Motor cyclists and their companions should wear protective helmets when riding. Any injury to the head must be reported to a medical doctor for proper examination and treatment.

## Care of the ear

1. Sharp objects should not be used to clean the ear as they may damage the eardrum.
2. Regular washing and cleaning of the ears are necessary to avoid accumulation of wax, dirts and growth of micro-organisms which may cause diseases to the ear.
3. Chest colds, fever, discharge from the ear and head ailments should be reported to medical doctor for treatment.
4. Avoid places where there are loud noises or wear earplugs if you want to stay in such places.
5. Immunise children against deadly diseases such as polio, measles and diphtheria which in some cases cause deafness.
6. Avoid listening to radio by using earphones.
7. Do not introduce any hot liquid into your ears as this may destroy the hearing organ.
8. See an ear specialist for any ear problem and for possible early treatment. Ear cleaning should be carried out at least twice a year by a medical doctor

## Organ of smell (nose)

The organ of smell is the nose. Inside the two nasal cavities are covered with a moist membrane and well supplied with blood vessels. The upper portions of the nasal chambers have many sensory nerve cells. The sensory nerve endings join together to form an olfactory nerve that goes to the olfactory lobe of the brain.

When chemical substances carried in the air pass through the nostril, their molecules *dissolve* in the moist membrane and stimulate the sensory nerve endings which join together to form the olfactory nerve that passes to the cerebrum of the brain. The brain then interprets the chemical impulses and a sensation of smell is produced.

Sensory nerves of smell that are exposed to a particular odour over a period of long time become **insensitive** or **conditioned** to the odour and unable to respond to that odour. For example, nurses hardly perceive the odour of **iodoform** in an hospital but visitors to the hospital do.

The sense of smell in man is poor and limited compared to other animals. Dogs have very good and well developed sense of smell hence they easily recognize strangers (by their odours).

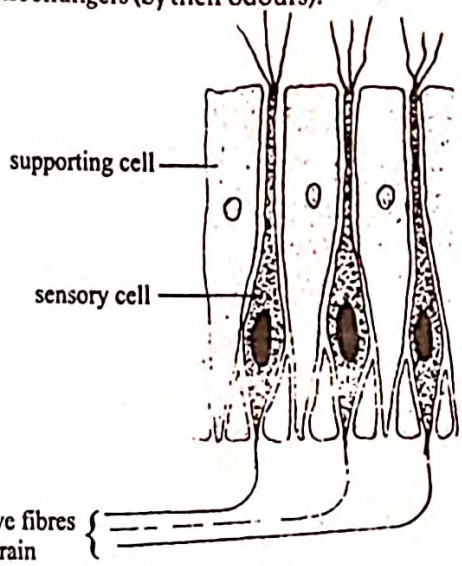



**Figure 11.13. The Olfactory cells of the nose**

## Functions of the organ of smell

1. It helps in avoiding bad and poisonous food.
2. Unfamiliar and dangerous odours such as those from wild animals can be detected and avoided.
3. Smell of burning food or leakage of cooking gas can be detected and immediate actions are taken to remedy the situation.
4. Animals depend on smell greatly to help them locate food, mates and escape from their predators.
5. Trained dogs are used to trail criminals. They detect the odours left behind by criminals and use such to trace them. When a dog finds itself in an unfamiliar environment, it can find its way home by smell.

6. **Salmon** uses its well developed organ of smell to undertake spawning migration. Young salmon fish are hatched by their parents in freshwater stream. After a short time, the immature salmon fish swim to the ocean. after about 4 to 5 years of swimming wide and far in the ocean, they return to the stream of their birth to spawn. The odours of the stream are imprinted in the young salmon before swimming to the ocean and can return to the stream when they reach spawning age.
7. The nasal mucus contains lysozyme which kills bacteria and viruses.

## Defect of the organ of smell

Among humans, there are individuals who cannot detect one particular odour. Such people are set to be odour-blind or suffer from anosmia. In the individuals, it is possible that the olfactory portion of the cerebral cortex may have been damaged, resulting in the defect.

## Organ of taste (tongue)

The organ of taste is the tongue. The sensory cells of taste called tastes buds are mainly located on the upper surface of the tongue and few in the mucous membrane of the mouth cavity and pharynx. A taste bud is flask-shaped and contains a group of sensory cells with hair-like nerve endings. Taste bud opens to the surface of the tongue by a pore. The pore allows dissolved chemical substances to reach and stimulate the nerve endings.

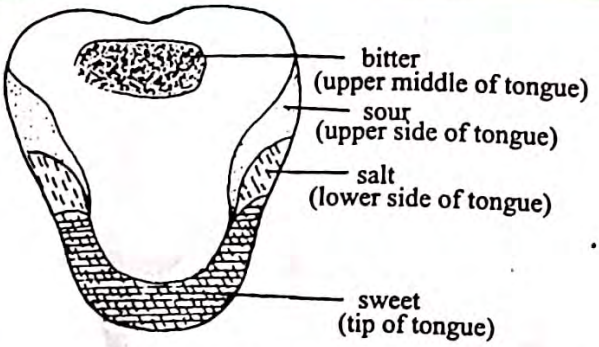



**Figure 11.14. The distribution of taste buds on the surface of the tongue of man.**

Taste buds are unevenly distributed over the surface of the tongue. There are four different kinds of taste buds classified according to the taste sensation each produces. They are taste buds for sour, sweet, salt and bitter.

Taste buds sensitive to sour are located at the *sides of the tongue* while those sensitive to sweet and salt are at the tip, and bitter at the base of the tongue. Pepper does not produce any flavour, rather it irritates the whole tongue resulting in burning sensation.

The ability to differentiate certain tastes varies among people. Some people find the taste of *phenylthiocarbimide (PTC)* to be bitter, while others find it tasteless. The ability to taste this chemical is inherited through a single pair of genes.

For a substance to be tasted, it must be dissolved in the solution (usually saliva) on the tongue. The molecules of the substance stimulate the sensory nerve endings which then pass impulses to the brain for interpretation as sweet, sour, bitter or salty.

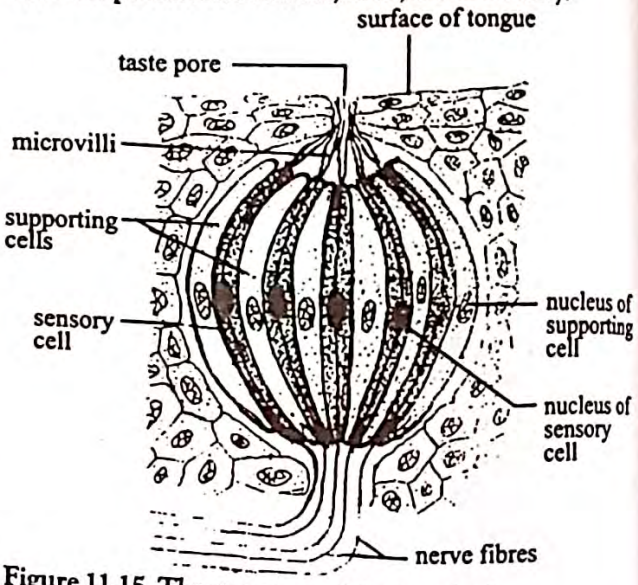



**Figure 11.15. The structure of the taste bud.**

## Defect of the organ of taste

Some people are however known to lack the ability to tell the taste of substances. They are called non-tasters. This may be due to damage to the taste area of the cerebrum of the brain.

## *Questions*

1. (a) *A drum beats and you hear it. Name the organ that enables you to hear the sound of the drum and make a labelled drawing of the whole organ.*
   (b) *Explain briefly how this organ carries out the function of hearing (W.A.S.C.).*

2. (a) *What is deafness?*
   (b) *Name two main types of deafness.*
   (c) *Name five causes of deafness and suggest ways of correcting or preventing them.*
   (d) *How do you care for your ears?*

3. (a) *Make a large well labelled drawing of a vertical section of a mammalian eye.*
   (b) *Give the function of the parts you have labelled.*
   (c) *What do you understand by the terms (i) short sight and (ii) long sight and how are tthey corrected?*

4. (a) *Briefly explain how the rays of light reaching the retina are regulated.*
   (b) *Explain why a person in a dark room is dazzled for some seconds when he is suddenly exposed to bright light. (SSCE 1995).*
   (c) *Explain why the eyes of many nocturnal animals shine in unidirectional light at night.*
   (d) *List five ways of taking care of your eyes.*
   (e) *When a person spins round rapidly for some seconds, things start turning round when he stops. Explain this phenomenon.*

# 12

# IRRITABILITY (SENSITIVITY)

**Irritability** (sensitivity) is one of the characteristics of living organisms. **By irritability (sensitivity) both plants and animals are able to respond to both external and internal environmental changes so that they can maintain suitable conditions of life. A temperature change is an example of external stimulus while a change of pH is an example of an internal stimulus. Every organism has its own peculiar irritability that enhances its chances of survival.** Whereas animals can show a very **quick response** to an **external stimulus** by perhaps moving the whole body away from the **direction** of stimulus **(taxis)**, the response of plants is very **slow** and usually involves the growth of the **stimulated part** towards or away from the direction of stimulus.

The unilateral growth of plant=s parts in response to an **external stimulus** is known as **tropism.**

## Tropisms

Plants respond to the stimulus of

**Light (phototropism)**
**Gravity (geotropism)**
**Water (hydrotropism)**

These responses which are controlled by certain plant hormones known as **auxins** are experienced in the root **growth regions** of the plants (regions close to the root or shoot tips). Auxins are produced at the tips of shoots. The **chemicals** diffuse **vertically downwards** to stimulate growth in both the shoot and root.

Auxins like the animal=s hormones are produced in **small quanties.** The effect of auxins is to increase the **growth** of plants. The growth rate of plants increases as the concentration of auxins becomes increased. But after a certain concentration, a further increase will **inhibit** rather than **promote** the growth of that plant.

## Phototropism

*This is the response of plant parts to the stimulus of light, especially* **sunlight.** Plant shoots normally grow towards the direction of **light.** Plant shoots are therefore **positively phototropic.**

## Experiments on phototropism

**Using a potted plant**

**Method:** Some cowpea seeds are germinated in two small containers such as milk cans filled with wet soil. After the appearance of the first foliage leaves, one of the cans is kept in a room by the side of a window, and the other is kept outside. They are left for about 48 hours.

**Result:** The shoots of seedlings by the window side bend towards the direction of light while those on the outside maintain straight stems.

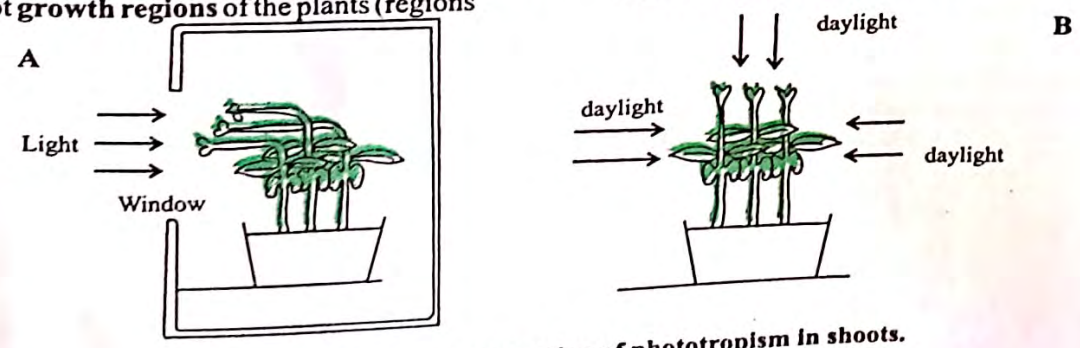



**Figure 12.1. Demonstration of phototropism in shoots.**
**A = Seedlings on window: shoots bends towards light.**
**B = Seedlings kept outside: shoots maintain straight growth.**

## Conclusion

A possible explanation of the bending of plant shoots towards one directional light source is based on the effect of light on the distribution of auxins. It has already been mentioned that auxins are produced at the terminal buds and transported vertically downwards to the growing regions. Light does not destroy auxins, but it lowers their rate of distribution. In the window experiment described above, the side of the shoots receiving light has lower amount of auxin than the other side in the dark.

There is more growth on the side with higher concentration of auxins and little growth on the side receiving light with low auxin concentration. This unequal growth causes the shoots to bend to the side where growth is reduced, that is towards the direction of light (Figure 12.2D).

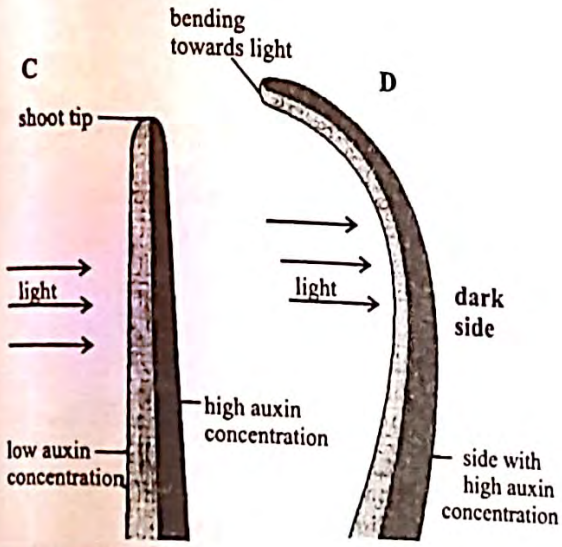



**Figure 12.2. Response of shoot to direction of light**
**C, Shoot before response**
**D, Shoot bending towards light**

The response of plant shoot to light also explains the reason why plants growing permanently in light and receiving light from all directions do not grow very tall. This is because the distribution of auxins is uniform but slow. Plants growing permanently in the dark especially the forest undergrowths, grow very straight and tall to reach the crown of the forest where they can receive maximum sunlight. Here the distribution of auxins is uniform and very fast.

## The Klinostat

The control for window experiment described above can also be performed using a **klinostat**. A **klinostat** is an instrument used to demonstrate or control the effect of light and gravity on growth of plants. It consists of a cylinder which can carry a seedling, an electric motor for a clockwise rotation of the cylinder. The speed can be altered to make one rotation (360°) in fifteen of thirty minutes as required. It can rotate either in a vertical or in a horizontal position.

### Method

The seedling is fixed to the cork in the cylinder. The klinostat is kept close to a window in a vertical position working at one rotation per fifteen minutes. At this rotational speed, all the sides of the seedling's shoot are equally exposed to light source from the window.

### Result:

After 24 hours, the seedlings in the can mentioned in method 1 bend towards the window (light source), the seedlings in the **klinostat** remain straight.

The seedling in the klinostat will however bend towards light if the klinostat is left stationary.

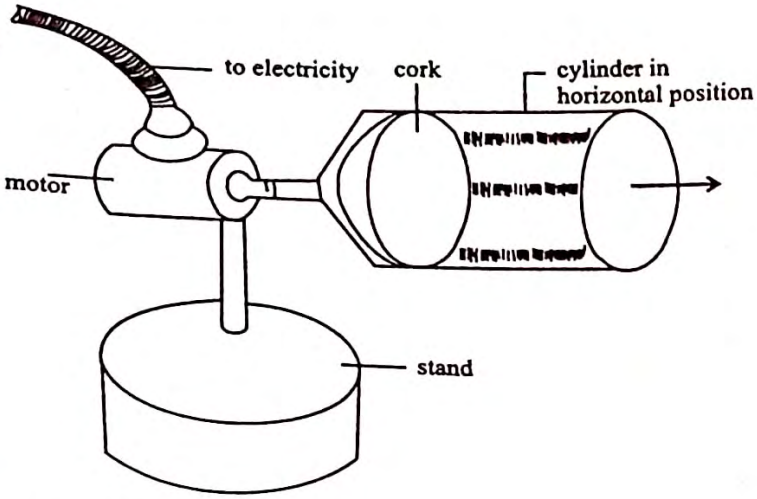
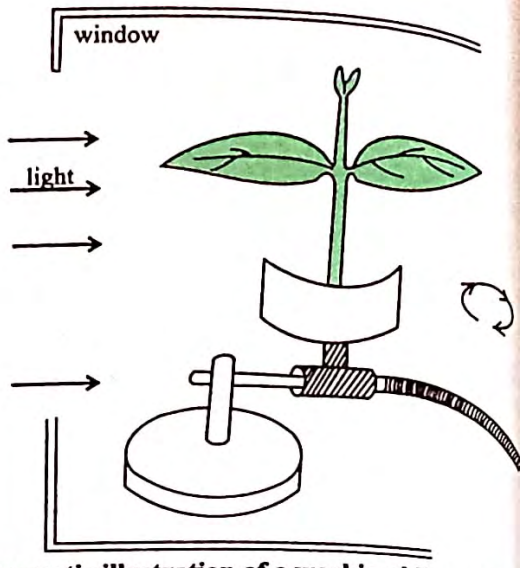


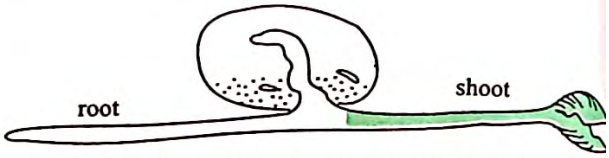

**Figure 12.3. A klinostat**




**Diagramatic illustration of a working klinostat in a vertical position.**

## Geotropism

This is the response of plant parts to the **stimulus of gravity**. Plant shoots grow away from gravity of the earth and are said to be **negatively geotropic**. Roots grow towards gravity and are said to be **positively geotropic.**




young seedling in a horizontal position

## Experiments to demonstrate geotropism

**1. Using germinating seedling (African yam bean seeds)**

**Method:**

Some African yam bean seeds are sown between moist filter papers in a beaker. As soon as the radicles and plumules emerge, some of the young seedlings are carefully removed and placed on a flat board in the dark, with the radicle and plumule lying horizontally (figure 12.4). (The purpose of keeping the experiment in the dark is to remove all responses due to light). Some of the seedlings are left in a vertical position to serve as control.

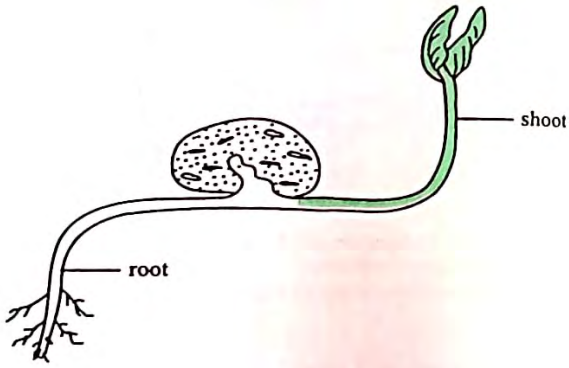



**Figure 12.4. Demonstration of geotropism in root and shoot.**

**Result**

After 24 hours the radicle, now the root, deviates from its horizontal position and grows vertically downwards, while the shoot grows vertically upwards away from the force of gravity.

The roots and shoots of those seedlings kept in a vertical position remain straight.

**Conclusion:** Shoot is negatively geotropic while root is positively geotropic

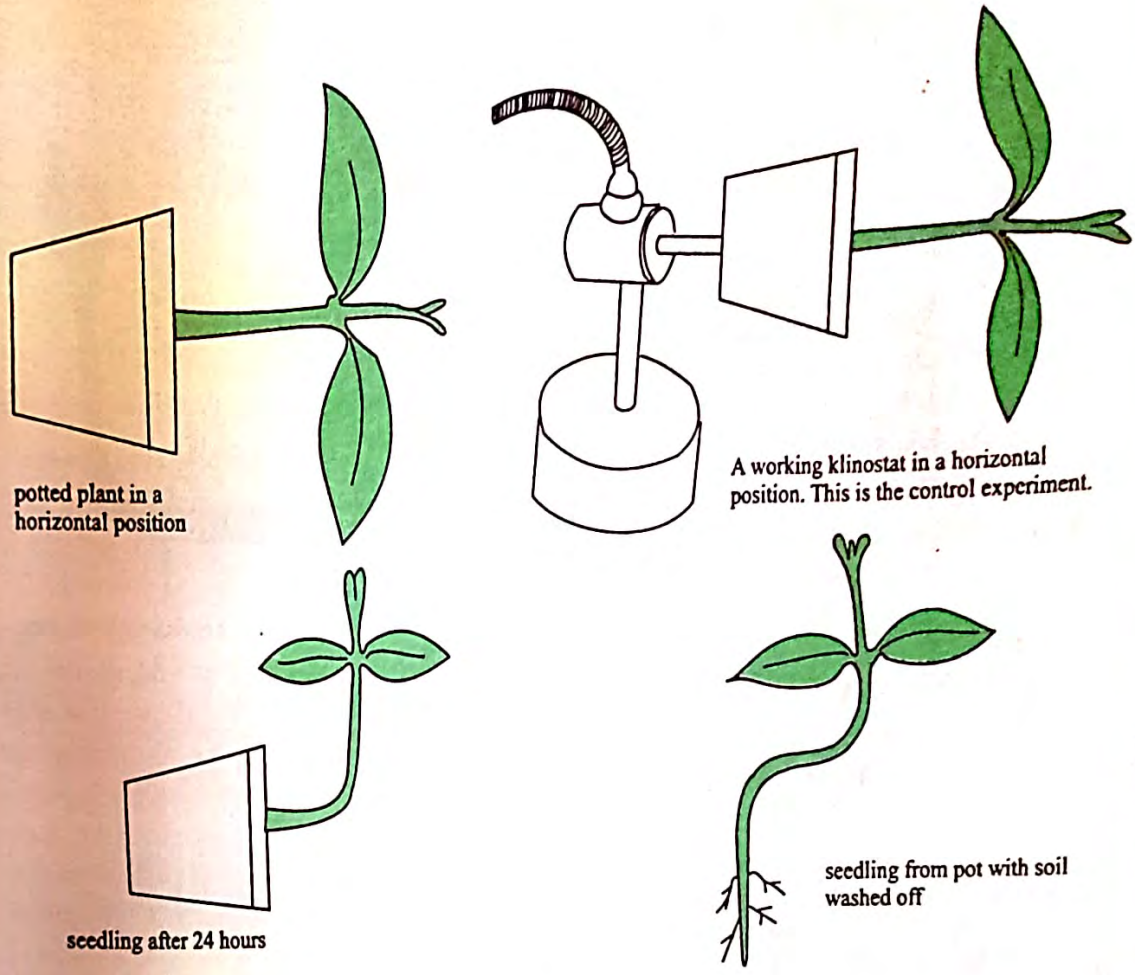



**Figure 12.5. Demonstration of geotropism with a potted plant.**

2. Using a potted plant and klinostat

Seeds of cowpea are sown in small pots (one seed per pot).

After the appearance of the first foliage leaves, the pots are placed in the dark with the seedlings in a horizontal position. A klinostat with a seedling is also kept working in a horizontal position to serve as a control. The whole set-up is left for about 24 - 36 hours.

**Result**

After 24 hours the shoot of the seedling in the pot curves and grows vertically upwards (away from gravity). If the soil is carefully washed off and the whole seedling is examined, the root is also seen to have curved and grown downwards (towards gravity).

The shoot of the working **klinostat** remains in a horizontal position and does not curve. It will however curve if the klinostat is left stationary.

## Explanation of result

**Auxin** produced at the terminal bud of the shoot under the influence of gravity is distributed to the lower half of the plant body lying horizontally. The **auxin concentration** which promotes the growth of the shoot is too much for the root and will inhibit its growth. The auxin distributed into the lower half of the plant increases the growth rate of the shoot in that lower half while inhibiting the growth of the root in the lower half where it is concentrated. Due to these unequal growths, the shoot bends away from gravity while the root whose growth is more on the upper half bends towards gravity. The effect of gravity on the root is opposite to its effect on the shoot.

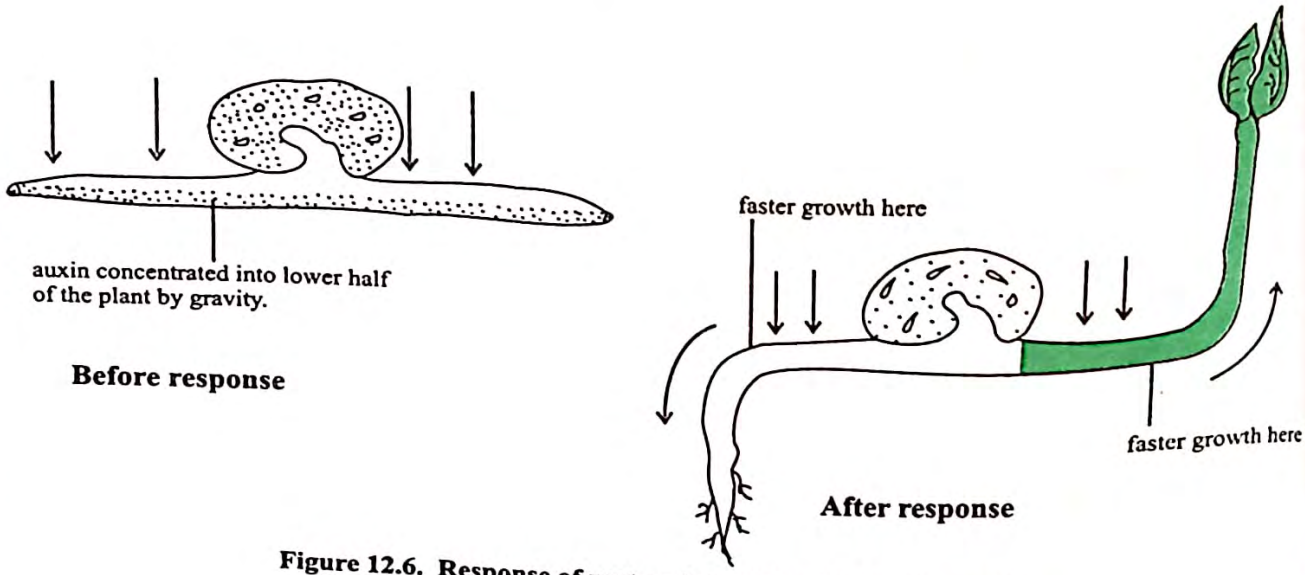



**Figure 12.6. Response of root and shoot to stimulus of gravity.**

The shoot in the working **klinostat** does not bend as the rotation of the klinostat equally rotates the plant body which receives the auxin equally at any one time. Growth is therefore uniform and gravity has no effect on it.

The advantage of this kind of response is that no matter the position of a seed in the soil, during germination the **radicle** is always **positively geotropic** while the **plumule** is always **negatively geotropic.** The **breathing roots** of mangrove trees are however **negatively geotropic.** They grow above water to obtain atmospheric oxygen for respiration.

## Hydrotropism

*This is the response of roots to the stimulus of water in the soil.* Plant roots are **positively Hydrotropic.** They grow towards areas where there is water which is very vital to life. Shoots do not absorb water and consequently they do not respond to the presence of water.

Some bean seeds are germinated in moist filter papers in a beaker. Two troughs are obtained and filled with soil to about two-third level. As soon as the seeds in the beaker germinate the seedlings with very straight radicles are selected and transferred into the soil in one of the troughs at some distance from the centre into which a porous clay pot filled with water is placed. The soil is left unwatered. Seedlings in the second trough without a porous clay pot serve as **control.** The soil is well watered. The experiment is left for 2 or 3 days after which the seedlings are carefully removed and examined.

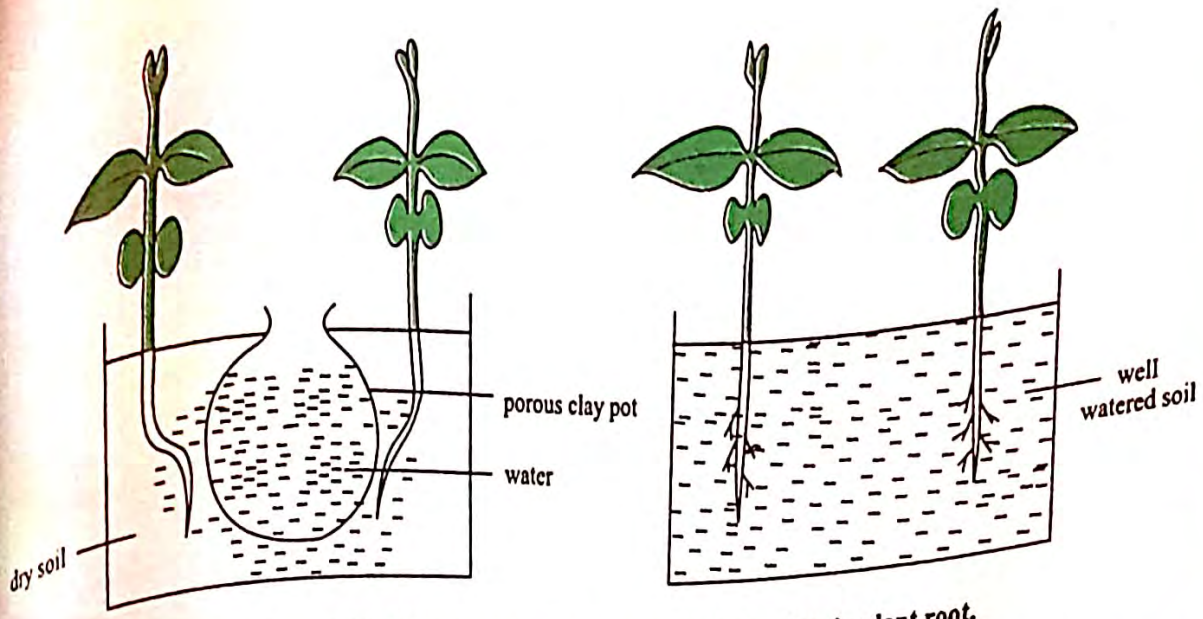



**Figure 12.7. Experiment to demonstrate hydrotropism in plant root.**

Result

The roots of seedlings in trough 1 are curved but those in trough 2 remain straight.

Conclusion

**In trough 1** water diffuses from the porous clay pot into the soil surrounding it. Since there is no water in the region of the soil where the seedlings are transplanted the roots have to grow towards the region of the soil where there is water. This brings about the curvature observed in these roots.

**In trough 2** (control) where the soil is watered uniformly, the roots grow straight because there is adequate amount of water in all parts of the soil. These roots do not have to bend because there is water in their vicinity for absorption.

## Other responses in plant

Apart from the **directional stimulus** of plants caused by light, gravity and water, some plants do respond to other types of stimuli. For instance, **pollen tubes** grow towards the **ovary after pollination** in response to the **sugary chemical** secreted by the stigma. Roots grow towards certain chemicals in the soil. *The response of plants parts to chemical is known as* **chemotropism.**

Some plants response to the stimulus of touch. This is **thigmotropism**. Examples of such responses are shown by **tendrils, leaves of sensitive plant** and the **carnivorous plants.** Tendrils are slender parts of the shoot modified for climbing. When they make contact with their support, growth is slowed down in that part where contact is made. It causes the tendril to twine round the support. The leaves of sensitive plant *Mimosa pudica,* are open when the **pulvinus** and **pulvinules** are turgid. When the leaves are touched at this time by a passing animal, the pulvinus and pulvinules suddenly loose their water content internally and become flaccid. The leaflets give a very fast response by closing up. They remain closed until they regain their turgidity. The leaves of certain carnivorous plants like the **Pitcher plant, Venus flytrap** and the **Sundew** are equipped with special mechanism to close up as soon as a visiting insect prey gets in. The leaves remain closed until the insects die and become digested.

## Nastic/sleeping movements

The **pinnate** and **bipinnate** leaves of many leguminous plants open and close as a result of certain changes in temperature, light intensity or humidity of the atmosphere. The process which is however gradual is known as **"sleeping movement"** and occurs in such leaves as St. Thomas plant, and **cassia**. Flowers of certain

plants are known to open only at certain time of the day. A good example is the **"Four O'clock"** plant which opens at about 4 pm daily. **Sunflower** changes its direction to face the **sun.** The flowers of **"Snake tomato"** remain closed during hot day and open at night or under conditions of high humidity. These flowers are pollinated at night by **nocturnal insects (moth).** These various responses of plant parts to external stimulus of the weather are known as **nastic responses** or simply **nastic movements.**

## Taxis (tactic movement)

**Taxis:** This is a **locomotory movement** of an **entire organism** or **cell** (e.g. gamete) in **response** to a **directional stimulus.** If the locomotory movement is towards the stimulus, it is **positive taxis,** if it is away it is **negative taxis.**

Animals respond to stimulus of:

1. Light (**phototaxis**)
2. Water (**hydrotaxis**)
3. Chemicals (**chemotaxis**)
4. Current (**rheotaxis**)

The response of animals to stimulus of light is called **phototaxis,** the response to stimulus of water is called **hydrotaxis** while the response to stimulus of chemicals is called **chemotaxis.** For example *Euglena* moves towards source of light (**positive phototaxis**). Earthworm move away from light (**negative phototaxis**).

Sperm move towards chemical substances produced by eggs (**positive chemotaxis**). Mosquitoes avoid repellent (**negative chemotaxis**).

Many freshwater fish (e.g. *Tilapia*) move against current (**positive rheotaxis**).

## Kinesis (kinetic movement)

**Kinesis** is the rate of change of a living organism in response to the intensity of **stimulus** and **not** the **direction** of the stimulus, that is, the stimulus does not control the direction of movement. For example, when food substances are added to water, the tentacles of *Hydra* increase their waving movement.

## Experiment

**Aim**

To demonstrate tactic responses to damp and dry environments.

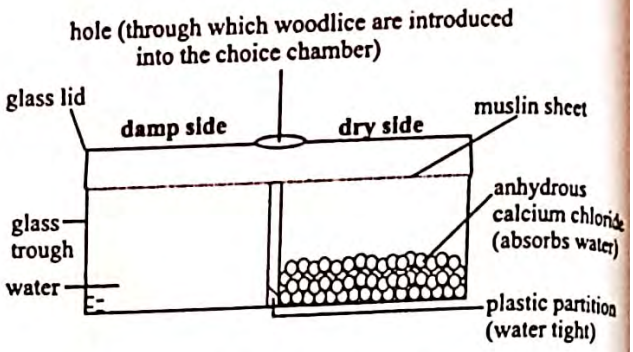



**Figure 12.8. The choice chamber**

### Method

The apparatus is arranged as in diagram. Twelve woodlice are placed on the muslin sheet in the centre of the choice chamber through a hole. The water on the left partition gives damp atmosphere while the anhydrous calcium chloride on the right partition gives a drier atmosphere. The experiment is left for 30 minutes.

### Results

Woodlice on the drier side show faster movement than those of the damp side. Majority of the woodlice on the drier side then move to the damp side and remain motionless with those of the damp side.

### Conclusion

Woodlice move faster away from a dry environment (negative hydrotaxis) to a damp environment (positive hydrotaxis).

**Note:** The response of woodlice to the dry environment by moving faster away from it also demonstrates kinesis.

**Table 48: Differences between nastic/sleep movement and tropism**

| Nastic/sleeping movement | Tropism |
|---|---|
| 1. Movements are reversible | Not easily reversible. |
| 2. Response does not lead to growth | Response leads to growth. |
| 3. Movements are due to changes in cell tugor. | Movements are not due to changes in cell tugor. |
| 4. Response to stimulus is not directed towards the direction of stimulus. | Response to stimulus is towards the direction of stimulus. |
| 5. Response is fast | Response is slow. |
| 6. Responses are due to changes in temperature, humidity, light intensity or touch. | Responses are due to water, light, gravity and chemicals. |
| 7. Responses is usually associated with the time of the day. | Not associated with the time of the day. |

**Table 49: Differences between the responses of mammals and flowering plants**

| Mammals | Flowering plants |
|---|---|
| 1. Possess a nervous system for proper coordination. | There is no nervous system. |
| 2. Co-ordination is by hormones and nerves. | Co-ordination is only by hormones. |
| 3. A short stimulus is required before a response. | A long stimulus is required before a response. |
| 4. Response to stimulus is very quick. | Response to stimulus is very slow. |
| 5. Response to stimulus results in movement. | Response to stimulus results in growth. |
| 6. Responso to stimulus is usually temporary | Response to stimulus is usually permanent. |

## *Questions*

1. (a) *What is meant by the term tropism? Describe one experiment to demonstrate a tropism in shoots and another to demonstrate a different tropism in roots.*
   (b) *What is meant by the term >irritability=? Illustrate the meaning by preference to the behaviour of (i) germinating seedlings (ii) Amoeba.*
2. (a) *Explain what is meant by nastic and sleep movements in flowering plants. Name two examples of flowering plants that exhibit these movements.*
   (b) *State three differences between nastic/sleep movements and tropism.*
   (c) (i) *Describe an experiment to demonstrate the response of shoots to a unilateral source of light.*
   (ii) *What is the advantage of this response to plant?*
   (d) *List six ways in which the responses of mammals differ from those of flowering plants.*
3. (a) *What is the biological meaning of the term irritability (sensitivity)?*
   (b) *Give an example of irritability in*
   *(i) a named invertebrate (ii) the root of a flowering plant.*
   (c) *How do plants response to the external stimulus of light?*
   (d) *Describe an experiment how you could demonstrate one tactic response in a named invertebrate.*

# 13

# HORMONAL COORDINATION IN ANIMALS AND PLANT HORMONES (ENDOCRINE SYSTEM)

## HORMONES

**Hormones** ***are chemical substances produced in small quantities by the cells of one part of the body and carried to all or some parts of the body by blood stream in animals or vascular system in plants, where they produce a response.***

**Hormonal action** may take minutes, hours, days, weeks and even months. Promotion of the body growth or sexual maturity are examples of long time actions of hormones.

A small quantity of hormone may produce a great effect on the organism=s behaviour, development or structure.

In animals, hormones are manufactured in **ductless (endocrine) glands** and poured straight into the blood stream. Hence hormones can coordinate the body functions in a place far away from where they are produced. Once a hormone is released in the blood, it is carried by blood plasma to the required organ called **target organ**. Once the effects of hormones are over, they are **destroyed** and excreted from the body.

Plants produce hormones only at the **growing parts** such as the **apical meristems** of the shoot and root, young growing leaves or developing seeds or fruits. Plants have no ductless glands as animals. In plants, the transportation of hormones is by **diffusion.**

The activities of the various parts of the bodies in higher animals are controlled and coordinated by two coordinating systems. These are **nervous** and **endocrine systems. The nervous system acts swiftly, instantly, electrically while the endocrine system acts slowly and chemically.** It is interesting to compare and contrast hormonal and nervous co-ordinations.

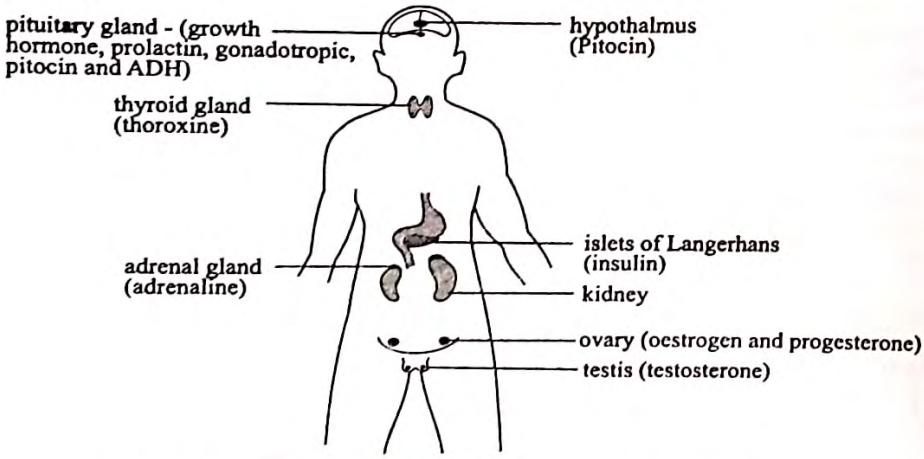



**Figure 13.1. The endocrine glands in the human body.**

Similarities

1. Hormonal and nervous systems provide means of communication within the body of an organism.
2. Both transmit messages when **triggered** by a stimulus.
3. The nerve effector of nervous system is similar to target organs of hormones.
4. In some cases, both evoke the same responses. For example, the hormone **adrenaline** when released into the blood accelerates the beating of the heart, the pupils of the eye dilate, the arterioles constrict, etc. The sympathetic nerves do the same.
5. Once the action is completed, boh cease to act.

**Table 50: Differences between hormonal coordination and nervous coordination.**

| Hormonal co-ordination | Nervous co-ordination |
|---|---|
| 1. Messages are carried chemically by blood stream. | Messages are electrically and chemically carried by nerves. |
| 2. Response to stimulus is slower. (adrenaline being an exception) | Response to stimulus is faster. |
| 3. Since it is poured into the blood, it is carried to any part of the body. | Nerve impulses are transmitted to a particular location by a particular set of neurones. |
| 4. Hormonal responses are usually widespread. Target is far away from site of production. | Responses may be localized. Sometimes one type of muscle may be affected. |
| 5. Responses may last for a longtime. For example, growth and sexual maturity are long term responses of hormones. | Responses are short-lived. For example, the contraction and relaxation of muscles. |
| 6. Their secretions, actions and responses are controlled by involuntary actions. | Their actions and response are under voluntary actions. |
| 7. Present in both plants and animals. | Present only in animals. |

**Table 51: Hormonal distribution and activities in animals**

| Gland | Location | Hormone | Cause (Stimulus for hormone production) | Functions | Effects of over secretion | Deficiency |
|---|---|---|---|---|---|---|
| **Pituitary:** This gland is referred to as a **master gland** because its secretions influence the activities of other glands. However, secretions of other glands such as thyroid and **adrenal** influence the activities of **pituitary gland** | Base of the brain | **1. Growth hormone (somatotropic)** | Age of an individual | Regulates the growth of the body | 1. In children gigantism occurs. The tallest pituitary giant is 272.034cm.<br>2. In adult acromegaly results. Hands and feet grow out of proportion, check bones enlarge and nose becomes thickened. | Stunted growth or dwarfism in children, that is, the child will be a midget. |

| Gland | Location | Hormone | Cause (stimulus for hormone production) | Functions | Effects of over-secretion | Deficiency |
|---|---|---|---|---|---|---|
| Some of the pituitary hormones are growth hormone (somatotropin) prolactin, gonadotropic, thyrotropic, pitocin and antidiuretic hormone (ADH). | | | | | | |
| | | 2. Prolactin | After birth | 1. Stimulates the secretion of milk from mammary glands.<br>2. Promotes motherly love (instinct) for the young. | Over-secretion of milk and Hypersensitivity. | Lack of milk production to feed the young. |
| | | 3. Gonado-tropic | Puberty | 1. Stimulates the development of sex organs (ovaries and testes).<br>2. Secretion of hormones from testes and ovaries | Early development of sex organs and greater sex urge. | 1. Poor development of sex organs.<br>2. Secondary sex characteristics will decline. |
| | | 4. Thyro-tropic | Thyroid gland | Stimulates thyroid gland to secrete thyroxin. | Over secretion of thyroxin. | Thyroid gland becomes inactive. |
| | Hypotha-lamus | 5. Pitocin (oxytocin) | Gestation period | 1. Causes the contraction of uterus muscles during child birth.<br>2. Regulates blood pressure.<br>3. Stimulates the contraction of smooth muscles lining the mammary ducts thus forcing milk from the mammary glands into the baby's mouth | Causes forced contraction of uterus muscles resulting in premature birth. High blood pressure. | Inhibits the contraction of uterus muscles during child birth. |
| | Hypotha-lamus | 6. Anti-diuretic Hormone (ADH) | Dehydration of the blood | More water is reabsorbed into the body by kidney tubules thus promoting osmo-regulation. | Water retained in the body leading to body swelling. | Dehydration of the body due to increase of water in urine. |

| Gland | Location | Hormone | Cause (stimulus for hormone production) | Functions | Effects of over-secretion | Deficiency |
|---|---|---|---|---|---|---|
| Thyroid | Neck below larynx | Thyroxin (this hormone is rich in iodine). | Trophic hormone (tropin) from pituitary gland. | 1. Accelerates the rate of metablolism in the cell<br><br>2. Controls growth. | Hyper-thyroidism, that is:<br>1. Increased metabolism<br>2. Increased heart beat.<br>3. Over-anxiety<br>4. Loss of weight.<br>5. Excessive growth of tissues behind the eyes leading yo a disease called **exophthalmos** | Hypo-thyroidism that is<br>1. Metabolic rate slows down<br><br>2. Increase in weight because less food is respired.<br><br>3. Mental activity slows down making a person less alert.<br><br>4. In infants, cretinism occurs leading to mental, physical and sexual retardation.<br>5. Goitre. |
| **Parathyroid glands.** Four small bodies embedded in the thyroid gland. | Neck (Back surface of thyroid lobes). | Parathormone | | Helps to maintain the normal level of calcium and phosphate ions in the body. | Hyper-calcaemia (bones become fragile, soft and prone to fracture). | Hypocalcaemia and tetany occur. The person is nervous and his muscular activity becomes uncontrollable and spasmodic. |
| Adrenal | Above Kidney | Adrenalin | Fright, anger, stress, danger. | 1. Increases body blood sugar by conversion of liver glycogen into glucose.<br><br>2. Increases muscular power and resistance to fatigue.<br><br>3. Increases the rate of heart beat.<br><br>4. Pupil of the eye dilates. All these reactions promote faster responses to external stimuli hence this hormone is sometimes called "emergency hormone". | 1. Over anxiety.<br><br>2. Over excitement. | Luck of energy, weakness and tiredness. |

| Gland | Location | Hormone | Cause (stimulus for hormone production) | Functions | Effects of over-secretion | Deficiency |
|---|---|---|---|---|---|---|
| **Pancreas** (Islets of langerhans). | Below and behind the stomach | Insulin | Increase in blood sugar level. | Converts excess blood sugar to glycogen and therefore lowers blood glucose. | Blood sugar falls below normal. | Diabetes mellitu |
| Ovaries | Pelvis | Oestrogen | 1. Pituitary gland<br>2. Ovary development | 1. Stimulates the development of female secondary sex characteristics e.g. breasts development, hair in the arm and pubic areas.<br>2. Controls menstrual cycle and the development of mammary glands.<br>3. Promotes sex urge. | Abnormal urge for sex. | 1. Poor development of reproductive system.<br>2. Decline of female secondary sex characteristics. |
| Ovary-corpus luteum | Pelvis | Progestrone | Ovulation | 1. Prepares and maintains the lining of the uterus after ovulation.<br>2. Aids the implantation of the fertilized eggs in the walls of the uterus.<br>3. Development of breasts during the later months of pregnancy. | Violent muscular contractions of the uterine wall may occur before birth or at birth.<br>This may lead to the death of the embryo. | 1. Irregular menstrual cycle.<br>2. Poor development of mammary glands.<br>3. Abortion of fertilized egg. |
| Testes | Scrotum | Testosterone and androsterone | 1. Tropic hormone (tropin) from pituitary gland.<br>2. Testes development | 1. Stimulates the development of male secondary sex characteristics e.g. muscular body, deep and loud voice, hair in the armpit and pubic areas.<br>2. Promotes sex urge.<br>3. Promotes cell respiration and blood circulation. | Abnormal urge for sex. | 1. Poor development of reproductive system.<br>2. Decline of male secondary sex characteristics. |

## Plant hormones [auxins, gibberellins and cytokinins (kinins)]

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 plants 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. Three important hormones in plants are **auxins, gibberellins** and **cytokinins.**

# PLANT HORMONES

## Auxins

Auxins help primarily in influencing cell elongation and enlargement hence sometimes referred to as **growth hormones.** Actions of auxins are to stimulate or inhibit growth hence they are regarded as **growth regulators.** The most abundant natural auxin manufactured in plants is **indoleacetic acid (IAA). IAA** is secreted most abundantly in the tips of shoots, developing leaves, flowers, fruits, cambial cells and root tips. Auxins have been artificially synthesised. An example of a sythetic auxin is **Dichlorophenoxy ethanoic acid** (2,4-D).

### The roles of auxins

1. **Phototropism of shoot**
   When light shines on one side of the shoot of a plant, the auxin on that side is reduced, and consequently the growth of that side slows down. The shaded side (side not receiving light) receives more auxins resulting in faster growth. This unequal growth produces bending of the shoot towards the side receiving light.
2. **Auxin as inhibitor of lateral buds**
   Auxins produced in the terminal bud stimulate the growth or elongation of the main stem while at the same time move downward to the shoot to inhibit 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.
3. **Auxins and fruit development**
   Once a flower is fertilized, auxins are produced and sent to the ovary causing rapid development of the ovary as it develops into a fruit. The presence of auxins also prevents the formation of **abscission layer** at the base of the flower stalk. This will help the fruit 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.
4. **Auxins and leaf abscission**
   Shedding of leaves is due to the formation of **abscission layer** at the base of the petiole. Reduced amount of auxins stimulates the formation of abscission layer. Shedding of leaves is an adaptation usually carried out during adverse condition by shrubs and some trees such as rubber and cotton trees.
5. **Auxins and cell division:** Auxins are involved in the process of cell division.

### Experiment to demonstrate the effect of auxins on the growing tip (coleoptile) of maize seedlings

**Method:**

Two maize grains are germinated in each of three beakers labelled **A, B** and **C.** The coleoptile tips of two of the maize seedlings in **A** are covered with an **aluminium foil.**

In beaker **B,** the coleoptile tips are cut off while the coleoptile tips of beaker **C** are left untouched and thus act as a **control.** The three beakers are placed in a **blackened box** with a small hole on one side to allow sufficient light in. The box is placed near a window with hole facing the source of light and left for four days.

**Results:** The coleoptile tips of beaker **A** do not bend. The coleoptile tips of beaker **B** do not bend. The coleoptile tips of beaker **C** bend towards the source of light.

**Conclusion:** There is no bending in beaker **A** because the elongation area is prevented from receiving light. There is no bending in beaker **B** because the coleoptile tips that produce auxins are cut off.

In beaker **C** which is the **control,** there is bending towards the light due to uneven distribution of auxins. Light inhibits auxin production. The side receiving light receives little auxins while the side not receiving light has a lot of auxins thus causing the bending.

## Modern applications of auxins

1. **Weed control:** Synthetic auxin called **2,4-D** is used in killing weeds. When applied to a lawn, it kills the weeds having broad leaves without killing grasses.
2. **Development of seedless fruits:** When auxins are applied to flowers that have not been

pollinated, fruits develop. Seedless water cucumbers, watermelon and tomatoes have been produced in this way.

3. **Preservation:** Yams and potatoes have been preserved for a long time by the application of auxins to tubers.
4. **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 fruit on the plants. Tomato and orange fruits have been prolonged on plants in this way.
5. **Stem cutting:** Auxins have been used to promote root growth in stem cuttings. A stem of desired plant is cut into pieces. Auxins are sprayed on the pieces of the stem. Adventitous roots spring up from the stems. In this way the propagation of the plant is ensured.

### The roles of Gibberellins

1. Gibberellins stimulate rapid stem elongation in dwarf plants and other plants that undergo little stem elongation.
2. **Dormancy** in seeds and buds are broken when gibberellins are released to them.
3. Stimulate the embryos in germinating seeds to produce enzymes that hydrolyse starch reserves in the seeds.
4. Stimulate some biennial plants to flower during their first year of growth.

### The roles of cytokinins (kinins)

1. Help in breaking dormancy in some seeds.
2. Promote flowering in some plants.
3. Promote fruit development in some plants.
4. Help to retard the onset of aging in leaves by maintaining protein and nucleic acid syhthesis.
5. Cytokinins and auxins act together in promoting the replication of DNA.

## *Questions*

1. *What is a hormone? Name three hormones and in each case say*
   - *(a) Where the hormone is produced*
   - *(b) Its purpose in metabolism and where possible the effects of its deficiency.*
   - *(c) Tabulate difference between nervous and hormonal responses.*

2. *(a) Copy and complete the table below.*

| *Name of gland* | *Location* | *Hormone* | *Cause of production* | *Function* | *Effect of deficiency* |
|---|---|---|---|---|---|
| *Thyroxin* | | | | | |
| *Adrenalin* | | | | | |
| *Insulin* | | | | | |
| Test *oterone* | | | | | |

   - ***(b) List two differences between the actions of plant and animal hormones.***

3. ***(a) Define growth***
   - ***(b) Mention five factors that influence growth in organisms.***
   - ***(c) What are the roles of the following hormones in plants: (i) Auxins (ii) Gibberellins and (iii) Cytokinins.***

# 14

# THE MUSCULAR AND SKELETAL SYSTEMS

## MUSCLES

Muscles can be referred to simply as the flesh mostly associated with bones to give shape to the bodies of animals. The flesh may be red in the case of mammals.

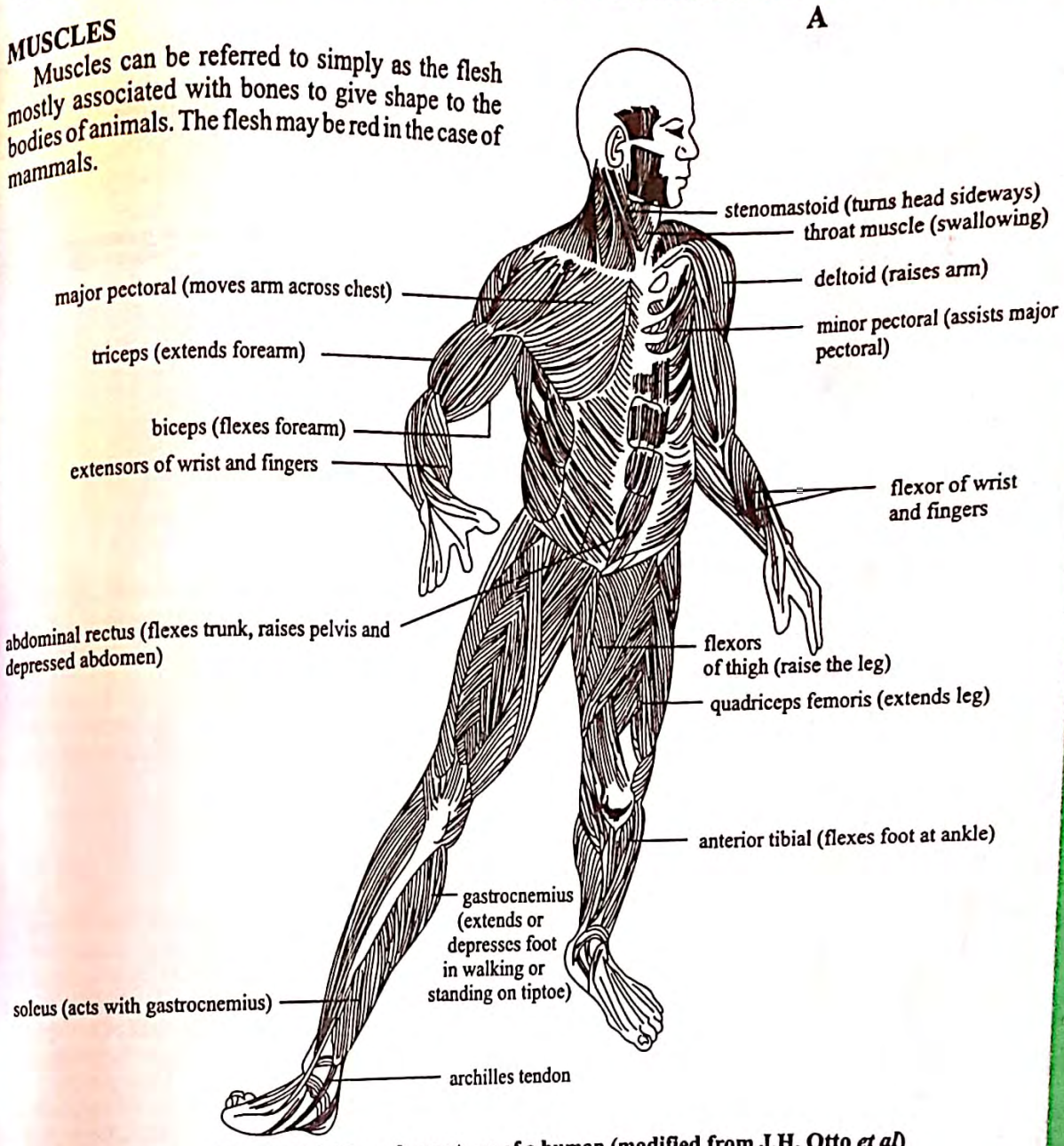
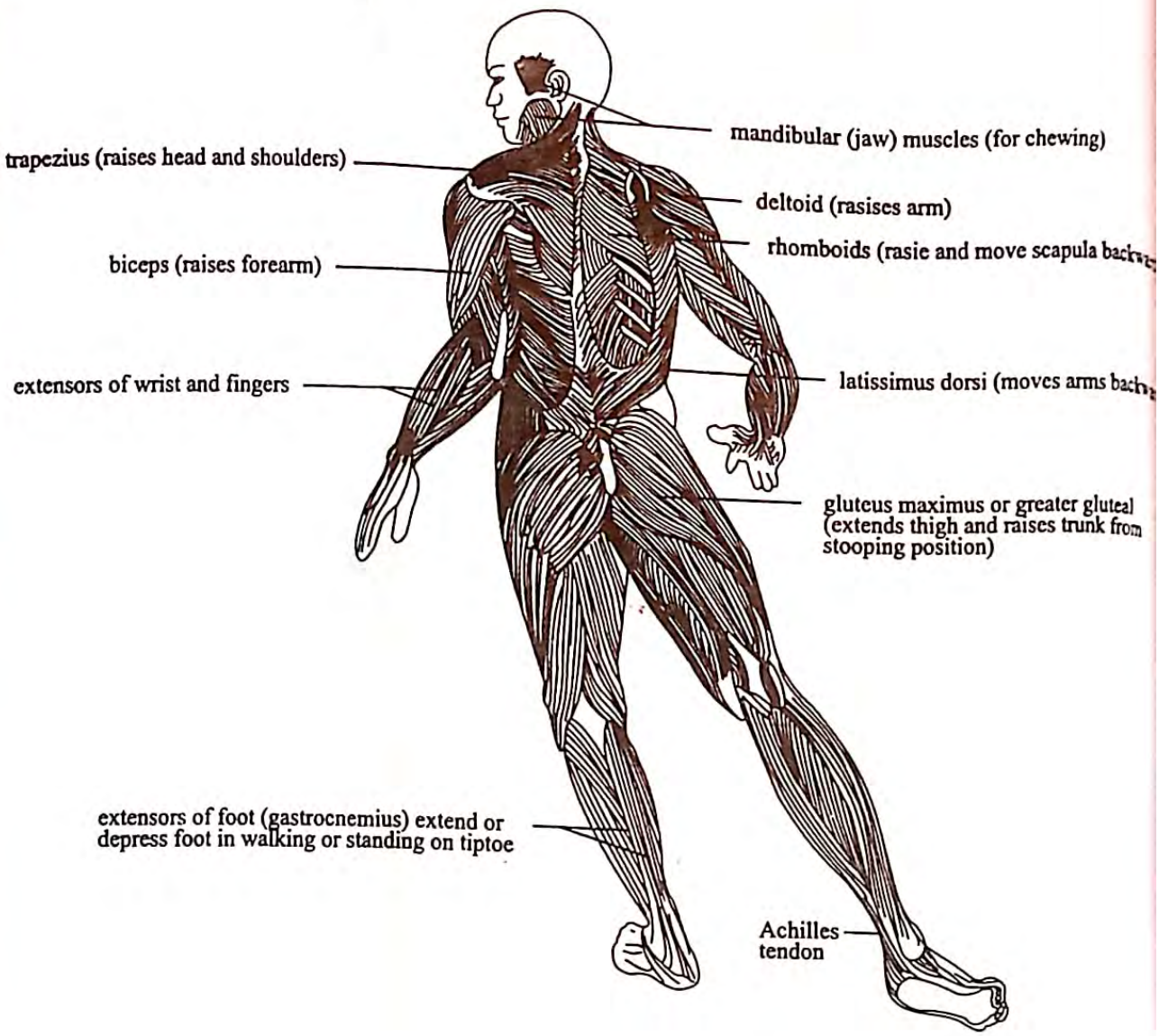



**Figure 14.1. Muscular systems of a human (modified from J.H. Otto *et al*)**
**A = front view**
**B = back view**

B




## General properties of muscular system

All muscular tissues are contractile. This means that the muscle pulls its **insertion** towards its origin thereby becoming **shorter** and **thicker**. In doing this, some muscles reduce to one-half or one-third of their resting length. A muscle is said to be at rest when it is not contracting visibly to bring about movement. This said **"resting"** is when it is in a slightly contracted state known as the **tone** or **tonus of the muscle**. The muscle is well supplied with nerve by nerve endings of the end-plate types.

If the nerve supply is severed, the muscle tone is lost and the muscle becomes flabby. The muscle is also well supplied with blood through numerous blood vessels and capillaries. The muscles account for about 40% of the total body weight of a mammal. It is 75% water and the remainder consisting of protein (actin and myosin), fat, glycogen, mineral salts, ATP and phosphagen. The muscle is made up of a number of elongated cells called fibres which are in turn made up fibrils and filaments. *The* ***Muscles are effectors, that is structures which respond directly or indirectly to stimulus.***

## Structure of muscle

A whole muscle, such as the **biceps** of the upper arm of man is made up of **numerous fibres** of various length ranging from 1 to 40 millimetres. At the two ends are strong bands of white fibrous tissues called **tendon** by which muscles are attached to the bones. The tendon is also contractile.

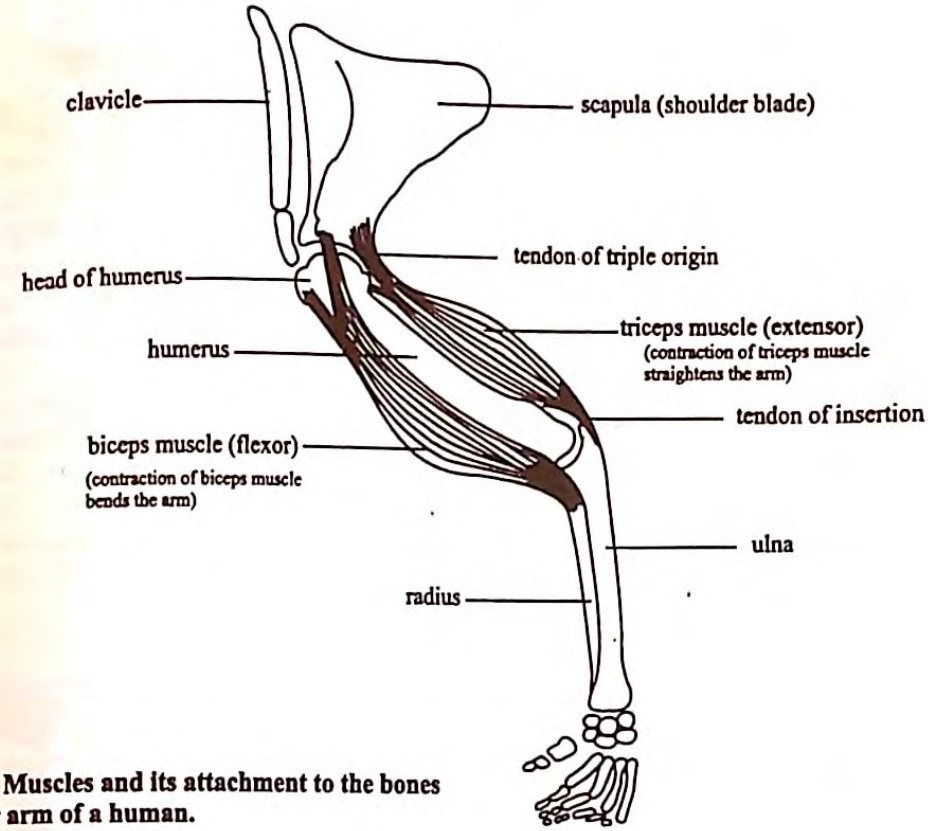
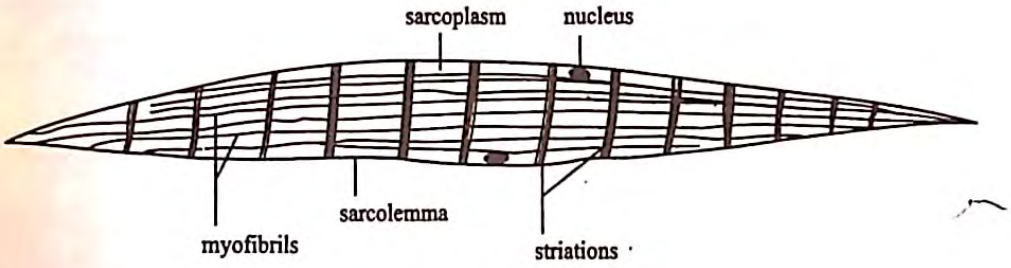



**Figure 14.2. Muscles and its attachment to the bones in the upper arm of a human.**

## Muscles and their attachment to bones in upper arm of man

Each muscle fibre is a multinucleate cell **(syncytium)** tapering at both ends, filled with specialized cytoplasm called **sarcoplasm.** The delimiting or bounding membrane is called **sarcolemma.**




**Ffigure 14.3. Whole striated muscle fibre.**

Myofibrils or fibrils are seen to run parallel from one end to the other. These fibrils are very important in the contraction of the muscle. Short striations cross the elongated myofibrils breadth-wise.

## Types of muscles

There are three types of muscles:
(1) unstriped muscle
(2) striped muscle and
(3) cardiac muscle.

## Unstriped muscle (involuntary muscle)

The unstriped muscle is also called **involuntary muscle, smooth muscle, unstriated muscle,** or **non-skeletal muscle**. It is found in the wall of the **gut, blood vessels, iris** and **ciliary body** of the eye and in the dermis of the skin. They are also present in the **urinary bladder, genital tracts** and **wall of bronchioles**. Unstriped muscle is made up **of long narrow spindle-shaped fibres**. Each fibre has a **central nucleus** surrounded by cytoplasm which contains fine **contractile threads** (myofibrils) running **longitudally**.

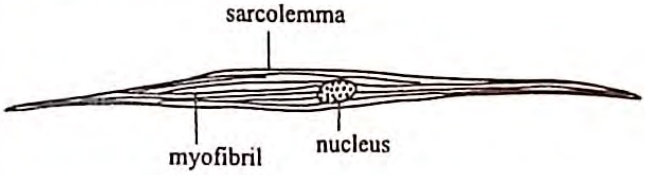



**Figure 14.4. The unstriped muscle fibre.**

Unstriped muscle is not easily fatigued and is not under the control of the will, its action is **involuntary**. It is under involuntary control being supplied **(innervated)** by **autonomic nervous system.** The movements are therefore slow.

**The functions of the unstriped muscle are:**

1. The closing and opening of cavities, tubes and ducts.
2. In the alimentary canal, circular muscles narrow the lumen while the longitudinal ones open it.
3. In the iris, circular muscles will narrow the pupil while the radial muscles dilate it.

## Striped muscle

(a) **Voluntary muscle** is **under** the control of the w
It receives its nerve supply from the **central nervo**
**system (brain). The voluntary muscles** are **stripe**
or **striated** in structure. Voluntary muscles are a
called **skeletal muscle** because they are attached
**bones**. They contract and relax **at will** to bring ab
movements of the parts to which they are attache
The point of attachment to the stationary bone
called **origin of the muscle** while that on the mova
bone is called **point of insertion**. Voluntary muscl
work in **pairs, a flexor** causing bending at a joint a
an **extensor** causing straightening (figure 14.2).

Biceps contract to bend the arm at the elbow while th
triceps is relaxed. The triceps contracts to straight
the arm while the biceps is relaxed. Each musc
consists of numerous fibres which are arranged
large numbers to form bundles called fascic
(singular fasciculus). **A fasciculus** is bounded by
membrane called **perimysium**. The entire muscle
bounded by a similar membrane called **epimysium**.

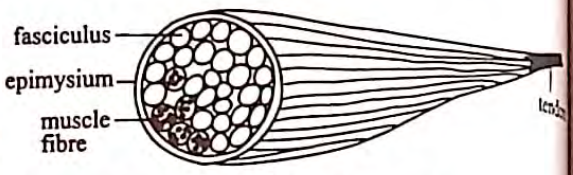



**Figure 14.5. Cross section of a muscle.**

Each muscle fibre within a fasciculus is in tur
made up of a number of **myofibrils** of simil
structure.

## Functions of voluntary muscles

1. Voluntary muscles contract to move the body i the various activities we carry out such as walkin swinging of the arms, running, swimmin jumping etc.
2. Lifting and carrying of weights.
3. Pulling, pushing, dragging, rolling and throwin of objects.
4. Opening and closing of the mouth, chewing o substances in the mouth, shouting etc.
5. Working on the field, playing games, sportin hunting, driving, riding etc.

## Cardiac muscle

Cardiac muscle is also called **heart muscle** because it is found in the walls of the heart. Each fibre of cardiac muscle is a short cylindrical cell. The cells are arranged in column connected by short oblique cross **connexions** to form the tissue. Cardiac muscle are **striated**. They are **intermediate** between the **skeletal muscles** and **involuntary muscles** in structure. Like the voluntary muscles its action is rapid but it is not easily fatigued. It contracts and relaxes without stop throughout the life of the animal. It is **innervated by both the cranial nerve** and the **vagus nerve** of the autonomic nervous system.

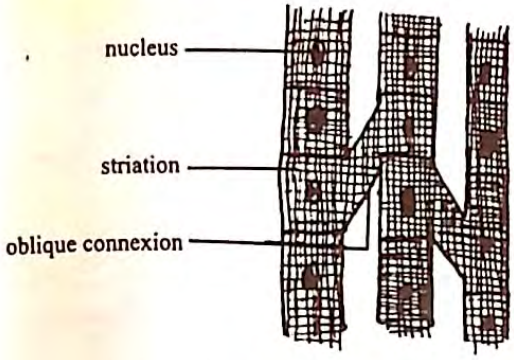



**Figure 14.6. A section through the cardiac muscle.**

The **vague nerve** of the parasympathetic nervous system slows down or **deaccelerates** the heart beat while the sympathetic nervous fibre accelerates or quickens the heartbeat. During muscular action, adrenaline is found to be on the increase in the blood and the heart beats faster as

more blood carrying oxygen gets to the tissue. More glucose is oxidized to release energy for the muscular action and more carbon (IV) oxide is produced. Adrenalin speeds up the heart beat.

## HOW REGULAR EXERCISE HELPS MUSCLES AND JOINTS

Regular exercise is very important for an efficient working of the body muscles in the following ways.

1. Help to tone the muscles so that they are able to contract well.
2. Well exercised muscles prevent aches.
3. Blood supply to the muscles is improved, thus making the heart and lungs muscles to work efficiently.
4. Body joints work efficiently and smoothly.

# SKELETON

### What is skeleton?

The protoplasm is an almost fluid substance in the single-celled organism like the *Amoeba, Euglena* and *Chlamydomonas*. The cell membrane, the pellicle and the cellulose cell wall are firm enough to support the entire cell. A multicellular and complex organism needs a much firmer frame work to support its body and keep it in shape. Examine the land snail for an example, its shell supports its soft body and gives it the characteristic shape.

*Skeleton is therefore, the hard framework on which the body is built.* This hard framework may be made up of **sand particles** as in *Arcellar* (a shelled *Amoeba*), exoskeleton as in insects and snails, **cartilage** as in the cartilaginous fish, **bones and less cartilage** in the bony fish and other vertebrates.

### Functions of the skeleton

1. **Protection:** It gives protection to the delicate organs of the body. For example, the skull protects the brain, eyes and ears. **The thoracic** bones protect the heart and lungs. The vertebral column protects the spinal cord.
2. **Support:** The rigid framework of the skeleton gives support to the body. The cervical vertebrate support the head and the bones of the hind-limbs support the upper parts of the body.
3. **Muscle attachment:** Skeleton provides places for the attachment of muscles.
4. **Movement:** The movement of certain parts of the body is brought about by the bones when muscles act on him. The contraction and relaxation of the muscles of the legs bring about motion.
5. **Manufacture of white and red blood cells:** The white and red blood cells are manufactured in the bone marrows of the long bones.
6. **Breathing:** The thoracic bones aid breathing movement.

7. **Shape:** Skeleton gives shape to the body.
8. **Transmission of sound waves:** The three small, soft and light bones found in the middle ear (malleus or hammer, incus or anvil, stapes or stirrups) vibrate and transmit sound waves from the middle ear to the inner ear.

## Types of skeleton

There are three types of skeleton found in animals and they are:

1. Hydrostatic skeleton
2. Exoskeleton
3. Endoskeleton

### 1. Hydrostatic skeleton

Hydrostatic skeleton is found in soft-bodied animals, such as earthworms and sea anemones. It consists of the body fluid secreted by the body wall and stored in the coelom. The fluid being inside a **closed system** presses against the muscles (longitudinal and circular) of the body wall. These muscles in turn contract against the fluid. Hydrostatic skeleton is thus constructed on the principles of the combined effects of fluid **pressure** and **muscle contraction in a closed system to maintain the shape and form of the animal.** It goes further to perform for the animals, the functions of support, protection and movement.

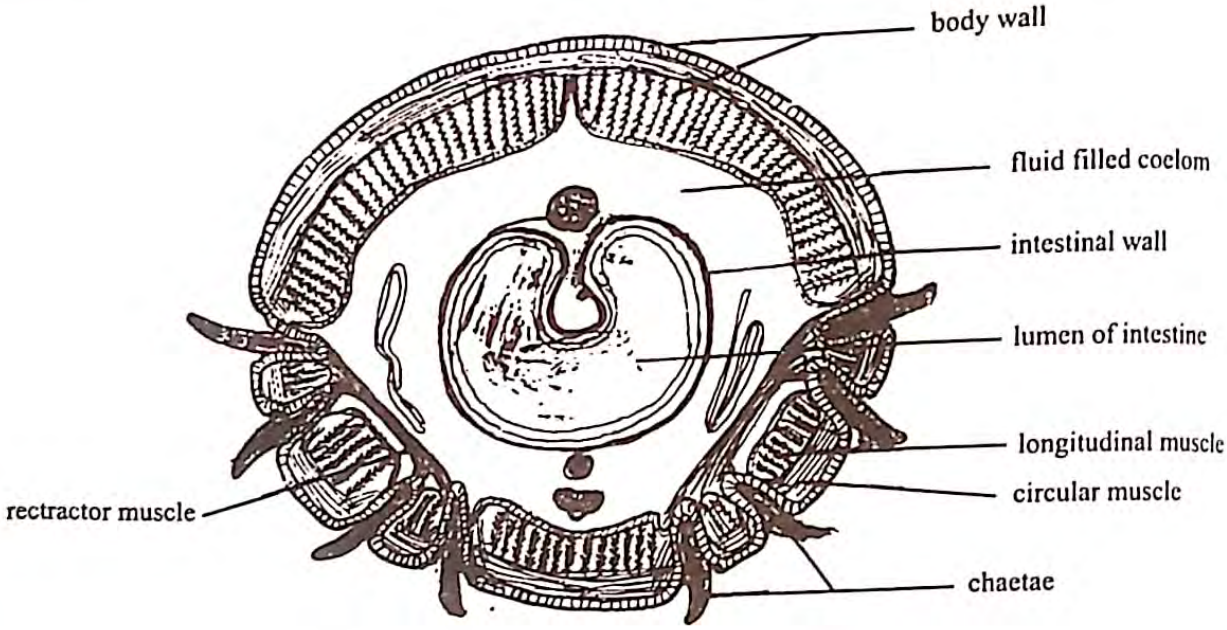



**Figure 14.7. Transverse section of an earthworm.**

### 2. Exoskeleton

Any hard structure which gives shape, and forms the framework of the body of the animals located externally on the animals constitutes the exoskeleton. The exoskeleton may cover the entire external surface of the of body such as in insects and many other arthropods where it protects the animals against dessication in the dry habitat, or serves as **hydrofuge** against wetting in aquatic habitat. The shells in the molluscs, tortoise and turtle are also of this type. Tortoise and turtle have both exoskeleton and endoskeleton.

### Endoskeleton

All hard parts of the body found inside the body of the animals (in other words the skeleton that lies inside the body of the animals), on which all the soft parts are built is called endoskeleton. Endoskeleton is found in the vertebrates with very few occurrence in invertebrates such as the corals, (Coelenterata), **sepla** and **octopus.** Endoskeleton is made up largely of bone with little cartilage. In the cartilaginous fishes, the endoskeleton is made up entirely of cartilage without bone materials.

## Chitin

Chitin is non living and non-cellular and is secreted by the underlying epidermis. It is a protein-carbohydrate compound. It is composed of several different substances. It is really made up of an outer waxy layer, a middle horny layer and an inner flexible layer. These layers are modified among the various arthropods and also among the different parts of the body. In some, the chitin is **soft** and **permeable** (aquatic insects) while in others it forms a **veritable coat of armour** (terrestrial insects). Between **joints** and between **segments**, it is **flexible** and **thin** to permit free movements. It is harder in crustaceans where it is infiltrated with **calcium salts**. In general its structure is admirably adapted for **protection** of delicate **internal organs**, for **attachment of muscles**, for serving as levers and centres of movement, and for preventing the entrance and loss of water.

Although hard protective structures are common among other groups of animals none have used them so effectively as the arthropods. Chitin in arthropods is used as biting jaws, for grinding in the stomach, as lenses of the eyes, for sound production (e.g. grasshoppers), as sensory organs (antennae and antennules), for coupulatory organs, organs of defence, and for ornamental purposes.

A **chitinous exoskeleton** limits the size and weight of arthropods. In order to increase in size or grow it has to shed its outer shell at intervals and grows larger. This process is called **ecdysis or moulting**. The presence of chitin helps arthropods to adapt to different variety of terrestrial habitats.

## Cartilage

A **cartilage** is a tough elastic and semi-transparent tissue devoid of blood vessels and nerves.

## Functions of cartilage

1. It prevents friction between two bones and allows smooth and free movement.
2. It absorbs shock between bones. For example the shock resulting from the vertebral bones are absorbed by cartilaginous intervertebral discs.
3. It keeps open the trachea (windpipe) so that air flows into the lungs always. The cartilage of the nose also keeps the nostrils open for in-take of fresh air and output of waste air.
4. The cartilage of the ribs allows contraction and expansion of the thorax thus enhancing breathing mechanism.
5. It forms cushion in the sockets of bones such as the glenoid cavity of the shoulder and hip sockets.
6. The ear cartilage keeps the pinnae (external ear) erect so as to collect sound vibrations from the air.
7. Cartilage and bone provide the firm areas for attachment of the tendons of the muscles.
8. Fibro-cartilage is found in the pubis symphysis where it allows for considerable expansion of the pubis during parturition (child birth) without complete breakage.

## Bone

A bone is strong, hard and tough connective tissue mainly made of calcified material.

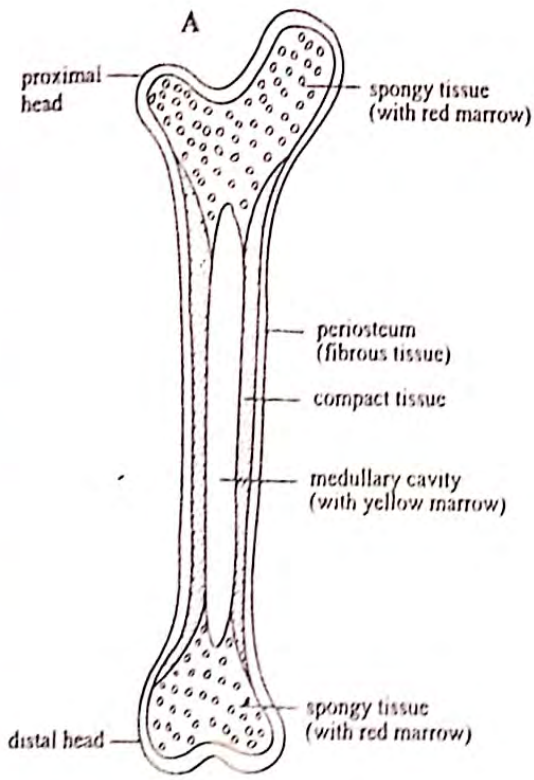
**Composition of bone:** A fully developed bone is hard and brittle. Bones can break, and a break in a bone is called **fracture**. The bone is however not the hardest substance in the body of man or other mammal. The dentine of the tooth is the hardest substance in the body of a mammal. A bone consists of organic and inorganic materials. The organic materials in a bone is **gelatinous** and accounts for the tenacity and elasticity of bones. The inorganic components of bone consist of **magnesium, phosphorous calcium** compounds and other mineral matter which give rigidity and hardness to bone. The organic matter of the bone is first formed and the laying down of inorganic substances takes place later. The laying down of mineral substances in the bone is called **ossi-fication.** When bones turn, it is the organic matter that is burnt off while the mineral salts remain as ash.The bones of young children are soft and flexible. They are not as brittle as those of the adults. The bones can be more brittle in the very old people. When bones are soaked in dilute acid, the mineral salts in them are dissolved out leaving the organic matter. The three bones in the **ears are not ossified**, they vibrate to transmit sound waves across the middle ear into the inner ear.

They are the **smallest, softest and lightest bones in**

the body of man. They are called **malleus, incus** and **stapes.** They are arranged in the inner ear in that order.

## The structure of a bone

Each bone has **two heads** and a **shaft** in between the heads. The head to the body is called **proximal head** and the other way from the body is called **distal head.** A long bone such as the femur of the thigh, the proximal head forms a joint which articulates with the hip bones, **ilium**, ischium and pubis, while the distal head forms a joint with tibia and fibula as the knee joint with the knee cap keeping them in position. The heads are not ossified and so remain soft throughout. They contain **red marrow** which manufactures **red blood cells, white blood cells** and **blood platelets.** The heads are therefore spongy and not compact so that a lot of capillaries enter them to supply nutrients and remove manufactured blood cells and waste products. The shaft is largely ossified, dense, compact and strong. For this reason, it is hollow at the centre. This cavity contains the **yellow marrow** which has a rich supply of blood vessels and fat. In this yellow marrow some white blood cells are manufactured. The shaft has numerous tiny holes called **Haversian canals.** These canals have blood vessels and nerves which carry nutrients and impulses to the cells of the bones respectively. The heads are covered with cartilage while the shaft is covered by a tough fibrous tissue called **periosteum.**



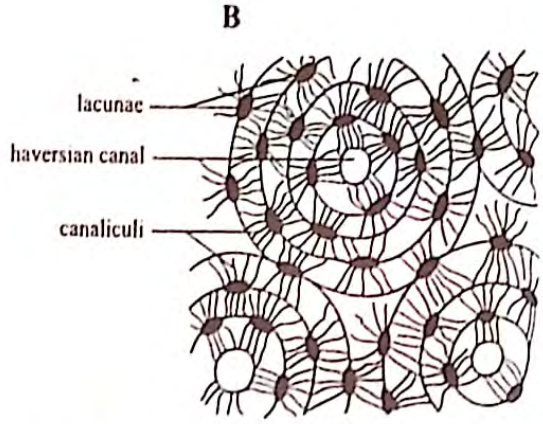




**Figure 14.8.**
**A = Longitudinal section of the long bone of human**
**B = Transverse section of a compact bone**

## Kinds of bones

The bones are classified according to their **shape** and **length** into four classes.

1. **Long bones**
   The long bones are found in the limbs such as the humerus of the upper arm, radius and ulna of the lower arm in the fore limb. The femur in the thigh and tibia and fibula in the leg all of the hind limb. The ribs and clavicles are also long bones. The longest of these bones is the thigh bone (femur). All long bones are curved at their shaft in order to give them strength.
2. **Short bones:** Short bones are largely made up of spongy tissue covered externally by a thin coat of compact tissue. The bones of the vertebral column, carpals, metacarpals, tarsals, metatarsals, phallanges and patella are all **short bones.**
3. **Flat bones:** Flat bones are thin and plate-like. A flat bone is made up of two sheets of compact tissue with a narrow layer of spongy

tissue in-between. Examples are the bones of the skull, scapula and ilium.

4. **Irregular bones:** These bones are peculiar in shape, structure and function. They are the small bones of the middle ear described earlier.

## Bones of the mammalian skeleton

The **mammalian skeleton** is made up of **axial** and **appendicular** skeleton. The axial skeleton consists of **skull, vertebral column** (backbone) and rib cage (sternum and ribs) while the **appendicular skeleton** is made up of **pectoral** and **pelvic girdles** and the **limbs.**

## Axial skeleton

**Skull:** The skull consists of two major parts namely the **cranium** (brain box) and the **facial bones.**

**Cranium:** The cranium is made up of **flat** and **curved bones** firmly fitted together by the saw- like edges called **sutures.** The main bones making up the cranium are **frontal, parietal, temporal** and **occipital bones.** The frontal bones make up the forehead. The parietal bone consists of top and side walls of the **cranium.** The temporal bones make up the sides of the cranium while the occipital bone forms the base of the cranium. At the base of the occipital bone exists a large hole called **foramen magnum** through which the **brain** joins the **spinal cord.** The cranium (brain box) encases the brain and protects it.

## Facial bones

The main bones of the face are the **cheek, nasal** and **jaw bones.** These bones are also fitted together by sutures. The jaw bones are made up of the upper and lower bones. The upper jaw is fused together with the base of the cranium while the lower jaws are hinged with the cranium so that the **mouth** can **open** and **close.**

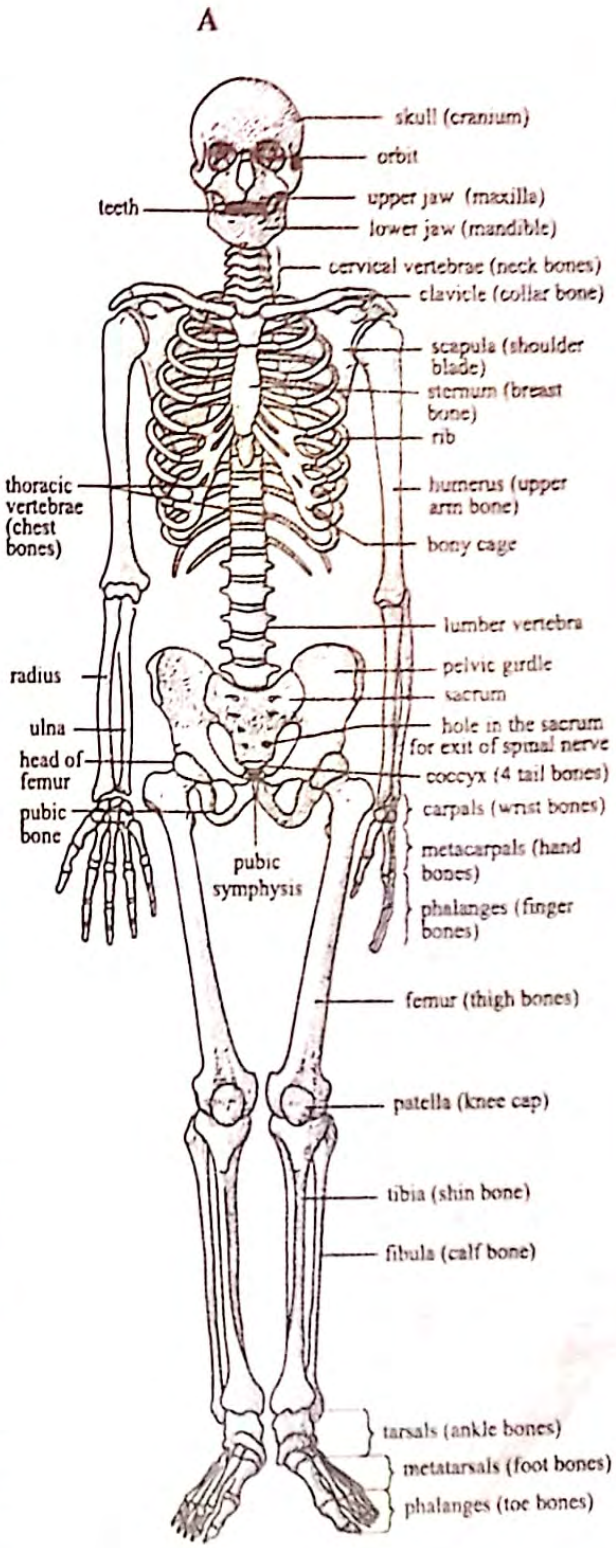



**Figure 14.9. Human skeleton.**
**A = Human skeleton**

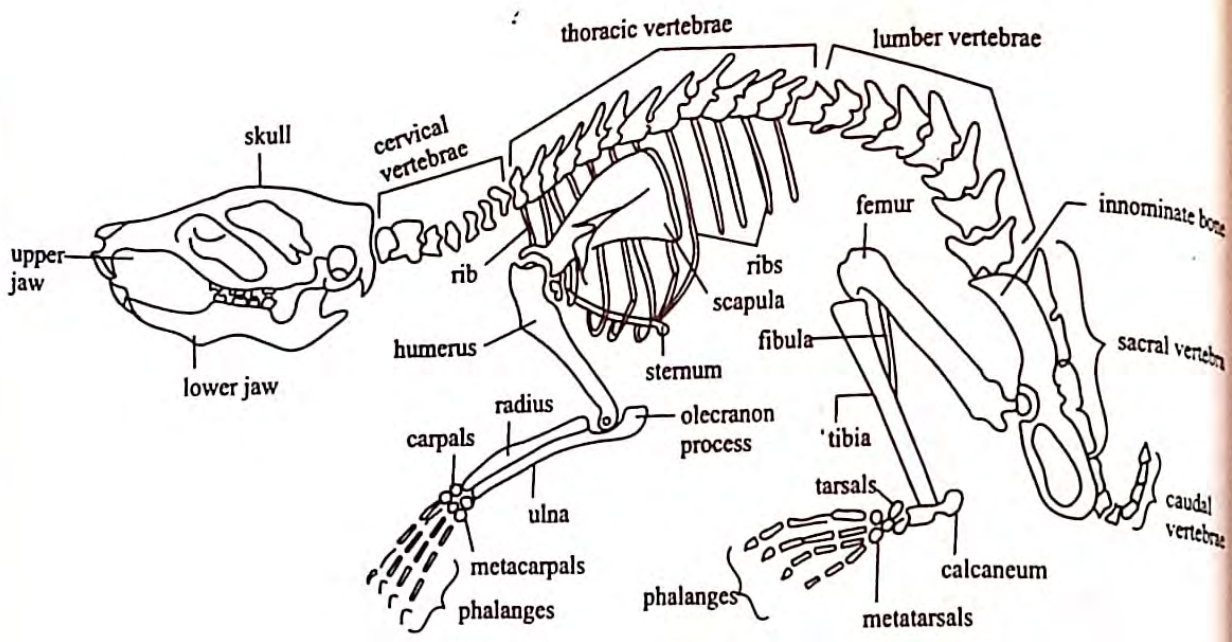



**Figure 14.9. Mammalian skeleton**
**A = Human skeleton.**
**B = Rabbit skeleton.**

At birth some of the bones on the top of the cranium have not yet developed fully. These bones are still connected together by **soft fibrous tissues.** These soft areas are called **fontanelles.** When these areas are gently touched with the finger, **a pulse beating** can be felt. It takes about 18 months for the fontanelles of the top of the head to harden while that at the back closes up also most immediately. The fontanelles allow movement of the bones of the head so that the head of the baby is properly shaped in order to pass through the **pelvic** of the mother during **delivery.**

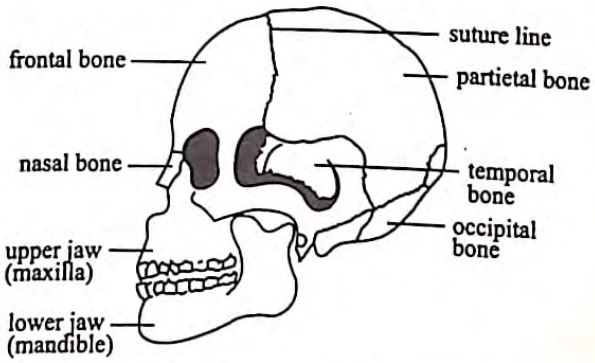



**Figure 14.10. Side view of the human skull.**

## The vertebral column (Backbone)

The vertebral column is also called **backbone.** It is made up of **33 short bones,** each one is called a **vertebra** (plural: **vertebral**).

## Common features of the vertebrate

A fairly wide central hole, the **Neural canal** is a fairly wide hole of the spinal cord.

**Neural arch** which forms the **neural canal.** It protects the spinal cord.It provides surface area for the attachment of muscles.

**Cervical ribs** or **transverse processes** at the sides of the neural arch. These also provide surface area for the attachment of muscles. They form articulating facets with the ribs in the thoracic region.

The **neural spine** is also a part of the neural arch. It increases the surface area for the attachment of muscles.

**Centrum** is the thickened base of the vertebra. It forms the main bulk of the vertebra. Centra articulate with one another in the vertebral column (spine) by **intervertebral discs.**

6. **Prezygapophysis** is a polished part on the neural arch at the **anterior view** of the vertebra. There are **two prezygapophyses** on each vertebra through which they articulate with the vertebra in front of it.
7. **Postzygapophysis** is a polished part of the neural arch at the **posterior view** of the vertebra. There are **two postzygapophyses** on each vertebra through which they articulate with the vertebra behind.

The **vertebrae** are hollow and placed end to end like beads in a string to form a continuous tube through which the spinal cord passes. Each vertebra is separated from the other by a tough fibro-cartilage tissue called **intervertebral disc.**

There is very little movement at each joint but there is a considerable wide range of movements in the whole column or spine.

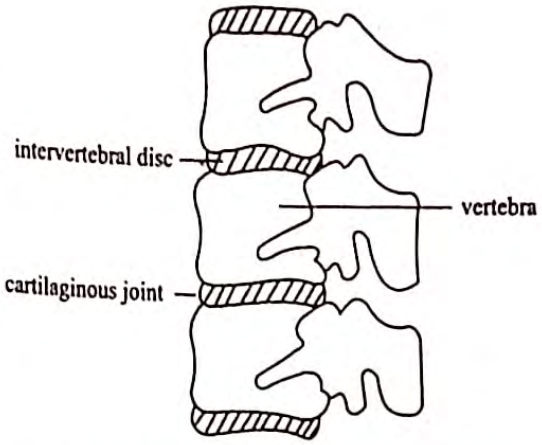



**Figure 14.11. A section of the vertebral column showing gliding joints.**

**Table 52: Distribution of the vertebrae in some mammals**

| Name of vertebrae | Man | Rabbit | Rat | Where found |
|---|---|---|---|---|
| 1. Cervical vertebrae | 7 | 7 | 7 | Neck region |
| 2. Thoracic vertebrae | 12 | 12-13 | 13 | Thorax |
| 3. Lumber vertebrae | 5 | 6-7 | 6 | Abdomen |
| 4. Sacral vertebrae | 5 | 3-4 | 4 | Hip |
| 5. Caudal vertebrae | 4 | 16 | 27-30 | Tail |
| Total | 33 | 44-47 | 57-60 | |

## Cervical vertebrae

There are **seven vertebrae** in the neck region of all mammals whether long as in giraffe or short as in rat.

## Characteristic features

1. Presence of transverse process (cervical ribs)
2. Vertebraterial canal on each side.
3. Small neural spine.

## Functions

## Cervical vertebrae

1. **Cervical vertebrae** give form to the neck and support the head.
2. **The atlas** and the **axis** give nodding and rotating movement to the head.
3. They give protection to the blood vessels particularly the arteries serving the head, by providing holes **(vertebrarterial canal)** for the vessels to pass through.

## Atlas vertebra

The first cervical bone is called **atlas.** It articulates with the skull on its anterior end and axis on the posterior end. It is **ring-like.** It has no centrum and no prezygapophyses .It has a reduced or less prominent neural spine. It has rounded and wing-like transverse processes. It has a pair of holes on either sides (vertebrarterial canal) for the passage of blood vessels to the head.

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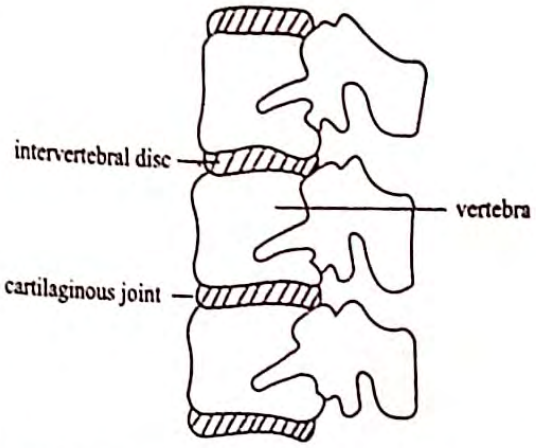


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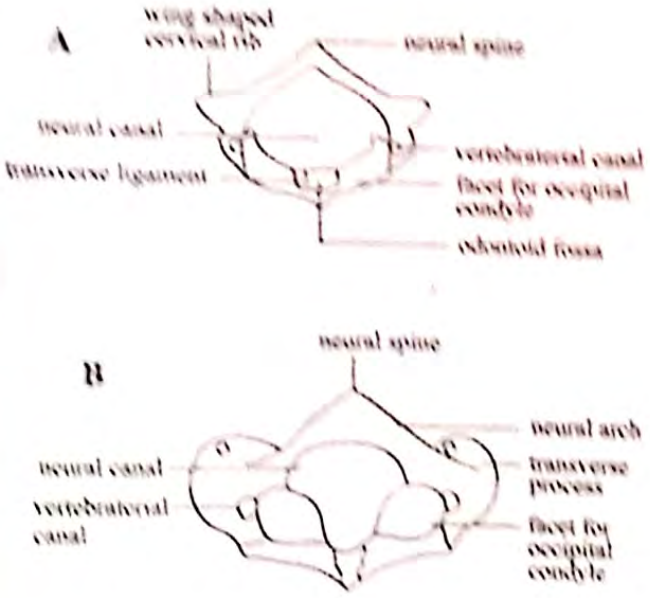



**Figure 14.12. Atlas vertebra**
**A = anterior view,**
**B = posterior view.**

## Axis vertebra

The axis is the second cervical vertebra. It has a well **developed centrum**. The centrum projects anteriorly as **odontoid process**. Odontoid process forms a **pivot joint** and **atlas**. It's neural spine is laterally flattened. The transverse process is tiny and peg-like.

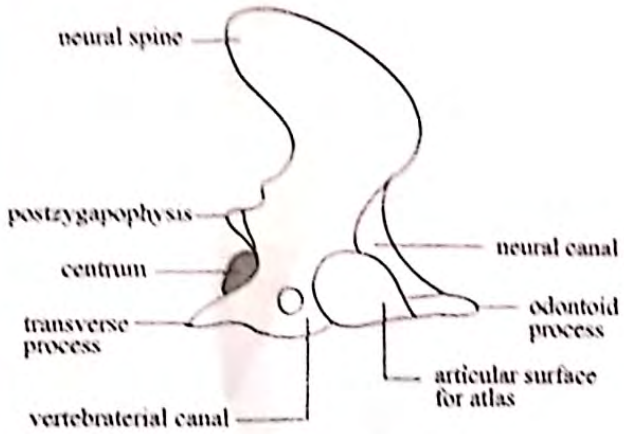



**Figure 14.13. The lateral view of the axis.**

## The normal cervical vertebra

They are the 3rd, 4th, 5th, 6th, and 7 cervical vertebrae. They are all similar to the typical vertebra described earlier.

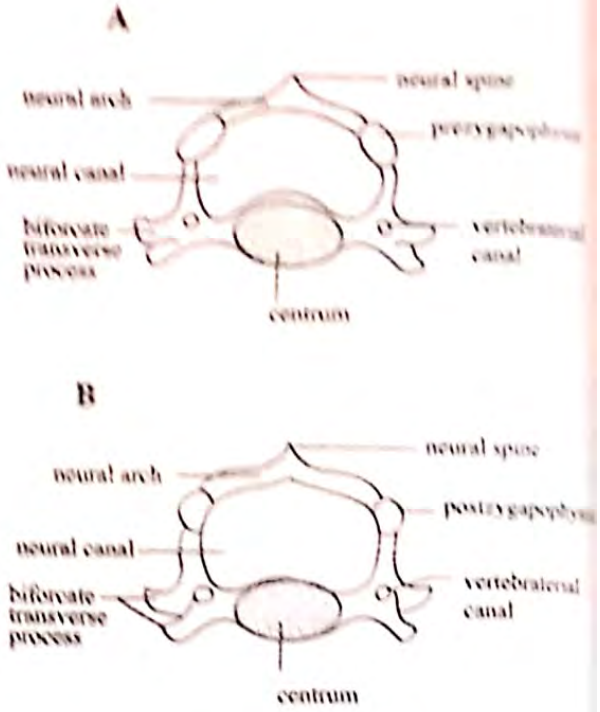



**Figure 14.14. Normal cervical vertebra**
**A = anterior view,**
**B = posterior view.**

The special feature of normal cervical vertebrae is the possession of a short **biforcate transverse** process.

## Thoracic vertebrae

### Characteristic features

1. Long neural spines.
2. Transverse processes have articular facets for movement against the capitular facets and tubercles of the ribs.
3. Demi-facets on centrum for articulation with the capitulum of the rib.

### Functions

They contribute to the formation of the thoracic cage with the **ribs** and **sternum**, which protect the lungs and heart in the thoracic cavity.

2. Their reduced and rounded transverse processes form articulating facets for the ribs.
3. They support the ribs and make it possible for the intercostal muscles to contract against them in the process of breathing in and out.

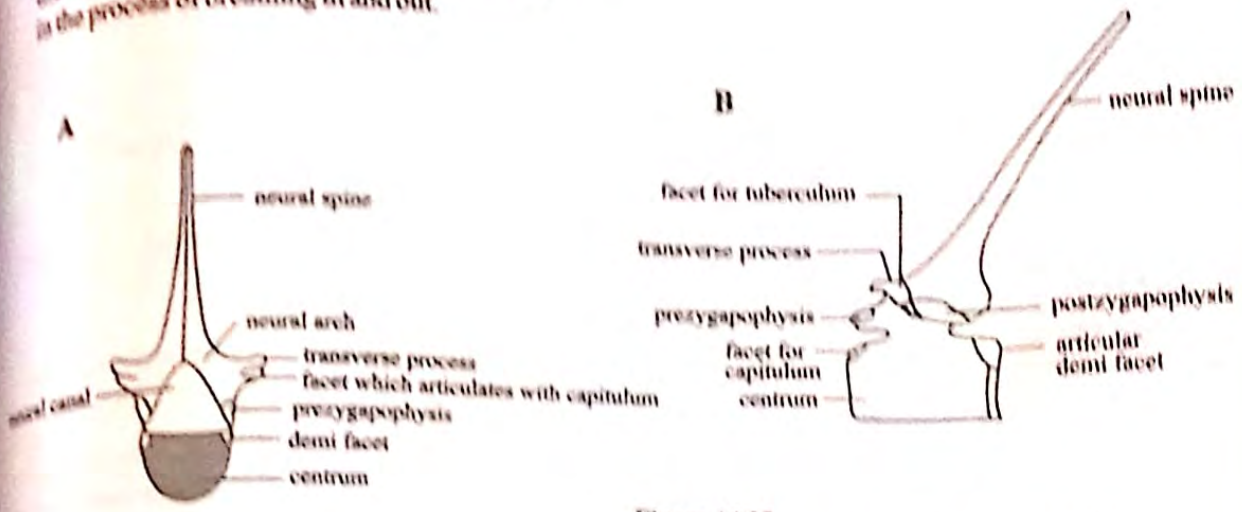



**Figure 14.15.**
**A – anterior view of the thoracic vertebra**
**B – lateral view of the thoracic vertebra**

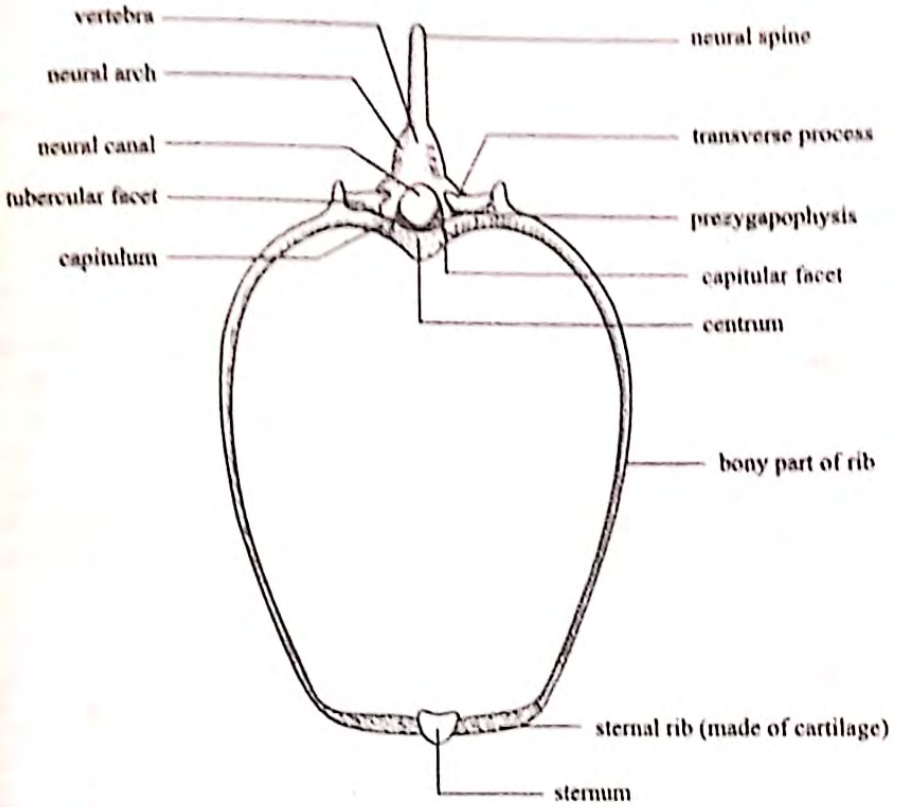



**Figure 14.16. Anterior view of thoracic vertebra showing articulation with ribs.**

**Table 53: Differences between cervical and thoracic vertebrae**

| Cervical Vertebra | Thoracic Vertebra |
|---|---|
| Less prominent neural spine | Very prominent neural spine |
| Prominent and bifurcate transverse process | Less prominent transverse process |
| Presence of vertebrarterial canal | Absence of vertebrarterial canal. |

## Lumber vertebrae

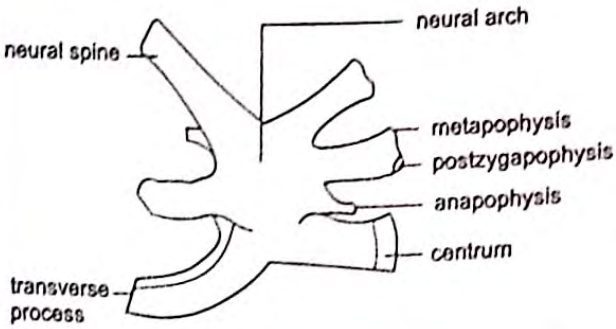
### Characteristic features

1. Stout vertebra.
2. Large transverse processes.
3. Neural spine is broad and massive.
4. The centrum and neural arch are massive.
5. Presence of extra process called **anapophysis** for attachment of muscles.
6. **Metapophyses** flank the neural spine on both sides for attachment of muscles.

### Functions

1. Lumber vertebrae bear the great weight of the body as they occupy the centre of gravity of the body.
2. They maintain the right and proper gait of the body.
3. Well developed lumbar vertebrae prevent sagging in the posture of tall people at old age.
4. They support pregnancy in the females.

A




B

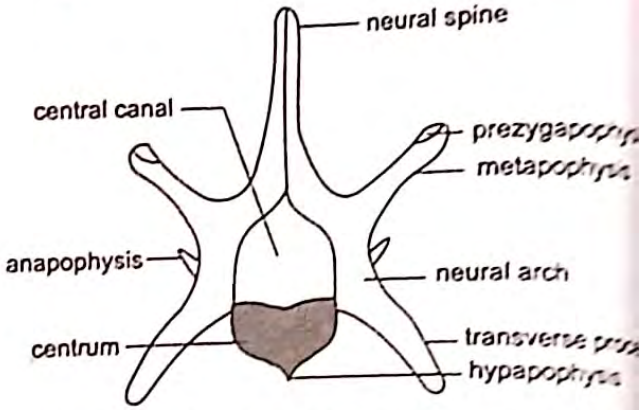



**Figure 14.17. Lumber vertebra**
**A = lateral view**
**B = anterior view.**

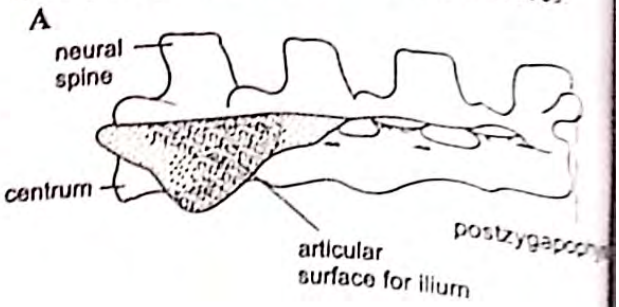
### Difference between a cervical and lumbar vertebrae

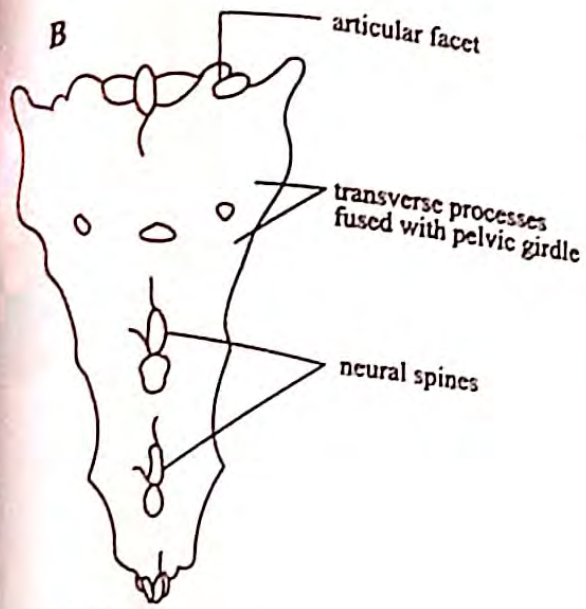
| Cervical vertebra | Lumbar vertebra |
|---|---|
| 1. Reduced transverse process. | Long and large transverse process |
| 2. Small neural spine. | Neural spine broad and massive |
| 3. Wide neural canal. | Narrow neural canal. |
| 4. Vertebrarterial canal present. | No vertebrarterial |
| 5. Centrum absent. | Centrum present and well developed |
| 6. Facets are few. | Facets are more |

## The sacral vertebrae

There are five sacral vertebrae in man. They are fused to form a structure called **sacrum**. They have greatly reduced centrum with numerous tiny holes for the passage of blood vessels and nerve fibres.

A





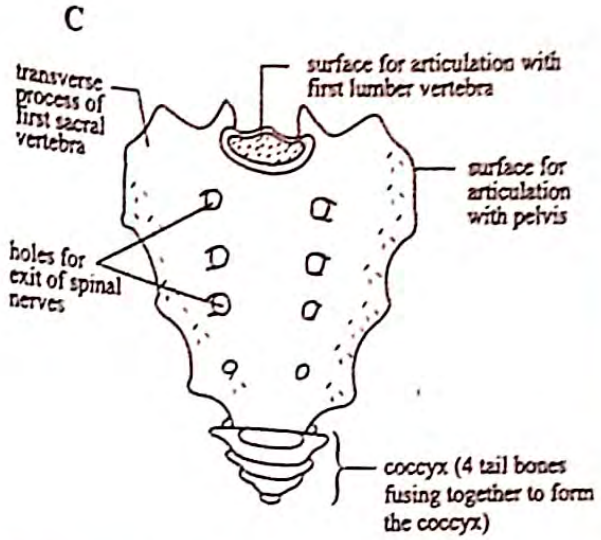




*Figure 14.18.*
**A=lateral view of the rat=s sacrum**
**B=dorsal view of the rat=s sacrum**
**C=anterior view of the rat=s sacrum**

## Functions

Fused into one piece called **sacrum** and helps to hold the right and left **ileum** together at the back.

Sacrum has many holes for the passage and protection of nerve fibres serving the lower limbs.

## The caudal vertebrae

There are four caudal vertebrae in the vertebral column of man while rat has 27 - 30. They are fused together to form the **coccyx**. They are also greatly reduced down to centrum only. The coccyx is tucked in between the **ischium** in man hence no external tail.

## Functions

1. Being internal and fused into a structure called **coccyx** in man, it stabilizes the rigid pelvic girdle.
2. **Coccyx** houses and protects blood vessels and nerve fibres from under the **ischium**.

## Appendicular skeleton

This is made up of the bones of **fore-limbs, hind-limbs** and **pelvic girdles.**

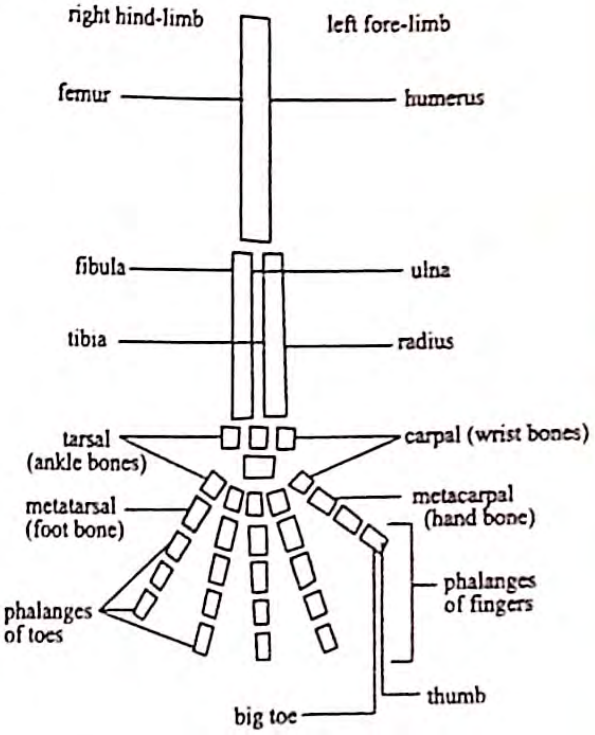



**Figure 14.19. The pentadactyl plan of the limb.**

## The pectoral girdles

The pectoral girdle consists of a triangular plate of bone called **scapula** or **shoulder blade, ribs** and **sternum.**

## Scapula

Scapula is a flat bone. It has one head-like end with two processes, the **coracoid** and **acromion** with a deep notch called the **glenoid fossa** or **cavity.** The rounded head of humerus fits into the glenoid cavity in a **ball** and **socket joint**. Another bone of the girdle is the **collar** bone or **clavicle** which glides over shoulder joint to keep the bones in correct position.

The **scapula** is not fixed to the spine, it is only bound to the posterior of the thorax by muscles. This allows considerable range of movement at the shoulder.

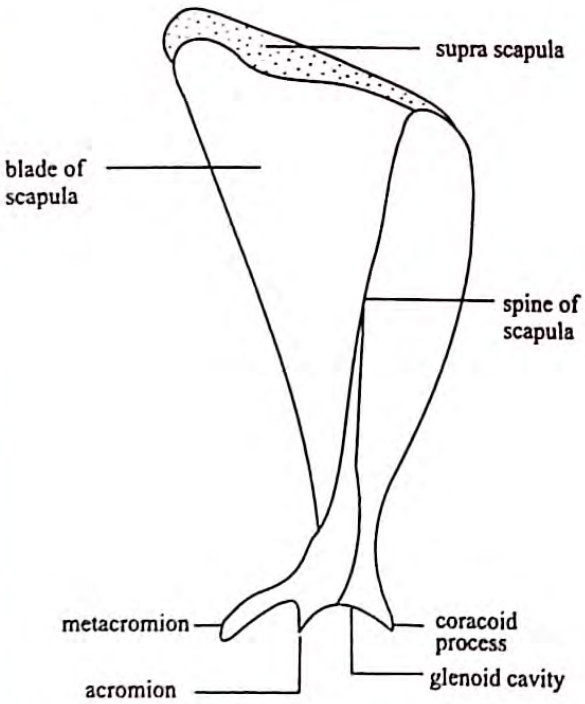



**Figure 14.20. Posterior view of scapula of a rat.**

## Fore-limb

The fore-limb is made up of a **humerus** in the upper arm, an **ulna** and **radius** in the lower arm, **carpals** in the **wrist** and **phalanges** in the **digits.**

## Humerus

The humerus has a shaft and two extremities. The **proximal end** consists of a **rounded head** without a neck. The **greater tuberosity** lies at the opposite side of the head while the **lesser tuberosity** is attached below the head. The flattened area from the head midway the shaft is the **deltoid ridge.** A **bicipital groove** lies in between the head and the greater tuberosity.

The distal end of humerus forms the **trochlea.** In between the trochlea is the supratrochlear foramen. Above the supratrochlear foramen at the posterior side lies a shallow groove called the olecranon fossa.

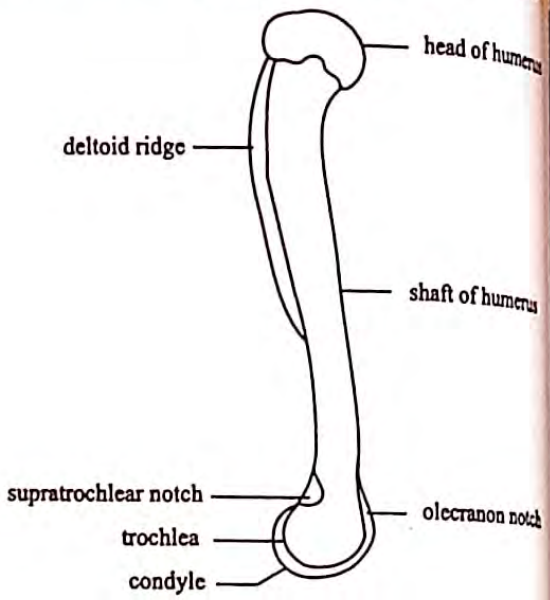



**Figure 14.21. Anterior view of humerus of a rat.**

## Functions

It forms attachment surface for biceps and triceps muscles.

The bicipital groove anchors the biceps muscles.

It forms the ball and socket joint at the shoulder.

It forms the hinge joint at the elbow.

It allows free movement of the arm.

## Radius and Ulna

The two bones in the lower arm are the radius and **ulna**. The radius is shorter and it lies on top of the ulna. They both form the **sigmoid notch** into which the trochlea of humerus fits in the elbow joint. The ulna projects behind to form the **olecranon fossa** of humerus to keep the joint in position. The distal ends of radius and ulna form the styloid process at the wrist joint.

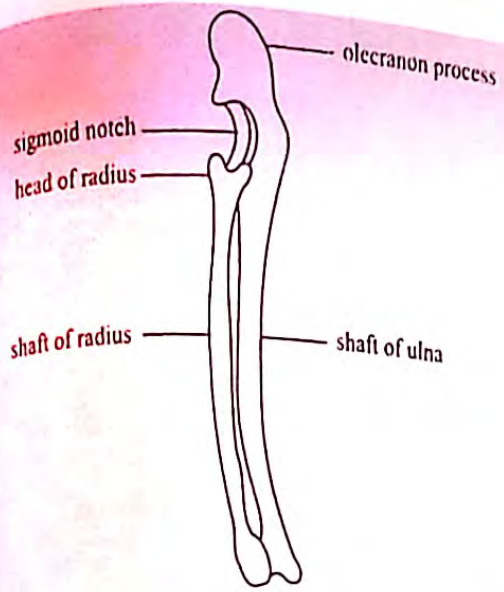



**Figure 14.22. Lateral view of radius and ulna of a rat.**

## Functions

They form the point of attachment for the insertion of the biceps and triceps muscles.

They provide large surface areas for the attachment of the extensor and flexor muscles of the lower arm. The muscles attached to the radius and ulna contract and relax to move the hand and digits.

## Carpals

The carpals are the wrist bones, which are eight in number, and irregular in shape. They are irregularly arranged in the wrist and held together by tough ligaments.

## Functions

They form a hinge joint which allows for the movement of the hand along one plane.

## Metacarpals

The metacarpals are the bones of the hand. They are long and slender like sticks of chalk or cigarettes. The metacarpal of the thumb is much shorter than the four others. There are five metacarpals in one hand.

## Functions

1. Metacarpals form the shape of the hand.
2. They provide surface area for the attachment of the muscles of the palm.

## Phalanges

The bones of the digits are called **phalanges.** There are two in the thumb and three in each of the four others.

## Functions

1. They support the digits
2. They are used for griping and holding on to objects.
3. They are used for walking in tetrapod animals
4. They bear claws which are used for climbing and digging in some animals such as rat.

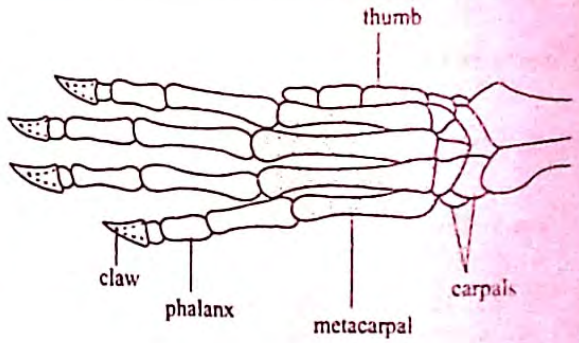



**Figure 14.23. Dorsal view of left hand (manus) of a rat.**

## Hind-limb

The hind-limb is made up of the **femur** of thigh bone, the **tibia** and **fibula** in the leg, the **tarsals** in the ankle, the **metatarsals** of the foot and the **phalanges** of the digits.

## Femur

The femur is the longest bone in the body. It has a cylindrical shaft and two extremities. The proximal extremity bears a **head** with a separating **neck**, and on the opposite side is the **greater trochanter**. Two **lesser trochanter** are located below the head and the greater trochanter. The distal end bears the **condyle** and the **patella** groove.

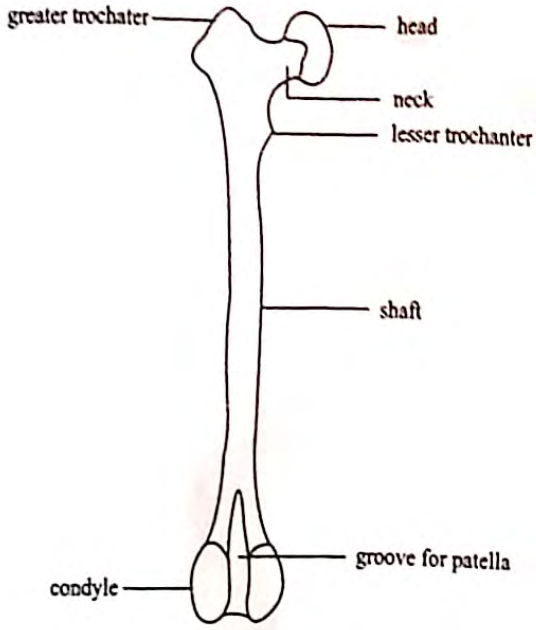



**Figure 14.24. Lateral view of femur of a rat.**

## Functions

1. Femur forms a **ball and socket joint** with the ilium allowing the free movement of the hind limb.
2. Forms attachment surface for the thigh muscles.
3. The distal end forms a hinge joint with the patella, tibia and fibula.

## The tibia and fibula

The skeleton of the leg consists of the **tibia** and **fibula**. That tibia is bigger than the fibula which fuses with it at the distal end to form the **tibio-fibula**. The proximal end is broad and has **facets** for articulation with the **condyles** of the femur and a notch for the patella to form the knee. The distal end has facets for articulation with the **ankle bones.**

## Functions

1. Tibia and fibula provide large surface area for the attachment of muscles of the leg.
2. Muscles that move the foot have their origin attached to the tibia and fibula.
3. They form the ankle joint which allows the movements of the foot along one plane.

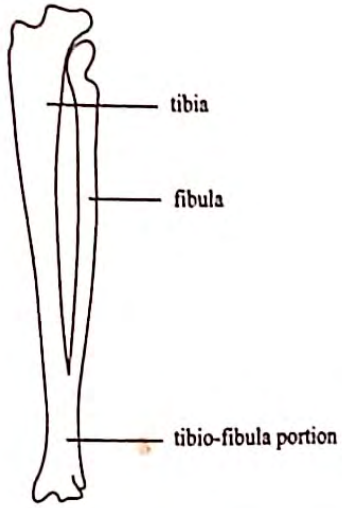



**Figure 14.25. Left tibio-fibula lateral view of a rat**

## Tarsals

The **tarsals** are the ankle bones. They are **eight** in number and irregularly arranged in two rows. The bones are of unequal sizes and irregular in shape. The three behind articulate with the **tibio-fibula** in the ankle. The five in the second row articulate with the metatarsals to the anterior of the foot.

## Functions

1. The tarsals provide attachment surface for the strong muscles of the legs.
2. They form the ankle for the movement of the foot along one plane.
3. Muscles for moving the foot and toes are attached to the tarsals.

## Metatarsals

There are five bones in the foot, called **metatarsals.** The first metatarsal is shorter than the rest four.

## Functions

1. The metatarsals support the foot which is used for walking.
2. The metatarsal bear the phalanges of the toes and support then.
3. Metatarsals provide surface area for the attachment of the foot and toe muscles.

## Phalanges

The bones of the digits or toes are called phalanges. The first toe called big toe has two phalanges. The remaining four toes have three phalanges each. The last phalanx in each digit is pointed to fit into the strong and sharp claw.

## Functions

1. The phalanges support the toes which are used for walking, gripping and digging.
2. They provide surface area for the attachment of muscles of the foot and toes.

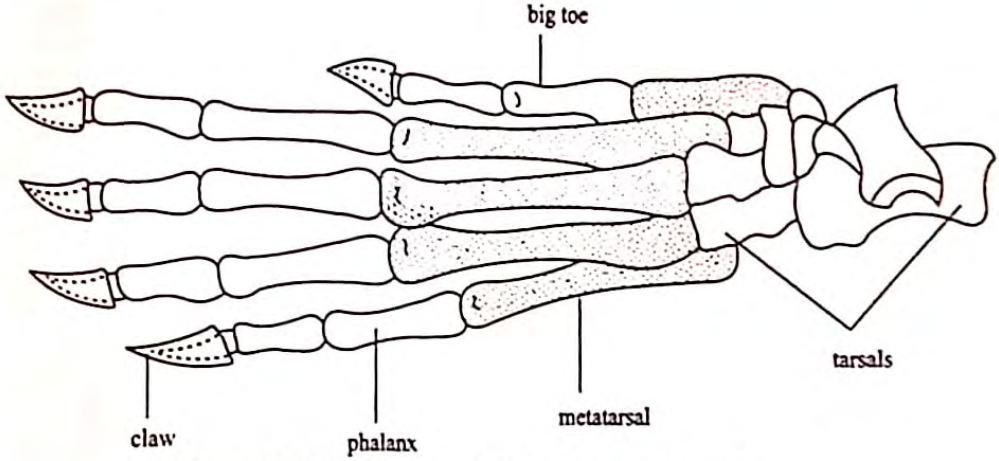



**Figure 14.26. Dorsal view of left foot (pens) of a rat).**

## The Pelvic girdle

The pelvic girdle consists of the **ilium** (hip bone), **ischium** and **pubis** all of which are fused together on each side of the body as the **innominate** bone. These **two halves** are rigidly joined at the last lumbar vertebra to the base of the spine at the back while in the front they are less rigidly joined at the pubis by the fibro-cartilage of pubis **symphysis**. The distal ends of these bones form a cavity called **acetabulum** into which the head of femur fits to form the ball and socket hip joint.

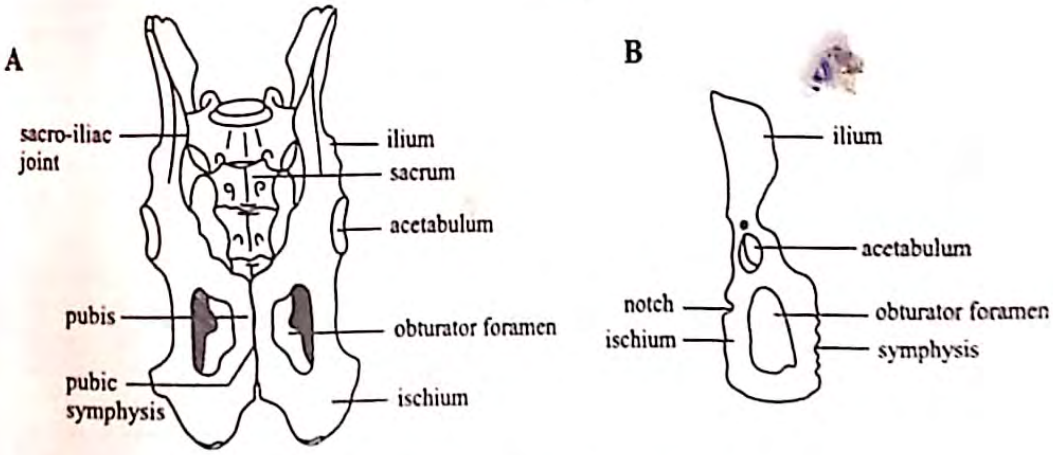



**Figure 14.27. Pelvic girdle of a rat.**
**A = The ventral view**
**B = The lateral view of the right half of the pelvic girdle.**

## Ribs

There are thirteen pairs of ribs in a rat. The first seven pairs of ribs are attached to the sternum and they are called **true ribs**. The eighth, ninth, tenth pairs of ribs have their coastal cartilages attached to the seventh pair of ribs. The eighth, ninth and tenth are therefore called **false ribs.** The last three pairs are attached only to the thoracic vertebrae. They are therefore called **floating ribs.** Each rib consists of a slightly curved shaft. The dorsal end of the shaft is the **Capitulum** and **head.** A little behind the capitulum is a **tuberculum** The capitulum articulates with the **demi-facet** of the centrum of the thoracic vertebra while the tuberculum articulates with the transverse process of the thoracic vertebra.

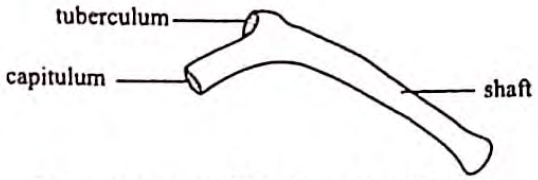



**Figure 14.29. (a) Side view of a rat's rib.**

## Sternum

The sternum is a jointed and an elongated structure. It is made up of a broad **manubrium** at the upper part, four **sternebrae** and a **xiphis-ternum** into which a **xiphoid** cartilage is attached.

## Functions

1. It protects the heart and lungs as it forms a protective basket with the ribs.
2. It articulates with the ribs to bring about breathing movement of the chest cavity.

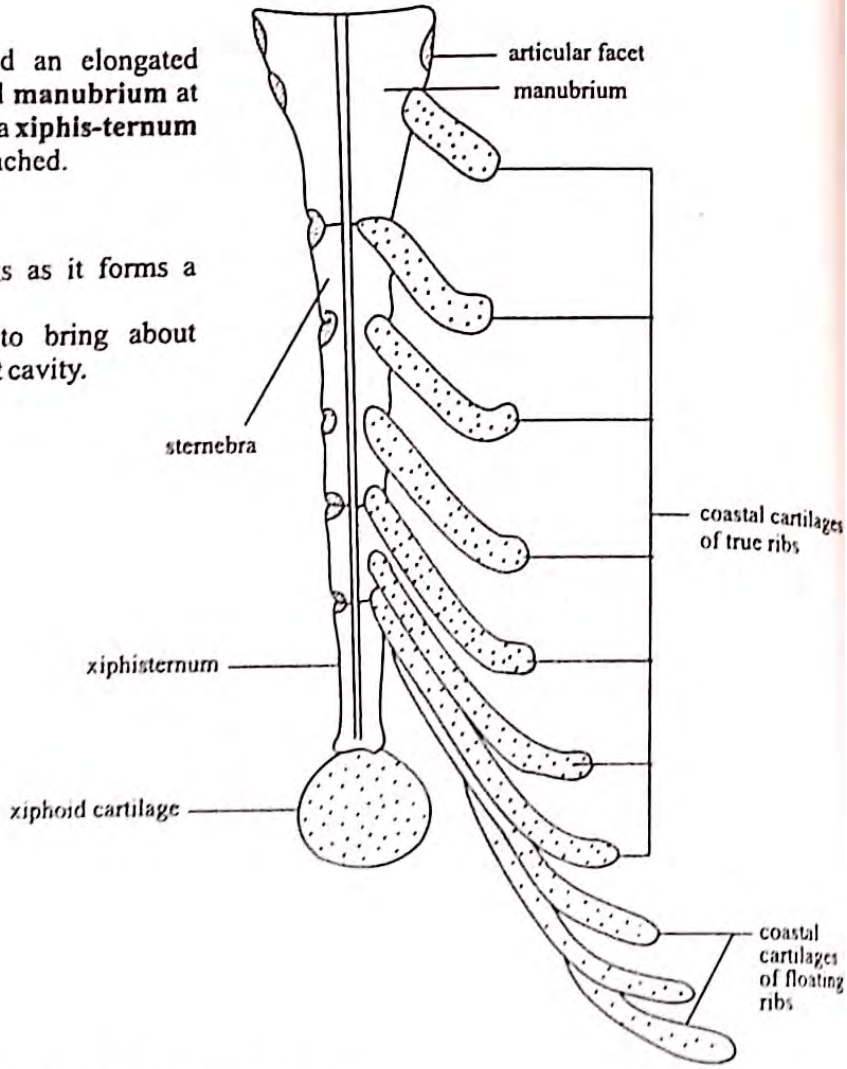



*Figure 14.29. The sternum of a rat.*

## Joints

The endoskeleton consists of numerous units of bones jointed at appropriate points. The place where two more bones are jointed is called **a joint**. The **ends** of the bones involved in a joint are rounded and firmly sealed with hyaline **cartilage**. The space between the articular surfaces of the jointed bones is filled with a pad of soft tissue called **synovial membrane**. The synovial membrane encloses a space called **synovial cavity filled with synovial fluid**. All these structures act as cushion to reduce friction and absorb shock from landing. Finally the bones involved in a **joint** are firmly held together by a strong connective tissue, called **ligament**.

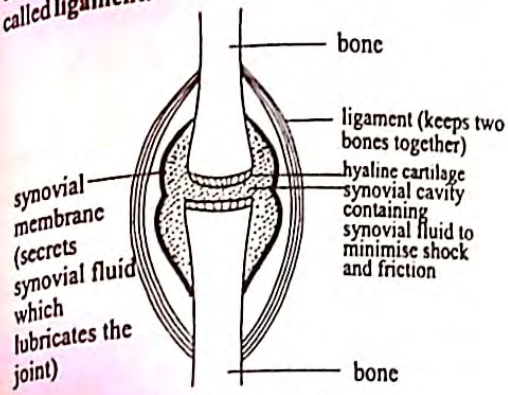



**Figure 14.30. Section through a joint**

### Types of joints

These are immovable, gliding, ball and socket, hinge and pivot joints.

1. **Immovable, suture or fixed joints:** These joints are different from the other conventional joints in that the bones are not held together by any structures. These bones have saw-like edges which interlock to form **sutures** at the joints. These joints are **immovable.** The joints are found among the bones of the **skull,** see figure 14.10, between sacrum and iliac of pelvic girdles and between bones of pelvic girdles. These joints provide support and strength for the body, protect the delicate organs such as brain.

2. **Gliding joints:** The bones involved in gliding joints are held together by **discs of fibro-cartilage materials.** A small joint cavity is however left to permit a slight or gliding movement. Such joints are found in the vertebral column and between the clavicle and sternum, wrist and ankle bones give strength to the limb and allow considerable movement. see figure 14.11.

3. **Ball and socket joint:** Here one bone has a rounded head called **ball** and the other has a cavity called **socket.** In the shoulder joint, the ball of humerus fits comfortably into the socket of scapula.

The hip is another example of the ball and socket joint. This joint is similar to that of the shoulder. The femur or thighbone has a round head, the ball, which fits into the socket of the ischium and ilium. They are held in position by tough ligaments. Allows movement in all planes capable of some rotation.

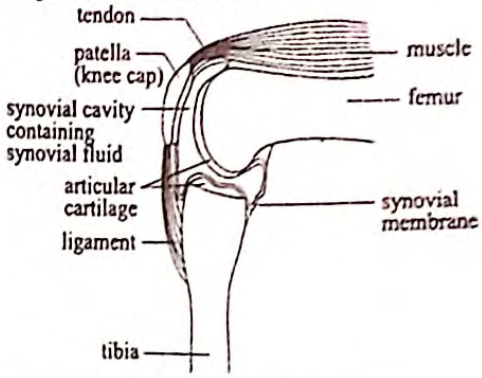



**Figure 14.31. Ball and socket of hip joint**

4. **Hinge joint:** This joint is found in the elbow, finger and knee of man. The ends of the two bones are deeply notched and the process of one is extended to **restrict movement on one plane only.** In the elbow the hinge joint is between ulna and humerus while in the knee it is between the tibia and femur.

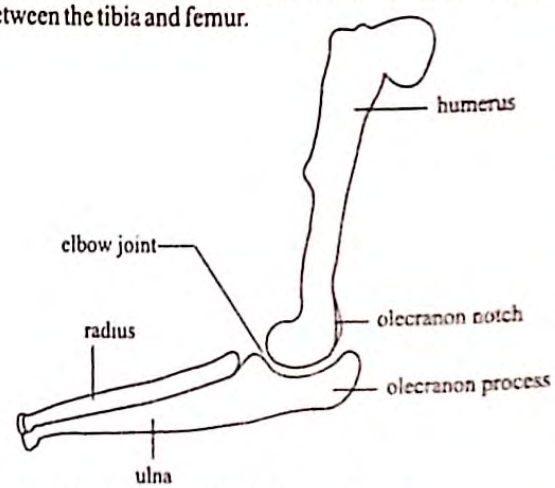



**Figure 14.32. Hinge joint of elbow of man**

5. **Pivot (rotating or swivel) Joint:** As the name suggests one bone fits onto another one on which it **pivots** e.g. the **atlas** fits onto the **axis** by the **odontoid** process and pivots on it to allow rotating and nodding movements of the head on the neck. Also allows the shaking of the head from side to side.

6. **Saddle joints:** Saddle joints exist between the

carpal and metacarpal bones of the wrist and foot. They allow considerable bending and side to side movement.

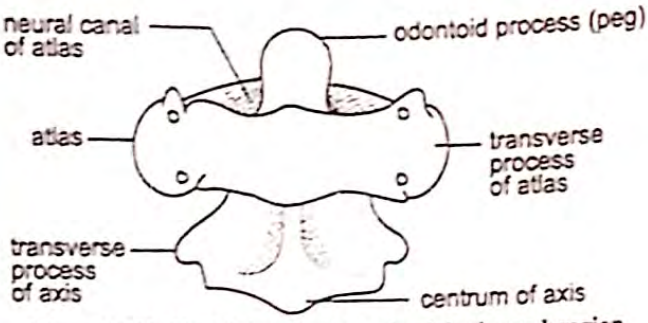



**Figure 14.33. Pivot joint of atlas and axis in the neck region.**

**Table 54: Differences between a bone and a cartilage.**

| | Bone | Cartilage |
|---|---|---|
| 1. | It is hard being made up of hard substances | It is relatively soft being made up of soft substances. |
| 2. | It is not elastic | It is elastic |
| 3. | It is composed of mineral salts. | It is not composed of mineral salts |
| 4. | Bone cannot be repl-aced by a cartilage | Cartilage can be replaced by a bone |
| 5. | Has blood vessels | Has no blood vessels in adult. |

## Importance of bones to the body

As hard structures, the bones give support to the soft tissues of the body and shape to the whole body. Well formed and healthy bones therefore mean good posture. Pasture means the position of the body. Weak and unhealthy bones will result in some postural defects such as round shoulder (kyphosis), hollow back (lordosis) and spinal curvature (scoliosis). Other defects associated with poorly nourished bones are rickets, poor teeth, bow legs, knock knees, enlarged joints and softness of bones.

## How to Develop strong Healthy Bones

1. As bones are built from organic and inorganic materials, food that contain sufficient organic and inorganic materials should be taken always.
2. Balanced diet is essential for strong healthy bones. Eating different kinds or assorted food is better instead of keeping rigidly to one particular type of food.
3. Vitamins also contribute to the growth of strong healthy bones and so assorted food, vegetables, fruits, fish and meat containing vitamins should be eaten regularly.
4. Live in clean houses and clean surrounding with free flow of fresh air and bright sunshine.
5. Conscious effort at maintaining good posture should be developed and shown in correct standing, sitting and walking posture.
6. Wearing of free and well fitted dresses and shoes help nature in forming good posture.
7. Regular exercises and proper rest are important for the proper development of healthy bones.

# INTERNAL STRUCTURE OF FLOWERING PLANTS

After the germination of a seed, the **radicle** develops into **root system** while the **plumule** develops into a **shoot system**. Internally, the roots, stems and leaves whether those of dicotyledonous or monocotyledonous **plants**, consist of different types of tissues, that is a group of similar cells performing the same function. Generally, the internal structure of the plant is best studied by preparing the transverse sections which are then treated with some dye solution (staining) and examine with a hand lens or under microscope.

## The internal structure of dicotyledonous (dicot) root

A transverse section through the root hair region of a young dicotyledonous root such as **cowpea** or *Tridax*, reveals that it is made up of the following tissues: **piliferous layer, cortex, endodermis, pericycle, xylem and phloem.**

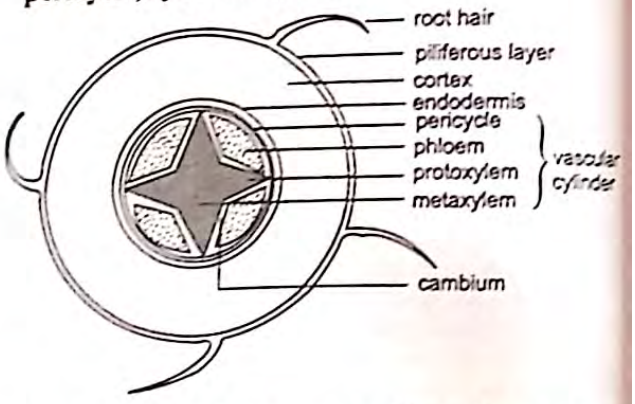



***Figure 14.34.* Transverse section of a young dicotyledonous root showing distribution of tissues (low power magnification)**

**Piliferous layer:** This is a single layer of thin rectangular cells bearing some unicellar hairs. Each root hair which is elongated and slender originates from one of the piliferous cells walls, cytoplasm and nucleus. The piliferous layer has no cuticle. As the plant grows old, the piliferous layer starts to break down and is being replaced with a protective cork layer.

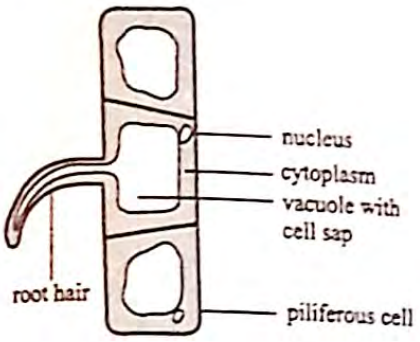



**Figure 14.35. A root hair projecting from a piliferous cell**

## Functions

1. Its major function is the absorption of water and mineral salts by the root hairs from the soil into the cortex.
2. It protects the underlying cells.

**Cortex:** This consists of a large number of thin walled and roughly spherical parenchyma cells with air space between them. The cortex is wide and occupies a large portion of the root.

**Function:**

1. Food is stored in the cortex.
2. It stores water which is later carried into the vascular bundles.

**Endodermis:** The endodermis is a single layer of cells marking the end of the cortex and surround the vascular cylinder. The endodermal cells are thickened with waxy materials. It contains some starch grains.

**Functions**

1. It controls the passage of substances into and out of the vascular cylinder.
2. It separates the cortex from the vascular cylinder.
3. The waxy nature of the cells prevents the diffusion of water into the cortex.

**Vascular cylinder:** The vascular cylinder is inside the endodermis. The vascular cylinder comprises **pericycle, phloem, cambium and xylem.**

**Pericycle:** This is the outmost layer of the vascular cylinder. It consists of one or more layers of parachyma cells. Even at maturity, these cells are capable of carrying out cell division thereby giving rise to other tissues.

**Phloem:** The phloem is made up of parenchyma cells lying between the arms of the xylem star. The cells are thin walked. The phloem is separated from the xylem by some undifferentiated parenchyma cells.
**Function:** It conducts food substances downward to other tissue in the root.

**Xylem:** The centre of the root is occupied by xylem.There is no pith. The cells of the xylem are arranged in the form of a star. The arm of the star ranges from two to six in dicotyledonous roots.The cells in the centre of the star are large and are called **metaxylem vessels** while those at the tips close to the pericycle are small and are called **protoxylem vessels.**

There is no much difference between the young and old roots except that the piliferous layer is lost in the old root. At this point, the outermost layer of the cortex develops into cork cells with thick protective walls. This layer becomes the **exodermis.** Regions of the old root without piliferous layer and root hairs can no longer absorb water from the soil. Secondary thickening also occurs in the old roots.

## The internal structure of a monocotyledonous (monocot) root

Maize, millet and grasses are typical examples of monocot plants. A transverse section through a root hair region reveals that the piliferous layer and cortex are identical with those of the dicot root. The major difference between dicot and monocot roots are seen in their vascular cylinders. In the monocot root, the xylem bundles are radially arranged, with the phloem bundles alternating between them (see the table below).

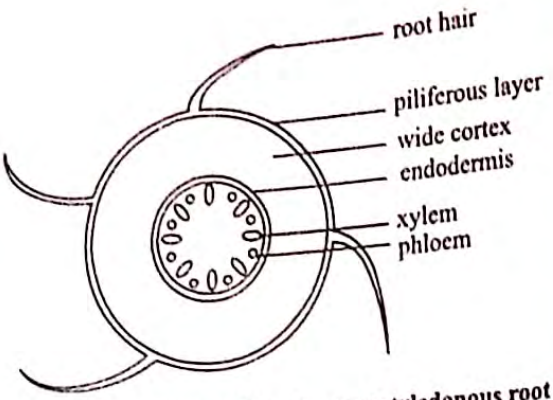



**Figure 14.36. Transverse section of monocotyledonous root showing distribution of tissue (Low power magnification).**

**The 55. Differences between dicot and monocot roots.**

| | Dicot root | Monocot root |
|---|---|---|
| 1. | Has only one star-shaped xylem bundle centrally placed. | Has many xylem bundles radially arranged. |
| 2. | Pith is absent. | Pith is present, usually large and well developed. |
| 3. | Cambium and cork-cambium develop during secondary thickening. | Cambium is absent.No secondary thickening. |
| 4. | Few phloem bundles | Many phloem bundles |

## Internal structure of a dicotyledonous (dicot) stem

In studying the internal structure, it is adviceable to take the transverse section of a young plant such as sunflower. When examined with a hand lens or under a microscope the stem consists of the following: **epidermis, cortex** and **vascular bundles.**

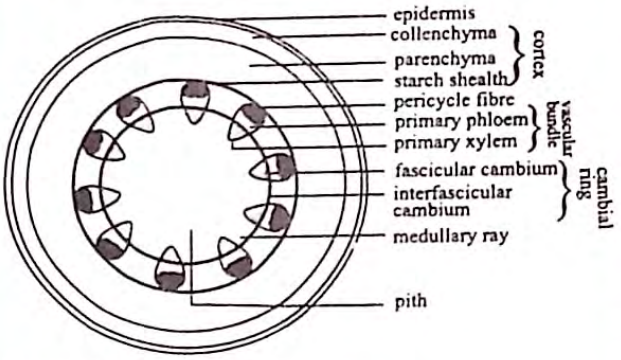



**Figure 14.37 Transverse section of a young dicotyledonous stem with cambial ring showing distribution of tissues (low power magnification**

**Epidermis:** The epidermis is made up of a single layer of cells. The cells are closely packed and rectangular in shape. The outer wall of the epidermis is cuticulari-zed.

**Functions:**

1. The cuticle in the epidermis is water proof thus protecting the inner tissues from desication and mechanical damage.
2. It disallows the entry of diseases like bacteria and fungi from entering the inner tissues.
3. The green parts of herbaceous plants such as sunflower may contain stomata for gaseous exchange.

**Cortex:** The cortex consists of **collenchyma, parenchyma** and **starch sheath.**

**Collenchyma:** The collenchyma lies below the epidermis. It consists of three layers of living cells containing some **chloroplasts.** The cells are thickened at their corners, a property which differentiates them from the parenchyma cells below. Collechyma cells are the first supporting tissues in young dicotyledonous plants.

**Functions**

1. It gives the plant strength and mechanical support.
2. Chloroplasts present help to carry out photosynthesis.
3. It provides resilience and flexibility to plants.

**Parenchyma:** It is just below the collenchyma. It is the most abundant tissue in a young plant. The cells are large and loosely arranged thereby allowing air spaces to occur. The cells are thin walled and contain chloroplasts. Parenchyma is the foundation of the plant body.

**Functions:**

1. It stores food and water.
2. Since the cells contain chloroplasts, photosynthesis takes place in them.
3. It maintains turgidity of the stem.
4. Allow air to diffuse among the cells.
5. Leaves drop when parenchyma cells are less turgid or flaccid thereby conserving water for the plant.

**Starch sheath:** This is a single layer of parenchyma cells marking the end of the cortex. The cells contain some starch grains.

*(Note: It is wrong to refer to the starch sheath as endodermis as endodermis occurs only in the root).*

Sclerenchyma (pericycle): Sclerenchyma consists of very long, narrow, thick and lignified cells. They taper at both ends thereby looking like fibres. The cells are dead. Sometimes sclerenchyma gets so thickened with the laying down of lignin that their lumen (cell cavity) gets blocked. Sclerenchyma cells are found in cortex, pith, phloem, hard seeds, nuts and stony fruits.

**Functions:**

The fibres give elasticity, flexibility and resilience to plants thereby preventing them from breaking easily when bent by forces such wind.

It gives rigidity and mechanical support to the stem.

**Vascular bundles:** These are bundles of conducting tissues which in a dicotyledonous stem are arranged in a ring below the cortex and leaving a pith in the centre. Each bundle consists of a **phloem tissue** on the **outside** and **xylem tissue** on the **inside.** Between the phloem and xylem is thin and actively single layer of dividing cells called **cambium.**

**Phloem:** The phloem is made up of four type of cells namely: **sieva tube, campanion cells, phloem parenchyma** and **phloem fibre** and **slereids.**

**Sieva tubes:** These are living tubes made of elongated cells. Their end walls are perforated to form sieve plates from which they derive their name. The sieve cells are arranged end to end to form a continuous tube.

**Functions:** Transport food and hormones both upwards and downwards.

**Campanion cells:** They have dense nucleated cytoplasm and are therefore living.

**Function:** They seem to control the activities of the sieve tubes and may help the sieve tubes to conduct food.

**Phloem parenchyma, phloem fibres and sclereids**

These are the same as those of xylem.

**Cambium:** This occurs only in dicotyledonous stems. It is a single layer of activity dividing cells. The cells continuously divide to form **more xylem** on the inside and **more phloem** on the outside.This process is known as **secondary thickening.** The cambium within the vascular bundle is called **fascicular cambium.**

**Xylem:** The first vessels occurring close to the pith are very small and are called **protoxylem** while the large vessels are called metaxylem. The xylem is made up of different types of cells namely: **xylem vessels, xylem tracheids, xylem fibres** and **sclereids.**

**Xylem vessels:** These are long, open and pipe like cells. The walls of the cells are thickened. Lumen which become continuous makes them to look like water pipes.

Help in the upward transport of water and mineral salts.

They give strength and support to the plant.

**Xylem trachelds:** They are elongated cells which taper at both ends. They have thickened cell walls and are heavily lignified with pits.

**Functions:** They transport water and dissolved mineral salts upwards through the vascular bundle. They give strength and support to the plant.

**Xylem fibres and scelereids:** They are much thicker than the vessels and tracheids. They have the smallest lumen.

**Functions:** They give tensile strength and resilience to the plant.

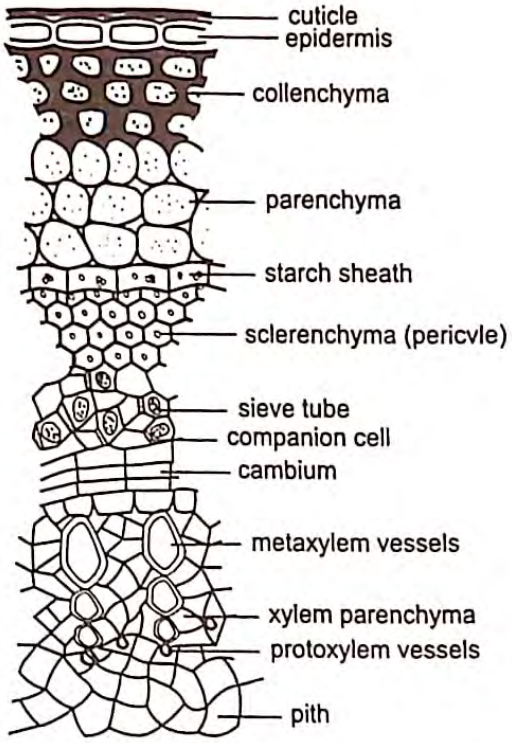



**Figure 14.38. High power magnification of the transverse section of a young dicot stem**

**Medullary rays:** These are parenchyma cells in the spaces between two vascular bundles. They are used for the radial transport of materials.

**Pith:** This is a mass of parenchyma cells occupying a large area in the centre. Pith is not a hollow. However, some plants such as cowpea, have hollow in the centre after a pith.

### A monocotyledonous (monocot) stem

In contrast in a dicot stem, a transverse section of a monocot stem (Fig.) clearly indicates that:

1. There is **no collenchyma tissue** below the epider-mis. Instead, there are **two to three** layers of sclerenchyma cells known as **hypoderml**

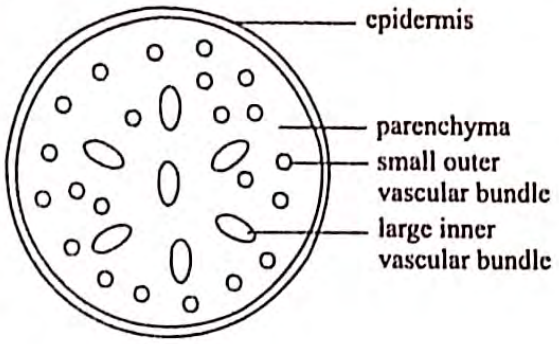



**Figure 14.39 Transverse section of a monocotyledonous stem showing distribution of tissues (low power magnification).**

2. There is very little area of cortex or ground tissue made up of parenchyma cells.
3. There are very many vascular bundles scattered all over the ground tissue. They are not arranged in rings.
4. A vascular bundle consists of xylem and phloem completely surrounded by sclerenchyma tissue. The bundles are smaller on the outside (near epidermis) and larger in the middle.
5. There is no cambium and hence no secon-dar) thickening.
6. There is no pith.

   Sclerenchyma is an important **strengthening tissue** in a monocot stem.

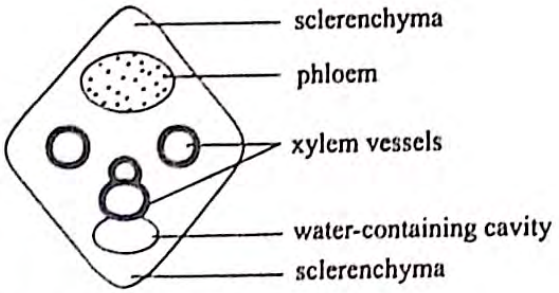



**Figure 14.40. Vascular bundle of maize**

## Secondary thickening (growth)

Refer to secondary growth in chapter 17.

**Table 56: Differences between the internal structures of dicot and monocot stems**

| | | Dicot stem | Monocot stem |
|---|---|---|---|
| 1. | Tissue below epidermis | Collenchyma | Sclerenchyma. |
| 2. | Size of cortex | Wide | Narrow. |
| 3. | Pericycle | Made of sclerenchyma, caps the indiv-idual bundles. | Sclerenchyma completely surrounds each vascular bundle |
| 4. | Vascular bundle | Few, arranged in a ring of cambium. | Numerous, scattered all over the ground tissue. |
| 5. | Cambium | Present. | Absent. |
| 6. | Secondary thickening | Occurs. | Does not occur |
| 7. | Pith | Present. | Absent. |

### Heartwood and sapwood

A transverse section through a very old woody stem such as Iroko or Mahogany, will show that the wood which now occupies almost the entire of the section, consists of two distinct portions. These are:

the **central portion** which is darker in colour called the **heartwood** and

the **outer portion** which is lighter and is called the **sapwood** (Fig. 14.41).

The heartwood is very hard and is more durable than the sapwood. The xylem vessels in the heartwood are blocked up with chemicals which become hardened to add to the mechanical strength of the stem. The heartwood no longer conducts water. Only the sapwood is used for water conduction.

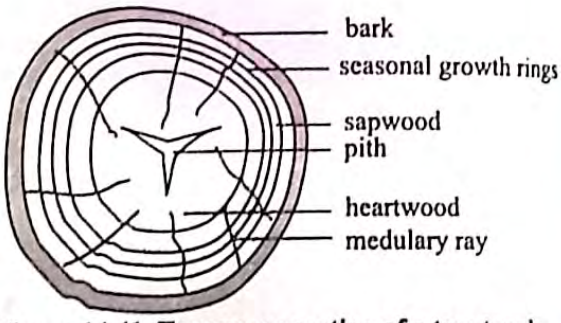



**Figure 14.41. Transverse section of a tree trunk.**

**Table 57: Structural and functional differences between stem and root**

| | | Stem | Root |
|---|---|---|---|
| 1. | Colour | Usual green due to present of chlorophyll and can manufacture food | White or brown and cannot manufacture food |
| 2. | Tip | Protected by overlapping leaves | Protected by root cap |
| 3 | Buds, leaves and flowers | Bears leaves, buds and flowers | Does not bear buds, leaves and flower |
| 4. | Stomata | Usually present in the epidermis of the green herbaceous plants. | Plants. |
| 5. | Root hair | Absent. If present as in goat weed are multicellular and cannot absorb water and mineral salts. | Present as unicellular hairs and absorb water and mineral salts. |
| 6. | Cuticle | Present | Absent |
| 7. | Cambium | Present between phloem and xylem | Absent in the young root. |
| 8. | Phloem and xylem | Occur together in a vascular bundles | Occur alternately in a vasculir bundle |
| 9. | Protoxylem | Point towards the pith. | Points towards the cortex |
| 10. | Pericyle. | Made of Scienchyma in a discontinuous band. | Made of parenchyma in a continuous band |
| 11. | Response | Positively phototropic and negatively geotropic and hydrotropic | Positively geotropic and hydrotropic but negatively phototropic. |

**Similarities and differences between the epidermis of a flowering plant and the mammalian skin.**

**Similarities**

1. Both form the outer protective layers of living organisms.
2. Both have hairs (although some plants have none).
3. Both have pores. Stomata in the epidermis of green herbaceous plants and sweat pores in the skin.
4. The cells of both layers are living.
5. Both protect the internal organs.
6. Both regulate the amount of water leaving the organisms.

**Table 58: Differences**

| | Skin | Epidermis |
|---|---|---|
| 1 | It is made up of many layers or cells | It is made up of a single layer of cells. |
| 2. | It has sweat glands which produces sweat. | No sweat glands. |
| 3. | Each sweat gland has a duct which ends up at the surface as sweat pore. | No sweat duct. |
| 4. | Sebaceous glands in the skin produce oil to lubricate the hair. | No sebaceous gland. |
| 5. | There is no cuticle. | Possesses cuticle. |
| 6 | It has blood vessels and network of blood capillaries | There is no blood vessel and blood capillaries. |
| 7 | The skin is a sensory organ | Epidermis is a tissue and is not sensory. |
| 8. | There are no guard cells. | There are guard cells. |
| 9. | Fatty cells are present | There are no fatty cells. |
| 10. | Capable of manufacturing vitamin D with the aid of sunlight. | Cannot manufacture vitamin D. |

## The internal structure of a leaf

The internal structure of a leaf consists of three main tissues namely:

1. The **epidermis** (upper and lower).
2. The **mesophyll** consisting of palisade and spongy cells.
3. The **vascular bundles** consisting of midrib and veins.

Transverse section of a leaf see figure 6.12 page 83.

**Epidermis:** This is a single layer of closely fitted cells found both on the upper and lower **surface** of the leaf. The upper epidermis is lined with waxy cuticle which prevents much evaporation of water and protects the inner cells from mechanical damage and from diseases (bacteria and fungi).

In many dicotyledonous leaves the upper epidermis has not stomata. However, a few species like cowpea and bitter-leaf have stomata on both lower and upper epidermis. The lower epidermis has numerous stomata. This lower position of the stomata helps to keep away direct rays of the sunlight which may damage the tissues and also prevent excessive water loss through evaporation.

**Mesophll:** The mesophyll is made up of

parenchyma cells. The tissues between the upper and lower epidermis is called **mesophyll.** Mesophyll is made up of two types of tissues namely **palisade tissue** and **spongy tissue.**

**Palisade mesophyll:** This consists of **one** or **two layers** of elongated cells closely packed at right angle to the upper epidermis. The cells contain numerous chloroplasts are mostly useful for photosynthesis.

**Spongy mesophyll:** This is made up of irregular cells that are loosely packed, thus providing a lot of **intercellular air spaces** in direct communication with the atmosphere, via the stomata. Air diffuses into the air spaces from where carbon dioxide is absorbed for photosynthesis, and oxygen is used for re-spiration. The spongy cells contain fewer chloroplasts.

**Midrib and veins:** These are the vascular tissues Consisting of **xylem** and **phloem** surrounded with few parenchyma cells. They are in direct communication with the vascular tissues of the stem and root to the leaves and from the leaves to the roots. The midrib is the main vein. The smaller or lateral veins which form **parallel venatation** in monocotyledonous leaves and **reticulale or network venation** in dicotyledonous leaves, can be seen on either side of the midrib.

## Stomata

Refer to page 193

## Supporting tissues in plants

Cells that give mechanical support to the plants are grouped as **supporting tissues** in plants. These are **parenchyma, collenchyma, sclerenchyma, xylem** and **phloem** which have been fully discussed in this chapter.

## *Questions*

1. (a) ***What are the features of the skeleton of named mammal? Draw a well labelled diagram of: (i) A hinge joint (b) ball and socket joint.***
   (b) ***State two places where they are found in the body. How would you identify: (i) Cervical (ii) Thoracic (iii) Lumber vertebrae?***
   (c) ***Describe the first aid procedures you would carry out for simple injuries to bones:***

2. (a) ***What are the functions of the skeleton in a mammal? Explain how the muscles in the arm of a manbring about bending and then straightening of the elbow joint.***
   **(b) What is hydrostatic skeleton? Name one animal with hydrostatic skeleton and briefly describe how it aids movement in the named animal.**
   (a) ***Describe a lumbar vertebra of named mammal. Of what use is this bone to the mammal?***
   (b) ***Which tissues in a young stem of a flowering plant perform functions similar to those of the skeleton of mammal? Describe briefly the position and structure of tissues named (WASC).***

3. (a) ***Make a large labelled drawing of a typical vertebra from any view of your choice.***
   (b) ***State the functions of: (i) Axis vertebra (ii) Thoracic vertebra (iii) Caudal vertebra.***
   **(c) What are the differences between an exoskeleton and endoskeleton**

4. (a) ***Make a fully labelled diagram to show the principal muscles and bones involved in the movement of fore limb of a named mammal.***
   (b) ***What are characteristic features of a muscular tissue?***
   (c) ***Compare the structure of the skeletal muscle with that of the smooth muscles***
   (d) ***Explain why strenuous exercise may cause fatigue in skeletal muscle***

5. (a) ***Compare the roles played by ligaments and tendons in skeletal movement.***

(b) State three differences between a cervical vertebra and a thoracic vertebra and relate the differences to their functions.

6. (a) Describe briefly the structure of four of the following
(i) xylem (ii) phloem (iii) parenchyma (iv) sclerenchyma (v) collenchyma
(vi) sieve tube. Show how each is related to the functions it carries out.

7. With the aid of well labelled diagrams, compare the distribution of tissues in a dicotyledenous root and stem in relation to the mechanical functions of the root and stem.

8. (a) Describe the structure of the root of a named monocotyledenous plant (Diagram is essential).
(b) What are the functions of the parts labelled?
(c) State three differences between the internal structures of dicot and monocot stems.

# 15 MOVEMENT

All animals at one stage or the order must move in order to find food, water, mates (for production), and breeding grounds, discover new habitats, avoid predators and areas infested with diseases or pests. Movement is either on land, through water or through air.

## CYCLOSIS (CYTOPLASMIC STREAMING)

The mass rotational streaming (movement) of the cytoplasm and its contents in cells with vacuoles is known as **cyclosis** or **cytoplasmic streaming.** In some cases, the streaming may be restricted to a particular region of the cell. In other cases, the whole cytoplasm may be involved in the streaming resulting in transportation of substances from one part of a cell to another.

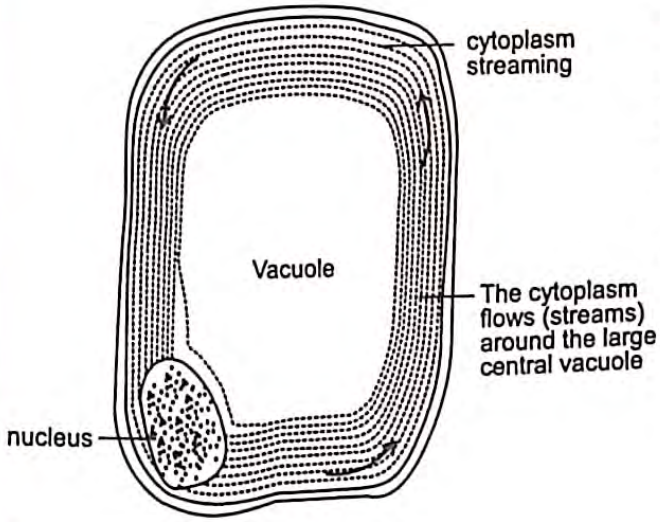



**Figure 15.1. Cyclosis in a plant cell.**

### Functions of cyclosis

1. In the cytoplasm, there are many organelles each being bounded by a different permeable membrane and separated from each other. Therefore, the interchange of materials between the organelles is partly by cyclosis.
2. The chloroplasts of some plants move independently (when the source of light is altered) by cyclosis thereby placing their broad surface parallel or perpendicular to the surface of the leaf in order to receive sufficient sunlight for photosynthesis.
3. The streaming of the food vacuole in *Paramecium* is brought about by cyclosis.

### Movement in *Amoeba*

Movement is by means of **pseudopodia** and is known as **amoeboid** movement. The **endoplasm** is divided into an outer viscous portion called **plasmagel** and an inner liquid portion called **plasmasol.** During locomotion, the liquid **sol** flows in the direction of movement and on reaching the tip of the pseudopodium it changes to **gel.** During this process of forward movement, more **sol** is flowing forward which consequently changes to **gel.** The back also changes from **gel** to **sol.** In this way movement is carried out on the substratum.

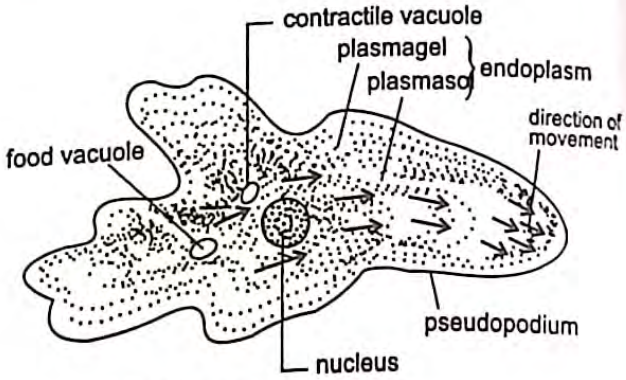



**Figure 15.2. Movement in *Amoeba*.**

## Movement in *Euglena*

*Euglena* carries out two methods of movement. These are **slow creeping (euglenoid) movement** and **flagella movement.**

### Slow creeping (euglenoid) movement

This type of movement is carried out by gradual change of the shape of the whole cell. Firstly, the **posterior end** of the cell is drawn forward making the cell to be rounded and then the **anterior end** of the cell is extended, thus making *Euglena* to creep forward.

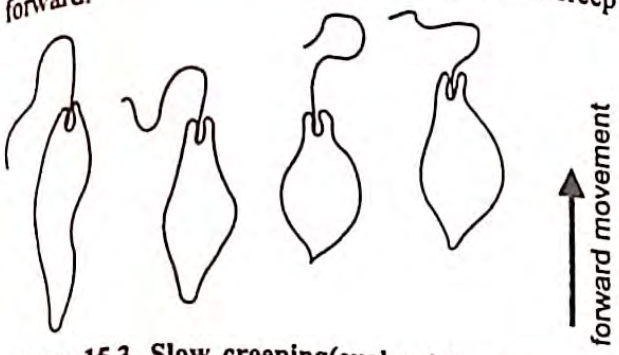



**Figure 15.3. Slow creeping(euglenoid) movement in *Euglena*.**

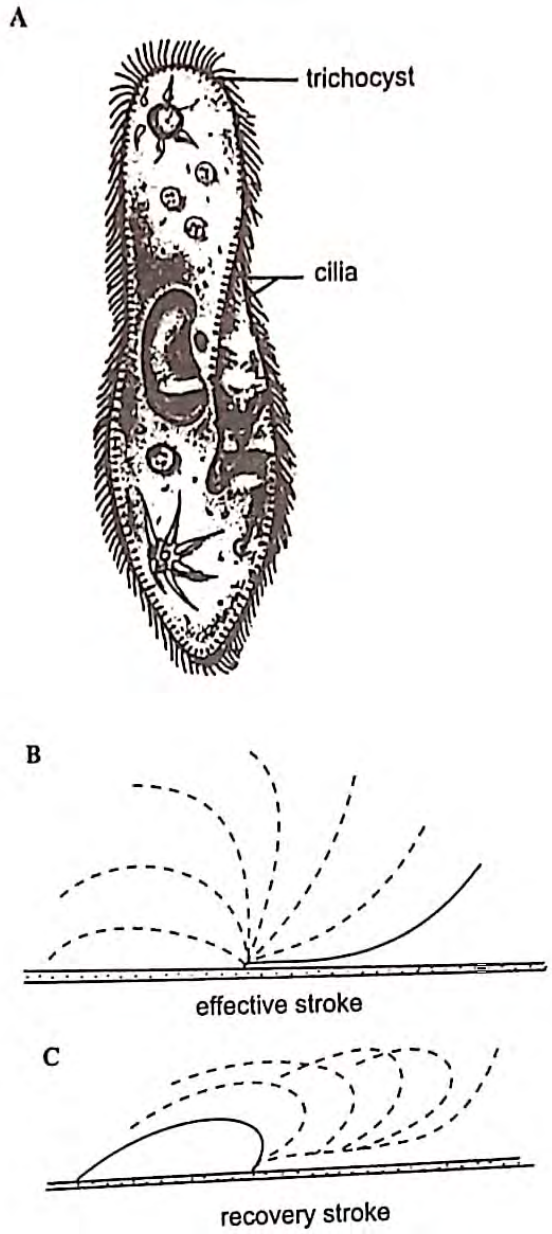
### Flagella movement

This is by the lashing of the flagellum by rowing or undulating motion which makes the flagellum to draw back water and propels the animal forward rapidly.

**Figure 15.4. Flagella movement in *Euglena*.**

## Movement in *Paramecium*

*Paramecium* swims in the water by the beating of its cilia. When the cilia are moved forcibly in one direction and returning them (cilia) backward weakly gives the animal a forward movement. The cilia beat from the anterior end progressively to the posterior end. The cilia also beat obliquely thus making the animal to revolve on its axis to give a spiral path. The animal is capable of reversing the ciliary beat in order to change its direction. It is important to note that the activities of cilia are co-ordinated by the neuroneme.



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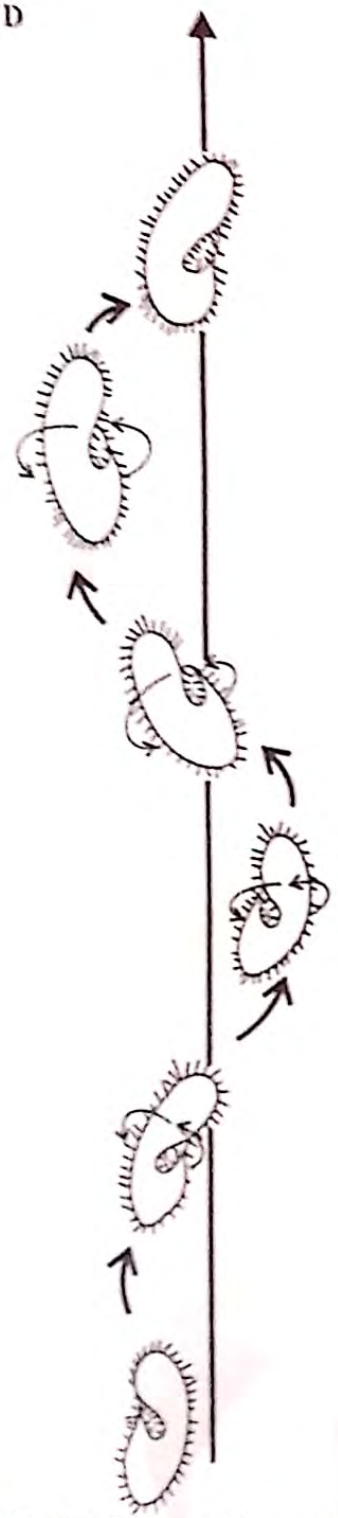


Figure 15.5. Movement in *Paramecium*
A = *Paramecium* with cilia
B = Effective stroke for forward movement
C = Recovery stroke
D = Spiral path of *Paramecium* swimming

## Movements in *Hydra*

1. **Swaying**
   Sometimes *Hydra* comes to rest on rock or other suitable hard surface in water and fixes itself temporarily with mucus substances at the basal disc. Even when *Hydra* is fixed, it is continuously swaying and this swaying is brought about by the contraction and elongation of the muscles on the sides of the body and tentacles.

2. **Swimming**
   *Hydra* is capable of swimming. This is brought about by the undulating movement of the tentacles.

3. **Gliding**
   Alternate contraction and elongation of the muscles of the basal disc results in a gliding movement of the animal.

4. **Looping**
   In looping, the animal bends until its tentacles touch the surface of the substratum, that is its body is in the shape of a **loop**. The foot releases its hold and moves **towards** the anchored tentacles. Next, the tentacles release their grip and in this way the animal moves **forward.**

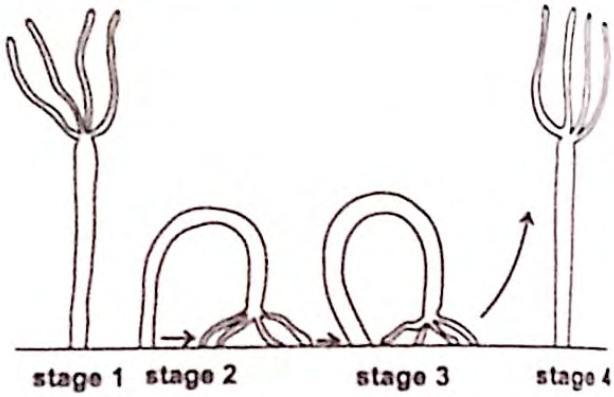



Figure 15.6. The stages in looping movement in *Hydra*

5. **Somersaulting**
   Sometimes instead of *Hydra* moving the base towards the attached tentacles, the base is swung right over and beyond the tentacles to achieve a

grip on the other side of the tentacles. This is the **somersaulting method of locomotion** and carries *Hydra* faster.

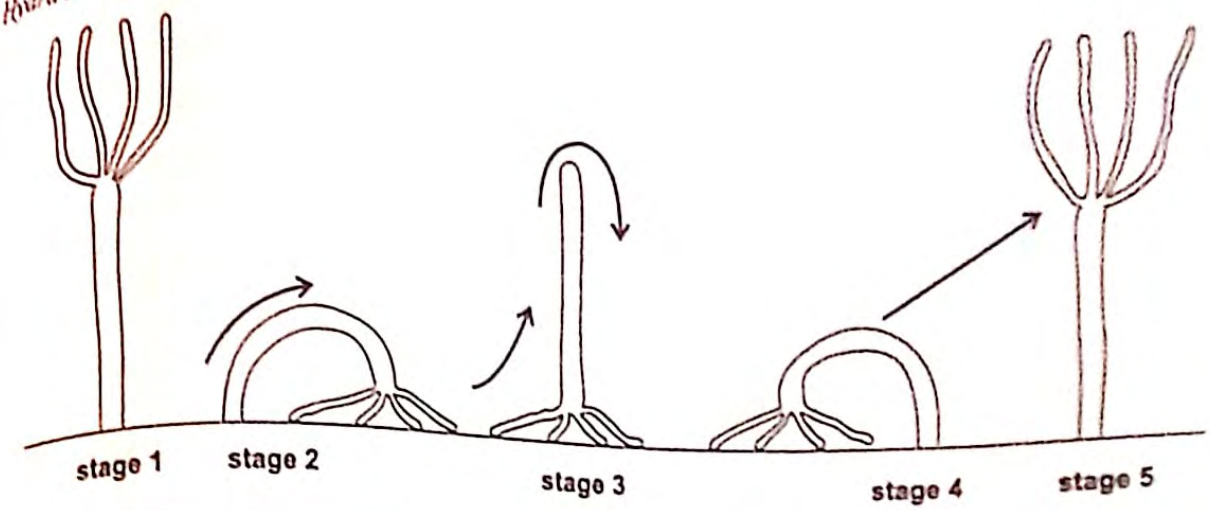



**Figure 15.7. The stages in somersaulting in *Hydra*.**

## Movement in earthworm

### Crawling

Animals lacking tails, limbs and fins adopt crawling movement. Earthworms, snails and snakes crawl.

The earthworm moves by crawling. It takes place in a stationary worm as follows:-

The **circular muscles** of a few of the anterior segments **contract.** The region becomes narrow and extends forward. The **chaetae** in this region are withdrawn. This allows the forward extension of the anterior segments. The anterior chaetae are **protruded.** Following the protrusion of **anterior chaetae, the longitudinal muscles** contract to pull up the posterior parts. This **contraction** of the circular and longitudinal muscles pass posteriorly down the body of the earthworm. The alternate waves of contraction circular and longitudinal muscles with the withdrawal and protrusion of the chaetae result in the forward movement of the earthworm. The contraction of the circular and longitudinal muscles is co-ordinated by the nervous system.

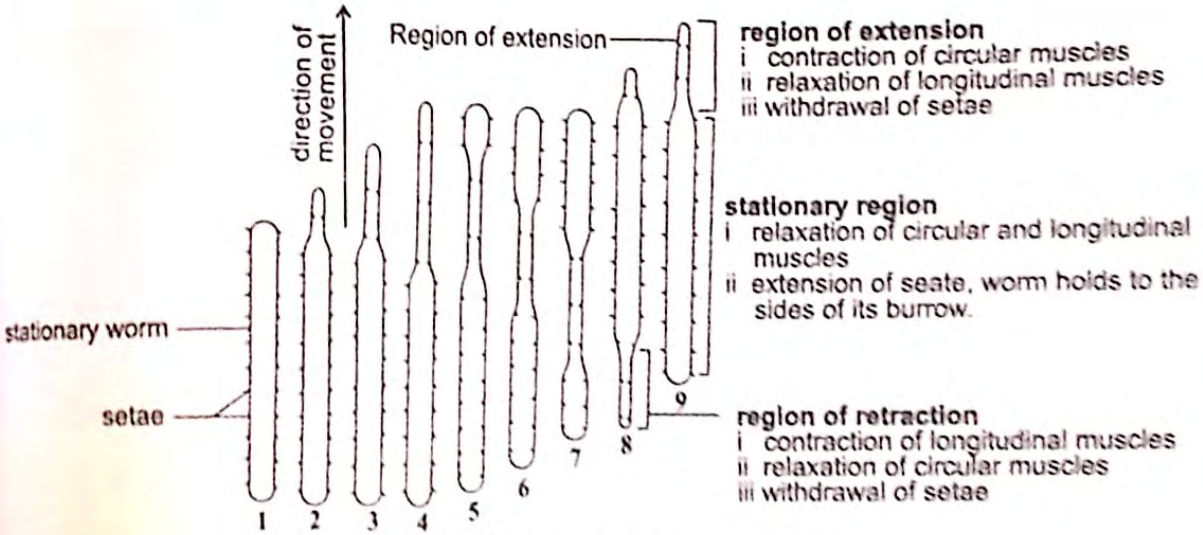



**Figure 15.8. Forward movement of an earthworm.**

## Movements in fish

### Swimming movements

Each side of the **vertebral column (flexible backbone)** of a fish is made of **muscle blocks or myotomes.** The muscle blocks are arranged in a **zig-zag fashion** from head to tail. Each muscle block starts from the transverse process of one vertebra and ends on the transverse process of next vertebra. Each muscle block is separated from another by a connective sheet.

Swimming is brought about when the muscle blocks of one side contract **bending** the **flexible vertebral column** and at the same time the muscle blocks of the other side relax resulting in the bending of the body. The alternate contractions and relaxations of the muscle blocks and the bending of the vertebral column create wave-like movements that run from head to the caudal fin causing the side to side (lateral) movements of the caudal fin.

The bending of the body which pushes the tail against water provides forward movements. Also the lateral movements (side to side lashings) of the caudal fins push water backward and propel the fish forward. When the fish is swimming, the head and the tail turn to opposite direction, thus enabling the fish to maintain a straight course.

In a compact fish like tilapia, it is the penducle (tail stalk) that lashes from side to side providing most of the forward movement. In slender fish such as **African spiny eel** and *Erpetoichithys calabaricus* (sail fish) the whole body bends from side to side creating two or more curved areas that help to push water backward, thus providing forward movement.

## Fin movements

### Fins

There are two kinds of fins: the **paired fins** which are the **pectoral** and **pelvic fins** and the **unpaired fins** which are the **dorsal, anal** and **tail (cauda) fins.**

### Paired fins

The pectoral and pelvic fins are used for slow movement. Their movements when the fish is not in motion help to bring in fresh oxygenated water. They are used for balancing and steering. They also help to act as brakes.

### Unpaired fins

### Dorsal fin

Is used as a stabilizer that keeps the fish steady.

### Anal fin

Also act as a stabilizer and helps the fish to maintain a straight course.

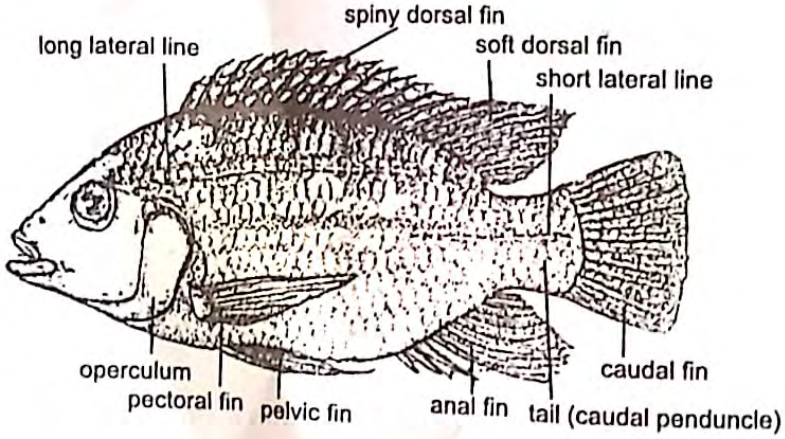
### Tall fin

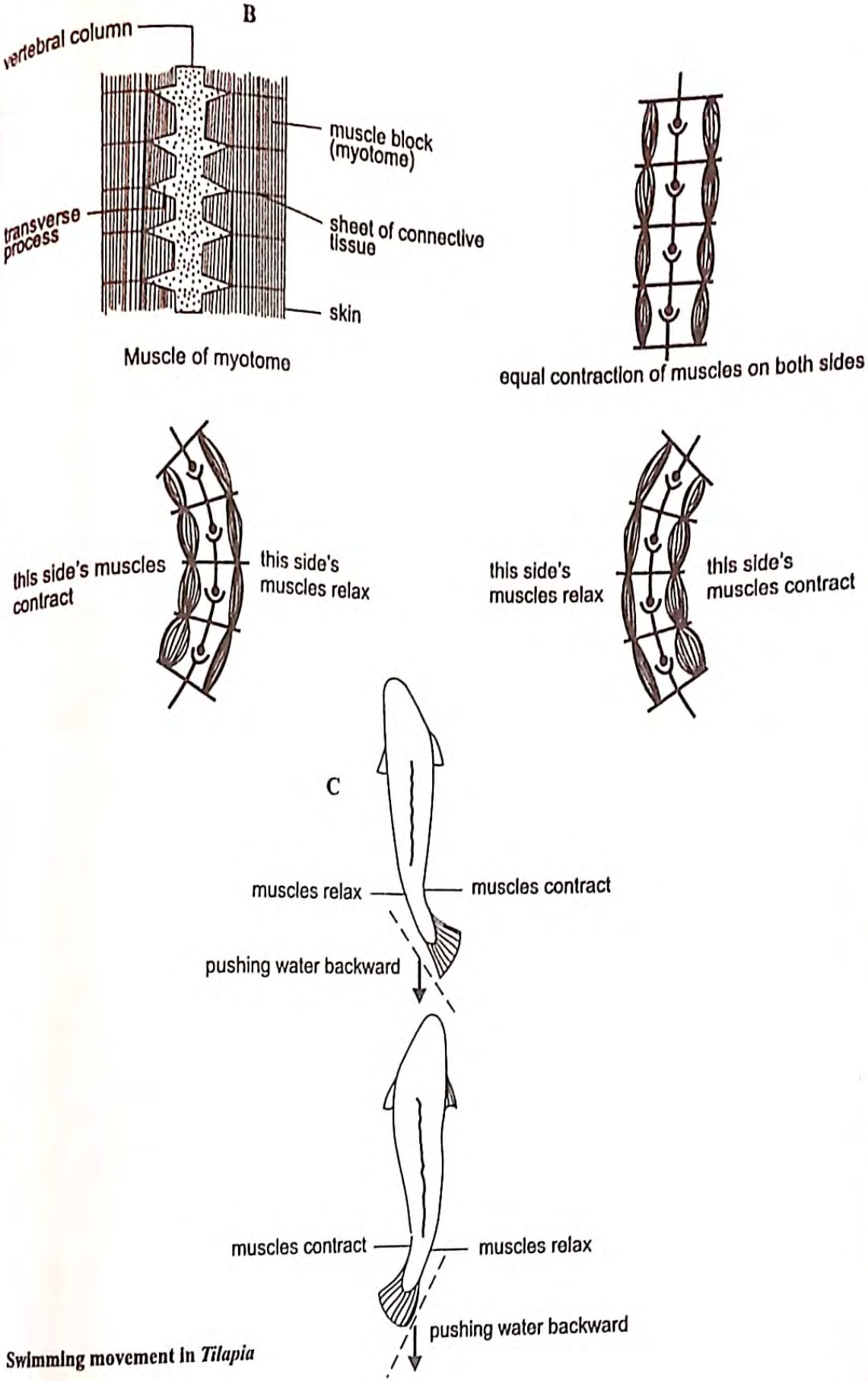
Is used for steering during locomotion. The streamlined shape of the body also helps for easy movement through the water.

### Swim-bladder (Air bladder)

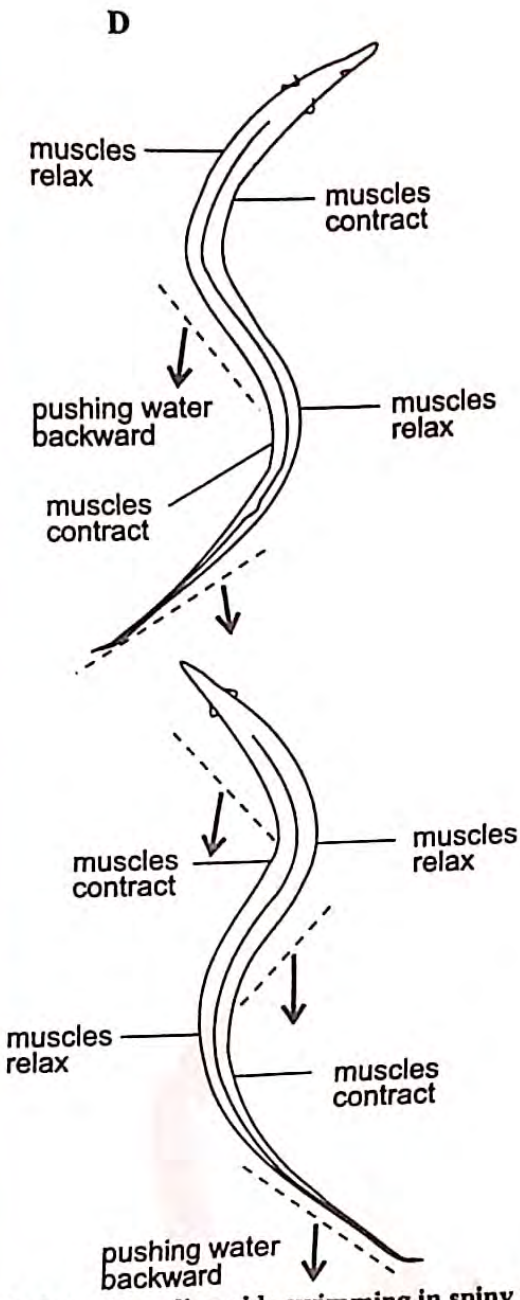
A swim-bladder is a sac-like organ in which gas accumulates in many fish. It functions as a **hydrostatic organ** which helps to maintain the specific gravity of the fish. By filling the swimming bladder with gas, the fish becomes lighter than water and thus rises up while the removal of the gas from the swim-bldder, the fish becomes heavier than water and therefore sinks.

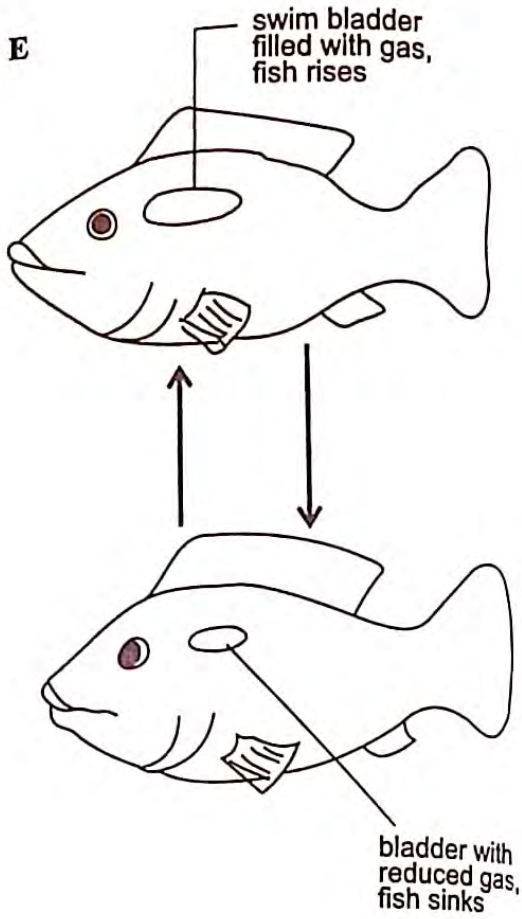
A






**Swimming movement in *Tilapia***




**S-shaped bending aids swimming in spiny eel**
***(Mastacembelus leonnbergii)***

**Figure 15.9. A -E: Structures involved in swimming movement in bony fish**

## Movements in the adult frog or toad

The adult frog or toad carries out two types of movement. These are **hoping** and **swimming.**

## Swimming

The body is **stream-lined in shape** for an efficient swimming. The powerful hind-limbs have webbed toes which are used as paddles. The hind limbs push water backwards providing forward movement for the animal while fore-limbs are used for steering.

## Hopping

The powerful hind-limbs provide the hopping mechanism. When the frog is at rest, the hind-limbs are folded in form of letter Z. When the hind-limbs are extended the force pushes the animal forward and upwards. The fore-limbs extend to take the landing shock while the hind-limbs are folded.

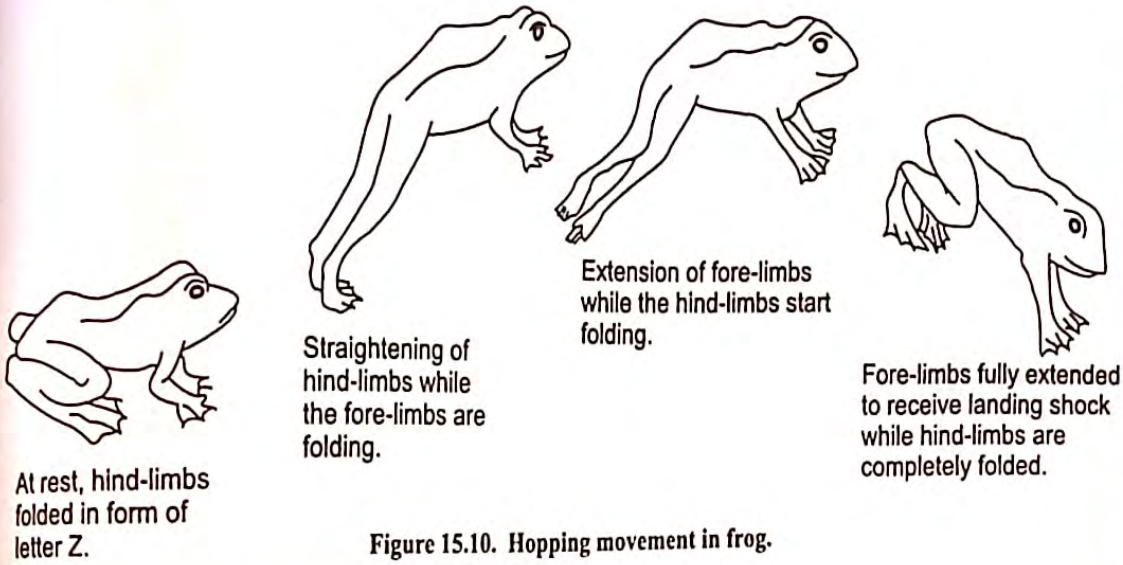



**Figure 15.10. Hopping movement in frog.**

## Movements in Lizard

### Running

*Agama agama* carries out short running movements with the head raised from the ground.

### Climbing

The sharp claws in the limbs make it possible for the animal to climb walls and trees.

### Press-up

(Head bobbing): After a fast brief running, the animal stops and carries out "press-up"movement, that is bobbing the head.

### Tail movement

During fighting, the male's tail moves frequently while the female shows its tail movement before mating.

## Movements in birds

Most birds move by flying. Such birds have well developed wings with flight feathers. The wings of birds which act as aerofoils are convex above and concave below. The air moving around the wings provides enough upward lift to encounter the pull of gravity and prevents the bird from falling to the ground. The air above the wings is thinner and moves faster than the air below the wings which is denser and moves lesser speed and therefore exerts a greater pressure and pushes the bird up providing the needed lift.

There are four types of movement in birds: **flapping, gliding, soaring** and **walking.**

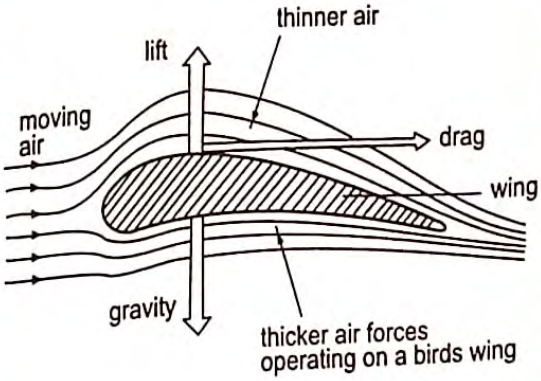



**Figure 15.11. Wing as an aerofoil.**

## Flapping

Flapping flight is achieved by the contraction of the powerful **pectoralis major** and **pectoralis minor muscles**. When the pectoralis major muscles contract, the wings are pulled downwards and forwards, thus giving the bird the necessary **lift and forward thrust**. At this time, the feathers are tightly closed while the wings are stretched out, thereby pushing as much air as possible. The contraction of the pectoralis minor muscles generates the upward and backward movement of the wings providing most of the forward movement. The whole process is repeated over and over. The tips of the wings and the feathers of the tail are used for steering. The tail feathers are also used for braking and balancing.

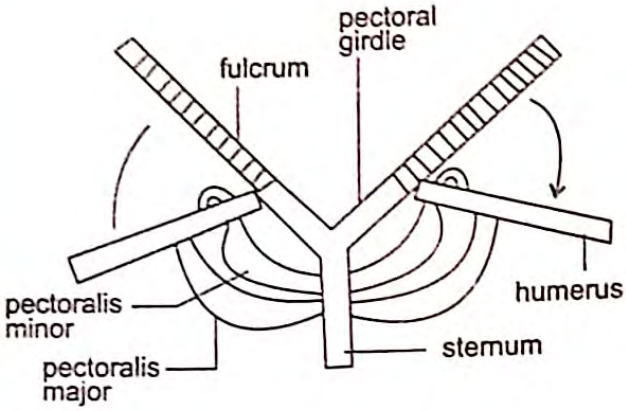



**Figure 15.12. A diagrammatic section to show how the muscles and bone work together to bring about flight.**

## Gliding flight

This type of flight occurs without flapping the wings. When the bird has reached a certain speed, or is about to land, the wings stop flapping. The wings, tail and all surfaces are expanded. These make the bird to move downward and forward slowly and eventually it lands on a tree or ground.

## Soaring flight

Not all birds are capable of soaring flight. In the birds that carry out soaring flight such as hawk and kite, they fly up to a certain height, spread th wings and stop flapping. They are then carried higher and higher by the warm air arising from warm areas of the earth thereby helping to conse energy.

### Swimming

The wings of penguins are modified swimming in water rather than flying in the air. T wings are far too small for the large body so they like propeller blades for steering the body swimming. On the other hand, birds of the d family (Anseriformes) such as the duck, goo heron, grebes use their webbed toes as paddles water for swimming.

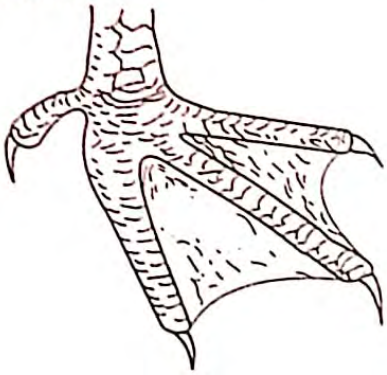


**Figure 15.13. Webbed toes of duck**

## Head movement

The head of a bird can easily turn through angle of 360°.

## Flying birds have the followin adaptive features

(1) The long and stream lined shape of the b provides an efficient device to fly throu the air with the least resistance.

(2) There are no projections apart from wings to retard movement in the air si the legs are retracted during flight.

(3) The fore-limbs are modified into wings w large surface area provided by t attachment of large firm feathers.

(4) The number of digits has been reduced four.

(5) The possession of powerful pecto muscles which operate the wings.

(6) The sternum (breast bone) is extended to

form a large keel for the attachment of the powerful pectoral muscles.

(7) The bones are light and hollow and in most cases marrow is absent. The hollow spaces are filled with air sacs which extend from the lungs. All these are attempts to reduce the weight of the bird.

(8) Some parts of the bones are fused together, e.g. the sacral bones are fused to give more strength.

(9) Another important adaptation is the complete covering of the body with feathers except the lower part of the legs. There are two classes of feathers:

(a) The **quill** feathers are large, flat and have barbs to form smooth complete surface. They overlap each other and have unequal vanes. These feathers are found on the wings and tail where they are used for flight and steering respectively.

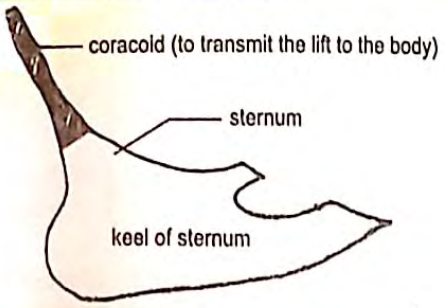
(b) The **contour** and **down** feathers are smaller and found all over body. They are used to keep the animal warm.

(10) The respiratory system is highly efficient. The lungs extend to all parts of the body including the bones. This is responsible for the high body temperature of about 42°C and a way of getting enough oxygen to reach all parts of the body for effective respiration and energy.

(11) The eyes are very keen, and posses nictitating membranes (third eyelid) which help to remove dirt from the eyes.

(12) There are no glands in the skin such as sweat glands to reduce heat by evaporation.

(13) The oil gland (preen) present is used in oiling the feathers to make them glossy and water proof for easy flight.




**The diagram of sternum and coracold**

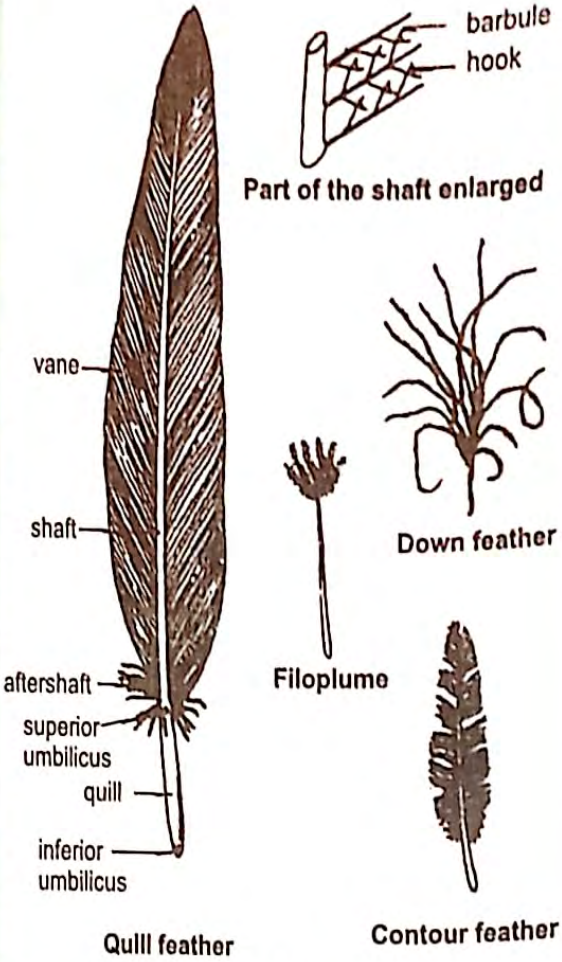



**Figure 15.14. The diagram of types of feathers**

## Movements in mammals

There is a wide range of types of movement in mammals. These include **walking, jumping, running, climbing, swinging, flying, gliding** and **swimming.** This accounts for the successful adaptive radiation in mammals which is also the hall mark of their success. As mammals radiate into the various available geographical regions the different habitats make these wide range of different types of locomotion possible. Mammals on land take to **walking, running, jumping** or **galloping.** Those in aquatic habitats **swim** and **dive** to move from one point to another. The tree top dwellers (arboreal forms) **climb, swing** and **jump** from branch to branch or glide from one tree top to another. The bat flies like the birds. Some mammals have combined two or more types of locomotion.

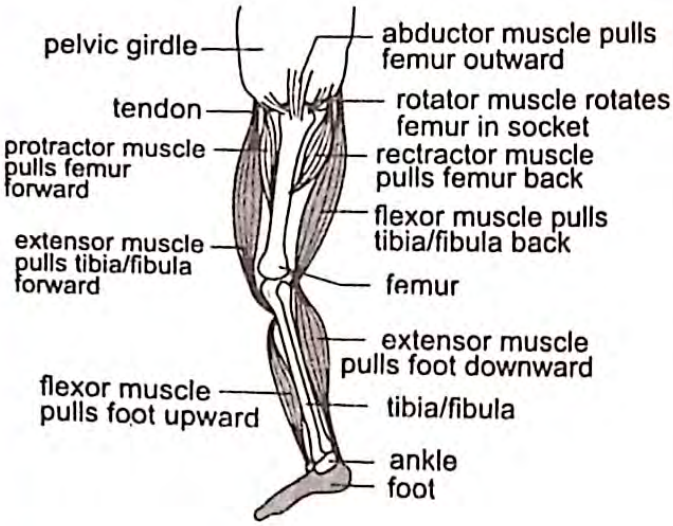
For example, man usually walks but can also run, jump, hop, gallop, climb, swim, dive and swing as the occasion demands. We shall now consider the usual methods of movements in man as the highest mammal on the evolutionary table.

## Walking in man

Man walks and in doing this, the legs and feet aided by the upper limbs (the arms) are moved by the contraction and relaxation of skeletal muscles against the skeleton. Man assumes a bipedal stance and he walks on two feet but the swinging of the arms facilitates walking, and running. Man walks on the ground and uses the ground to support himself.

From a stationary position a step in walking is taken when:

1. Flexor muscle contracts to pull the foot upward.
2. Extensor muscle contracts to pull the tibia-fibula forward.
3. Protractor muscle contracts to pull femur forward.
4. Extensor muscle contracts to pull foot downward.
5. Flexor muscle contracts to pull tibia-fibula back.
6. Retractor muscle contracts to pull femur back. This same process is carried out on the second foot and alternately between left and right. Walking is thus accomplished. The upper limbs (the arms) are swinging at the same time in an equal and opposite direction to displace instability.



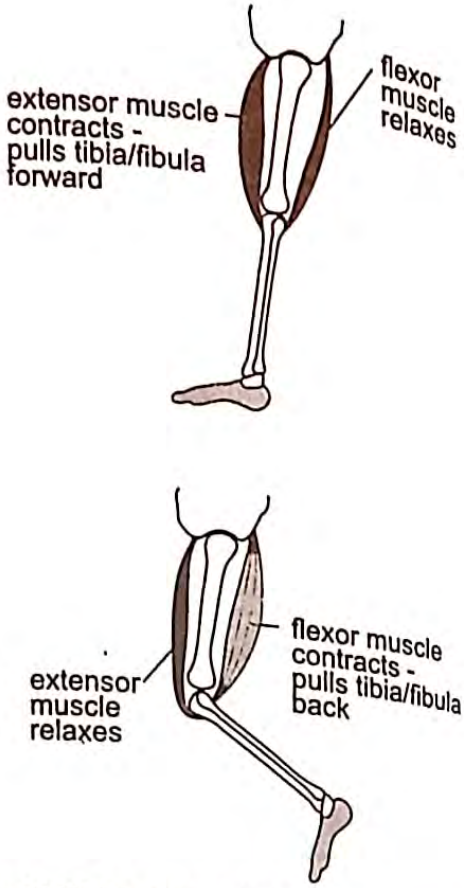




**Figure 15.15. Muscle involve in the movement of the leg of a man.**

## Bending and straightening of the elbow joint

The bones of the body are clothed with muscles. The skeletal muscles are made of striped fibre called **voluntary muscles** since they contract only on receipt of an **impulse** from the **central nervous system.** These muscles are always attached at one end **(origin)** to a fixed bone (the scapula) and at the other (insertion) to a movable bone **(olecranon)**.

These muscles always work in pairs, one contracting while the other relaxing. It is by the pull of contracting muscle that a bone is made to move about a joint, e.g. elbow joint. The humerus articulates with the radius and the ulna.

The bones are bound together by ligaments. In front of the humerus is the biceps muscle attached

to a fixed bone of the shoulder by two tendons. At its outer end, the biceps muscle is attached again below the joint. At the back of humerus is the triceps muscle of lesser diameter than the biceps. Its origin is attached to the shoulder and its insertion to the ulna.

On receiving an impulse from the central nervous system, the biceps contracts becoming shorter and thicker. At the same time the triceps relaxes. Since the tendons do not stretch, the shortening of the biceps results in a pull being put upon the radius. Thus the lower arm is pulled upwards by the contraction of the biceps. The lowering of the arm is effected by the contraction of the triceps at which time, the biceps relaxes and a force is exerted upon the ulna.

Thus the movement of the elbow joint calls for a pair of muscles. The one whose contraction results in bending is called **flexor muscle (biceps)** while the muscle whose contraction results in straightening is called the **extensor muscle (triceps)**. These are **antagonistic muscles**, that is, a pair of muscles which work together in opposite way.

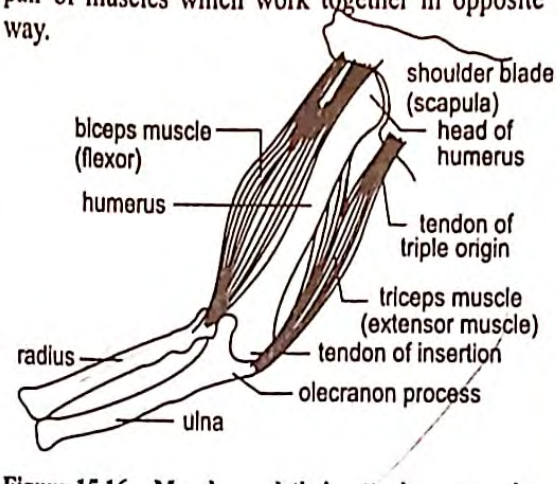



**Figure 15.16. Muscles and their attachment to the bones of the upper arm of a man.**

## *Questions*

1. (a) *With an aid of a diagram, explain the meaning of cyclosis*
   (B) *State three functions of cyclosis.*
   (c) *Describe how Amoeba or Paramecium moves.*

2. (a) *Describe with the aid of diagrams four ways in which Hydra moves.*
   (b) *Briefly describe how flight is achieved by the action of bird's wings.*
   (c) *Explain the action of the muscles and bones in the movement of the legs of man.*

3. (a) *Briefly describe movements in any two of the following animals: Diagrams essential. (i) Euglena (ii) earthworm (iii) toad.*

4. (a) *Explain with a diagram how a pair of antagonistic muscles carry out movement of the limb of a man.*
   (b) *Name four types of movement in birds and describe briefly any two with diagram if necessary*

# 16 REPRODUCTION

All living things reproduce since life span is limited. Reproduction is necessary for increase in number and perpetuation of life, and therefore, organisms must reproduce themselves either asexually or sexually.

## Asexual reproduction

This is a type of reproduction in which only **one parent** is involved No gamete is formed. Asexual reproduction occurs in both plants and animals.

## Asexual reproduction in plants

Plants reproduce asexually by the following methods (1) **fragmentation** (2) **budding** (3) **spore formation** (4) **vegetative** propagation.

### Fragmentation

An organism may break into two or more pieces and each piece can then develop into a new indi-vidual organism. Example is *Spirogyra*.

### Budding

This is a type of asexual reproduction in which a new cell is produced as an **outgrowth** of a parent cell. Yeast is an example.

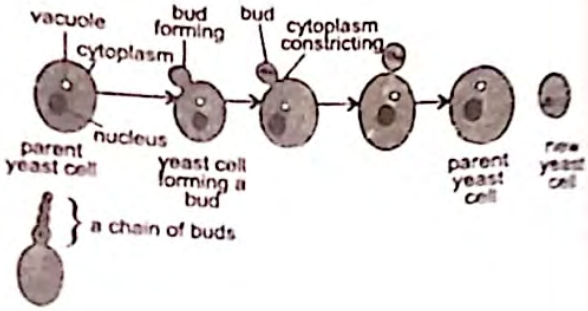



**Figure 16.1. Budding in yeast**

### Spore formation

Some plants reproduce asexually by spores. Some cells of the organisms divide by mitosis to produce spores. Each spore when dispersed develops into a new organism.

Plants such as *Mucor* and *Penicillium* reproduce asexually by means of **spores.**

*Mucor* under favourable conditions of moisture and temperature, mycelia rise to form hyphae which grow from the substrate into the air. These are termed aerial hyphae or sporangiophores and are slightly thicker than the rest. The tips of these aerial hyphae become swollen to form sporangia. The protoplasm of each sporangium divides to form numerous **small spores** which contain several **nuclei.** Eventually a dome shaped cross wall termed **columella** is formed at the base of the sporangium which eventually leads to its bursting. Insects alighting on the sporangium can also cause its bursting. Spores are liberated as adhesive mass but on drying they become separated and can be blown about by wind. Insects can carry large quantity of spores on their bodies. When each spore reaches a suitable substratum, germination takes place immediately.

In *Penicillium*, spores are borne on conidium (plural= conidia).

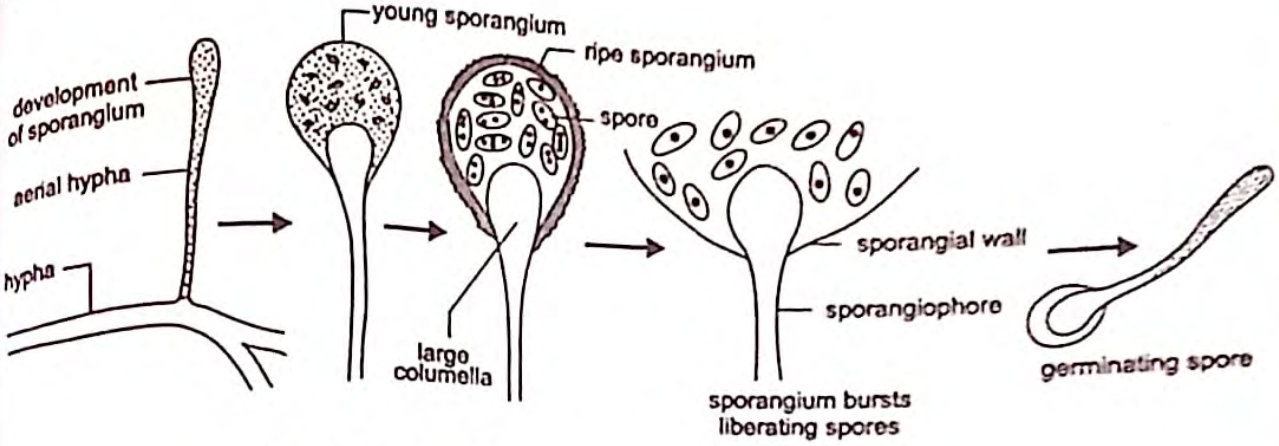
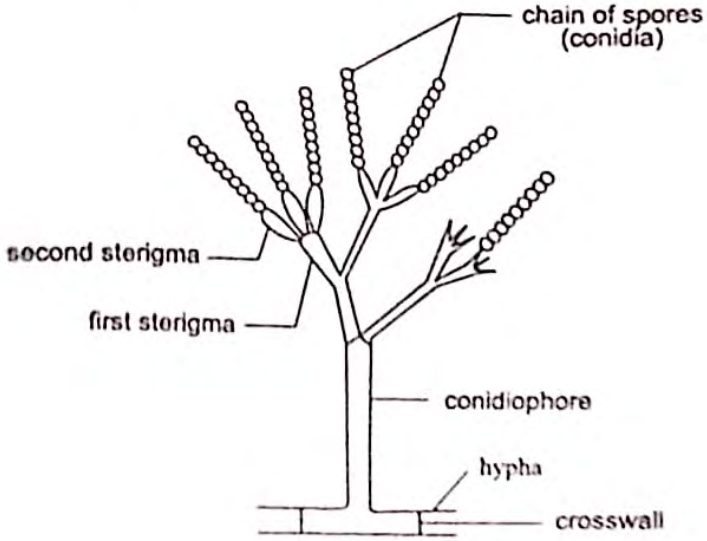



**Figure 16.2. Asexual reproduction by spore formation in *Mucor***




**Structure of *Penicillium***

**Figure 16.3. Structure and Asexual reproduction by spore formation in *Penicillium***

*Mucor, Penicillium* and yeasts are examples of saprophytes and are of great economic importance.

## Economic importance of saprophytes

1. Some are used as food. Mushroom is an example, canned mushrooms are sold commercially.
2. Some saprophytes are poisonous to man when eaten.
3. Saprophyes cause the decay of dead organic matter thereby helping in the formation of humus, which is a fertile soil for good growth of plants, and high yield crop production.
4. Some saprophyes are used in making antibiotics. Penicillium is used in making penicillin and streptomycin for treatment of diseases.
5. In the preparation of alcohol, yeast is used to ferment sugar to alcohol.
6. The blue green moulds are needed for the good ripening of cheese.

## 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** propagations.

## Natural vegetative propagation

Natural vegetative propagation is carried out by the plants themselves by means of leaves, stems and buds.

## Leaves

Tiny plants grow from the leaf which later break off to form a new plant. *Bryophyllum* and *Begonia* are good examples. In *Bryophyllum* the tiny plants grow from the veins at the end of the leaf margins while in *Begonia*, they grow from the veins on the surface leaf.

## Stems

Stems of different plants have modified themselves in different ways to carry out vegetative propagation. Some stems are modified as **runners, rhizomes, corms** and **tubers.**

## Runners

The stems of runners (such as sweet potato) grow **horizontally** along the ground. At the tips of run

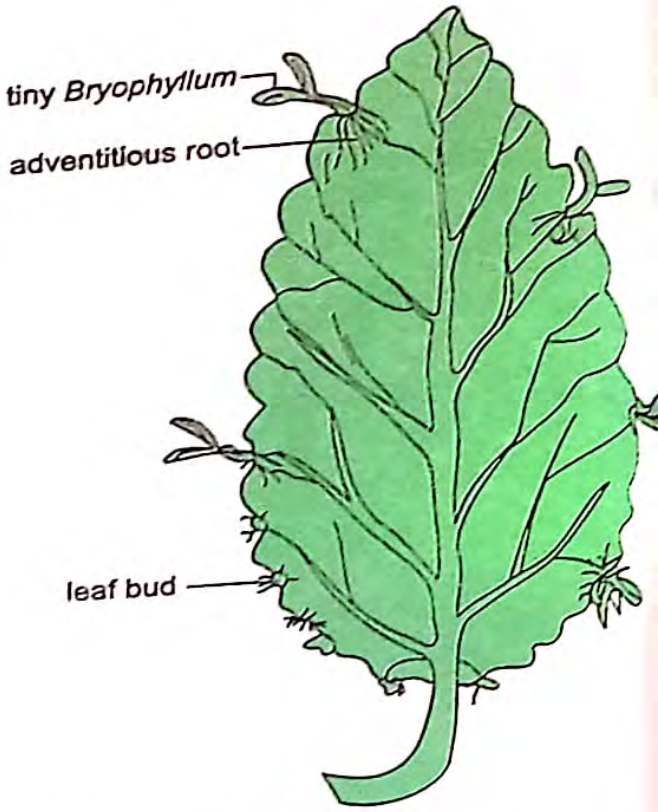



**Figure 16.4. A leaf of a *Bryophyllum* showing developing *Bryophyllum* plants.**

Runners, there are **terminal buds** which develo leaves and adventi-tious roots. When the we internodes die and decay, new independent plan are established.

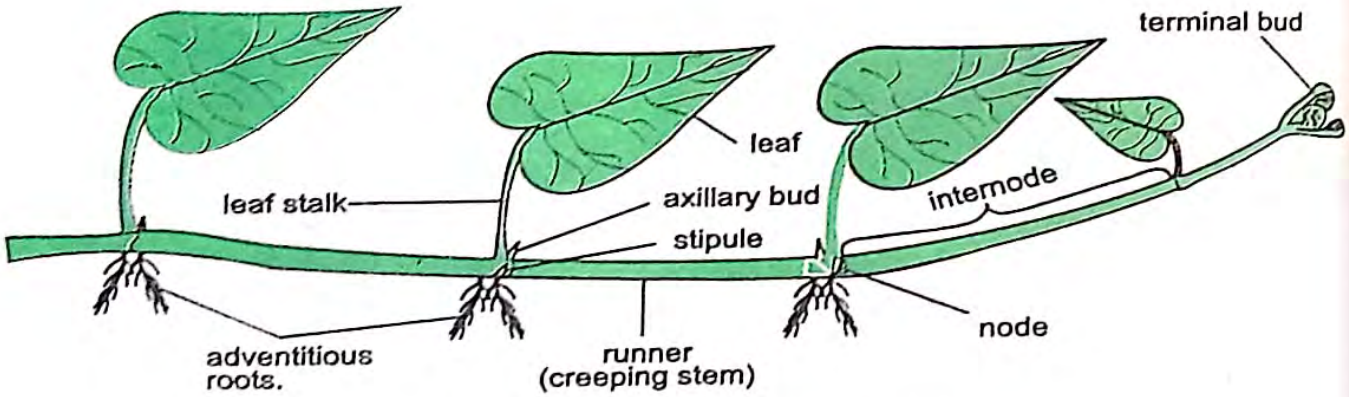



**Figure 16.5. Runners of sweet potato.**

## Rhizomes

A rhizome is a thick fleshy underground stem which grows more or less horizontally beneath the surface of the soil. Food stored in the stem is **starch.** It has **nodes** and **internodes.** The scale leaves are membraneous and cover lateral buds at the nodes. Circular scars left by aerial shoots of previous year are present.

## Vegetative propagation of rhizomes

The terminal bud manufactures food during favourable conditions by photosynthesis. Some of the manufactured food is sent to the lateral buds and the remaining ones stored. Eventually when the older parts of the rhizome die, the lateral buds grow into new aerial shoot. Examples of rhizomes are **canna lily and ginger.**

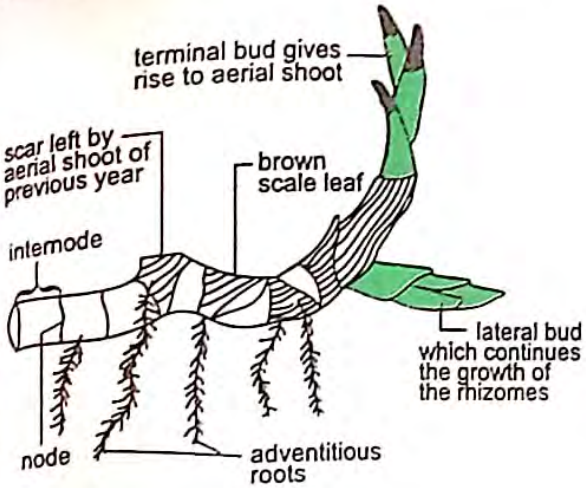



**Figure 16.6. Rhizome of cannalily.**

## Corm

This is an **underground** stem which grows vertically in the soil. The stem is short and swollen with food reserve. Scale leaves, nodes, lateral buds are arranged over it while terminal bud is at the top. During favourable season, the terminal bud grows upward to form leaves. Food is manufactured by the leaves and translocated to the top of the old corm and stored there. From there, a new corm develops. The new corm has **adventitious** and **contractile roots.** The contractile roots help to hold the corm firmly in the soil thereby preventing it from growing to the surface of the soil. From season to season, this process is repeated so that a corm will possess many old corms in the ground. Adventitious roots are used for absorbing water and mineral salts from the ground.

Some lateral buds receive food from the old corm and form new daughter corms. When the old corm dies, these daughter corms grow to become independent corms.

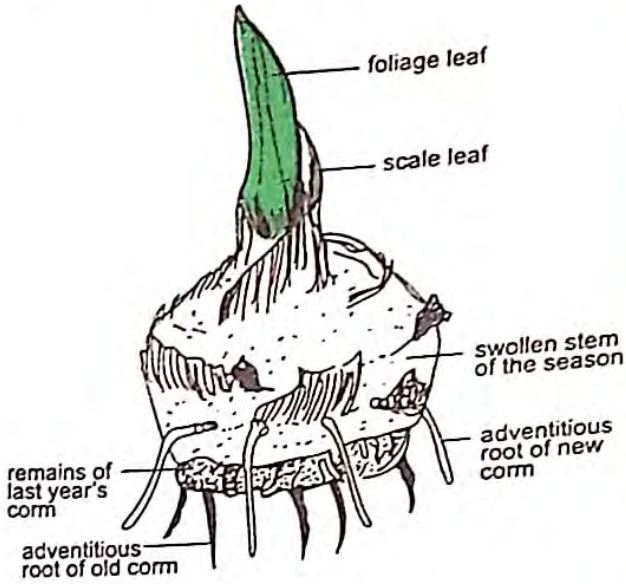



**Figure 16.7. Corn of gladiolus**

## Stem tubers

Stem tubers have the terminal ends of their underground stems **swollen with food reserve.** Plants like **yams** and **sweet potatoes** which develop tubers are usually annuals and their stems or shoots die down at the end of one growing season or year. The underground stem tuber is left below in the non-growing season. The dormant under-ground tuber gives rise to another **aerial shoot** when rains return in the next growing season. In **sweet potato,** the tuber has axillary buds covered with scale leaves which are referred to as "eye". In artificial propagation if sweet potato tuber is cut into pieces and each piece with an **axillary bud** is planted, the axillary bud grows adventitious roots and aerial shoot. The aerial

shoot manufactures food by photosynthesis. As the shoot grows it starts creeping on the ground and forming axillary buds. These axillary buds grow into the soil instead of growing upward. The tips of the axillary buds become swollen with food translocated from the shoot to them.

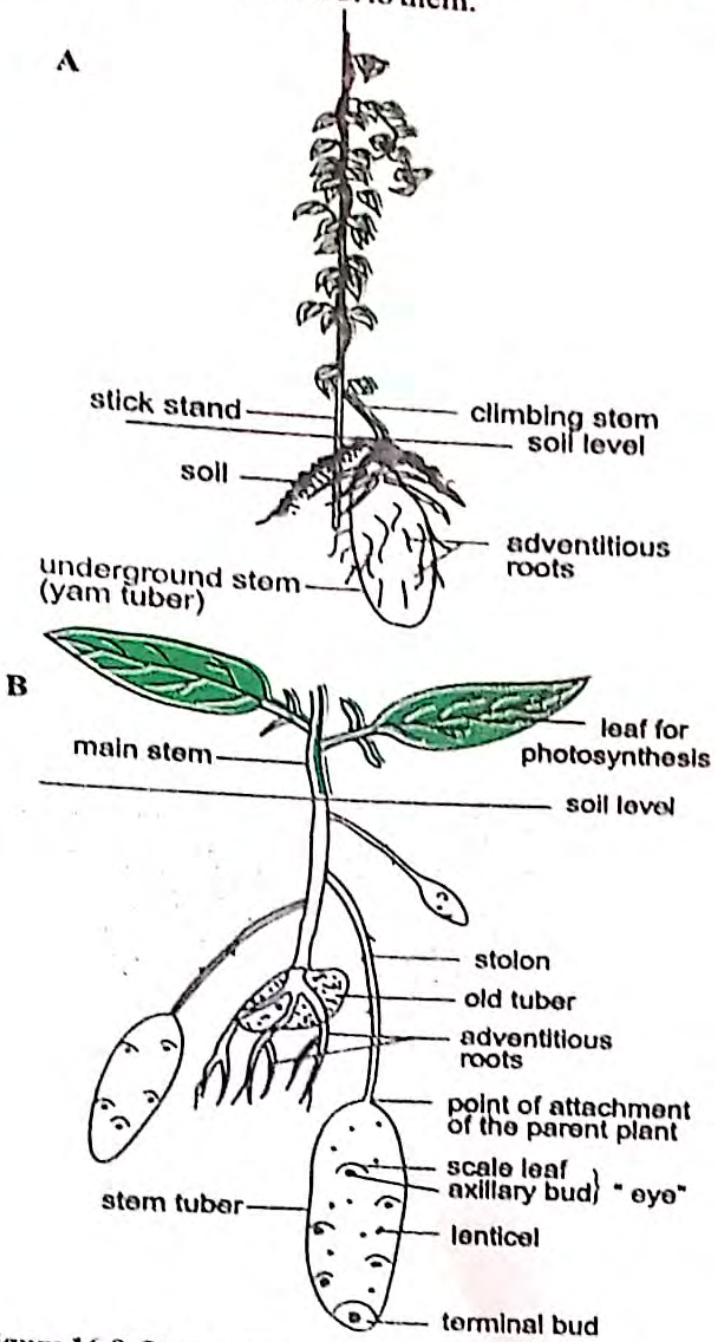



**Figure 16.8. Stem tubers**
**A = Yam**
**B = Sweet potato**

## Suckers

Suckers are underground young plants which develop from the **axillary buds** of the parent plant. The terminal buds of suckers grow above the soil to form shoot. Inside the soil, the suckers form adventitious roots. Naturally, suckers grow and mature into other plants around the parents bringing about increase in number of the plants. The ecological consequence of this is over-crowding leading to **competition** for space, light and available food resources. Man can consciously detach these suckers at their young or bud stage and transplant into a new habitat for better growth and yield. Examples of plants that develop suckers at the base of their stems are **plantain, banana and pineapple**.

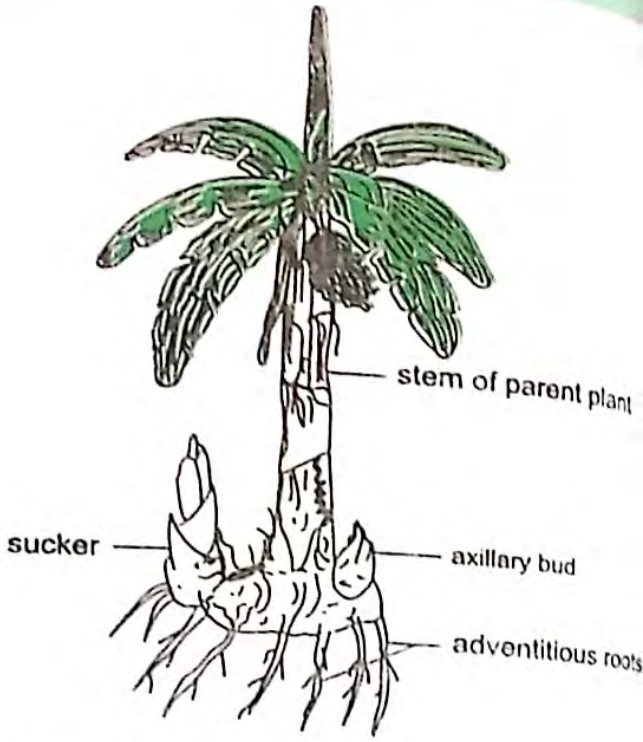



**Figure 16.9. Parent plantain showing sucker and axillary bud.**

## Shoot

The shoots of some plants are modified to form **underground buds** for vegetative propagation. Bulbs are examples.

**Bulbs** are under ground compressed shoot or buds. The stem is very short with inner scale leaves

which are fleshy and swollen with food reserves. They overlap. The outer leaves are dry, scaly and brownish. Terminal and lateral buds are present. Adventitious root arise from the short stem. Examples of bulbs are **onion, tulip** and **daffodil.**

## Vegetative reproduction in onion

A parent bulb produces one or more bulbs which break away. The leaves of the terminal bud grow up to manufacture food (mainly sugar) for the formation of a new lateral bulb. The newly formed lateral bulb then breaks away to become an independent bulb.

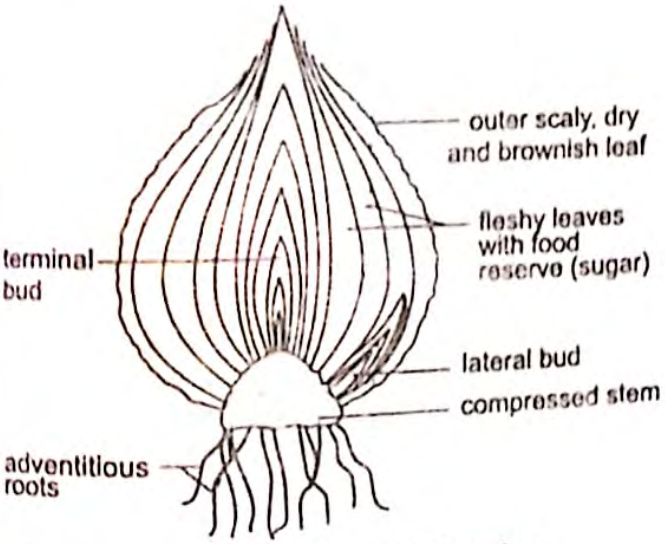



**Figure 16.10. Longitudinal section of an onion**

## 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.

### 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 **camblum.** The bud is care-fully slopped into the raised bark and pressed firmly to ensure that the **cambia** of both bud and stock unite together. 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 together 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 **eltrus** to select desired species.

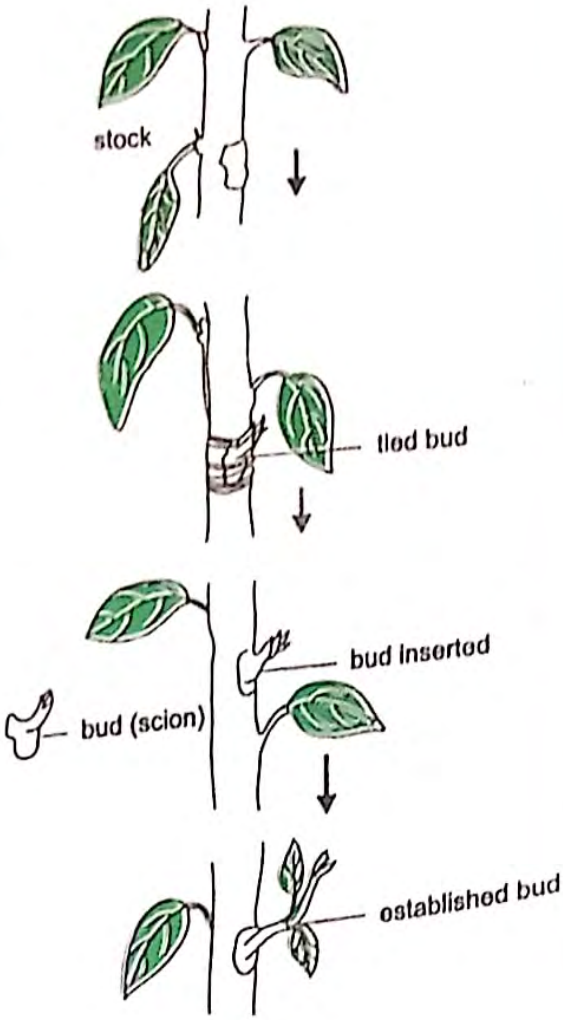



**Figure 16.11. Stages in budding**

## 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 then 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.

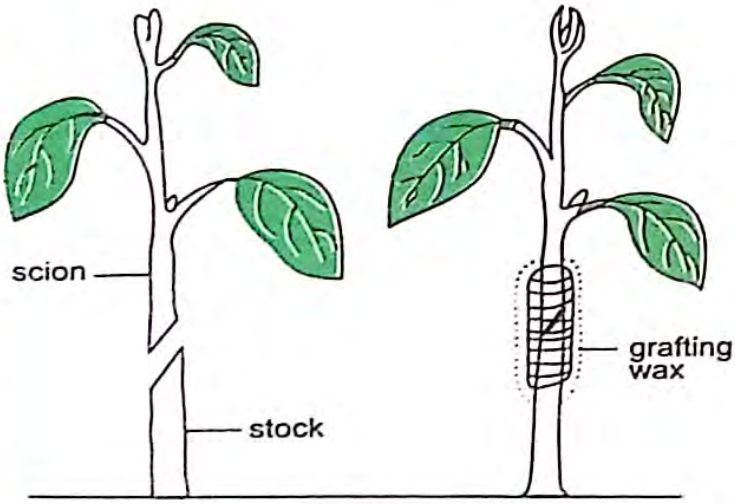



**Figure 16.12. stages in grafting**

### 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.

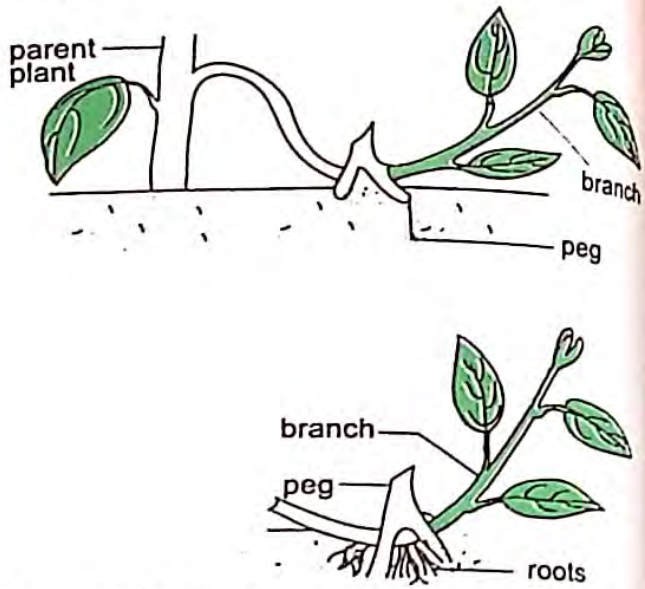



**Figure 16.12. Layering**

## 4. Cutting

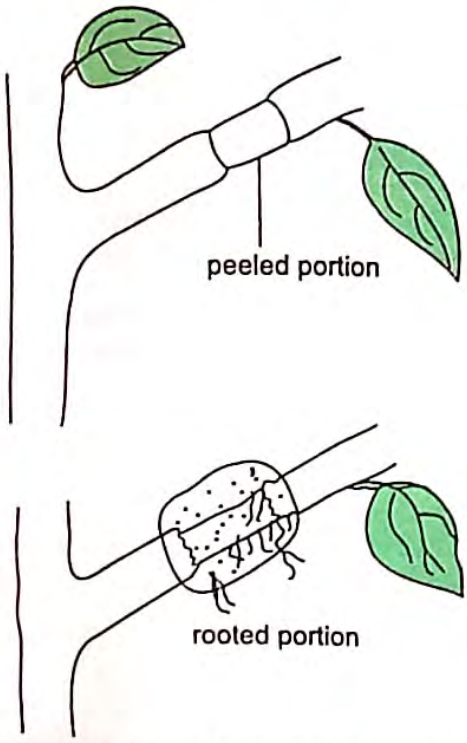
This involves the use of mature stem or branch stem to propagate plants. This is a very common method of asexual propagation in many crops such as **cassava,** *Ixora*, **croton** and **sugar-cane.** The plants produced have the same characteristics as the original plant from which the cuttings were 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 about 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 shrubs.



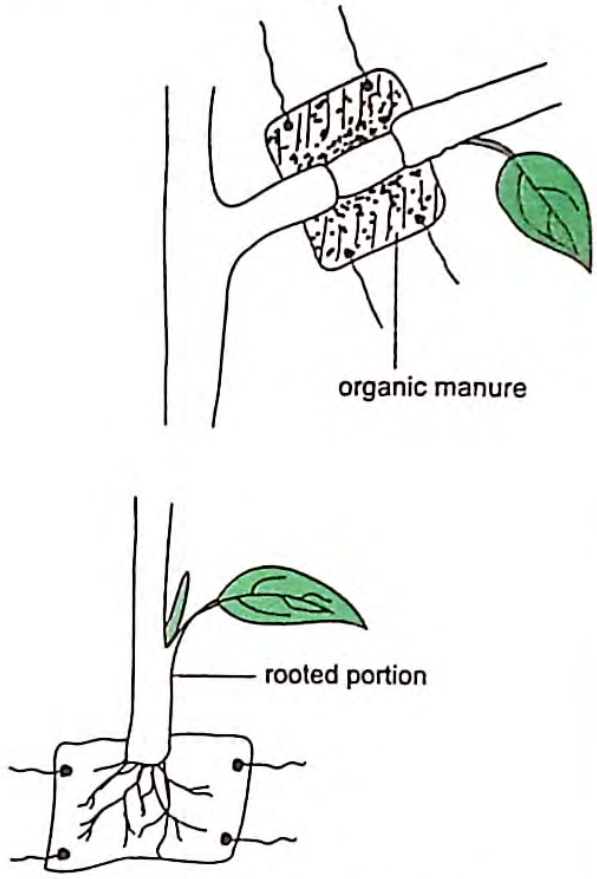




**Figure 16.13. Stages in marcotting rooted branch cut for planting.**

rooted branch cut for planting

## Advantages of asexual reproduction

1. The offsprings 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.

5. Vegetative parts of plant cannot be stored for a long time for planting.
6. Genetic improvement of plants is not possible.

## Asexual reproduction in animals

**Fission, budding** and **fragmentation** are some of the methods of asexual reproduction in animals.

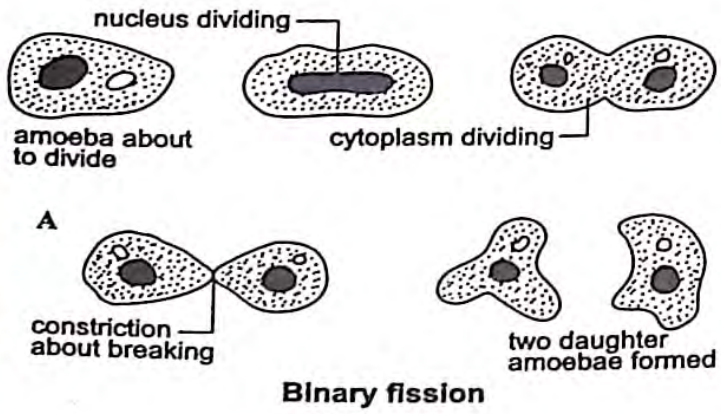
### Fission

Fission is a reproduction in which a **cell splits into two parts or more than two equal parts.** If the cell splits into two equal parts it is known as **binary fission** and if more than two equal parts is called **multiple fission.** Reproduction by fission occurs in *Amoeba* and *Paramecium.*

### Binary fission in *Amoeba*

When *Amoeba* reaches full size, it stops moving. It divides into two by binary fission. The nucleus first divides into two equal parts. Then follows the division of the cytoplasm. After the completion of the division of the cytoplasm, two daughter amoebae are formed.

Another method of reproduction is **multiple fission** (spore formation). During an adverse condition, *Amoeba* becomes rounded and secretes around itself a **cyst.** Inside the cyst, the nucleus divides several times. When conditions become favourable, the cyst bursts; each nucleus is surrounded by a part of the cytoplasm of the parent. In this way many small Amoebae are formed



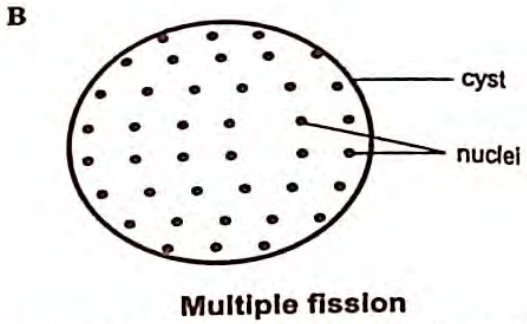




**Figure 16.14. Binary and multiple fission in *Amoeba***

### Binary fission in *Paramecium*

Under favourable conditions *Paramecium* reproduces by binary fission. The **micronucleus** (small nucleus) divides into two equal nuclei mitotically and move to opposite ends of the cell. The **meganucleus** (large nucleus) elongates and divides amitotically. The cytoplasm at the same time constricts at the middle of the cell. After the completion of the cytoplasm, the two young **paramecia** are produced. Binary fission may occur two to four times a day. About 600 generations are produced annually (others die during struggle for existence) from one individual *Paramecium* by binary fission. These 600 generations are genetically alike and referred to as **clone.**

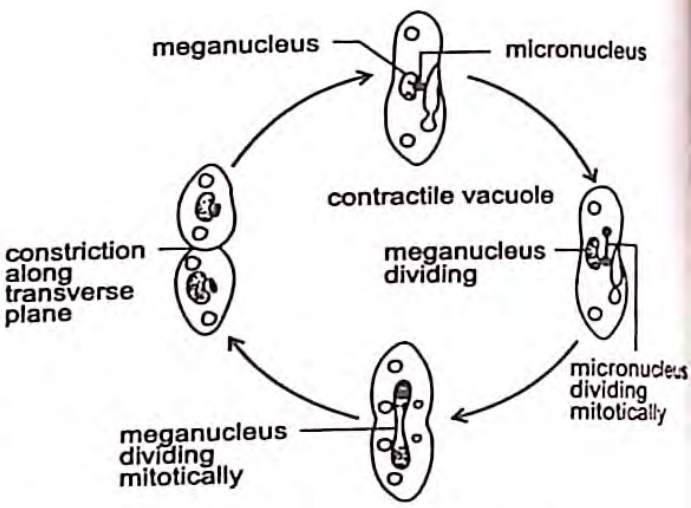



**Figure 16.15. Binary fission in *Paramecium***

## Budding in *Hydra*

*Hydra* reproduces by budding during favourable condition. With abundant food, a bud grows out from the parent body. As the bud grows, constriction takes place in its wall until it finally breaks away to become an independent animal.

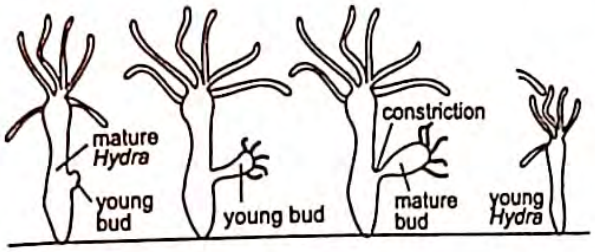



**Figure 16.17. Budding in *Hydra***

## Fragmentation

An organism may break into two or more pieces and each piece can then develop into a new independent organism. Examples are flatworms (e.g. planaria and tapeworm) and starfish.

## Sexual reproduction

Sexual reproduction is the reproduction that involves the **sex cells** - the **sperm** and the **egg**, and it takes place when the nuclear content of the sperm unites with the nuclear content of the egg (ovum). The result is a **zygote** with the complete **diploid chromosome number**. The zygote resulting from the fertilization of an ovum (female sex cell) continues to grow, producing new cells by **mitosis**. This will continue until it reaches sexual maturity. At this time the organism then produces new and different kinds of cells by **meiosis**. These new cells, the **germ cells**, give rise to **sex cells** or the **gametes**. The female sex cell is the egg (ovum) and the male sex cell (sperm), each is **haploid** and contains half the chromosome number characteristic of the species.

## First meiotic division

## Meiosis (Reduction Division)

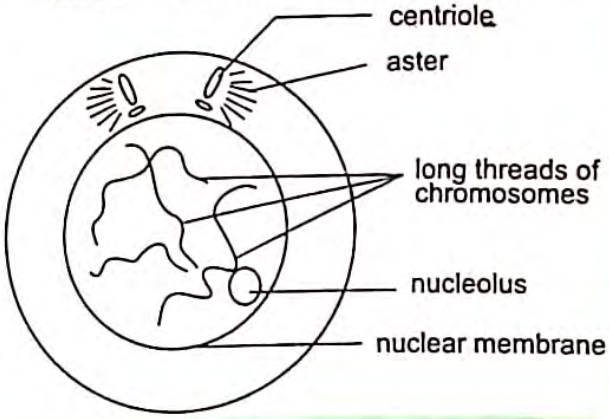
**Meiosis** is a type of cell division during **spermatogenesis** (sperm formation) and **oogenesis** (egg formation) in which there is a reduction of chromosomes to half of the original number of chromosomes. During spermatogenesis or oogenesis in human, the 46 chromosome are reduced to 23. Therefore each sperm or egg now has 23choromoseomes. The fusion of the sperm and egg gives 46 chromosomes which every human being has.

### 1. Prophase

There are three phases of the prophase stage. These are: **early prophase, middle prophase** and **late prophase.**

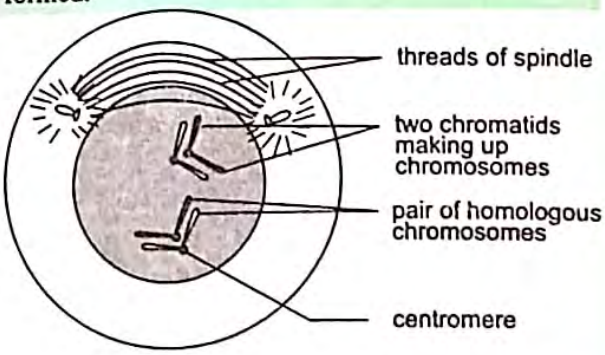
**Early prophase**

Chromosomes become visible as long threads.




**Middle prophase**

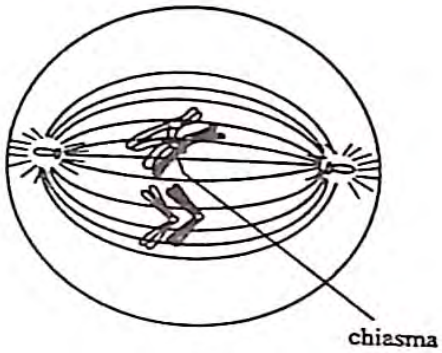
Homologous (marching) chromosomes become thicker, shorter and clearly visible. Spindle is formed.

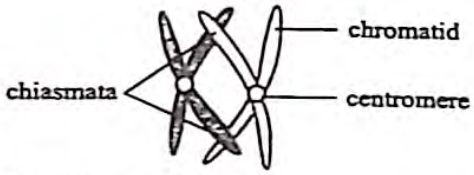


**Late prophase**

Each chromosome reproduces replica of itself (double-stranded). Nuclear membrane starts disappearing. Cross-links called **chiasmata** (singular = **chiasma**) are formed between chromosomes. Chiasmata help to hold two homologous chromosomes together and also exchange of genetic materials (or genes) takes place between homologous chromosomes which leads to variation or mutation.

C

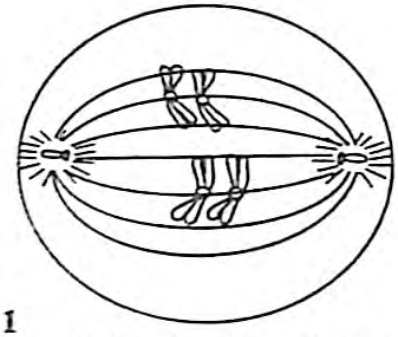



2. **Metaphase 1**

Nuclear membrane gets dissolved in the cytoplasm. **Bivalent chromosomes** are arranged at the equator and attached to the spindle by their centromeres.

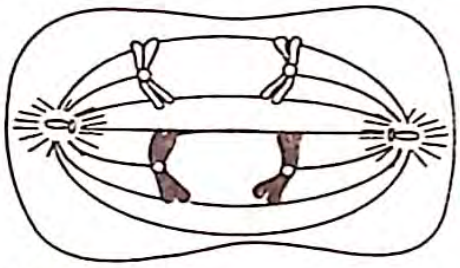
D



3. **Anaphase 1**

Each member of the bivalent chromosomes moves apart and moves towards the poles of the cell by the shortening of the spindle.

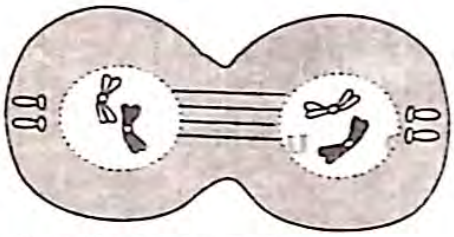
E



4. **Telophase 1**

Bivalent chromosomes arrive at the poles of the cell. A new nuclear membrane is formed around each group of chromosomes. Chromosomes uncoil. Nucleolus appears on each nucleus. Nucleus looks granular again. The two nuclei have half the number of chromosomes of the parent cell. This is the **reduction division** of meiosis. No cleavage of cytoplasm takes place. The short interphase that follows does not witness replication of DNA as in the interphase of mitosis. The cell proceeds to the second division of meiosis.

F

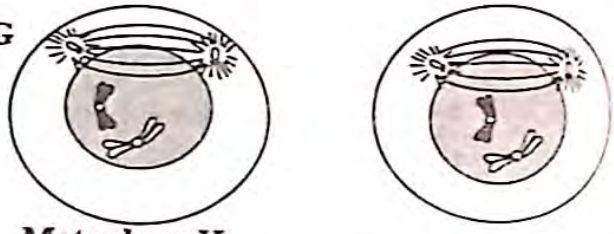


## Second meiosis division

1. **Prophase II**

Chromosomes become distinct in the two nuclei. Centrioles divide, separate and move to the opposite poles of the cells. Spindles are formed.

G

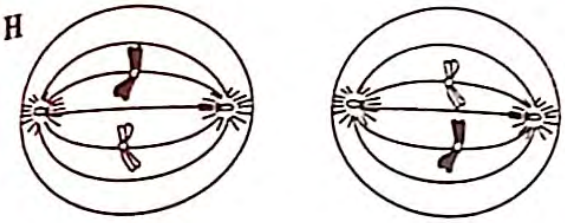


2. **Metaphase II**

Nuclear membrane gets dissolved in the cytoplasm, chromosomes are attached to the spin-

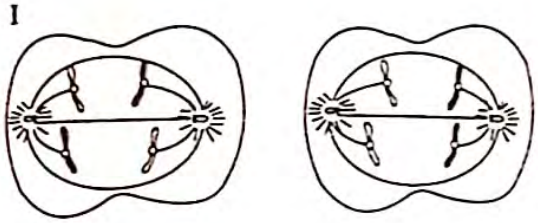
dle by their centromeres. The two chromatids of the chromosomes become more distinct.

H



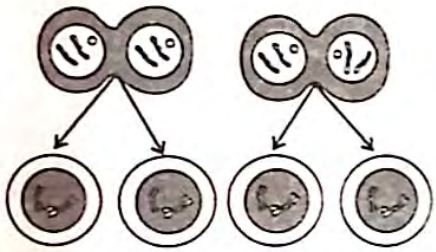
3. **Anaphase II**
The chromosomes get attached at the **centromeres.** The chromosomes separate and move to the poles.

I



4. **Telophase II**
The **chromatids** arrive the poles of cells. Nuclear membranes are formed round the four cells. A nucleolus appears in each cell. Spindles get dissolved in the cytoplasm. Cleavage of cytoplasm follows. Four haploid cells are formed at the end of the second meiotic division. Each cell has half the number of chromosomes characteristics of the mother cell hence called **haploid (n).**

J



**Four daughter cells each contains half (haploid) the original number of chromosomes of the parent cell.**

**Figure 16.17. A - J Stages in the first and second meiotic division (only four chromosomes are shown for clarity)**

## The importance of meiosis

1. **Meiosis** ensures that the fertilized egg (zygote) has a diploid number of chromosomes. Therefore, meiosis brings about the reduction of chromosomes to half the original number both in the male (sperm) and the female (egg) gametes. For example, every human being has 46 chromosomes. During the sperm or egg (ovum) formation, in a process known as **gametogenesis,** the **46 chromosomes** will reduce to **23 chromosomes.** When the sperm fuses with the egg, a **zygote** with 46 chromosomes result.
2. **Random assortment** of genes during meiosis leads to genetic variation among offspring of the same parents. This is why no two individuals can look exactly alike unless identical twins.
3. **Meiosis** can lead to a marked **gene change (mutation)** which can also bring about variation among individuals.

## Life processes involving meiosis

7. Formation of spermatozoa.
8. Formation of eggs.
9. Formation of pollen grains in flowering plants.
10. Formation of ovules in flowering plants.

## 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 59: 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. |

## The advantages of sexual reproduction

1. It permits **variability of individuals**, which enhances survival in a new environment.
2. It permits the production of **hybrids** for some desirable traits.
3. It provides a mechanism for **recombination** of **genetic materials** that otherwise would not have come together.
4. It also provides a means for the maintenance of the **chromosome number** characteristic of the species from generation to generation.
5. It permits **speciation** (new species formation). In short, without it, new species formation would be suspended by unalterable genes and chromosomes.

## Disadvantages of sexual reproduction

1. In most cases, two organisms (male and female) are needed before reproduction. Therefore, the absence of one will prevent reproduction.
2. Defenseless offspring in animals are produced. Parents have to provide care and protect them against enemies.
3. The process is slow for an optimum population size to be achieved for organisms that have very long reproductive cycles.

## Fertilization (Syngamy)

*The fusion of a minute haploid male gamete (sperm) with a haploid female gamete (egg) to form a diploid zygote is called* ***fertilization.*** If fertilization occurs outside the body of the parent, it is called **external fertilization** (aquatic animals such as toad, frog and fish are examples) but if fertilization occurs inside the body of the parent, it is called **internal fertilization** (terrestrial organisms such as birds and mammals are examples).

## Self-fertilization

Occurs when the male and female gametes produced by **one parent** fuse to form zygote. Self-fertilization is common among internal parasites such as tapeworms whose chances of looking for another individual for mating are remote. This is an exception to the definition of sexual reproduction that two different individuals are involved. Usually only one tapeworm is found in its host. The only way for this parasite to survive is to adopt self-fertilization.

### Cross-fertilization

Cross-fertilization occurs when the male and female gametes from different parents fuse to form zygote. Vertebrates (fish, toads, frogs, lizards, birds and mammals including man) carry out cross-fertilization.

### Hermaphroditism

This is a situation in which both ovaries and testes are present in **one parent** and is able to produce both eggs and sperm. An organism that exhibits hermaphroditism is called a **hermaphrodite.**

Examples are *Hydra*, tapeworm, earth-worm, mango and orange trees. Even though hermaphroditism occurs in many organisms, self-fertilization is prevented by two mechanisms called **protandry** and **protogyny**. In protandry, male gametes **mature first** and are released **before female gametes mature** while in **protogyny** the female gametes mature first before the male gametes mature later.

### Parthenogenesis

This is a development of diploid egg which has not been fertilized into a new individual. Parthenogenesis is found in some insects such as bees, **aphids,** and **wasps** and in some plants such as **dandelion**. The queen honeybee reproduces the drones parthenogenetically while the queens and workers develop from fertilised eggs. The off-spring of parthenogenesis are genetically identical and sterile.

### Oviparous reproduction

This is laying of eggs in which the embryos hatch outside the body of the parent. Examples are amphibians (toads and frogs), most fish (e.g. *Tilapia, Heterotis, Synodontis, Gymnachus* and *Clarias)* and most birds (e.g. hen, pigeon, duck, sunbird, hawk and eagle).

### Ovoviviparous reproduction

Fertilized eggs are produced, developed and nourished inside the body of the mother **without placenta** and hatch before or soon after laying of the eggs such as in tsetse fly, snakes, lizards and snails.

### Viviparous reproduction

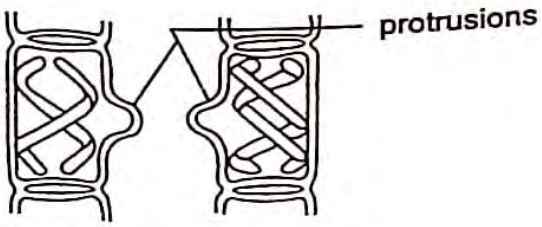
Fertilized eggs are produced, developed, nourished inside the body of the mother through **placental.** Examples are all placenta mammals such as the females of human, goat, sheep, dog, cat, cattle and monkey.

## Sexual reproduction in selected non-flowering plants

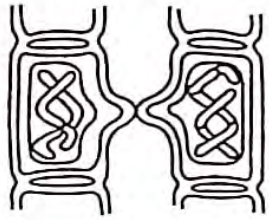
### *Spirogyra*

Spirogyra carries out a type of sexual reproduction known as **conjugation.** The cells of two filaments come to lie side by side. Two opposite cells bring forth **protrusions**. These protrusions elongate and eventually meet to form conjugation tube. At this point, the contents of the two cells are regarded as **gametes** usually **"male"** and **"female" gametes.** The "male" gamete passes through the conjugation tube to meet the "female" gamete. The two fuse forming a **zygote**. The zygote secretes a thick resistant wall around itself and is now known as zygospore.

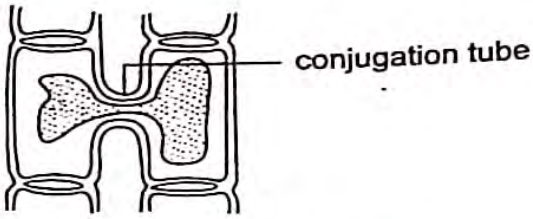
The parent cell wall decays to release the **zygospore**. The zygospore can be blown away by the wind or sinks to the bottom of pond. After a period of rest and conditions are favourable, the outer coats burst and a young filament grows out.



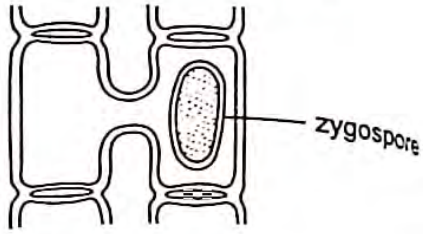

**Stage 1: Opposite cells develop protrusions**



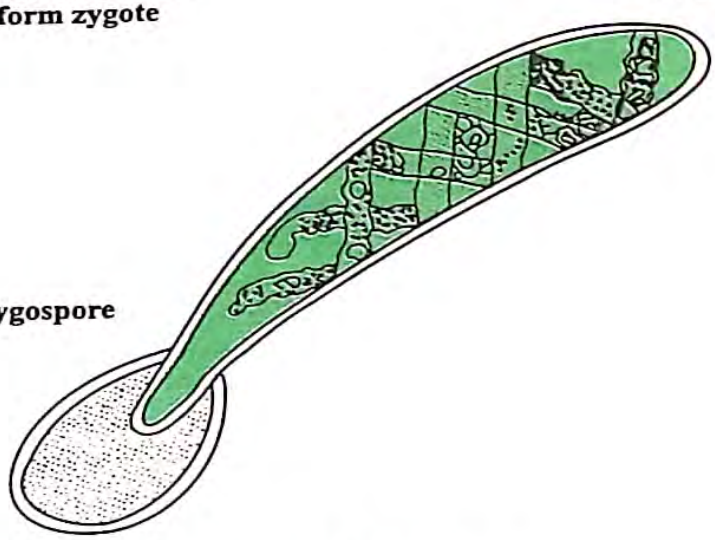
**Stage 2: Protrusions meet cell contents shrinking**




**Stage 3: Conjugation tube formed, contents of one cell pass to the other to form zygote**




**Stage 4: Formation of zygospore**



**Stage 5: Germinating zygospore**

**Figure 16.19. Stages in sexual reproduction in Spirogyra**

## Mucor

Sexual reproduction in *Mucor* is by conjugation. It begins when **two hyphae** come in contact and produce small projections on their walls which develop into **progametangium** with several nuclei. The two progametangia enlarge and push the hyphae slightly apart. Each progametangium develops a cross-wall to divide it into two parts, the gametangium and suspensor. Later the wall common to the two gametangia dissolves and their contents unite to form a zygote. The zygote develops a thick wall to form a resistant zygospore. The zygospore remains dormant until it reaches a favourable environment where it germinates into a hypha which bears a sporangium at its tip. The sporangium produces numerous spores which when discharged each develops into new **mycelium**.

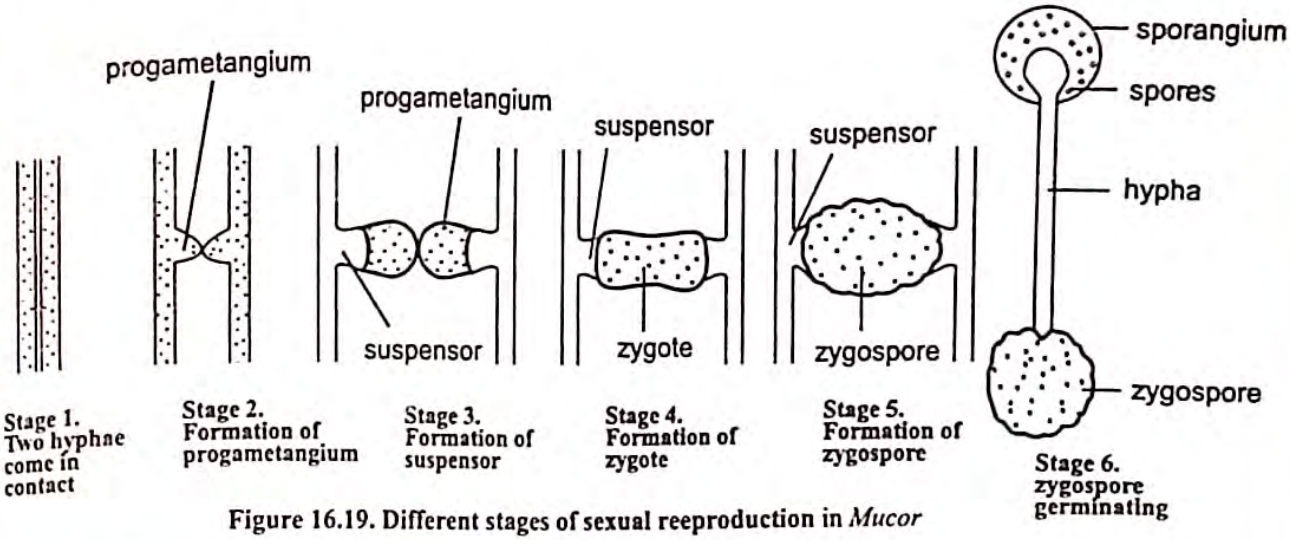



**Figure 16.19. Different stages of sexual reeproduction in *Mucor***

## Mosses (Musci)

Mosses are small, green and simple land plants belonging to phylum **Bryophyta** and class **Musci**. They are found growing on damp places. A common example of mosses is *Funaria hygrometrica* commonly found growing on old blocks, block fences, tree trunks and rock surfaces. They grow close together in large numbers forming velvet-like carpets.

The plant (gametophyte) consists of a **false stem** (because it lacks xylem and phloem) and **root-like rhizoids** (rootlets) also lacking xylem and phloem. The false stem is erect with leaf cells arranged on it **spirally** or **alternately**. The erect nature of the stem is partially due to turgor pressure (fluid pressure) in the cells *(Turgor is like inflating a ballon with air which makes it to stand erect)*. The rhizoids (rootlets) which grow from the stem help to anchor the plant to substratum and also absorb water and nutrients from soil. The whole plant is capable of absorbing water and nutrients.

## Alternation of Generation

The life cycle of bryophytes and pterodophytes demonstrate a clear phenomenon of **alternation of generations**. Two clear organisms, a **haploid gametophye generation** and a **diploid sporophyte generation**, alternate in their life cycles. The haploid generation is the **gametophye** (gameto = gamete; phyton = plant) as it produces gametes from mitotic division resulting in haploid gametes. The haploid gametes fuse to form a diploid zygote which germinates into next generation resulting into diploid sporophyte (sporo = spore; phyton = plant). Spore formation is by meiosis resulting in haploid spores which give rise to haploid gametophyte.

## Life cycle of *Funaria hygrometrica*

When a gametophyte has attained maturity, and ready to reproduce, sex organs develop on top of the stem on the middle of the leaves. Male and female organs develop on separate branches as indicated in the diagram. Male organs called **antheridia** produce coiled biciliate **antherozoids** (spermatozoa) while the female organ called **archegonium** produces one large ovum (egg) at its base. The **archegonium** releases certain chemical that attracts **antherozoids** to it. After heavy rainfall, water covers the plant, **antherozoids** are then released. **Antherozoids** then swim in water into the **archegonium** of the female plant within the tufts. One **antherozoid** then fuses with egg in the **archegonium**. A diploid **zygote** is then formed on top of the female plant which then grows into a diploid **sporophyte**. This constitutes the sporophyte generation. The **sporophyte**

reproduces asexually to produce **haploid spores** by meiosis.

The **sporophyte generation** consists of **sporangium** which is made up of seta and capsule. The capsule contains spores. When the spores mature the capsule breaks off to liberate haploid spores. The spores are tiny and light and float in the air. They are dispersed by wind. When a spore lands on suitable substratum it germinates into a gametophyte.

*The gametophyte (moss plant) which produces gametes (antherozoids and ova) represents the* ***gametophyte generation*** *while the sporangium which produces spores represent* ***sporophyte generation.***

*The* ***sporophyte generation*** *depends upon* ***gametophyte generation*** *for most of its nutrients.*

**Economic importance of mosses**

1. Mosses help to break down rock surfaces into soil in which other plants use.
2. Their death add humus to the soil.
3. They prevent soil erosion since they grow together in large numbers forming carpet on the ground.

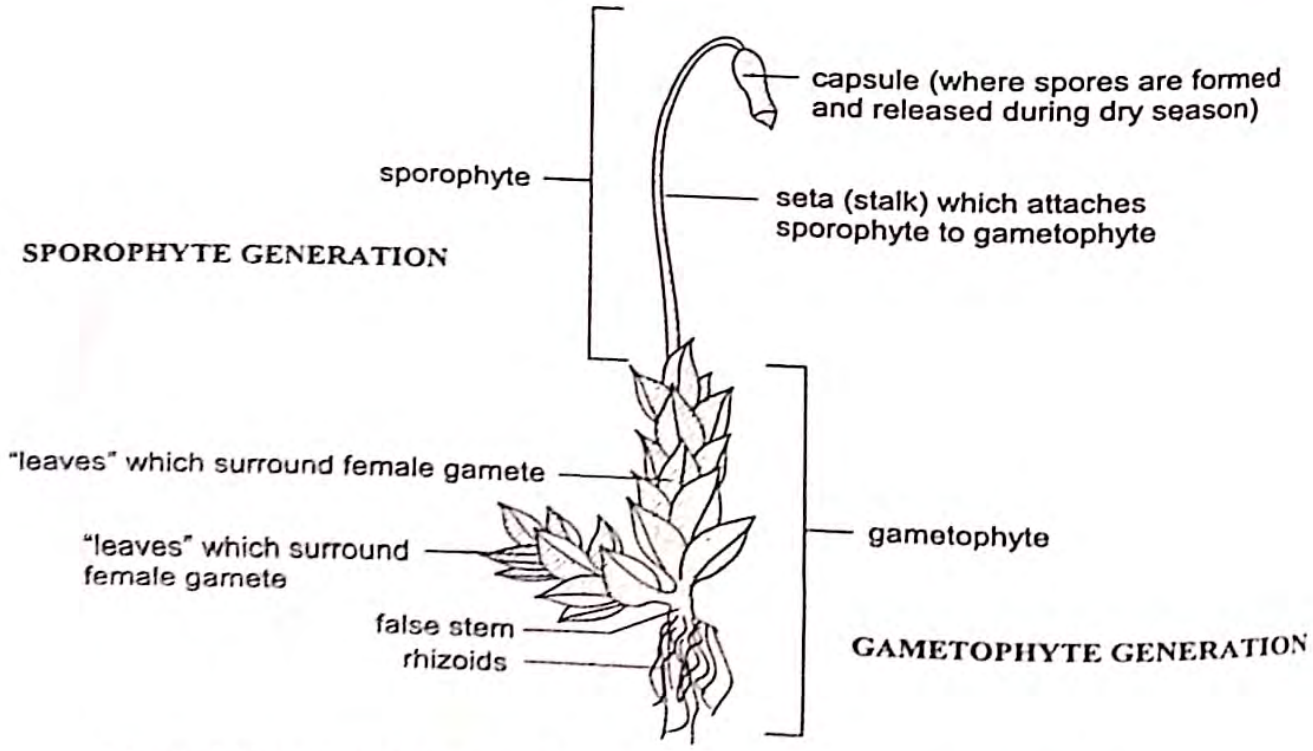



**Figure 16.21.** ***Funaria hygrometrica*** **showing gametophyte and sporophyte.**

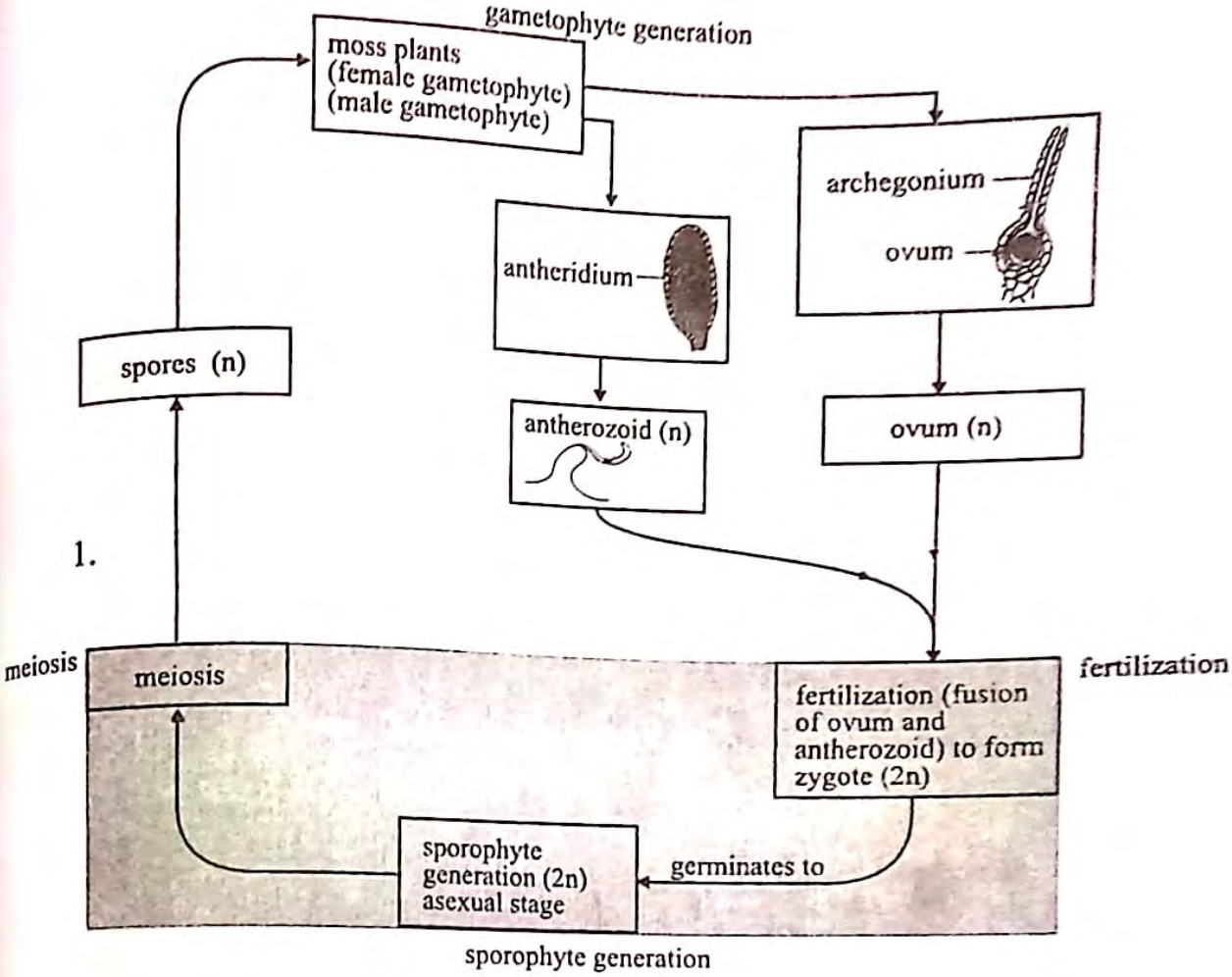



**Figure 16.22. Life cycle of *Funaria hygrometrica***

## FERN

The group-Pteridophyta consists of ferns and club-mosses. **Dryopteris** is a fern. It is seen growing in large number as epiphytes on oil palm trees. *Dryopteris* has a tuft of strong adventitious roots, a short unbranching stem and leaves in the form of fronds.

The leaf is a frond made up of a main axis the **rachis**, the leaflet called **pinna** and the sub division of the leaflet called **pinnule**. It is like the compound leaf of a flowering plant.

Unlike the bryophyte, the vegetative plant is the **sporophyte** which reproduces **asexually** by spores. In **Dryopteris** as in most Pteridophyta, spores are borne on the **under surface (abaxial surface)** of the leaves. Many spores are produced in a single **sporangium**. Many sporangia are organized into a **sorus** with or without a cover or **indusium**.

When the spores mature, the indusium breaks open to expose the sporangia. Each sporangium breaks open on drying and the spores fall off. The spores are dispersed by wind. In *Dryopteris*, the spores are (homosporous) all the same. Each germinates into a **bisexual prothallus**. The **prothallus** is a separate plant on its own. It is chlorophyllous and photosynthetic. It has both male and female reproductive organs. It repro-duces sexually by gametes. The prothallus is flattened and shield-like in structure. It is seen growing on the stem of oil palm trees in the rainy season.

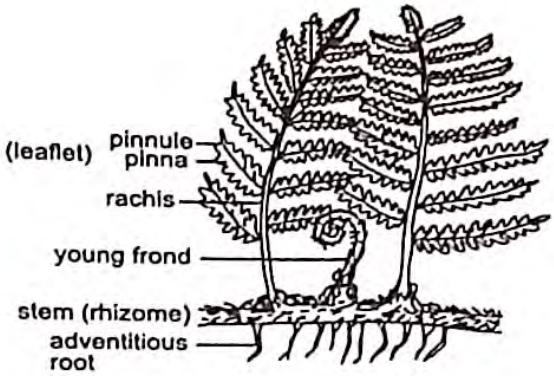



**Figure 16.23. A whole plant of *Dryopteris***

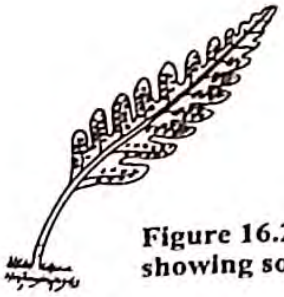


**Figure 16.24. A fertile leaf showing sori on abaxial surface.**

The **antherozoids** (male gametes) are ciliated and swim in the film of water between the prothallus and the substratum. One antherozoid enters the **archegonium** and fuses with the egg.

A **zygote** develops within the **archegonium** in the prothallus. The **zygote** germinates into the **sporophyte** sending the young root into the substratum and the young shoot above the prothallus.

**Germinating young sporophyte on a prothallus**

As the sporophyte grows older, the prothallus (gametophyte) breaks down and rots away.

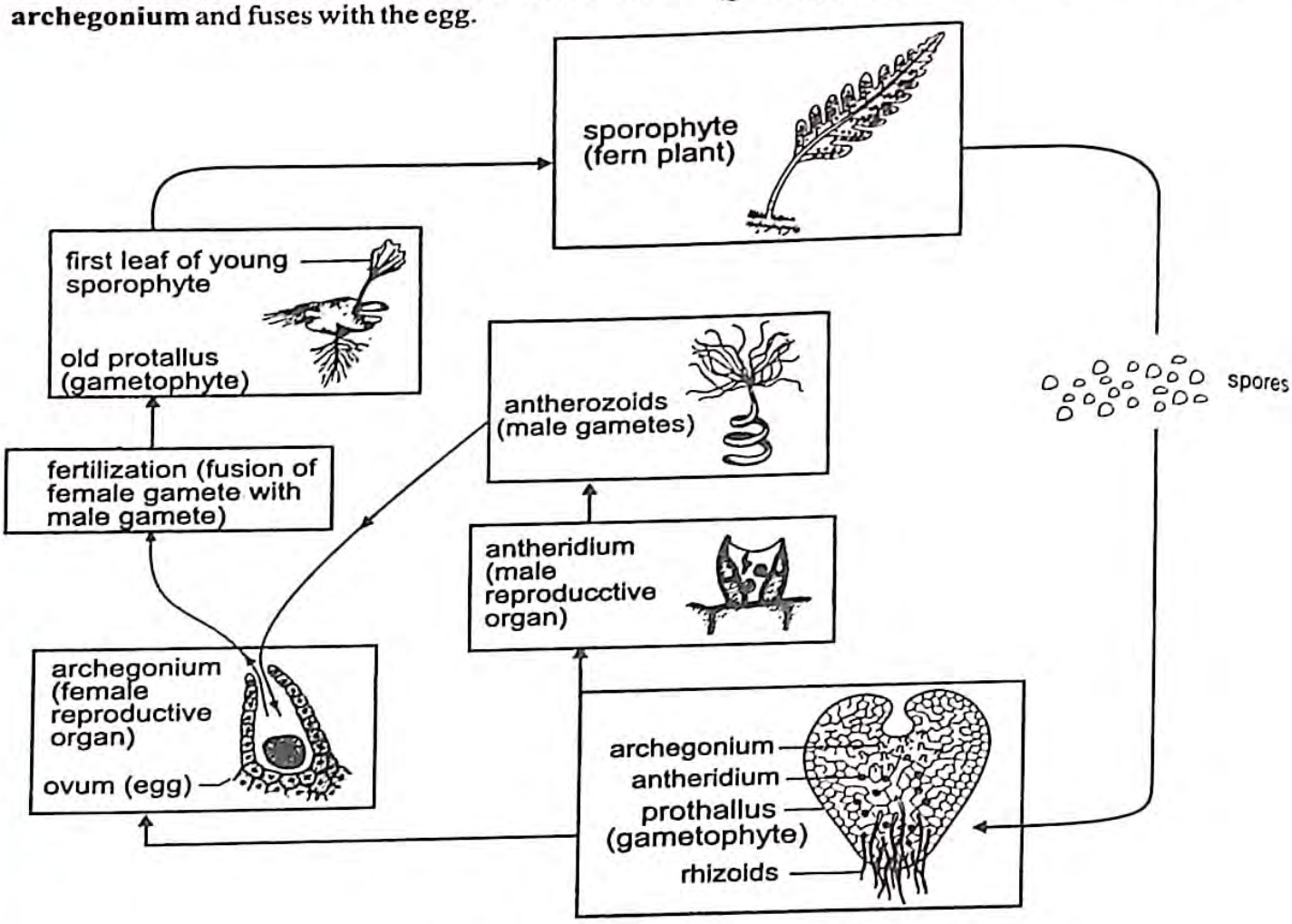



**Figure 16.25. The life cycle of Dryopteris**

# SEXUAL REPRODUCTION IN FLOWERING PLANTS

Sexual reproduction occurs within the structures found in a flower. It will be proper to begin this chapter with the study and description of flowers to know how they are specialized for this important function in flowering plants.
The process is summarized as follows:

Flower formation ⟶ pollination ⟶ fertilization ⟶ fruit and seed formation ⟶ fruit and seed dispersal and seed germination.

## Flower

***A flower is that part of the 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 have the same colour with the petals. Such 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.

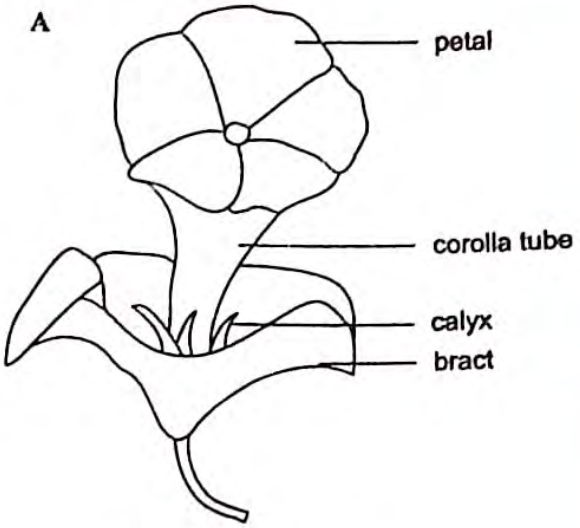
## Functions of Calyx

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 unusual to find in some flowers, some structures which look very much like the calyx. These are:

1. **Epicalyx.** These are additional floral leaves occurring below the calyx as in *Hibiscus rosasinesis*. In *Crotalaria*, 4the 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.




***Ipomea* flower with bract.**

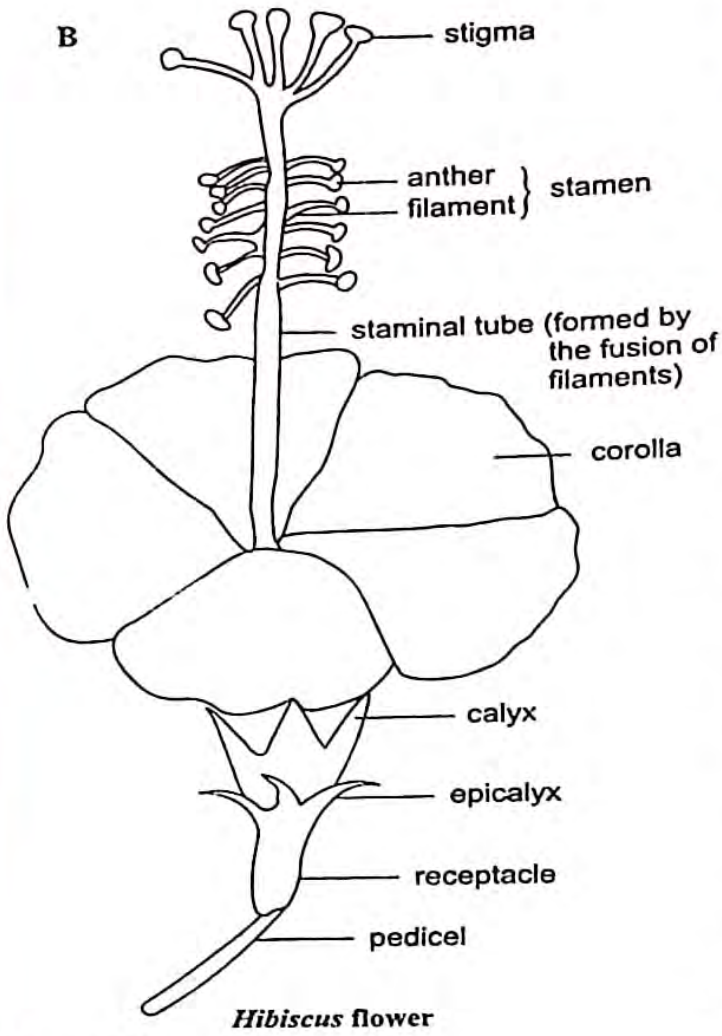



**Figure 16.26.**
**A = *Ipomea* flower**
**B = Hibiscus flower**

## Corolla

The petals of a flower make up the corolla which is the next inner whorl to the calyx.

Petals are the most conspicuous 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 reproduction.

## Androecium

The androecium is made up of all the stamens which are the male reproductive organs of a flower. A stamen (figure 16.25A) consists of an **anther** and a **filament** which is attached either to the receptacle 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 16.25B).

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 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.

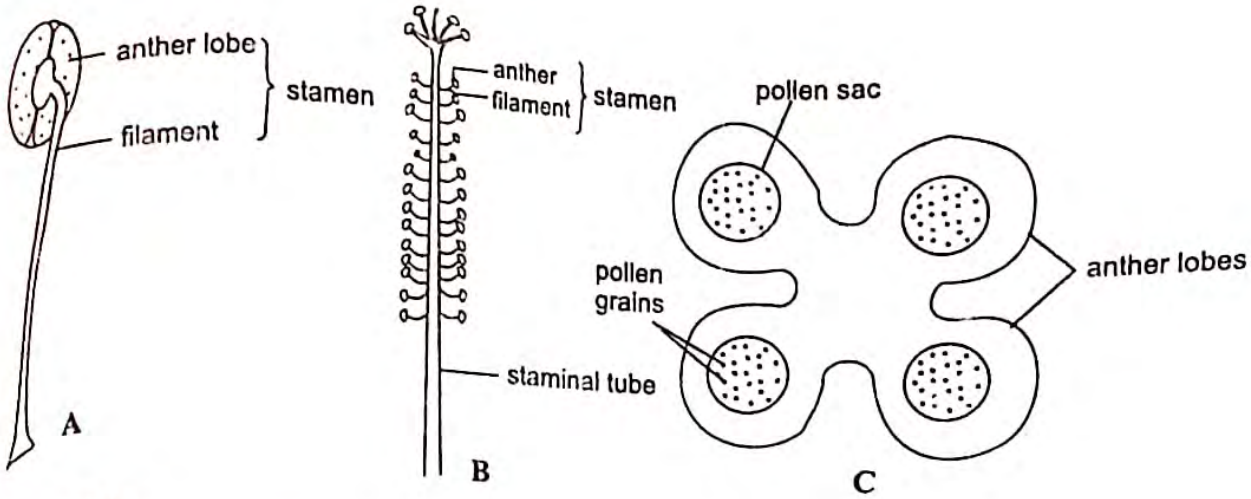



**Figure 16.27**
**A = A Stamen**
**B = Staminal tube of Hibiscus**
**C = Transverse section through an anther showing the pollen sacs in the anther lobes**

## The Gynoecium (Pistil, Carpel)

This is the female reproductive organ consisting of an **ovary**, a **style** and a **stigma** (fig **16.28**). 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.

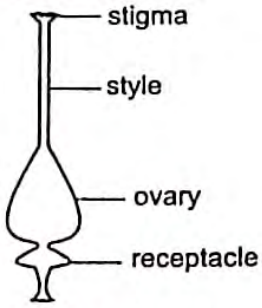



**Figure 16.28. The female reproductive organ of a flower.**

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

In an apocarpous ovary there are two or more carpels which are free from each other as in **Rose periwinkle** and *Bryophyllum* (figure 16.27B). An ovary is syncarpous if it consists of two or more united carpels as in *Hibiscus* and **orange (16.28c).**

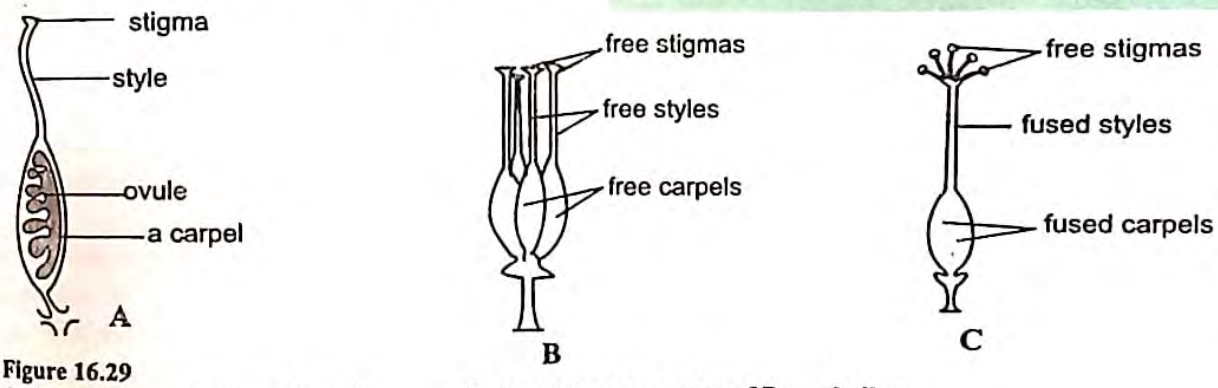



**Figure 16.29**
**A: A monocarpous ovary of cassia**
**C: A syncarpous ovary of Hibiscus**
**B: An apocarpous ovary of Bryophyllum**

## PLACENTATION

This is the arrangement of ovules in the **placenta** of the ovary. An ovule is attached to the placenta by a short stalk known as **funicle**. There are different types of placentation.

### Marginal placentation

The ovules are arranged in a single row at the margin of a monocarpous ovary. Examples are *Delonix regia*, *Crotalaria*, *Cassia* and other leguminous flowers.

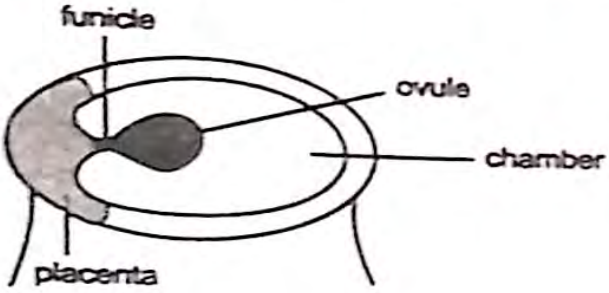



**Figure 16.30. Marginal placentation**

### Parietal placentation

Sometimes the placentae occur at the edges of the fusion points of a syncarpous ovary. A transverse section will show the ovules at such edges. Example is paw-paw.

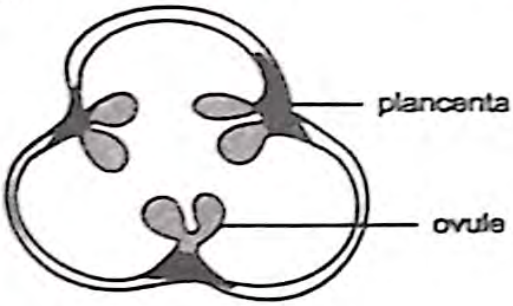



**Figure 16.31. Parietal placentation**

### Axile placentation

In another form, the carpels of a **syncarpous ovary** is divided into chambers which extend to form a placenta in the centre where the ovules are attached. This is known as **axile placentation**. Examples are **tomato** and **orange**.

**Figure 16.32. Axile placentation**

Finally the ovary may be syncarpous with the placenta occurring freely in the centre. There is only one chamber resulting from the disappearance of the connecting walls usually seen in an axile placentation. This is known as **free-central placentation** (figure 16.31) Examples are **water leaf** and **coconut**.

**Figure 16.33. Free - central placentation**

## Position of ovary

The ovary of a flower often maintains a certain position when compared to the other floral whorls. Sometimes the ovary is attached to the receptacle at a position higher than the points of attachment of the calyx, corolla and androecium. This is a **superior ovary** (figure 16.32A). Examples are *Hibiscus*, *Crotalaria*, *Delonix regia*, *Allamanda* etc. When the ovary is attached below the other floral whorls it is said to be an **inferior ovary** (figure 16.32B). Examples are Guava, Sunflower, *Tridax*, *Emilia* and *Ixora*. The receptacle completely encloses the ovary.

The androecium and gynoecium are considered the **essential organs** of a flower. This is because they produce the gametes which will ensure fertilization. There are other terms which are employed in the description of a flower. For instance, a flower with-

all the four floral leaves mentioned above is said to be **complete.** A flower with any of the floral leaves missing is **incomplete.** For example in the flower of female paw-paw there is no androecium or stamens.

A flower with the two essential organs is **bisexual** or **hermaphrodite**. A flower with one of the essential organs absent is **unisexual.** Any unisexual flower is incomplete. If a unisexual flower contains the male organ alone, it is a **staminate flower**, eg. the ray florets of **Sunflower** and *Aspilia*.

A flower can be described as **regular** or **irregular**. A flower is **regular** if it can be cut longitudinally into two **equal halves from any one plane.** Examples are *Hibiscus*, sweet potato, and tomato. A flower is irregular if it can be cut longitudinally into **two equal halves from only one plane.**

Examples are Pride of Barbados, *Delonix regia*, *Cassia*, *Crotalaria* and cowpea. In *Delonix regia*, for instance, there are five petals, four of which are equal in size, similar in shape and in colour, the fifth which is called the **odd, posterior** or standing petal is tube-like, slightly folded and coloured red and white on its ventral surface. This odd petal makes the flower irregular. To cut this flower into two equal longitudinal halves, the blade must cut through the odd petal. This is the only one plane through which the cut can be made.

The cutting of a flower into two equal longitudinal halves is very important as it is the only means of exposing the four floral parts as well as ovary and ovules, and in deciding whether the ovary is **superior** or **inferior**.

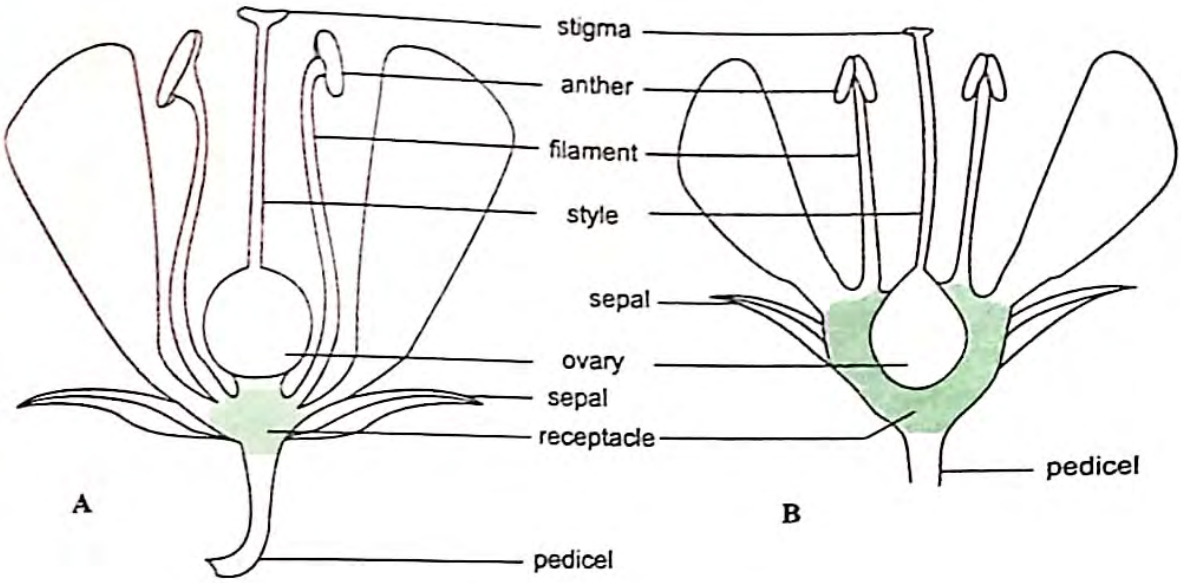



**Figure 16.34. Position of ovary.**
**A = Superior ovary**
**B = Inferior ovary**

## Description of *Delonix regia*

This flower is also known as **Flamboyant**, or **flame of the forest.** The flower is showy, complete, irregular, hermaphrodite with a lo pedicel. There are no epicalyx. A half-flow diagram is shown in figure 16:23.

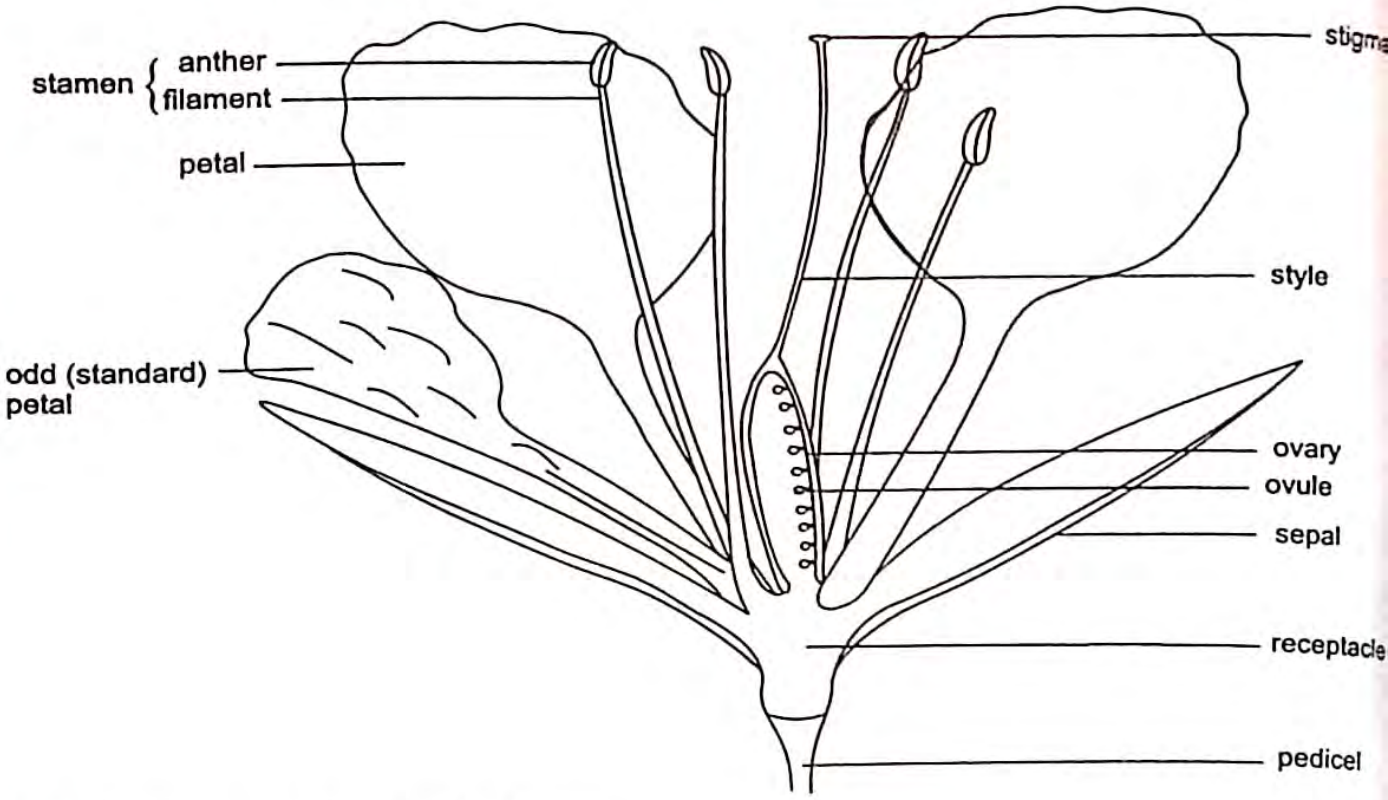



**Figure 16.33. Longitudinal section of *Delonix regia***

**Calyx:** There are five sepals of equal size and shape. The sepals are fleshy, greenish in colour on the dorsal surface. They are, however, petaloid on the ventral surface. In the bud stage all the sepals are united. the flower is therefore **gamosepalous.** The sepals however appear to be separated when the flower is mature.

**Corolla:** There are five red petals lying in between the sepals. Four of them are fan-shaped. But the fifth which appears smaller in size is upright and folded to form a tube believed to be the **"honey guide"**. This is known as "odd", posterior" or "standard" petal. This **"standard petal"** makes the flower to be irregular. it is reddish in colour with some white patches on its ventral surface. Th flower is **polypetalous.**

**Androecium:** There are ten stamens consisting o long erect filament ending in oval shaped bilobe anthers. The filaments are hairy at the base an completely surround the ovary.

**Gynoecium:** Consists of an elongated ovary curvin into a **style** which ends in a **stigma** at the top. Th ovary contains many ovules in a **marginal placenta** It is superior and mono-carpous.

## Description of *Allamanda*

The flower is very conspicuous, complete, regular with a short pedicel and no epicalyx. A half-flower diagram of this flower is shown in figure 16.36.

**Calyx**: There are five free sepals greenish in colour. The flower is **polysepalous**.

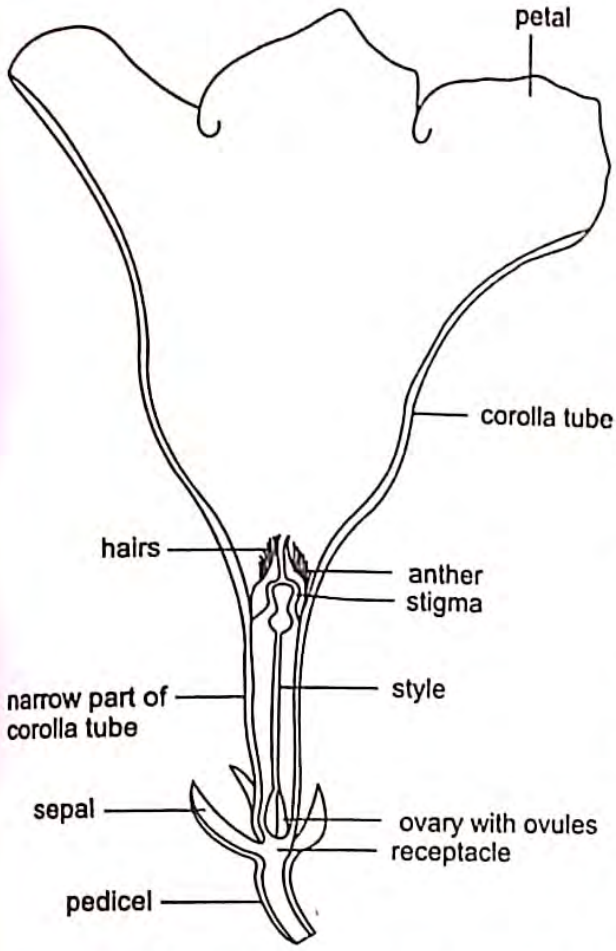



**Figure 16.36. Longitudinal half-flower of *Allamanda***

**Corolla**: There are five bright yellow petals which unite to form a **corolla tube**. The flower is gamopetalous. The corolla tube narrows down before joining the receptacle, thus giving it the shape of a bell. The tube encloses the essential organs of the flower (stamens and carpels).

**Androecium**: There are five short, thick arrow-head shaped stamen with numerous hairs protecting them. In a mature flower, pollen grains are often seen deposited on the stigma just below the stamens. The stamens are joined to the corolla tube at the base.

**Gynoecium**: It consists of one superior ovary with ovules in an **axile placenta**. The ovary is **bicarpous**. It has a long narrow style ending in a thick expanded stigma..

***The reader should be familiar with the terms used in describing a flower. It is nice to describe a flower in a set pattern, that is, to mention whether it is complete or incomplete, regular or irregular, hermaphrodite or unisexual, with or without epicalyx etc. This is followed by detailed description of the calyx, corolla, androecium and gynoecium in this order, using the descriptive terms.***

## Pollination and fertilization

### Pollination

***Pollination is the transfer of pollen grains from the anther to the stigma of flowers.*** There are two types of pollination. These are **self- pollination** and **cross-pollination.**

***Self pollination is the transfer of pollen grains from the anthers of one flower to the stigma of the same flower, or to the stigma of another flower on the same plant.***

***Cross pollination** is the transfer of pollen grains from the anther of a flower to the stigma of another flower on a different plant of the same species.* The emphasis is on "the same species". For instance, pollen grains may be transfered from a pawpaw flower to a mango flower. This transfer cannot be described as cross-pollination since pawpaw and mango are not of the same species. Such a transfer cannot lead to fertilization.

Some individuals have often regarded the process in plant B **(Fig. 16.37) page 318.** as cross pollination. The male and female gametes in the flowers on the same plant have the same genetical make-up. Hence the transfer of pollen grains between flowers on the same plant is **self-pollination** and not **cross-pollination**.

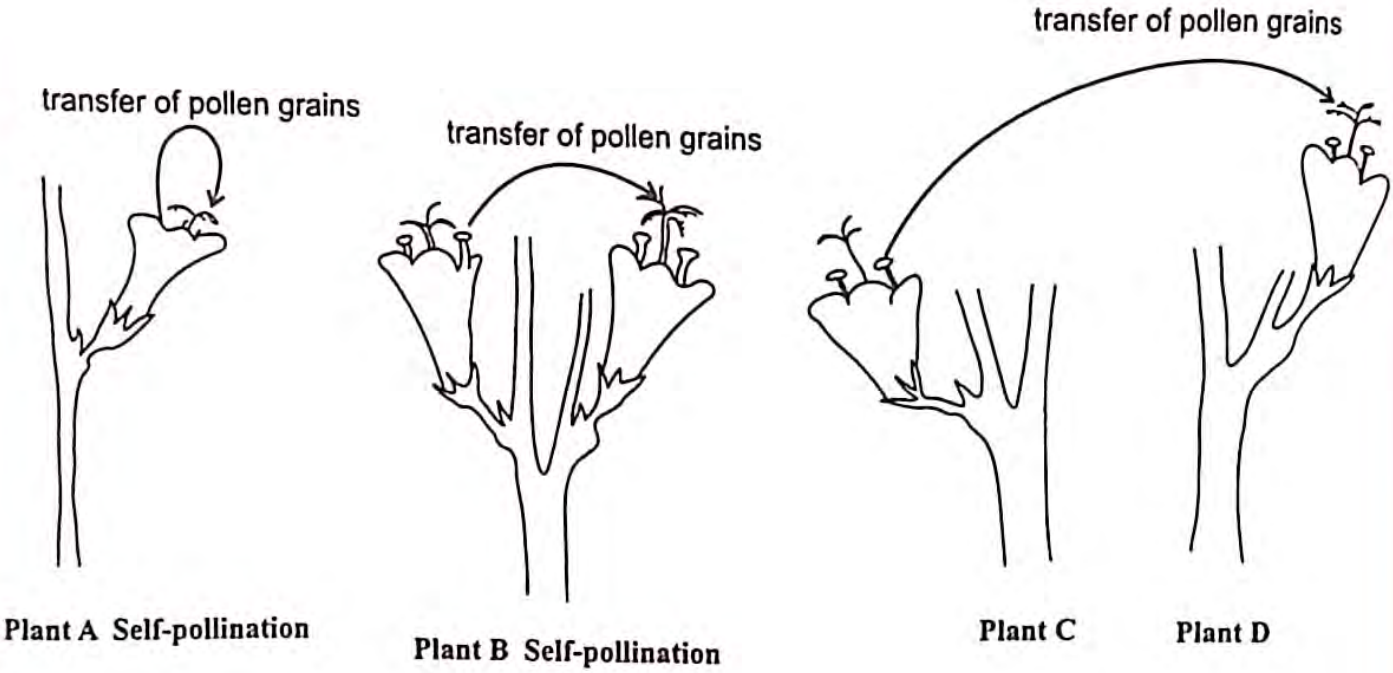



**Figure 16.37. Illustrations of self - and cross-pollination**

## Advantages of cross pollination

1. It leads to the production of more seeds.
2. It produces healthier seeds
3. The seeds develop into stronger plants, which will produce more fertile offspring.
4. Plants produced from cross-pollination are more likely to survive changes in environmental conditions since their genetical products are mixed up.
5. It leads to greater variations among species and a faster rate of evolution.

## Disadvantages of cross-pollination

1. It is less certain to occur since it involves two separate plants which may be at a great distance.
2. Pollen grains are likely to be wasted during the process as the pollinating agents may be transferring them to wrong plants. To compensate for the waste, pollen grains must be produced in large quantity.
3. Cross-pollinated flowers are often more complicated in structure than self-pollinated flowers and often require some special

## Advantages of self-pollination

1. Pollen grains are produced in small quantity and most of them are not wasted.
2. Once the pollen grains are mature, pollination is more certain to occur as it does not involve any distance.
3. The flower structures are less complicated and may not need any complex mechanism to achieve pollination.

## Disadvantages of self-pollination

1. Seeds produced are less healthy than seeds pro duced from cross-pollination.
2. Plants produced from self-pollination are less likely to survive when there are changes in con ditions of the environment. This is because they are usually more adapted to a particular condition.
3. There are little or no variations among species and the rate of evolution is slower.

## Arrangement of flowers favouring cross-pollination

Cross-pollinated flowers are differently arranged on the plants to favour cross-pollination.

1. **Unisexual flower**

These are flowers with only one sexual reproductive organ. In other words, the male and female reproductive organs are in two different flowers. Unisexual flowers occur either in **dioecious** plants or in **monoecious** plants.

**Dioecious plants** ***are plants with male and female flowers on separate plants.*** Male flowers occur on male plants while the female flowers occur on female plants. In such plants cross-pollination is the only means of pollination. Examples are pawpaw, Christmas bush and pumpkin.

**Monoecious plants** ***are plants with male and female flowers borne separately on the same plant.*** In such plants self-pollination is possible, but many of them have some other devices to ensure cross-pollination at different times. **Maize** and **palm trees** are good examples of monoecious plants.

2. **Dichogamy**

This is the maturation of **stamens** and **stigmas** of a bisexual flower at different times.

a. When the stamens or androecium mature first, the flower is **protandrous**. At this time the stigma is still immature and cannot receive the pollen grains. By the time the stigma is mature the pollen grains should have been liberated. So only pollen grains from different flowers will be useful for pollination.

b. When the gynoecium matures before the stamens, the flower is **protogynous**. Their pollen grains will not be useful for their pollination. Example is **Dutchman's pipe**.

3. **Self-sterility and self-incompatibility**

This is a situation in which pollen grains of a flower or of another flower on the same plant will not result in fertilization even if they reach the stigma. In such flowers the pollen grains and stigmas are **incompatible**. Sometimes the flowers become sterile when their own pollen grains pollinate them. This is self-sterility which is common in tobacco, *Crotalaria* and many other leguminous flowers. In such flowers, only pollen grains from flowers of other plants of the same species will effect pollination and fertilization.

4. **Position of stigmas and anthers**

In many erect flowers, the stigmas are kept higher than the stamens so that a visiting insect reaches the stigma before the anthers. Only pollen grains collected by a visiting insect from another flower can reach the stigma of the visited flower.

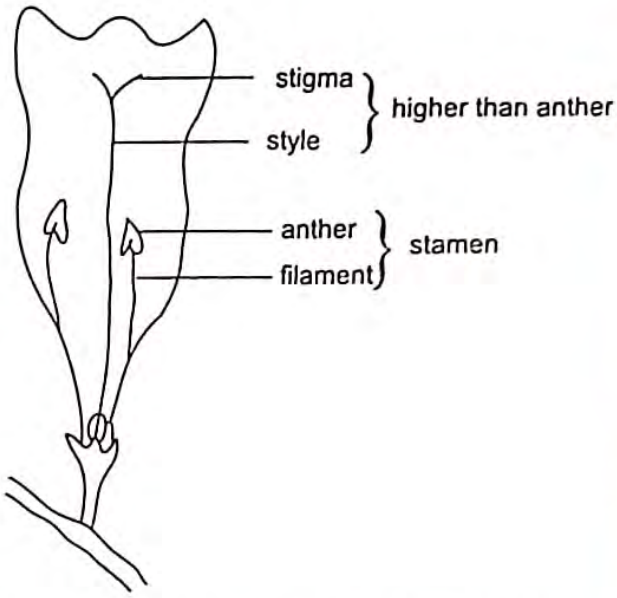



**Figure 16.36. Erect flower with style higher than stamens.**

## Arrangements for ensuring self-pollination

1. Self-pollinated flowers are **bisexual**, with the anthers and stigmas maturing at **the same time**.
2. Anthers are higher than stigmas so that a visiting insect can brush the pollen grains into the stigma.
3. Sometimes, anthers and stigmas make direct contacts as in *Allamanda*. In sunflower, the stigmas at maturity curl back to make contact with the anthers if cross pollination fails to take place.

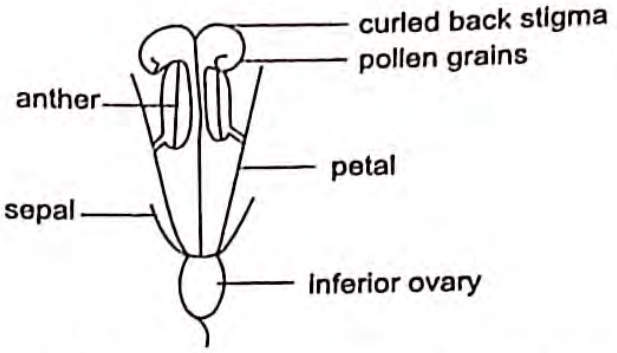



**Figure 16.37. Illustrative diagram of a mature disc floret of sunflower in a process of self-pollination.**

4. Some flowers never open until self-pollination has taken place. Examples are **groundnut** and **cowpea.**

## Agents of pollination

Flowers can be pollinated by:
1. Wind
2. Animals - mostly insects, birds, bats and man
3. Water.
4. The growth of the stigma towards the anthers to make contact with them (self-pollination).

**Wind** and **insects** are the principal agents of pollination. Pollination by water current is not very common. However, for flowers to be polli-nated by water they must have the following characteristics:
1. They must produce plenty of pollen grains as many of them are likely to be wasted or carried away by water current.
2. The pollen grains must be smooth and able to float for a long time.
3. The plant must have a flexible inflorescence to bring the flowers to the water surface at maturity.

*Ceratophyllum* and **bladderwort** are some of the few examples of flowering plants whose flowers are pollinated by water.

**Silk-cotton** tree is pollinated by **bats**

## Characteristics of wind-pollinated flowers

1. They are often **inconspicuous** and not bright coloured.
2. They are scentless.
3. They have no nectary.
4. Calyx and corolla are reduced to perianth segments or sometimes absent.
5. Anthers are comparatively large and loosely attached to long filaments which are freely exposed to the air.
6. The male inflorescence is usually in an uppermost position where there is no obstacle to wind action.
7. Anthers produce large quantity of pollen grains most of which are going to be wasted since pollination by wind cannot be controlled.
8. The pollen grains are usually tiny, light and smooth (powdery) so that they can easily be carried by air current.
9. The styles are elongated to keep the stigmas in the best position to receive the pollen grain.
10. The stigmas are large, feathery and or with sticky surfaces to retain any pollen grains which land on them.

## Characteristics of insect-pollinated flowers

1. Flowers are very conspicuous, with large and brightly coloured petals. Where the flowers are small, they are massed together in a conspicuous inflorescence such as in *Clerodendron*, *Lantana* and sunflower.
2. Flowers are often scented. (The scent and colour of petals attract the insects and other animals).
3. Flowers have nectaries at the base which secrete nectar or flower juice. This is food for the visiting insects and birds.
4. Anthers produce little quantity of pollen grains. There is little or no wastage since pollination is controlled.
5. Pollen grains are rough, spiny or sticky so that they can stick to the body of the insect or other animal pollinators (pollen grains are food for

insects, birds and bats. The bees use the pollen grains and nectar to make honey).

6 The stigmas are broad or rounded and sticky for effective retention of pollen grains after pollination.

## Wind pollination

### Structure and pollination of maize *(Zea mays)*

**Structure:** Maize has male and female flowers separately on the same plant and it is therefore **monoecious.**

#### Structure of a male flower

The male flowers are contained in a **panicle of inflorescence** in the uppermost part of the plant and they are made up of many **spikelets.** The spikelets are arranged in **pairs** on the **main axis**. A single spikelet consists of **two green bracts** or **glumes** which become brown at maturity. Inside the glumes are two sets of flowers each covered by two smaller bracts known as **pales** (outer and inner pales). One of the flowers matures before the other. At maturity, the pales open with **three long stamens** hanging freely in the air. At the base of the stamens are two small structures called **lodicles** or **reduced perianths.** (There are no **petals** and **sepals**). The lodicles have no function except that they help to open the pales when they swell.

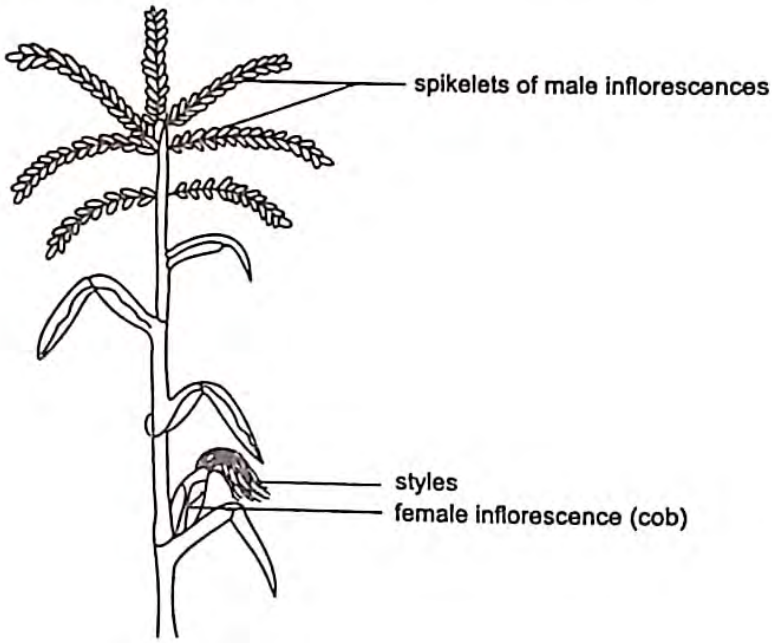
#### Structure of a female flower

The female flowers are borne in a **cob** which develops from the axis of a leaf far below the **male inflorescence**. The cob has numerous green bracts known as **husk** covering the spikelets of flowers inside. A spikelet also has a pair of **glumes** with a flower made up of an **ovary** with a **long style** ending in **hairy stigma** and two **lodicles**. The second flower in the glume is **sterile.**

#### Pollination

The male flowers mature before the female flowers, therefore, **self pollination** does not occur. When the **stamens** mature, the **lodicles** swell to open the **pales**. The elongated filaments of the stamen hang out the **ripe anthers** out of the **glume**. The slightest air current shakes the anthers which release a cloud of powdery **pollen grains** which are carried by **wind**. These pollen grains then land on the **hairy sticky** stigmas of cob thereby pollinating the flowers.

A



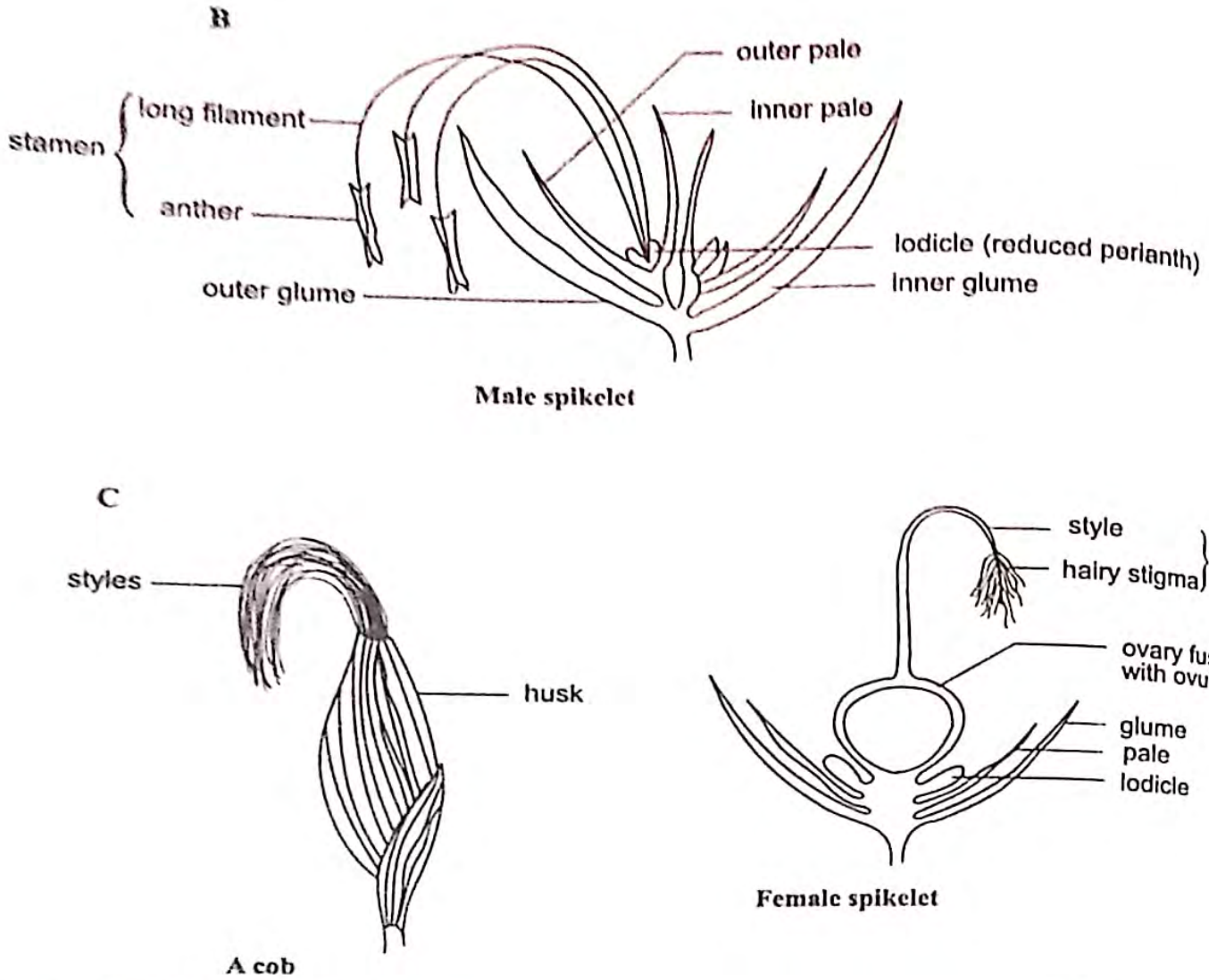
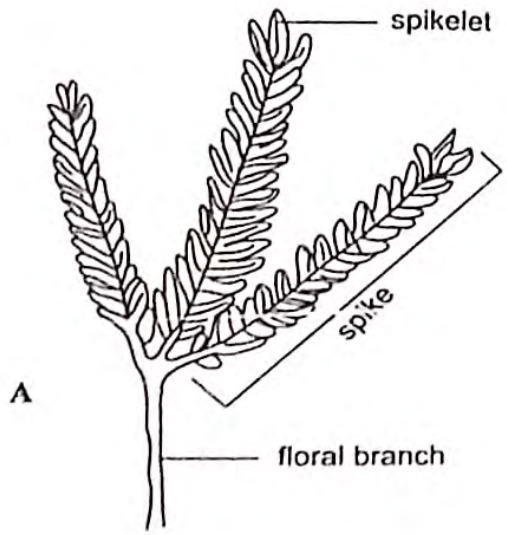
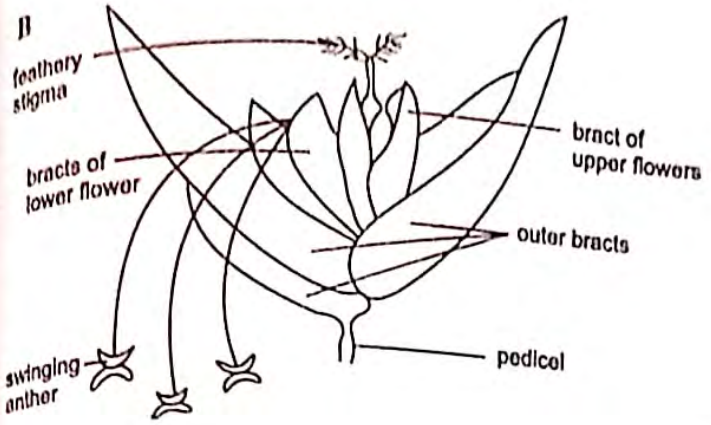


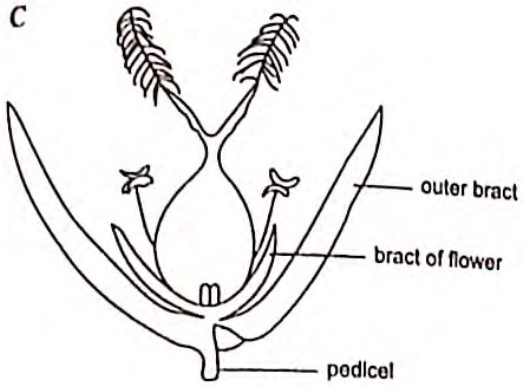

**Figure 16.40. Maize plant and its flowers**
**A = Mature maize plant with male and female**
**B = Male spikelet**
**C = Female spikelet**




## Pollination of grass

Many grasses have their flowers in **compound raceme inflorescence** or in spikes (figure 16.39 A and B). The flowers are borne in certain unit structures known as **spikelets** (figure 16.39 C). A spikelet consists of three or more bracts enclosing one or two flowers. At maturity the **bracts** open to expose the flowers.



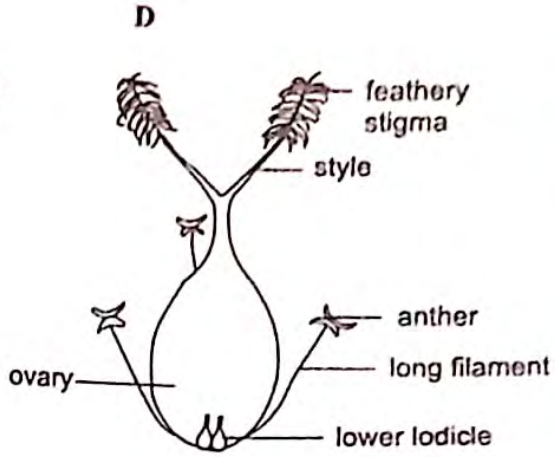




**Figure 16.41. Structure of *Elensine indica*, an example of grass.**

**A = Spikes**
**B = Mature spikes with two flowers**
**C = A single flowered spikelet**
**D = Structure of upper flower with bracts removed**

## Pollination of flamboyant

Flamboyant is pollinated by **large butterflies.** The structure of this flower has earlier been described. (The reader should make a description of the flower before describing how it is pollinated).

The **butterfly** is attracted by the brightly coloured petals of the flowers. The butterfly lands on one of the **fan - shaped petals** and inserts its long **tongue** into the tube of the folded **standing petal** which is believed to be directing the tongue to the nectaries at the base of the ovary. The posterior petal is thus known as **"honey guide"**. During this process the body of the insect becomes dusted with pollen grains. The flower is **protandrous**, that is, the stamens mature before the stigma. The butterfly carries the pollen grains to another flower whose stigma is mature. In an attempt to collect more nectar, the stigma makes contact with the body, brushing up some of the pollen grains from the previously visited flower. Cross-pollination has thus taken place.

## Pollination of *Allamanda*

*Allamanda* is mostly pollinated by **sunbirds.** The sunbird has a long slender beak adapted for sucking flower juice. The structure of this flower has been described on page -. The bird lands on a stem close to the flower, and inserts its long beak into the **corolla tube** to collect some nectar. The anthers are normally protected inside the corolla tube and their pollen grains are retained after liberation from the anthers. The bird struggling to collect nectar pushes some of the pollen grains into the stigma which is closely below the anthers. This is **self-pollination**.

Self-pollination is also possible in *Allamanda* without the help of any pollinating agent. This is because the stigma can grow to meet the anthers above. (see figure 16.35)

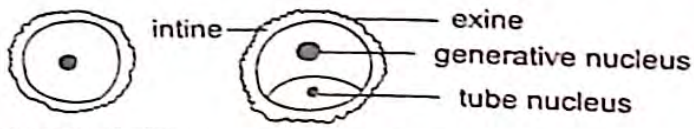
## Fertilization

Immediately after pollination, fertilization follows. Fertilization 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.

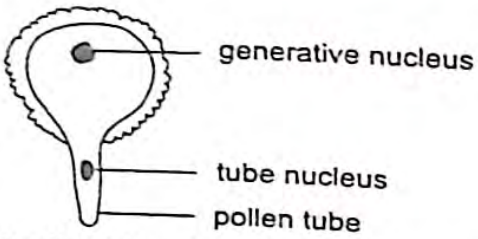
## Development of pollen grain

When a pollen grain develops from an anther, it contains only one nucleus. This nucleus later divides to form a **generative nucleus** and **tube nucleus**. At the time of pollination therefore, a pollen grain contains **two nuclei**. A pollen grain has an **outer thick wall** or **exine**, surrounding an inner thin wall or **intine**. Immediately after pollination, the stigma secretes a **sugary substance** which stimulates further development of the pollen grain. The outer thick wall dissolves at a point of stimulus. From this point the inner thin wall **protrudes** and develops into a **tube**. The **tube nucleus** moves into the tube now known as **pollen tube**. It is believed that the tube nucleus directs the growth of the pollen tube through the tissues of the style towards the ovary.

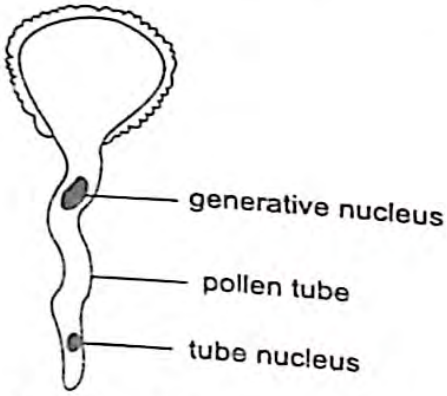
Meanwhile the **generative or male nucleus** also moves into the pollen tube where it divides into two **male gametes**. The two male gametes move closely behind the tube nucleus. They will later be used for fertilization when they reach the ovary.



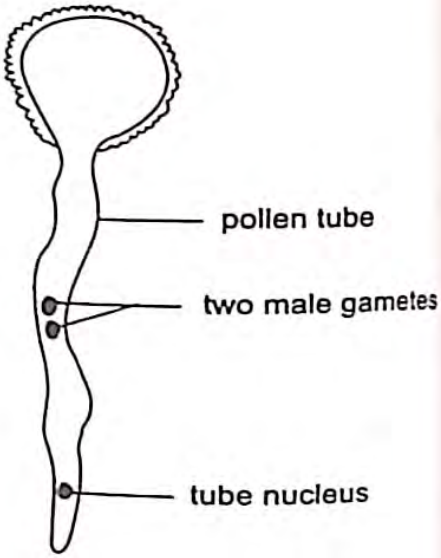

**I. Pollen grain before pollination** **II. Pollen grain at pollination**




**III. Growth of pollen tube stimulated by secretion from stigma.**




**IV. Movement of generative or male nucleus into the pollen tube.**




**V. Division of generative nucleus into two male gametes.**

**Figure 16.42. Stages in the development of a pollen grain**

## Development of ovule

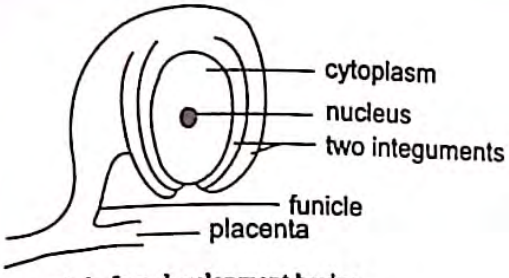
The ovules are contained in the ovary attached to the placenta by a short funicle. An immature ovule contains nucleus and a cytoplasm sur- rounded by two protective coats known as **inte-guments**, leaving a tiny **hole** or **micropyle** through which the pollen tube enters the ovule.

At maturity the ovule develops by three nuclear divisions resulting in the production of **eight nuclei** in an embryo sac (figure 16.41).

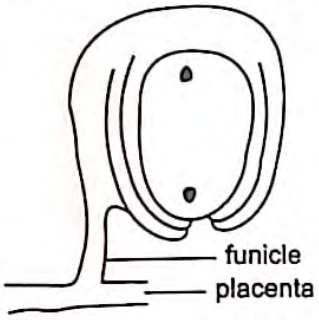
Four of the nuclei occur at the micropylar end and the other four occur at the opposite end known as **chalaza**. One nucleus from each end moves to the centre where they unite to form a **polar** or **secondary nucleus**. The remaining three at the chalaza end acquire a wall each to become the three **antipodal cells**.

The three at the micropylar end become arranged into an ovum or egg cell at the top and two guard cells below it. The ovule is now ready for fertilization.

The pollen tube growing through the tissues of the style gets to the ovary and enters the ovule through the micropylar end.

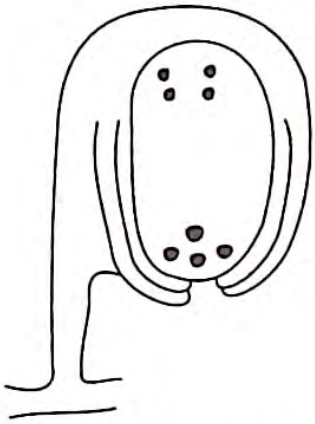



**I. An ovule before development begins.**

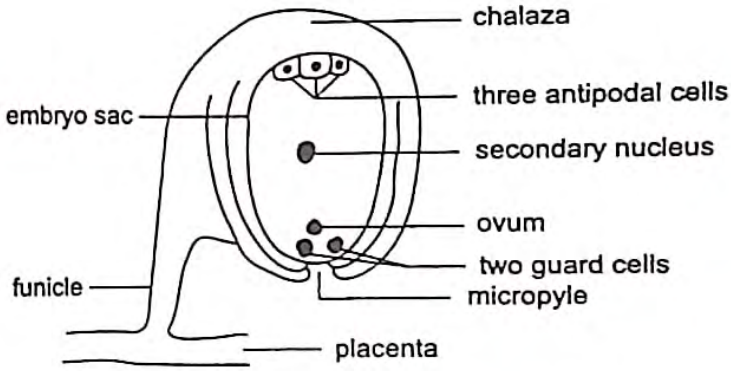



**II. Result of first nuclear division.**

**III. Result of second nuclear division.**



**IV. Result of third nuclear division leads to formation of eight nuclei in an embryo sac.**




**V. Rearrangement of nuclei in the embryo sac.**

**Figure 16.43. Stages in the development of an ovule**

## Process of fertilization in flowering plant

As soon as it makes contact with the wall of the embryo sac, the wall dissolves to create a free passage for the male gametes. The tube nucleus **degenerates**. One of the male gametes moves in and unites with the ovum to form a **zygote**. Thus fertilization has taken place. The second male gamete unites with the secondary or polar nucleus to form an **endosperm nucleus**. This is known as **"double fertilization"** characteristic of flowering plants alone.

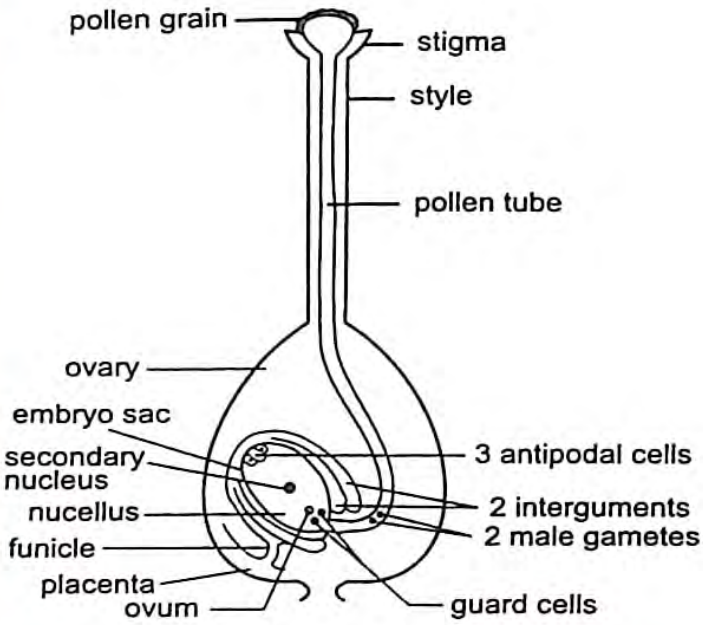



**Figure 16.44. Process of fertilization in flowering plants.**

## Changes after fertilization of flower.

Immediately after fertilization, the flower is deemed to have completed its function. The stamens, corolla and calyx wither off. In some flowers like *Crotalaria*, **tomato, garden egg** and *Tridax*, the calyx is persistent, that is, they do not fall off but are retained in the fruit. In *Tridax* and related family, the calyx becomes modified into hairy pappus for dispersal by wind. The stigma and style wither to a point on the ovary where it is seen as "remains of style". The endosperm nucleus develops into a food reserve or **endosperm** used for nourishing the developing embryo. The zygote develops into an embryo. The antipodal and guard cells degenerate. The **ovule** becomes the seed while the **ovary** enlarges and grows into a fruit. The integuments form a protective coat or testa over the seed, while the wall of the ovary becomes a pericarp.

# Seeds and fruits

## Seeds

A seed is a structure which develops from the ovule after fertilization. A seed consists of an **embryo** and one or two **cotyledons**. It may con-tain 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 seeds contain only one seed leaf are called **monocotyledonous** plants (**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 fertilization. Immediately after fertilization 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 **fruit-coat**. At maturity the pericarp is either hard and dry or soft and fleshy. A fruit can therefore be regarded as a mature ovary, con-taining one or more seeds.

Sometimes a fruit may be so small that it may be mistaken for a seed. Conversely a seed may be so large that it may be mistaken for a fruit. Size is not an identification mark. Fruits and seeds can be identified with 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** repre-senting **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 carpels (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 fertilization.

## True and false fruits

Fruits can be **true** or **false** according to what part of the flower ripens after fertilization. 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 inflore-scence. For example, the inflorescence stalk of pineapple, the pedicel and receptacle 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.

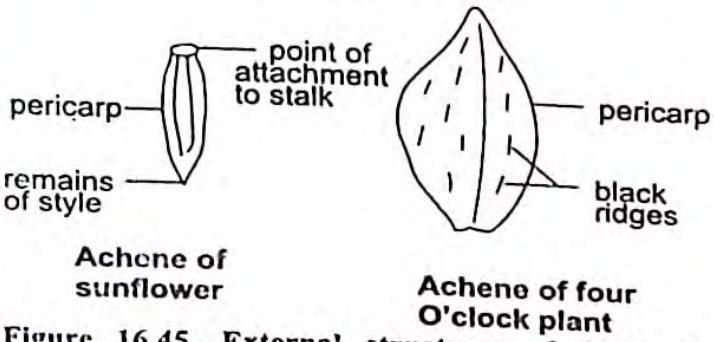



**Figure 16.45. External structures of fruits of sunflowers and Four O'clock plants.**

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.

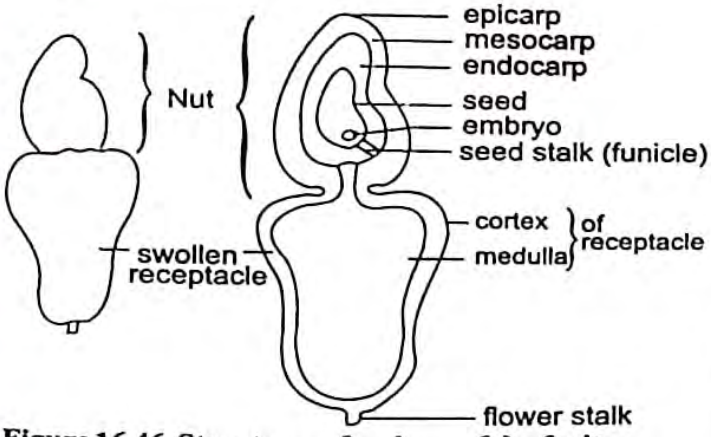



**Figure 16.46. Structures of cashew, a false fruit.**

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.

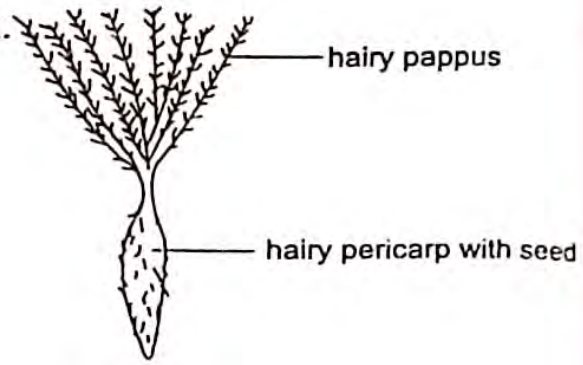



**Figure 16.47. Mature fruit of *Tridax***

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 (figure . -), 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.

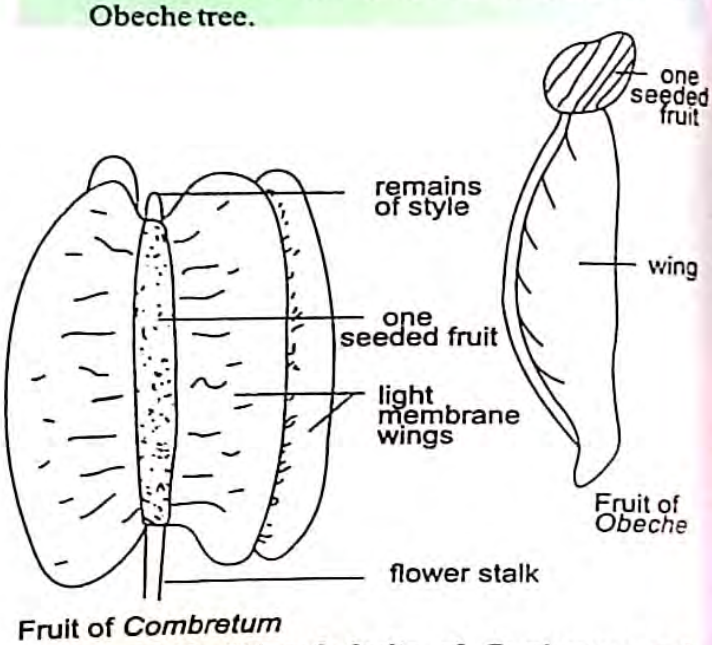



**Figure 16.48. Winged fruits of Combretum and Obeche**

## 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.

### 1. Follicles

These are dry fruits which open longitudinally by one line. Many of the known follicles as a matter of fact are aggregate of follicles. Examples are periwinkle, cola and cnestis

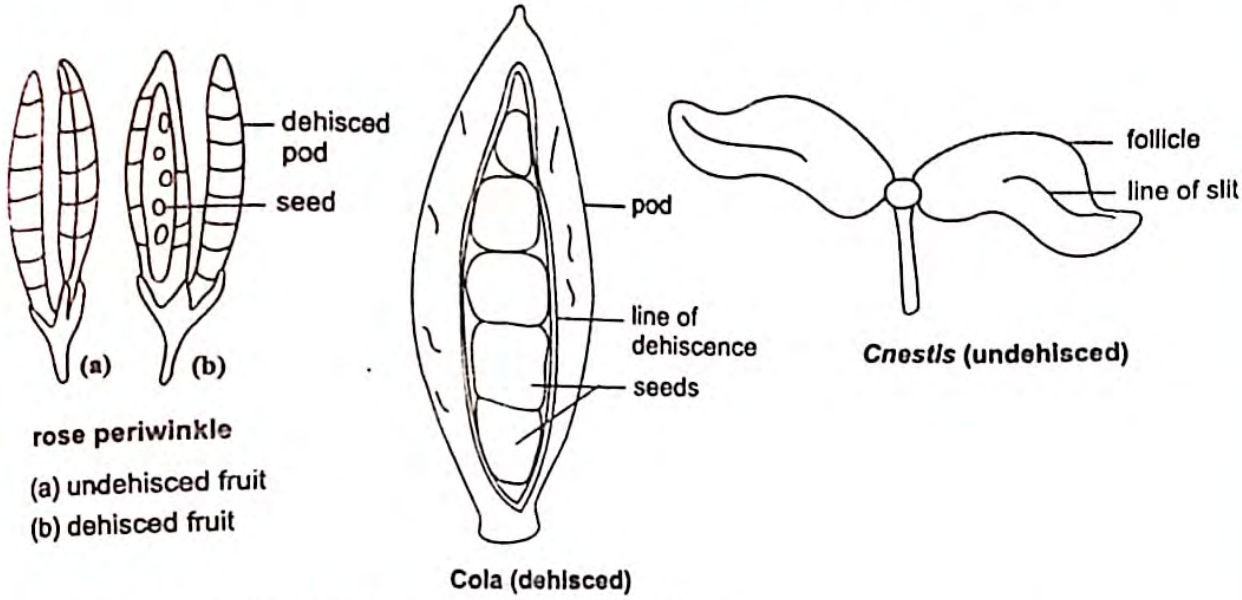



**Figure 16.49. Follicles of Rose periwinkle, cola and *cnestis*.**

### 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.

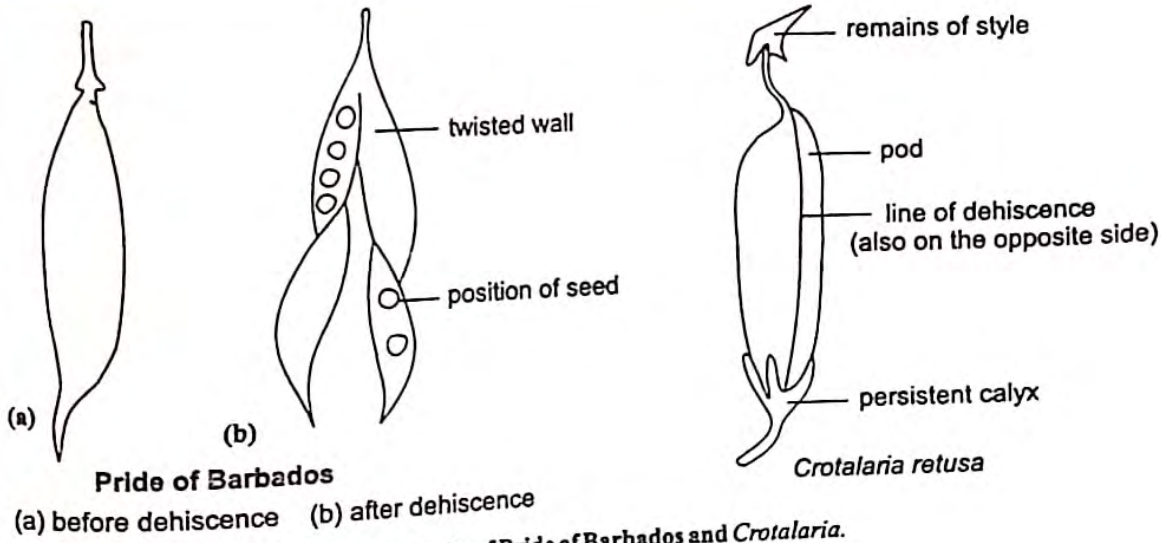



**Figure 16.50. Leguminous fruits of Pride of Barbados and *Crotalaria*.**

## 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 many lines into separate parts, each part containing many seeds.

**Figure 16.51. Capsules of castor oil and Queen of flowers.**

## 4. Schizocarp

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

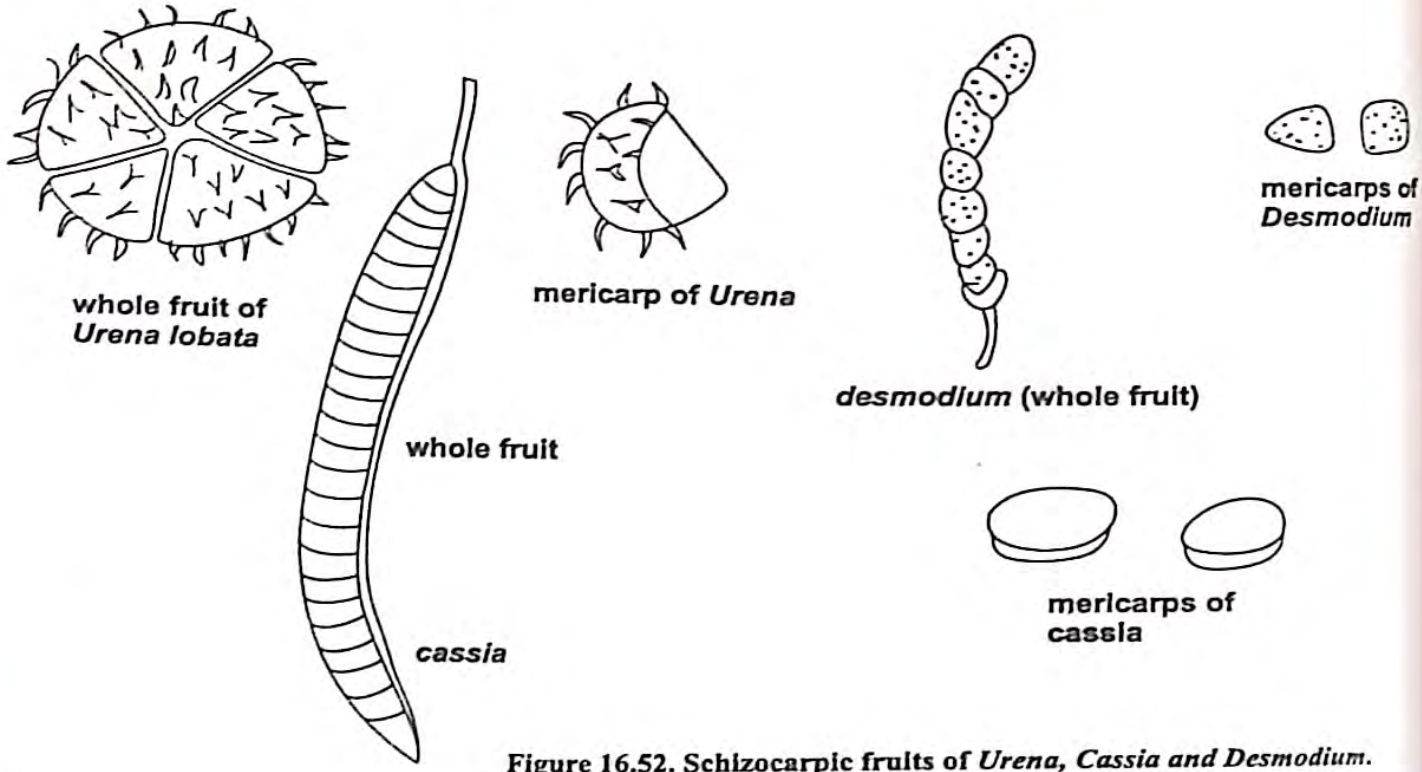



**Figure 16.52. Schizocarpic fruits of *Urena, Cassia and Desmodium.***

## 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 are:

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

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.

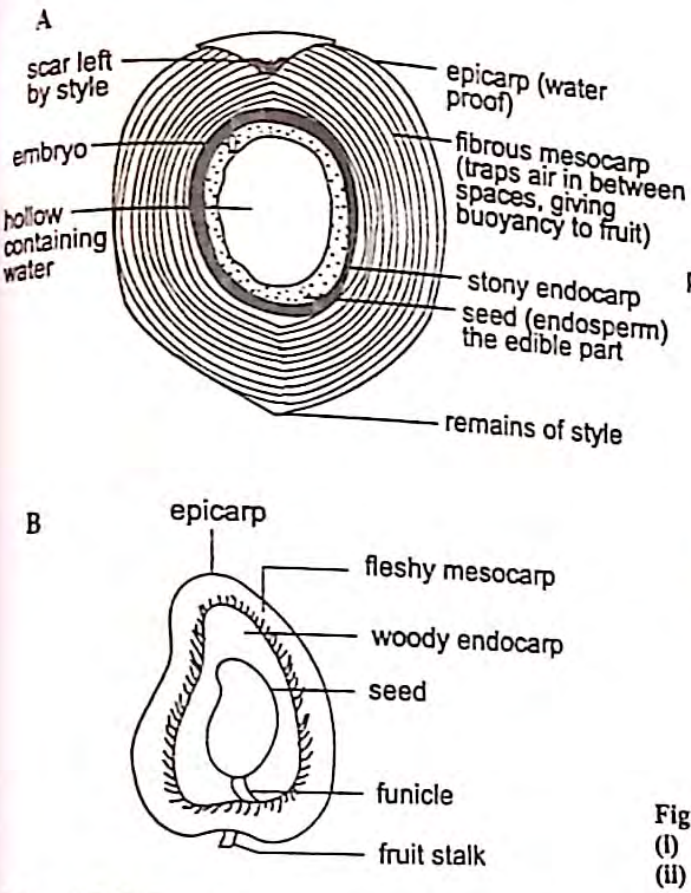



**Figure 16.53. Drupes.**
**A = Fibrous drupe of coconut fruit in longitudinal section.**
**B = Longitudinal section of mango fruit.**

### 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**. These 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.

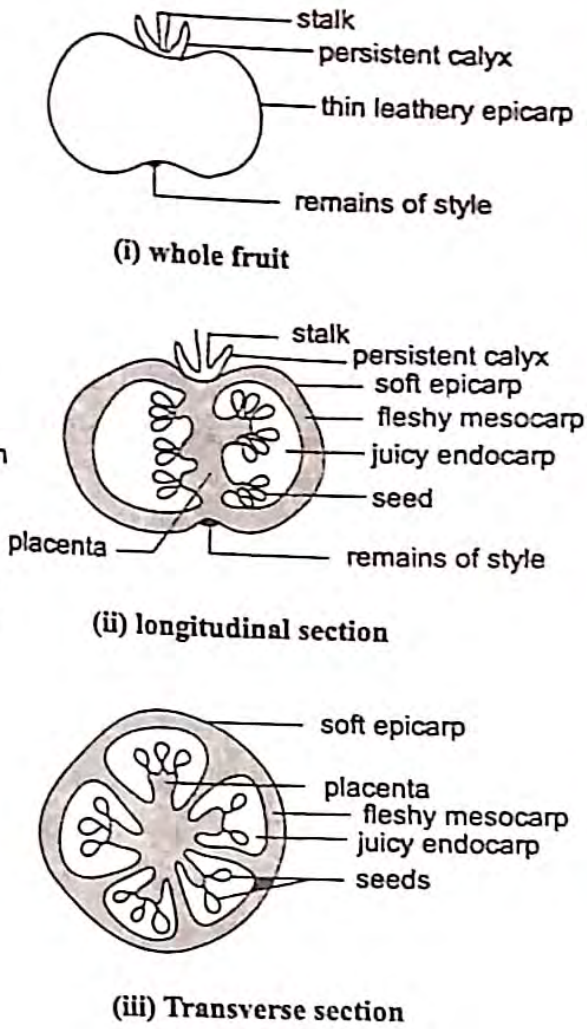



**Figure 16.54. Berry of tomato.**
**(i) Whole tomato fruit**
**(ii) Longitudinal section**
**(iii) Transverse section.**

## Pepo

A pepo is a simple true fruit with the epicarp and mesocarp fused together to form the rind (or skin). There are many clear chambers with each chamber being separated from one another by sheets of endocarp. Within each chamber are succulent hairs attached to the endocarp. Examples are **orange, lemon** and **lime**. In **orange**, the epicarp contains many oil glands.

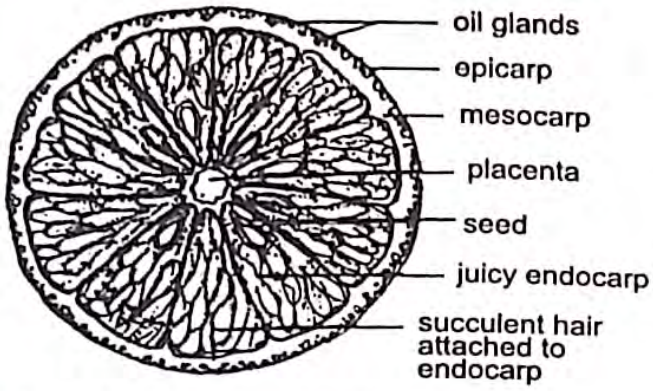



**Figure 16.55. Transverse section of an orange.**

## Pome

A pome is a simple false fruit with the fleshy and edible parts formed from the receptacle. The hard core enclosing the seeds is formed from the ovary. Examples are apple and African pear.

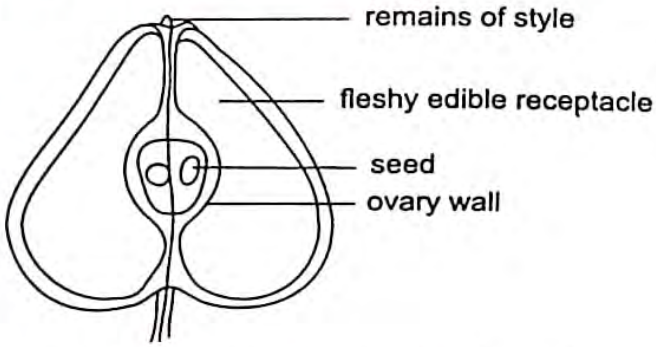



**Figure 16.56. Apple pome (longitudinal section).**

## Aggregate fruits

As has earlier been mentioned, **aggregate fruits** are formed from an ovary with many free carpels. Each carpel may develop into a follicle, drupe or a berry. Hence there exists an aggregate of fol-licles 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.

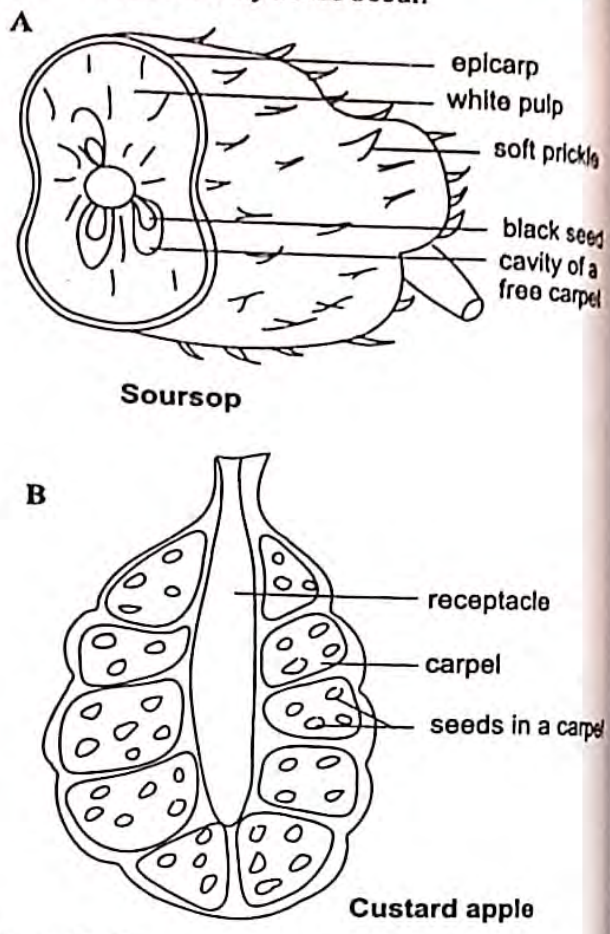



**Figure 16.57.**
**A = Cross section of the fruit of soursop, an aggregate of drupes.**
**B = Longitudinal section of the fruit of custard apple, an aggregate of berries.**

## 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.

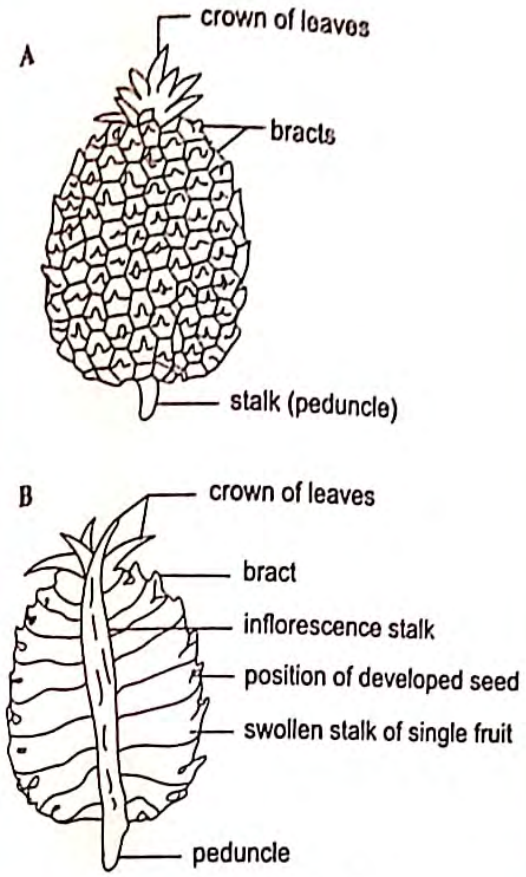



**Figure 16.58. Multiple frut of pineapple**
**A = Whole fruit**
**B = Longitudinal section.**

**Table 60. Differences between seed and fruit.**

| | Seed | Fruit |
|---|---|---|
| 1. | Has one scar. | Has two scars |
| 2. | No remains of style. | Has remains of style |
| 3. | Has testa. | Has no testa. |
| 4. | Has no pericarp. | Has pericarp. |
| 5. | There is a micropyle. | There is no micro-pyle. |
| 6. | There is no line of suture | There is line of suture |
| 7. | Has no stalk (penduncle) | Has a stalk (penduncle) |

## 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 pericarps 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 alone. Their various structural adaptations are designed to carry them over a short or long distance from the parent plants.

## Dispersal by wind

For fruits and seeds to be dispersed by wind they must have the following characteristics:

(1) They are generally small.
(2) They are generally light.
(3) Where they appear heavy they have some large and light membranous wings which make them buoyant in the air.
(4) They may also possess some long hairy or thread-like structures which act as parachutes in the air.

## Fruits dispersed by wind

These include *Tridax*, *Emilia*, goat-wee **Combretum**, Obeche and *Bougainvillea*. In *Trid* there is a tuft of hairy pappus formed from a persistent calyx. The hairy pappus and the o seeded fruit formed from an inferior ovary,beha very much like a parachute in the air. The fruit can parachuted to a very long distance from the pare place by the action of wind. In *Combretum* (fig 16.57B) the pericarp has become extended into light membranous wings which propel the o seeded fruit in the air to some distance away from plants. **Obeche** (figure 16.57C) has a sing elongated wing with the fruit at one end, while *Bougainvillea* (figure 16.57D), the wing is form by a persistent bract.

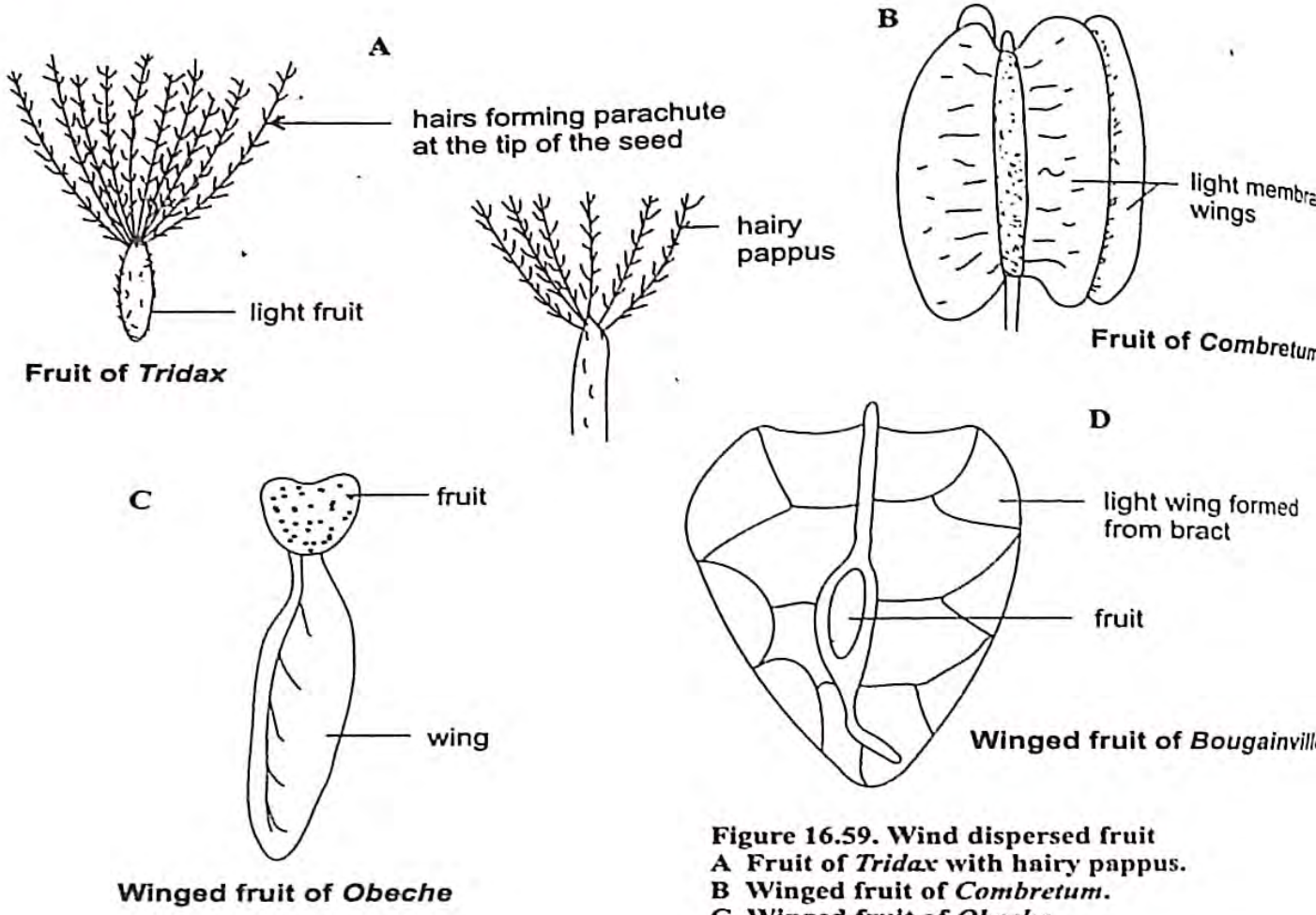
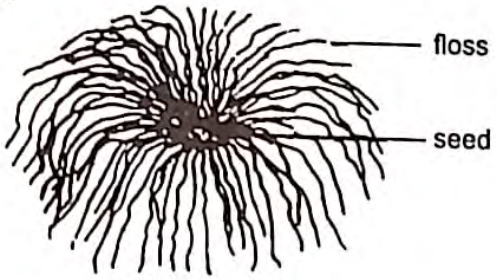


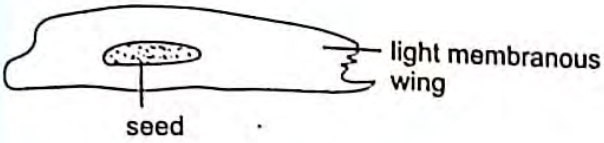

**Figure 16.59. Wind dispersed fruit**
**A Fruit of *Tridax* with hairy pappus.**
**B Winged fruit of *Combretum*.**
**C Winged fruit of *Obeche*.**
**D Winged fruit of *Bougainvillea*.**

## Seeds dispersed by wind

These include **cotton seeds, *Tecoma, Plumeria* and *Neubouldia***. In cotton, the seeds are surrounded by a mass of floss (figure 16.58A) which makes them light and can easily be carried by wind. In ***Tecoma, Plumeria*** and ***Neuboldia***, the seed testa become extended into membranous wing (figure 16.58B) which can also be blown about by the wind and carried many meters away from the parent plants.




**Cotton seed with floss**




**Winged seed of *Neubouldia levis***

**Figure 16.60. Seeds dispersed by wind**

## Dispersal by animals

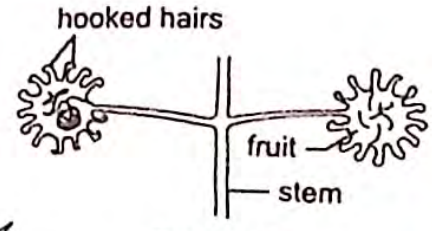
There are four ways by which fruits or seeds can be dispersed by animals.

### (1) Fruits with hooks

The walls of certain fruits possess some hooks which can fasten them to the furs of animals or clothes of man passing through the bush. Such fruits will later fall off their bodies several meters away from the parent plants. Examples of fruits with hooks are *Urena lobata, Bidens, Triumfetta* and *Acanthospermum hispidium*.

***Urena lobata***

***Bidens***




***Triumfetta***

***Acanthospermum hispidium***

**Figure 16.61. Fruits with hooks for dispersal by animals.**

### (2) Fruits with sticky hairs

These are fruits whose walls possess some sticky hairs which can stick to the furs of animals or clothes of human being. Examples of fruits with sticky hairs are *Boerhavia diffusa* and *Desmodium*.

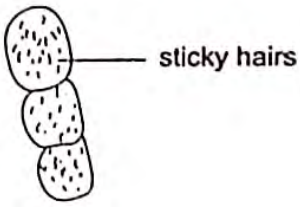



**Figure 16.62. Fruit of *Desmodium* with sticky hairs**

### (3) Seeds swallowed and passed out with faeces

Many birds and cattle eat certain fruits whose seeds are swallowed. Such seeds possess hard and thick seed coats which can resist enzyme digestion in the guts. The seeds are therefore passed out with faeces several kilometres away. They germinate if conditions are suitable. Examples are **tomato, pepper** and seeds of many grasses, such as *Sporobolus* species and *Eluisine indica*.

### (4) Fruits and seeds transported by man

Man is a very important agent of fruit and seed dispersal. The distribution of farm products to

different parts of the world market is a kind of dispersal. These products are further dispersed to different homes by buyers and the fruits or seeds which are not immediately eaten may be recultivated. Sometimes the fruits are eaten after which their seeds are thrown away into a nearby bush. Examples are **mango, orange, palm fruits, tomato,** and **pear**. The fruits and seeds of many weeds are mistakenly collected and transported along with food crops from the farm. Such weeds then have a chance of reaching new areas where they are not naturally found. They may become easily established in their new environments. *Amaranthus spinosus*, goat weed, *Eupatorium* and many grasses belong to such group of weeds.

## Dispersal by water

For fruits and seeds to be dispersed by water, they must possess a floating device to prevent them from sinking. For this reason not many fruits and seeds are dispersed by water. Seeds of water lilies and fruits of coconuts are few examples of fruits and seeds dispersed by water. Seeds of water lilies have air spaces which enable them to float for sometime in water until they are brought to the shore by waves. The fibrous mesocarp of coconut offers a good floating device to the fruits (figure 16.52A). They can float for up to one hundred days covering many kilometres away from the parent coastal plants, still retaining their ability to germinate if carried off-shore by tidal waves. Tomato seeds are also carried away by run-off waters through gutters and gulleys to plain lands where they germinate.

## Dispersal by explosive mechanism

When the fruit is getting ripe, it begins to dry up. The drying causes strains on the pericarp which eventually splits violently with sound along the two lines of weakness flicking out the seeds to a considerable distance from the parent tree. Explosive mechanism is common in leguminous fruits such as oil bean, Pride of Barbados and Flamboyant. Other plants include the **para-rubber, mahogany** and **balsam**.

In most of the leguminous fruits, explosive mechanism is accompanied with the twisting of the fruit-wall due to the high tension set up inside the dry walls. The explosion is particularly loud in the oil bean fruits whose seeds are very large and heavy. The seeds can be thrown to so many metres away from the parent plant.

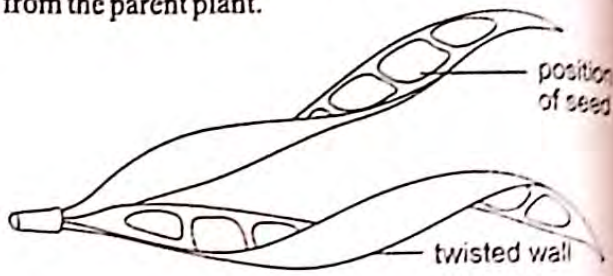



**Figure 16.63. Dehisced fruit of Pride of Barbados**

## Dormancy

After the dispersal of seeds, the seeds are likely to germinate if the conditions required for germination are available. Seed cannot germinate unless they are viable. When a viable seed fails to germinate in the presence of all the conditions necessary for germination, such a seed is said to be in a **state of dormancy.**

**Dormancy** has been described as a short period of rest which precedes the germination of seeds. The dormant seeds are not resting, but are perhaps undergoing some other changes which will enable them to germinate.

## Causes of dormancy

1. The embryo may not be fully matured at the time the seed is released from the fruit. The seed will remain dormant to bring the embryo to maturity.
2. The seed-coat may be too hard and may not be able to absorb water that is necessary for germination. In this case the seed-coat will have to decay before water can be absorbed.
3. The seed-coat may absorb water but fails to swell to allow the emergence of the radicle. Again the seed-coat needs to decay.
4. Sometimes the seed-embryo needs the presence of certain chemicals from the soil before it can germinate and unless these chemicals are available it will remain dormant.

...ancy differs in many plant ...l seeds, it ranges from days to months or even years. There are many seeds which do not undergo any period of dormancy. Such seeds can germinate immediately after their release. The seeds of tomato, pepper and *Amaranthus* are typical examples.

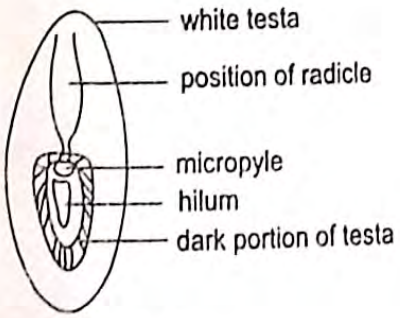
## Structure and germination of seeds

In most cases seeds become very hard and dry after they have been freed from the fruits. During the resting period the soluble food products in the cotyledons or endosperm are converted to complex insoluble products. The general features of any seed have been discussed. In this section, the structures of named seeds are treated. The structure of any dry seed is better studied after soaking it in water for some hours. During this time, the seed absorbs water and swells. The water softens the internal tissues.

### Cowpea seed

Cowpea is a member of the bean family. The seeds occur in the pod of a leguminous fruit. There are many varieties. The white variety (figure 16.62) is about the commonest.

Externally there is a **hilum** surrounded by a thick dark portion of the testa. The rest portion of the testa is white. The hilum is the point of attachment of the seed to the placenta of the ovary. Looking at the front view of the seed, a small swelling can be observed above the hilum. This is **micropyle** which is often difficult to see. It occurs between the hilum and the swelling of the radicle. The micropyle can be seen if a soaked seed is wiped with a filter or blotting paper and squeezed gently between the thumb and first finger. A droplet of water oozes out through the micropyle.




External front view

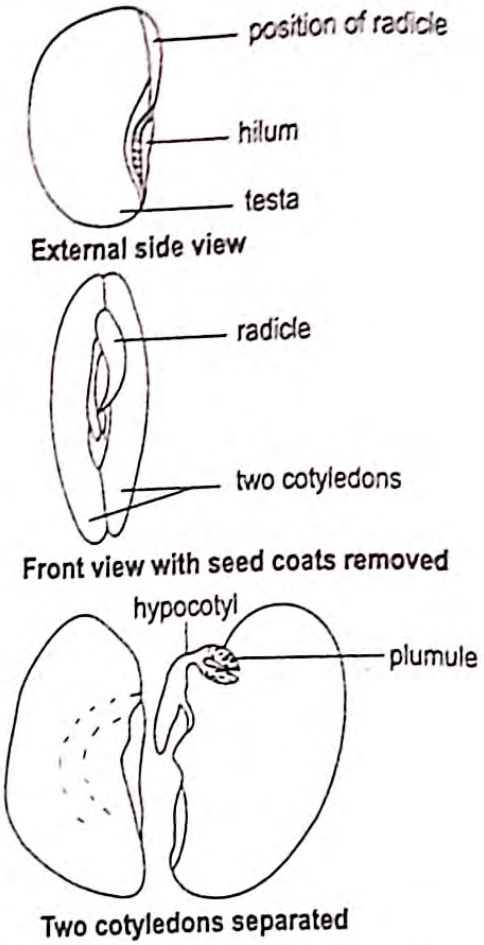



**Figure 16.64. Structures of a cowpea seed**

A careful removal of the seed coats reveals that the seed has two cotyledons (a dicot seed). Seed coats are easy to remove after soaking. The radicle is also very visible at this time. When the cotyledons are carefully separated, the radicle and plumule are well exposed on one half. The seed is non-endospermic. The food contents of the seed are stored in the two cotyledons. These are mainly proteins and little starch. The radicle is the future root while the plumule which consists of two delicate leaf-like structures is the future shoot.

Many dicotyledonous seeds are built almost on the same pattern with the cowpea. Exceptions are those dicot seeds with endosperms. Examples are castor-oil and walnut seeds.

### Castor oil seed

This is an endospermic dicotyledonous seed, three of which occur in a capsule fruit. Each seed consists of a very hard testa with black and brown coloration. The testa is impermeable to water but there is a

spongy knob at one end, known as *caruncle* through which water is easily absorbed (figure 16.63).

A longitudinal section through the seed shows a large mass of endosperm surrounding the two thin cotyledons as well as the radicle and plumule. The endosperm contains mainly oil. It is covered by a thin tegmen.

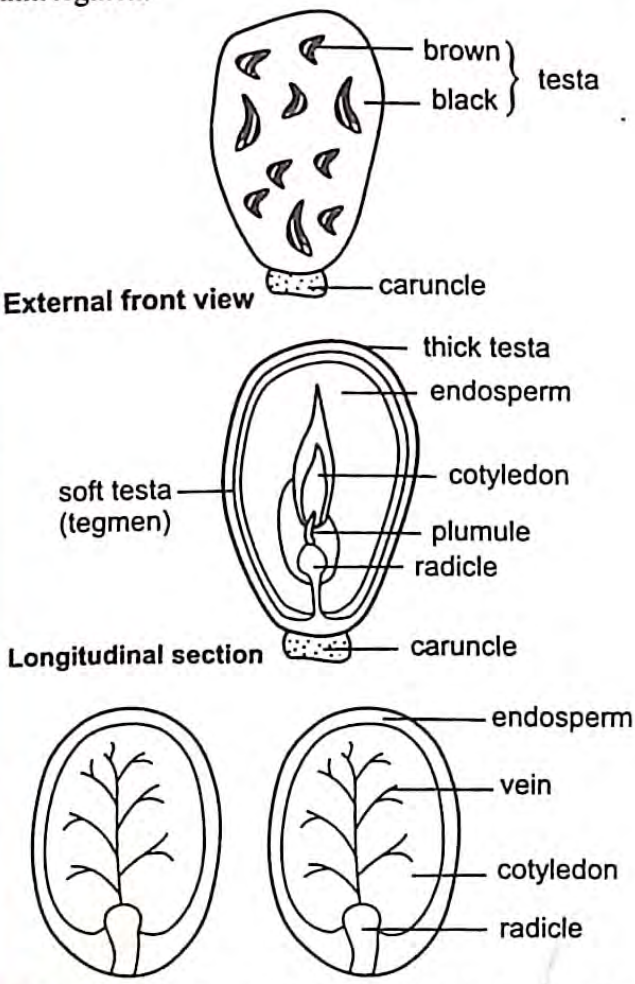



**Figure 16.65. Structure of Castor oil seed.**

If the testa is removed and the endosperm carefully cut open from the side, the two cotyledons can be removed. The cotyledons are thin, flat and oval in shape with a network of veins. They contain no food material. They act as organs of food absorption from the endosperm to the embryo during the germination of the seed.

## Maize grain

This is another endospermic seed but unlike the castor oil seed the maize grain is a monocotyledonous seed. The maize grain as a matter of fact is a fruit in which the pericarp has fused with the testa (caryposis). The seed can therefore not be separated from the fruit.

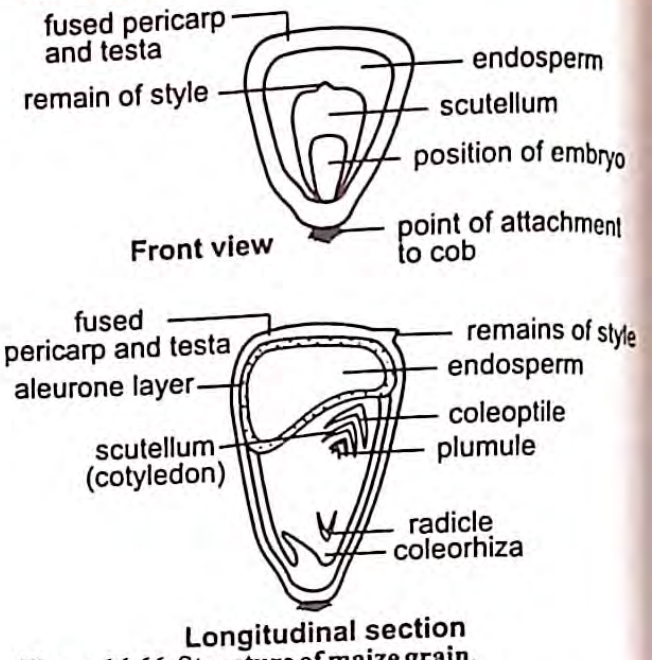



**Figure 16.66. Structure of maize grain.**

Externally, a maize grain has two scars (figure 16.64). These are the point of attachment to the cob and a tiny remains of style. The positions of **plumule, radicle** and the shield-shaped **cotyledon** or **scutellum** are also visible externally. A longitudinal section through the embryo of a soaked grain shows a large area of endosperm which is filled with starch and very little protein. This area is white and can be coloured black if iodine solution is applied to the cut surface. The remaining portion is occupied by the **cotyledon** and **embryo**. The *embryo* consists of a short radicle protected by a **radicle sheath** or *coleorhiza* and a plumule protected by a **plumule sheath** or *coleoptile*.

The single shield-shaped cotyledon is attached to the meeting point of the radicle and plumule.

## Germination

Germination is a process by which the embryo of a seed grows out of its testa and develops into a seedling.

## Conditions necessary for germination

(1) The seed must be viable.
(2) Moisture or water must be available.
(3) There must be a suitable temperature.
(4) There must be adequate supply of air (oxygen).

## Types of germination

There are two types of germination based on whether the seed cotyledons are carried above the soil or left behind in the soil.

The germination in which the cotyledons are carried above the soil (into the air) is known as *epigeal germination*. The type in which the cotyledons are left below the soil is *hypogeal germination*. Most dicotyledonous seeds show epigeal germination while most monocotyledonous seed exhibit hypogeal germination. *Mucana* bean, (the yam bean) and rubber are some of the dicotyledonous seed with hypogeal germination.

## Germination of cowpea seed (epigeal germination)

Cowpea is a dicotyledonous non-endospermic seed with **epigeal germination** (figure 16.65). The seed in the soil in the presence of moisture, air and suitable temperature, absorbs water and swells. Water is absorbed largely through the **micropyle** and also through the **wet seed coat**. The swelling of the seed causes the seed coat to rupture. After about 24 hours the radicle pushes out, grows downwards.

The **radicle** elongates and develops some root hairs to become a **primary root**. Within 48 hours the part of the embryo just below the cotyledons known as *hypocotyl* elongates and forms a loop above the soil. The **hypocotyl** later strengthens up, carrying the cotyledons into the air. The cotyledons which have been protecting the plumule open to expose the plumule. Both the **cotyledons and plumule turn green** in the presence of light. The plumule becomes the first **foliage leaves**. The cotyledons from which food is being absorbed into the growing embryo diminish in size. They later wither as the newly formed green leaves take over the function of food production by photosynthesis.

Meanwhile the primary root elongates deeper into the soil and develops into a tap root system. From it some lateral roots with root hairs develop. The root hairs absorb water. And so within 96 hours a cowpea seed by these changes becomes a young plant or seedling, the final result of sexual reproduction.

All germinations begin with the emergence of the radicle. The difference which occur in different seeds depends on whether the radicle develops into a tap root or a fibrous root system; whether the cotyledons are carried above (epigeal) or left in the soil (hypogeal) or whether the growing embryo gets its nourishment from food stored in the cotyledons or in the endosperm.

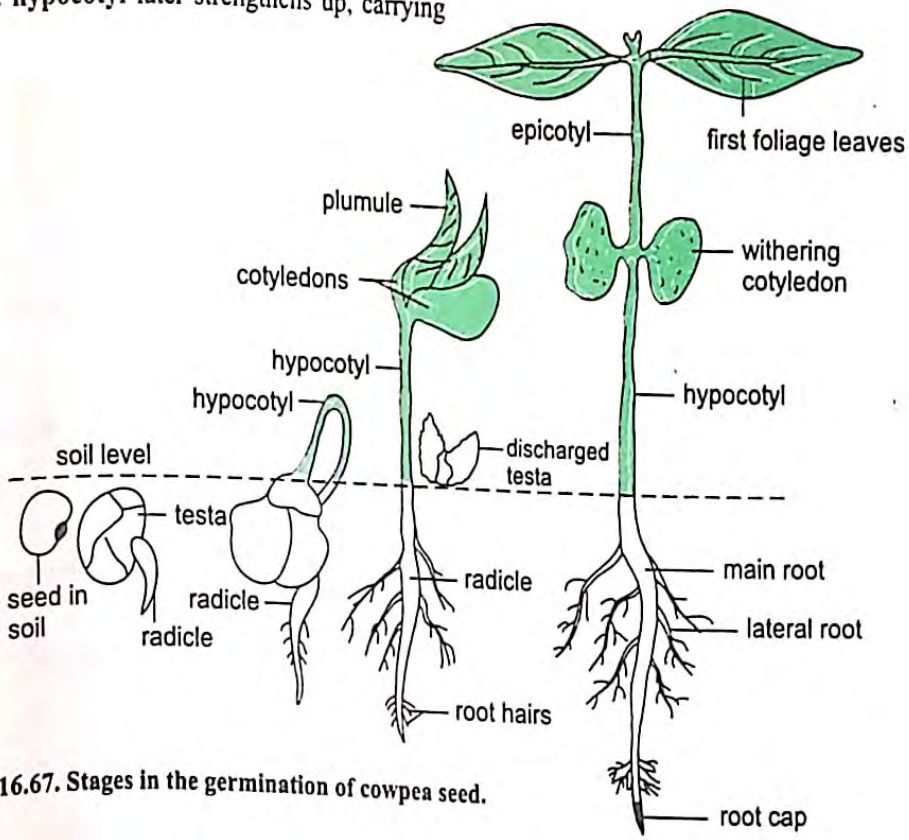



**Figure 16.67. Stages in the germination of cowpea seed.**

## Germination of maize grain (hypogeal germination)

The maize grain is a monocotyledonous endospermic seed with **hypogeal germination**. The seed in the soil absorbs water and swells.

The radicle is stimulated into growth. The **radicle sheath** elongates and pushes out through the fused pericarp and testa. Later the sheath breaks at its end due to the pressure of the elongating radicle which grows out and develops into a **primary root**. Similarly the plumule sheath grows up due to the elongation of the **epicotyl** (part of the embryo above the cotyledon). The plumule sheath comes above the soil, breaks and

releases the plumule which later turns green to become the first foliage leaf (figure 16.66). The cotyledon remains within the grain in the soil absorbing food from the endosperm into the growing embryo. Meanwhile the primary root stops growing. This is because some secondary roots develop from the base of the plumule sheath to form a fibrous system.

### Note

A tap root system is characteristic of the dicotyledonous plants while a fibrous root system is characteristic of the monocotyledonous plants.

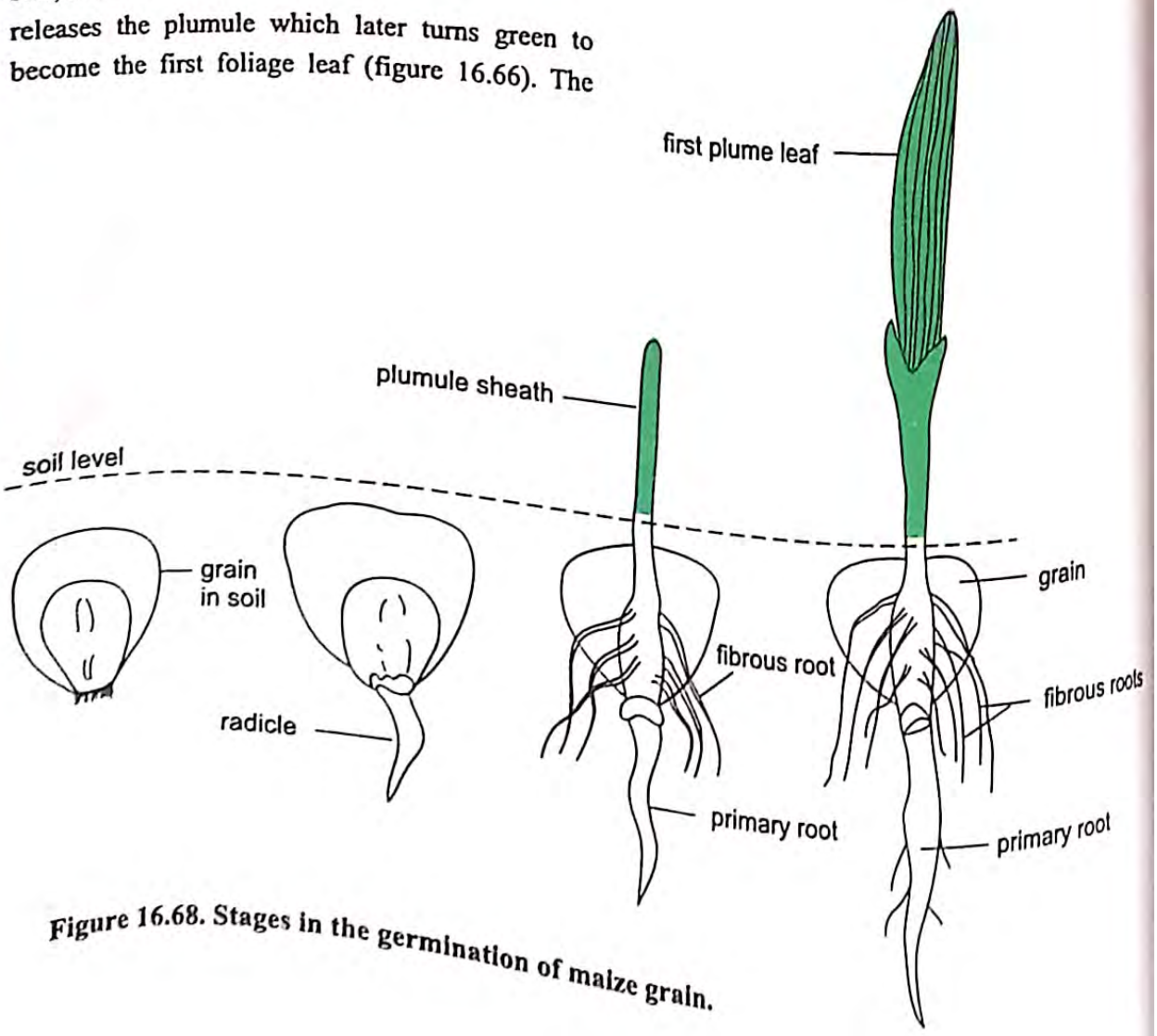



**Figure 16.68. Stages in the germination of maize grain.**

## Germination of African yam bean seed (hypogeal germination)

This is a dicotyledonous non - endospermic seed with hypogeal germination. Its germination is similar to that of cowpea, except that the cotyledons are left in the soil.

Germination begins with the absorption of water from the soil and subsequent swelling of the seed. The seed coat breaks and the radicle emerges and grows downwards. The epicotyl grows and loops above the soil. The looping of the epicotyl is important because it offers enough protection to the plumule by pushing through the soil before it. The epicotyl straightens and carries the plumule into the air (figure 16.67). The plumule opens, turns green in the presence of light to become the first foliage leaves. The radicle develops into a tap root system.

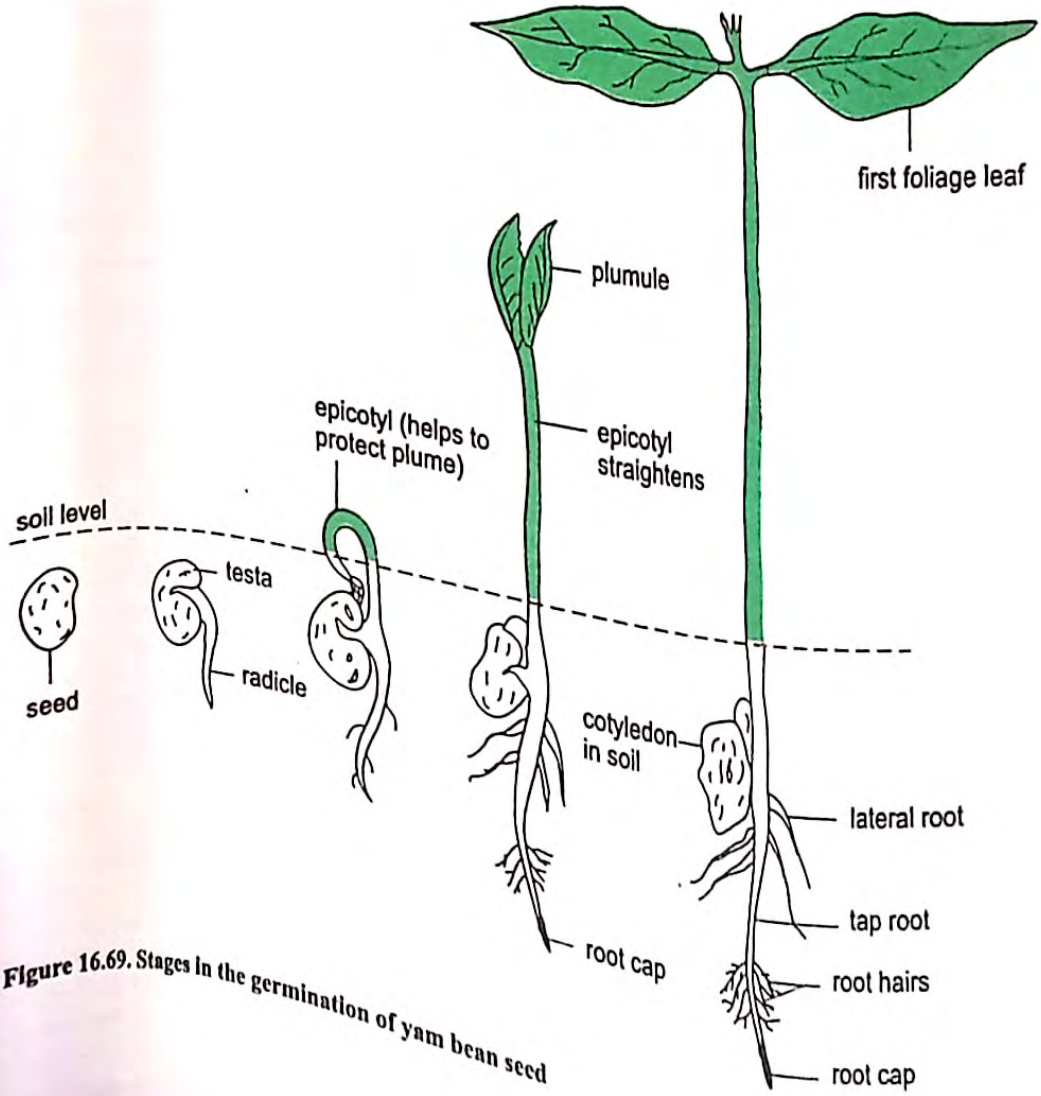
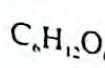



**Figure 16.69. Stages in the germination of yam bean seed**

## How the developing embryo obtains energy during germination

It has earlier been pointed out that for a viable seed to germinate, certain conditions are necessary. These are water, oxygen and suitable temperature. **Water** is necessary to reactivate the enzymes which hydrolyse the complex food materials stored either in the cotyledons or in the endosperm of the seed to simple soluble products which can be passed to the embryo for respiration and growth. It is for this reason that germination starts with the absorption of water. During the enzyme hydrolysis, starch is hydrolysed to **simple sugar**, proteins are hydrolysed to **amino acids** and fats and oils are hydrolysed to **fatty acid** and **glycerol**. The **oxygen** of the air is required to oxidize the simple sugar to carbon (IV) oxide, water and energy, a process known as aerobic respiration. This is expressed in the equation.



$$C_6H_{12}O_6 + 6O_2 \text{---------}> 6CO_2 + 6H_2O + \text{Energy}$$

This reaction takes place in the growing cells of the embryo (**radicle + plumule**) thus providing the energy required for growth.

## The importance of suitable temperature

Seeds germinate over a range of temperature. But for a particular seed, there is a certain maximum temperature which is most suitable for its germination. This is called the *optimum temperature*. Any temperature far below the **optimum temperature** retards the rate of germination. Also temperatures above the optimum reduce the rate of germination and when the temperatures become too high or too low, seeds fail to germinate.

The reason is that enzymes responsible for hydrolysis in the seed are very sensitive to changes in temperature. They act best at the optimum temperature. At a lower temperature they are less active while at a very high temperature they are destroyed hence no germination occurs even if all other necessary conditions are available. Seeds therefore require a suitable temperature to germinate.

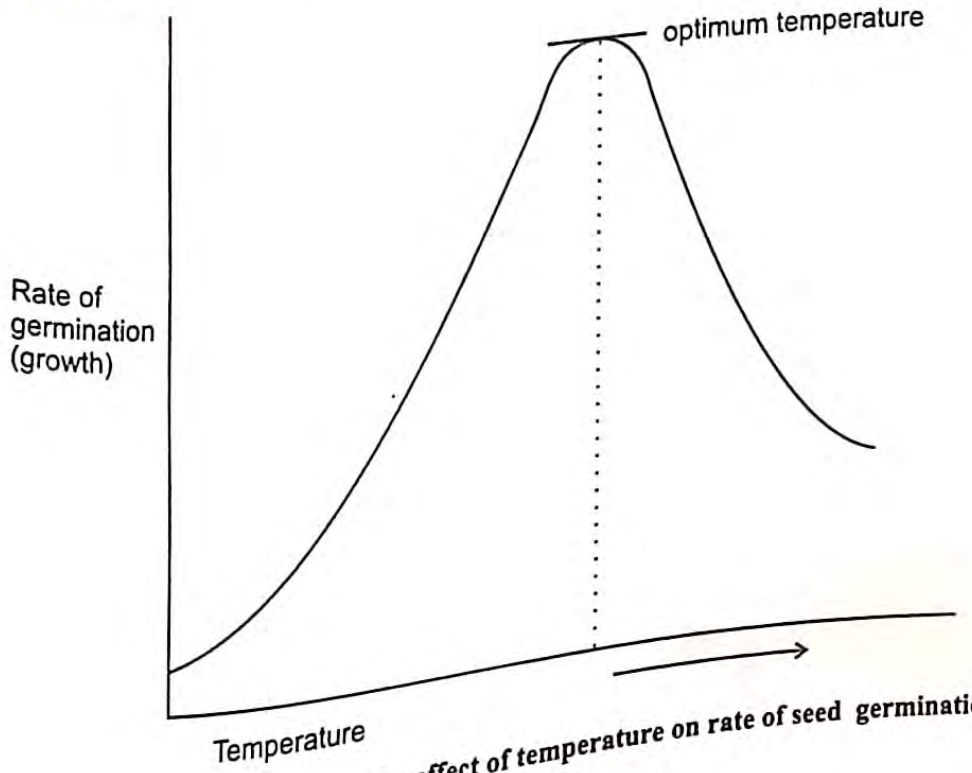



**Figure 16.70. Graph showing the effect of temperature on rate of seed germination (growth)**

## Conditions necessary for germination

For seeds to germinate the following conditions are necessary: water, suitable temperature, oxygen and viable seeds.

## Experiment

**Aim:** To demostrate that water, oxygen and suitable temperature are necessary for germination.

**Method:** Into each of four boiling beakers, a piece of cotton wool is placed in the bottom. The boiling tubes are labelled with letters **A,B,C,D**. In boiling beaker **A** are placed dry broad bean seeds and placed in suitable temperature and air. There is no water.

Into beaker **B**, the cotton wools is moistened with water. Broad beans seeds are placed inside. The beaker and its contents are placed in a refrigerator regulated at 4EC. The seeds receive oxygen and water.

In beaker tube **C**, are placed broad bean seeds and the beaker is filled with water which has been boiled and cooled and oil is placed on the top of the water to prevent air from dissolving in the water. The beaker is placed in a suitable temperature.

In beaker **D**, the cotton wool inside is moistened, and the beaker and its content are placed in a suitable temperature and well provided with air. This is the "control experiment.

The seeds are left for 4 days.

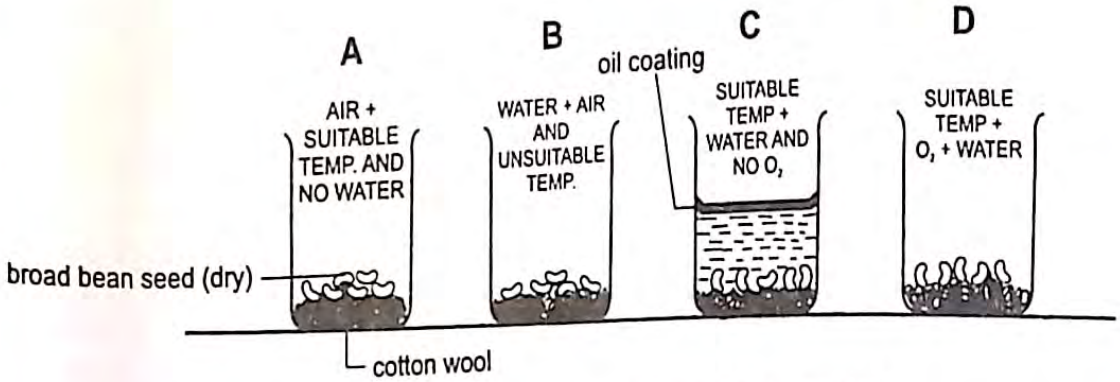



**Figure 16.71. Demonstrate conditions necessary for germination.**

**Observation:** The seeds in beaker **A,B,C.** fail to germinate while those in **D** germinate.

**Conclusion:** The seeds in beaker `A' fail to germinate because there is no water. Water is needed by germinating seeds to speed up biochemical activities of the seeds and also to soften the testa.

No germination in beaker `B' because of unsuitable temperature. At this temperature, the enzymes necessary to digest the food will not work effectively.

No germination in beaker **C** because of the absence of air ($0_2$) which is necessary for the breakdown of stored food.

In **D** where all conditions necessary are present, the seeds germinate.

Therefore water, suitable temperature and oxygen are necessary for germination.

## Viable seed

A **viable seed** is a seed which is living and healthy. It can be shown that only viable seeds germinate, by boiling some of the seeds used in the above experiments, and exposing them to the three conditions necessary for germination. They will not germinate because boiling kills the living cells of the seed as well as destroying their enzymes.

# Courtship behaviour in animals

Courtship behaviour consists of **instinctive behaviours** in response to certain **external stimuli**. The behaviour is being carried out as a series of fixed actions. Each action is alternately performed by male and female animals that brings about a **response** which in turn causes another response. Courtship behaviour may involve acquiring a territory and defending it, pairing of female and male and display of beautiful parts to attract opposite sex, territoriality and migration.

## Importance of courtship

1. Courtship keeps both male and female together thereby stimulating the sexual physiology of both male and female, thus making the female partner more receptive to the male.
2. In some cases, during courtship the male acquires a territory. The territory ensures adequate supply of food, nesting materials for the young thus ensuring better growth. The female and the young are protected from the attack of other males.
3. Since each species has its own peculiar courtship behaviour, it ensures that the female chooses the right male species.
4. When courtship behaviour coincides with ovulation period, mating occurs leading to the release of mature gametes and consequently promotes fertilization of eggs.

Examples of courtship behaviours include **pairing, display, territoriality and seasonal migration**.

## Pairing

This is a type of reproductive behaviour in which a mature female and male leave their home or homes and establish a new home elsewhere. For example the male and female frogs or toads pair up with the female backing the male during the breeding season. The pairing stimulates the female to lay eggs and the male releases sperm to fertilize the eggs as they are being laid. Matured male and female ***Tilapia zilli*** pair up and move to an acquired territory for reproduction. A male and female ***Clarias gariepinus*** pair up by moving side by side or the male follows behind and both move to flood plain for spawning. A mature **boy** and **girl** pair up for marriage and establish their home. Mature **male** and **female winged termites** pair up and leave their colony to establish a new colony with male becoming the king and the female queen.

**Figure 16.72. Pairing in *clarias gariepinus*.**

## Displays

Display is a reproductive behaviour or activity that an animal exhibits to attract an opposite sex into mating. In most cases, the male carries out displays to attract the female into mating. Displays can be in form of sound, beautiful colour, dance, song, release of chemicals and make-ups.

## Sound

Male crickets produce **shrilling sound** with their wings. The pregnant female crickets are attracted by sound and use the sound to locate the males. The **croaking noises** produced by male frogs attract females with eggs that they are ready for mating. The female *Aedes* mosquitoes ready to mate produce a **buzzing sound** with their wings during flight. The males use the buzzing sound to locate the females and copulate. The he-goat pro-duces gentle sound, with his upper lip frequently raised up and aggressively chasing the she-goat to submission. The male pigeon produces a continual cooing sound to attract the female for mating.

## Beautiful colours, body movements or dances

The male *Tilapia zilli* becomes colourful and attractive during the mating season. It dances round the females. One female ready to spawn then follows the male and both move out to establish a new territory where mating takes place. The male lizard *(Agama agama)* during the mating season displays its attractive colours, bobs the head and frequently wags its tail. The attracted female responds by curving its back and lifting up its tail vertically to allow the **hemipenis** of the male to come in contact with its **cloaca.**

**Display behaviours** are common in birds. The **domestic male fowl** (cock) displays its attractive feathers by expanding the neck, wing and tail feathers. The male also carries out side ways dance and scratching the ground. In some cases, unwilling female may be chased to submission by the male. The male also drives away another interested male usually resulting in bitter fighting. The peacock displays its long and brightly coloured feathers by expanding them to attract the female. The turkey expands the tail feathers in fan-like shape with some sound to attract the female.

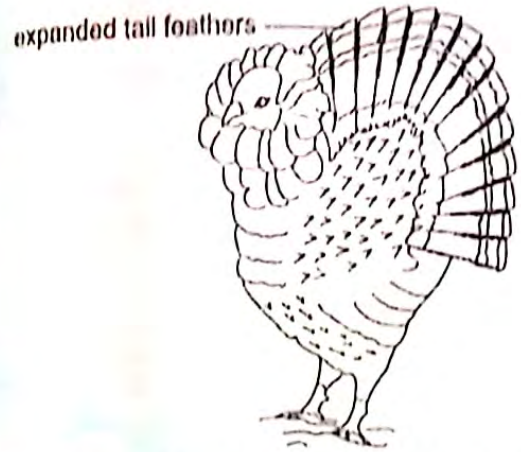



Figure 16.73. A male turkey displaying its tail feathers to attract the female.

Courtship display in male duck involves raising both tail and head up out of water. The wings are also raised high. (a) The stern may be raised up while dipping its beak in water (b) It may put its beak in water and quickly raise its head and flick it to one side and curve the head and body upward

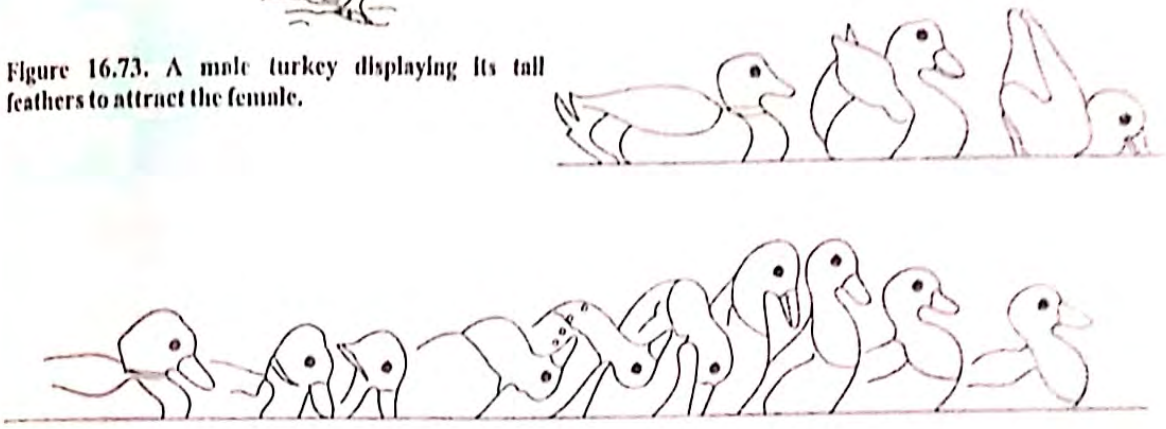


Figure 16.74. Courtship display in male duck

The male *Clarias gariepinus* repeatedly approaches the female partner with an erect dorsal fin and gently bumps the abdomen of the female. The male curves its body and blocks the female in front and both stay together for seconds. After which the male raises the middle part of the female to induce it to release eggs.

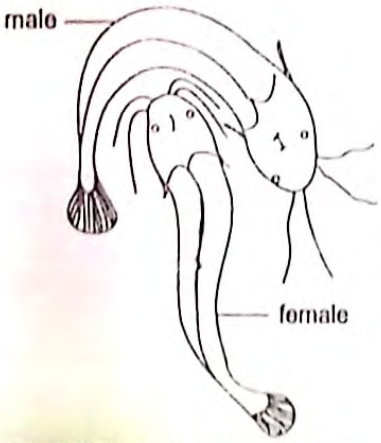



Figure 16.75. Display behaviour in clarias

## Display behaviours in human beings

Display behaviours in human beings involve physical appearances and make-ups of both sexes. Mature girl may show some physical attractions such as:

1. Applying lip-stick to lips and powdering of the face, and sometimes neck.
2. Weaving, platting, curling of hair, wearing wigs of different colours.
3. Wearing of attractive hats and head gear.
4. Wearing of large and brightly coloured bangles and dangling ear-rings.
5. Wearing of tight fitting dresses to display the body curves (commonly referred to as figure of 8) or generally wearing of brightly coloured dresses.
6. Display of thighs by wearing short dresses.
7. Well built feminine stature.
8. Wearing of transparent or perforated dresses to show the attractive parts of the body.
9. Wearing of artificial eye lashes, finger nails, breasts and buttocks.
10. Use of perfumes for amorous attraction and

possible concealment of body odour.

11. Walking with the shaking of buttocks.
12. Attractive dancing or singing melodious songs in public gatherings especially in social or religious gatherings.
13. Showing kindness, favour and generosity with good manners.
14. Attractive smiles with dazzling eyes and genuflecting to senior males.

Mature boy may show some physical attractions such as:

1. Attractive hair cut, high lighting the reigning style.
2. Wearing neat and colourful reigning dresses, shoes and cap to match.
3. Use of perfumes for amorous attraction and possible concealment of unpleasant body odour.
4. Exposing hairy body.
5. Well built musculine stature.
6. Display of money and other valuable jewels.
7. Singing melodious songs especially in public gatherings.
8. Walking gracefully and majestically.
9. Attractive dancing especially during social gatherings.
10. Attractive smiles.
11. Showing kindness, favour and generosity with good manners

### Light flashing display

Male fireflies flash lights in different patterns depending upon the species. A female firefly recognizes her own male species by the pattern of the light flash and is consequently attracted to the male for mating.

Figure 16.76. Light flashing display in firefly.

## Chemicals (Chemical sex attractants)

Chemical substances called pheromones have been used as sex attractants. A female silkworm moth ready to mate ,releases a pheromone. The pheromone is very powerful and can attract males from a distance of about three kilometres to test for mating.

## Territoriality

*Territoriality is a phenomenon in which an animal acquires a specific area, advertises it and defends it against intruders, particularly of its own species.* Usually it is the male animal that establishes the territory. A female animal is allowed to share the territory with it for the purpose of mating.

## Establishment and defence of territory

A male bird for example chooses unoccupied area and starts singing loudly and vigorously within the area. The song warns other males that the area has been claimed. The boundaries of two male birds are patrolled regularly. The male bird chases away intruders. A male *Agama agama* (Rainbow lizard) acquires an area and defends it against any other male. It allows only female lizards into the territory. A mature male *Tilapia zilli* establishes its territory at the bottom of a pond and defends it against other male intruders. A resident dog will chase away a strange dog. People build fences around their compounds or land signifying their ownership. The defence of a territory is greatest during the mating season.

## Functions of territory

1. Territoriality ensures an adequate supply of food, nesting materials for the young thereby resulting in better growth.
2. The young and the female are protected from the attack of other males.
3. The population is reduced to a density that the territory can support.
4. It reduces the attack of diseases and parasites.

5. It makes the male to be familiar with its site.
6. It is important in wildlife management. For example, if the territorial habit of an animal is known, it will help to determine the number of such animals that will occupy an area.

- Successful establishment of a territory and defending it by the male gives an adequate assurance to the female to be convinced that the male is strong and healthy and resources for the upkeep of the young will be available. A male which is unable to establish a territory may not be able to attract a female partner as the resources to feed the young may not be available and the young are likely to die of starvation and lack of protection from possible predation.

## Seasonal migration

*Seasonally, some animals undergo periodic and directional journeys from their natural habitats to different habitats for the purpose of breeding in favourable conditions, or avoiding unfavourable climate or due to shortage of food supply and later return home to their habitats.* This seasonal journey may be long (covering thousands of kilometres) or short (covering less than one kilometre). For examples, salmon move thousands of kilometres to their breeding grounds while *Clarias gariepinus* (catfish) travels from deep river to the flood-plains which may be less than one kilometre to breed.

## Migration in fish

In the tropical waters, many fishes undergo seasonal spawning migration from deep streams, rivers or lakes to the floodplains. *Clarias*, *Heterobranchus* (catfish) and *Cathorinus* (moonfish) are examples.

## Seasonal migration in fish

### Migration in *Clarias gariepinus*

During the onset of rainy season adult males and females which are about to spawn move in schooll from the deep streams, rivers or lakes to shallow waters of the floodplains to spawn. After spawning they (adults) move back to deep stream or river leaving behind the fertilized eggs which hatch, feed and grow fast in the floodplains. By the time the flood is receding the young Clarias now post-fingerlings move to the stream or river.

## Migration in eels

The adult eels live in freshwater streams and rivers in Europe and North America. It takes about 8 - 15 years for eels to develop to maturity. Eels spawn in the sea. On reaching the spawning age, the **females move down-stream** to join the **males that stay in brackish waters near the coast** and migrate together across the Atlantic ocean to their spawning grounds which is **Sargasso sea**. The migratory journey to their spawning grounds may take about **one to two months** covering **thousands of kilometres**. They spawn at the **depth** of about **110 metres**. After spawning, the adults die. The fertilized eggs hatch into pelagic floating larval forms called **leptocephalia**. It takes about three years for the larval forms to reach the freshwater streams and rivers of Europe and America. The males remain in the brackish waters while the females move up stream to stay in pure freshwater.

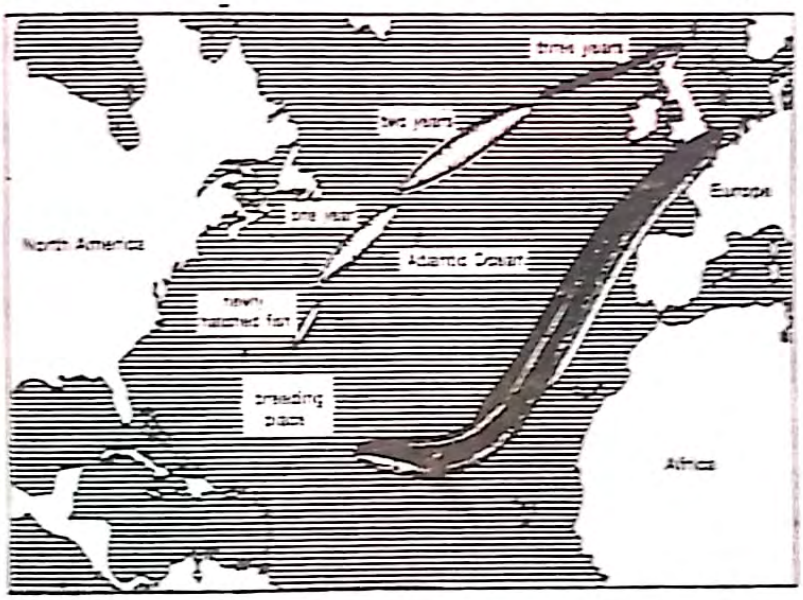



Figure 16.77. Seasonal migration of the European eel (Courtesy M.B.V Roberts)

## Migration in salmon

The adult salmons live far in the sea for about **three to four years** after which the male and female salmon assemble and undertake a long migratory journey from the sea to the upper part of **freshwater stream or river** and the very area of their birth some years ago. There are **two species** of salmon. These are **Atlantic** and **Pacific** species. After spawning, the adults of Pacific species die but those of the Atlantic survive, migrate back to the sea again and are able to undergo a second or third migration before death. After spawning, they stay in the stream until their **rectal glands** (salt secreting glands) have been well developed before returning to the sea.

## Migration in birds

The phenomenon of seasonal migration in some birds has been well studied. Seasonal migration in birds may be promoted by **food needs, breeding habits** or **changes in climatic conditions**. Thus, the **swallows** and **storks** migrate from northern Europe during autumn to South Africa and spend spring in northern Europe. This migratory journey covers a distance of about 8,000 kilometres.

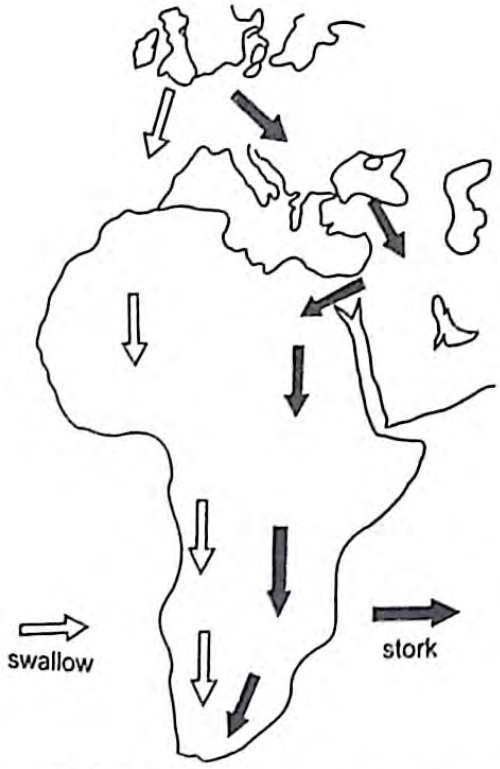



**Figure 16.78. The migratory route of swallow and storks**

The **golden plovers** migrate to northern Car during summer to breed and during autumn (f they migrate to South America to spend the winter. The migratory journey from northern Canada South America is about 15,000 kilometres.

In Nigeria, **kites** undergo local migration. At th beginning of **dry season** (November), kites migrate from northern part to southern part o Nigeria and stay till the end of April when the rainy **season** is about to start. During this pe-riod, they build nests and breed. At the end of April or early May, they migrate to northern part. During the dry season, the food of kites is scarce in the northern part but plentiful in southern part and also during the rainy season the food of kites is scarce in the south due to flooding of most parts but plentiful in the north. Therefore the seasonal migration of kites is due to **breeding** and **food supply.**

**Migratory journeys** may be during the day or at night depending upon the species. **Night migratory birds** seem to be directed by the **moon** and **stars** while those that migrate in the day are guided by the **sun** and the **coastal lines.**

The **instinct** that dictates the time and route of seasonal migration is not well understood. A migratory animal follows the same route year after year and arriving at the same time and the same point or area.

The earth's magnetic field has been known to be important in migration.

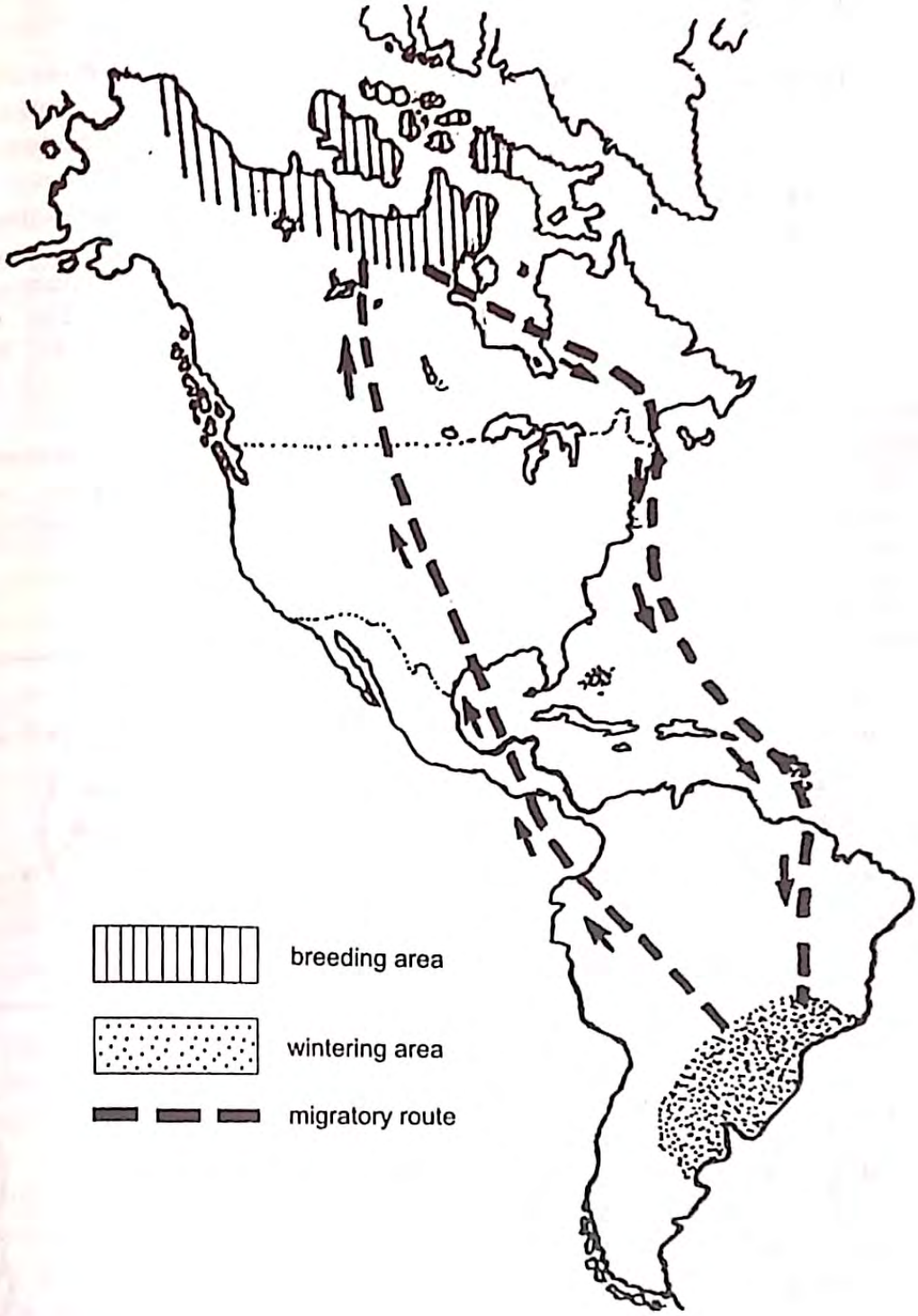



**Figure 16.79. The migratory route of golden plovers**

# SEXUAL REPRODUCTION IN SELECTED ANIMALS

## Sexual reproduction in *Paramecium caudatum*

The sexual reproduction is by conjugation of **two individuals of different lines of descent.**

## Stages in conjugation.

### Stage 1

Two individual **paramecia** ready for conjugation, come together and get **fused** by their **oral grooves.** In each conjugant the **meganucleus** gets dissolved in the cytoplasm while the **micronucleus** remains to take part in the whole process of mating.

### Stage 2

The **micronucleus** divides twice by **meiosis** and four nuclei are formed in each **conjugant.** Three of these nuclei get dissolved in the cytoplasm in each conjugant. The remaining micronucleus divides unequally into two in each conjugant.

### Stage 3

The **smaller micronuclei** are exchanged between the two conjugants.

### Stage 4

The **migratory micronucleus** fuses with the **stationary micronucleus** in each conjugant to form **zygote.** The two conjugants then separate.

### Stage 5

The zygote in each conjugant divides **thrice** to form **eight nuclei.** Four of the eight nuclei form **four meganuclei** while three of the remaining four get dissolved in the cytoplasm. The remaining **micronucleus** divides twice to form four micronuclei.

### Stage 6

Each **ex-conjugant** with **four meganuclei** and **four micronuclei** divide to form four **paramecia.** Each *Paramecium* has one meganucleus and one micronucleus.

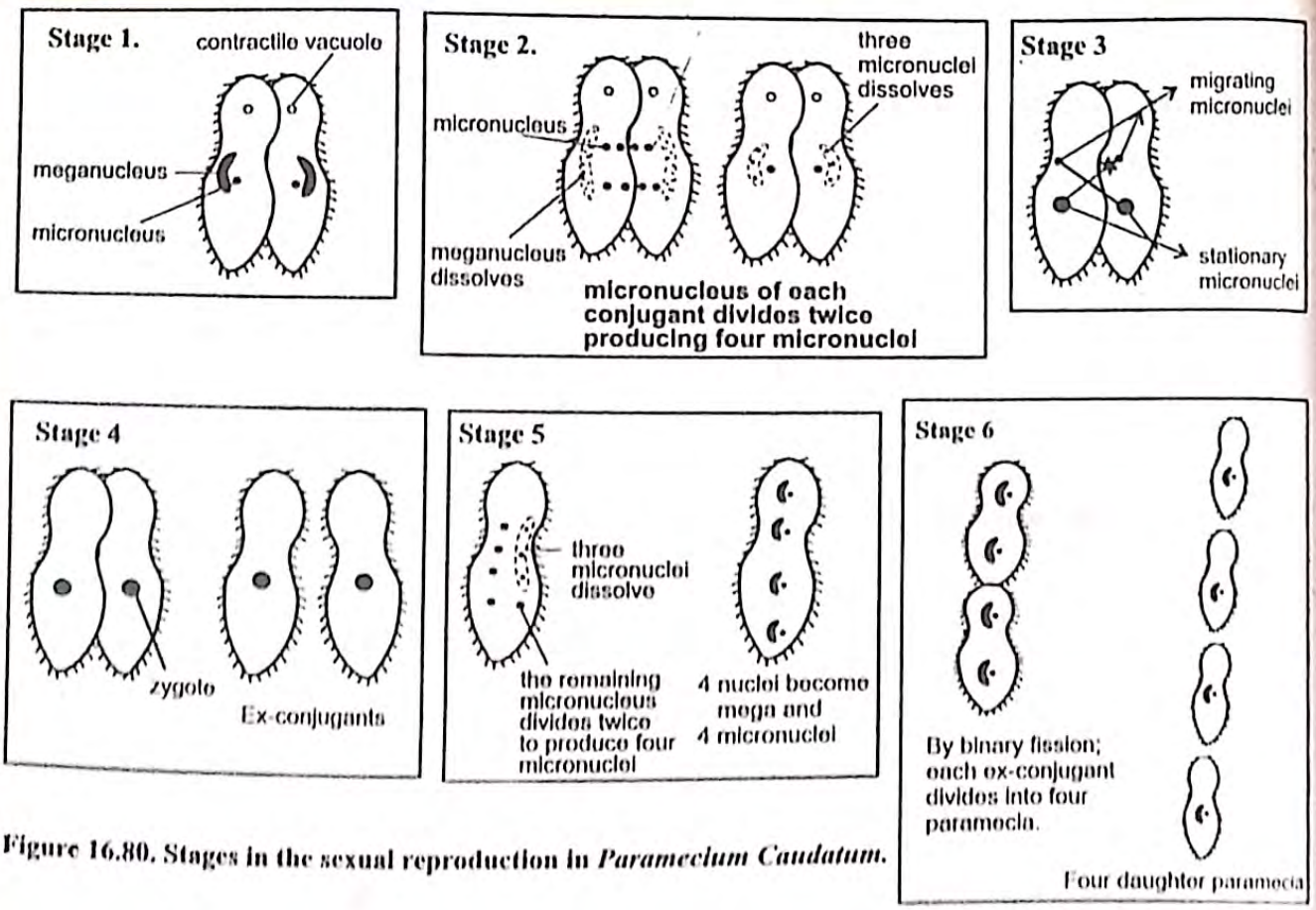



**Figure 16.80. Stages in the sexual reproduction in *Paramecium Caudatum*.**

## Sexual reproduction in *Hydra*

*Hydra*, in addition to asexual reproduction by budding, reproduces sexually by gametes. Sexual reproduction is seasonal in Hydra. It reproduces in the dry season when food is in short supply, temperature is high and osmotic concentration of the water is increased due to drying up of water. Some species of *Hydra* are **hermaphrodites** which means that one individual hydra bears both male and female structures, while sexes are separate in others. As sexual reproduction is about to take place certain **interstitial cells** form testes towards the tentacles and ovary towards the base in the ectoderm. The interstitial cells give rise to nume-rous **spermatozoa** in the testes and only **one egg** or ovum in the ovary. Mature spermatozoa are re-leased into the surrounding water by the rupture of the ectoderm covering the testes. The mature egg is not released, it is only exposed by the rupture of the ectoderm over it, so that spermatozoa can gain entry into it. The egg or ovum is fertilized in the ovary. Spermatozoa and ovum do not mature at the same time. Spermatozoa mature first. This prevents self-fertilization. When spermatozoa are released into water they swim about and eventually one spermatozoon comes in contact with the ripe ovum of another hydra and fuses with it to form a **zygote**.

The zygote is retained for long in the ovary during which a hard **spiny cyst** is secreted round the embryo. When the encysted embryo, resistant to the adverse condition is eventually released, it drops to the muddy bottom of aquatic habitat. When favourable conditions return, the cyst wall breaks open and the young hydra comes out. The mouth opens on the **hypostome**, the tentacles are formed and the animal starts to feed and grow.

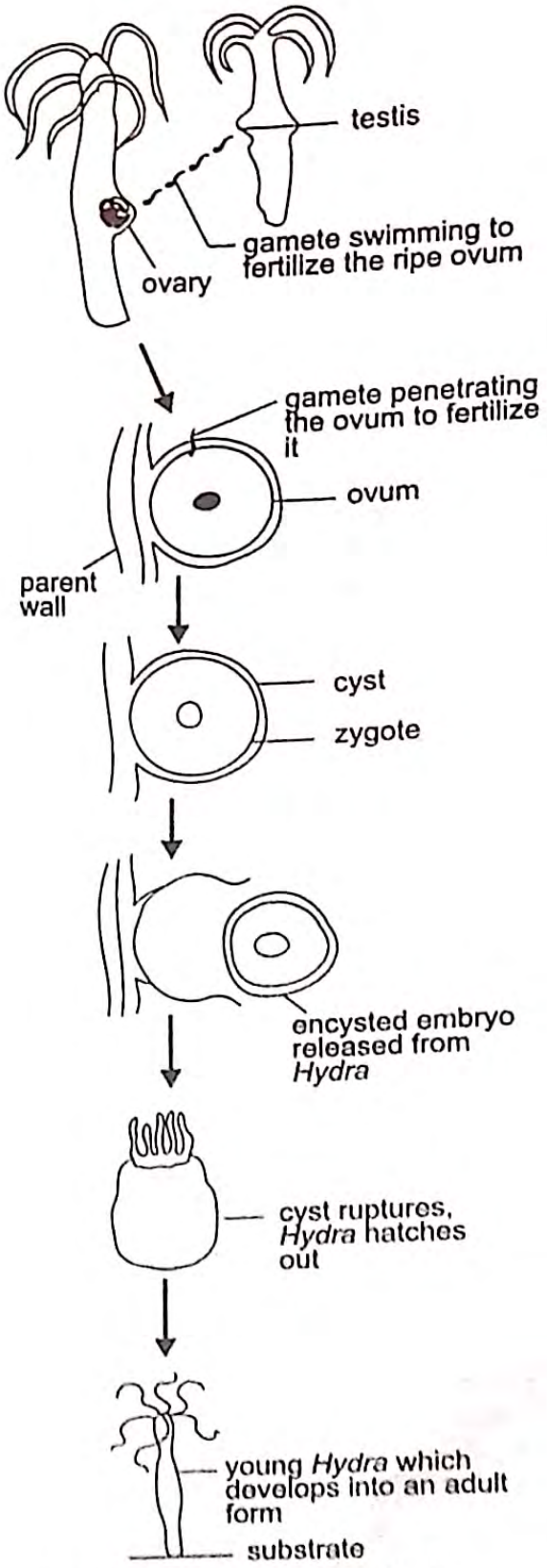



**Figure 16.81. Sexual reproduction in *Hydra***

## Reproduction in Tapeworm (*Taenia solium*)

### Life history

A ripe proglottid with fertilized eggs breaks off from the rest of the tapeworm and passes out with faeces into the soil. A man is the **primary host**. The eggs remain viable for weeks in the soil. If a pig which is the **secondary host** eats the eggs, the eggs hatch into larvae in the small intestine of a pig. The larvae bore through the wall of the small intestine and enter the general blood or lymphatic circulation and are carried to the muscles where they develop into cyst-like ABladderworm@ or *cysticerci*.

A man becomes infected when he eats a raw or inadequately cooked meat usually (pork) infected with bladderworm. The bladderworm passes into the small intestine and grows into an adult tapeworm in 5 to 12 weeks and attaches itself into the wall of the small intestine of the host by means of its hooks.

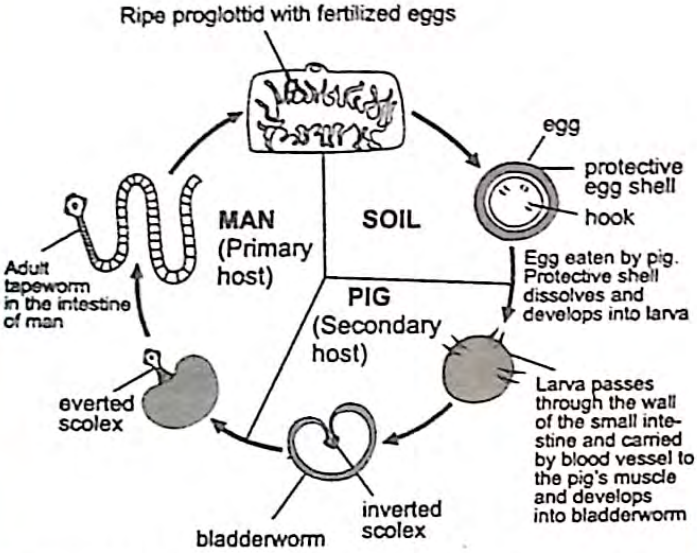



**Figure 16.82. Life history of a tapeworm (*Taenia solium*)**

## Sexual reproduction in earthworm

Earthworms are **hermaphrodites**. This means that every earthworm has both the male and female sex organs and therefore produces both male and female gametes. Earthworms reproduce by sexual method only. Even though the worms are hermaphrodites, there is however copulation between two worms leading to exchange of male gametes. The exchange of gametes ensures cross fertilization thereby preventing self-fertilization.

### Processes of copulation

Two worms to be engaged in copulation come to close together with their ventral surfaces touching. Copulation takes place at night outside the burrow. The reproductive organs of earthworm are anterior located. The worms lie in such position that the segments 9-15 of one worm are opposite the **clitellum** (segments 32-37) of the other.

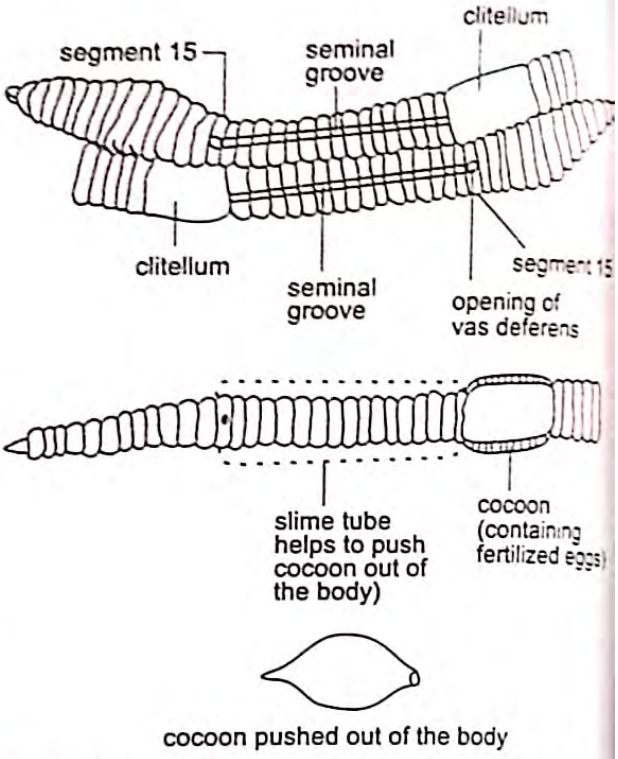



**Figure 16.83. Sexual reproduction of earthworm.**

### Earthworms in copulation position

Chaetae assist in holding the worms together in close contact throughout the copulation process. The worms secrete mucus which binds them firmly together at the points of contact. These binding tubes ensure the flow of spermatozoa in one direction and prevent **mixing of spermatozoa** during the exchange between the two worms. The worms now

discharge **spermatozoa** which are carried in the **seminal fluid** along the **seminal grooves** from **segment 15** to the **clitellum**. The seminal fluid flows into the **spermothecae** of each worm.

Spermatozoa have been exchanged and copulation has ended. The worms then separate and move into their burrows.

Laying of eggs starts some days after copulation and eggs are laid for a long time until the seminal fluid is used up. The clitellum secretes the **cocoon** in which a batch of eggs is laid. As the cocoon is pushed from the clitellum to the anterior end of the worm, seminal fluid containing spermatozoa is discharged into it. Eggs are **fertilized inside the cocoon**. The development of the embryo takes place also inside the cocoon. Only **one worm** hatches from a batch of eggs in one cocoon.

## Economic importance of earthworm

1. Earthworm burrows into the soil thereby aerating the soil.
2. It loosens the soil particles thus making it easier for plant roots and water to penetrate.
3. It drags leaves into its burrow thereby increasing the humus contents of the soil for luxuriant growth of plants.
4. Its burrowing activities help to mix top soil with sub soil thereby improving the soil texture.
5. Its faeces and dead body add nutrients to the soil.
6. It is used as food by some birds and other animals contributing to their well being.
7. It is used as bait for fishing by anglers (fishermen who fish with rod and line).

# Insects

## Metamorphosis (*meta = change; morphe= form*)

**Metamorphosis is the series of gradual changes that occur during the development of an animal from the zygote (fertilized egg) to the adult stage.** There are two types of metamor- phosis in insects. These are **complete metamor- phosis** and **incomplete metamorphosis.**

In the **complete metamorphosis**, the egg hatches into larva, the larva changes to pupa and pupa finally changes to an adult. Examples are housefly and butterfly.

Egg ------> Larva ----->Pupa --->Adult

In the **incomplete metamorphosis**, the egg hatches into a nymph (in insects) which resembles the adult form except that there are no wings, the gonads are not yet developed and is very small in size. There is no pupal stage. Examples are cockroach and termite.

Egg---->nymph----->adult (cockroach or termite)

**Metamorphosis** provides the juvenile and adult forms to live in different habitats, feed on different kinds of food items thereby reducing competition for space and food resources. For example, the adult butterfly feeds on nectar of flowers with its proboscis while the larvae feeds on leaves with the help of its mandibles. The adult toad lives on land and feeds on insects and worms while tadpoles are aquatic in habitat and feed on aquatic weeds.

**Molting** is controlled by molting hormone (**ecdysome**). The number of times molting takes place depends upon the quantity of molting hormones present in the juveniles (nymphs) or larvae and pupae. When the quantity of molting hormone is high, another molting takes place producing another larva or nymph. But when molting hormone is low, the larva produces the pupa and when lowered further, it then leads to the formation of the adult stage.

**Table 61. Differences between incomplete and complete metamorphosis**

| Incomplete metamorphosis | Complete metamorphosis |
|---|---|
| 1. Development of wings is external during the juvenile stage. | Development of wings is internal during the larval stage and only appears externally at pupal stage. |
| 2. There is no pupa (resting) stage. | There is a pupal (resting) stage. |
| 3. Nymph similar to the adult is present. | No nymph stage is present. |
| 4. No larva stage. | Larva stage which is quite different from adult is present. |
| 5. Nymphs and adults live in the same habitat and food. | Larvae, pupae and adults live in different habitats; preventing competition for space and food. |
| 6. Nymphs and adults feed on the same food items leading to competitions for food and space. | Larvae and adults feed on different food items preventing competitions for food and space. |

## Complete metamorphosis (*meta=change; morphe=form*)

## Butterfly

### Mode of life

The yellow butterfly is a day time (diurnal) active insect. It flies from one flower to another in search of nectar which it feeds upon, pollinating flowers in the feeding process. It rests at night with its proboscis coiled. Its flight is weak and slow.

## Complete metamorphosis in butterfly

The butterfly passes through a complete metamorphosis. This comprises the egg, larva, pupa and imago.

### The egg

The female butterfly lays its eggs in a small batch on the under surface of a leaf of a selected plant that will provide food for the caterpillar. The eggs are therefore shaded from direct rays of sunlight and hidden from view of possible predators. They are also protected from being washed away by rain drops from other leaves. Each egg is rounded or spherical in shape and it is about the size of the head of an office pin. It is coloured blue, green or white according to the species of the butterfly.

### The larva (Caterpillar)

The eggs hatch into the **larvae** in about 10 days. The larva of a butterfly is called **caterpillar.** The caterpillar is worm-like. The body is hairy which makes it to look dirty and unpleasant to eat by predators. It has a cylindrical body which consists of a head, thorax and abdomen. The head is rounded in shape. It bears a pair of short and segmented antennae, three pairs of simple eyes (ocelli) and a pair of powerful mandibles. The powerful mandibles help in grinding the egg shell which serves as the first meal of the larva (caterpillar). Later the larva feeds on the leaves of the plant frequently using the mandibles to cut and grind leaves for food. The thorax consists of three segments, each bearing a pair of short jointed true (thoracic) legs for crawling and attachment to leaves and twigs.

The abdomen consists of **ten segments** each bearing a pair of spiracles. Four pairs of false legs called **prolegs** are borne on the third, fourth, fifth and sixth abdominal segments. The last abdominal segment bears a pair of **claspers** for attachment. As the larva grows, it moults about **five times** in about one month. After the fifth moult, the **caterpillar** spins thread-like silk around itself and becomes a **pupa** which is motionless and does not feed. The pupa of a butterfly is called **chrysalis.**

The pupa hangs itself on the twig with the silk **thread.** Internal organs of the adult are formed at this stage. After the complete formation of the adult organs in about a month or more, the pupal case splits open and a **young imago** emerges. After resting for about three hours, its wings become fully stretched and flies away in search of food and mate. The adult butterfly feeds on nectar of flowers with its proboscis.

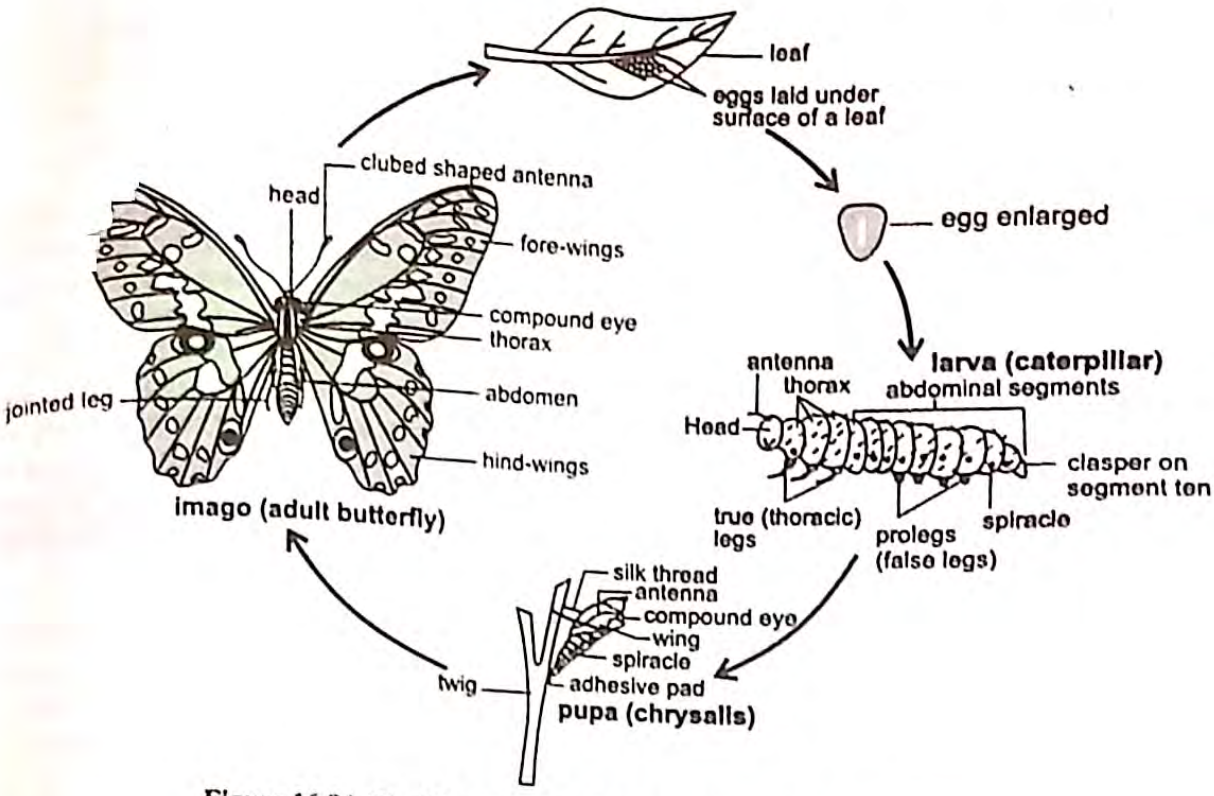



**Figure 16.84. The life cycle of a citrus swallowtail butterfly.**

## Economic importance

1. The adult butterfly is a very useful insect. It pollinates flowers during its visit to flowers in search of nectar. Pollination brings about fertilization of flowers leading to production of seeds and fruits hence increase in food production for man.
2. The larvae referred to as caterpillars are very destructive to plants. Caterpillars feed greatly on the green leaves and young stems destroying them during the feeding process. The photosynthetic activity plants may be greatly reduced and therefore food production will also be greatly reduced leading to shortage of food for man. In some cases, the attacked plants may die.
3. In trying to control the caterpillars, a lot of money is needed to buy chemicals to kill them.

## Complete metamorphosis in housefly or mosquito

### Housefly

The adult male and female mate. Within two to three days fertilized eggs are laid. The laying of eggs takes place in the day light. The female alights on the material to which it is attracted, generally decomposing organic such as human and animal faeces. The eggs are laid in **five** or **six batches** of one hundred to one hundred and fifty. The eggs are creamy white with length of about 1mm. They are like the shape of banana. The eggs hatch in about 6-12 hours depending on favourable temperature into tiny white **larvae (maggots).**

#### Larva

The larva has small head bearing hooked mandible which enables it to move and for tearing of its food. The head can be withdrawn into the body. Eyes and legs are absent. There are **twelve segments** behind the head. The first three segments form the thorax. There are small pads on the segments which also aid locomotion. The first thoracic segment bears a pair of anterior spiracles while another pair of posterior spiracles are present on segment twelve. The larva feeds continuously and hiding away from the surface. It moults two times. Before pupation, the third stage larva stops feeding and then migrates

usually at night from the breeding material particularly if the breeding material is still moist. It then burrows into the soil (few mm) and in loose dry soil it burrows further. To pupate, the larva contracts its length and becomes barrel-shaped. The larval stage lasts for five to fourteen days.

### *Pupa*

The pupa is shorter in length than the larva. It is barrel-shaped. The skin of the third stage larva form the **puparium**. It becomes hardened and brownish in colour. The anterior and posterior **spiracles** are still present. The pupa stage is the **resting stage** where internal reorganization of body organs takes place.

### *Imago*

The imago emerges in about four to five days in warm weather. The **puparium** cap is forced open by **ptilinum** which helps the fly to come out of the soil. On reaching the surface, the fly rests until its wings are unfolded and body wall hardens. It flies off in search of food. After a few days, it finds a partner and mates. The process of the female laying eggs starts again. The imago is divided into head, thorax and abdomen. The head has one pair of large compound eyes, three ocelli, one pair of antennae. The thorax is divided into prothorax, mesothorax and metathorax each carrying one pair of jointed legs. The mesothorax carries one pair of wings and metathorax carries one pair of modified wings called **halteres** which act as stabilizers during flight.

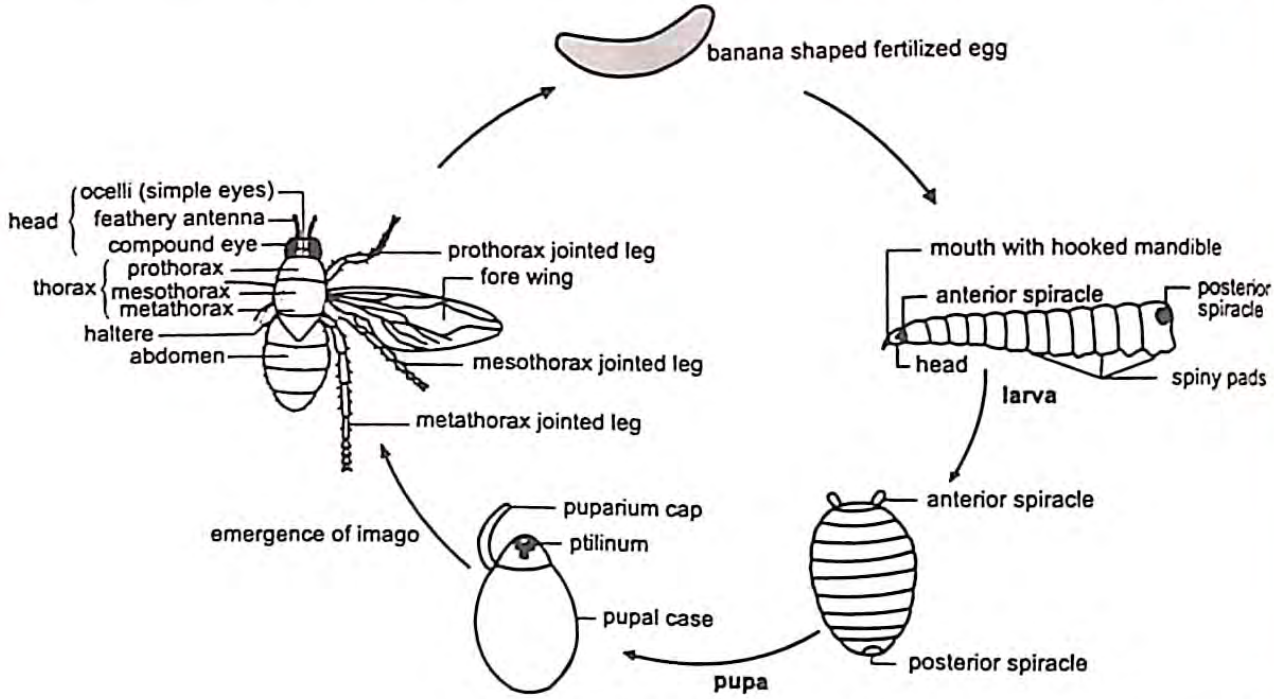



**Figure 16.85. Stages in the metamorphosis of housefly.**

## *Economic Importance.*

The economic importance of a housefly lies on its disease transmission. A housefly is the vector of viruses, bacteria and protozoans which cause polio, cholera, typhoid fever, yaws and dysentry. A housefly also carries ova of cestodes and nematodes to our food causing worm infection.

## How a housefly is adapted to transmit diseases

1. **Hairy body:** The body of the fly is hairy; this makes it easy to pick up disease germs in any part of its body to our food. The tips of the legs are wide with adhesive pads. This sticky nature of the pads enable them to pick up disease germs easily.
2. **Indiscriminate habit of feeding:** The indiscriminate habit of sucking nourishments of wide varieties of substances including food of man, excretion such as faeces, sputum, pus of sores, wounds and nasal easily make it to be contaminated with diseases.

3. The fly is able to **regurgitate** (vomit) fluid from the crop to moisten solid food. This brings viruses and bacteria picked up from the faeces and other places to our food.
4. Housefly defecates constantly on our food thereby contaminating our food with bacteria and viruses it has taken to the digestive system.

### Control

***Control measures against the larvae and pupae***

1. Breeding materials and places should be located and cleared off.
2. Breeding grounds should be sprayed with chemicals such as Diedrin to kill them.

***Control measures against the adult***

1. Screening of doors and windows of houses and kitchens will prevent the flies from entering our houses to contaminate food.
2. Screening foodstuffs in markets or putting food items in glass cases will prevent contamination of foodstuffs or food by flies.
3. Using very sticky resins or poisons to kill the flies.
4. Spraying with domestic pesticides kills them.
5. Using good latrines (such as water system type) will prevent the flies from carrying germs from the faeces to our food.
6. Houseflies should be killed physically when seen.

## Complete metamorphosis in mosquitoes (*Anopheles, Culex* and *Aedes*)

### Mating and laying of eggs

The adult male and female mate. The female lays fertilized eggs on the surface of a stagnant water. Eggs are laid in partially sunny but shaded places. Female *Anopheles* and *Aedes* mosquitoes lay eggs singly while Culex mosquito lays eggs in batches. (Students can describe any the named mosquitoes above such as *Anopheles*, *Culex* or *Aedes*).

## Anopheles mosquito

Here the author describes the life history of anopheles mosquito.

## Egg Laying

About 300 eggs are laid singly. The eggs are boat shaped, with air-floats to keep them floating. After about two days, the eggs hatch into larvae.

### *Larva (Wriggler)*

The larva has a distinct head, thorax and abdomen. The head has a pair of antennae, and mouth brushes for collecting food particles in the water. A pair of eyes is present. Movement is by wriggling.

The thorax is the largest portion of the body. The abdomen is the longest and is divided into nine segments. The eighth abdominal segment bears a pair of **breathing spiracles**.

At first, the young larva absorbs oxygen from water and feeds on suspended particles. Later, it breathes the atmospheric air through a pair of breathing spiracles. The larva moults **four times**. After the fourth moulting, it changes to a pupa.

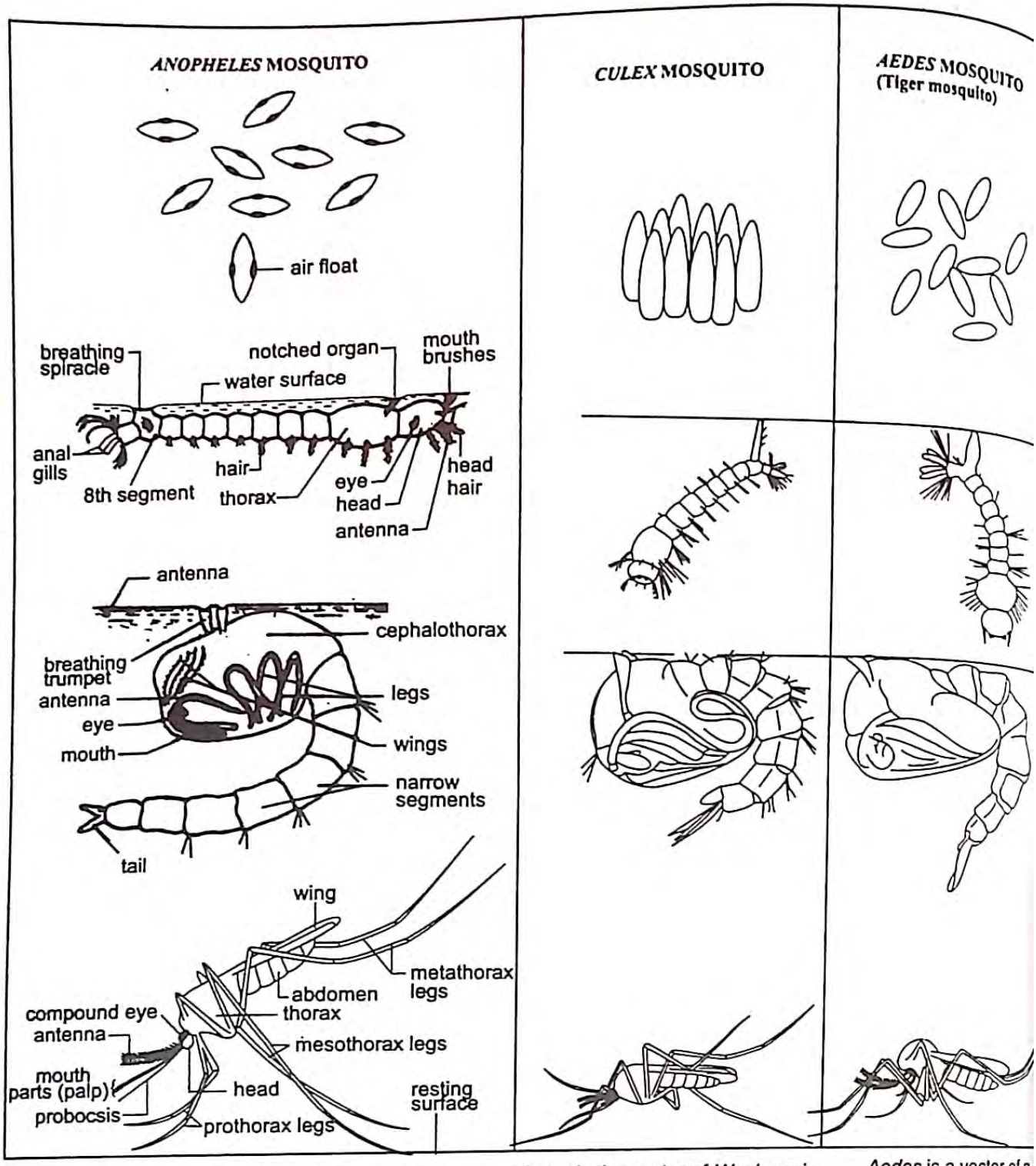
### *Pupa*

The body of the pupa consists of **cephalothorax** (head and thorax fused together) and a narrow and segmented abdomen. There are two **breathing tubes** (breathing trumpets) projecting from the cephalothorax which hang on water surface for breathing the atmospheric air. The pupa does not feed. When disturbed, it carries out wriggling movements downwards into the water. The pupa stage lasts for about 2 days after which it changes into imago (adult).

### *Imago*

It rests on the surface of water for some hours for the wings to expand and harden. Mating takes place and eggs are laid. The cycle starts again.

The adult rests in a sloping position with head downward forming an angle of 30-40° with the resting surface.




*Anopheles* is the vector of *Plasmodium* (malaria parasites - protozoans which cause malaria fever)

*Culex* is the vector of *Wuchereria bancrofti* ( a roundworm which causes elephantiasis or filariasis).

*Aedes* is a vector of a virus which causes .yellow fever.

**Figure 16.86. Stages in the metamorphosis of anopheles mosquito**

## CONTROL

### Control measures could be achieved in three ways:

1. Against the vectors ( mosquitoes).
2. Measures to reduce contact with the vectors.
3. Against the parasites in man.

**Against the vectors:** These measures are against adult mosquitoes, larvae and pupae.
**Adult mosquito control:** Spray all living places with insecticides such as pyrethrum to kill the mosquitos. Kill any mosquito physically. If seeing

### Against larvae and pupae:

1. All breeding places should be filled with soil.
2. All broken vessels which can retain water must be turned upside-down.
3. Where drainage is not applicable, kerosene or oil mixed with pyrethrum should be poured on the water surface to kill both the larvae and pupae since the oil layer will prevent respiration.
4. Paris green is also used in the control of the larvae. Pouring Paris green on the water surface and subsequent consumption of the chemical by larvae and pupae kills them.
5. Introduce fish such as *Alestes* and *Tilapia* to feed on the larvae and pupae. This is a biological control.
6. **Reduction of contact with mosquitoes.**

a. When siting living houses, avoid marshy areas that are breeding grounds of mosquitoes.
b. Screen living houses with wire gauze to prevent mosquitoes from entering.
c. **Use of mosquito nets.** Sleep under mosquito net to prevent mosquitoes from biting you.
d. Wear anti-mosquito clothes that repel mosquitoes.
e. Use mosquito repellant such as Dimethyl phthalate to rub the body. This chemical repels mosquitoes.

7. **Against parasites in man:** Use preventive drugs such as Daraprin or Paludrine. Taking one tablet every week will help to prevent malaria attack.

### Mode of transmission of malaria parasites

By the bite of an infected female anopheles mosquito.

**Symptoms**

Fever, headache, vomiting, body pains, high body temperature, profuse sweating, bitter mouth and loss of appetite.

**Treatment**

Curative drugs such as nivaquine, chloroquine, resochin, etc will help to destroy the parasites in the blood.

## Economic importance

**1. Vector of parasites**

Mosquitoes are of great economic importance as they are vectors carriers of parasites that cause malaria fever, yellow fever, filariasis (elephantiasis) and dengue fever. Malaria fever alone kills over three million people world-wide every year. These blood sucking mosquitoes transmit the parasites by sucking blood from an infected person and transmitting the parasite to another uninfected person through their bites. The female mosquitoes need blood meal to nourish their eggs before laying are the vectors (carriers) of malaria parasites.

**2. Cost of treatment and prevention**

A lot of money is spent in buying drugs for the treatment and prevention of malaria. The purchase of mosquito nets and insecticides require money. Many people especially the poor can hardly afford money to buy drugs leading to frequent malaria attack.

**3. Low productivity**

Mosquito diseases cause ill-heath. Sick people especially workers are less efficient in their working places resulting in low economic productivity.

4. The financial cost of destroying the breeding grounds of mosquitoes is high.
5. **Sleep disturbance:**

The biting and buzzing noise of mosquitoes at night disturb sleep may result to an ill-heath and lack of mental concentration.

## Incomplete metamorphosis in cockroach.

### Mode of life of cockroach

Cockroaches are nocturnal active insects. At night, they run about with their raised antennae which are frequently waved in the air to feel and smell the environment. When suddenly frightened, they can carry out short aerial flight to escape from

possible enemy. They are dorso-ventrally flattened hence they can hide in crevices, making them difficult to catch.

In the day time, they hide in holes, drawers, cupboards, cracks, boxes, bookshelves and dark places. Cockroaches are omnivorous scavengers, feeding on a wide range of food items such as bread, sugar, biscuits, dead insects, books, papers and clothing. When caught, they quickly release an offensive chemical odour to prevent predators from catching them.

### The life history of cockroach

The cockroach is an example of an insect with an **incomplete metamorphosis**. Male and female cockroaches mate. The male introduces sperm into the **genital** opening of the female. The sperm are then stored in **sperm pouch** until the eggs are released from the two ovaries. As the eggs are released, they are fertilized by the stored sperm. Fertilization is therefore internal. The fertilized eggs are arranged in groups of 16 inside purse-like, leathery, hard and brown **egg cases** or **oothecae**. The leathery and hard **egg-case** prevents water loss and gives protection to the egg. The brown colour blends with the environment thus offering protective camouflage. The ridged surface of the **egg-case** is for firm attachment to substratum. The 16 fertilized eggs in each egg-case are arranged in two rows of 8. The female cockroach carries the egg-cases about for some time in her abdominal **pouch** of the seventh segment before depositing them in a suitable dark place. The egg-cases are then cemented against the place they are deposited. After about 30 to 90 days, the eggs hatch into **nymphs** which resemble the adult in all respects except that they are very small, wingless, colourless and their reproductive organs are not developed. The nymphs feed, grow and become dark brown in colour and moult. Moulting occurs about six or seven times before adult size is attained. In the later moults, wing buds appear and in the last moult, the wings and body attain full size. It takes about 40-60 weeks for the nymphs to reach adult size.

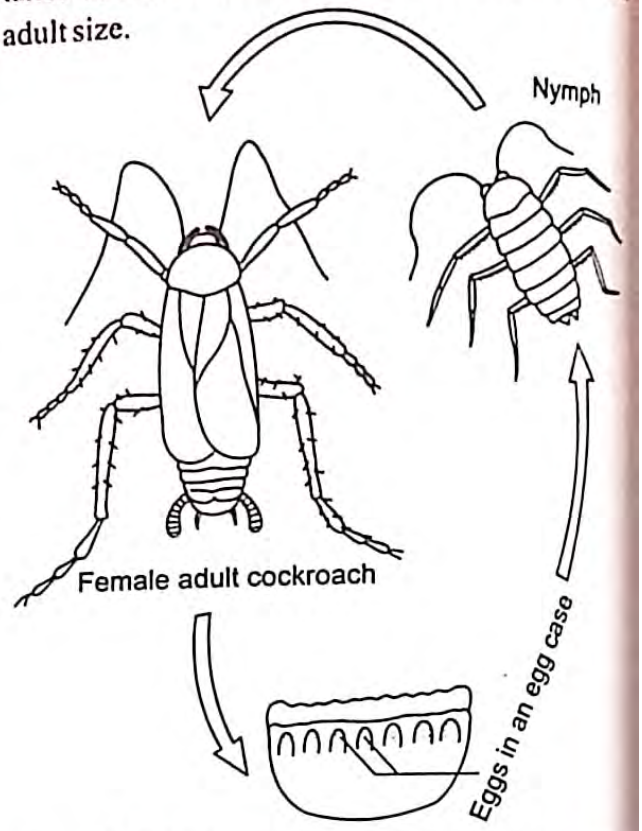



**Figure 16.87. Stages in the life history of cockroach**

### *Economic Importance*

1. Cockroaches are household pests, destroying books, clothes, food and other useful materials.
2. Since they eat indiscriminately, they have been known to contaminate our food with diseases such as cholera, dysentry and tuberculosis.
3. They deface materials such as clothes with their faeces.
4. Their repulsive odour and dirty habits make them a nuisance.

### *Control:*

1. Commercial insecticides when sprayed into their hiding places help to kill them.
2. Kill physically all cockroaches when seeing.
3. Since cockroaches develop in dirty places, good house cleaning practices are important in reducing their population.

## Social insects

### Termites

### Mode of Life

Termites are social insects that spend most of their lives in their constructed tunnels. Some live in soil, wood, while others live in their own built anthills (termitaria) well above the ground (about 2.50metres in height or more) commonly found on farmland, grassland and wasteland.

Termites have preference for cool and humid environment. They avoid bright light. Food gathering outside the anthill is usually early morning and late evening. They are saprophytes feeding on dead wood and leaves. There are different castes namely: **workers, soldiers, reproductives, queen** and **king**. These castes have their different specific functions.

Termites live symbiotically with certain micro-organisms (bacteria and protozoans) in their intestines. Workers feed on plant cellulose. They, therefore, rely on these micro-organisms to predigest the cellulose in their intestines. The predigested food is then fed to the queen, king and nymphs by regurgitation from their intestines. The nymphs acquire the micro-organisms by the food they eat from the regurgitated food of the workers.

**Termites are regarded as social insects because of the following reasons:**

1. They live together in nests or colonies.
2. There are distinct castes or individuals.
3. There is a clear division of labour.

The name of different castes of termite nest are:

1. **workers** (2)**soldiers**(3) **queen**
4. **king** and (5)**winged reproductives (alates)**

**The functions of each caste**

**Workers:** They are blind, wingless and sterile females. They build the nest, gather food, take care of the nymphs, clean the nest, repair the nest and feed other members of the nest by partially digested **regurgitated food.** They remove the eggs away from the queen's royal chamber to another chamber for care and development.

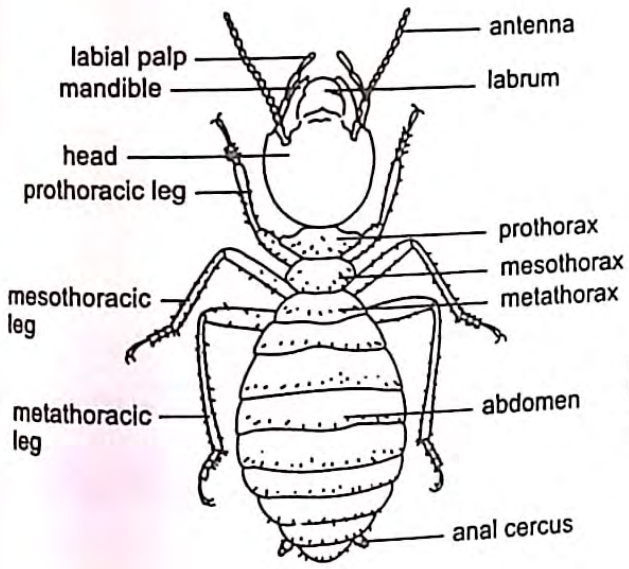



**Figure 16.88. Dorsal view of worker caste of *Macrotermes bellicosus***

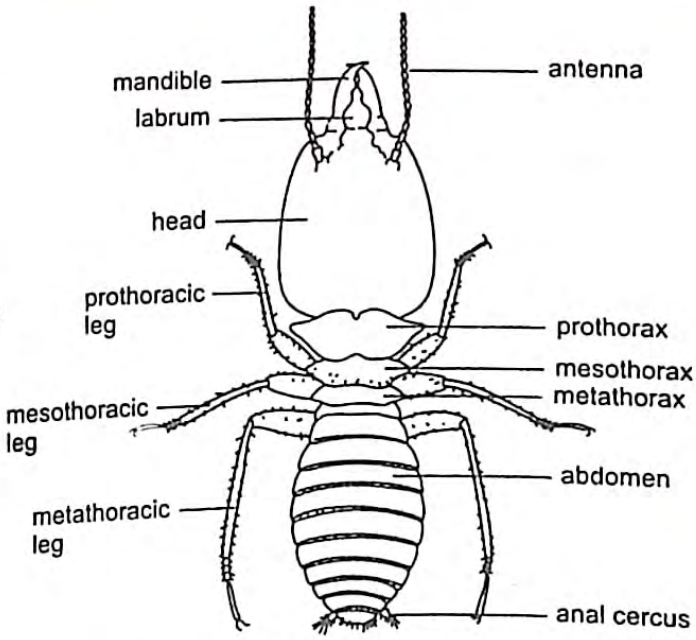



**Figure 16.89. Dorsal view of soldier caste of *Macrotermes bellicosus***

**Soldiers:** They are blind sterile males. They defend the nest from enemies and also protect the workers during food gathering.

**Queen:** They only duty of the queen is to lay eg
She can live up to 30 years.

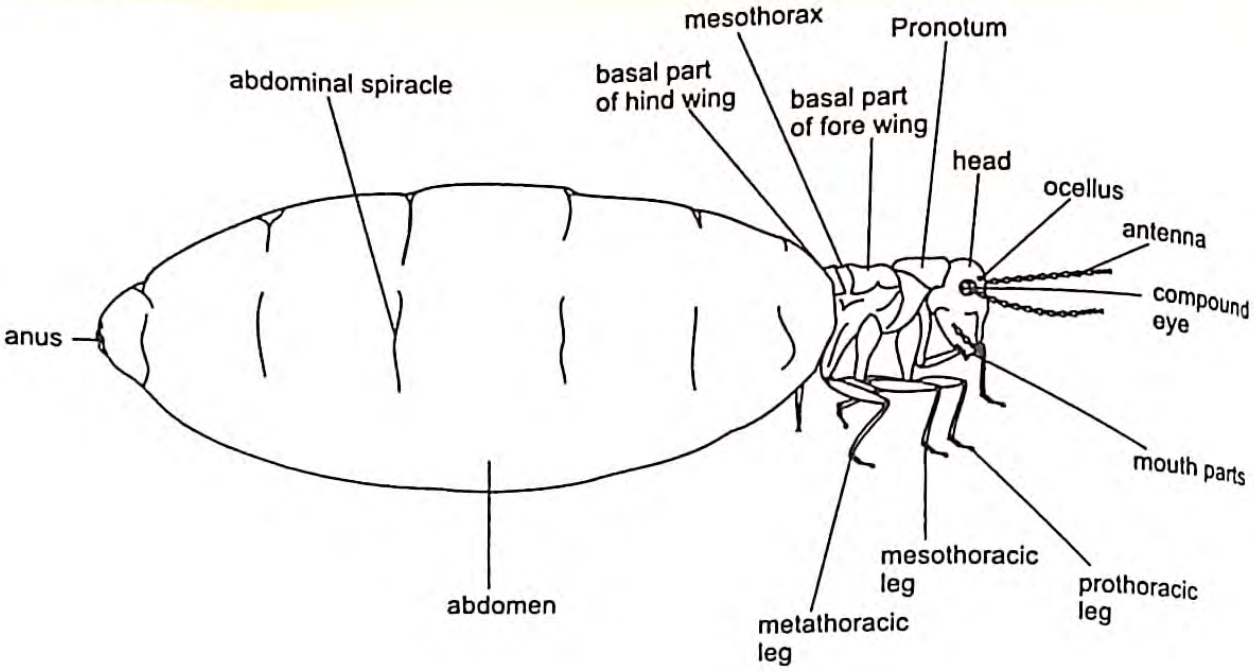



**Figure 16.90. Side view of queen of *Macrotermes bellicosus*.**

**King:** Mates with the queen to fertilize her eggs.

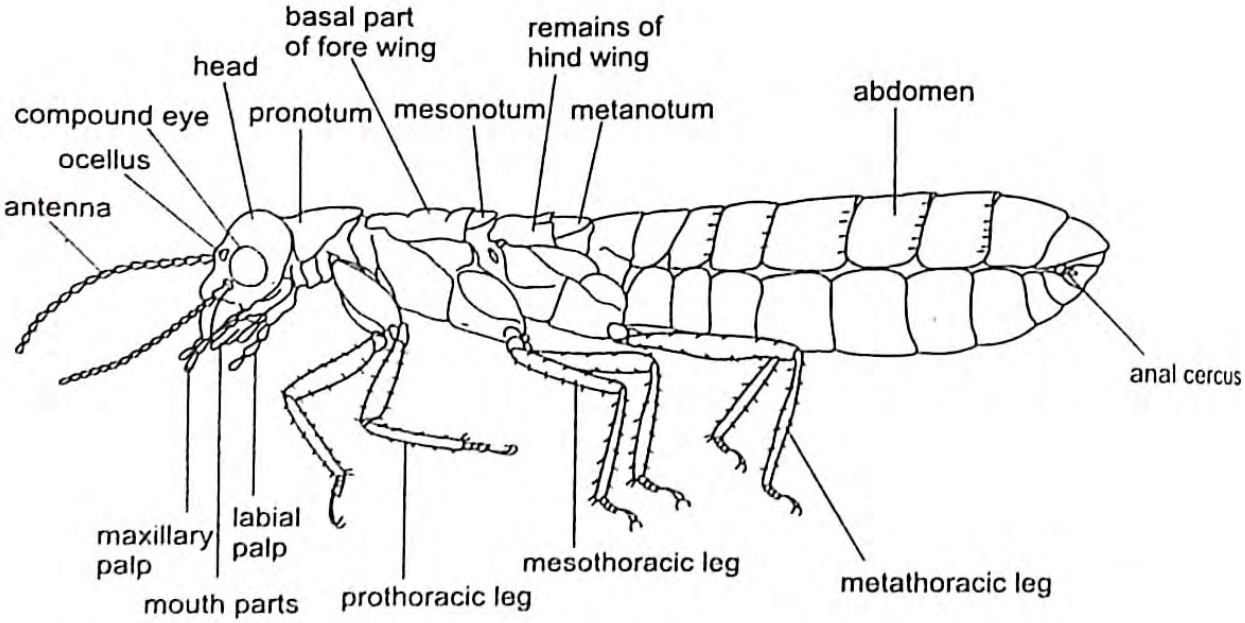



**Figure 16.91. Side view of king of *Macrotermes bellicosus*.**

**Reproductives (alates)**

1. They are future queens and kings of new colonies. They have wings.
2. They help to form new colonies.

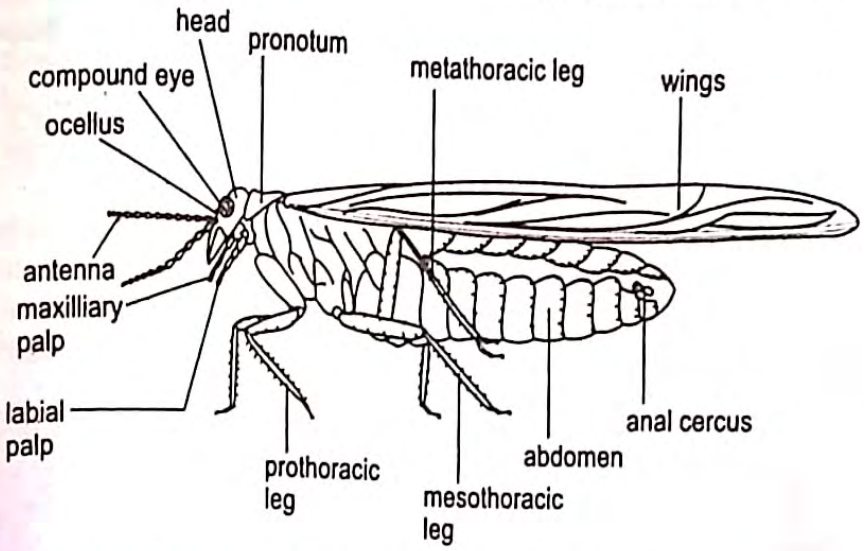



**Figure 16.92. Side view of winged reproductive caste of *Macrotermes bellicosus*.**

(All the diagrams of *Macrotermes bellicosus* were traced from S.L.O. Malaka *(1996)* and is duly acknowledged)

**Termite mound**

## Life history of mound termites (*Macrotermes bellicosus*)

Termite is another example of an insect with **incomplete metamorphosis**. When the colony (anthill or termitarium) is becoming over-crowded leading to possible competition for food, space and air leads to an establishment of a new colony by swarm of reproductive castes. Also when the queen is showing signs of old age, the workers stave her to death and eat up the body. Before swarming, workers make holes on the walls of the termitarium for their exist. Male and female reproductives leave the colony in about equal numbers in swarm and undertake a **nuptial (mating) flight**. Since they are weak flies, the nuptial flight is not usually far away from the old anthill. Nuptial flight is often undertaken after heavy rainfall which softens the soil for an easy excavation. Rainfall also provides much needed high moisture during the initial formation of the colony. They are attracted to any source of artificial light such as electric light, lantern light and gas light. Within a short time, the weak and over-sized wings break off and they start crawling on the ground. At this time, predation from animals such as birds, lizards, toads, snakes and even man is high. However, few survive the predation and crawl about on the ground and pair up while looking few a suitable new site to establish a colony. On finding a suitable site, one member of the pair becomes a king while the other becomes a queen. They now construct a small tunnel on the soft soil. The king and queen then mate. The queen starts laying small

quantity of eggs (about 15 to 60) that hatch into nymphs that she and the king can nurse and feed. As the population of the workers increases, the duty of nursing the eggs and nymphs (including feeding) are completely taken over by workers. The workers construct a royal chamber or cell for the king and queen. Workers remove all laid eggs from the chamber as they are laid. Eggs hatch into nymphs. Nymphs after moulting for about three to four times become adults. Some of the nymphs metamorphose into **workers, soldiers** and **winged reproductives**

**Economic importance of termites**

Termites are both harmful and useful to man.

### Harmful effects

1. They destroy roofing timber of houses, wooden doors, windows, tables, chairs, boxes, clothes, ceilings, leathers and fabrics such as polythene, plastics, metal foils and books.
2. Many species of termites attack and destroy economic plants such as cocoa, cassava, groundnuts, maize, guinea corn, yams, mango, oil palm, rubber.
3. Termites attack and destroys wooden electric poles and insulation of electric cables.
4. Termites drive earthworms from soil that enhance soil fertility.
5. When they form their anthills within the roots of trees, the soil is loosened thus weakening the anchorage of trees and forcing the trees to fall during strong winds.

### Usefulness of termites

1. They are eaten by many people as they provide good source of animal protein. In some parts of the world, termites are regarded as delicacy.
2. They carry vegetation into their tunnels which when decay add manure and humus to the soil. They also feed on dead vegetation thereby returning plant remains to the soil and speeds up decay.
3. Their termitaria (anthills or mounds) could be used in painting houses especially in rural areas.
4. The anthill materials are good fertilizers for soils and are used to make earthen pots.
5. The anthill materials are used to cover the surface of athletic tracks and tennis courts.
6. Tunnels of termites help to aerate the soil, affording the roots of plants dissolved oxygen for respiration.
7. Termites improve soil fertility by breaking down dead leaves and wood on the soil surface.
8. When they form their anthills within the roots of trees, the soil is loosened thus weakening the anchorage of trees and forcing the trees to fall during strong winds.

### Control

Termites could be controlled by the following methods:

### Direct attack on the anthill

1. Make three or four big holes on the top of the anthill. Pour 27.3 litres of water containing 71ml of dieldrin or aldrin into the holes in equal volume. This method will kill all the termites in the anthill. This method is only applicable to nest-building termites that disturb sports arena, farms etc.
2. A mixture of 250ml of dieldrin or aldrin to 68.20 litres of water and sprayed on soil is effective in preventing termite infestation.
3. Before framing a house with timber, it is advisable to treat the planks with preservatives such as solignum.

### Biological control

Some ants (*Monomorium* sp, *Acantholepis* sp and *Oecophylla longinoda*) prey on certain termites species. Therefore breeding these ants and introducing them to termite infested area will control termite population.

### Honeybees *(Apis mellifera)*

### Mode of Life

Bees are social animals (insects) living in a large number in a **nest (hive)** and in different **structural forms (castes)** performing different functions to the overall well being of the **colony.** This social structure is obligatory and necessary for the successful existence of the species. The society is so perfectly organized to the extent that it does not usually accept members of other colonies of the

same species. They show a clear example of **perfect cooperation and hard work.**

The colony of honeybees which is over 75,000 individuals consists of the **three castes - the queen** ( reproductive female), **workers** (sterile females) and **drones** (males). These castes share the various duties of the hive. This sharing of the various duties by the different structural forms is termed **division of labour.**

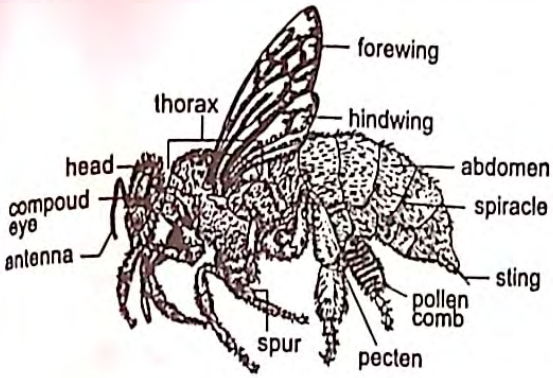
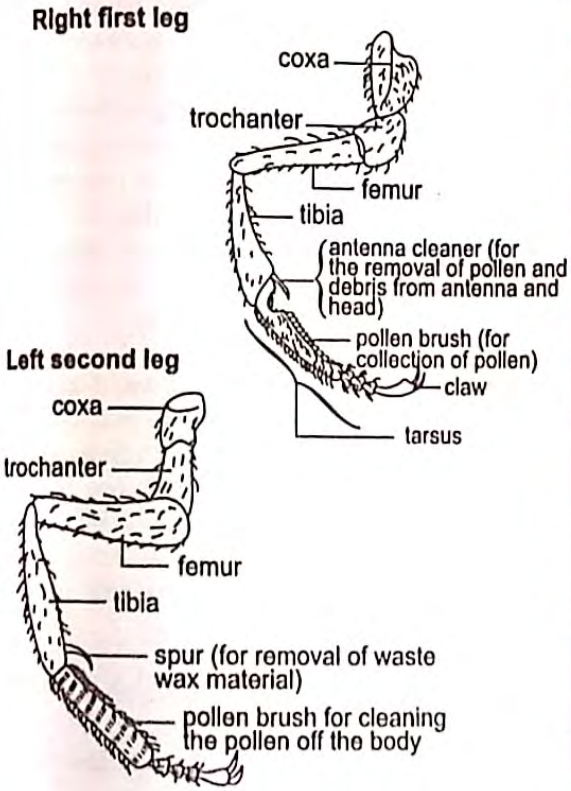



**Figure 16.93. A honeybee worker, showing external feature.**



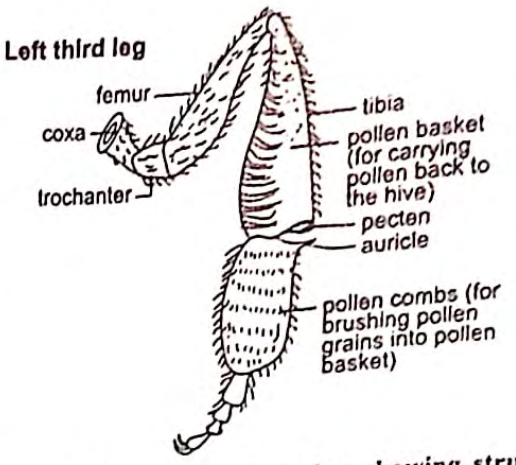




**Figure 16.94. Legs of honeybee showing structural adaptations for different functions.**

## The roles of the three castes: Queen, Workers and Drones

**Queen (reproductive female or the mother of the colony).**

The **queen** is the **only fertile female** bee in the hive. It is twice as large as the worker bee. The queen is developed from a **fertilized egg** and brood in the largest special wax cell called **royal cell** and fed from the richest food called **royal jelly** made from **honey pollen, nectar** and **special secretions** from the **mandibular glands** and thoroughly mixed together.

**Functions**

The queen alone lays all the eggs that hatch and develop or metamorphose into workers and drones of the colony.

**Workers (sterile females)**

The **worker bees** are the most **active caste** of the colony. They acquire the appellation as **Abusy as the bees".** These field bees are the most specialized in the colony. They have leg parts structurally adapted for the collection of pollen grains from various flowers, removal of pollen grains from the antennae and the hairy body.

The workers are the most numerous in the hive and perform the following functions:

1. They go out of the hive daily collecting nectar and pollen grains which they mix with honey to form bee-bread.
2. Feeding of the queen, with royal jelly, while the drones and the larvae of others in the brood cells with bee bread.
3. Building of the six-sided wax cells of the comb in the hive.

4. Cleaning of the hive.
5. Wing-fanning of the hive to reduce heat and to evaporate excess water from the honey before the honey cells are sealed.
6. They guard and defend the hive aggressively by stinging any intruder that comes near the hive thus ensuring the protection and survival of the population.

**Drones (males)**

The **drones** are male bees that develop from **unfertilized haploid eggs** laid in the **normal brood wax cells** and their larvae are fed from **nectar** and **pollen grains** known as **bee bread.** They are larger than the workers but smaller than the queen. They have **broad thick bodies** with **large eyes** and **powerful wings.** They have short hypopharynx (tongue) which cannot obtain nectar from flower.

**Functions:**

The sole function of the drones is for one of them to mate with the queen to fertilize her eggs.

**Figure 16.95. The different castes of the honey bee.**

## Life history

Honeybees are social insects that undergo **complete metamorphosis** under the following stages:

1. Population increase of colony (hive).
2. Emergency of a new queen in the old colony.
3. Swarming and nuptial (mating) flight.
4. Establishment of a new colony and egg-laying.

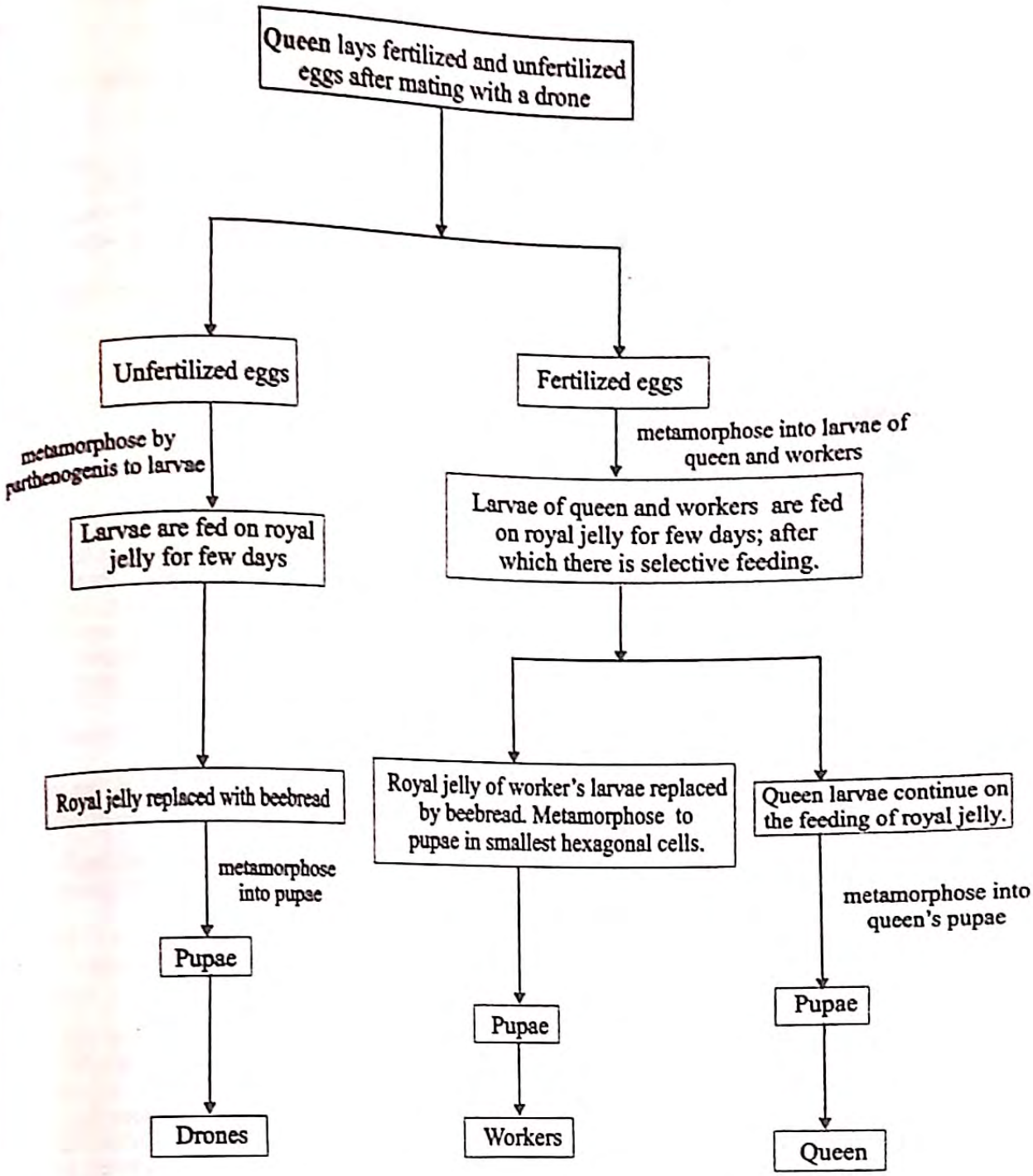
**Population increase of colony (hive)**

Increase in population beyond the capacity of the hive leads to overcrowding and competition for air, space and food. The existing queen then leaves the hive with a swarm of about half the population of the workers and drones. They undergo a flight journey to establish a new colony and in some cases they stop on their way forming a cluster of bees on tree branch(es) and even a wooden plank of uncompleted building in a town. This temporary stopover may last for about 1-3 days depending upon when a new site which is usually a tree cavity has been found by some workers referred to as **Ascouts**".On locating a new site, the **Ascout bees**" return to inform the migratory bees and the flight journey resumes. On arriving, the workers collect **propolis** (combination of resins) which they use in sealing up all holes except the entry hole. The sanitation of the hive starts after which the construction of the six-sided (hexagonal) wax cells in plates (combs) starts. The cells are constructed close together like walls so that the opposing ends of their cells are sealed up leaving other ends of the cells open for the queen to lay eggs. These open ends are sealed up later by workers when larvae metamorphose into pupae. On settling down in the new colony, the old queen starts laying eggs.

**Emergence of a new queen in the old colony:** Immediately after the departure of the old queen from the colony, larvae of new queens left behind hatch out from the fertilized eggs left behind. The first to metamor-phose into a queen kills others emerging queens by stinging them and assumes the queen-ship of the colony without dispute.

**Nuptial (mating) flight of new queen:** The new queen with some drones (reproductive males) after few days, fly out of the colony. This flight is called **nuptial (mating) flight** during which one of the drones succeeds in mating with her in mid-air, depositing millions of spermatozoa that are stored in **spermatheca** (seminal receptacle) that will last her for about 3 to 5 years of her life span.

**Egg-laying and feeding of larvae:** On returning to the hive, the new queen starts her function of laying eggs. Up to one million of fertilized and




**Summary of life history of caste system of honeybees**

unfertilized eggs are laid each year. Both **unfertilized** and **fertilized eggs** hatch into larvae in three days. The larvae of the drones and workers are fed with **beebread** made from undigested honey and pollen. The larva of the queen is fed with **royal jelly** (a high protein food made from digested honey, nectar, pollen and special secretion from mandibular glands and thoroughly mixed). All larvae grow and moult about **four to five times** after which each cell opening is sealed up with a **lid** by workers and develop into pupal stage. Reorganization of internal organs takes place inside the pupa. After some days, young bee of each caste consumes the lid wax of the cell and comes out. The pupae of drones, workers and queen emerge as drones, workers and queen respectively.

## Economic importance

1. **Pollination of flowers**: Honey bees are pollinators of flowers. When they visit flowers to collect nectar and pollen grains, their bodies are dusted with pollen grains which they carry to other flowers. When flowers are pollinated, fertilization takes place leading to formation of seeds and fruits which provides food for man and other animals.
2. **Production of honey**: They produce honey.

(i) Honey and honey comb are used by pharmaceutical companies to manufacture drugs such as **cough syrup.**

(ii) Cosmetic industries use honey to prepare **body creams** and **lotions.**

(iii) Honey forms raw material in the production of **ice-cream**, **chewing gum**, **toffee** and **mead.**

(iv) Bee wax is used for home-made **polish** and **candles.**

(v) The sugar in honey has been predigested into fructose and glucose , hence it is a source of instant energy when taken. The percentage of fructose is about 40% while that of glucose is 25%. Depending upon the source of flora collection, glucose percentage may go down to 5%. This is why honey is usually recom-mended for diabetic patients. So when ever we take honey, we are putting much more fructose into the blood than glucose. Fructose does not need insulin action before going into cell for metabolic activity leading to energy release while insulin is needed by glucose for metabolic activity.

3. **Bee farming:** This is a lucrative business. The demand for honey is high and the market value is equally high. It also affords employment opportunity for the unemployed.
4. Export of honey enhances foreign exchange earnings.

## Other insects

The life histories of grasshopper (*Zonocerus variegatus*), cassava mealybug (*Phenacoccus manihot*), bean weevil (*Callosobruchus maculatus*), yam beetle (*Heteroligus meles*) and tsetsefly have been treated in chapter 20.

## General economic importance of harmful and useful insects

### Harmful insects

1. Insect pests destroy crops through their sucking, burrowing and defoliation activities, leading to reduction of yield and in some cases, attack may lead to total crop failure and also the quality of crops either in field or in the store may be reduced.
2. Farmers' profits are drastically reduced.
3. Cost of production is increased as large sum of money is expended on their control.
4. A lot of precious time and energy that would have been expended on other useful farm operations are spent on their control.
5. They render vegetables and fruits unattractive and unmarketable.
6. There is also reduction in viability of stored produce.
7. They are disease carrying agents/vectors.
8. Site of injuries may be proned to diseases attack.
9. Act as nuisance to farmers and farm labourers thus reducing their productive capacity, e.g. tsetse flies, bees.
10. Transmit diseases to crop and farmers thereby reducing their productivity.

### Useful insects

1. **Pollination**
   Many insects pollinate flowers of plant crops thus resulting in high food production. Butterflies, and honeybees are examples of insects that pollinate flowers.
2. Termites, crickets, bettles (including their larvae and pupae) are eaten by many people.
3. Honey is not only food but also medicinal
4. **Soil fertility:-** The burrowing of termites and crickets help to aerates soil. The pieces of wood they carry into their tunnels and holes eventually decay and add to soil fertility. Fertile soil promotes healthy growth of plants, leading to high crop yield

**Table 62. Summary of some common insects Orders, their distinctive features, mouth parts, type of metamorphosis and economic importance**

| Order | Distinctive features | Type of Metamorphosis | Adaptation of mouth parts | Economic Importance | Example of insects |
|---|---|---|---|---|---|
| **Odonata** *(Greek odontos = tooth + pteron = wing)* | 1. Two equal membranous wings with net-like veins.<br>2. Eyes very large and prominent.<br>3. Antennae very short.<br>4. Mouthparts well developed and toothed | Incomplete | Biting and chewing | Feed on harmful and useful insects | Dragonflies |
| **Orthoptera** *(Greek orthos = straight + pteron + wing)* | 1. Wings straight and membranous.<br>2. Mandibles well developed.<br>3. Prothorax enlarged.<br>4. Hindlegs enlarged for jumping and digging | Incomplete | Biting and chewing. | 1. Damage crops by eating leaves and roots.<br>2. Aerates soil<br>3. Add to soil fertility. | Grasshoppers, locusts and crickets. |
| **Dictyoptera** | 1. Antennae well developed with many segments.<br>2. Mouthparts with well developed mandibles.<br>3. Legs similar. | Incomplete | Biting and chewing. | Cockroaches destroy clothes, books, shoes and carry germs to our food. Praying mantis feed on harmful and useful insects. | Cockroaches and Praying mantis. |
| **Isoptera** *(Greek: isos = equal + pteron = wing)* | 1. Wings equal, similar and membranous (Only males have wings. King and queen wingless).<br>2. Anterior veins thickened | Incomplete | Biting and chewing. | 1. Destroy wood in buildings and forest.<br>2. Destroy clothes and books.<br>3. Aerate soil with their tunnels.<br>4. Add to soil fertility by dragging pieces of wood into their tunnels which later decay to form humus. | Termites |
| **Hemiptera** *(Greek: hemi = half + pteron = wing)* | Front wings thickened and leathery at anterior half and membranous at posterior half | Incomplete | Mouthparts modified for piercing and sucking. | 1. Damage plants.<br>2. They are pests of agricultural products and agents of plant diseases. | Aphids, cassava mealy bug and cotton stainer. |
| **Lepidoptera** *(Greek: lepis = scale + pteron = wing)* | 1. Wings with broad scales<br>2. Two pairs of wings membranous<br>3. Mouthparts generally modified into proboscis.<br>4. Larvae mouthparts equipped with mandibles | Complete metamorphosis | Proboscis for sucking nectar of flowers. | 1. Adults pollinate flowers.<br>2. Production of silk.<br>3. Larvae damage plants by feeding on green leaves | Butterflies and moths. |

| Order | Distinctive features | Type of Metamorphosis | Adaptation of mouth parts | Economic Importance | Example of Insects |
|---|---|---|---|---|---|
| **Diptera** *(Greek: dis = two + pteron = wing)* | 1. Single pair of membranacous wings.<br>2. Hind wings modified into halteres.<br>3. Mouthparts modifies for sucking.<br>4. Prothorax and metathorax small and fused with the enlarged mesothorax | Complete metamorphosis | Mouthparts adapted for piercing or sucking. | Vectors (carriers) of diseases such as malaria fever, yellow fever, Cholera, sleeping sickness and river blindness | Houseflies, mosquitoes, tsetseflies and blackflies. |
| **Hymenoptera** *(Greek: hymen = membrane + pteron = wing)* | 1. Two pairs of membranous wings.<br>2. Abdomen usually constricted between the first segment of the abdomen and metathorax.<br>3. Generally, ovipositor present used for peircing or stinging | Complete metamorphosis | Mouthparts adapted for sucking or chewing. | 1. Pollinate flowers.<br>2. Production of honey.<br>3. Some are pests.<br>4. Their stinging is harmful to intruders including man. | Bees, ants and wasps |
| **Coleoptera** *(Greek: koleos = sheath, + pteron = wing)* | 1. Forewings modified into horny and hard elytra<br>2. Hindwings membranous, folded under the elytra. Prothorax large and moveable. | Complete metamorphosis | Mouthparts adapted for biting and chewing. | Destroy crops, grains tubers. | Beetles and Weevils |

## Fish *(Tilapia zilli)*

Sexes are separate but the males and females look alike and are difficult to distinguish one from each other. Fertilization of eggs is exter-nal in all bony fish. **Eggs** and **spermatozoa** are discharged into water where fertilization takes place. The eggs are numerous and tiny.

### Spawning

There is an elaborate courtship behaviour in some fish before spawning takes place. *Tilapia zilli* is one of such fish. The male establishes a territory which it defends against other male *Tilapia* species. The male constructs a **saucer shaped nest** of about 20 to 25cm in diameter and 5 to 8cm deep. The male becomes brightly coloured and dances around some females until one female gets attracted to it. A gravid female (one with ripe eggs) follows the male into the nest. The female lays all her eggs in a single batch (about 7000 eggs) in the nest. The male discharges spermatozoa over the eggs. The dis-charging of eggs and spermatozoa into water by aquatic animals is known as **spawning**. The spermatozoa fuse with the eggs and thus fertilization is achieved externally in water.

### Parental care

1. Male builds nest where the fertilized eggs are laid and hatch into fry.
2. Both parents guard the eggs and fry against predators for 45 to 50 days.

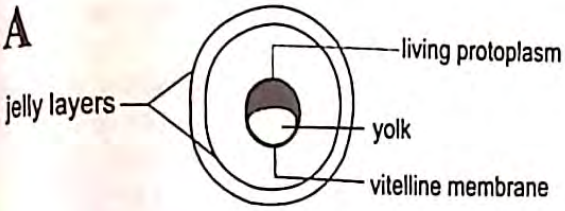
## Toad

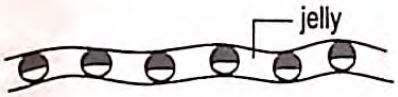
During the rainy season toads carry out breeding migration to streams, ponds and where there is a large volume of water. The males start gentle croaking nois s which are swollen with eggs. The male mounts on the back of the female and holds her firmly. The eggs are laid in a string which is attached to vegetation. The male discharges sperms to fertilize the eggs as they are shed. Egg laying may last 10 to 15 minutes and occurs at night or early dawn.

The jelly coat of each fertilized egg is partly white and partly black. The dark portion contains the living protoplasm of the egg.

The white portion is the yolk which nourishes the tadpole during development. The yolk is hea-vier than the rest of the egg hence the dark side is up. The dark side absorbs heat from the sun while the white blends it with the light from the sky and makes the eggs difficult to see from below.

A

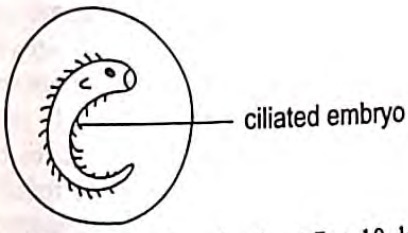



eggs in string of jelly

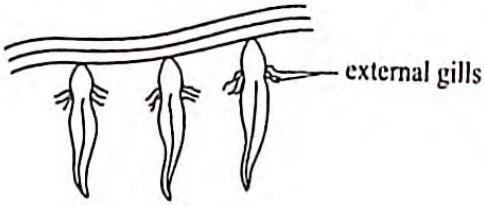
The first cleavage occurs in about 4 to 13 hours depending upon temperature. After cleavage, the egg elongates within the jelly coat. At the end of 24 hours, the head, body and tail can be distin-guished. Due to lack of space it is curved in form of letter "C" and the embryo is ciliated.

B




Hatching takes place in about 7 to 10 days into tadpole with rudiments of external gills. At this stage the mouth has not opened and it lives on the remaining yolk packed in its gut. It clings to submerged vegetation or on the surface of its jelly with its sticky secretion produced by mucous gland. Respiration is through the skin and external gills.

C

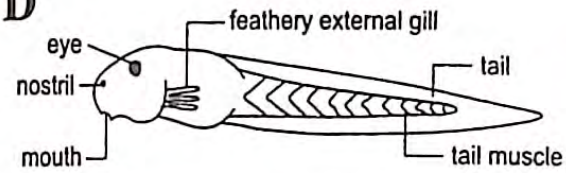



**Newly hatched tadpoles attached to submerged vegetation.**

## External gilled stage

The three pairs of external **feathery gills** and **mouth** become developed. Intestine becomes long. It can now feed on water weeds and respire by external gills. When the tail is well developed, the sticky secretion or sucker disappears and the tadpoles can now swim about in the water.

D

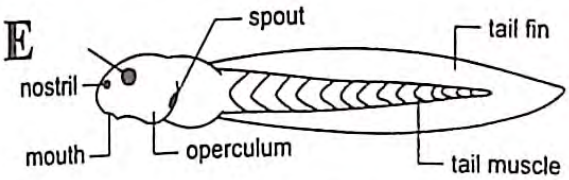



**External gilled stage (side view)**

## Internal gilled stage

In about 12 days, operculum develops in place of external gills which degenerate and are replaced by **internal gills**. A spout develops on the left which is used as exit for water. Breathing is like that of fish, water enters by the mouth and passes over the gills and out through the spout.

E

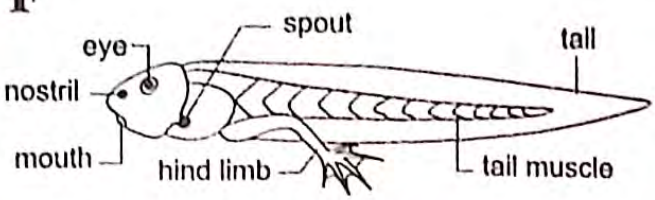



**Internal gilled stage (side view) with internal gills**

## Development of hindlimbs

Hindlegs first appear at the base of the tail. In about 39 days, hind-limbs are well developed.

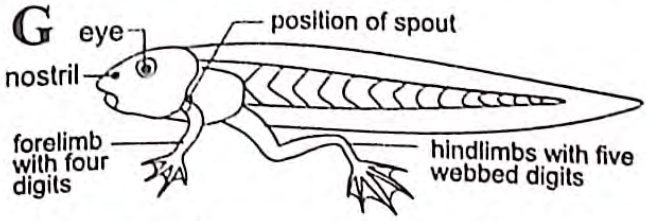
F




## Development of forelimbs

The forelimbs emerge through the spout. Internal gills are replaced by lungs. Nostrils then open. Tail shortens by re-absorption. The tadpole comes to the surface of water to gulp atmospheric air.

G

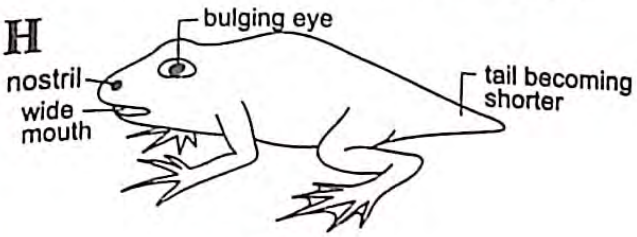



The mouth becomes widened, and the lungs are fully developed. Tail is considerably reduced by re-absorption into the body.

The young toad with a reduced tail now leaves water for land and feeds on insects and worms. Intestine becomes reduced in length due to change of diet. All these developments take place in about 60 days.

Sexual maturity is attained in about three years.

H




I

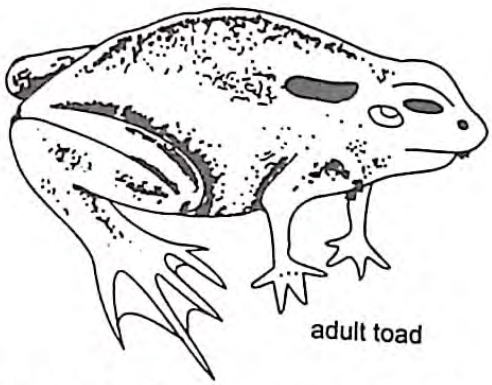



**Figure 16.96. A-H. Stages in the life history of toad.**

## General Adaptations of toad

1. The toad is capable of camouflaging. The pigments (chromatophores) in the skin can change the colour of the toad to suit its background. This prevents it from being seen by its enemies.
2. The glands in the skin produce a distasteful and poisonous secretion when attacked by an enemy. This makes its enemy to leave it.
3. The skin is sensitive to both chemical and mechanical stimuli.
4. The attachment of the thick sticky tongue to the front of the lower jaw makes it an effective organ for catching insects.
5. The vomerine teeth and the teeth on the roof of the mouth help to hold its prey.
6. The large bulging eyes give the toad a keen and wide range of vision since it depends on good sight to see its enemies and food. The eyes are placed in a position where they are above water when the animal is submerged in water.
7. The nictitating membrane helps to keep the eyeball moist and clean when the toad is on land and serves as a protective covering when it is in water.
8. The stream-like body and the webbed digits of the hind feet help it to swim fairly easily.
9. The ventral side of the toad is light and the dorsal side is grayish brown. This makes is difficult for enemies to see from below and above the water.
10. The absence of neck and tail facilitates easy movement both on land and in water.
11. The powerful long hindlimbs are used for hopping and the short forelimbs are used for landing.
12. The skin, the mouth and the lungs are used for respiration. Therefore the toad can carry out effective respiration on land or in water.

## Rainbow lizards (*Agama agama*)

The female is dull in colour while the male is brightly coloured. The nodding and the coloura-tion of the male lizard is a courtship behaviour. These are displayed to attract the female which comes near the male, stops and **arches** its back, and lifts the tail completely off the ground. The male responds by running and closing on the female. It grips the female with jaws from behind and moves over to press its vent against the cloaca of the female. The hemipenis protrudes to dis- charge spermatozoa into the female's oviduct. Thus mating is accomplished.

The male lets the female go. Fertilization is internal and the shelled egg is laid. The egg shell is soft and leathery as in most reptiles. The female about to lay eggs is seen digging the soil in an open place where the heat of sunlight can reach. The female lays six eggs in a batch into the hole and covers it up smoothly. It takes 6 - 12 weeks to hatch. The young lizards dig their way out of the soil and dry themselves in the sunlight. They look very much like the adult except for size and sexual maturity. There is no metamorphosis, development is **direct**. The young lizards feed and grow to adult size and take about three years to attain sexual maturity.

## Bird (Domestic fowl)

The domestic fowl is a bird that does not usually fly. It is kept at home in the local practice as a free range livestock. The male is called **cock** and the female is called **hen**. They both possess colourful feathers but the male has more prominent and colourful comb, wattle and tail feathers. There is a complex **courtship behaviour** in the cock. There is a lot of **display** in the form of **running, dancing** and **sound production** to attract the female. When a female responds by presenting its **genital area** and putting its beak on the ground, the male rides it and presses its cloaca against that of the female. The spermatozoa are dropped at the cloaca close to the oviduct. Fertilization is internal and eggs are covered by hard and brittle shell. Pairing and mating is frequent all the year round except when the hen is brooding and feeding the newly hatched chicks.

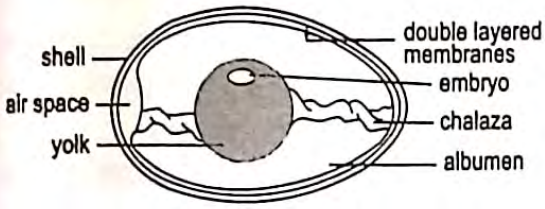



**Figure 16.97. Longitudinal section through the egg of a domestic fowl.**

There is no breeding season. The hen builds a kind of nest in a carefully selected place and lays her eggs there. The eggs are laid singly at least one a day. About twenty eggs are laid. The hen broods or incubates her eggs for twenty one to thirty days during which she sits over the eggs to keep them warm. The hen occasionally turns the eggs round to make sure they equally receive warmth. Hatching is done by the young chicken using its beak to break through the brittle shell. The newly hatched chicken are soft and moist. They are tightly covered up under the wings of the hen to keep them warm. They are weak and covered by down feathers only. Their major problem is temperature regulation and so the hen keeps them covered under her wings most of the time.

## Parental care

1. Eggs are laid on a nest prepared by the hen to ensure that eggs are not cracked.
2. Eggs are incubated by sitting on them for 21-31 days.
3. The mother searches for food for the chickens until they develop fully grown feathers and are able to fend for themselves.
4. The chickens are guarded and protected against predators such as hawks and snakes.
5. The newly hatched chickens which have only down feathers are covered with the wings of the mother to keep them warm, especially at night.

**Table 63. The structural differences between an egg of an amphibian and that of a bird.**

| | Amphibian egg | Bird egg |
|---|---|---|
| 1 | Egg is covered with a flexible layer of jelly | Egg is covered externally with a hard, porous, calcareous and brittle shell. |
| 2 | The yolk is not suspended by chalazae | Yolk is suspended by chalazae. |
| 3 | Albumen and yolk are not surrounded by any membrane | Egg is surrounded by double layered membranes. (chalaza) |
| 4 | There is no air space. | There is an hair space. |

# Reproductive systems in mammals

Mammals are biparental in reproduction that is sexual reproduction involves two distinct and separate individuals, sexually mature male and female.

## Male reproductive system

The male reproductive system in man consists of testes (singular = testis), **vasa efferentia, vas deferens** (sperm duct), **penis and glands.**

**Testes (testicles)**

There are two testes. Each testis is oval in shape and is housed in a wrinkled sac called **scrotum** which hangs out of the body behind the penis. The scrotum functions as a **thermoregulator** that pro-tects the sperm from high temperature. The body temperature is too high for the formation of sperm hence the testes are positioned out of the body that is slightly cooler (2 or 3°C lower) than the normal body temperature. When there is cold, the scrotal sacs contract and the testes are moved nearer the body.

Each testis is made of a large number (about 1000) of tiny highly coiled tubes called **semini-ferous tubules** (sperm tubules) and interstitial cells which lie within the seminiferous tubules. The **seminiferous tubules** produce sperm while the **interstitial cells** produce **testosterone** (male sexual hormone).

## Vas deferens ( Sperm duct)

Vas deferens are small number of tubes which are connected with seminiferous tubules and unite to form **epididymis.** Vas deferens collect sperm from the seminiferous tubules to the epididymis.

## Epididymis

This is highly coiled tube (about 6 metre long) which receives sperm from vasa efferentia. One epididymis serves each testis. Sperm are temporarily stored to mature and develop in the epididymis.

## Urethra

Each vas deferens leads from the epididymis to join a common tube called the **urethra.** Thus the urethra serves as a passage for both urine and sperm.

It is interesting to note that both **urine** and **semen** are not passed at the same time. This is because when the penis is erect, it is difficult to urinate as a muscular valve closes the bladder and when the penis is limp, it is not possible to discharge semen.

## Penis

This is an organ through which the urethra runs. The enlarged end of the penis is called **glans** and the skin extending downward from the glans is called **foreskin** (prepuce). The practice of removing the foreskin in man is called **circum-cision.**

Inside the penis is an **erectile** or **spongy tissue.** When the blood vessels of the erectile tissue are loaded with blood, the penis gets erect. The erection of the penis happens when there is a sexual urge. It is when the penis is erect that it can penetrate the **vagina** leading to the release of sperm.

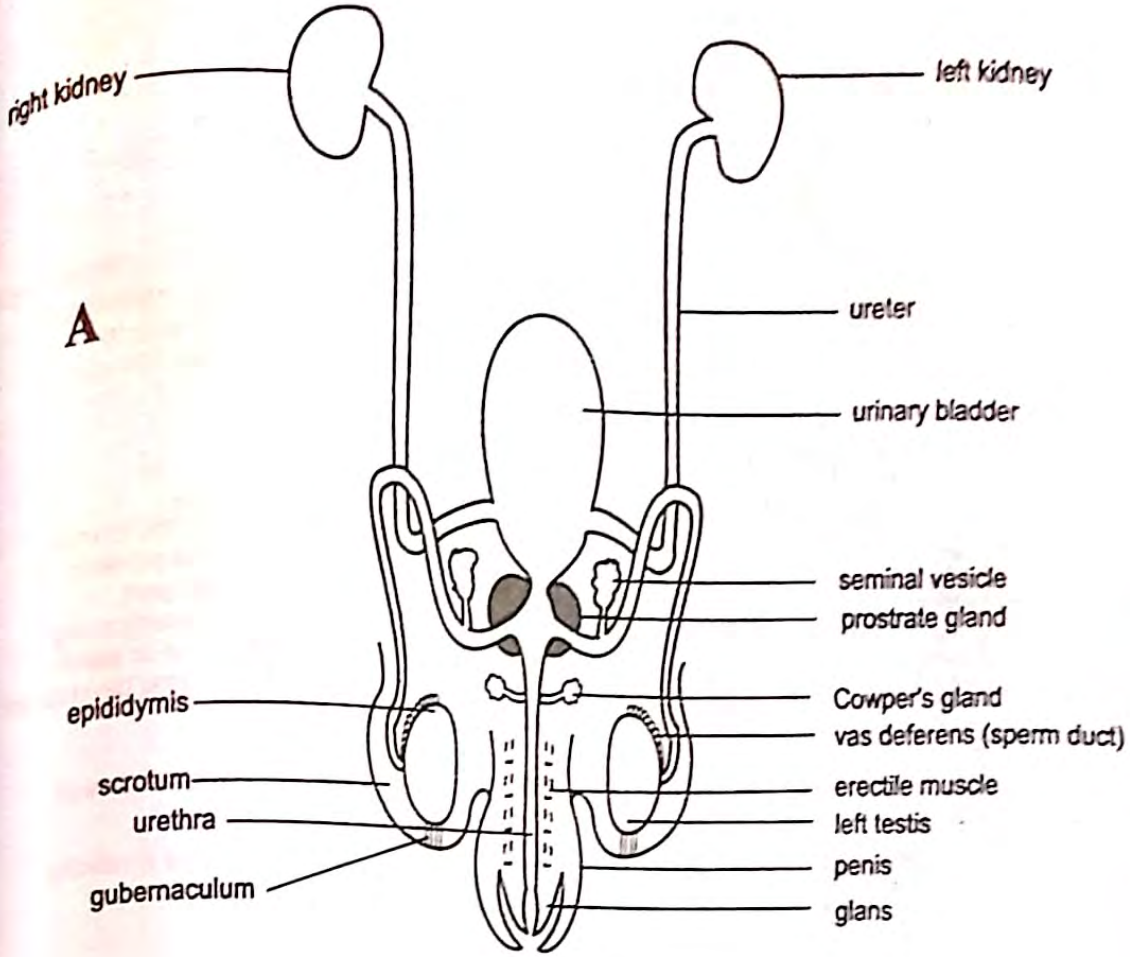
## Glands

Three glands open into the male reproductive system. These are **seminal vesicle, prostate gland** and **Cowper's gland.**

The seminal vesicles is a small sac which opens into the vas deferens before it meets the urethra. The seminal vesicles secrete a thick colourless fluid that nourishes the sperm. The prostate gland is located a little below the bladder. The prostate gland secretes a white milky fluid the neutralizes any trace of acid from urine and also protects the sperm from the acidic secretion of the female body. A pair of Cowper's glands is situated below the prostate gland. The Cowper's glands secrete lubricant.

These three glands secrete **seminal fluid** in which the sperm swim. The fluid activates sperm to swimming. It provides food for the sperm and lubricates their passage. The sperm swim freely in the seminal fluid.

The seminal fluid plus the sperm make up the **semen.**



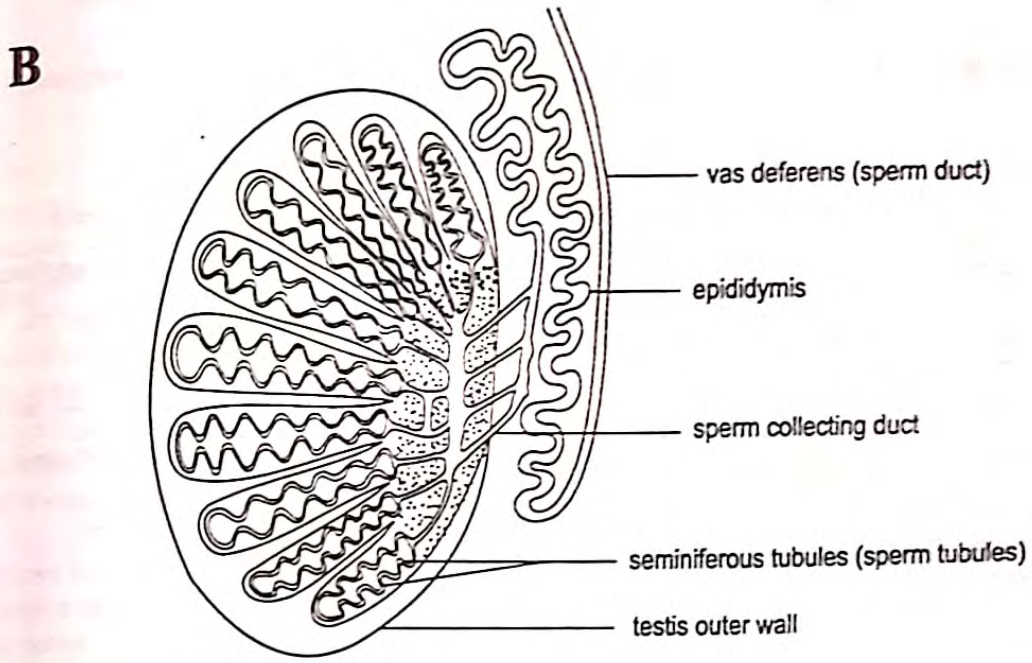




**Figure 16.98.** A = Reproductive system of human male
B = Vertical section through testis

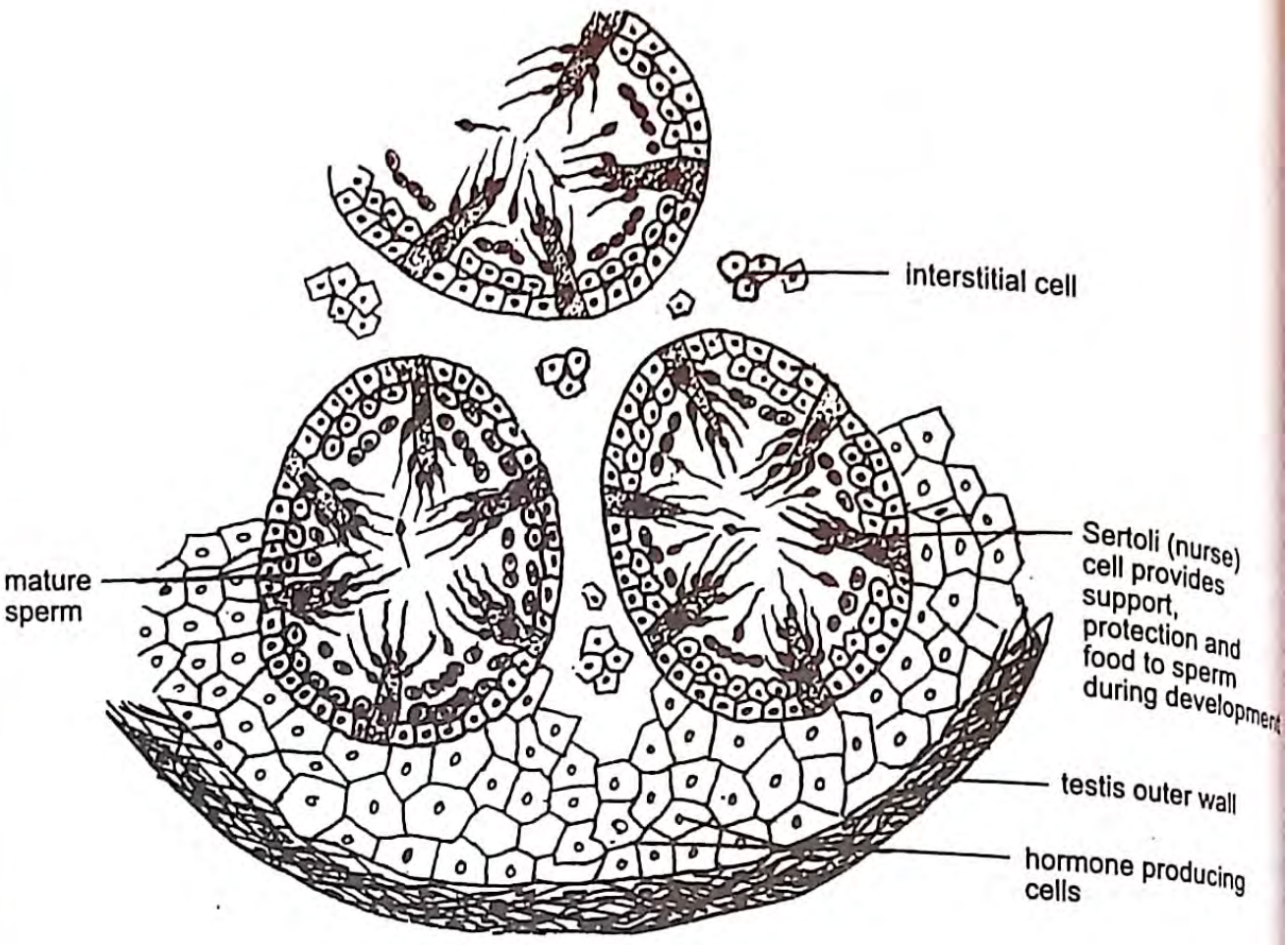


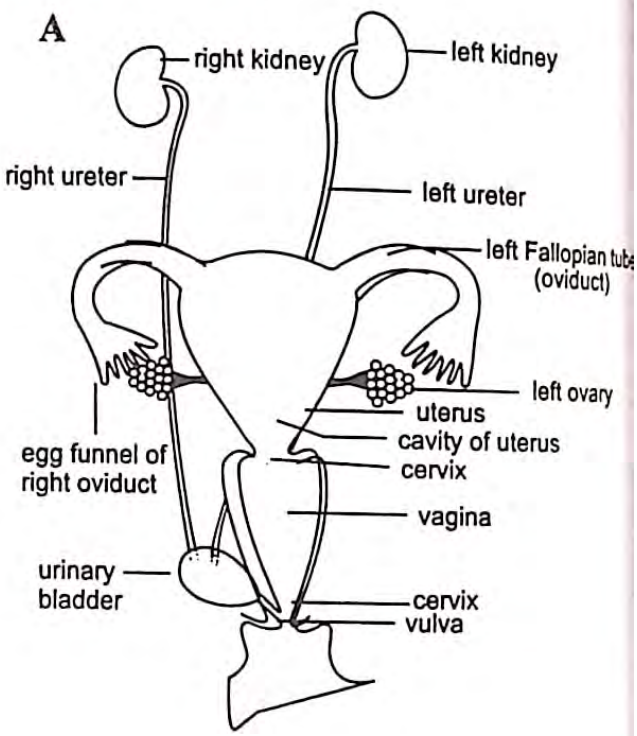

**Figure 16.99.. Cross section through seminiferous tubules**

## Functions of the male reproductive system

1. Formation of sperm to fertilize the eggs of the female.
2. Produces male hormones.
3. Introduces sperm by the help of the penis(an intromittent organ) into the vagina of the female to fertilize the egg thus forming a zygote and an embryo.

## Female reproductive system

The female reproductive system consists of **ovaries, tubes** (oviducts), **uterus, vagina** and **vulva.**



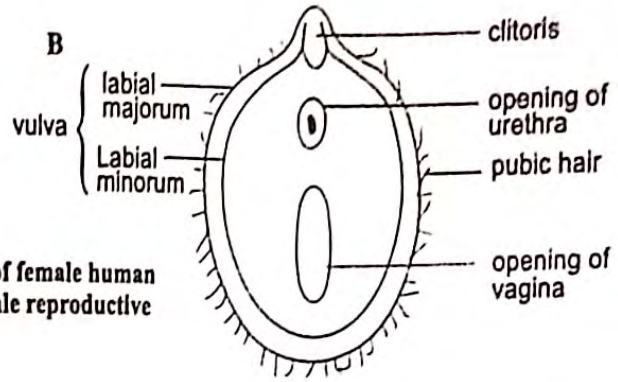



**Figure 16.100.**
**A = Reproductive system of female human**
**B = The front view of female reproductive openings of human**

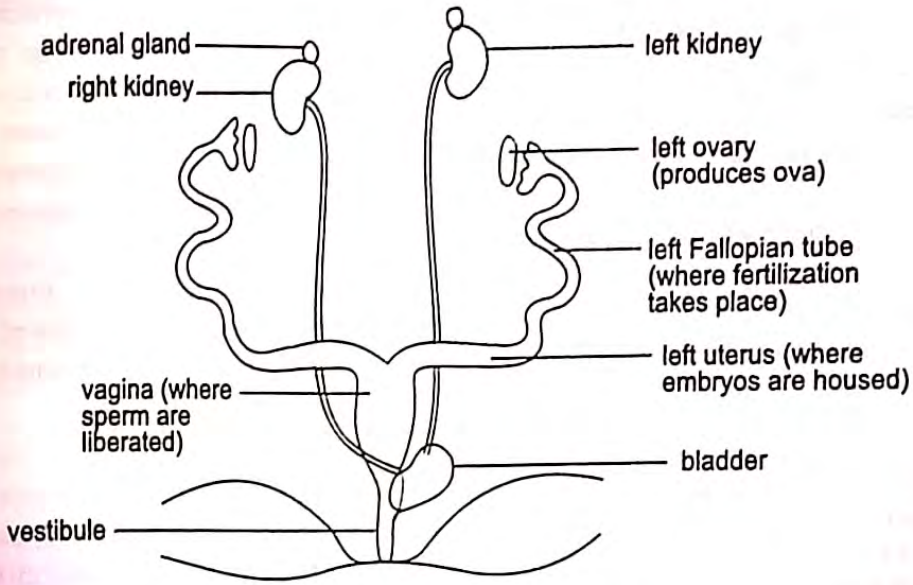



**Figure 16.101. Female reproductive organs of a rat.**

## Ovaries

There are two oval-shaped ovaries each located in the abdominal cavity on the side of the uterus.

Each ovary is held in position by ligaments. Ovaries are small and short. Each ovary has thousands of undeveloped eggs (ova). It is only when a girl has reached the age of **puberty** (9-15 years) that one ripe egg is released alternatively each month by the ovaries. During the fertile period (about 30-35 years) of a woman, thirteen (13) eggs mature each year.

The ovaries stop producing eggs at about the age of 45-55 years, a condition referred to as **menopause**. Of about seven thousand (7000) undeveloped eggs in the ovaries, only about 400 eggs reach maturity, the rest degenerate and get absorbed.

## Functions

1. Ovaries produce and release mature eggs.
2. They produce female sex hormones (oestrogen and progesterone).

## Fallopian tubes (Oviducts)

Arising from each side of the uterus is a narrow Fallopian tube about 9-13cm long. The free end is funnel-shaped. The Fallopian tubes are not connected with the ovaries but lie close to them. The funnel-shaped free ends of the Fallopian tubes are lined with cells having cilia. When an egg is released the **cilia** beat to direct the egg into the fallopian tube.

## Functions of fallopian tube

1. Directs the released egg from the ovary to itself.
2. **Fertilization** takes place inside the **Fallopian tube.**
3. The fertilized egg (zygote) is pushed down to the uterus by the cells of the Fallopian tube.

## Uterus (Womb)

The uterus is a wide and thick-walled muscular chamber of about 8cm long and 5cm wide. Two fallopian tubes enter into it at the top while the lower narrow part terminates as a **neck** or **cervix**. The inner side of the uterus is lined with

## Functions of uterus

1. Implantation of the fertilized egg (the zygote).
2. The foetus is housed for nine months in the uterus.
3. The uterus provides a place for the attachment of foetal placenta.
4. Before the development of placenta, the uterus provides nutrients for the embryo.

## Vagina

The vagina leads from the cervix of the uterus to the outside of the body. It is an elastic and muscular tube of about 10 to 14cm long. The walls are wrinkled. The opening of the vagina is partially covered by a thin membrane called **hymen.** If the hymen is intact, it means that the girl is still a **virgin.** However, the hymen can be torn during vigorous physical exercise such as athletics or during sexual intercourse.

## Functions of vagina

1. It receives the male penis which deposits sperm into it.
2. It serves as a birth canal during the expulsion of the foetus from the uterus.
3. The woman menstruates through the vagina.

## Vulva

The external female organs are collectively called **vulva.** These include the two thick folds of skin covered with public hair (in the mature girl) called **labia majora,** two folds of hairless skin called **labia minora,** a small erectile organ called **clitoris.** The **clitoris** is a sensitive organ that is well supplied with blood vessels and nerves. It causes excitement during sexual intercourse and accelerates orgasm in females. Like the penis, it becomes erect in sexual excitement.

Cutting of the clitoris (a practice called circumcision) must not be allowed because it prevents orgasm in female and also makes childbirth difficult and harmful.

## Functions of Vulva

Vulva protects the opening of the vagina.

## Functions of the female reproductive system

1. It produces eggs (ova) for ovulation.
2. It prepares the uterus to receive the fertilized egg (zygote).

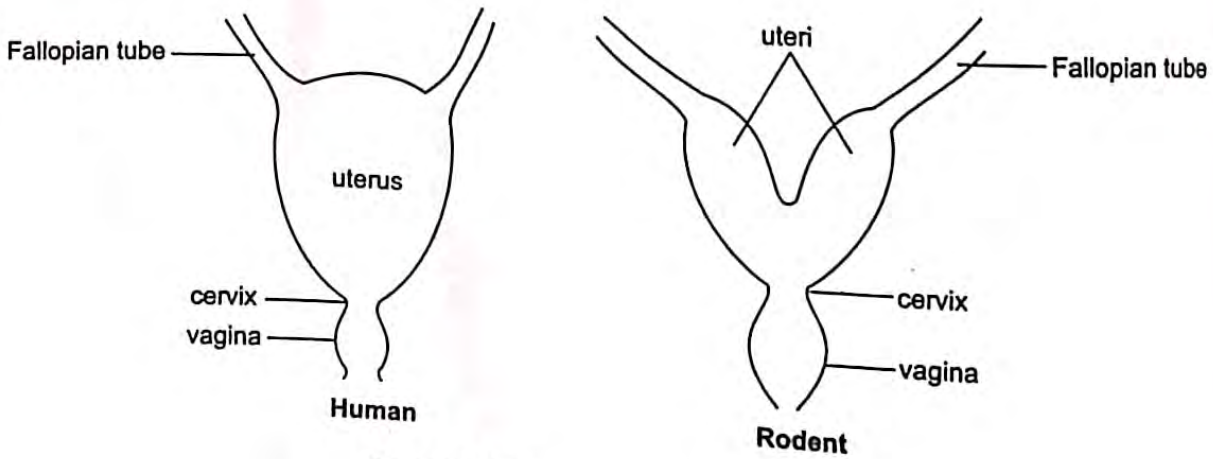



**Figure 16.102. Uteri of human and rodent**

3. The woman menstruates through the vagina.
4. It receives the penis during sexual intercourse so that sperm can be discharged.
5. It provides food and protection for the foetus throughout the gestation period.
6. It expels the mature foetus from the uterus when the foetus is ready to be born.
7. It expels unfertilized egg and other unused material during menstruation.
8. It provides female hormones to maintain menstrual cycle.
9. The system provides milk to feed the baby after birth.
10. It stops the production of new eggs at old age when the woman's body may not be able to carry pregnancy.

## The structure of mammalian gametes

The mammalian gametes are male gametes called **sperm** or **spermatozoa** (singular = spermato-zoon), while the female gametes are called eggs or ova (singular = ovum)

## The structure of sperm

This is a single cell, microscopic in size and consists of head, neck, body (middle piece) tail. The head is about 2.5 $\mu$ in diameter. The head is flat, oval-shaped and contains a large nucleus with **haploid number** of chromosomes. The nucleus is surrounded with very small cytoplasm and capped with a thin sac called **acrosome** which contains enzymes that help to digest (dissolve) the cell membrane of the female ovum during fertilization. Attached to the head is a short neck. Immediately after the neck is the body (middle piece) containing many **mitochondria** and axial filaments which run to the tail.The mitochondria contain respiratory enzymes that provide energy for locomotion. The body ends up with a long tail. The tail has two **centrioles** on its top. The tail is used for locomotion (swimming) in the semen.

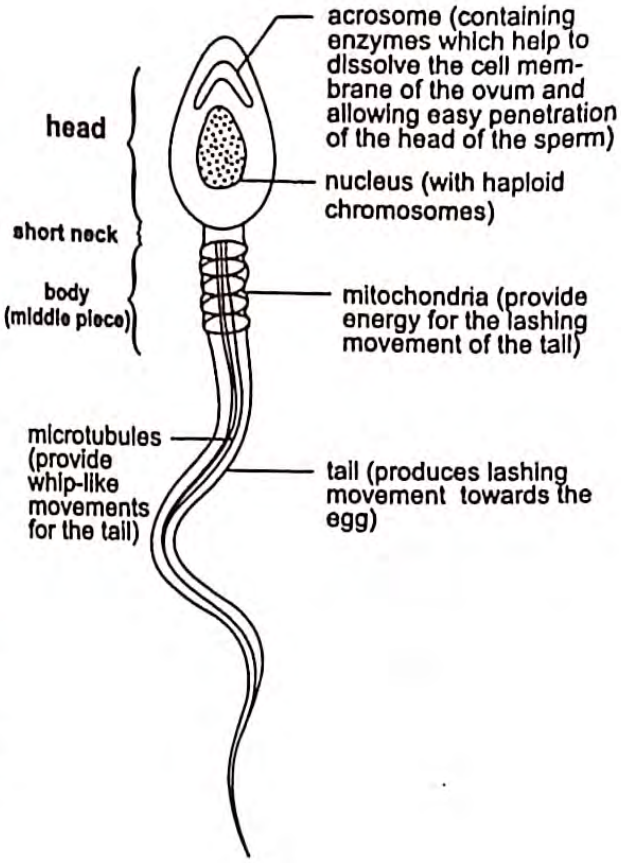



**Figure 16.103. The structure of human egg (sperm)**

## The structure of egg (ovum)

The egg is a round single cell much larger than the sperm. The egg is about 0.1mm (120μ) in diameter. It consists of a nucleus and cytoplasm. The nucleus with haploid number of chromosomes is almost centrally placed in the cytoplasm and is bounded by **nuclear membrane**. The yolky cytoplasm, relatively larger than the nucleus is surrounded by a thin plasma membrane, **vitelline membranes** and a layer of jelly.

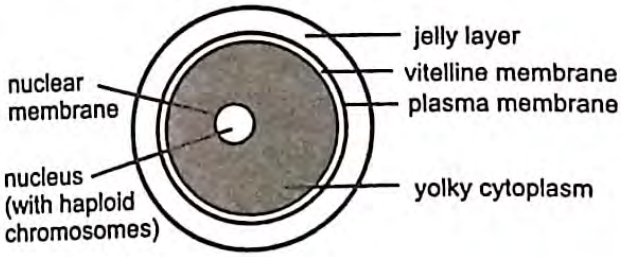



**Figure 16.104. The structure of human egg (ovum)**

**Table 64: 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. Sperm are manufactured by testes with outside temperature | Eggs are manufactured by ovaries with body temperature |
| 3. Millions of sperm 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 | Vas deferens absent |
| 7. Sperm pass through the urethra | Eggs pass through the fallopian tubes into the uterus |
| 8. Seminal vesicle present | Seminal vesicle absent |
| 9. Prostate 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 sperm 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. |

## Puberty

Puberty is the beginning of sexual maturity, that is the stage between chid hood and adult hood. It starts when sex hormones are released from the pituitary gland. In males testosterone is released, starting the production of sperm while in females, ovaries release oestrogen, starting menstrual cycle.

## Secondary sexual characters in boys and girls at the age of puberty.

**Boys**

1. Development of hairs in the pubic areas, face, chest and armpits).
2. Muscles develop.
3. Penis and testes increase in size
4. Increase in voice. Voice becomes coarse
5. Production of sperm starts.
6. Love feelings towards opposite sex.

Girls

1. Development of breasts and increase in uterus.
2. Hips increase in size.
3. Development of hair in the pubic area and armpits.
4. Menstruation and ovulation start.
5. Love feeling towards opposite sex.
6.

## Similarities between male and female reproductive organs

1. Both possess sex organs (testes in male and ovaries in female).
2. Haploid gametes are produced by both (haploid sperm by testes and haploid eggs by ovary)
3. At certain age both stop producing gametes. (andropause in men and menopause in women)
4. Both are influenced by sex hormones
5. Both have external openings to the outside world.
6. Both have pubic hairs on their external surfaces at maturity.
7. Before puberty, both do not produce gametes.

**Table 65: Differences between male and female gametes.**

| Sperm | Egg |
|---|---|
| 1. Very small with a diameter of 2.5 microns. | Far larger than sperm with a diameter of 120 microns |
| 2. Divided into head, neck, middle piece and tail. | Round and not divided into head, middle piece and tail. |
| 3. It is capable of swimming from vagina to the fallopian tube | Not capable of swimming. It is moved by the beating of Fallopian tube cilia and muscular contraction of the fallopian tube. |
| 4. Very small cytoplasm present. | Large cytoplasm present. |
| 5. No yolky cytoplasm. | Yolky cytoplasm present. |
| 6. Millions of sperm are released during each ejaculation. | Only one egg or rarely two eggs are released monthly. |

## Production of eggs (ova)

Of about 7000 undeveloped eggs in the ovaries, only about 400 eggs reach maturity, the rest degenerate and get absorbed. Each egg is surrounded by a sac of smaller cells called **Graafian follicle**. As the egg increases in size so also is the Graafian follicle. When the egg reaches maturity, the Graafian follicle then bursts and releases the mature egg. Each ovary ovulates one egg every month in an alternate manner. Ovulation in most females occurs in about **8 days** after the menstrual flow has stopped. However, considerable variation is experienced by some females. Some ovulate between 9 and 14 days after menstrual flow. The release of the egg is called **ovulation**.

The Graafian follicle stays behind in the ovary and develops into a yellow body called **corpus luteum.** The corpus luteum produces a hormone called **progesterone**.

About two weeks after ovulation, the **corpus luteum** withers away, the production of progesterone ceases, and lining of the uterus breaks down if fertilization does not occur. Read the functions of follicle-stimulating hormone, oestrogen and progesterone in Chapter 13. (Page 248)

## Menstrual cycle (oestrous cycle)

*Menstrual cycle is the series of changes that occur in the reproductive organs of a mature female to release an egg on the average of every 28 days* (**mensis** *means month) under the influence of hormones.* The changes are accompanied by discharge of blood, mucus, unfertilized egg and uterine materials resulting from the breakdown of the soft tissue lining the uterus, via the vagina. The bleeding lasts for about 4-5 days although variation exists.

## Copulation (Sexual intercourse) and ejaculation

Before copulation, the male and female usually have sexual interest leading to **excitement**. The male penis becomes erect when the erectile tissues are filled with blood and is inserted into the **vagina**. The **up** and **down stroking** of the penis is facilitated by the mucus secretions from the urethral and mucus glands of the male and the glands of the vagina. When the male reaches the peak of sexual excitement (**orgasm**) **ejaculation** occurs resulting in the release of about twenty to one hundred and twenty million (20,000, 000 -120,000,000) sperm into the vagina.

The orgasm of the female brings about **peristalstic contractions** of the muscular walls of the vagina and uterus which assist to propel the sperm into the **Fallopian tubes**.

## Fertilization

### Fertilization is internal

***The fusion of the nucleus of the sperm and the nucleus of the ovum is called fertilization.*** The released sperm in the vagina swim through the cervix into the uterus and from the uterus into the **Fallopian tubes**. The sperm move partly by the lashing of their tails and partly by the peristalstic contraction of the vagina, uterus and Fallopian walls. They are slow swimmers, swimming at the rate of 2-4cm per minute. Millions of sperm surround the egg in the Fallopian tube but only the **head of one sperm penetrates the ovum**. The head of the sperm has a sac (acrosome) which contains **enzymes** that help to dissolve the egg membranes. When the head of the sperm touches the jelly layer of the egg, the acrosome secretres enzymes which digest the egg membranes. Millions of sperm are needed to produce enough enzymes to digest the protective layers surrounding the egg before the head of one sperm penetrates into the egg and fuses with the nucleus of the egg. *(**NOTE** This is the reason why a man with low sperm count below 20,000,000 may not be able to pregnate a woman. Males with less 20,000 sperm per millilitre generally regarded to be sterile. Few sperm may not secrete enough enzymes to digest all the protective layers of the egg).* The tail is left behind. The sperm nucleus makes its way through the cytoplasm of the ovum until it reaches the nucleus of the ovum. The two **haploid nuclei take** 24 hours to fuse together to form one **diploid nucleus** called **zygote**. Immediately after the **zygote** formation, fertilization **membrane** is formed around the zygote to prevent other sperm from entering the zygote.

Sperm can stay alive for about 72 hours in the uterus and Fallopian tubes. Therefore fertilization can still occur if ovulation occurs **two to three days after ejaculation.**

### Pre-embryo and Foetus

### Pre-embryo

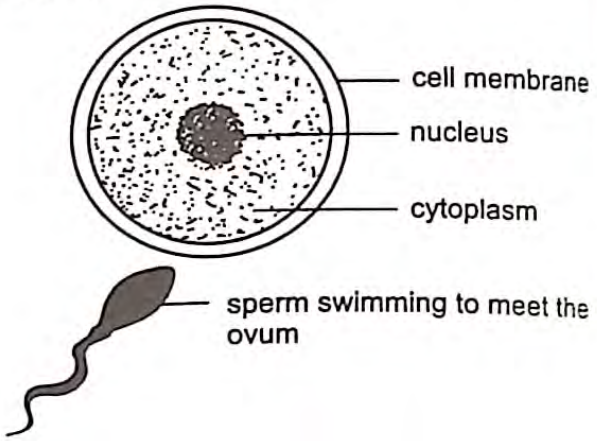
is the development of the zygote in the first 14days.

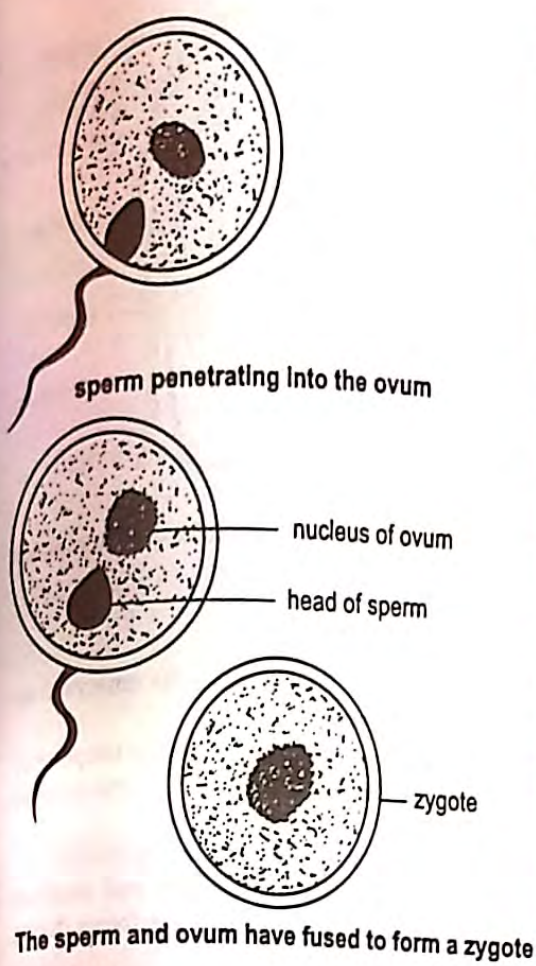
**Embryo:** The development of pre-embryo from 14days (2weeks) until the end of 8weeks.

**Feotus:** The development of the embryo from 8weeks till birth is called foetus.

## Implantation of the embryo

The zygote divides into two, four, eight, sixteen cells etc., as it moves along the Fallopian tube to the uterus. The movement is aided by the peristalstic contractions of the Fallopian muscles and lasts for five to seven days before arriving in the **uterus**. On reaching the uterus, it secretes enzymes which destroy a few cells of the soft uterine lining (**endometrium**) and penetrates into the uterine lining at this point and gets itself firmly implanted in the **uterine wall**.





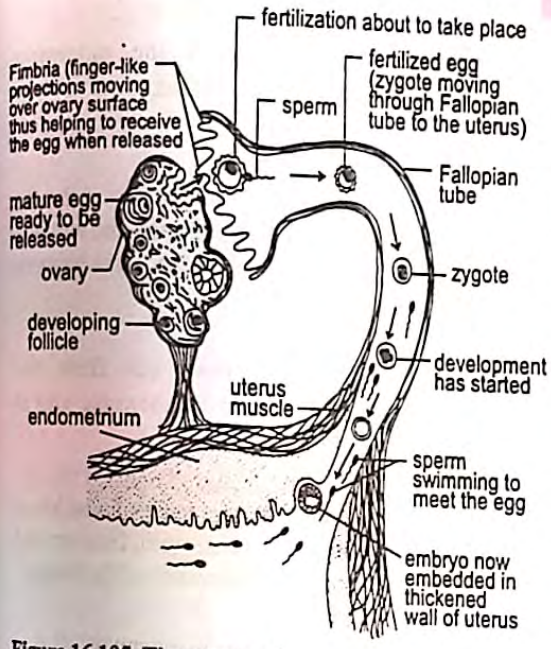




**Figure 16.105. The process of ovulation, fertilization and implantation of the embryo.**

## Development of placenta

The embryo at first feeds on the yolk of the ovum but when the yolk is exhausted, it feeds on the food substances in the fluid of the uterus. As the embryo grows, it develops placenta and membranes. ***Placenta is a disc of vascular tissue formed partly by embryonic tissue and partly by uterine lining.*** Placenta has villi which grow into the uterine lining (endometrium) to anchor it firmly. The embryo is attached to the placenta by an **umbilical cord** which contains an artery and a vein. The blood vessels of the embryo come very close to those of the mother so that food and oxygen can diffuse across from the maternal circulation to the embryonic circulation. Waste substances, carbon (IV) oxide and urea diffuse from the embryonic circulation to the maternal circulation. It is important to note that oxygen and food in solution from the artery of the maternal blood diffuse into the vein of the embryo for circulation. The blood of the mother **never passes** to the embryo because:

(a) it would damage the embryonic capillaries since the mother's blood pressure is greater;
(b) waste substances, antibodies and hormones of the mother may damage the embryo and
(c) the disease in the mother's blood would pass to the embryo's blood and cause damage.

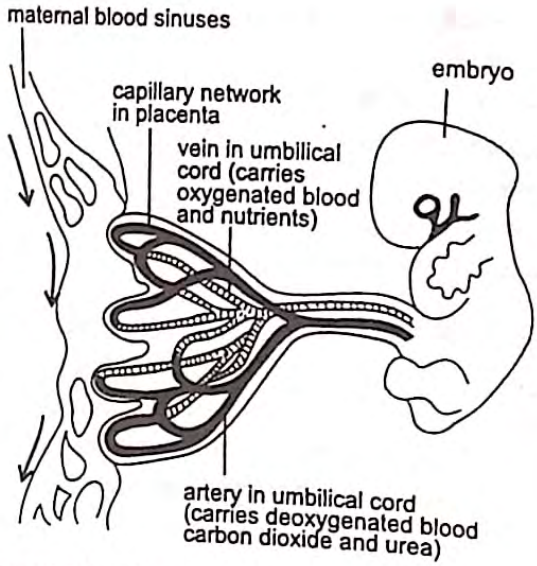



**Figure 16.106. The relationship between the foetus and placenta of mother.**

## Functions of placenta

The placenta serves the embryo as liver, kidneys, lungs, intestines and hormonal gland.

1. **As liver**: The placenta processes some of the mother's blood cells to make certain components such as iron and transfers them to the embryo's circulatory system.
2. **As kidney**: The placenta filters urea out of the baby's blood and transfers it to the mother's kidneys.
3. **As lungs**: It oxygenates the foetal blood. It exchanges carbon (IV) oxide (carbon dioxide) from the embryo's blood for oxygen from the mother's blood.
4. **As intestines**: Digested food is absorbed from the mother's blood and passed to the embryo by **diffusion**.
5. Placenta prepares certain hormones for the embryo and the mother.
6. **Protection**: It prepares certain ingredients such as antibodies that protect the embryo against infection.
7. Placenta selects what is to pass to the embryo's blood.

## Extraembryonic membranes

When the embryo has been implanted, it produces four extraembryonic membranes (membranes outside the body of the embryo namely: amnion, chorion, allantois and yolk sac). Since these membranes are located outside the body of the embryo, they are referred to as **extraembryonic membranes.**

**Amnion:** Amnion is a thin inner most membrane that covers the embryo. The amnion lines the cavity that surrounds the embryo. The space between the amnion and the embryo is called **amniotic cavity.** The space is filled with watery fluid called **amniotic fluid.**

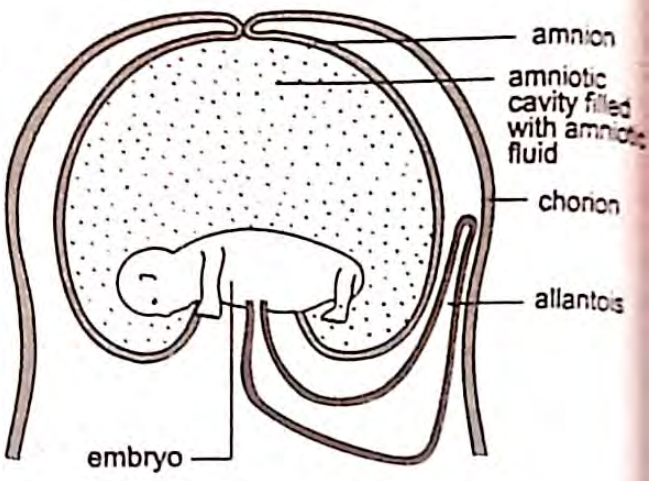



**Figure 16.107. The extraembryonic membranes and embryo.**

## Functions of amnion

1. The amniotic fluid protects the embryo from shock and mechanical injury.
2. The amniotic fluid provides an even temperature for the embryo and allows the embryo to move freely.
3. The amniotic fluid keeps the embryo moist.
4. The amniotic fluid is slippery and therefore helps for an easy passage of the foetus during child birth.

**Chorion:** The chorion is the outermost membrane that surrounds the amnion.

## Functions of chorion

1. Protects the embryo outside.
2. It helps in the formation of placenta. After the full formation of placenta, chorion and amnion, the embryo is now called **foetus**. This happens after about eight weeks.

**Allantois:** Allantois grows out from the embryonic gut and fuses with the chorionic villi in the uterine wall.

## Functions

It is a part of umbilical cord that carries foetal blood vessels to and from the chorionic villi, thus serving for respiration, nutrition and excretion of the foetus

**Yolk sac:** It has no function in mammals. It is hidden in placenta.

## Parturition (labour) or child birth

*Parturition is the expulsion of the foetus, placenta and foetal membranes from the uterus.* After about 270-280 days in the uterus, the foetus is now prepared to come to the world. The foetus at this stage has turned its head towards the **cervix**.

Three stages are involved. These are (1) **dilation stage**, (2) **expulsion stage** and (3) **expulsion of placenta and membrane stage.**

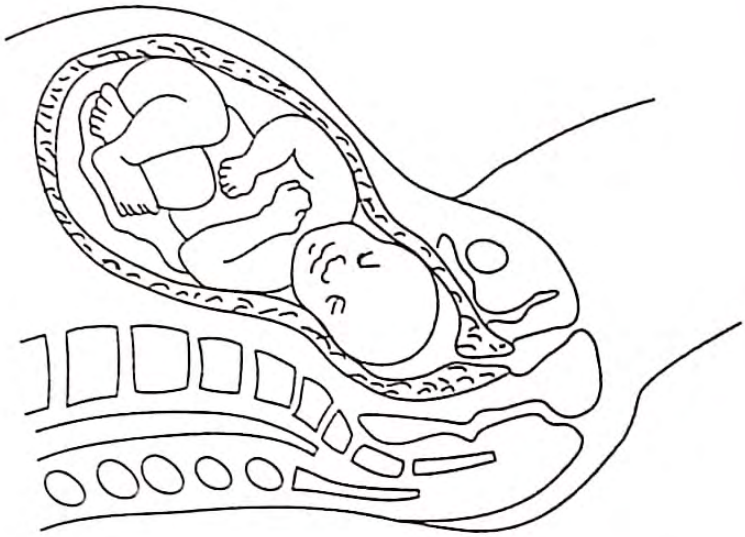
### 1. Dilation stage

The corpus luteum produces a relaxing hormone called **relaxin** which causes the **pelvic ligaments** to **relax**. Also another hormone called **oxytocin** (pictocin) is secreted from the pituitary gland causing the uterus muscles to contract strongly and regularly resulting in **pains.**

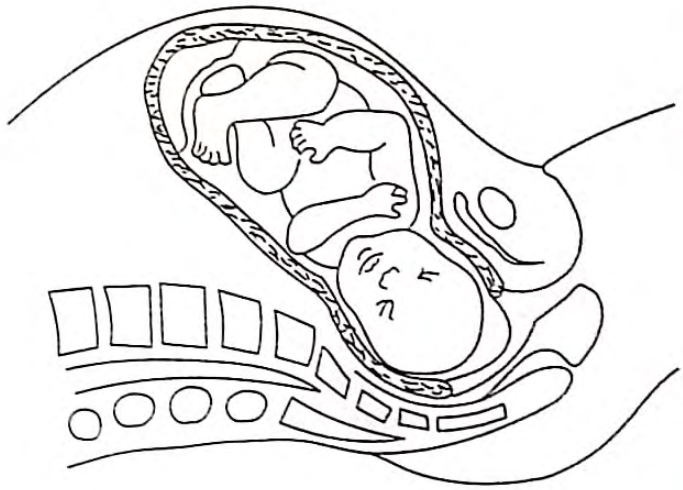
The cervix expands and the amnion and chorion burst releasing the amniotic fluid to the vagina.

### 2. Expulsion stage

The contractions of the uterus muscles become frequent and stronger. The cervix and vagina become fully enlarged. The foetus is gradually pushed out from the uterus to the vagina via the cervix and from the vagina to the world. **The sudden change in temperature** makes the baby to cry for the first time. The cry helps to fill its lungs with air for respiration.

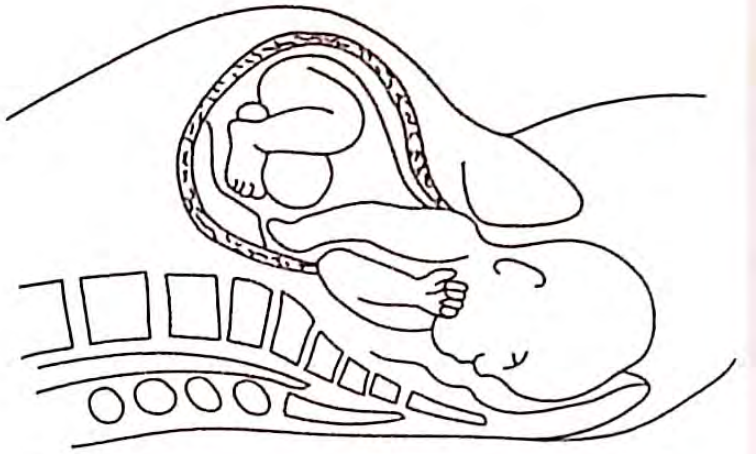


(a) Position before birth.



(b) Birth has started.

(c) Head emerges first.



(d) Head has come out.
It will be over soon.

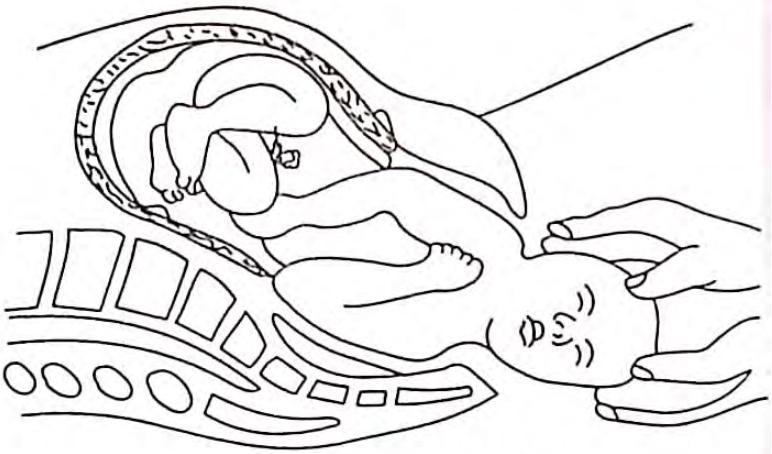


**Figure 16.108. Stages in the birth of a baby.**

### 3. Expulsion of placenta and foetal membranes

After the birth of the baby, the uterus muscles continue to contract and the placenta and foetal membranes are forced out as **"after-birth"**. The umbilical cord connecting the placenta to the baby is cut and tied. The remaining portion dries up and falls off about seven days later. The scar of the healed umbilical cord is called **navel.**

## Gestation period

***The period of fertilization of the egg (concep-tion) till the birth of foetus is called gestation.***

**Table 66: Gestation periods of some mammals and average number of the young born.**

| Mammal | Gestation period in days | Average number of young |
|---|---|---|
| 1. Man | 270-280 | 1 |
| 2 Cow | 284 | 1 |
| 3. Horse | 336 | 1 |
| 4. Monkey | 168 | 1 |
| 5. Elephant | 600-660 | 1 |
| 6. Pig | 114 | 9 |
| 7. Cat | 63 | 4 |
| 8. Dog | 63 | 4 |
| 9. Rat | 21 | 4 |
| 10 Rabbit | 30 | 8 |
| 11 Goat | 151 | 2 |

## Twins

There are two types of twins. These are **ordinary (fraternal)** and **identical twins**.

**Ordinary or fraternal twins**

This results when two ova are released and each ovum is fertilized by a separate sperm. Two babies are produced which may be a boy and a girl or the same sex but their physical characteristics, mental ability and personality are different. During pregnancy each foetus has its own **placenta, amnion** and **chorion**.

## cal t vins

Identical twins are produced when a fertilized egg splits into two equal halves before developing. Each half develops into a baby. The resulting babies are of the same sex and the same genetical makeup. They look alike in all aspects and are very difficult to distinguish.

Identical twins share the **same placenta** and **chorion**.

## Siamese twins

Siamese twins are produced when a fertilized egg splits incompletely.

## Triplets

Triplets are formed by set of identical twins and one ordinary baby.

## Quadruplets

Quadruplets are formed when one fertilized egg splits into four equal parts before developing or two fertilized eggs with each producing identical twins.

## Parental care after birth

## Parental care by Humans

Parent care ensures that an infant does not need to look for its own food, protection or home until the age he or she can compete with adults.

Parental care in humans lasts for many years.

1. The baby is breast-fed on milk from the mammary glands. The breast milk contains all classes of food including **antibodies** which protect the baby until it develops its own immunity. As the baby grows bigger and older, solid food is given in addition to breast milk until the baby is old enough to stop breast milk and depends upon solid food.
2. Clothing and shelter are provided for the child for many years until puberty.
3. The mother bathes, cleans and keeps the baby warm until the baby has grown big enough to take care of itself.
4. **Protection:** The baby is protected against playing with dangerous objects. The baby is also immunized against deadly diseases such as whooping cough, tuberculosis, measles, poliomyelitis, tenatus and diphtheria.
5. **Medical treatment:** The baby is given medical treatment when ill.
6. Both parents educate the child at home first and later the child is sent to school for formal education.
7. Parents teach their babies how to sit and walk at early age.
8. Both parents teach their children the culture and social skills of the people.
9. Parents advise their children the good ways of life. Gross misbahaviours in some times by punishment.

## Parental care in giant rat or rabbit

1. The young are born in hole dug in the ground by both parents to protect them from enemies and temperature change.
2. The young are naked, blind and helpless. They are fed on milk from the mammary glands of the mother for some weeks.
3. The mother cleans and keeps them warm.
4. Both parents protect them from enemies.
5. Both parents teach the young by giving examples. Correction is by punishment.
6. When the young animals are old enough to fend for themselves, the parents disperse them.

## Table 67: Comparison of reproduction among vertebrates

| Types of vertebrate | Breeding time | Number of eggs laid | Site of fertilization | Site where embryo is developed. | 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. | Internal (Oviduct) | Uterus | Protection, feeding and teaching for a long period. |

## Table 68: Differences in sexual reproduction between mammals and flowering plants

| Mammals | Flowering plants |
|---|---|
| 1. Reproductive organs are present through out life. | Reproductive organs are temporary. |
| 2. Sexes are separate that is male and female are separate individuals. | They are mostly hermaphrodites that is male and female organs exist in the same plant. |
| 3. Copulation takes place before sperms are released | No copulation. |
| 4. No pollination | Pollination takes place during which pollen grains are transfered. |
| 5. Offspring grow continually until maturity | There is a period of dormancy of seeds before germination. |
| 6. Offspring need no agents of dispersal since it is mobile. | Agents of dispersal (water, wind and animals) are needed. |
| 7. Few offspring are produced. | Many offspring are produced. |
| 8. There is a parental care for offspring. | No parental care for offspring. |
| 9. High survival rate of offspring. | Low survival rate for offspring. |

# Family planning

## Family planning

Is a method adopted by a couple to control the number of children they can adequately cater for and the right time to have them.

## Benefits of family planning

1. It prevents unwanted pregnancies thereby avoiding the danger of illegal abortion.
2. It ensures good health care and qualitative education for the children.
3. It reduces maternal death rate usually caused by frequency of pregnancy.
4. Adequate nutritional care to the children is ensured.
5. It eliminates child dumping which is the main cause of motherless babies.
6. It prevents population explosion in a country.
7. A well planned population helps the Government in providing social amenities, educational and health facilities that could be enjoyed by all citizens.

## Methods of birth control

Birth control could be grouped into two main classes. These are **natural** and **modern** methods.

## Natural methods

1. **Abstaining from sex**
   This is a very reliable method. Sex is only performed when the desire to be pregnant is approved by both partners.

2. **Breast feeding**
   During breast feeding there is a delay in fertility of woman as the woman does not menstruate. This helps to prevent pregnancy. This method, however, is not reliable.

3. **Withdrawal**
   This involves withdrawing the penis from the vagina when a man is about to ejaculate so that sperm are released outside. This method is very unreliable as some sperms may be released into the vagina before withdrawal.

4. **Basal body temperature**
   During ovulation period, the body temperature of a woman rises above normal. For a woman to know her ovulation period, she must take her temperature every morning. When her temperature rises above normal, she is on her ovulation period and must not have sex. This method is not all that reliable as a faulty thermometer may give an inaccurate temperature and a cold environment may reduce the body temperature at ovulation period.

5. **Cervical mucus billing ovulation**
   When an ovulation is about to occur, the cervical glands are stimulated to produce a **thick** and **cloudy mucus** which could be observed on a tissue paper or on the woman's pant. This mucus later becomes thin and slippery looking like an albumen of an egg. This thin and slippery mucus stretches out without breaking when placed between two fingers. This is the ovulation period and sex must be avoided if pregnancy is not wanted.

6. **Calendar or rhythm**
   This involves the use of calendar. This method is to predict the ovulation period of a woman based on the duration of previous menstrual cycles. The calculation of the ovulation period is based on the following three assumptions.
   (a) Ovulation occurs 14 days before body starts preparing for another menstrual cycle.
   (b) Sperms can stay alive for 2-3 days.
   (c) Ovum can stay alive for 24 hours.
   A woman has to take accurate records of her menstrual cycles for 6-12 months. With this, she can easily know her ovulation period and stop having sex seven days before and after ovulation. This method is not all that reliable as sometimes miscalculation of ovulation period may occur.

## Modern methods

1. **Hormonal (Family planning pills) method**
   This involves the use of contraceptive pills by women. A doctor must be consulted to recommend the particular type of pills suitable for her body. One pill is taken every day for **21 days**. No pill is taken for the **remaining seven days** so as to allow menstruation to occur. The pill prevents the release of the egg (ovulation) from the ovary. This method is reliable but it is safer for the man to use spermicidal cream in addition.

2. **Injectable hormonal drugs** This involves injecting a hormone called **progesterone** into the woman's body. It prevents ovulation. It lasts

for two to three months in the body and is repeated unless pregnancy is needed.

3. **Norplants**

This drug is inplanted subdermally (under the skin) into the arm to prevent pregnancy. It lasts for five years. It could be removed whenever pregnancy is desired.

## Barriers

4. **Sheath or condom**

This is a thin sheet of rubber. A man fits the sheath or condom over his erected penis before having sexual intercourse. The sperm are discharged into the condom instead of the woman's vagina. One condom should not be used twice as it may burst and sperm liberated into the vagina. It is not 100% safe as some sperm may escape into the vagina and cause pregnancy. It may also burst liberating all the sperms into the vagina. Therefore spermicidal cream should be used in addition.

**Figure 16.109. Male condom.**

5. **Diaphragm**

This is a thin rounded rubber sheet. It is inserted into the vagina by the woman before sexual intercourse to prevent sperm from reaching the uterus and oviduct. It is removed eight hours after sex. It is not very reliable as some sperm may escape into the vagina and therefore it must be used with spermicidal cream.

6. **Female condom**

This is a thin rubber sheet fitted inside the vagina to cover the vagina and cervix and tired externally to the woman's body. Sperm are prevented from reaching the ovum. It is not 100% safe. Spermicidal cream should be used in addition.

**Female condom**

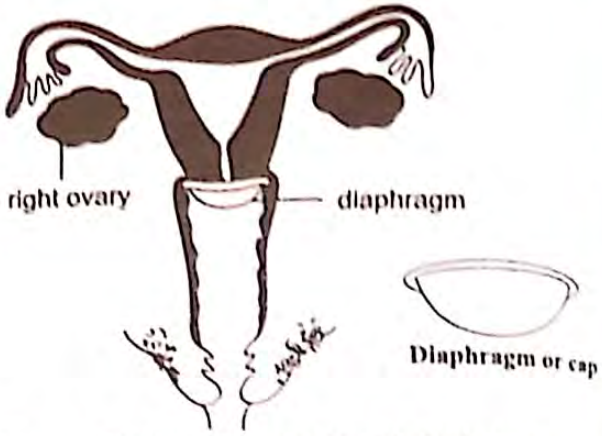



**Figure 16.110. Diaphragm inserted into vagina**

7. **Intra-uterine device (IUD)**

This is a small coiled piece of plastic or iron. It is inserted by a doctor into the woman's uterus and it may stay for years if the woman's body does not reject it. **IUD** stops the fertilization of the ovum or prevents the implantation of the **zygote** in the uterus. It is a very safe method but it must be checked by doctor at interval to make sure it is in proper position. If it is out of position, pregnancy can occur. **IUD** can be removed if pregnancy is wanted.

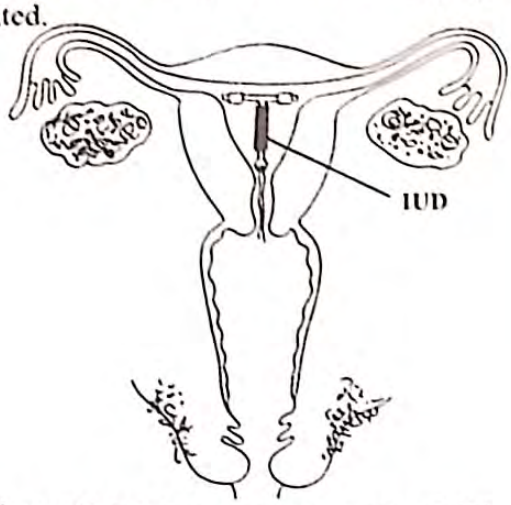



**Figure 16.111. Intra-uterine device (IUD) inserted in the uterus.**

8. **Spermicidal creams or foaming tablets**

These creams or foaming tablets kill the sperm thereby preventing sperm from reaching the egg. A woman applies the cream or foaming tablets deep into her vagina before sex. This method is not very safe as not all the sperm may be killed. Therefore condom or diaphragm should be used in addition

**9. Sterilization**

This involves the cutting or tying of the sperm ducts in case of a man and oviducts (Fallopian tubes) in case of a woman. This prevents sperm from being released from the testes and ova from the ovaries. Sterilization is by operation (called vasectomy) and is not reversible. It is very reliable.

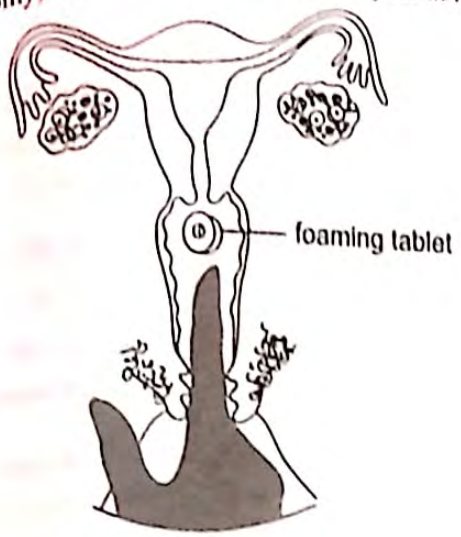



**Figure 16.112. Foaming tablet in vagina.**

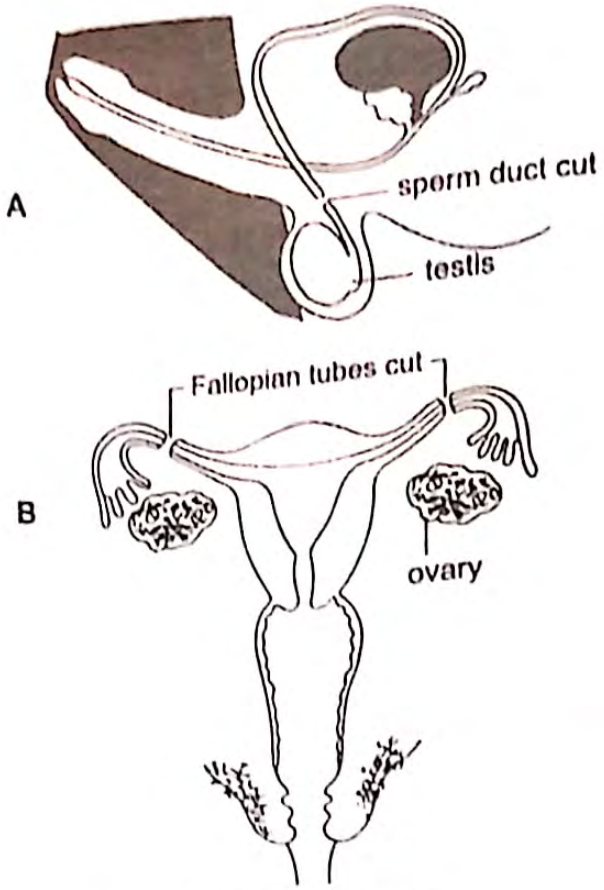



Figure 16.113. Sterilization
A = man
B = woman

## *Questions*

1. *(a) What is (i) vegetative reproduction (ii) asexual and (iii) sexual reproduction?.*
   *(b) Explain the meaning of the following, giving one named example of each (i) bulb (ii) corm (iii) stem tuber.*
   *(c) Describe one of these and explain how it serves for reproduction.*

2. *(a) Describe the external appearance of the rhizome of a named plant.*
   *(b) Why is this organ regarded as a modified stem and not a root.*
   *(c) What are advantages and disadvantages of reproduction of this plant by its rhizome rather than its seed?*

3. *(a) Describe the structure and reproduction of Mucor (or other mould fungus).*
   *(b) List the methods of reproduction in Amoeba and Spirogyra.*
   *(c) List the advantages of budding and grafting.*

4. *(a) Describe two methods of reproduction in unicellular animal you have studied.*
   *(b) List the attributes which show that Amoeba and Spirogyra are both living organisms.*

5. *(a) Distinguish between asexual reproduction and sexual reproduction.*
   *(b) List the advantages and disadvantages of sexual reproduction.*

*(c)State the four similarities and five differences between mitosis and meiosis.*

6. *(a) Distinguish between asexual reproduction and sexual reproduction.*
   *(b) List the advantages and disadvantages of sexual reproduction.*
   *(c) State the four similarities and five differences between mitosis and meiosis.*

7. *(a)Briefly explain the following: (i) oviparous reproduction (ii) ovoviviparous and (iii) viviparous reproduction. Give one example in each case.*
   *(b)Describe budding and fragmentation as methods of reproduction in Hydra.*
   *(c)List two differences between reproduction in a named moss and a named fern.*

8. *(a) Give an illustrated description of the structure of a named insect-pollinated flower which you have studied.*
   *(b) Define pollination.*
   *(c) Name the insect which brings about pollination in the flower you have selected and describe briefly how the flower is pollinated by this insect.*

9. *(a)What are the essential differences between wind-pollinated and insect-pollinated flower?*
   *(b)Describe with the aid of labelled drawings the method of pollination in one insect pollinated flower.*
   *(c)In a tabular form state six differences between sexual reproduction in flowering plants and mammals.*

10. *(a)Explain the term pollination in flowers.*
    *(b)State the characteristics of wind pollinated and insect pollinated flowers.*
    *(c)What are the advantages and disadvantages of cross pollination?*

11. *(a) Briefly describe the structure of a named wind pollinated flower you have studied.*
    *(b)How is pollination carried out?*
    *(c)Name one mammal that pollinates a named flowering plant. State three features adapted by the plant that enables the named mammal to pollinate it.*

12. *(a) State the conditions necessary for the germination of seeds.*
    *(b)By means of diagrams only show the structure of a maize grain.*
    *(c)Name one example of a seed having hypogeal germination and one having epigeal germination. By means of three labelled drawings only, show what is meant by these terms.*

13. *(a)By means of two labelled diagrams, show the structure of a named seed. Also make three further diagrams to show stages in its germination.*
    *(b)Name two food substances which are stored in this seed and explain how these food substances are made available to the developing seedling.*

14. *What do you understand by the term germination? State the conditions necessary for germination of seeds. How would you attempt to demonstrate the conditions that are necessary for germination of seeds?*

15. *(a) (i) What do you understand by dispersal of fruits and seeds?*
    *(ii)What is the use of this dispersal to plants?*
    *(b)Name two plants with fruits or seeds dispersed by wind.*

16. *Distinguish between a fruit and a seed. Draw fully labelled diagrams of three seeds or fruits dispersed by different methods. Describe how each is brought about.*

17. *(a)Describe the external features and life history of any intestinal parasite you have studied.*
*(b)What preventive measures could be used to control the spread of the parasite you have described?*
*(c)How does fertilization occur in a named bony fish?.*
*(d)Describe the various ways in which the adult tapeworm is adapted to a parasitic life.*

18. *(a)What do you understand by metamorphosis in insects?*
*(b)Describe the life history of a named insect with complete metamorphosis.*
*(c)Briefly state how the metamorphosis of a toad or frog differs from that of the insects.*

19. *(a)What are the external general characteristics of insects as illustrated by either a cockroach or grasshopper or locust?.*
*(b)What is the economic importance of any one of the following: a mosquito, a honey bee, an ant and a termite?.*

20. *Give an account of the life history, describing the four stages of a housefly. What is its economic importance and how is it adapted to carrying disease? How is the insect controlled? (WASC).*

21. *(a)Describe the life history of an insect with incomplete metamorphosis. Indicate the differences between complete and incomplete metamorphosis.*
*(b)How is the insect adapted to its environment?*
*(c)What is the economic importance of the insect and how is it controlled?*

22. *(a)Describe the life history of a named mosquito or gnat.*
*(b)How is this insect controlled?*
*(c)Name three diseases in which mosquitoes act as vectors.*

23. *What do you understand by the term metamorphosis? Describe the development of a toad (or frog) from the fertilized egg to the time the young animal leaves the water to live on land. Name one animal other than an amphibian in which metamorphosis occurs (W.A.S.C.).*

24. *(a)Make a full labelled drawing of the side view of the internal gill stage in the development of a frog or toad.*
*(b)Briefly describe the changes that take place after this in the development of the tadpole into the adult toad.*
*(c)How do the external features of the frog or toad differ from those of a lizard? (WASC)*

25. *Study carefully the diagrams below. Use them to answer the following questions.*

*(a) Name the process represented in the diagrams above.*

*(b) State the type of cells in which this process can occur.*

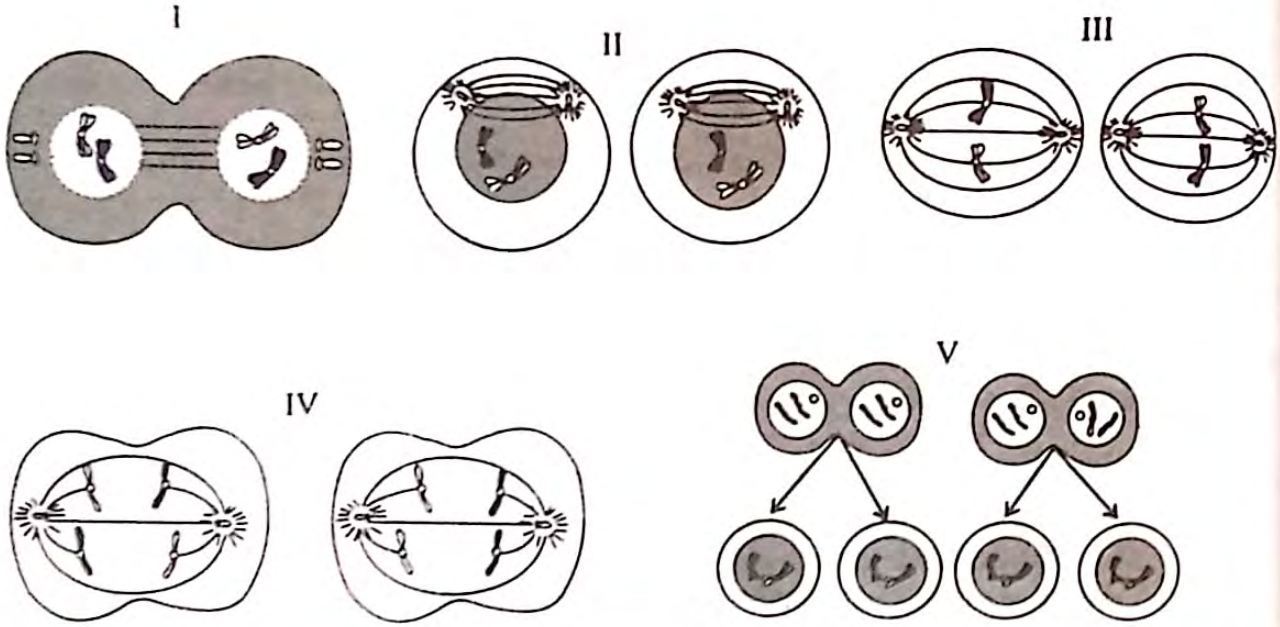
*(c) Give examples where the process can occur in (i) plants and (ii) animals.*

*(d) Identify each stage of the process label: I to V.*

*(e) State the differences between structure labelled I and II.*

*(f) (i) If the chromosomes number in II is 46, what will be the chromosome number in each of the cells in V?*

*(ii) What is the significance of the process?*




26. *Describe the egg production and parental care in a named amphibian, and a named bird. (OXF).*

27. *Give in general outline, the fertilization, feeding and birth of the embryo of any mammal. (Diagrams optional). Why is it that the mother's blood does not pass to the embryo's blood?*

28. *(a) State the similarities and differences between the following:*
*(i) male and female reproductive organs.*
*(ii) sperm and egg of mammals.*

29. *(a) Briefly explain the meaning of family planning.*
*(b) What are the benefits of family planning?*
*(c) Briefly describe the methods of birth control in your country.*

30. *Write brief notes on the following:*
*(i) seasonal migration*
*(ii) territoriality and*
*(iii) swarming in termites.*

31. *(a) (i) Explain the term courtship behaviour in animals.*
*(ii) How does courtship aid reproduction in animals?*
*(b) Describe the process of fertilization in flowering plants. (SSC 1994).*

# 17 GROWTH

Growth is one of the characteristics of living organisms. Growth in living things is an irreversible increase in size following the utilization of food to make new or additional protoplasm within the body of the 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 new 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 new 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.**

All living things have a pattern of growth inherited from their parents. As long as food is available in sufficient amount, this pattern is maintained. Even though food supply is in excess of demand or need, a rat, for an example, will not grow to the size of a goat. 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.

The process of growth is in three stages. These are:

1. **Assimilation** of nutrients absorbed from the environment in the process of feeding.
2. **Expansion of the cell** due to increase in the protoplasm and
3. **Cell division** which takes place when the cell is fully matured.

In most plants, growth is throughout life though it may slow down at certain stages whereas in most animals growth stops at maturity.

## Nature of growth

The nature of growth is that it is **irreversible**. The materials that have been formed as a result of growth are irreversible. Some people question the irreversibility of growth on the ground that a person who was once fat can become lean. In looking at size or volume as an aspect of growth, care should be taken to note that when cells come in contact with free water, they absorb it and swell, they become turgid and increase in volume. If the same cells lose this water in a changed situation they become smaller in size and decrease in volume. But the materials of the protoplasm of the cells remain the same. The materials built as protoplasm is the dry weight of the organism and it does not decrease. The water which can be gained or lost is the **fresh weight** of the organism and it changes freely. While fresh weight can change and alter volume or size of an organism, the dry weight remains the same. The only problem is that dry weight cannot be measured without killing the organism. The increase in the number of cells and the length or height of an organism as an irreversible phenomenon is not questioned. **In concluding, therefore, growth is an irreversible increase in the dry matter incorporated in the mass, volume or size, weight, number of cells and in the length (height) of an organism.**

## Basis of growth

### Mitosis

Basis of growth involves three major processes namely **(1) cell division, (2) cell enlargement and (3) cell differentiation.**

## 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 **repli-cation**) 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).

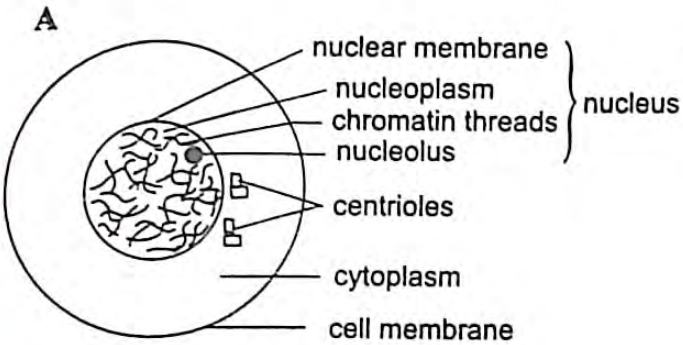
**Mitosis** is therefore a division of a cell to produce two identical cells with the same number of chromosomes and characteristics as those of the parent cell. Mitosis occurs in somatic (body) cells such as skin, bone marrow, lymph nodes and injured place and meristematic tissues in plants.

## Interphase

Chromosomes become elongated and form 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.




Interphase stage

## Prophase

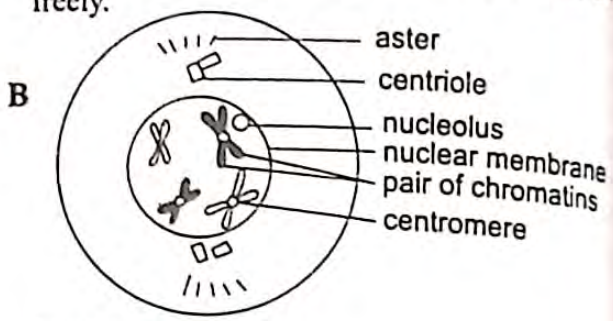
There are two stages in prophase, namely early and late prophase.

### 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

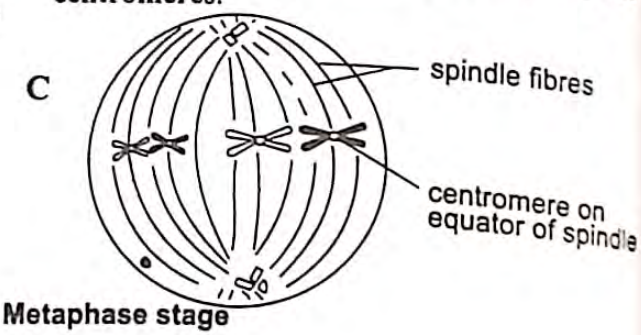
1. Chromosomes become shorter, thicker and very visible.
2. Each chromosome now forms two distinct chromatids joined by a centromere.
3. Nucleolus disappears entirely.
4. Nuclear membrane disappears allowing the mixing up of cytoplasmic and nuclear materials freely.




Prophase stage

## Metaphase

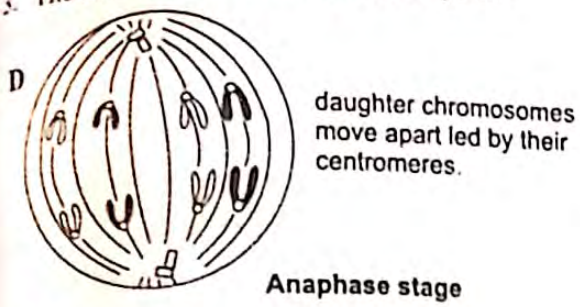
1. The chromosomes (now paired chromatids) arrange themselves along the equator of the spindle.
2. The chromatids are attached to the spindle by the **centromeres.**




Metaphase stage

## 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.




## 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.

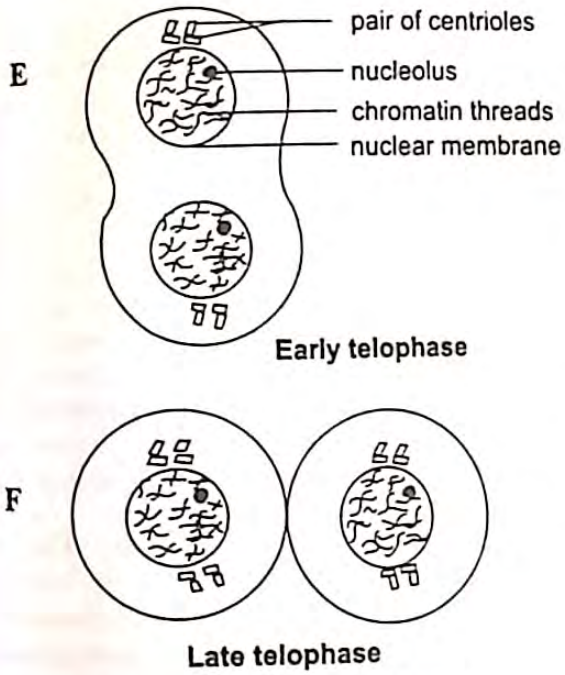



**Figure 17.1. A to F. Different stages of mitosis.**

### 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 fertilized 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.

### Cell enlargement and differentiation

After mitosis in animals the daughter cells absorb nutrients from the 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.

### Apical and intercalary growth

Growth does not occur any how in all 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 differentiation 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.

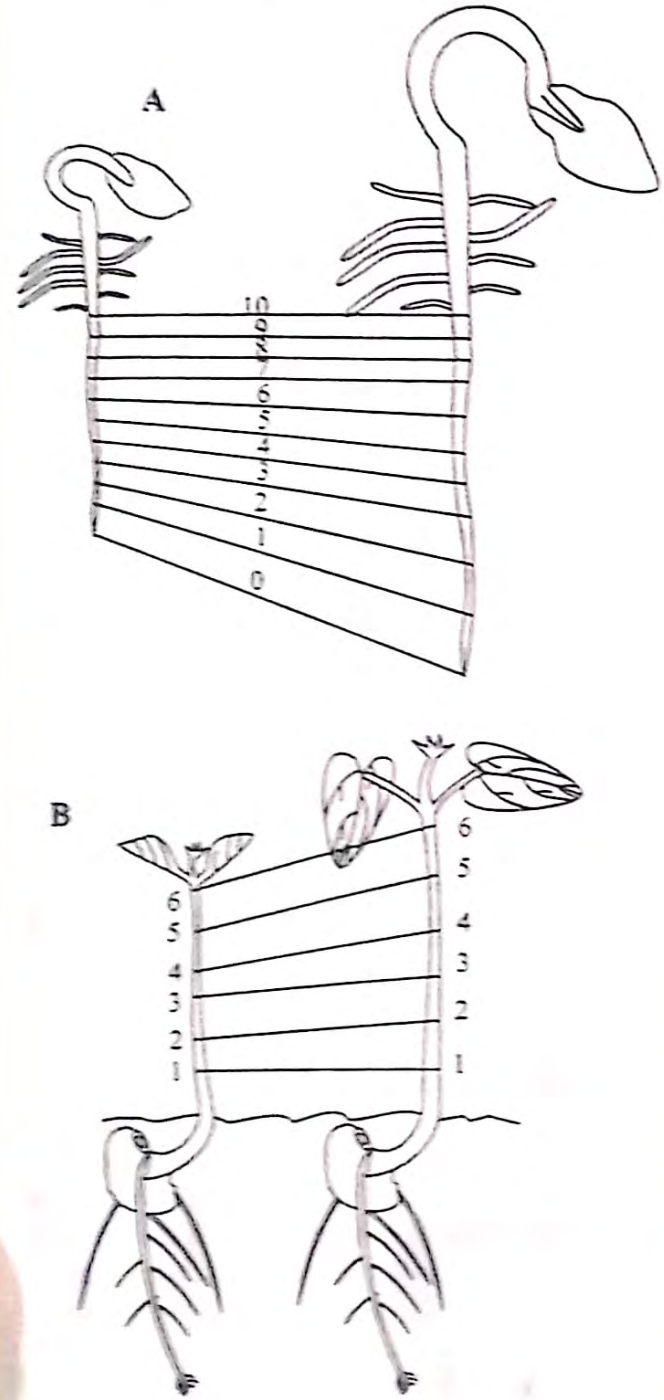



Figure 17.2.
A = Region of growth in a root of broad bean seedling.
B = Region of growth in the shoot of African yam bean.

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 root and stem tips or apices.

Growth which occurs at the meristems of the base of internodes is called ***intercalary*** **growth.**

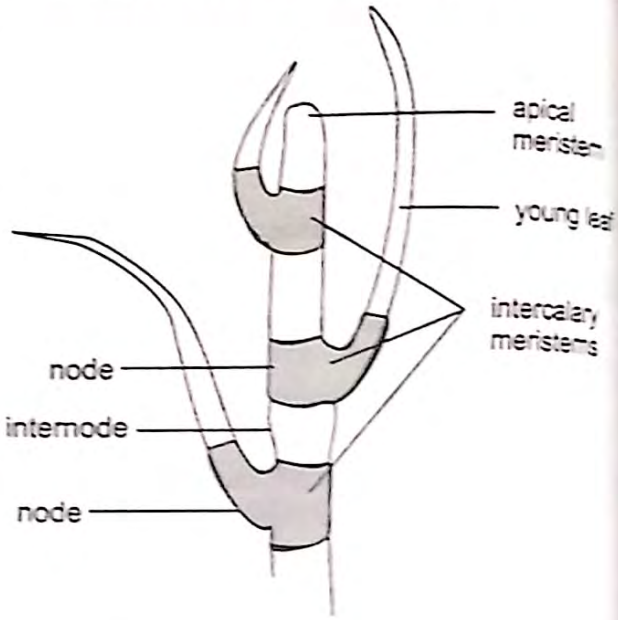



**Figure 17.3. Intercalary growth at the nodes of stem.**

It is responsible for the development of the branching system of the stems and roots. The formation of lateral appendages such as root 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.

## 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 females 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 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 starts to diminish. In most plants, growth continues and increase in size and development of new stem and root branches, leaves, flowers and fruits containing seeds are recorded from time to time throughout their life history.

## 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 conditions. In animals generally body parts are numbered. In **tapeworm**, however, there is an exception to this rule for the number of proglottides is not fixed or pre-determined in its embryo. It produces pro-glottides throughout its life cycle as most plants produce leaves. In most plants the number of nodes and internodes, root 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 through-out the life cycle of the plants. This is an instance of indefinite growth in most plants.

## 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 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 the 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 structures*. 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 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 both plants and animals show **isometric growth** while their sexual reproductive organs shows **allometric growth**.

## 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 and 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.

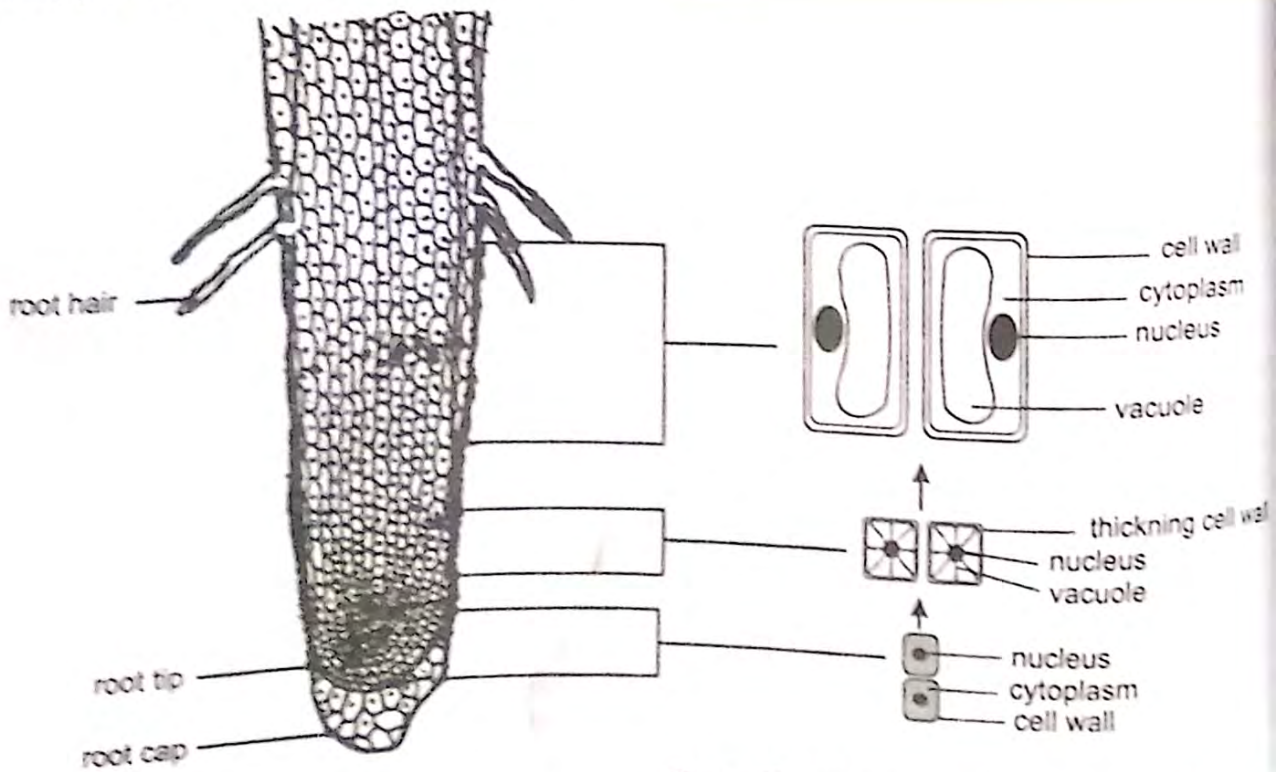



**Figure 17.4. A longitudinal section through a root tip area of cell division (meristem) cell enlargement and cell maturation.**

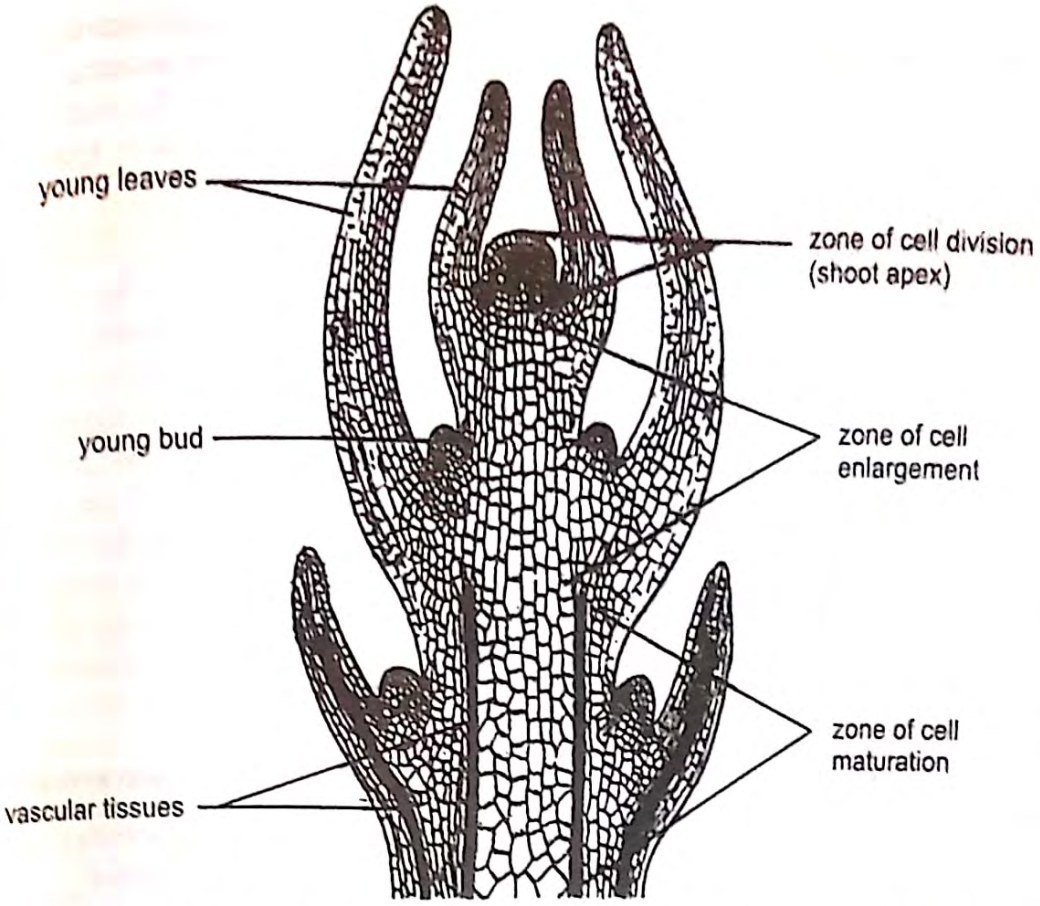



**Figure 17.5. A longitudinal section of a shoot tip showing apical meristem of the stem**

There is no sharp distinction between the regions of **elongation** and **differention**. 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 only 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 **outside**.

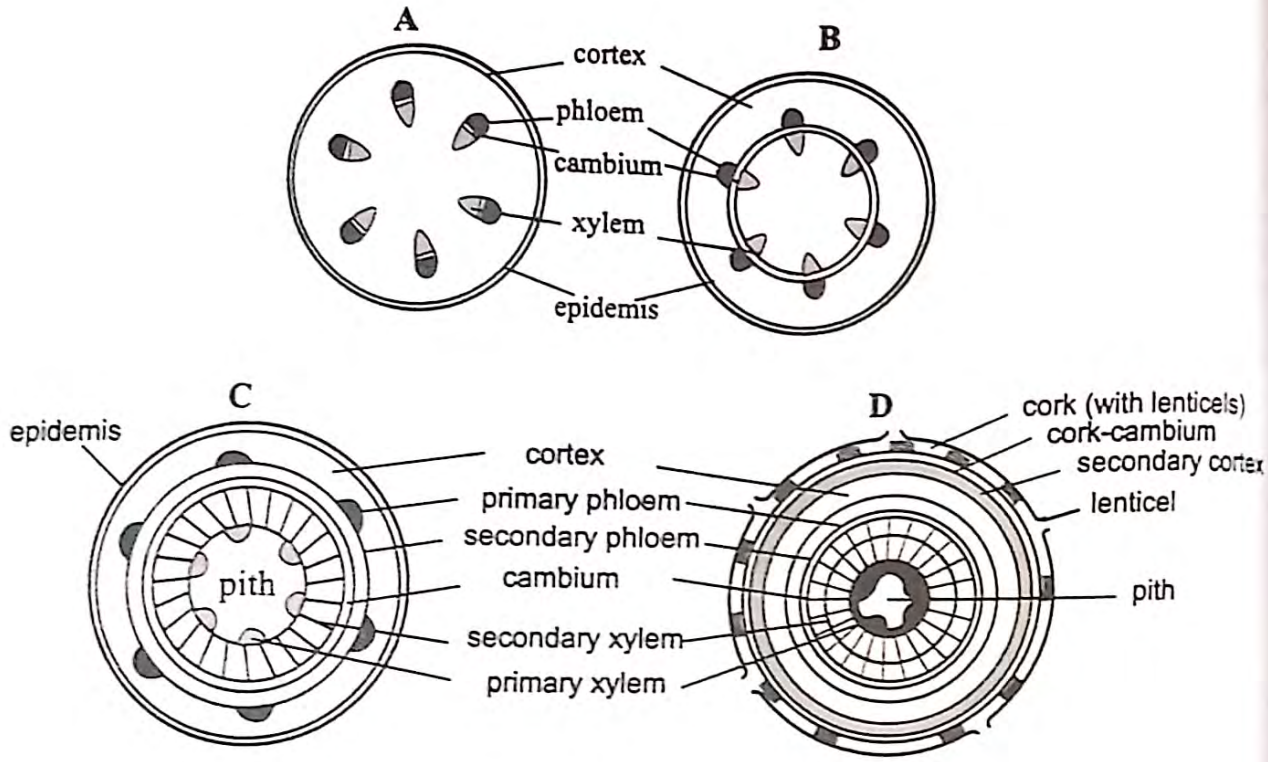



**Figure 17.6 Transverse section of stem showing the arrangement of primary and secondary tissues as secondary growth occurs.**

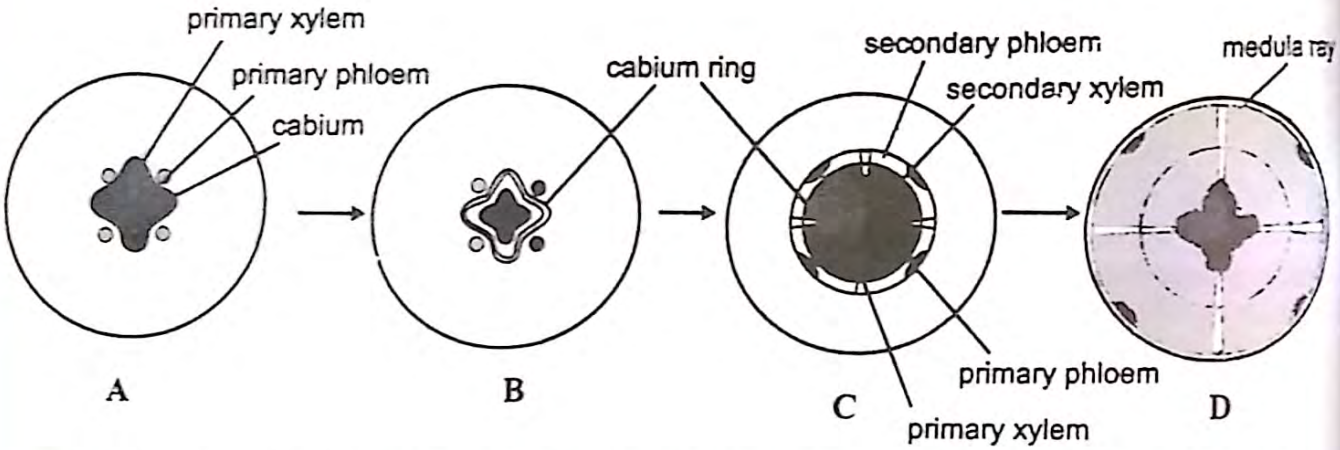



**Figure 17.7 Transverse section of root showing the arrangement of tissues as secondary growth occurs.**

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 tissue on the inner side of the cambium and new phloem tissue on the outer side of the cambium. The new 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* or **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.

## Rate of growth in plants

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 circumference 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 intervals over a known period of time represents 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.

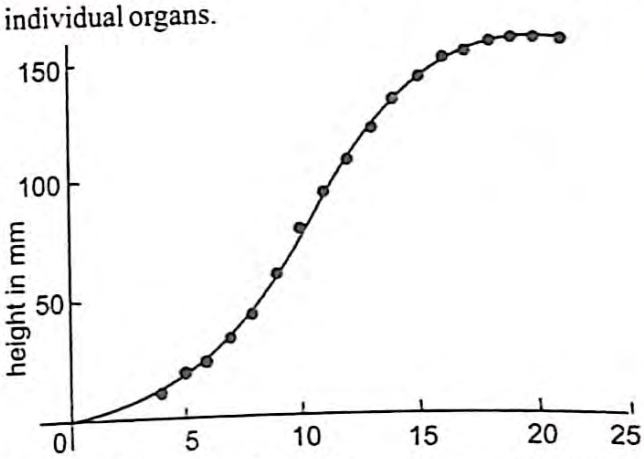



**Figure 17.8. Graph to show the sigmoid growth curve (After Simpsin, 1989).**

## 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. 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 root 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 comparison of length increase and distribution of growing areas.

## 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 measurements 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 henceforth, daily measurement is taken until growth diminishes or stops when the plant dies.

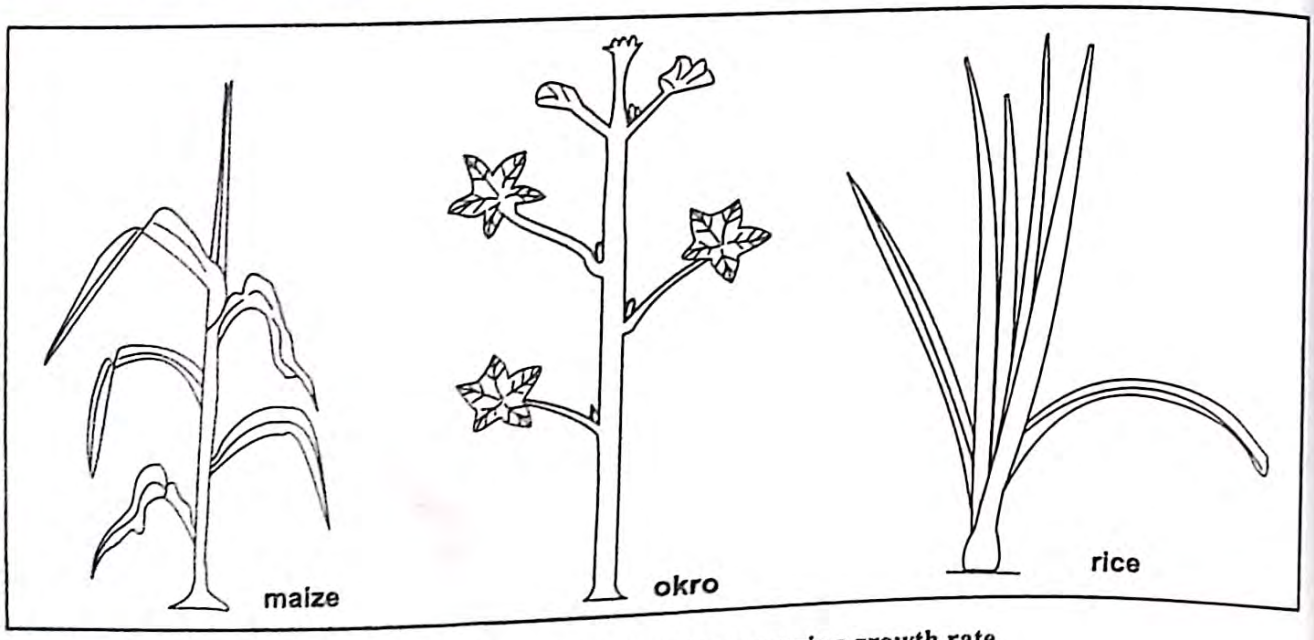



**Figure 17.9. Some plants used in measuring growth rate.**

Another available instrument that can be used in measuring height increase in whole stem of a plant is called **auxanometer**. The auxanometer is an instrument for measuring the smallest growth increase by magnifying it a hundred times so that the distance moved by the indicator on the graduated arc is divided by 100 to get the actual growth achieved by the stem.

This type of an auxanometer, fitted with a graduated arc and an indicator is called **arc indicator auxanometer** or **lever auxanometer**. There are many other types of auxanometer in use and the principle on which they operate remains the same.

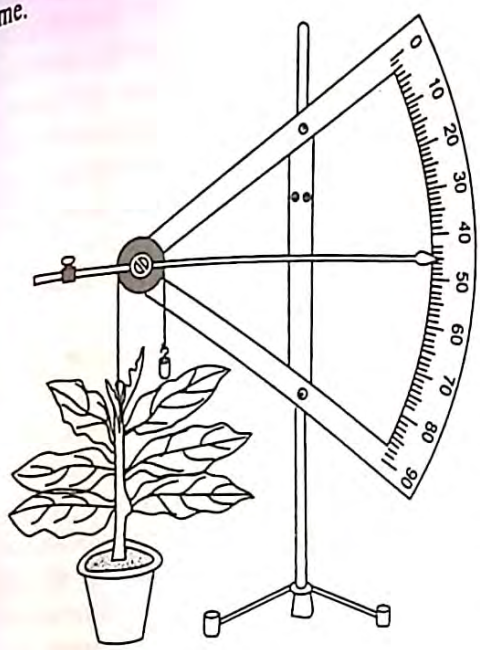



**Figure 17.10. Arc. indicator or lever auxanometer**

The auxanometer can be read at any time interval depending on the growth rate of the plants in the experiment. Readings can be taken at the end of 24 hours for the time the measurements last. At the end of the recording the pulley should be adjusted to move the lever back to O point on the graduated arc. This enables the instrument to start another day's measurement afresh without mixing it with the previous day's reading.

If the lever moves a distance of 50mm in 24 hours, the actual growth increase is calculated as follows:-

Distance = 50mm
Magnification = x100
Growth increase = 50/100 x 1/24 = 0.02mm in 1 hour.

The actual growth increase is 0.02mm in 1 hour. At the end of this exercise, the growth increase should be plotted against time for the selected annuals and their growth curves compared. They are likely to show the same **S-shaped** or **sigmoid curve** even though the rate of growth is likely to be different. From the data and graphs, information about the growth pattern as a whole, the rate of growth at any time during the growing period can be obtained.

## Measurement of growth of organisms by dry-weight method

The dry-weight or solid weight of organisms is the measurement of the amount of living sub-stances (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 inevi-table 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.

## 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).

## Factors affecting growth

### Temperature

Temperature has a profound effect on growth. Enzymes act best at a particular 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 plants manufacture 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 respiration 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 [illegible] carry out photosynthesis. [illegible] formed during photor[illegible] respiration, growth and f[illegible] seeds, fruits, buds and roots. [illegible] plant food for growth and oth[illegible]

### 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 enzyme controlled activities including the synthesis of new protoplasm, an essential 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 animal populations. Dead bodies of plants and animals 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 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 and the [illegible]

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 substances 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 animals. Their under-secretion and over-secretion 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**.

Animal hormones are more complex and they are secreted by ductless organs called **endocrine organs**. The endocrine organs and the hormones have been discussed in chapter 13.

## Growth in animals

Generally animals show **intercalary growth** in the sense that they grow from all parts of their body with the exception of reproductive organs. Most parts of the animals body grow side by side at the same time showing isometric growth while the reproductive organs and the brain in man which do not grow side by side with other body parts show allometric growth. In man, the brain grows to its maximum size far before the age of 10 and therefore ceases to grow, while growth in most other parts of the body continues. The reproductive organs grow to maturity at a time when growth in the other parts of the body is diminishing or approaching a stop in some cases. Measurement of growth in terms of length, height, size, volume or weight increase for most animals from hatching or birth to maturity will show the conventional **S-shaped** or **sigmoid curve**, the growth pattern in which the rate is slow at the early stage, becomes faster and continues to maturity before diminishing and stopping eventually.

The exception to this general pattern includes the *Hydra* where growth is restricted to the upper half and the basal end deteriorating. Only the interstitial cells retain the ability to divide and so by their

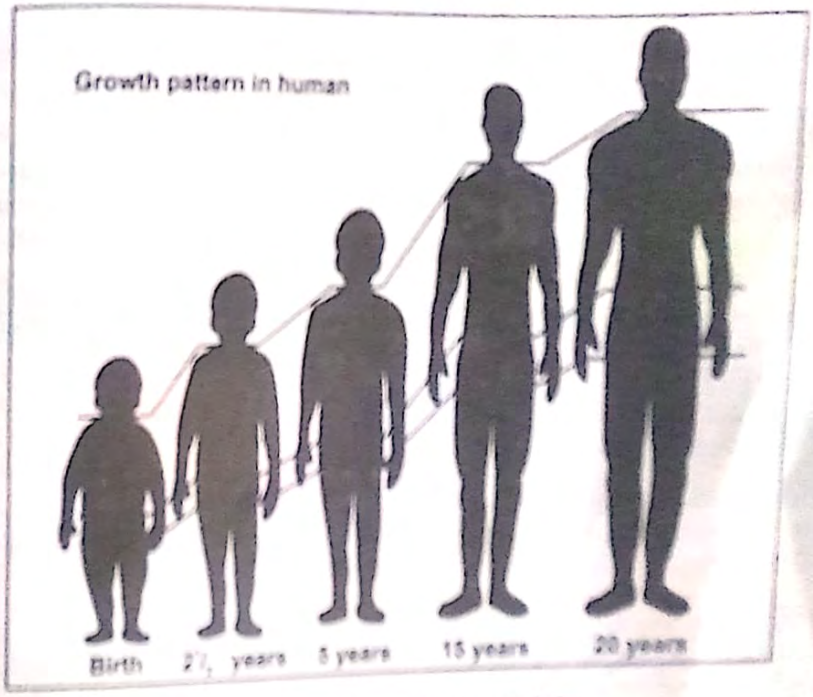



Fig. 17.11. Pattern of growth in human being

activities the cells of the basal end are continuously been renewed. With this unending renewal, *Hydra* shows continuous growth and tending to be immortal, if not for the unfavorable ecological conditions. Another exception is the class **Insecta**. The insects show intermittent growth pattern because of the hard exoskeleton which must be shed before the body can grow (expand or lengthen). Growth in the insects is therefore not smooth and regular as in most other animals. Each species has a definite number of times it moults in its life time. This imposes limit on growth as no adult insects moult. Another animal with a different growth pattern is the lobster which shows unlimited growth and grows, even though at diminishing rate, long after the last moult and maturity.

We can safely conclude by saying that growth is limited in most animals, especially the higher land forms such as birds and mammals where growth stops as soon as the maximum size is attained at maturity.

## Similarities between growth in plan and animals

1. Both multicellular plants and animals grow mitotic cell division of pre-existing cells form new cells.
2. Both achieve a certain amount of vegetative body growth before reproductive growth sets
3. Both show sigmoid growth curve in which rate of growth is slow at first, becomes fa later until the maximum is reached, then grow rate starts to decline.
4. Both plants and animals require food growth.
5. Both secrete growth hormones for growth.
6. Growth is irreversible in both plants and Animals.

**Table 69: Differences between growth in plants and animals**

| Plants | Animals |
|---|---|
| 1. Growth in plants is restricted to special areas as the meristemic tissues at the root tip and shoot apices. | Growth in animals is not restricted to special areas instead it takes place all over the body. |
| 2. Growth is continuous throughout life in the growing regions. | Growth is not continuous throughout life in most animals. However animals such as lobsters and fish grow 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 e.t.c. | Growth in animals is usually not directly influenced by such external factors. |

## *Questions*

1. *(a) Define the term growth as applied to living organisms*
   *(b) State three similarities and three differences between the growth in plants and animals.*
   *(c) List four factors that affect the growth of living organisms.*

2. *(a) Define the term mitosis.*
   *(b) What role does mitosis play in growth?*
   *(C) Briefly describe the process of mitosis in an animal or plant cell.*

# 18

# GENETICS AND VARIATIONS

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 the grand parents. This tendency of the offspring to look like their parents or grand parents 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 thousand years ago, that is "**like tends to beget like**".

Very often in our homes such questions are asked about inheritance of traits such as colour, hair colour or colour of eyes that a particular individual has. At other times a particular child may be described as showing some traits resembling one of his grand parents. When questions of this nature are asked one is asking genetic questions. **Genetics, may then be described as the science that deals with questions and answers 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's curiosity to unravel the mechanism for the transmission of traits from parents 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 recognized that parental characters were transmitted by both the pollen and the ovule. However, studies of heredity before 1866 were not conclusive. The results obtained by earlier investigations offered little explanation of the way inheritable features were transmitted from one generation to the other.

Work in genetics continued to draw the attention of natural scientists, and in 1866 an **Austrian monk** who lived in the monastry in Brun, published two small treatises on the laws of heredity in the journal of the local natural Science Society. This man, **Gregor Mendel**, later became the head of the monastry. His many added responsibilities prevented him from continuing his study of heredity. He died in 1886 without realising that his two small contributions could form the foundation for all the work that has since been done in genetics. It was not until 1900 that three investigators working independently discovered what they thought were new findings about heredity. These men, **de Vries** in Holland, **Correns** in Germany and **Von Tschermak** in Austria rediscovered the phenomenon of regular, predictable ratios of the types of offspring produced by mating pure breeding parents. But, then, searching through literature in the field, they came across Mendel's earlier reports on the same subject. They then realized that Mendel was the pioneer in these investigations and gave him full credit for his work by naming two of the fundamental principles of heredity **Mendel's laws**. All the work that has been done in genetics has made use of Mendel's basic discoveries, and so, today, he is known as "**the father of modern genetics**". Great advances have been made in genetics, cytogenetics and related fields but Mendel's two laws still remain the fundamental laws of heredity in genetics.

## Cell

The cell is the basic unit of the body and the study of heredity is centred on the **nucleus** of a living cell. The details of the cell have earlier been treated in **chapter.2.** However, not much was mentioned about its hereditary properties. In the following paragraphs a consideration is given to

the **nucleus** which is concerned with **reproduction** and **heredity**. Within the nucleus of the cell are materials that control the heredity of the individual. We should remember that only the **chromosome** is involved in heredity which is determined during the process of **meiosis** during **gametogenesis**.

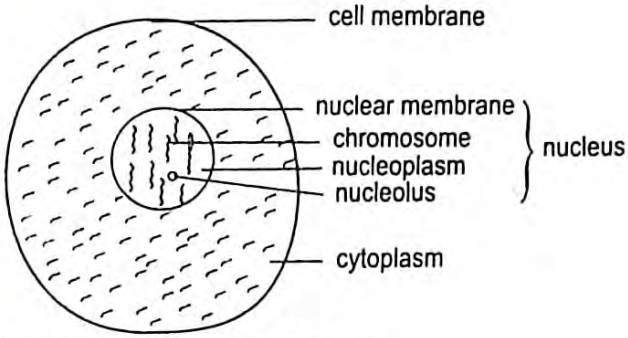



**Figure 18.1. Typical animal cell.**

## Chromosonal basis of heredity

Within the nucleus of non-dividing cells are strands or string-like structures known as **chromosomes**. As the cell is about to divide, the chromatids become more visible as strands with bead-like structures on them. These are the chromosomes and contain **genes**, which carry the genetic information which are transmitted from the parent to the offspring. We may then say that the chromosome is a nuclear component having a **special organization, individuality and function. It is capable of self-reproduction (duplication) during cell division and of maintaining, its morphological and physiological properties through successive cell divisions.**

Within the chromosomes and arranged in a linear order are the elements or factors that determine both the mental, physical and physio-logical attributes of the individual. These factors are called the **genes**. One can, therefore, say that a **gene is a unit of heredity, that is, the element that determines the character of the individual such as height, or the stem length, colour of flower and so on**. Studies have shown that these genes are made up of a long chain of **deoxyri-bonucleic acid** molecules (**DNA**).

### DNA AND RNA

**DNA** (deoxyribonucleic acid) is a chemical substance present in the nucleus of every cell. It is passed from parents to offspring and is being regarded as a **code of life**. Since **DNA** is present in the nucleus and is acidic in nature, it is also referred to as nucleic acid.

## The structure of DNA

DNA is made up of two chains of small chemical units called **nucleotides**. Each nucleotide consists of a **phosphate group**, a sugar called **deoxyribose** and a nitrogenous base. The nitro-genous bases are purines and pyrimidines. The purines are adenine (**A**) and guanine (**G**) while the pyrimidines are thymine (**T**) and cytosine (**C**).

The nucleotides are twisted into each other to form a double helix, something like a spiral staircase. The chemical structure of these bases are bond in certain pattern as adenine always joins thymine and guanine always joins cytosine. In other words the nitrogenous base from one chain (purine) links up with a compatible base (pyrimidine) of the opposite chain like rungs (steps) of a ladder. The four bases of the **DNA** chains are held together by hydrogen bonds.

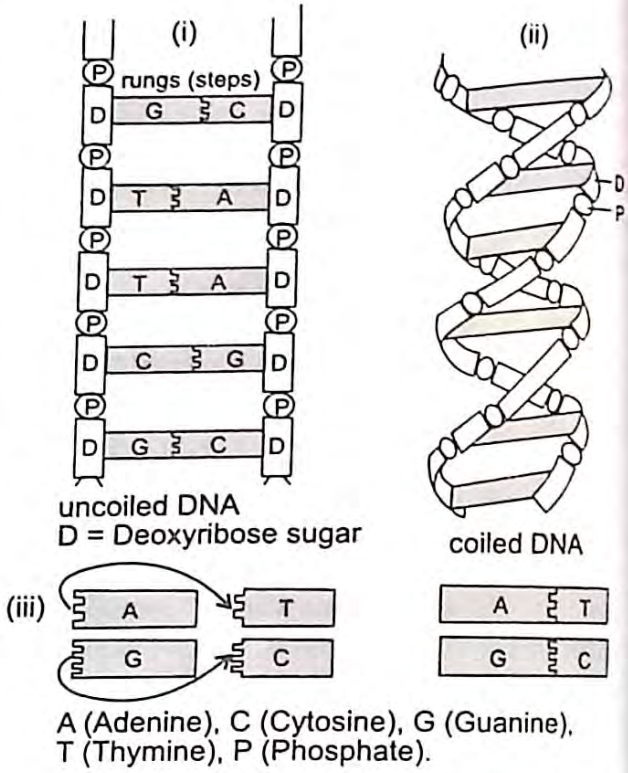



**Figure 18.2A. (i) Structure of *DNA* is like a ladder**
**(ii) It is twisted into a helix in nature**
**(iii) Units of *DNA***
**(iv) Combination of *A* with *T*, *C* with *G***

## The role of DNA

DNA transcribes the hereditary characteristics of the parents onto the offspring.

DNA keeps the number of chromosomes peculiar to the organism constant from generation to generation. DNA does this by doubling its number (replication or duplication) during mitosis and meiosis in the processes of asexual and sexual reproduction. Under the arrangement, the newly divided cells contain the complementary number of chromosomes of the parent.

DNA controls growth and development in every living thing. It does this by controlling protein and enzyme synthesis in the cytoplasm of the cell. The growth of an organism solely depends on the type of protein it can build following the instructions passed onto it by the DNA. At the same time the kind of enzymes an organism can secrete determines its development. The kind of enzymes secreted by an organism is directly controlled by the DNA. The DNA uses three types of **ribonucleic acid (RNA) (messenger RNA, ribosomal RNA and transfer RNA)** in starting and controlling the synthesis of proteins and enzymes in the cytoplasm of the cell since it does not leave the nucleus.

1. It uses the messenger **RNA (mRNA)** to dispatch specific codes for the synthesis of protein to the cytoplasm.
2. **DNA** controls the synthesis of ribosomal **RNA (rRNA)** and later dispatches it to the cyto plasm where it is responsible for the attachment of ribosomes to the **messenger RNA.**
3. **DNA** dispatches transfer **RNA (tRNA)** into the cytoplasm where it picks and hands over various amino acids to the ribosomes to be joined together in long chains during protein synthesis.

Enzymes are protein in nature and are therefore synthesized under the same circumstances in the cytoplasm under the control of the DNA. All the differences among the living things are due to the number and type of codes contained in the DNA of the individual organism. For example most animals lack the cellulose digesting enzymes called **cellulase.** Such animals starve when placed on a diet that contains more cellulose than other food types. The absence of **melanin pigment** in the skin accounts for **albinism.** The **albinos** lack the enzyme **tyrosinase** and so cannot secrete tyrosin for the production of melanin.

## The structure of RNA

The **ribonucleic acid** commonly called **RNA** is similar to the deoxyribonucleic acid, **DNA.** They are both referred to as nucleic acid because they are acidic and are found in the nucleus even though **RNA** is widely distributed in the cytoplasm of the cell.

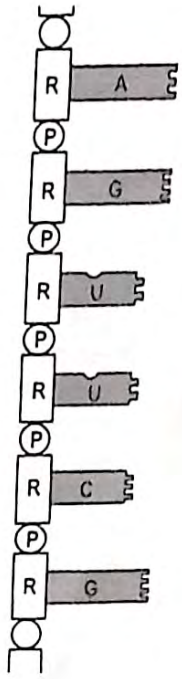



**Figure 18.2B. The structure of RNA Ribose sugar.**

**RNA** is different from DNA in having a sugar which contains oxygen while the sugar of DNA has no oxygen hence the name **deoxyribonuclei acid.** The nitrogenous bases **purines** are the same in both **DNA** and **RNA** while they differ in the

**pyrimidines.** The pyrimidines of DNA consist of **thymine** and **cytosine** while those of RNA are made up of **uracil** and **cytosine**. Both DNA and RNA carry genetic code. This is why some viruses that lack DNA have RNA to carry out their genetic functions. RNA occurs as half of a molecule. It consists of a single upright strand of sugar and phosphate units. The nitrogenous bases of RNA are not in pairs. They occur singly. Three of the four nitrogenous bases are the same as those of DNA, **adenine** (A), **cytosine** (C) & **guanine** (G). The fourth base **thymine** (T) is replaced with **uracil** (U) in RNA.

There are three types of RNA synthesized by the nucleus under the control of the DNA. These are

1. **Messenger RNA (mRNA)**
   This is the strand of RNA that collects the specific codes for the synthesis of particular amino acid in the nucleoprotein bases. It breaks off and moves through the nuclear membrane into the cytoplasm. Ribosomes get attached to the strand of the RNA and protein is synthesized.
2. **Ribosomal RNA (rRNA)**
   It is synthesized in the nucleolus under the control of the DNA. It is responsible for the attachment of ribosomes to **messenger** RNA. It regulates the enzymes involved in the activities of ribosomes.
3. **Transfer RNA (tRNA)**
   The strands of **transfer** RNA are shorter than those of the **messenger** RNA. Various amino acids that will be joined together in long chains during protein synthesis are dispersed throughout the cytoplasm. There is a system in the **messenger** RNA that determines the exact amino acids and the sequence in which they are linked. The role of the **transfer** RNA is to pick the amino acids individually and bring them to the **ribosomal** RNA in the proper order during the protein synthesis.

Some early studies by **Drs Morgan, Bridges and Sturtevant** indicated that some of the hereditary characteristics of the fruit fly **Drosophila** could be related to definite regions for the chromosomes of this animal. By a careful analysis of the results from breeding flies with different features, it was possible to locate within the chromosomes the regions that contained specific hereditary characteristics.

Studies carried out with the chromosomes of salivary glands of the fruit fly *Drosophila* demonstrate these structures have produced interesting and valuable results. The chromosomes in these glands are many times larger than those in the **gametes** or the other body tissues of the animal. It evidences shows that these chromosomes are made up of numerous minute chromatids, perhaps as many as a thousand. These chromosomes are said to be **polytene**. In giant chromosomes are properly arranged alternating bands of DNA and light material are seen. By comparing these giant chromosomes with ordinary chromosomes it has been found that the **same genes** are present at exactly the **same points** in chromosomes at which genetic method long the genome of genes.

## Cell divisions in a developing embryo

Following the fertilization, the egg cell now known as a **zygote**. The zygote then divides by mitosis to form two cells and later four cells, eight, and so on. As first these divisions are regular but soon the mathematical sequence is lost since some cells start to divide more rapidly than others. As a result of this change in division rate, certain tissues develop earlier or till has the other tissues. Finally there are two types of cells and the division patterns are equally different.

## Gametes or body cells

There are the cells of the living body which are concerned with sexual reproduction. Each of contains the full chromosome number characteristic of the organism. This is called the diploid number for the somatic cells divide by **mitosis** which multiplies chromosomes, and produce two or more daughter cells each having the same number of chromosomes as the parent cell.

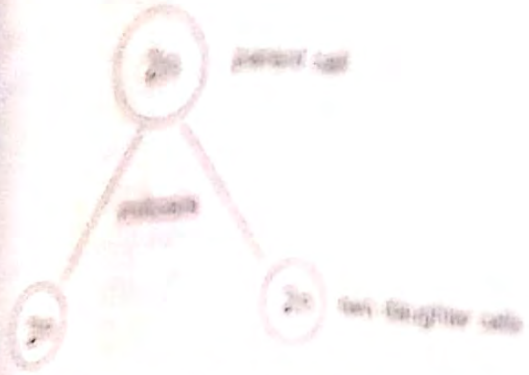



Figure 18.3. The somatic (body) cells.

## Germ cells (reproductive cells)

It has been noted that during the development of the reproductive organs, the cells divide by mitosis just like the other body cells. Each cell receives the same number and type of chromosomes as the others.

The second group of cells are referred to as the **germ cells**. These cells are specialized kinds of cells found in the gonads (**testes** and **ovaries**). They are also found in plant structures such as **anthers** and **ovaries** for the formation of gametes (sperms and eggs). Whereas somatic cells divide to produce daughter cells having the same number of chromosomes as the parent cells, division of a germ cell gives rise to daughter cells in which the number of chromosomes is reduced to **half** or **haploid number (n)**. This type of division is called **meiosis** or **reduction division** and it takes place only during the formation of the sex cells, the sperms and eggs.

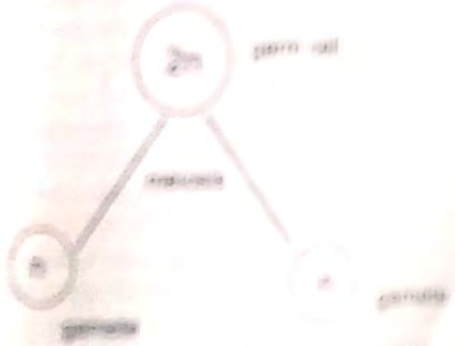



Figure 18.4. The process of meiosis in gametes.

The somatic cells of man contain 46 chromosomes and, example, each egg or sperm contains 23 chromosomes. The number of chromosomes of each organism is constant from generation to generation. It is the meiotic events in the reduction division that keep it constant from generation to generation.

During reproduction in man:

Egg cell + Sperm = Zygote

n + n = 2n

23 + 23 = 46 (23 pairs)

Each gamete has the **haploid number** of chromosomes. During fertilization, there is a fusion of the nucleus of the sperm with the nucleus of the egg thus restoring the diploid number of chromosomes (2n) characteristic of the organism.

The diploid number of chromosomes varies from one organism to another. Except in a few cases, the number of the chromosomes does not be the principal factor in determining the complexity of an organism. Rather, it is the quality of the genes that is of utmost importance in determining the complexity of the organism. The following table shows the chromosomes the variation among a few selected plants and animals.

**Table 7.1: Diploid and haploid number of chromosomes in some organisms.**

| Organism | Diploid number | Haploid number |
|---|---|---|
| Man | 46 | 23 |
| Vibrion | 24 | 12 |
| Horse | 64 | 32 |
| Lupin | 48 | 24 |
| Fruit fly | 8 | 4 |
| Honey bee | 32 | 16 |
| Cockroach | 156 | 78 |
| Fig | 26 | 13 |
| Rice | 24 | 12 |
| Corn | 20 | 10 |

## Genetic terminologies

In order to have a full appreciation of the subject matter there is a need to define some genetic terms which the student is likely to come across from time to time.

## Hybrids

These are the **progeny (offspring)** of a cross between genetically unlike parents or individuals. The parents for the production of a hybrid show contrasting features, for example, tall and dwarf parents.

## Genotype

This refers to the individual genetic constitution which is the sum total of all the genes that the individual has inherited from his parents.

## Dominant

A trait is said to be dominant when it is expressed in the presence of another character that is suppressed.

### Recessive

A character or trait is said to be recessive when it is not expressed in the presence of another character. In other words, such a character is suppressed.

## Phenotype

This refers to the appearance of the individual. This may also include not only physical appearance but also physiological responses of the individual and is affected by both the genotype and environmental influences.

## Alleles

This refers to a pair of contrasting genes on the chromosome for expressing a pair of contrasting character e.g. Tt for height.(T = tall; t = short)

## Monohybrid cross

With the knowledge of the cell more especially the nuclear components at the background one is now in a better position to appreciate the work of Mendel, to see how the biologists came about some of the terms applied in the study of genetics. Mendel's work was concerned with the inheritance of various characteristics shown by the **pea plant.** He grew plants of this species in the monastry garden and kept very careful notes on the results he obtained. One feature which made the pea particularly suitable for this study is that pea plant is normally self-pollinated. This feature enabled Mendel to control his experiments. Mendel con- centrated on one characteristic at a time, and made his crosses between plants which had shown the trait through several generations.

## Mendel's Experiment on Dominand and Recessive characters

Mendel's work was concerned with the inheritance of various characteristics shown by the **pea plant.** He grew plants of this species in the monastry garden and kept very careful notes on the results he obtained. One feature which made the pea particularly suitable for this study is that pea plant is normally **self-pollinated.** This feature enabled Mendel to control his experiments. Mendel concentrated on one characteristic at a time, and made his crosses between plants which had shown the trait through several generations.

Mendel crossed a pure tall pea plant with a pure short (dwarf) pea plant by transferring pollen grains manually from the stamen of pure tall pea plant to the stigma of pure short pea plant. Or transfer pollen grains from pure short pea plant to the stigma of pure tall pea plant.

After fertilization, the resulting plants were observed. To his greatest surprise, all the plants were **tall.** No short pea plant appeared. Could this mean that **"tallness"** overpowered **"shortness"** or the shortness is lost? The question was answered when Mendel germinated some of the seeds from the tall pea plants which he called the **"First Fillial Generation** or simply called **$F_1$ generation.** He allowed the tall pea plants of the **$F_1$ generation** to self pollinate to produce **"second filial generation" or $F_2$.** The result of this self pollination was interesting and quite striking as some of the pea plants were **tall** and while others were **short**. No intermediate height. Three fourths (3/4) of the plants were tall while one fourth (1/4) were short, that is, in the ration of 3:1. The reappearance of short pea plants in the $F_2$ generation showered that $F_1$ pea

plants possessed characters of short without showing it. These findings are summarized in figure 18.5.

Figure 18.5 (a) Gregor Mendel experimenting with garden peas.

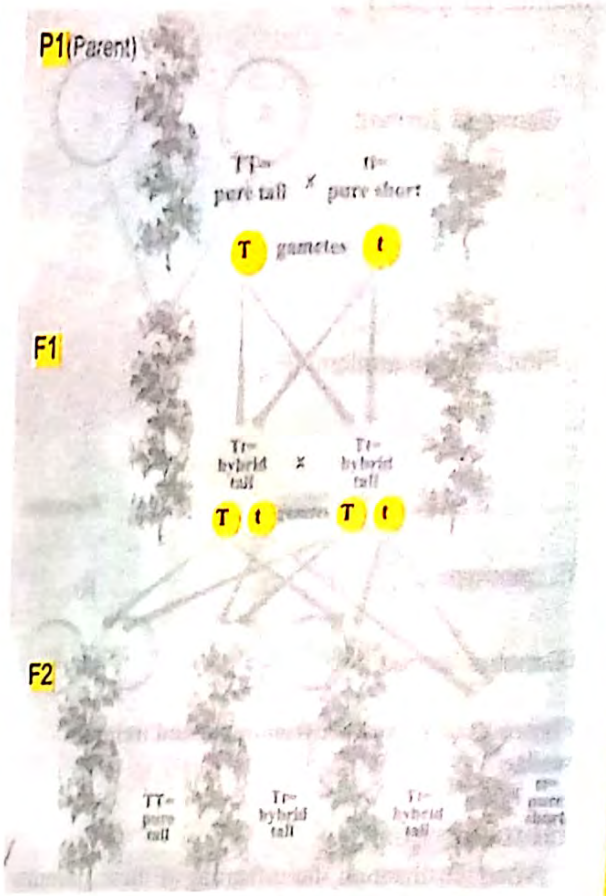



Figure 18.5 (b) Result of Mendel's experiments with pea plants.

Mendel also observed that whenever he cross-pollinated two purebred plants with any pair of contrasting characteristics one of these would appear in the offspring while the other did not.

To the characteristic that appeared in the offspring he gave the name **dominant character- istic**, while the characteristic that did not appear he called the **recessive characteristic.**

**Table** 71 shows some dominant and recessive pairs discovered by Mendel in his work with garden peas.

**Table 71: Dominant and recessive pairs**

| **Dominant** | Recessive |
|---|---|
| Tall plants | Short plants |
| Round seeds | Wrinkled seeds |
| Green pods | Yellow pods |

## Further terminologies

### Homozygosity

Since the parents in this case show pure breeding characteristics for roundness vs wrink-leness, or tallness vs dwarfness, they are said to be homozygous. (**Homo = equal, Zygosis = going**). In other words, a homozygous parent would be **RR** = roundness or **rr** = wrinkleness; ***TT*** = tallness. **tt** = dwarfness.

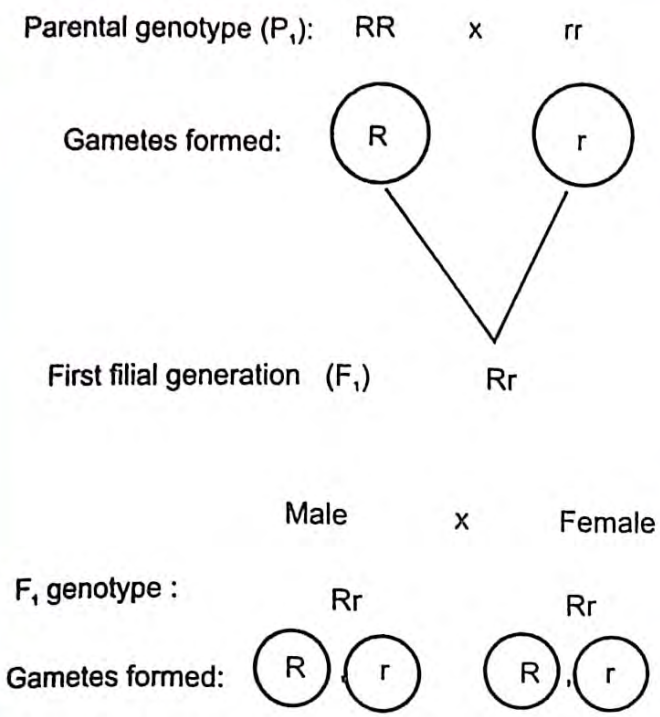



**Figure 18.6. A cross between round and wrinkle seeds.**

## Heterozygosity

After fertilization, the offspring of these parents contain one gene for roundness **R**, and one gene for wrinkleness, **r**.
They are said to be heterozygous (**Rr**).

## Mendel's conclusions from his experiments.

From his findings Mendel reached the following conclusions:

1. There must be **discrete factors (genes)** which control inherited characters in the offspring.
2. These factors which determine characters must exist in **pairs**.
3. In the formation of the gametes, the members of these **pairs** separate from each other at **meiosis** with the result that each gamete receives only one member of each pair. Genes are known to be located on the chromosomes in pairs. As the homologous chromosomes separate at meiosis, they carry along with them their genes so that members of each homologous pairs find themselves in different gametes.2

All of these conclusions are embodied in **Mendel's First Law or the law of Segregation**, which states that: ***The characteristics of an organism are controlled by genes which occur in pairs. Of such a pair of genes only one can be carried in a single gamete.***

4. One striking feature worthy of note is that there are no intermediate types amongst the offspring. It is either they are **round** or **wrinkled, tall** or **dwarf**. From this, one may conclude that inheritance is not a process in which features of two parents are blended to produce intermediate types.
5. Another important fact to emerge is that there are no wrinkle-seeded plant in the $F_1$ **generation**, despite the fact that one of the parents is wrinkle-seeded. From this two conclusions can be drawn:
   (a) Although the $F_1$ plants are round-seeded, they must have received from their wrinkle seeded parent a gene for wrinkleness which remains **"overshadowed"** or **"suppressed"** in the $F_1$ plants and does not reveal itself in the phenotype of the plants until the $F_2$ generation.
   (b) Only in the absence of the gene for roundness does the gene for wrinkleness expresses itself. In otherwords, the gene for roundness is **dominant** to the gene for wrinkleness which is described as **recessive.**

## Explanation of Mendel's first law

The events of **meiosis** help to explain Mendel's first law. In meiosis homologous chromosomes segregate from each other as a result of which a gamete receives only one type of each chromosome instead of the normal two. Genes also occur in pairs each being located on one of two homologous chromosomes.

This means that a parent with the genotype RR will have a single allele **R** in every gamete

**Table 72: Parental genotypes and gametes.**

| Parental genotype | Gametes |
|---|---|
| RR | Only one type (R) |
| Rr | Two types (R) and (r) |
| rr | Only one type (r) |

Gametes may be **eggs** or **sperm**. In his experiment on seed shape, Mendel cross-bred the traits round (**RR**) and wrinkled (**rr**) thus:

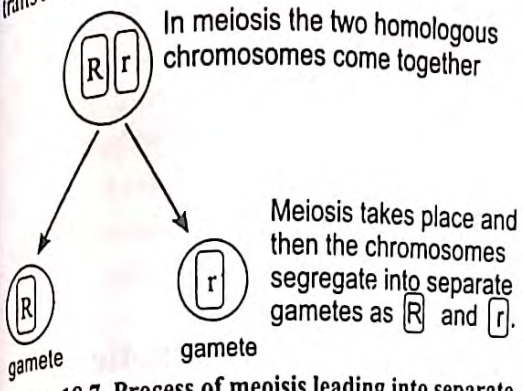



**Figure 18.7. Process of meoisis leading into separate gametes.**

It should also be noted that as homologous chromosomes segregate at meiosis, they take their genes along with them, and thus the gametes receive only one of a pair of alleles - just as they receive only one of a pair of chromosomes.

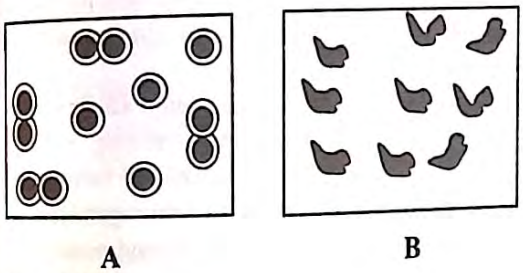



**Figure 18.8**
**A = Normal red blood cells**
**B = Sickled red blood cells.**

Thus each gamete contains only one of the original pair of genes. This serves as a convenient explanation of Mendel's law of segregation.

As all the seeds of $F_1$ generation were all round, one concludes that the round allele (**R**) is dominant to the wrinkled allele (**r**).

Allowing self-fertilization in members of the $F_1$ generation, Mendel obtained the following results.

| | Male | x | Female |
|---|---|---|---|
| $F_1$ genotype | Rr | | Rr |
| Gametes formed | R r | | R r |

| | | R | r |
|---|---|---|---|
| Female gametes from ovules | R | RR | Rr |
| | r | Rr | rr |

**$F_2$ generation**

The $F_2$ generation has the genotype ratio:
**RR** (homozygous dominant) 1 : round seeds
**Rr** (heterozygous) 2 : round seeds
**rr** (homozygous recessive) 1 : wrinkled seeds
The phenotypic ratio is:

**Rounded seeds : Wrinkled seeds**

i.e 3 : 1

This means that $^3/_4$ of the total number of seeds were round and $^1/_4$ were wrinkled. The following table 73 shows the actual number of seeds collected from ten pea plants selected at random from $F_2$ generation of a monohybrid cross.

**Table 73: Results of monohybrid cross.**

| | Round | Wrinkled |
|---|---|---|
| 1. | 45 | 12 |
| 2. | 27 | 8 |
| 3. | 24 | 7 |
| 4. | 19 | 16 |
| 5. | 32 | 11 |
| 6. | 26 | 6 |
| 7. | 88 | 24 |
| 8. | 22 | 10 |
| 9. | 28 | 6 |
| 10. | 25 | 7 |
| | | |

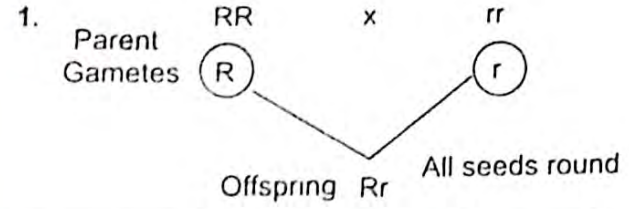
**Ratio : Round : Wrinkled**
**3 : 1**

## Test - Cross

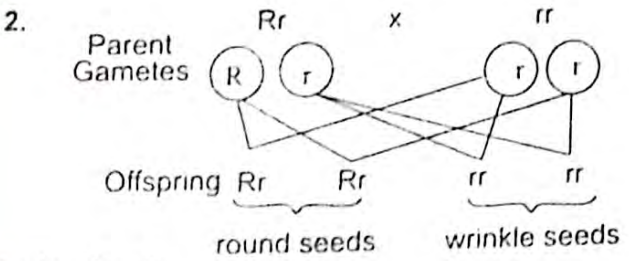
The 3:1 ratio of the $F_2$ generation is based on the phenotype, that is, by observation. The ratio of the round seeds does not reveal which seed has the homozygous genotype **RR** or heterozygous genotype **Rr**. A test-cross is performed to find out which plant is homozygous dominant or heterozygous. This involves the crossing of the round seeded plants with the plant showing the recessive traits which must be double recessive (**rr**).

Plants with **RR** genotype will produce only round seeds while plants with **Rr** genotype will produce both round and wrinkled seeds in a 1 : 1 ratio. In other words about half of the total number of seeds produced will be round while the other half would be wrinkled.

The crosses are represented thus, if the unknown genotype is **RR**:




All seeds round (100%) but if the unknown genotype is Rr, the cross is thus:




**Ratio 1 : 1**

It should be noted that in these experiments, consideration is given to the inheritance of a single trait controlled by a pair of allelic genes. In this instance we are concerned just about the seed shape which is either **round** or **wrinkled**. A cross which deals with only one inheritable character is known as **monohybrid cross**. Mendel's first law gives consideration to only one inheritable character and is therefore known as **monohybrid** or **one character inheritance**.

## Explanation of the results of the monohybrid cross in terms of probability.

In the monohybrid cross it is observed that in the $F_2$ generation $^3/_4$ of the offspring showed the dominant trait and the recessive **trait**.

This ratio 3:1 only holds true when there is a reasonable number of offspring produced.

What Mendel's experiments reveal is that if an $F_2$ plant is selected at random, there is a three in four chances of its seeds being round-seeded and one in four chances of its seeds being **wrinkled**. In other words the probability of its being round-seeded is $^3/_4$ and wrinkled $^1/_4$. A very large number of offspring must be involved for this ratio to hold true.

## The role of chance in genetic ratio

When we talk about $^3/_4$ of the $F_2$ plants being round-seeded (**dominant**), we really mean that approximately $^3/_4$ of plants are expected to be round-seeded. Observations through several experiments and trials have shown that it is unlikely that exactly $^3/_4$ of the $F_2$ offspring will be round-seeded. This is so because **chance** plays an important role in sexual reproduction. (**Random and independent assortment** of **genes**).

It should be noted that even though **allelic genes** are separated from each other during gamete formation (**gametogenesis**), it does not follow that they are distributed between viable gametes in exactly equal numbers. After all, a good number of gametes or potential gametes may die or be rendered impotent prior to fertilization. It should also be noted that the union of gametes (sperms and eggs) is not controlled or guided. That process is a completely random affair. Whether or not a particular male gamete unites with a particular female gamete is a matter of chance. For

the above reasons the actual ratio obtained in genetic experiments is a mere approximation of the expected ratio.

This deviation from expectation becomes significant only when the sample one is dealing with is very small.

The difference between the **expected ratio** and the **observed ratio** is known as the **sampling error.** Experimentation has shown that sampling error is brought to a minimum when one is dealing with a very large sample.

## Genetics of monohybrid inheritance in man

It is noted that the transmission of some conditions in man and their inheritance follow the Mendelian fashion and very vividly serves to illustrate the principle of heredity as postulated in Mendel's first law. Some of these conditions will now be discussed in subsequent paragraphs.

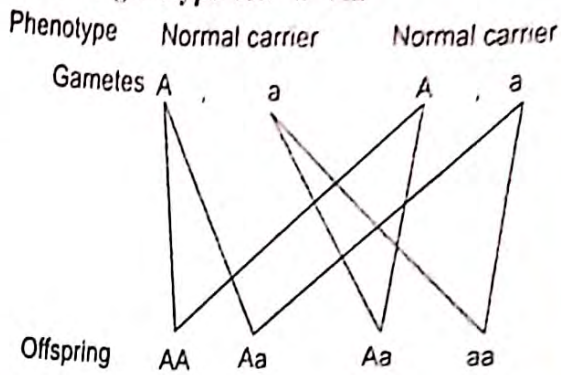
### 1. Albinism

This is a condition in which external pigments fail to develop resulting in the person having a **light skin, white hair and pink eyes.** Studies of this condition in man show that it is due to lack of **melanin pigments** in the malpighian layer of the skin epidermis. Albinism occurs when an allelic gene fails to produce a certain enzyme **tyrosinase** which synthesizes the pigment, **tyrosine**. Such a gene (mutant gene) persists in the cell and can be inherited by the offspring.

The recessive gene (a) responsible for albinism can only exert its effect in the homozygous state (aa). The gene for normal skin (A) is dominant. The genotype of a normal person is therefore **AA** or **Aa** and of an albino **aa**.

Let us then take a look at a **cross** between two parents who themselves are not **albinos** but carry the **albino gene**. Let (A) be the normal gene and (a) the albino gene.

**Parental genotype Aa x Aa**




**AA** homozygous dominant = $\frac{1}{4}$ or 25%

**Aa** heterozygous dominant = $\frac{1}{2}$ or 50%

**aa** Albino = $\frac{1}{4}$ or 25%

This is what is to be expected when both parents are **carriers** of the albino gene

The above **cross** indicates that for every four children born by two parents who are carriers, one is likely to be an albino. In man there is a deviation from the simple Mendelian 3:1 ratio. The reason for this is obvious especially when one considers the number of offspring involved. Man in most cases reproduces only one offspring at a time. The coming together of two gametes with "**good**" or "**bad**" genes is a matter of chance or "**luck**". Two parents who are carriers of bad gene may be so unlucky that five out of six children are albinos, or so lucky that none of them is an albino. The Mendelian ratio is obeyed only in organisms that can reproduce many offspring in a single reproductive event. This is because the different types of gametes have almost equal chances of coming together.

### 2. Inheritance of sickle cell anaemia

Sickle cell is a serious heritable disease caused by an abnormal shape of the red blood cells. The **abnormal red blood cell** is inherited from both parents by an offspring. The function of the normal red blood cells is to transport oxygen with the help of haemoglobin contained in it to all the living cells of the body. The abnormal red blood cells contain less haemoglobin, therefore not efficient as oxygen carrier. For a person to become a **sickler** he must inherit the gene for the sickle cell in a double recessive condition

A person who inherits the recessive gene from both parents suffers from sickle cell anaemia. The disease is so called because the red blood cells look like a **sickle**.

The sickle-shaped red blood cells contain less haemoglobin and therefore carry less volume of oxygen to respiring cells and hence the loss of energy in sufferers. The distorted shape of the red blood cells **hinders free flow of blood in the vessels resulting in severe pains experienced by sufferer.** Some other complications of the restricted blood flow to various parts of the body as a result of the abnormal red blood cells are as follows:

1. Failure of blood supply to the muscles leading to **rheumatism**.
2. Failure of blood supply to the brain leading to **paralysis**.
3. Failure of blood supply to the intestine leading to severe **abdominal pains**, and
4. Failure of blood supply to the lungs leading to **pneumonia**.
5. The efficiency of the kidney is reduced and this could lead to kidney failure.

The sickle cells are rapidly destroyed. The patient becomes anaemic. The bone marrow becomes over active in an attempt to build new red blood cells. This causes severe pains on the bones. Severe anaemia causes the weakness of the heart. This could lead to heart failure. Generally there is a poor physical development and the individual is usually very weak. Life is miserable and where there is no proper medical attention, the patient dies in his youth.

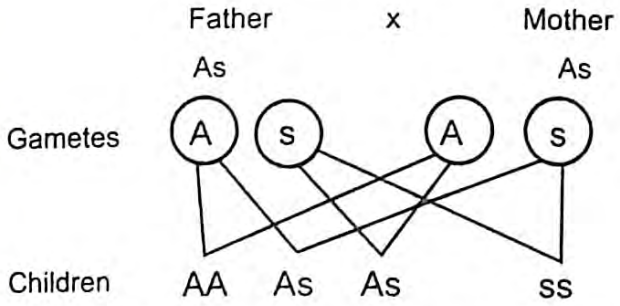



**Figure 18.9. Results of cross of parents where both parents are carriers of sickled cell traits.**

For an individual to become a **sickler**, he must be a double recessive for the condition, that is, his genotype must be (**ss**). This could arise where both parents are carriers of the sickle-cell trait. Let us consider a situation where a couple each has genotype **As**.

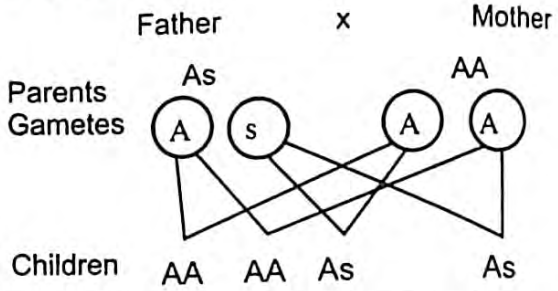



**Figure 18.10. Results of cross in which one parent is a carrier of sickle-cell trait.**

**AA** is normal and healthy.
**As** is healthy but a carrier of the sickle cell trait.
**ss** is a sickler and suffers from the disease described above.

So far there seems to be no known cure for sickle cell anaemia. The disease can only be prevented by giving the individuals who wish to **marry, genetic counselling**. Blood tests are usually carried out to determine the genotypes of couples wishing to marry. Such tests are usually done in good hospitals. A carrier of the gene `s' can protect his children by marrying an **AA** individual. In this case their children are either **AA** or **As** all of whom are healthy.

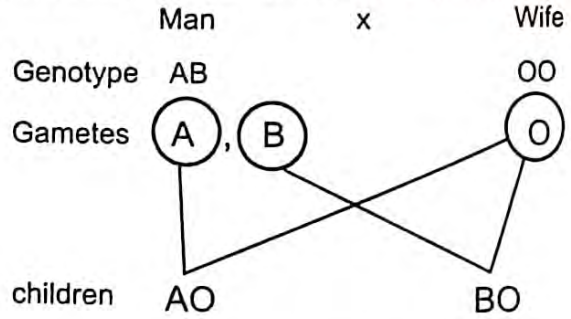



**Figure 18.11. Results of a man with blood group AB and his wife blood group O**

For the purpose of simplicity normal haemo- globin HbA is written as **A**. Sickle cell haemoglobin is written as **s**.

## 3. Blood groups

Normally, as we are already aware, a phenotypic trait is controlled by a pair of allelic genes at a specific locus. Sometimes, however, more than two alleles may be responsible for controlling the same trait. Where we have more than two alleles controlling a phenotypic trait,the situation is described as one of **multiple alleles**. This condition is provided by three genes controlling the A,B, and O blood groups in man. A person may only have two allelic genes (one on each of a pair of homologous chromosomes). **A** and **B** are equally dominant while **O** is recessive to **A** and **B**. It is interesting to know that two parents of blood groups **A** and **B** respectively can have children of blood group **O**.

There are four groups of blood in man based on genotype. An individual can belong to only one group based on what he has inherited from both parents.

The blood group of the individual is a genetic trait and remains unalterable in the life of the person and its inheritance is from both parents.

The groups to which individuals may belong are thus:

| Phenotype | Genotype |
|---|---|
| Group A | AA or AO |
| Group B | BB or BO |
| Group AB | AB |
| Group O | OO |

These groups have been determined according to the type of antigens present in the red blood cells and the anti-bodies present in the plasma of the individual.

People without antigen in their red blood cells belong to blood group **O**. In the various groups.

**A** is dominant to **O**

**B** is dominant to **O**

**A** and **B** show equal dominance with respect to one another.

**O** is recessive.

**Table 74: Blood groups.**

| | Antigen in the red blood cell | ANTIBODY IN PLASMA |
|---|---|---|
| GROUP A | Antigen A | Anti - B |
| GROUP B | Antigen B | Anti - A |
| GROUP AB | Antigen A + Antigen B | None |
| GROUP O | None | Anti - A + Anti - B |

In recent times blood groups have been found useful in settling most paternity cases. These are cases where the paternity of the individuals are in dispute.

Consider the two cases listed below to illustrate the point.

1. A man of blood group **AB**, married to a woman of blood group **O**, refuses ownership of her **child** who belongs to group **O**. Is he right to refuse the child? The answer can be worked out genetically since the transmission of genes determining the blood groups follows the Mendelian fashion.

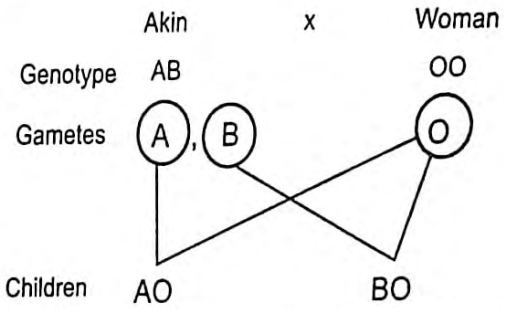



**Figure 18.12. Results of Akin with blood group AB and a woman with blood group O.**

The man can produce two types of sperms **A** and **B**. The wife has only one type of eggs. Their children will belong either to blood group **A** from genotype **AO**, or to blood group **B** from genotype **BO**. Never can the couple produce any child with group **O** since the man has no **O** sperm.

2. A woman of blood group **O** has a child of blood group **B**. She accuses Mr.Akin who has blood group **AB** of being the father of her child. The case goes to court. What should the judgement be?

**Answer:**

It is possible that Akin is the father of the child since he can produce sperm **B**. Certainly any man of blood group **B** or **AB** can produce a child of group **B** with a woman of group **O**. The available evidence is not conclusive enough. A different test may have to be carried out based on other genetic factors in the blood.

## Blood transfusion

Blood is stored in blood banks according to the different blood groups. In cases of severe blood loss, for example, following an accident the patient is transfused with blood from donors. During blood transfusion care is taken to ensure that only the correct type of blood is given to **recipients**. If incorrect type of blood is given during transfusion **agglutination** or **clotting** takes place in the recipient and this can result in death.

The "**care**" is to ensure that the **antigen** in the red blood cells of the donor does not react with the **antibody** in the plasma of the recipient. Such a reaction will cause the blood of the recipient to agglutinate. Table 66 shows the groups from which a recipient can be given blood. People in blood group **O** are called **universal donors** because the red cells do not have any **antigens** which will react with the anti-body in the recipients plasma. They can, therefore donate blood to any group in need without fear of agglutination. People in blood group **AB** are called **universal recipients** because they can receive blood from any group. The **AB** group has the **A**, **B** antigens but lack the plasma factors or anti-bodies which would react with the donors antigens. This is the principal reason why members of **AB** group are regarded as **universal recipients**.

Group **A** cannot give blood to group **B** because **B** has anti-**A** plasma factor or anti-body which will agglutinate with Antigen **A** in the red blood cells. For a similar reason group **B** cannot give blood to group **A** because group **A** has Anti-plasma factor or anti-body. Group **AB** can receive blood from group **A** or **B** because group **AB** has no Anti-**A** or Anti-**B** plasma factor or anti-body. There will be agglutination. Whereas group **O** can give to any person since that group lacks antigen in the red blood cells, groups **A**, **B** and **AB** cannot give blood to group **O** because **O** has Anti-**A** and Anti-**B** plasma factors or antibodies which can cause agglutination with Antigen **A** and Antigen **B** present in the red blood cells of these group of donors. Group **O** persons receive blood only from group **O** persons

**Table 75: Blood transfusion.**

| | | Recipients | | | |
|---|---|---|---|---|---|
| | | A | B | AB | O |
| Donor | A | ✓ | X | ✓ | X |
| | B | X | ✓ | ✓ | X |
| | AB | X | X | ✓ | X |
| | O | ✓ | ✓ | ✓ | ✓ |

**Table of Blood tranfusion**

**✓ = Correct tranfusion**

**X = Incorrect transfusion**

The percentages of the various blood groups in the population are:

Group **O** 60%
Group **A** 18%
Group **B** 18%
Group **AB** 4%

## Dihybrid inheritance

This is inheritance involving **two pairs of contrasting characters** and is seen in a **dihybrid cross**. Take, for example, a tall plant possessing characteristics, **tall** and **coloured**. A contrasting plant is one that is **dwarf** and **white**. When there is a combination of traits through sexual repro- duction between these two contrasting plants, the resulting offspring is called a **dihybrid**. **Phenotypically** it looks like one of the parents that

is tall and possessing coloured flowers but genotypically it is different from either of the parents. Its genotype is a combination of the genetic materials inherited from both parents - one half from one parent and the other half from the other parent. Such an individual inheriting genes determining two pairs of contrasting traits is the **dihybrid**.

In an experiment to illustrate this, Mendel worked with plants having two pairs of contrasting characteristics. He crossed a pure-breed tall pea plant having coloured flowers with a dwarf plant having white flowers.

Carrying out his experiments a step further, he **self-pollinated members of the $F_1$ generation.** The result was an $F_2$ generation showing four different kinds of plants. These were grouped thus.

1. **tall plants** possessing **coloured flowers**
2. **tall plants** possessing **white flowers**
3. **dwarf plants** possessing **coloured flowers**
4. **dwarf plants** possessing **white flowers**

The $F_2$ offspring showed these two pairs of characteristics in all possible combinations of the traits.

Mendel's actual result in one of such experiments showed 96 plants which are tall with coloured flowers; 31 plants are tall with white flowers; 34 plants are dwarf with coloured flowers; 11 plants are dwarf with white flowers giving a ratio of approximately 9:3:3:1. This crossing is illustrated below:

Tall, Coloured flowers (Homozygous) x Dwarf White flowers (Homozygous)

$F_1$ (Heterozygous) Tall, coloured flowers

selfed

| $F_2$ Tall, coloured flowers | | Tall, white flowers | | Dwarf, coloured flowers | | Dwarf, white flowers |
|---|---|---|---|---|---|---|
| 9 | : | 3 | : | 3 | : | 1 |

## Conclusions from the dihybrid cross

From the result of the **dihybrid cross** the following conclusions easily come to ones mind:

1. The principle of **dominance** and **recessiveness** is in operation once again. The fact that all the $F_1$ plants are **tall** with **coloured flowers** tells us that **tall** is dominant to **dwarf**, and **coloured** is dominant to **white** flowers.

   As it is the common practice in genetics to use letters to represent the genes, **T** is the gene for tallness, **t** is for dwarfness, **C** represents coloured flowers while **c** stands for white flower. Being pure-breeding (showing the trait through several generations) the parent plants must be **homozygous** for both pairs of alleles.

2. One can further conclude that the genotype of the **tall plant** with **coloured flowers** must therefore be **TTCC** and the dwarf plant with white flowers, **ttcc** - both parents being homozygous individuals and also true-breeding. Bearing in mind Mendel's **first law (the law of segregation)**, the gametes produced by the parent plants must be **TC** and **tc** respectively. All the $F_1$ offspring will therefore be **Tt Cc** genotypically and heterozygous for both pairs of alleles. If all four possible combinations of characteristics are to show up in the $F_2$ generation, it is obvious that the $F_1$ plants must produce four different kinds of gametes: **TC, Tc, tC, tc**. The **Punnet square** or the **checker board** shows immediately how these different gametes can fuse together to form the genotypes of the $F_2$ offspring. The following table 67 illustrates the combinations of gametes.

To be **tall** the genotype of the plant must contain at least one **T** gene; to be **coloured**, it must contain at least one **C** gene. Of 16 possible $F_2$, 9 will be tall with coloured flowers, 3 will be tall with white flowers; 3 will be dwarf with coloured flowers; and finally 1 will be dwarf with white flowers. The assumption here is that all possible fusions of gametes occur with equal frequency. In other words, there are no chance happenings to cause loss of a gamete somewhere along the line.

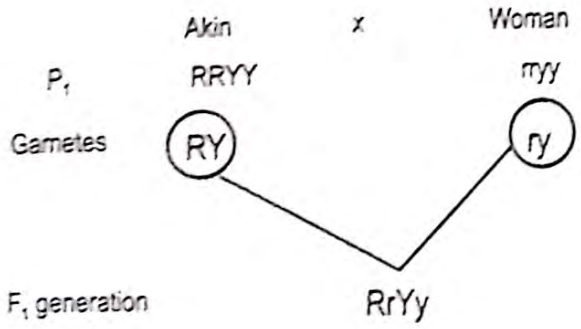
## Table 76: Results of dihybrid cross

| Female gametes (egg cells) | Male gametes (pollen grains) TC | Tc | TC | Tc |
|---|---|---|---|---|
| $^1/_4$ TC | TTCC Tall coloured | TTCc Tall coloured | TtCC Tall coloured | TtCc Tall coloured |
| $^1/_4$ Tc | TTCc Tall coloured | TTcc Tall white | TtCc Tall coloured | TtCc Dwarf coloured |
| $^1/_4$ tC | TtCC Tall coloured | TtCc Tall coloured | ttCc dwarf coloured | ttCc Dwarf coloured |
| $^1/_4$ tc | TtCc Tall coloured | Ttcc Tall white | ttCc Dwarf coloured | ttcc Dwarf white |

$F_2$ Ratio: 9: 3: 3: 1

$^9/_{16}$ Tall coloured, $^3/_{16}$ Tall white; $^3/_{16}$ Dwarf colour, $^1/_{16}$ Dwarf white

Mendel also considered two characters present in the seeds of pea plants. He obtained pure stocks of round seed **RR** with yellow seed coat **YY**. He cross bred them with another **pure stock** of wringle seeds with green coat. $F_1$ generation were all round and yellow. It means that **round** is dominant over wrinkle while yellow is dominant is dominant over green.




When Mendel allowed self-pollination in members of F1 generation, the following combinations were obtained in the seeds of $F_2$ generation:

**Round and Yellow**
**Wrinkle and Green**
**Wrinkle and Yellow**
**Wrinkle and Green**

From the result Mendel concluded that when two or more allelic genes are together in a parent, they are independently selected into the gamates. Hence a parent with the genotype **RrYy** will have four types of gametes.

The reader should note that the two laws are obeyed together. **Rr** or **Yy** segregate and do not occur in one gamete (first law). A gamete can contain **Ry, rY, Ry** or **ry** (second law)

From the foregoing, one can conclude that the two pairs of genes are transmitted independently from parent to offspring and assort freely. This idea is expressed in **Mendel's second law** otherwise known as **the law of independent assortment.** ***This law states that each member of a pair of allelic genes may combine randomly with either of another pairs.***

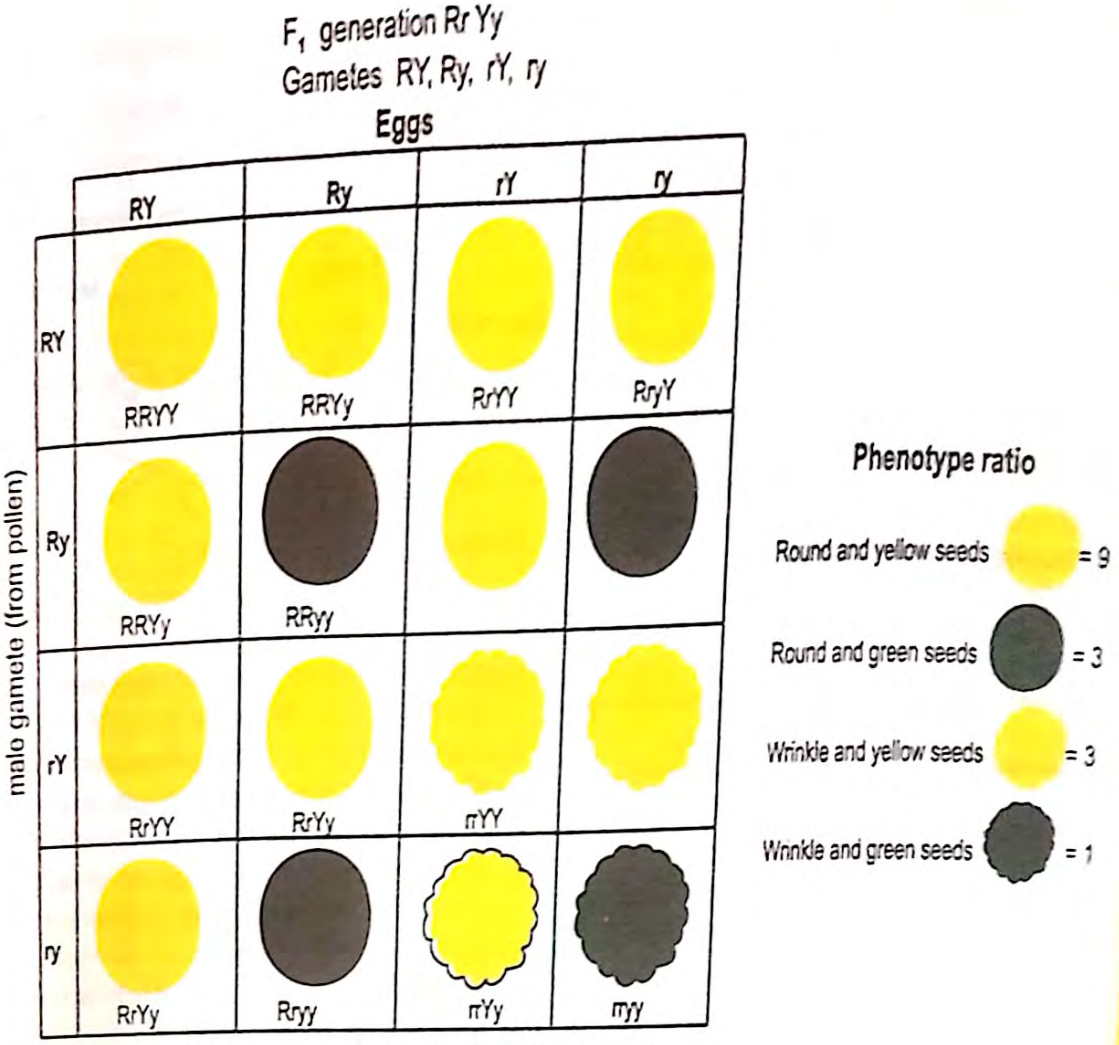



**Figure 18.13. Mendel's second law showing two characters in seeds.**

## An explanation of the results of the dihybrid cross in terms of probability

The transmissions of genes determining size and flower colour from parent to offspring are independent events. If we then consider the genes for size on their own, the probability of any of $F_2$ plant being tall is $^3/_4$ (i.e. dominant), and of its being dwarf, $^1/_4$ (i.e. recessive).

In a similar manner, if we consider the flower colour genes alone, there is a probability of $^3/_4$ that an $F_2$ plant will be coloured, and of $^1/_4$ that it will be white.

What, then, is the probability of an $F_2$ plant being tall and coloured? The answer follows from a statistical rule that if two events are **independent**, the probability of their occurring together is the product of their respective probabilities. Let us assume that the genes are transmitted **independently**, the answer is:

$^3/_4 \times {}^3/_4 = {}^9/_{16}$. In practical terms this means that the chances of any one $F_2$ plant, chosen at random, being tall and coloured are 9 out of 16.

Similar reasoning can also be applied to the other possible combinations as follows:

The probability of an $F_2$ plant being tall and white is $^3/_4 \times {}^1/_4 = {}^3/_{16}$;

dwarf and coloured is $^1/_4 \times {}^3/_4 = {}^3/_{16}$;

dwarf and white is $^1/_{16}$

The results are in complete agreement with those obtained by the **Punnett square** method and with the results of Mendel's experiments. They can only be explained by postulating that the two pairs of genes are transmitted independently and that they assort freely.

## Sex determination

In our previous discussions on inheritance, we saw that genetic traits are determined by genes located on the chromosomes. The sex of an organism is a genetic trait which like other traits is transmitted from parent to offspring during sexual reproduction.

In all organisms with sexual reproduction there is a pair of chromosomes designated as **X** and **Y** chromosomes. In this instance, the entire chromosome, rather than the gene, controls the sex of the individual. Every normal female carries the pair **XX** and every normal male carries the pair **XY**.

Because of **reduction division (meiosis)** which takes place at gamete formation (**Gametogenesis**), the number of chromosomes is halved so that each mature gamete receives **23 chromosomes**, distributed as follows:

**Table 77: Sex determination**

| Sperm | Ova |
|---|---|
| 22 + X | 22 + X |
| 22 + Y | 22 + X |

We have to bear in mind that a normal human has 46 chromosomes (23 pairs) and reduction division at gamete formation brings the number down to 23.

The sex of the individual is determined by the sex chromosomes, X and Y. Fertilization of an ovum by a sperm containing an X chromosome results in the development of a **female child**, while a male child develops if the sperm fertilizing the ovum contains a Y chromosome. We can therefore correctly say that femaleness is determined by the X chromosomes while maleness is determined by the Y chromosome. Boys inherit X chromosome from their father and Y chromosome from their mother while girls inherit X chromosome from their mother and X from their father.

The X and Y chromosomes have equal chances of fertilizing the ovum. Theoretically, this should result in an equal distribution between male and female births in the population as a whole. Clinical records have shown that there is a slight tendency in favour of male births. An explanation of this is the greater **motility** of sperm carrying the Y chromosomes over that carrying the X chromosome.

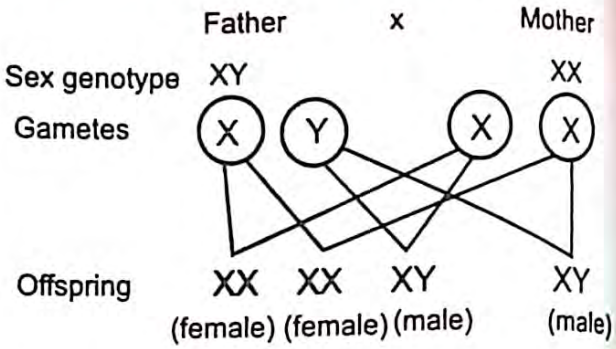



**Figure 18.14. Sex determination in human beings.**

Ignorance of these facts about sex determination has often placed severe strain on many marriages as the blame for the "**wrong sex**" often goes to the wife especially if she continuously delivers baby girls. Knowledge about sex determination is of great importance especially to young couples and it is hoped that modern advances in bioche-mistry and genetics will be of immense value in helping couples to select the sex of their children rather than to abandon one"s fate to nature. Knowing the high motility of the sperms carrying the Y-chromosome, it may be interesting to investigate the effects of introduction of different media into the uterus of a female, or of continuously altering the pH values of the internal environment of a woman on successive deliveries. Does the frequency of male deliveries remain the same or is the balance tilted as a result of such introductions? These are some problems for the young biologists to attempt to answer.

## Inbreeding

There is a common belief that the mating of two closely related individuals such as **brother** and **sister** or **father** and **daughter** is harmful and may possibly lead to the production of **monstrosities** in the population. Such a practice is called **inbreeding**.

Carefully controlled experiments using many different kinds of animals and plants have shown that there is nothing harmful in the process of inbreeding itself. In the commercial production of cattle, corn and other agricultural products, inbreeding has been widely practiced. It is the standard procedure for getting purebreeding individuals for certain desirable traits such as small size or early maturation. Inbreeding is not encouraged in human species because it may bring certain hereditary diseases to the family. It must be observed that the hereditary disease, **haemophilia**, first appeared in the British Royal family as a result of marriages between members of the family.

In all animals or plants it simply tends to make the strain homozygous. All natural populations of individuals are heterozygous for many traits. Some of the hidden recessive genes are for desirable traits, others are for undesirable ones. In populations at **equilibrium** there is a tendency to maintain the relative proportions of homo-zygous and heterozygous individuals. Inbreeding will be moving the population gene pool away from heterozygous and leads to the unmasking of the good or bad traits. If a stock has good qualities, inbreeding will further improve them, but if a stock has many undesirable recessive traits, inbreeding will lead to their phenotypic expression as the individuals from such inbred lines become double recessives.

## Outbreeding

The crossing of two completely unrelated strains is called **outbreeding**. It is another widely used genetic manoeuvre for the combination of certain desirable characteristics from different sources in one individual.

It has been found that the offspring of such a mating are **much larger, stronger** and **healthier than either parent**. Such an individual is said to exhibit **heterosis** (hybrid vigour).

Much of the corn grown in the United States is a special hybrid variety developed by the U.S.D.A. (United States Department of Agriculture) from a mating of four different inbred strains. Each year the seed to grow this uniformly fine hybrid corn is obtained by mating the original inbred lines. If the hybrid corn were used in mating, it would give rise to many different kinds of corn since it is heterozygous for many traits.

## Uses of the knowledge of genetics

The practical applications of knowledge of genetics have helped in no small measure to solve, if not completely, at least in part, some human problems which are as follows:-

1. **Food shortages**

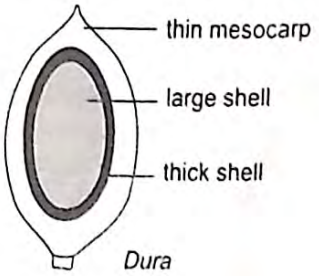
   The problems of hunger and food shortages are so serious all over the world today - especially in areas of huge population densities. We hear of starvation everywhere and riots over food shortages. Making use of special plant breeding techniques, man has strived to overcome these problems of food shortages. Man adopts various crop improvement measures to produce new varieties of crops. These new varieties may be especially bred and selected for higher yields, better taste uniform early ripening varieties and drought resistant verities, or early maturation. The wheat breeding programme in India initiated by the U.S.A. has helped India to solve its wheat shortage problem within a very short time of commencement. It is hoped that if such a programme is adopted in Nigeria, the problem of wheat will be a thing of the past as more wheat will be produced in Nigeria.

2. **In plant breeding**

   In the oil palm improvement programmes at N.I.F.O.R. Benin City, the cross between the *Dura* palm and *Pisifera* palm gives the *Tenera* palm. The fruit of the *Dura* palm has a thin mesocarp, thick shell and a large kernel while the *Pisifera* has very thick mesocarp and a very small kernel. The hybrid called *Tenera* palm has a moderate mesocarp and a kernel with a thin shell.

The advantages of the hybrid (Tenera) are:

(a) It has more oil than the *Dura*



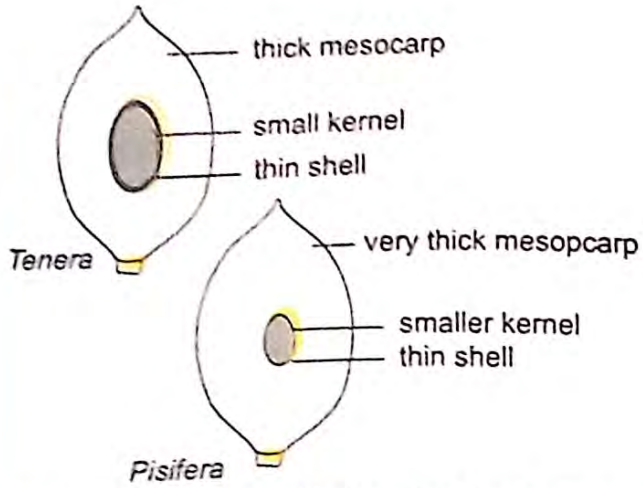



**Figure 18.15. The longitudinal sections *Dura*, *Tenera* and *Pisifera* to show differences in their structures.**

(b) 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.

(c) It is also dwarf and has a greater production period.

3. **Disease resistant crops**

The knowledge of genetics is used to solve the problem of food shortages by breeding disease resistant crops. It is common knowledge that plant parasitic diseases can wipe out the entire crops of a farmer thereby bringing the entire cropping season to a total disaster. Through well planned plant breeding programmes and careful selection, a farmer can acquire crops that are disease resistant. By continuing to grow such disease resistant crops he can thereby guarantee the yield of his crops.

4. **In animal breeding**

The knowledge of genetics has long been used to solve human food problems in animal production. Here, animal breeders making use of the knowledge of genetics to breed for higher meat quality, rapid growth, greater milk yield, increased egg production in poultry, and endurance in beasts of burden. For example, the crossing of **bull buffalo** with domestic **cow** gives an offspring known as **cattalo**. The **cattalo** is larger than both parents and produces meat of higher quality and quantity.

The **mule** is an example resulting from the crossing of two different species; the **male donkey** and the **female horse**. The mule inherits characters such as long ears, hardiness, endurance, great stamina and the ability to eat rough food from donkey and from the horse, it (the mule) inherits the size of the horse. The combination of these inherited characters makes the mule a more hard working animal than both the donkey and the horse, hence the mule is used as beast of burden.

5. **In marriage**

The application of knowledge of heredity in marriage counselling is of great importance in reducing the incidence of hereditary diseases such sickle cell anaemia and haemophilia to mention a few. Where blood tests 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**.

Where a man is Rh-positive and his wife is Rh-negative such a 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 his 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 to avoid the condition described above.

6. **In medicine** In medicine, knowledge of genetics has been found very useful in blood transfusions (earlier

referred to) and in the determination of paternity in cases of disputed parentage. Blood groups are phenotypic traits determined by certain genotypes which are transmissible from parent to offspring. These genotypes are permanent attributes and remain unalterable throughout life. More recently the genetic material - the gene, has been employed in the determination of parentage. Since the genetic material is known to be essentially the **DNA**, the individuals involved in law suit over parentage are required by law to undergo the **DNA** test.

7. **In genetic engineering**

More recently, knowledge of genetics is used in what is referred to as **genetic engineering** to transfer the ability to produce an essential chemical substance from one organism to another that may be lacking in the ability to produce it. It is now known that by a manipulation of the gene which regulates the production of **thyroxin** in one organism such a gene can be transferred to another organism which then begins to synthesize thyroxin. By so doing, a hereditary defect can be corrected. The science of **eugenics** is now gaining ground - and it is hoped that genes in certain individuals which made them geniuses can be extracted, preserved and transferred to other individuals. Research in this area is continuing and the scope is widely open to younger generation of scientists to embrace the challenge.

# VARIATIONS IN POPULATION

Observations of nature and of the results from carefully controlled experiments in both plant and animal breeding have shown that no two individuals are exactly alike. Even the so-called identical twins show clear differences when closely looked at. In short, variation exists in nature, and it simply refers to the differences between individuals. These differences may be large or minor but regardless of the magnitude, play a very significant role in the survival of the individual.

In the struggle for existence, only those better adapted to their environment survive. Thus a natural selection takes place; the unfit do not survive. Variations are of two kinds:

1. Environmental and
2. Genetic.

We shall come to a discussion of these later.

Let us consider the human population where there is a continuous variation in height. With the concept of **Mendelian inheritance** in mind, a man is described as **tall** or **short** depending on the genetic factors he has inherited. Among the tall people some are observed to be taller than others. Similarly some people are shorter than the others in that group. This gives a continuous variation in height. Why is this so? It is now known that the height of an individual is not controlled by a single pair of allelic genes alone, but by the contribution of many pairs.

## Genetic variations

Sometimes in nature, certain changes suddenly occur in the chromosomes without necessarily destroying them. Such changes are known as **mutations** and may simply involve an alteration in the 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. A discussion on the causes and types of mutation is above the scope of this book but suffice it to say that mutation will lead to changes in gene frequency in the population giving rise to individuals that are referred to as **variants** or varieties - all members of the same species.

## Morphological variations

A careful look through a seed catalogue will reveal several varieties of beans offered for sale, namely, green string, beans, yellow wax beans, navy beans, etc. No matter where we plant these

these bean seeds, so long as conditions permit growth and production of seeds, we shall obtain bean seeds similar to those that we planted. Such variations are **inherited** variations. They are genetic variations, and it appears probable that they are the more important variations from an evolutionary point of view. Observable genetic variations in the populations include such parameters as height, weight, length and skin colour in man. In skin, colour is governed by two pairs of genes **ABAB** for the black race and **abab** for the white race. A cross between a black person and a white person will give a hybrid **ABab** otherwise referred to as a mulatto. A cross between two mulattoes will produce 16 different combinations of genotypes giving rise to individuals with different gradations of skin colour forming an interesting example of **continuous variation**.

The following Figure 18.16 is a histogram showing variations in the lengths of one hundred **Pride of Barbados** fruits collected from a single plant. The lengths range from 6.0 - 10.3 cm.

| Number of fruits | Length |
|---|---|
| 4 pods | 6.0 - 7.0 cm |
| 10 pods | 7.1 - 8.0 cm |
| 36 pods | 8.1 - 9.0 cm |
| 43 pods | 9.1 - 10.0 cm |
| 7 pods | 10.1 - 10.3 cm |

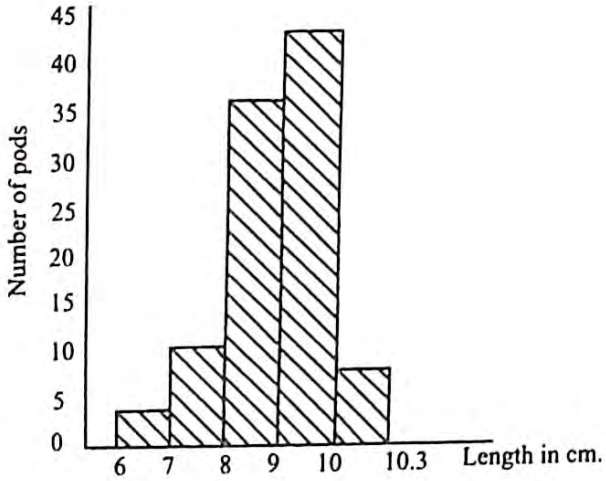



**Figure 18.16. Variations in lengths of mature pods of Pride of Barbados.**

The result reveals that the majority of the mature pods are between 8 and 10 centimetres in length.

## Finger prints

Besides height, weight, size and skin colour, other morphological variations still exist in the population. The human finger print provides another example of morphological variation in the population.

Any human population can be divided into seven distinct classes according to the variations in human finger prints. These variations in finger prints are classified as **arch, tented arch, loop, plain whorl, accidental, central pocket loop** and double loop. The contouring and ridges found in different individuals are peculiar to the individuals. No two individuals have the same pattern of contour of finger prints hence it forms a basis for detection of individuals.

Human fingerprint is a **phenotypic trait** that remains unchanged throughout the life of a person. A person"s fingerprints can be taken by police and stored in a memory bank. In an event of a crime, photographs are taken of the fingerprint marks left on objects by the criminal and the result cross-matched with the one stored in the memory bank. This helps to identify the criminal.

Fingerprint marks left behind by a criminal at the scene of a crime for example on the door, table or weapon provide a valuable clue in the detection and subsequent arrest of a criminal. The fingerprint marks left on the scene of crime are photographed. A criminal suspect is arrested and his fingerprint marks are taken and compared with the fingerprint marks at the scene of crime. If they are the same, then the person is the criminal.

The same principle of fingerprints has been used by police to arrest those who take monetary bribe. Marked currency notes (money dusted with special invisible chemical powder) is given to a person demanding bribe by a plain uniform policeman. On receiving the money, the person is arrested and taken to police station. At the police station, his fingerprints are taken and compared with the fingerprint marks on the currency notes. If the fingerprint marks are the same, the person is then prosecuted.

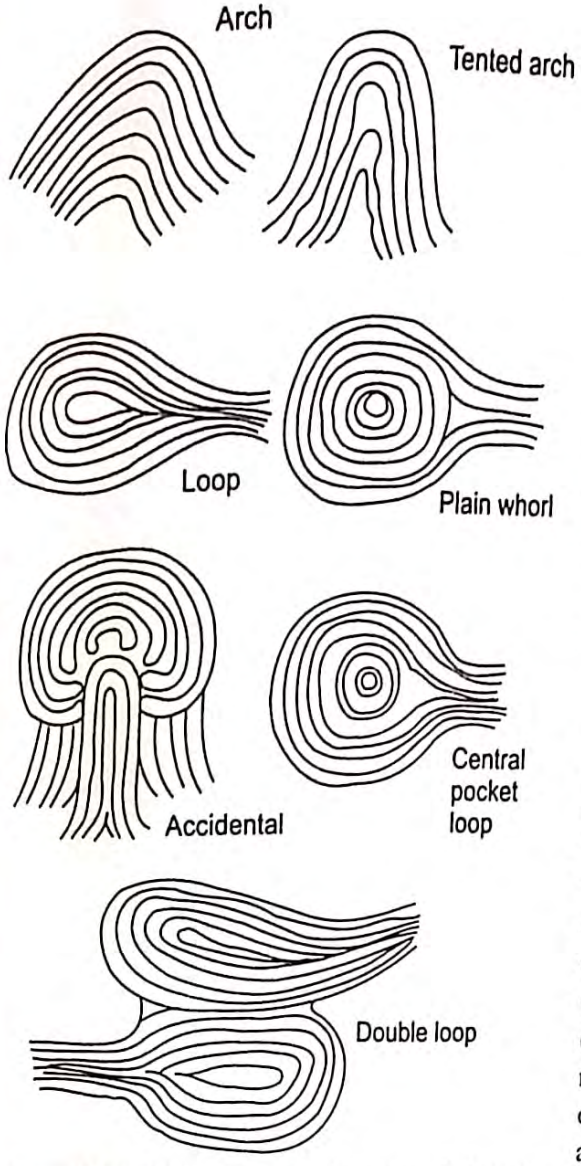



**Figure 18.17. Different types of contours in human fingerprints.**

## Physiological variations

Another means of distinguishing between individuals is what referred to as **physiological variation**. This includes ability to roll tongue for a person is either a **tongue roller** or **not a tongue roller**. This is discontinuous variation. Further example of discontinuous variation is the ability to taste the chemical, **phenyl thiocarbamide - (PTC)**. Not everybody can taste this chemical. So, the population can be grouped into two, namely, **tasters** and **nontasters**, thus forming a discontinuous variation in the population.

## Blood groups

The blood groups found in the human population have already been referred to earlier. All persons in the population can be grouped into one of the following four blood groups, **A, B, AB** and **O**. This is also a further example of **discontinuous variation** because there is nothing in between any two groups. A person is either this or that. There are no intermediate types. All of the above examples of both morphological and physiological variations are measurable and are heritable attributes of the individuals which remain with the person for life.

## 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 a poor feeding. Such environmental factors as temperature, rainfall, sunlight can also bring about sharp variations among individual members of the same family. The growth rate and pattern of development are mostly affected. The variations which exist in identical twins could result from the differences in the positions they occupy in the mother"s womb. There are many factors in the environment which can cause variations. The appearance of an individual depends on the degree to which he has been affected by these environmental factors. Some of these factors are poverty, richness, hardwork, laziness, thoughts, sorrows, food, restlessness, diseases and weather conditions among others. It must, however, be noted that environmentally induced variations are not heritable. Environment is important for the modifying effect it has on genotypic expression. If the environment is good, the genotypic potentials are well-expressed, but if the environment is unfavourable, the genotype is not well expressed, leading to some variations in nature. The consequences of such variations could be unfavourable and will likely affect the species in a negative manner.

## Applications of variations

1. **Variation provides a mark of identity**

   Because variation is common feature among living things, it provides a clear mark of identity between organisms of the same species. Among human beings, variation in finger print is used to identify a person because of definite characters of the finger print. For example at Banks.

2. **Variation in crime detection**

   The use of fingerprints in crime detection has been earlier explained as **arch, tented arch, loop, plain whorl, accidental,** and **central pocket loop** (see figure.18.17).

3. **Variation in blood groups**

   Human population is divided into four classes according to certain factors found in the red cells and plasma as groups **A, B, AB** and **O**. That shows definite variation in the human population - based on blood grouping. When a person needs blood, for example in cases of severe blood loss following an accident or during child birth, blood is not just transfused at random from a donor to a recipient. Care is taken to ensure that the blood of the donor matches that of the recipient otherwise agglutination of the red blood cells will take place leading to the death of the recipient whose life we want to save (see text on blood groups).

4. **Determination of parentage**

   It is a biological fact that **like begets like** and therefore an offspring can only inherit the genetic attributes of his parents and nothing else. In cases of disputed parentage, use knowledge of genetics and variation in blood types to determine the possible parent of a child. The blood group of a person shows definite variations from that of another person but where two persons have the same blood group, reference is made to other factors to determine who the parent of a child might be.

## *Questions*

1. *(a) Define the following terms:*
   - *(i) gene*
   - *(ii) homozygous*
   - *(iii) hybrid*
   - *(vi) mutation*
   - *(v) recessive character*
   - *(vi) antigen*

   *(b) (i) Name the four groups of blood in man with their antigens in the red blood cells and antibodies in the plasma. You may arrange your answer in a tabular form.*

   *(ii) Why are the people of blood group O regarded as universal donors and people of blood groups AB universal recipients?*

   *(iii) What is the importance of the knowledge of blood groups in blood transfusion?*

2. *(a) State the blood groups which are likely to be inherited by children whose father is blood group B and mother blood group A.*

   *(b) A man of blood group AB claims that a woman of blood group A has a child for him. The blood group of the child is O. Has this man the right to claim this child?*

   *(c) Give four examples of man"s benefits from the knowledge of genetics in plant and animal breeding. (Give two examples from plants and two from animals).*

3. *(a) (i) What are chromosomes?*

   *(ii) How are chromosomes used to determine sex?*

   *(b) What is sickle cell disease?(c) Explain the genetic constitution of the children of a man with one, sickle cell gene (carrier male) married to a woman with one sickle cell gene (carrier*

*male) married to a woman with one sickle cell gene (carrier female).*

4. *A given species of plant reproduces by seed after cross pollination and also reproduces vegetatively. If plants are given from the same parent plant by both methods, state, giving reasons which of the two sets of plants will probably show the greater variation. Mention some examples of man"s practical use of this knowledge.*

5. *When a pure-bred red-flowered plant is crossed with a pure-bred white-flowered plant all the seeds formed produce plants bearing red flowers. What conclusion can you draw from this? Explain what would happen if these red-flowered off-spring were crossed with (a) each other, (b) the white parent (c) the red parent.*

6. *(a) State the first and second laws of Mendel.*
   *(b) Use genetic crossings only and use words such as parental phenotypes, parental genotypes, meiosis, gametes, fertilization, $F_1$ genotypes and $F_2$ to explain the results of Mendel"s laws.*
   *(c) Define the following terms:*
   *(i) heterozygous and homozygous offspring.*
   *(ii) heredity.*
   *(d) What are the implications of a marriage between*
   *(i) a girl with a negative Rhesus factor and a boy with a positive Rhesus factor and*
   *(ii) first cousins.*
   *(iii) Suggest remedies.*

7. *(a) State the major causes of variation within a specie.*
   *(b) Briefly explain how meiotic division gives rise to variation in a population.*
   *(c) State Mendel"s first and second laws of inheritance.*
   *(d) A pure breeding brown rat, BB was crossed with a pure breeding white bb. By means of diagrams only, show the genotypes of the offspring up to the second flial generation.*
   *(e) State two uses of variations to man.*

8. *(a) Explain what is meant by the term "variation"*
   *Illustrate your answer by giving specific examples in animals or plant species.*
   *(b) In human beings, brown eyes are usually dominant over blue eyes. If a blue-eyed man marries a brown-eyed woman whose father was blue-eyed, what proportion of their children would you predict will have blue eyes?*

9. *(a) List three transmitable characters in:*
   *(a) human beings;*
   *(b) plants.*
   *(b) State three ways in which genetics has contributed to improvement of agriculture.*
   *(c) A homozygous tall parent was crossed with a homozygous short parent. The offspring in $F_1$ generation were all tall. An offspring of $F_1$ generation was then crossed with another homozygous short individual.*
   *(i) Illustrate the crosses with suitable diagrams.*
   *(ii) What is the phenotypic ratio of offspring in the $F_2$ generation?*
   *(iii) What is the genotypic ratio of offspring in the $F_2$ generation?*

   *(d) What is the probability that an individual that has genotype Tt will produce a gamete with T, gene? Briefly explain your answer. (S.S.C.E 1996)*

10. *(a) Define the following terms:*
    *(i) gene (ii) gene mutation*
    *(b) Name two structures each for plants and animals where the following processes take place:*
    *(i) Mitosis (ii) meiosis*
    *(c) State four advantages a farmer may hope to derive in cross breading two different breeds of cows.*
    *(d) State three applications of the knowledge of genetics in medicine. (SSCE 2007)*

# 19

# SOIL

Soil is the upper surface which is essential for the growth of plants. The earth is not uniform all over the world. In one place it may be yellow and yet in another place it may be brown or dark brown. In some places it may be sand while in other places it may be clay. In the same manner it may be deep in some places and shallow in other places. Though soils vary from place to place, all soils have certain properties in common.

## Soil components

All soils are made up of mineral matter, organic matter, air, water and living organisms.

The mineral portion of the soil usually forms the greatest proportion of the soil components. The mineral portion comes from the **rocks** after **weathering. Minerals** are chemical substances which occur naturally. They are inorganic and have definite composition. There are three types of rock on earth according to how they have been formed.

(i) **Igneous rocks** (ii) **sedimentary rocks** and (iii) **metamorphic rocks**.

## Igneous rock

These are rocks that are formed from **molten magma** on cooling. The heat far below the earth's surface is extremely hot and so it can melt the rocks lying at that level. The molten rock is called **molten magma** and this erupts usually above the earth's surface where it cools, solidifies and forms rock or cools and forms rocks half way through the earth's column. Rocks that are formed after eruption above the earth's surface are called **extrusive rocks** while those that cool and solidify before reaching the earth's surface are called **intrusive rocks**. Examples of igneous rocks are **granite** and **basalt.**

## Sedimentary rocks

These are rocks that are formed by **consolidation of products of weathering**. Deposits of mineral materials, usually under water are subjected to **great pressure** to consolidate the minerals into **rock material.** Examples of sedimentary rocks are **sandstone, limestone, dolomites** and **shale.**

## Metamorphic rocks

These are rocks that are formed from pre-existing rocks - igneous or sedimentary rocks which have been subjected to great pressure and high temperature so as to change the structure and size of the mineral to form new rocks. Examples are marble, **quartzite, granite, gneiss and slate.**

## Composition of soil

Soil is composed of the following:

1. **humus** (organic matter)
2. **water**
3. **air**
4. **mineral matter**
5. **living organisms**

## Humus

It consists of decaying plant and animal remains or animal faeces. It is usually dark in colour and found on the surface of the soil. It contains mineral elements and affects the physical properties of the soil such as improving the structure of heavy soil like clay soils or light soils such as sandy soils.

### Importance of humus to the growth of plants.

Humus is important to the growth of plants for the following reasons:

1. Humus which comprises decayed organic matter is rich in mineral nutrients which are

needed by plants for growth.

2. Humus is `spongy' in texture. It therefore absorbs moisture which it retains for the use of plant roots.
3. Humus aids the formation of soil aggregates which improve soil aeration and entry of water into the soil. Improved aeration facilitates respiration in plant roots as a result of available oxygen while entry of water into the soil improves the quantity of available water to plants and this in turn enhances the growth of plant.

## Experiment 1

**Aim:** To determine the percentage weight of organic matter (humus) in a soil sample.

**Method:** Put some quantity of the dry garden soil into crucible and weigh. Heat the crucible to redness using a **bunsen burner** and **stirring occasionally**. Weigh at intervals until a constant weight is obtained.

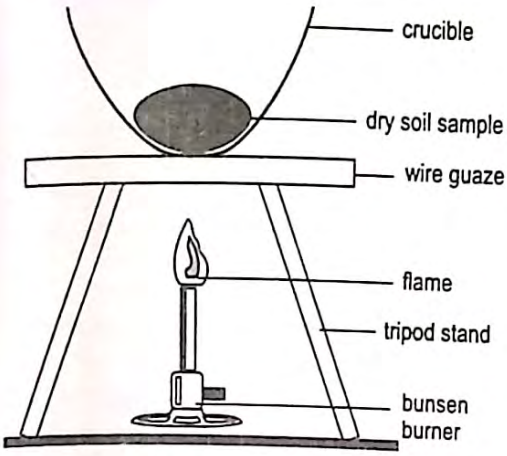



**Figure 19.1. Expriment to determine the weight of organic matter in a soil sample.**

**Result:** Smoke is seen as organic matter burns away. When the smoke ceases, cool the crucible in a desiccator and weigh. The difference between the **first weighing** and **last weighing** is the weight of the organic matter

Weight of crucible = a grammes

Weight of crucible + dry soil = (a+b) grammes

Weight of dry soil only = (a+b-a) = b grammes

Weight of burnt soil = (a+c-a) = c grammes

$$\text{Weight of organic matter} = \frac{(b-c)}{b} \times \frac{100}{1}$$

OR

$$\frac{\text{Weight of organic matter} \times 100}{\text{Weight of dry soil sample}}$$

**Conclusion:** Soil contain **organic matter** (humus).

## Water

Water is another component of the soil. Water is found in a thin film around soil particles which may be clay, sand or silt. Water around the soil particles is held under **capillary attraction** or by the **forces of adhesion.** Soil water is needed for transpiration, photosynthesis and dissolution of nutrients. Water is also found in the spaces between aggregates or between sand particles.

## Experiment 2

**Aim:** To determine the percentage weight of water in soil sample.

**Method:** Weigh an evaporating dish and put into it a weighed amount of soil. Heat the soil over a water-bath for some hours to dryness. Cool the dish and its content in a desiccator and weigh again. Repeat the heating, cooling and reweighing several times until two or more weighings become constant. This means that all the water in the soil sample has evaporated.

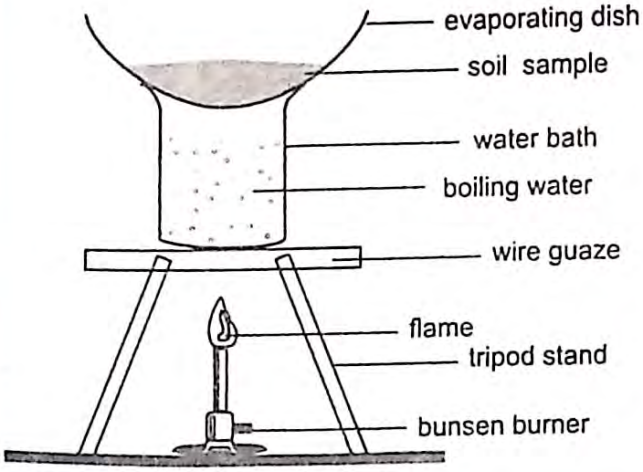



**Figure 19.2. Experiment to determine the percetage weight of water in soil.**

**Result:** The weight of water in the soil sample is given by the difference between the original and the final weighings.
**Calculate the weight as in experiment 1**

**Conclusion:** Soil contains water.

## Air in the soil

Air is found in the pore spaces, that is spaces between soil aggregates or soil particles. Soil air contains oxygen, nitrogen, carbon (1V) oxide and other gases.

Air is important to the growth of plants. Carbon (IV) oxide and oxygen are used by plants in photosynthesis and respiration respectively. And without photosynthesis, no green plant survives. Carbon (1V) oxide which is a raw material for photosynthesis is therefore very important to plants. Oxygen on the other hand is used for respiration. During respiration, oxygen combines with glucose to form carbon (1V) oxide, water and energy as shown in the equation below:

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

As a result of the chemical reactions involved in respiration, plants obtain their energy requirements for various biological processes.

## Experiment 3

**Aim:** To show that garden soil contains air.

**Method:** A container of known volume with both ends open is pressed into the soil and carefully removed with its soil content. Any excess soil on the sides of container is removed to ensure that the soil being used is of the same volume with the container. The soil is then carefully emptied into a measuring graduated cylinder containing water of a known volume. The mixture of the soil and water in the cylinder is stirred for about three minutes and allowed to stand undisturbed for about ten minutes. At the end of this period, the final level of the soil and water in the measuring cylinder is read. From the above various readings, the volume of air in the sample of soil used can be obtained as follows:

**Result:**
Volume of soil = X $cm^3$
Volume of water in measuring cylinder = Y $cm^3$
Volume of water and soil (after stirring) = Z $cm^3$
Volume of air = (X + Y) - Z $cm^3$

**Conclusion:** Soil contains air.

### Alternative experiment

**Method:** A sample of soil is poured into a graduated 500$cm^3$ cylinder. 250$cm^3$ of water is poured into the graduated cylinder. The mixture of soil and water is stirred.

**Result:** Bubbles of air is seen rising from the water and escaping at the surface.

**Conclusion:** Soil contain air.

## Living organisms

This is also a component of the soil. They are either plants called **soil flora** or animals called **fauna.** The soil flora consists of the higher forms such as the plant roots and lower form such as the bacteria, **algae, fungi.** The soil fauna also consists of various insect, burrowing animals and the earthworm, nematodes and protozoans.

## Experiment 4

**Aim:** To demonstrate the presence of micro organisms in the soil.

**Method:** To each of the conical flask labelled A and B, a known volume of lime water is kept. A known amount of **fresh soil** is kept in muslin bag and tied as in conical **A**. An equal amount of well **heated soil** is kept in muslin bag and tied as in conical **B**. The well heated soil ensures that all living organisms have been killed. Conical **B** acts as a **control experiment**. The experiment is left for six hours.

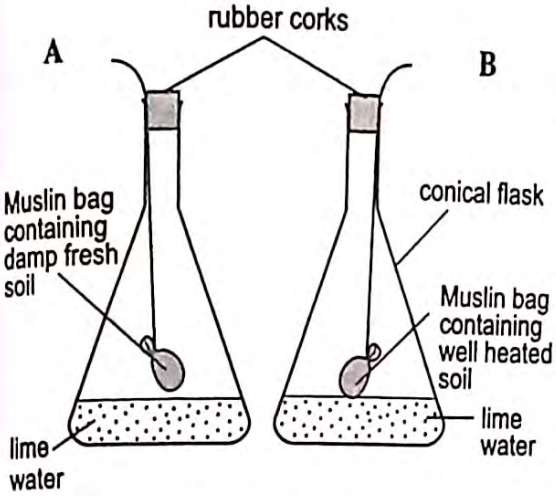



**Figure 19.3. Experiment to show the presence of living organisms in the soil.**

**Result:** The lime water in conical flask A turns milky due to the release of carbon (IV) oxide during respiration by the living organisms. In conical flask **B** the lime water remains clear. This is because the living organisms in the soil have been killed by heating and so respiration does not take place.

**Conclusion:** Soil contains living organisms.

## Soil profile

Every soil consists of the constituents discussed in the preceding paragraphs though their proportions may vary, Every soil also has a profile. A soil consists of two or more layers lying one below the other and parallel to the land surface. The layers are called **horizons.** Each horizon differs from one another in thickness, colour, structure, texture, porosity, consistency and reaction.

Most soil profiles have three main horizons. These are horizon **A**, horizon **B**, horizon **C** and horizon **D**. **A** and **B** horizons together form the true soil and the major part of a profile.

**Horizon A** is the topmost layer and is called the **top soil.** It has a lot of organic matter and most of the organisms are found in it.

**Horizon B** is called the **sub-soil.** The horizon **C** comes after the **horizon B** and it consists of loose and partly decayed rock. It is consequently called **parent material.** The parent material may have resulted from the breakdown of the underlying bedrock or brought to where it is now found by water or ice.

Horizon **D** is the bed rock which has been broken down.

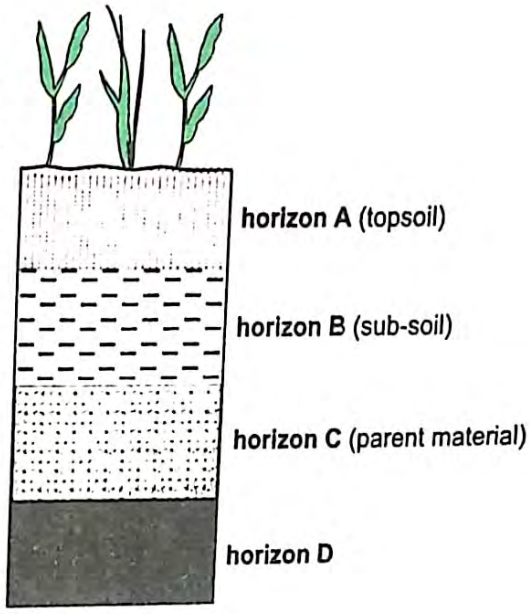



**Figure 19.4. Soil profile.**

## Soil formation

For clarity purpose, soil formation is usually discussed in two stages. The first stage is described as rock **weathering** while the second stage discusses the **factors** affecting soil formation. In reality the two stages go on at the same time.

## Rock weathering

This is brought about by physical and chemical agents.

## Physical agents or physical weathering

These include the following:

1. **Temperature:** The minerals in the rocks have different rates of expansion and contraction and these cause the rocks to crack and fall into pieces.

2. **Ice:** Water in the crevices and cracks of rock freezes when the temperature becomes so low. Water expands in volume when it solidifies and the pressure exerted by the increase in volume is so much as to cause the rocks to crack and break into pieces.

3. **Running water:** River, streams and seas carry big boulders of rocks along their course. As the rocks roll along they knock against one another reducing the big boulders into smaller and finer pieces.

4. **Wind:** Smaller particles of sand are frequently blown against rock surfaces. This action causes gradual wearing away of rocks.

5. **Pressure:** Roots of plants that grow in cracks and crevices of rocks exert pressure that can cause further cracking of the rocks.

## Chemical weathering

This is mostly brought about by oxidation and reduction processes and water. When minerals in the rocks are oxidized by oxygen they cause the rock to break up. Tropical laterite soils, for example, are formed from granites that have been oxidized. Easily soluble minerals in rocks can dissolve in water thereby causing the disintegration of such rocks. **Hydration, hydrolysis** are also chemical processes through which rocks break up into soil.

## Factors of soil formation

The following factors affect the second stage of soil formation: (1) parent material (2) climate (3) living organisms (4) topography and (5) time.

**Parent material:** The type of material and chemical in the parent material affects the type of soil. Example of soils that are formed from rocks with a lot of ferromagnesian minerals are usually rich in iron and red in colour. Parent material that is mainly of quartz mineral gives rise to sandy soils. If the soil has been formed from parent material resulting directly from the break down of the bedrocks, it is called **sedimentary soil**.

**Climate:** This is the most influential as it controls the kind and rate of weathering. It also controls the type of vegetation which influences indirectly the biochemical actions in the soil. Weathering is very rapid in areas with high annual temperatures.

**Topography:** Soil formed at the water valleys are usually poorly drained while those at the hill tops are well drained. The soils at the bottom of valleys are also under the effect of the rise and fall of the water table which changes most compounds in the soil (iron compounds mostly) thereby producing a mixture of colours in the soil called **mottling**. Well drained soils at the hill tops usually have one characteristic colour.

**Time:** Time is needed for the various activities involved in soil formation (weathering, decaying or growing of vegetation).

## Characteristics of soil

We have said earlier that each **horizon** of the soil has its own characteristics and we have equally seen how the factors of soil formation affect the soil characteristics.

The common soil characteristics are (1) **colour** (2) **texture** (3) **structure** (4) **soil constituents.**

**Soil colour:** Every soil has a colour. In most soils, the top soil is dark because of organic matter while the sub-soil may be red or reddish brown. Soil colour is affected by water so that it is very necessary to state the condition of the soil with regard to how wet or dry or moist when describing the soil colour for any given soil. An internationally accepted colour chart for reading soil colour is the **Munsell soil colour chart.**

**Soil texture:** Soil texture refers to the proportion of sand, silt and clay in a soil. Sand, silt and clay are called **soil particles** or **separates.** The sizes of each group is shown below:

| Soil particle | Diameter of particle |
|---|---|
| Stone or gravel | Above 2mm |
| Coarse sand | 2mm - 0.2mm |
| Fine sand | 0.2mm - 0.02mm |
| Silt | 0.02mm - 0.002mm |
| Clay | Less than 0.002mm |

**Soil structure:** In the soil, the soil particles join together by certain means to form groups of particles called **aggregates** and they have definite patterns. The arrangement of the **primary particles** and the **aggregates** is called **soil structure.** If a soil is light it is said to have **loose structure**, that is particles and the **aggregate** are loosely arranged so that there are wider pore spaces between them and therefore water and air can enter easily. Example is **sandy soil.** On the other hand, if the soil is heavy or tightly packed, it means that air and water cannot enter easily since there are few pore spaces. This is common with **clayey soils.** A good soil is that which has enough pore space for air and water so that plant roots have enough water for their use. This is found in a **loamy soil,** which has adequate proportions of sand, clay and a high quantity of humus. This is the best soil for agriculture.

## Sandy soil

The sandy soil has 86% more of sand particles. The particles are large (0.2 to 2mm in diameter). Sandy soil has large pore spaces between them.

### Characteristic features of sandy soil.

1. It has a low water retentive capacity.
2. It is easily carried away by erosion.
3. Its particles do not aggregate together even when wet.
4. Sand particles are sharp to feel when rubbed between palms or fingers.
5. It is easily heated by sun.
6. It is not a fertile soil.

## Clayey soil

Clayey soil contain not less than 35% of the soil mixture.

### Characteristic features of clayey soil

1. It is very sticky when wet hence it can be moulded into various shapes.
2. Its particles are very fine usually below 0.002mm in diameter. It is very smooth to feel when rubbed between fingers.
3. It is usually cold and is not heated by sun. It becomes hard when dry.
4. The spaces between the particles are very small hence its water capillary is high. It can retain much water.
5. The clayey soil is poorly aerated.
6. It is easily waterlogged.
7. It has high cation exchange capacity.

## Loamy soil

Loamy soil is made up of 7 - 27% clay, 28 - 50% silt and less than 52% sand. It is the best type of soil for crop production because of its combination of good physical properties of sand with the chemical properties of clay. It also contains a good proportion of organic matter.

### Characteristic features

1. It is moderately smooth and plastic or sticky.
2. It is not very sharp when rubbed between palms or fingers.
3. It is well aerated or drained.
4. It is easy to cultivate or till.

## Experiment 5

**Aim:** To show that soil contains different sizes of particles.

**Method:** Some quantity of soil sample is put into 250cm³ graduated cylinder. Sufficient water is added to cover the soil sample. Some sodium carbonate or hydrogen peroxide is added to quicken the dispersion of the soil particles. The open end of the cylinder is covered with palm and shaken very well for two minutes. The cylinder is then placed on a table for one hour to allow the content to settle.

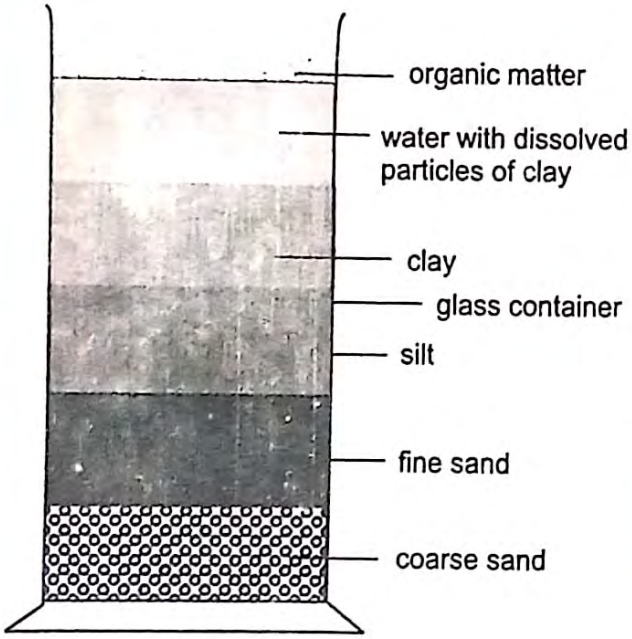



**Figure 19.5. Experiment on separation of soil particles by sedimentation.**

**Result:** The content settles in layers. The larger and heavier particles settle first, that is, coarse sand, fine sand, silt and clay. Light organic matter floats on top of the water surface.

**Conclusion:** Soil is a mixture of different sizes of particles.

## Experiment 6

**Aim:** To compare capillarity of soil samples

**Method:** Into each of three glass tubes put equal amounts of clay, loam and sand. Plug the lower end of the glass tubes with cotton wool and then stand the tubes vertically in a beaker of water as shown in figure 19.6.

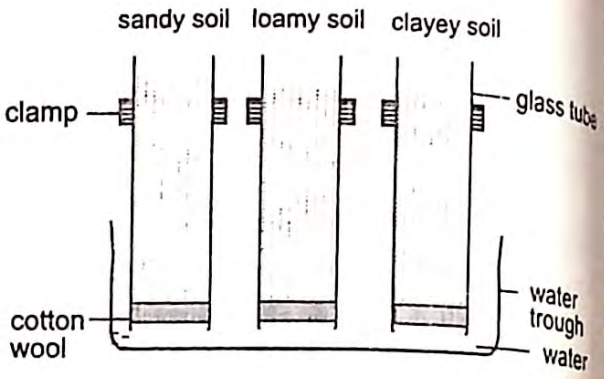



**Figure 19.6. Experiment to compare capillarity in soil types.**

**Result:** After some hours water will be seen rising in the columns of soils. Water will rise highest in the clayey soil and lowest in the sandy soil.

**Conclusion:** Capillarity is highest in clayey soil and lowest in sandy soil.

## Soil consistence

This describes the resistance of soil to pressure at various moisture contents. For example, a clayey soil will be sticky after rain. If the soil is partly dry, it becomes plastic and when it dries completely the soil becomes hard. Terms commonly used to describe consistence are **loose, hard, firm, plastic, sticky and friable.**

## Role of organic matter in tropical soils.

Organic matter is dead animals and plants at varying degrees of decomposition. When organic matter is decomposed the end product is **humus**. Sources of organic matter in the soil as we have discussed earlier are the organic remains and it has the following functions:

1. Organic matter is a source of plant nutrients more especially nitrogen, phosphorus and sulphur.
2. Organic acid released during decomposition of organic matter helps to dissolve minerals in rocks.
3. Organic matter increases the cation exchange capacity of soils.
4. Presence of organic matter lowers the soil pH. That is why soils containing organic matter tend to be acidic.
5. One of the products of decomposition of organic matter is carbon (IV) oxide and this is released to the atmosphere for photo-synthesis.
6. Organic matter reduces the problem of wind erosion by binding particles together.
7. Organic matter used as surface mulch reduces evaporation.
8. It improves soil structure by making heavy soils more porous while inducing better aggregation in coarse textures or sandy soils.
9. Fresh organic matter provides for animals such as earthworm, ants and rodents that burrow into the soil and consequently allowing better air and water infiltration.
10. The decomposition of organic matter leads to The formation of humus which improves the fertility of the soil.

## Porosity

**Porosity** refers to the pore spaces of the soil. Pore spaces are those portions of soil occupied by water and air. The arrangement of the soil particles and aggregates determines the amount of pore space in the soil. Thus **porosity** gives an indication of the compactness of the soil, that is, the way in which the soil particles and aggregates are held together. Particles of heavy soils lie very close together and hence the total porosity is low. Medium textured soils high in organic matter have high porosity. Cropping tends to lower the total pore space. Forest soils and uncropped soils have high porosity. Porosity is measured in **percentages.**

## Experiment 7

**Aim:** To compare porosity and water holding capacity of different soil types.

**Method:** Plug the neck of the filter funnels with glass wool and put equal weights of the soil samples into each of them. Pour equal volume of water on to each soil sample and record the volume of water collected by each cylinder after no more water drains through each of the funnel. Calculate the result as shown below.

Volume of water added
Volume of water in cylinder = ycm$^3$
Volume of water retained by soil = (40 - ycm$^3$

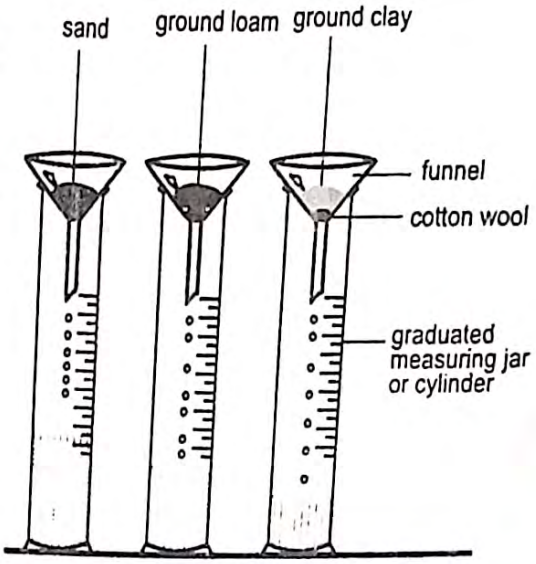



**Figure 19.7. Experiment to compare porosity and water holding capacity of different soil types.**

**Result:** It will be observed that clay retains most of its water while more volume of water is collected in the measuring cylinder carrying the sandy soil. This shows that clay retains more water than the 2 others while loam retains more water than the sandy soil.

**Conclusion:** Sand is more porous than loam and loam is more porous than clay.

## Water movements in soil

Water in the soil is often held in thin film around the soil particles. Such water is held with great pressure and plants cannot make use of it. This water is called **hygroscopic water.** However, during rain and immediately after, all the pore spaces in the soil become filled with water and due to gravitational force, the water drains downwards as more water is added. The excess water drains to the bottom of the soil into the **water table.** Some of the water flows out somewhere as spring while some of it will rise to fill empty pore spaces in the upper layers of the soil by **capillary action.** This is called **capillary water** and it contains dissolved nutrients which the plants need. Plants absorb capillary water and the nutients dissolved in it.

The ability of the soil to retain water is termed its **water retentive-capacity**. Various soils have varying retentive-capacities. Sandy soils cannot retain much water because they have large pore spaces such that water in them drains off easily. Clay and loam retain much more water because they have smaller pore spaces and so drainage is very slow.

## Leaching

As water drains through the soil it carries with it dissolved mineral salts. The amount of lime carried away by drainage is large for humid region soils and this explains why the soil is acidic. Leaching soils can be helped by draining off excess water through adequate drainage systems of the field and through judicious use of fertilizer.

## Soil erosion

**Soil erosion** is the detachment and transferring of the top soil by water or wind or other agents to another place.

The main aim of soil conservation is to prevent and control soil erosion. The causes of soil erosion are:

(a) **Deforestation:** When trees are cut down and there is no plan to replant as is often the case with farming along slopes, the soil will no longer be protected by the shade of the trees and direct rain drops hit the ground and wash out soil down the valley.

(b) **Overgrazing by animals:** When animals graze repeatedly on a piece of land, there will be little vegetation to cover the top soil. The animals also trample on the soil thereby compacting it. The structure is destroyed and water will not infiltrate sufficiently into the soil. The water may collect and flow out as run-off carrying along soil particles. On the other hand, because the soil does not receive sufficient water, it soon dries out and the top soil can be blown away easily.

(c) **Poor farming method:** Ploughing on a soil with an incorrect moisture content destroys structure of the soil and exposes the land to erosion hazards.

(d) **Burning:** Burning to clear the debris after felling and burning of farmlands often leaves the soil bare at the mercy of wind and water erosion.

There are two main agents of erosion. These are water and wind.

**Erosion by water:** This is carrying away of soil particles by running water. Erosion by water is most serious on steep slopes. There are two types (a) **normal erosion** and (b) accelerated erosion.

**Normal erosion:** In this case, the rate of removal equals the rate of replenishing. It goes on all the time particularly in virgin forests.

**Acelerated erosion:** This kind of erosion may take any of these three forms:

1. **Sheet erosion**: The soil particles are removed uniformly over an area such that it may not be noticeable. Sheet erosion also goes on all the time.

2. **Rill erosion:** This occurs when the effect of the erosion becomes slightly apparent in form of tiny channels or furrows.

3. **Gully erosion:** In advanced stage of rill erosion particularly in steep slopes deep channels through which the run-off moves is seen all over the field.

## Control methods of sheet and rill erosion.

1. **Contour cropping:** Ridging of farm lands should be constructed along the contour of the land or across the slope.

2. **Strip cropping:** A good control measure is to alternate **row crops** like maize or cassava with grasses and legumes. Grasses and legumes resist erosion by giving adequate cover to the land.

3. **Terracing:** On steep slopes the most effective method is to construct terraces across the slopes to reduce the speed of run-offs.

4. **Vegetative cover:** Water erosion can be checked by putting the farmlands always under vegetative cover of some sort.
   Uncultivated areas can be covered by cover crops and grasses.

**Wind erosion (erosion by wind):** As wind blows across an uncultivated loose and dry soil, it carries particles of soil away. Erosion by wind depends on the velocity of the wind and the nature of the soil. A soil with a stable structure will resist the wind.

## Control of wind erosion

1. **Wind brakes:** These are trees planted in rows to check the velocity of wind. This is practiced in areas strongly threatened by desert encroachment.
2. **Crop residue:** Crop residue left on the surface of the land prevents wind from carrying away top soil particles.
3. **Vegetative cover:** As stated earlier.

## Conservation and renewing soil fertility

The soil contains a reservoir of plant nutrient which farmers continuously reduce each time they cultivate the land. If the farmers return all they planted to the land it will remain fertile. But for each crop harvest we remove, we are also removing some amount of plant nutrient the soil has, thereby making the soil poorer or less fertile. Since we need the crops, it means that we cannot return them to the soil at that time, hence other means of maintaining the fertility of the soil must be used. Manuring is one method of maintaining the fertility while crop rotation is another.

**Manuring:** A manure is anything that provides plant nutrients. There are two types of manure. These are **organic and inorganic manures**. Organic manures are made up of plant and animal remains that have decayed while inorganic manures are called **fertilizers**

**Organic manures:** These are the main sources of organic matter to soil. There are different kinds of organic manures. The common ones are (1) Farm yard manure, (2) Green manure,
(3) Compost manure.

**Farm yard manure:** This consists mainly of animal's faeces, urine mixed with their bedding or straw. The mixture is packed in a place where after decaying it could be used to supply plant nutrients and organic matter to the soil.

**Green manure:** Is any crop planted so that it can be ploughed into the soil when it is still fresh and green. If the crop is legume it will add a lot of nitrogen to the soil. Green manures supply organic matter and increase the microbial population of the soil.

**Compost manure:** Consists of vegetable matter that has been specially decayed or decomposed in pits or stacks and can be applied to the field to supply mineral nutrients and organic matter mainly.

**Inorganic manures:** These are called **fertilizers** which supply mineral nutrients only. There are two kinds of fertilizers which are (1) **straight fertilizers** which supply one main nutrient e.g. sulphate of ammonia that supplies nitrogen, and (2) **mixed compound fertilizers** which furnish the soil with more than one major mineral nutrients, e.g. the compound fertilizer 15. 15. 15, that gives nitrogen, phosphorus and potassium in equal proportions. Liming, that is the addition of lime-stone or chalk is also very essential to most soil in the humid tropics. This is because liming improves soil structure of clay soils by making them porous. Soil acidity is also reduced by liming and certain mineral nutrients become more available to the plant if acid soils are limed.

## *Questions*

1. *(a) What are the constituents of a fertile soil?*
   *(b) Discuss briefly, how a farmer or gardener would maintain the soil fertility?*

2. *Describe carefully how you would show that*
   *(a) humus and*
   *(b) air are present in a garden soil.*
   *Why are these two substances important to the growth of plants? (WASC).*

3. *(a) (i) Define soil erosion.*
   *(ii) What are the causes of soil erosion? Name the agents of soil erosion.*
   *(iii) Briefly explain sheet and gully erosions. What methods are used to control soil erosion?*
   *(b) What is the importance of organic matter in tropical soils?*

4. *For a sample of soil describe precisely how you would determine:*
   *(i) the percentage by mass of the water content, and*
   *(ii) the percentage by volume of the air content of a sample of soil. Explain any calculations you would have to make from your measurements. (OXF)*

5. *(a) Name the non-living and living components of a balanced soil and briefly explain how each component contributes to soil fertility.*
   *(b) State the role of organic matter in tropical soils.*

# 20

# RELEVANCE OF BIOLOGY TO AGRICULTURE

## Different types of farming methods

Man has been practising different methods of farming to meet his food requirements. Some of these methods are:

### 1. Shifting cultivation

This is a system in which a parcel of land is cropped for one season and left to fallow for some years before being cultivated again.

### Advantages of shifting cultivation

(i) During the fallow period, the soil is enriched with the decay of vegetable matter.

(ii) The fertility of the soil is maintained by the activities of the **nitrogen-fixing bacteria** associating with roots of the wild leguminous plants such as ***Desmodium scorpiurus*** and ***Centrosema*** spp.

(iii) With this farming method, fertilizers are not all that necessary thereby saving money for the farmers.

(iv) Soil erosion is not encouraged as soil is quickly covered with weeds after harvesting crops.

(V) The legumes that grow during the fallow period help to provide nitrate needed for crops to hone high yield.

### Disadvantages of shifting cultivation

(i) Where there is scarcity of land, it creates a problem as there would be no alternative land to shift to for cultivation. The fallow period will be short and therefore the soil will not fertile enough and this will lead to poor harvest.

(ii) Clearing of a fallow land involves hard labour. A lot of money is needed to hire labourers.

(iii) Valuable trees are destroyed during clearing. Big trees which could have grown to timber size are burnt down.

### 2. Crop rotation

**Crop rotation** is a system of crop cultivation in which selected crops are grown on a piece of land continuously for years in a definite order best suited to a given district. This system is aimed at obtaining the highest yield possible while at the same time maintaining or possibly increasing the fertility of the soil.

Besides geographical factors, the principle which guides the choice of crops in any crop **rotation system** ensures that a **deep - rooted crop** (yam, cassava, cocoyam) is followed by **shallow - rooted crop** (maize, rice, melon) or vice versa. An example of four year crop rotation is shown below:

| | | | | |
|---|---|---|---|---|
| 1st year of cropping | A<br>Fallow (*Centrosema*) | B<br>Yam | C<br>Maize | D<br>Cassava |
| 2nd year of cropping | A<br>Cassava | B<br>Fallow (Mucuna) | C<br>Yam | D<br>Maize |
| 3rd year of cropping | A<br>Maize | B<br>Cassava | C<br>Fallow (Mucuna) | D<br>Yam |
| 4th year of cropping | A<br>Yam | B<br>Maize | C<br>Cassava | D<br>Fallow (*Centrosema*) |

Referring to the example of a four year crop rotation, plot A for instance is left to fallow during the first year of cropping but put to cassava in the second year, maize in the third and yam in the fourth year. Similar cropping sequence is also formed in plots B, C and D

In the above example, it is assumed that only a single crop per plot is cultivated and the cassava grown is harvested after twelve months. Depending on the degree of fertility of the soil, it is advisable that fertilizers should be applied as from the se-cond or third year of cropping for good yield

The leguminous plants (*Centrosema and Mucuna*) planted in the fallow land is to enrich the fertility of the soil for next year's crop

## Advantages of crop rotation

(i) Where there is scarcity of land, a piece of land can be used continuously.

(ii) The plant nutrients in a piece of land is well utilized. For example the fibrous roots of maize utilize food nutrients within 15 - 30 cm deep, while yams utilize nutrients of 40 - 90 cm deep. Maize and yam are not competing for nutrients and both will grow well

iii. Crop rotation provide plant residue which serves as source of nutrients for the next crops to grow well.

iv. Competition for nutrient by different crops in the same land is removed.

## Disadvantages of crop rotation

(i) When crop rotation is practised, the land is constantly cultivated. This makes the soil friable as a result of long exposure and constant tillage. Such soils are prone to erosion either by wind or running water.

(ii) Besides, crop rotation involves the use of fertilizers which are not very cheap at least from the local farmer's consideration. Money spent on fertilizers could have been saved if a new and fertile farmland is cropped each time as it is in shifting cultivation.

(iii) In West Africa, crop rotation is not yet widely practised as the farming population consists mainly of illiterates who are traditional and conservative. Consequently, farmers are prone to adopt the shifting cultivation system which is native. The trend may with change as more educated persons take farming and as the **Extension Division** of the **Ministry of Agriculture** and **Natural Resources** intensifies the crusade for improved farming method.

(iv) Besides the above reason, availability of land seems to enhance non adoption of crop rotation system in West Africa. As at present farmers still have fresh sites for use during the cropping season. This privilege may work out with increase in the farming population change which would result in scarcity of land. When farmland becomes scarce, farmers would then be compelled by circumstances to adopt crop rotation.

## 3. Pastoral farming

This involves the rearing of animals such as cattle, sheep and goats that feed on herbage or grasses and legumes. There are two forms of pastoral farming. These are **ranching** and **nomadic herding**

**Ranching** is the keeping of animals in **fenced area** of land containing grasses and legumes for them to feed on. This type can be found in Igarra cattle ranch in Edo State of Nigeria.

**Nomadic herding** is the movement of grazing animals from one place to another in search of fresh herbage and water.

## Advantage

Pastoral farming enables the provision of animal protein, and labour requirement is less.

## Disadvantage

It brings about exposure of land thereby causing erosion. This would lead to land wastage and reduction in productive land.

## 4. Ley farming

This is the practice of growing crops and pasture in **alternation**. Crops are grown for a season and followed by pasture in the next one or two planting seasons before the area is cropped again after it has been grazed.

Scanned with CamScanner

### Advantages

Ley farming brings about high production of crops and animals. When properly planned, it helps to prevent erosion as the land is always under vegetation. Also, the fertility of the soil is maintained with the droppings from grazing animals.

### Disadvantages

The farmer may not be too convenient to be out of crop production for the period of ley, that is, the period in which the land is under grass.

## 5. Continuous cropping

This is the cultivation of crops (mainly arables) continuously on a piece of land for two or more years.

### Advantages

(i) Different kinds of crops (both shallow and deep rooted crops) are planted on the same piece of land. Soil nutrients are utilized to the fullest by the crops.

(ii) Labour to prepare the land is cheap as the land carries only small vegetation.

### Disadvantages

(i) Crop yield will decrease with time.

(ii) Fertilizers are needed to enhance soil fertility and this will involve extra monetary cost.

(iii) It encourages pests and diseases if mono-cropping is practised.

## 6. Monoculture (Mono-cropping)

This is a farming system of planting only one type of crop on a piece of land.

### Advantage

It makes the crop to grow efficiently as the soil nutrients are only utilized by the crop.

### Disadvantages

(i) If practised for a long period, it depletes the soil of nutrients which the crop utilizes while other nutrients are left unutilized.

(ii) The pests and diseases of the cultivated crop increase in population if this farming system is continued for a long period.

## 7. Mixed farming

This is the practice of cultivating crops and rearing of animals on the same piece of land at the same time.

### Advantages

(i) The droppings (faeces) and urine of animals increase the soil fertility.

(ii) The left-over of crops and grasses are used as animal feeds.

(iii) Grazing of the land by farm animals reduces the growth of weeds.

(iv) The farmer gets cheap animal proteins from his farm animals.

### Disadvantages

(i) The farm may be overgrazed by farm animals leading to soil erosion.

(ii) The trampling action of farm animals may alter the physical nature of the soil thereby bringing about poor aeration of the soil.

(iii) Farm animals may damage valuable crops.

## 8. Mixed cropping

This is the practice of cultivating two or more species of crops on a piece of land at the same time. For example, planting of yam and cocoyam, or yam, beans and okro together. In most cases maize or groundnuts are planted at the boundaries.

### Advantages

(i) The soil nutrients are fully utilized by shallow and deep rooted crops.

(ii) It reduces the spread of insect pests and fungi diseases.

### Disadvantage

When all crops are harvested, the soil is seriously depleted of nutrients.

## Food production, wastage, preservation and storage

### Food Production

1. **Ways of improving crop yield**

The yield of crops per unit area can be improved through many ways. These are:-

(a) **Development and use of high-yielding varieties of crops**

Most of the crops grown in most developing countries have low yield potentials. The development and adoption of new crop varieties that give higher yield per area of land will therefore improve crop yield.

(b) **More extensive use of fertilizers**

The addition of chemical fertilizers such as **urea** and **N.P.K.** fertilizers and organic manures such as **compost**, **farm yard manure** and **green manure** will raise the nutrient status of the soil for crop use. Adequate plant nutrients in the soil will ensure and improve the yield of crops harvested per unit area.

(c) **Adequate tillage practices**

Good tillage practice will not only ensure good seed emergence and root development, but would also prevent the destruction of soil structure and soil erosion. The natural state of the soil has to be maintained if crops planted are to give their best.

(d) **Timeliness of farm operations**

For crop yield to be good, all operations involved with crop production such as **land preparation, planting, application of fertilizers** and others have to be carried out at the right time. Improved yield from yam is only possible in **southern Nigeria** if only the seedlings are planted between **late March** and **early May**.

(e) **Adequate water supply**

Water supply through irrigation to supplement insufficient rainfall will ensure and increase crop yield. Adequate water supply will ensure that plants are able to carry out physiological processes at all times.

(f) **Pests and disease control**

Pests and disease are threats to good crop yield if they are not prevented and controlled. Pest infestation and disease outbreak can result in total crop failure.

(g) **Weed control measures**

Weeds which are crops or plants growing where they are not wanted compete with planted crops for available nutrients and space. This will result in poor crop yield. Weed control through physical, biological and chemical methods are necessary to ensure good crop yield.

### 2. Causes of food wastage

In solving food problems, effort has been directed towards more production. Before the food gets to the final consumer, a lot has been wasted. The wastage is caused by:

(a) **Inadequate storage**

Most agricultural products such as grains, fresh vegetables and fruits, fish, meat and dairy products cannot be stored for a long time because of tropical conditions such as **high temperature** and **humidity**. Modern storage facilities such as the **silos** for grains, cold store for animal products and vegetables are lacking. The result is that large proportion of the products go bad after production and before they finally reach the consumers of the products.

(b) **Inadequate and untimely harvesting of agricultural products**

In most cases, because of poor harvesting tools and methods, the crop products such as yam tubers are damaged during harvesting. The damage done reduces the **storage life** of the products. In some cases, products such as rice, maize and guinea corn are not harvested

immediately after maturity. The result is that a lot of pest infestation takes place in the field leading to severe damage to the products in storage.

**(c) Poor preservation of agricultural products**

Some agricultural products such as grains can be preserved through proper **drying** before **storage**. Others like vegetables, fish, meat and milk require cold condition to avoid spoilage. Where the products are not properly dried or not given cold conditions, most of them would be lost before they are made use of.

**(d) Pest infestation**

This is a very serious cause of wastage both in the store and in the field before harvesting. Agricultural products, such as yam and cassava tubers are eaten by **giant bush rats** and other rodents. The effect of this is poor storage life of the tubers tampered with. **Weevil infestation** starts in the field where grains such as rice, maize and guinea corn are planted. This continues in the store leading to serious destruction of the grains.

**(e) Separation or extraction of edible from non -edible part of crops.**

Some edible parts of crops are lost during separation from the non-edible. Instances are the peeling of yam tuber, cassava tuber, cocoyam and fruits such as mango and pineapple.

**(f) Processing of agricultural products**

Processing is the conversion of edible food into another form more acceptable or convenient to the consumers. In most cases, a lot of wastage is observed during processing. The waste is more if the processing plant is not efficient. Examples are the baking of bread from wheat, processing garri from cassava tubers, brewing of beer from barley and making of sausages from meat.

**(g) Inadequate transportation**

This is one of the causes of food wastage in developing countries of the world. Because of bad roads, and dilapidated motor vehicles, a lot of time is spent between the **site of production of agricultural products** and the **markets**. The result is that some of the products go bad before getting to the destination. In some cases, parts of the products are lost on the way because of poor packaging.

## 3. Methods of preserving and storing food

Preservation of food involves prevention of food from spoilage. **Storage** on the other hand means holding food till consumption time. The storage could be for a long or short period. The methods of **holding food** till consumption also aims at preventing the food from spoilage.

The methods of preserving and storing food are therefore as follows: **silos, cribs, refrigerators** and **coldrooms, barns, boxes** and underground **pits or trenches, bags or sacks**. Others such as **baskets, bins** and **roofs** of buildings.

**(a) Silos**

The silos are usually tall, round looking towers made of aluminium or other metals. A silo is a **modern storage structure for storing grains such as maize, rice, millet, and guinea corn**. The structure is **air tight** and the products are well protected from **insects** and **rodents**. It can accommodate large quantity of grains which can also last long. Grains should be properly dried before they are kept in the silos to prevent mould.

**(b) Cribs**

The cribs consist of side poles covered by wire mesh or lined closely with split bamboo. The floor is raised from the ground while the top is roofed with thatch or corrugated iron sheets. Crib is used to store grains especially **dry unshelled maize cobs** which have been **dehusked**. This method of storage can protect grains from rodents and birds, keep them from spoilage for a long time. This method only stores small quantities of grains at a time. The method however does not protect grains from weevils.

**(c) Refrigerators and coldrooms**

These are modern storage equipment that work with electricity. They are very efficient for the preservation and storage of fresh perishable products such as fruits, vegetables, meat and fish. Refrigerators and cold rooms can keep products in good condition for a very long time if there is constant power supply of electricity. This storage method is however expensive for many people to adopt.

**(d) Barns**

This storage method involves **tying yam tubers** with **twine** to small **vertical poles**, supported with strong horizontal poles which are tied to solid stakes. Shade is provided to prevent excessive drying of the yam tubers. This method safe-guards tubers from being eaten by animals. With this method, it is easy to detect any tuber going bad for removal. The barn can keep yam tubers for many months without going bad. However, yam tubers stored with the barn become dehydrated with time because of the hot tropical weather.

**(e). Boxes and underground pits or trenches**

These are used in storing cassava and yam tubers for a short period after harvest. When using the **underground pit** to store tubers, **layers of palm fronds** are laid at the bottom of the pit. After this, one or two layers of cassava tubers are arranged on top of the palm fronds. Another layer of fronds is laid and tubers arranged on top. The procedure is allowed until the pit or trench is filled or the tubers exhausted. The top of the tubers is finally covered with layers of palm fronds and some quantity of soil which is about 10cm thick. The use of boxes has the same procedure as the underground pit. The differences are that **moist saw dust** is used in place of palm fronds and that saw dust is placed round and on top of the tubers.

The use of boxes and underground pits are cheap methods of storing tubers until **6 - 8 weeks** if processing and marketing is not carried out immediately.

**(f) Bags and sacks**

The bags used for storing food include the jute **hessian** and **polythene bags**. Products such as rice, beans, melon, groundnuts and garri can be stored in bags and sacks after the moisture contents have been reduced to a level when they will have good storage life. The bags are later kept in rooms and raised from the ground level. The bags are cheap, available and simple to use.

**(g) Other methods of storage** include the bins used for storing grains, garri and flour. Baskets are used to store products such as fruits and vegetables for a short time. The under roofs of building and huts are used to store unshelled maize with the husks used in hanging the maize cobs. Here they are protected from pests and wet conditions. Only few quantity of grains can be stored with this method-salting, drying, smoking, refrigration, canning and use of chemicals.

## Population growth and food supply

**Population** simply refers to **number of people living in a place or country**. Food on the other hand means materials that can be eaten by people or animals to keep them living and promotes growth.

The population of a place must be such that the **available food** can sustain it. For a very long time, the questions of **population** and **population growth** and the **related food** and **growth in food production** are serious concern to nations and their leaders. This is because increased population has direct consequence on food consumption.

In most developing countries, **population growth rate** is close to **crisis situation**. In Nigeria, the present population growth rate is estimated to be above 3.2 % per annum. This is considered to be one of the highest in the world. The consequence of rapid population growth rate is the apparent need to feed more mouths resulting in rise in aggregate food demand. However, the growth rate in food production has always lagged behind that

of population growth rate.

Many factors have been advanced for the rising population growth rate especially in developing countries of the world. Among these factors are:

(a) **Improvements in medical care** that has led to a continuous fall in **death rate** while **birth rate** is increasing. Medical programmes such as the **Expanded Programme on Immunization (EPI)** and **Oral Rehydration Therapy (ORT)** have greatly reduced death among children.

(b) **Improved feeding habits** of the people have resulted in increased fertility among the population. The effect of this is the production of more children.

(c) **Early marriages and lack of birth control measures** especially among the **rural populace** are serious factors that have led to the increase in population growth rate.

In spite of the efforts being made at providing food, man still faces a **gloomy future** because of fear of **famine** and **malnutrition.** In Nigeria, various programmes have been embarked upon to increase food production and availability. These include the **Operation Feed the Nation**, the **Green Revolution** of the Second Republic and the **Agricultural Development Project.**

## Factors affecting the realization of adequate food supply for the growing population.

(a) **Low utilization of land in Nigeria** is one of the factors affecting availability of food for human consumption. **Out of the 98.32 million hectares** of land in Nigeria, **only 34 million hectares** are presently under culti-vation. This represents about 48% of poten-tially cultivable land in the country. The small land area devoted to cropping invariably limits food output.

(b) **Drought and other weather conditions** affect the availability of food. Favourable weather conditions are crucial to good crop yield.

Adequate water or rainfall is essential for crop growth and development. Bad weather conditions in forms of **drought, late rainfall** and **insufficient rainfall** can constitute major problem of food production.

**Drought**, more than any other factor has contributed to African food problem.

(c) There is relatively static farming technology in most developing countries. Increase yield of crop can be achieved through the planting of **high yielding varieties of crops** and **extensive use of fertilizers.** In Nigeria, majority of the illiterate farmers who produce the bulk of the food need of the people are still **conservative** and have not fully embraced the **new technologies** being introduced to them.

(d) **Improper food storage and transportation** affect availability of food. The available storage methods are poor and inadequate resulting in huge food wastage after production. There is problem of moving food from **sites of production to sites of consumption** because of bad roads and lack of adequate motor-vehicles.

## Relationship between availability of food and human population

**Adequate food** is required to maintain a healthy citizenry and maintain good standard of living. Good food supply tends to favour population growth. On the other hand, limited food has grave consequences on the growing population. This is because **poorly fed population** is susceptible to **deficiency** and **infectious diseases**, thereby reducing energy for hard work.

**Inadequate food supply** increases **morbidity** and **high mortality rates** among the population and hence population growth rate is reduced.

### Effects of food storage

The holding of food products till consumption has effects on the products and the people. Among these effects are:

(1) Ensures even and regular supply of food throughout the year.

(2) Reduced quality of stored food. This is due to deterioration caused by pests such as weevils

and rodents such as rats.

(3) The viability of products such as seeds is reduced due to storage. Where seeds are stored to be used for subsequent planting, viability can be reduced due to pest damage and disease infection.

(4) In some cases, the quality and taste of some food products are improved as a result of storage. For example yam tubers taste better when cooked after it has lost some moisture as a result of storage.

(5) The texture of some food is affected as a result of storage condition. For example the texture of meat is seriously affected by becoming loose after it has been kept for a long time in cold storage.

## Pests and diseases of agricultural importance

### What is a pest?

A **pest** is an **organism** which harbours disease organism(s) or causes damage to other organism(s). There are **crop** and **livestock** (animals) pests.

**Crop pests** include **insects** such as **grasshoppers, mealybugs, myrids, beetles, birds** and **mammals** (such as rodents) while **livestock pests** are **ectoparasites** such as **ticks, lice, mites** and **endo-parasites** such as **liverflukes, roundworms** and **tapeworms.**

### Crop pests

These attack crops both on the field and in the store, causing considerable damage and economic loss. Some examples are **variegated grasshopper, stem borer, aphids, bean weevils** and **cassava mealybugs.**

### Grasshopper (*Zonocerus variegatus*)

#### Life history

Male and female mate and eggs are then fertilized internally. The female then digs a hole with her **ovipositor** in the soil usually near the roots of plants and lays about 40 to 100 eggs in the hole.

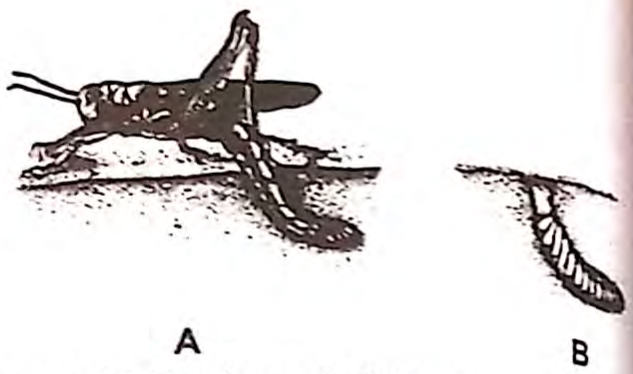



**Figure 20. 1. Grasshopper laying eggs.**
**A = process of egg laying;**
**B = egg mass in the ground.**
**(After Walton)**

A protective material is produced to cover the eggs. After about 3 days, the eggs hatch into **nymphs.** A nymph resembles the adult in all respect except it is **sexually immature** and **wingless.** The nymph moults several times. They hop about feeding on the shoots of plants nearby. They begin to migrate into areas where there are cassava farms and start feeding on the cassava leaves until an adult stage is attained.

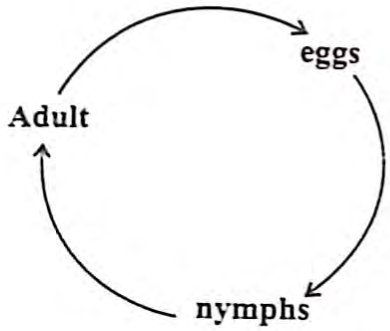



**Figure 20.2. Life history of a grasshopper.**

#### Effects of grasshoppers on cassava

Nymphs and adults feed on the leaves, shoots and barks of cassava thereby reducing cassava yield drastically as photosynthesis is seriously impaired.

**Control:** Spray with gammalin 20.

## Cassava mealybug (*Phenacoccus manihot*)

### Life history

The female insect lays eggs without fertilization by the male. This type of reproduction is called **parthenogenesis**. The unfertilized eggs hatch into larvae which are wind borne or carried with cassava stem cuttings during planting because they hide in the buds of the stem. The larvae undergo 3 moulting stages before adult stage. One generation is completed in about 22 days and the adult has life span of about 145 days.

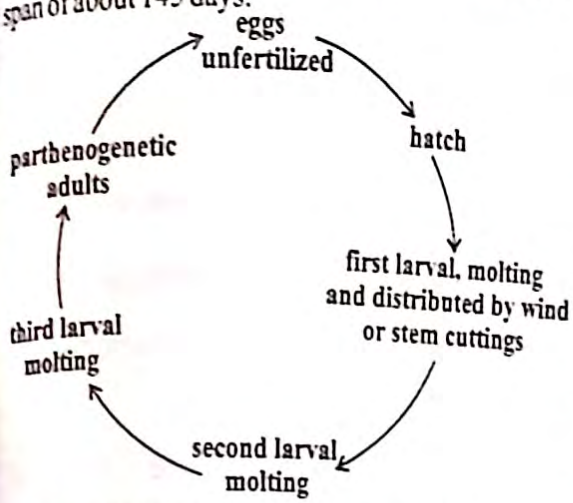



**Figure 20.3.Life history of cassava mealybug.**

### Effects

1. They suck the sap of cassava leading to the stunted growth of shoot.
2. The shoots develop bunchy tops.
3. The leaves of the shoot die and drop.
4. Mealybug infestation impairs photosynthesis in cassava resulting in low root tubers.

**Control:** Dip cassava cuttings in **0.1% rogor** or **ultracide solution** for one minute before planting.

## Bean weevil (*Callosobruchus Maculatus*)

**Figure 20.4. Bean weevil**

### Life history

Male and female adults mate. Fertilized eggs are then laid in the ripening pods in the farm. The eggs hatch into larvae which enter into the bean seeds before harvesting. In the store, the larvae feed on the cotyledons of the beans. The larvae develop into pupae in the store. The pupae later develop into adults which fly away to mate again in the farm.

### Effects

The larvae feed on the cotyledons of the seeds thereby reducing the quality and value of the beans.

### Control

Fumigate the store in which beans are stored with fumigants such as **methylbromide**.

## Cocoa myrids (*Capsids*)

These are piercing and sucking insects. They attack the young shoot of cocoa, introducing **toxic saliva** into the sap. This may kill the plant. It can introduce viral diseases into the plant.

### Effects

Cocoa myrids cause dieback disease which reduces the growth of cocoa plants. Fruit yield is reduced.

### Control

Spray the cocoa farm with **kokotine** or **gammalin 20**.

## Yam beetle (*Heteroligus meles*)

### Life history

The mating of the female and male yam beetles takes place between November and December in riverine areas and fertilized eggs are laid. Between December and February, eggs hatch into larvae that feed on the decayed organic substances. The larvae moult thrice before developing into pupae. In March the pupae develop into adults after moulting. The adults then fly to areas where yams are plant-ed between April and June. They dig into the soil to search for the yam tubers. When they eventually come in contact with tubers they feed on them and seriously damage the tubers. Between

October and November, the adult yam beetles undergo **breeding migration** to the riverine areas again for mating.

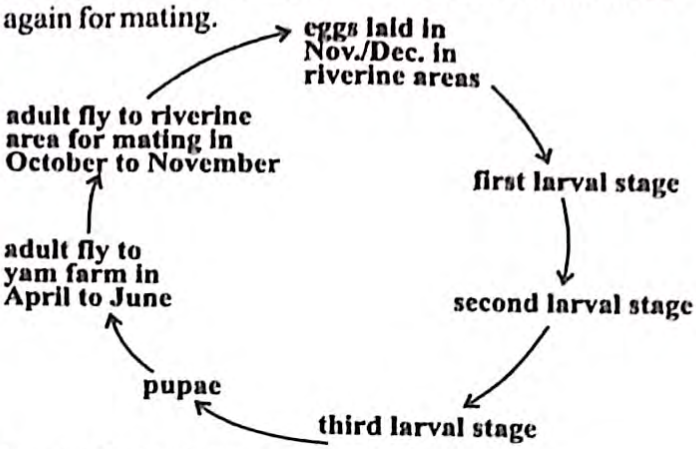



**Figure 20.5. Life history of yam beetle.**

### Effects

Adult beetles feed on the yam tubers causing serious damage to the tubers and render the tubers valueless. If the tubers are attacked at early stage, the yield is poor.

### Control

Dust yam or yam sets with **Aldrin** before planting.

## Animal pests

Animal pests include flies such as **tsetsefly**, ectoparasites such as **ticks** and **lice**. Endoparasites such as **liver flukes** and **roundworms** are also pests.

### Tsetsefly

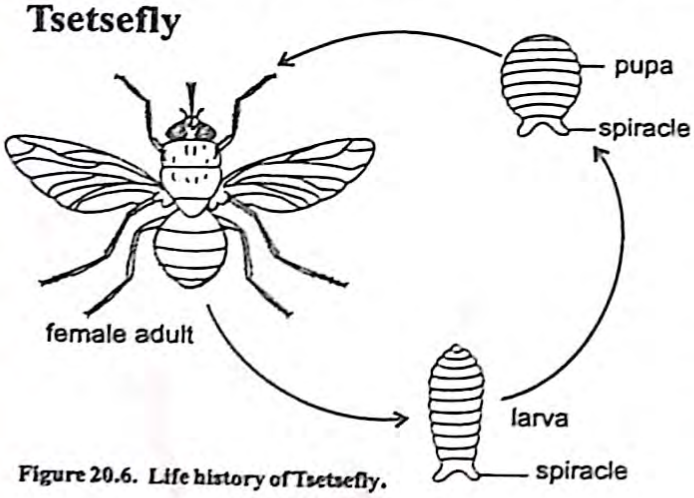



**Figure 20.6. Life history of Tsetsefly.**

### Life history

Male and female adults mate. Only one egg is fertilized and the fertilized egg is retained in the body of the female which later hatches into a larva. The larva feeds on fluids from **"milk gland"**. The larva stays about 8 days inside and moults thrice. The female tsetsefly needs three blood meals to complete the development of each larval stage.

As the female tsetsefly sucks blood it takes **trypanosome** along with the blood from animals already infected.

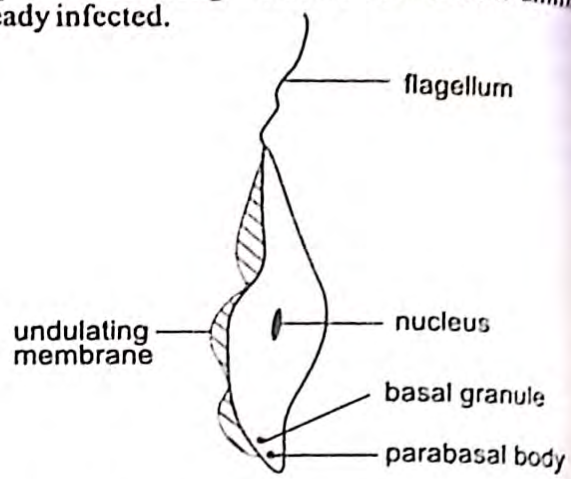



**Figure 20.7. Structure of trypanosome**

Having been sucked by the insect, the trypanosome (protozoan parasite) multiplies rapidly by **binary fission**. They then live in the salivary glands of the insect. The infective forms (trypanosome) are injected with saliva into the blood of other animals. In the blood, they obtain their own food and can even migrate to other organs of the body.

After third moulting, the larva is born in a shady place where the soil is not too dry or loose.

The larva penetrates into the soil and burrows. Burrowing and moving in the soil is by peristaltic movements and longitudinal contractions of the entire body.

The integument of the larva quickly hardens to form a dark brown **puparium**. Inside the pupa-rium, the larva moults to become **pupa**. The pupa stays inside the puparium for about 21 days or more depending upon the soil temperature and moisture. The pupa moults several times to become a young adult after breaking open the end of the pupal case by the help of **ptilinum**. The young adult climbs to the surface, dries up its wings and place like forest. This

type of reproduction in which the egg is fertilized inside the body of the mother, developed, nourished and hatched **without a placenta** is called **ovoviviparous reproduction (ovoviviparity).**

### Effects

Tsetse fly transmits a protozoan parasite called trypanosome to cattle. Trypanosome causes **sleeping sickness, anaemia,** loss of weight and relapsing fever.

### Control

1. The control of this pest is by clearing bushes around the breeding grounds.
2. Spray the resting places of tsetsefly with DDT or other insecticides.
3. Rear resistant cattle in an infected area.

## Lice (singular: louse)

Lice are small insects without wings. They are dorsoventrally flattened. They live under the hairs of mammals and feathers of birds. They suck the blood of their hosts. There are two kinds of lice namely: **body lice** (e.g. chicken body louse) and **biting lice** of domesticated mammals (e.g. *Bovi-cola bovis*).

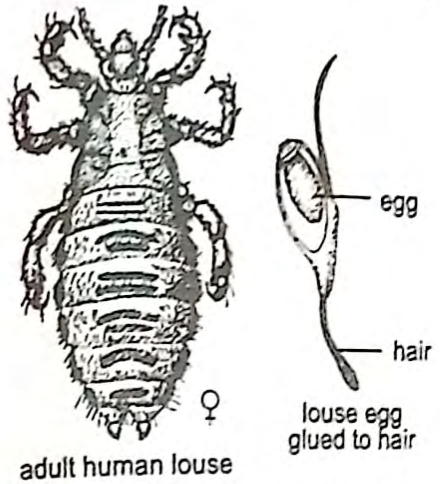



**Figure 20.8. A female body louse and its egg.** (After Hunter and Hunter)

### Life history

Adult male and female mate. The female lays fertilized eggs attached to the hair or feathers. The eggs hatch into nymphs. The nymphs moult thrice to reach adult stage. Lice are spread through contact with infected animals.

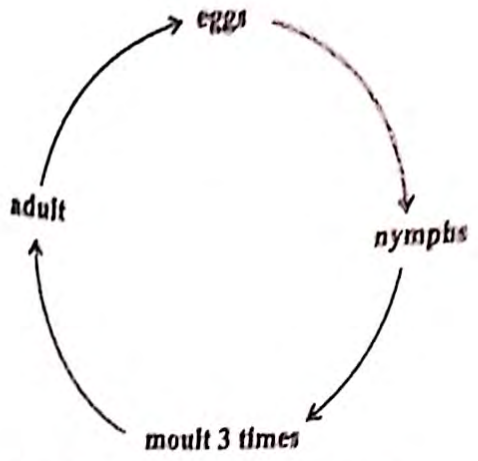



**Figure 20.9. Life history of lice,** ***Bovicola bovis.***

### Effects

1. Lice suck blood of their host. The chicken lice also attack and destroy the feathers.
2. Sucking of blood causes great irritation and restlessness leading to loss of weight and poor egg production in birds.
3. Heavy infestation of lice results to anaemia due to loss of blood.

### Control

1. Maintain good sanitation all the time.
2. Prevent over-crowding of reared animals.
3. Dip infected animals into a solution of 5% DDT or solution of **sodium fluoride** or **lindane.**

## Ticks

Ticks are ectoparasites of many animals such as cattle, goats, sheep and dogs which feed on blood of animals. There are two types of ticks namely: **Soft-bodied ticks** belonging to family **Argasidae** and **hard-bodied ticks** belonging to family **Ixodidae.**

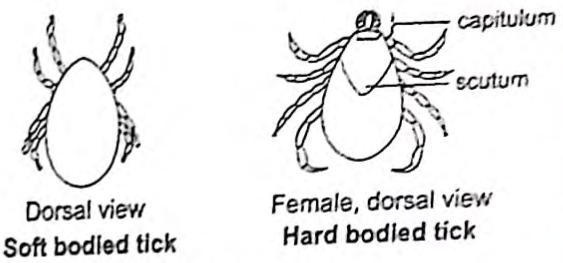



**Figure 20.10. Soft and hard bodied ticks (Courtesy of R.M. Cable).**

***Boophilus microplus*** is a hard bodied tick which parasitizes on cattle, horses etc.

### Life history

The mature female attaches itself to the skin of its host such as cattle, horse, goat or sheep and sucks blood. The stomach becomes filled with blood. The mature male crawls about until it finds a female. Mating takes place. The male dies after mating. After fertilization, the female tick drops to the ground. It lays its eggs on the ground or crevices of stones. The eggs hatch into larvae with six legs. The larvae are active and climb to the top of blades of grasses or other objects waiting for a host to pass by. When a host passes, they become attached to it. The larvae then pierce the skin of the host and suck blood. When the larvae are fully fed, they drop to the ground again. On the ground, the larvae develop into nymphs with eight legs. The nymphs crawl to the blades of grasses again waiting for another host. At this time the nymphs feed on the blood of its host and drop to the ground again where they moult into adults. The adults crawl to the blades of grasses and plants and as the host animal passes and rubs its body against the leaves of grasses and plants, ticks stick to it.

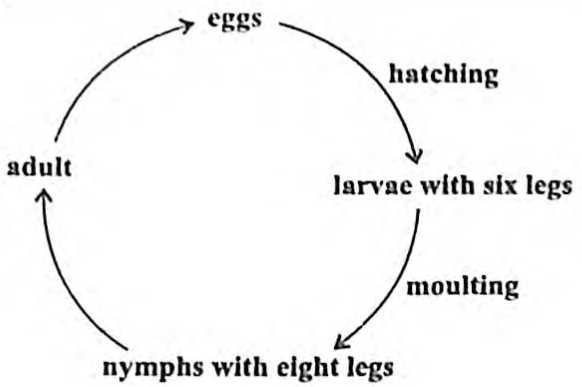



**Figure 20.11. Life history of tick.**

### Effects of ticks

1. Blood sucking of the ticks causes irritation resulting to restlessness and leading to loss of weight.
2. Sucking spots develop sores on the skin providing areas for disease infection.
3. Sucking of blood results in loss of blood and consequently the animal becomes anaemic and weak.
4. The skin of the animal is destroyed leading to poor hides.
5. Ticks transmit diseases such as **red water fever relapsing fever, East coast fever**, etc
6. Infestation of young animals results in retarded growth.

### Control

1. Keep environment clean.
2. Physically remove ticks from the body of the animal.
3. Spray animal houses with insecticides such as **BHC** or **Malathion**.
4. Dip infected animals into a solution of arsenic
5. Rotation of the pasture and livestock. Livestock removed from infected areas to uninfected areas. The larvae and nymphs will die of starvation due to lack of hosts.

## Liver fluke (*Fasciola hepatica*)

### Life history of liver fluke

The adult liver flukes live in the liver and bile ducts of cattle, sheep and goats. It attains a length of about 3cm. The female fluke lays eggs which are shed with urine or faeces into a damp place or water. The eggs then hatch into ciliated larvae called **miracidia** (singular-miracidium) after about 14 days. The miracidia swim about finding a suitable **intermediate** (secondary) **host** - water snail (*Lymnaea spp.*). When the miracidia come in contact with water snail, they penetrate the soft tissues. Inside the tissues they develop into **sporocysts**. The sporocysts then develop into **radiae**. The radiae produce **cercariae** which burrow out of the tissues of the water snail into water and swim about for a short time and encyst on aquatic vegetation.

When a grazing animal such as cattle, sheep or a goat eats grasses **infected** with the **cysts**, the cysts are swallowed. In the stomach of the grazing animal, the cysts dissolve and the cercariae develop into adult young flukes. These young flukes then burrow through the walls of the small intestines and body cavity to the liver and bile ducts where they settle as adult flukes.

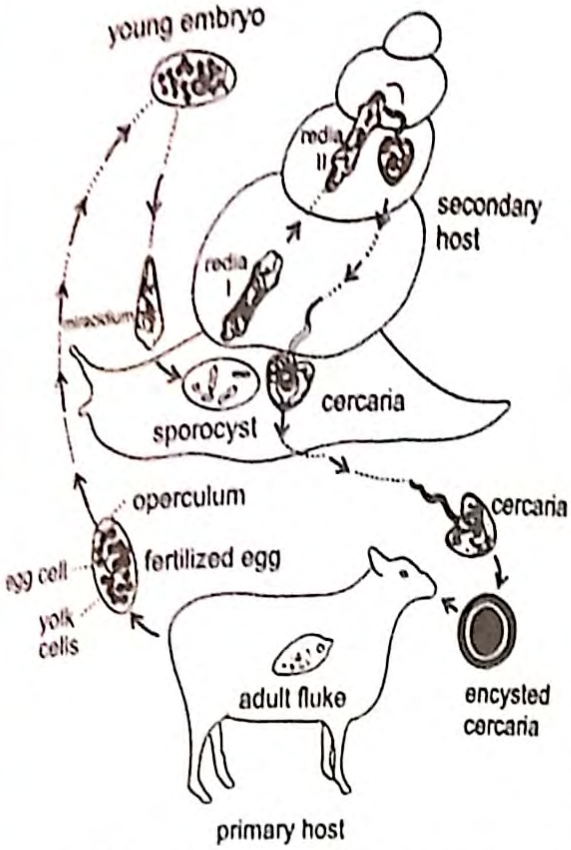



Figure 20.12. Life cycle of *Fasciola hepatica* (After Grove and Newell).

### Effects

1. It damages the liver resulting in loss of blood. The animal becomes anaemic and death results if not treated.
2. Loss of weight leading to poor meat production.

### Control

1. Ducks that eat the intermediate host (water snails) should be introduced to pools and streams. This will deprive the miracidia of an intermediate host (water snail) and will eventually die within hours.
2. Pools and streams should be treated with copper sulphate [copper (11) tetraoxo sulphate (VI)] solution to kill the miracidia and cercariae.
3. All water snails on the grazing grounds should be physically collected and destroyed.
4. Supply clean drinking water to the animals.
5. Consult a veterinary doctor to treat the infected animal.

## Roundworm of Pig *(Ascaris suum)*

### Life History of *Ascaris suum*

The life history of *Ascaris suum* is the same as that of *Ascaris lumbricoides* in man.

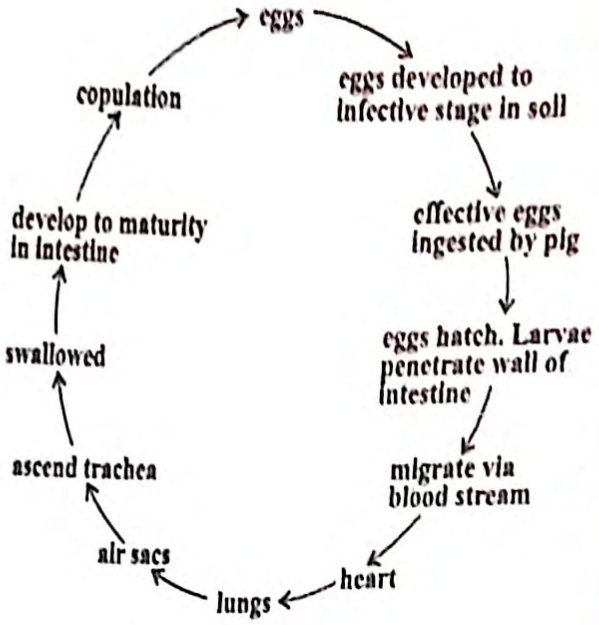



Figure 20.13. Life cycle of round worm of pig (*Ascaris suum*).

### Life history

The male and female worms copulate in the small intestine of the host. The female starts laying fertilized eggs at daily rate of about 200,000. The eggs pass out with the faeces and are deposited on the ground. The fertilized eggs develop into small worms inside the shells. This is the infective stage. If swallowed into the body in this form, through the eating of contaminated food items they will grow into mature adults.

When the infective eggs are swallowed, they pass to the intestine and hatch into tiny larvae which burrow through the small intestinal wall into the veins or lymph vessels.

In the blood, they pass through the heart to the lungs, then ascend the trachea, cross over to the oesophagus and they are swallowed back to the small intestine where they grow to maturity and copulatory activities begin again.

Note: Only one host (pig) is involved. As the larvae pass through the body, they moult three times before reaching maturity.

### Effects on pig

1. It robs the animal of digested food resulting in loss of weight, slow growth and general weakness.
2. The migratory worms may damage lungs making breathing difficult.
3. Serious infestation may lead to blockage of the digestive track and bile duct thereby causing digestive disorders such as **diarrhoea** and **vomiting** and **jaundice**.
4. During the migratory journey, it destroys organs such as heart, kidneys, liver and lungs. Blood vessels may also be damaged.

*Note*: These effects are also applicable to man in case of

infection of *Ascaris lumbricoide.*

**Control**

1. Good sanitary conditions in the pen and buildings.
2. Great care must be taken not to contaminate the feeds and water of healthy animals with the infected droppings or dungs of infected animals.
3. Use appropriate drug to expel the worms from the stomach or intestines. This practice can be done on routine basis. For example, adding **sodium fluoride** to dry feeds helps to expel the worms from the stomach and intestine.

**Preventive measures of *Ascaris lumbricoides* in case of a man**

1. Hands must be properly washed before eating and after attending latrines. Children must be educated early in life of the importance of washing hands before eating.
2. Good latrines should be used. Water system types are excellent.
3. Flies must be kept away from our food as they are known to carry the eggs of *Ascaris* to our food.
4. Vegetables and fruits must be washed carefully and properly.

**Treatment**: Antepar, Combatrin and Mintezol are effective drugs for expelling the worms.

## Diseases

A disease can be generally referred to as an *abnormal condition in health*. Diseases cause damage to parts of plants and animals and in some cases death may occur. Below are some examples of diseases which are of agricultural importance.

### Diseases of crops

**(i) Corn smut**

This affects maize and is caused by **fungus**. The spores of the fungus are transmitted by air. This makes it possible for the disease to spread. The grains of the maize cob become covered with large mass of spores. Later the whole cob may be covered. This renders the grains useless.

**Control**

Control is by using clean seeds in planting. Seeds should also be treated with fungicides before planting.

**(ii) Rice blast**

This is also a fungus disease which affects rice. The spores are distributed by air. Affected crops develop dead areas on leaf surface. This reduces the yield.

**Control**

This is by growing resistant varieties and treating seeds with fungicides before planting.

**(iii) Groundnut rosette**

This is a virus disease of groundnut. It is trans-mitted by piercing and sucking insects such as **aphids**.

**Effects**

1. Affected crop develops closely packed leaves which become wrinkled and mottled. They curl and turn yellowish.
2. The whole plant becomes stunted thus reducing yield.

**Control**

Control can be achieved through (a) early planting (b) use of resistant varieties (c) uprooting and burning of an infected plant.

**(iv) Cassava mosaic**

This is a disease of cassava caused by **virus**. It is mainly transmitted by the *Bemisia* fly which introduces the pathogen into the plant as it sucks the sap from the plant. Infected plants show yellowish pale areas alternating with green patches on the leaves. This is followed by leaf distortion and stunting of plant. Crop yield is highly reduced.

**Control**

The use of resistant varieties is the only control measure available.

**(v) Root knot**

Root knot is caused by nematodes in the soil, usually called **knot nematodes**. It affects mainly tomato and some times okra. Nematodes are soil-borne.

**Effects**

Their attack results in the enlargement of certain cells of the plant roots resembling knots. This causes the wilting and retardation of plant growth, thereby reducing yield.

**Control**

Control can be achieved through (a) crop rotation (b) use of resistant varieties (c) use of nematicides such as **furadan**.

**(vi) Sigatoka**

This is a fungus disease of banana which is transmitted by air (air-borne).

It causes yellowish or brownish spotting of leaves. The spots later unite into bands of chlorotic areas on the leaf surface, running parallel to the leaf veins. The disease can greatly reduce the yield of banana.

**Control**

Spraying with copper fungicides can effect some control.

**(vii) Black pod disease**

This is a serious disease of cocoa caused by fungus - *Phytophthora palmivora*. The spores of the fungus are spread by rain drops, insects or animals from infected pods to healthy ones.

The disease leads to the development of brown spores on pod which later become powdery. The whole pod becomes rotten and black. Infection of black pod disease greatly reduces the yield of cocoa.

**Control**

(1) Regular weeding of farm
(2) Remove and burn all infected pods
(3) Spray with copper fungicides such as perenox

### (viii) Bacteria blight

This bacterial disease affects cotton. It is also called **black arm**. The pathogen (*Xanthomonas malvacearum*) enters the plant through the stomata of the leaves. It is favoured by water-logging conditions and low temperature.

Infection results in angular spots on leaves and branches.

**Control**

(1) Use of resistant varieties

(2) Destroy the infected plant.

**Table 79: Some common livestock pests and diseases.**

| Name of disease | Causative agent | Animal affected | Symptoms | Mode of transmission | Control |
|---|---|---|---|---|---|
| Rinder pest | Virus | Cattle | High fever, blood stained diarrhoea, difficulty in breathing. Death rate is very high & this reduces animal population | Through contact with infected animals & by eating contaminated food. | Vaccination. Isolate infected animals from healthy ones. |
| Newcastle disease | Virus | Poultry | 1. Drop in feed consumption 2. Difficulty in breathing 3. Neck twisting 4. Paralysis of legs and wings. 5. Greenish-watery diarrhoea. 6. There is high mortality rate leading to loss of birds. | Through contact with substances contaminated by the virus such as nasal discharges and feeds. | 1. Good sanitation 2. Routine vaccination |
| Anthrax | Bacterium (*Baccillus anthracis*) | Cattle, sheep and goat | 1.Blood-stained discharges from nostrils & mouth. 2.Swellings in the neck, genitals & in the lower abdomen. 3.In acute cases,the only symptom is death of the animal. The disease is zoonotic. | Through contact with infected animals or the products from them. | 1. Vaccination. 2. Burn or bury deeply any diseased animal |
| Ringworm (*Fungus favus*) in poultry | Fungus | All animals | 1. Lesions or scars develop on the animal's skin. 2.This causes irritation. 3. Hairs fall off. 4.The disease produces gray patches on the combs & wattles of birds. | It is spread by contact | 1. Good hygiene. 2. Affected areas should be treated with iodine. |
| Trypanosomiasis | Protozoa (Trypanosome) | Mainly cattle, goats & sheep are attacked. | 1. There is an intermittent fever. 2. General weakness. 3. Hairs on the tail of the animal pull out and the animal finally dies. | Transmitted by tsetsefly through its biting and sucking habit. | 1. Use of drugs (Trypanosomide). 2. Rear resistant breed. 3. Spray tsetse flies with insecticides. |

| Name of disease | Causative agent | Animal affected | Symptoms | Mode of transmission | Control |
|---|---|---|---|---|---|
| Hog cholera | Virus | Pig | 1. High fever.<br>2 Loss of appetite.<br>3. Sticky discharges from the eyes. | Contact with contaminated substances such as faeces, urine and secretions from nostrils, eyes and mouths. | 1. Vaccination<br>2. Kill and bury infected animals |

## Table 80: Local farm and livestock pests and diseases they cause.

| Pests | Diseases caused/transmitted |
|---|---|
| 1. Aphids | Transmit virus disease such as groundnut rosette, swollen shoot of cocoa |
| 2. Mealybug | Mealybug disease of cassava |
| 3. Nematodes | Root knot |
| 4. Yam beetle | Tuber rot of yam |
| 5. Round worm | Anaemia |
| 6. Tick | Red water, East Coast fever, relapsing fever. Anaemia. |
| 7. Lice and mites | Anaemia |
| 8. Tsetse fly | Trypanosomiasis |
| 9. Tape worm | Anaemia |

## Table 81: Some diseases of plant crops

| Name of crop | Name of disease | Causative organism | Mode of transmission | Effects on crop | Control |
|---|---|---|---|---|---|
| Maize | 1.Maize streak | Virus | By piercing and sucking of insects | Leaf surface discoloured in form of streak running parallel to the vein. Low crop yield. | 1. Plant early.<br>2. Affected crop is removed and destroyed.<br>3. Spray with insecticide. |
| | 2. Corn smut | Fungus (*Ustilago zea*) | The spores of the fungus are carried by air and deposited on the leaves. The spores grow inside the crop tissues and attack fruits. | Grains are covered with large mass of spores. The whole cob is also covered with black spores rendering the cob valueless. | 1. Use clean seeds in planting.<br>2.Treat grains with fungicides before planting. |
| Groundnuts | Rosette | Groundnut virus | Transmitted by an insect called aphid. | Leaves are closely packed and become wrinkled and mottled. Leaves also curl and turn yellowish.<br>Stunted growth and yield is poor. | 1. Early planting.<br>2. Plant resistant varieties.<br>3. Uproot and burn infected plant. |

| Name of crop | Name of disease | Causative organism | Mode of transmission | Effects on crop | Control |
|---|---|---|---|---|---|
| Yam | Tuber rot | 1. Nematode<br>2. Fungus | Nematode first attacks the yam tuber in the soil and infection by fungus follows in the barn. | Yam tissues turn brown and soft rendering the yam tuber valueless | 1. Destroy the affected yam<br>2. Use Aldrin dust during planting |
| | Leaf spot | Fungus | Air borne spores are deposited on the leaves of the plant crop. | Dead spots develop on leaves reducing photosynthesis and consequently reducing tuber formation. | 1. Spray the plant with fungicide<br>2. When planting space widely |
| Cassava | Cassava mosaic | Virus | Transmitted by *Bemisia* fly which introduces the virus as it sucks the sap of the plant. | Development of yellowish pale areas alternating with green patches on the leaves.<br>Leaves are distorted resulting in stunted growth.<br>Plant yield is poor. | Plant resistant varieties |
| Tomato or okra | Root knot | Root knot nematode | The nematodes attack the roots | Some cells of the roots are enlarged to form knot-like structure. Wilting of plant. Stunted growth. Poor yield. | 1. Practise crop rotation<br>2. Use nematicides when planting<br>3. Plant resistant varieties |
| Onion | Downymildew | Fungus | Spores are carried by wind and deposited on leaves. | White coating of fungus appear on leaves leading to the death of the leaves. Bulbs unable to develop. | Dust with mixture of lime and sulphur or spray with sulphide of potassium. |
| Banana | Sigatoka (Leaf-spot) | Fungus | Spores are carried by wind and are deposited on the leaves.<br>The deposited spores grow on the leaves | Yellowish or brownish spots on leaves. Spots later develop into chlorotic areas on the leaf surface running parallel to the leaf veins.<br>Low yield. | Spray with copper fungicides. |
| Palm oil | Freckle | Fungus | Spores are carried by wind and are deposited on the leaves. | Attack the young palm at pre-nursery and nursery stages. Brown spots develop on leaves leading to their drying up and death follows. Growth is retarded. | Spray with fungicide such as **perenox** or **captan**. |
| Cocoa | Black pod | Fungus (*Phytophthora palmivora*) | Spores are spread by rain splash, insects or animals. | Brown spores on pods.<br>The pods gradually turn black and dry up. The beans inside rot. | 1. Regular clearing of the farm.<br>2. Remove and burn all infected pods.<br>3. Spray with fungicides such as perenox, lime bordeaux mixture and carbide bordeaux mixture. |

| Name of crop | Name of disease | Causative organism | Mode of transmission | Effects on crop | Control |
|---|---|---|---|---|---|
| | Swollen shoot | Cocoa virus | The virus is transmitted by the nymphs of mealy bugs and white flies from infected plants to healthy plants. | Stems and roots become swollen. Leaves become chlorotic. Growth is reduced. | 1. Cutting down and burying of infected plants 2. Check plantation regularly for any out break 3. Plant resistant varieties. |
| Cotton | Bacterial blight | Bacterium (*Xanthomonas malvacearum*) | Carried by wind or insects to the stomata of leaves. Waterlogging conditions also spread the disease. | Angular spots on leaves and branches. Boll rot causes low yield of cotton lint. | 1. Plant resistant varieties 2. Destroy all cotton debris during off season. 3. Dust seeds with Agrosan 5W before planting |
| Rubber | Root rots | Fungus | Roots are infected by the hyphae of fungus in the soil. | Tap roots are attacked by fungi leading to the breakdown of tissues and to loss of leaves after they have turned yellow. The plant eventually dies. | 1. Dig a trench round the roots and the exposed roots are treated with fungicides 2. Infected plants Should be cut down and burnt |

## THE EFFECTS OF VARIOUS AGRICULTURAL ACTIVITIES ON ECOLOGICAL SYSTEMS

### 1. Bush clearing/burning:

The removal of vegetation from the land exposes it to agents of **erosion** such as **rain** and **wind**. The effects of erosion in terms of cost and wastage of productive land is a serious impediment to agriculture and development of the society. Also, equipment used during clearing like heavy machines have the tendency to compact the soil thus making the soil to be poorly aerated. The top fertile soil could be removed in some cases while clearing and this will cause the level of crop production in the area to be poor.

Burning, also reduces the amount of plant minerals in the soil. It is the usual practice to burn after clearing, especially in the rain forest zone of Nigeria. Essential nutrients like nitrogen, carbon, and sulphur are lost from the soil as a result of heat. They are broken down into their gaseous oxides, such as dioxonitrate (III)ion, Carbon (IV) oxide and sulphur (IV) oxide. Organic matter which forms a useful source of plant food is burnt and essential micro-organisms are killed. This affects the physical properties and nutrient status of the soil. Also, animal life in the area is endangered during burning. This could lead to the extinction of biologically important species. Land becomes bare and exposed to possible erosion. Also, leaching of essential mineral nutrients becomes high.

However, ash, if not blown-off by wind, consists of calcium and magnesium which help to raise the soil pH. Also weed competition is reduced and pest as well as disease agents are killed. It makes for easy access to the farmland. Also it eases the working condition of the area.

## Tillage:

Tillage provides a suitable soil medium for seed germination. It brings about better arrangement of particles for good root development. It helps to improve air supply to the soil or aeration and reduces weeds, whose seeds become exposed. While tillage is being done, organic materials could be worked into the soil. This becomes food for plant and soil organisms. Organic materials also reduce erosion due to its binding action on soil.

However, some tillage practices such as total tillage could lead to the compaction of soil, due to the movement of heavy equipment, leaching of soluble nutrients and erosion as a result of exposure to climatic factors. This has brought about the discovery of different tillage practices such as minimum or zero tillage, conservation tillage. Tillage may be minimum or zero when planting is done in an unploughed land with no seed bed except the opening where seeds are dropped, or total when all types of suitable implements and equipment are used to till the land.

## 3. Fertilizers/herbicides application:

Fertilizers are materials either in form of powder,crystal or granules that are added to the soil to supply certain elements essential to plant growth. There are basically two types of fertilizers namely **simple or straight fertilizers** and **mixed or compound fertilizers.**

### (a) Simple or straight fertilizers:

These contain only one of the major fertilizer elements such as nitrogen, potassium or phosphorus in their composition. Examples are, muriate of potash, urea, sulphate of ammonia, single super phosphate and others.

### (b) Mixed or compound or complex fertilizers:

These contain more than one of the major fertilizer elements like nitrogen, phosphorus and potassium in their composition. The major nutrients are represented in ratios as contained in their proportion in the composition. Examples are N.P.K. 15:15:15:,N.P.K. Mg 12:12:17:2.

Fertilizers play a very important role in an ecological system. It is the main source of incremental food production through increasing productivity of cultivated land, and poor soils. It also broadens the choice of crops to be cultivated and quality of some crops. In addition, it brings about industrialization in a country or a place where it is manufactured. It encourages organic matter development in marginal soils.

However, some leave acidic residues in the soil such as sulphate of ammonia. This situation limits the production of most food crops and activities of essential soil microbes. The use of empty sacks of fertilizers for consumable food items to man constitutes danger.

**Herbicides** are chemicals which are used in the control of weeds. They are important in controlling small initial infestation or cleaning up after tillage or cropping method have been used.

**Herbicides** are classified into two groups based on the mode of action. These are:

### (i) Selective herbicides:

These are herbicides when applied to mixed plant population, would kill certain species of plants without harming others. Example is 2,4-D (2-4-dichlorophenoxyacetic acid) that is capable of killing weeds with broad leaves growing among cereals like rice and other crops such as soyabean, sugar cane, cotton etc.

### (ii) Non-selective herbicides:

These are herbicides when applied to the leaves of plant or soil, destroy all plants regardless of species. Examples are **arsenicals, chlorates, carbon disulphide**, etc.

Herbicides provide convenience in terms of labour input in weed control on a commercial farm. It is effective when used according to specification.

However, herbicides are injurious to man and cultivated crops if proper care is not taken when in use. Some add ingredients which are undesi-rable to the environment.

Herbicides are washed out of soil to streams, rivers and lakes where they can endanger aquatic life. Empty containers could be a source of poison when used as containers for food. Some useful herbs could be destroyed along with weeds.

## *Questions*

1. *Give an account of the planting, cultivation, harvesting and subsequent treatment of one named cr plant that you have studied. What is the main food reserve in the crop that you have selected? H may the presence of the food reserve be detected?*
2. *Explain clearly what is meant by crop rotation. Describe an example of crop rotation and say wh its disadvantages are.*
3. *Explain briefly how the following practices are used in conserving or renewing soil fertility:*
   *(a) crop rotation*
   *(b) shifting cultivation*
   *(c) natural manuring*
   *(d) prevention of erosion.*

4. *(a) Write briefly on how four of the following agricultural practices destroy the balance of a ecosystem:*
   *(i) deforestation*
   *(ii) use of chemicals (pesticides, fungicides and herbicides)*
   *(iii) over use of fertilizers.*
   *(iv) bush burning*
   *(v) over grazing by animals and*
   *(vi) monocropping.*
   *(b) List ten ways in which your government is encouraging farmers towards self sufficiency in food production.*
5. *(a) In a tabular form, state two diseases, causative organisms, effects and control of any two of the following crops: maize, groundnut, cocoa, rice and cassava.*
   *(b) Name two pests of the two crops chosen above and state how they are controlled.*
   *(c) Name one viral and one bacterial disease of any of the following domestic animals: chicken and cattle and state the effects and control of each disease on the animals.*

# 21

# MICRO-ORGANISMS: MAN AND HEALTH

## Micro-organisms around us

Micro-organisms (microbes) are tiny organisms which are invisible to the naked eye. They can only be seen with the help of microscope.

## Where micro-organisms are found

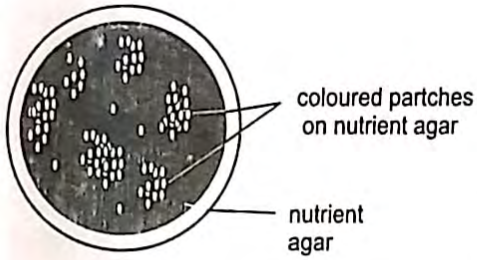
**Micro-organisms** are found in air, water, soil, under the fingernails, mouth cavity, inside ears, nose, on the skin, decomposed organic matter, and food.

## Experiment 1

**Aim:** To show that micro-organisms are present in the dirt under the fingernail.

**Method:** Scrape the dirt under the nail with a sterilized knife into a petri-dish. Five drops of distilled water are added into the dirt in the petri-dish and well stirred with a sterilized needle. The solution is then spread on the surface of a nutrient agar mixture in petri-dish "**A**". Into a petri-dish "**B**" containing a nutrient agar mixture, four drops of distilled water are added and spread on the surface and this acts as "**control experiment**". Both petri-dishes **A** and **B** are covered and kept in the laboratory at room temperature.

A




B

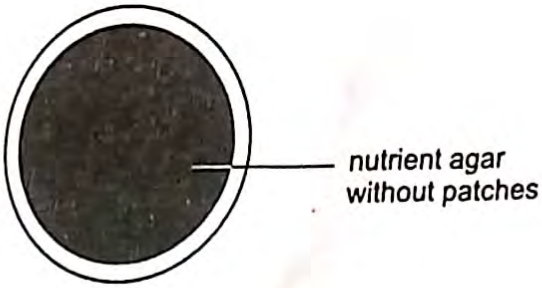



**Figure 21.1. Experiment to show that micro-organisms are present under the fingernail.**

**Results:** After three days, coloured patches are seen on the surface of petri-dish **A**. On making a **methylene blue stained** temporary slide from the coloured patches and viewed under the low and high power magnification of the microscope, bacteria of round and rod-shape types are seen. Fungi such as *Mucor* and *Rhizopus* can also be identified. No coloured patches are observed in petri-dish **B**.

**Conclusion:** Micro-organisms are present in the dirt under the fingernail.

## Experiment 2

**Aim:** To show that micro-organisms are present in the mouth cavity.

**Method:** A clean and sterilized cotton swab is used to rub the tooth at the region of the neck or the tongue or the cheek. Transfer the scrapings or debris with the sterilized swab into a clean test tube containing five drops of sterile distilled water. Use a sterilized dropper to turn the debris in the distilled water and transfer a drop into a clean, plain microscope slide.

View under the microscope in the low and high power magnifications.

**Results**: The micro-organisms that are likely to be seen are *Entamoeba gingivalis* and rod-shaped bacteria (Bacilli). A lot more micro-organisms that cannot be identified can be seen as well. (Note:- The debris from the cheek may contain squamous cells containing distinct nuclei. These are not micro-organisms.

**Conclusion:** Micro-organisms are present in the mouth cavity.

## Experiment 3

**Aim:** To show that micro-organisms are present in air.

**Method:** Nutrient agar mixture is a suitable growth medium or culture medium for micro-organisms. Get a prepared agar mixture and a sterilized petri-dish. Pour the agar medium into the petri-dish and allow to solidify and cool. Open the agar mixture dish and expose it to air for 30 minutes. The dish is then covered and placed in the laboratory at room temperature and left for four days. Another petri-dish containing an agar mixture and not opened to air is also kept and this acts as a **control**.

**Results:** On opening the petri-dish kept in the laboratory at room temperature, coloured patches are seen. On examination under the microscope, the coloured patches contain bacteria and fungi (yeasts, *Mucor*). No patches will be seen in the petri-dish not exposed to air.

**Conclusion:** Micro-organisms are present in the air.

## Experiment 4

**Aim:** To show that micro-organisms are present in our food.

**Method:** Collect 3 petri-dishes A, B, and C containing prepared nutrient agar mixture. Into petri-dish A, place some tiny pieces of cooked yam which have been cooled and exposed to air for 5 minutes and cover them again quickly. Into petri-dish B, place tiny pieces of cooked meat which have been cooled and exposed to air for 5 minutes and cover quickly.

Petri-dish C is left intact, that is, not opened and contains no food material. The petri-dishes are then kept in a warm place in the laboratory for 2 to 3 days.

After 3 days, sterilized needles are used to take tiny samples from each petri-dish and spread on microscope slides. Smears are prepared and stained. The slides are viewed under the high power magnification of the microscope.

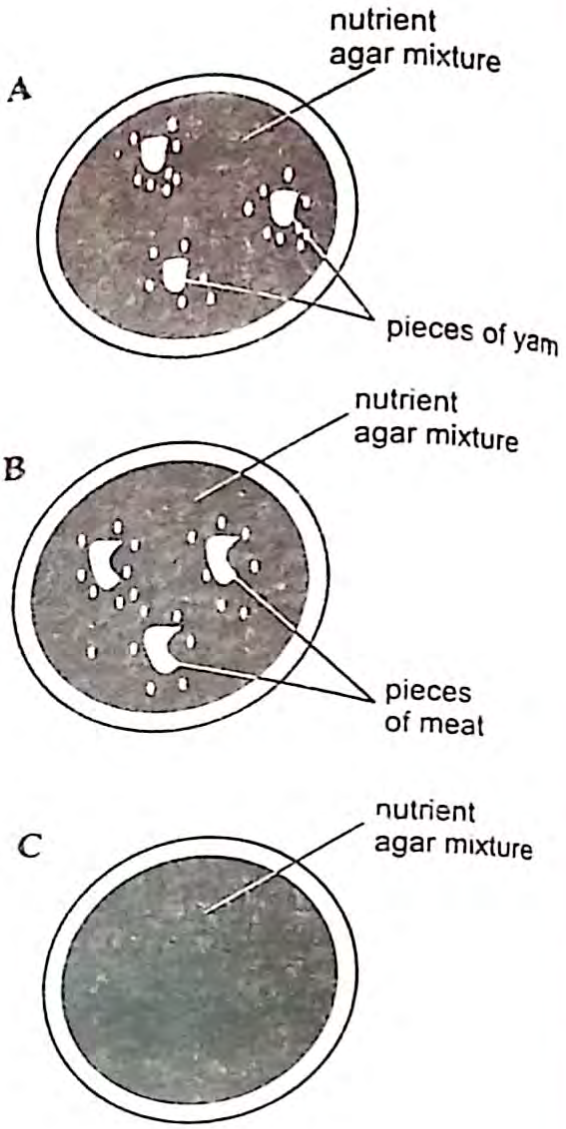



**Figure 21.2. Experiment to show that micro-organisms are present in our food.**

**Result:** The petri-dishes A and B into which food materials (cooked yam and meat) are added, will show growth of micro-organisms such as bacteria and fungi while petri-dish C remains clear of any patches of growth of micro-organisms.

**Conclusion:** Micro-organisms are present in exposed food.

## Staining procedure

If macro-organisms are not distinct on the slides under microscope, then fix and stain as follows:

1. To fix, pass a slide quickly across the flame of a Bunsen burner three times. The smear on the

slide is then dried on it.

2. Allow slide to cool for 2 or 3 minutes.
3. Stain the slide by addition of a few drops on the smear of any one of the following stains: methylene blue or cotton blue, crystal violet and carbon-fuschin for 2 or 3 minutes.
4. Tilt the slide and allow the stain to run off.
5. Allow 5 minutes for the air to dry the slide.
6. Rinse the slides to clear them of excess stain by running clear water over them gently.
7. Use absorbent paper to dry the slide.
8. View the slide once again and micro-organisms will at this time be seen distinctly.

## Group of micro-organisms

Micro organisms are grouped as follows:

1. **Viruses**
2. **Bacteria**
3. **Protozoa**
4. **Some fungi and**
5. **Some algae.**

### Viruses

Viruses are non-cellular organisms without nucleus, cytoplasm and cell membrane. They are invisible under the highest magnification of a light microscope. They can only be seen under an electron microscope.

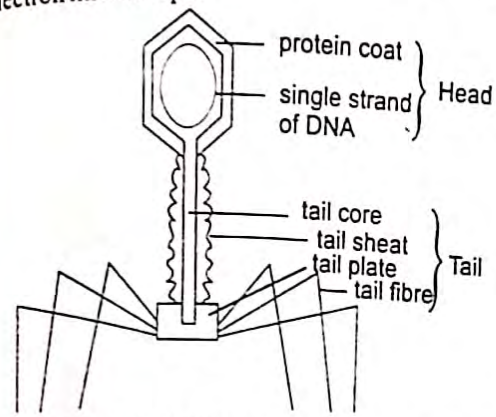



**Figure 21.3. The electron microscope structure of a bacteriophage.**

Structurally, a bacterial virus (also called **Bacteriophage**) is made up of a protein coat (capsid) and **DNA** (nucleic acid). The protein coat is divided into head and tail regions. The head contains DNA. The tail region is made up of a tail core protected by a tail sheath. The tail region ends with six tail fibres. (Note: some viruses have **RNA** instead of **DNA** while some others have both **RNA** and **DNA**). The six tail fibres radiate from a tail plate.

## How viruses reproduce and damage cells

Viruses can only reproduce in the cells of living organisms. Reproduction is the only characteristic of living organisms possessed by viruses, if not they could have been called non-living things.

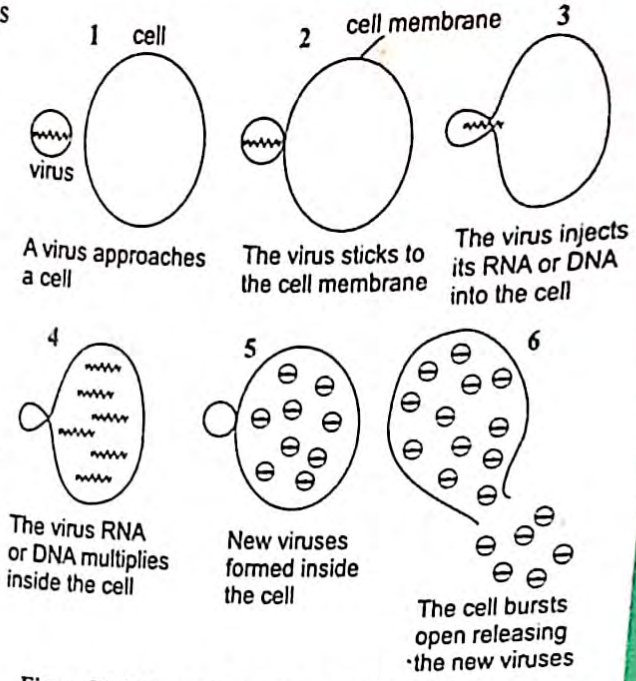



**Figure 21.4. Stages in the reproduction of virus**

First the virus attaches itself to the surface of the cell. It then injects its **RNA** or **DNA** (strand of nucleic acid) into the cell just as a doctor or nurse injects a patient. The viral **RNA** or **DNA** multiplies in thousands forming new viruses inside the cell. The infected cell eventually bursts releasing new viruses. This process does not take more than thirty minutes to complete. The new released viruses then attack other cells.

**Some viral diseases of animals are:**

1. **Rinderpest of cattle**
2. **Newcastle of chicken.**
3. **Rabies in dogs and cats.**

### Culturing viruses

Viruses can only be cultured in living cells.

In laboratory, a virus can be cultured by injecting it into a fertilized egg of a hen or any other bird. It quickly multiplies.

## Some viral diseases of man

### Poliomyelitis

Polio is a serious infectious disease caused by **virus**, characterized by fever and meningeal symptoms, and by paralysis of some parts of the body.

**Causative agent**: Poliovirus.
**Mode of infection**: By drinking an infected water or eating infected food. Infection also occurs from carriers. Breathing an infected air.

**Location in the host**: Spinal cord, brain, intestinal tract, blood stream and lymph glands

**Incubation period**: 7 - 14 days.

**Symptoms**: Fever, headache, vomiting and general discomfort. Backache, stiffness of the neck. Paralysis of muscles. Difficulty in swallowing and breathing.

**Control**

1. Mass vaccination.
2. Good sanitation by both individual and public health workers. Wash the hands before eating and using toilet.
3. Do not swim in dirty water.
4. Do not get overtired by work, hard play or travel, because if you have the polio virus in your body, it may trigger off serious poliomyelitis infection.
5. Keep away from getting chilled. Chilling can lower your body resistance against poliomyelitis.
6. Watch for early signs of poliomyelitis and report to the doctor immediately.

### Chicken-pox

Chicken-pox is an acute infectious viral disease characterized by spots with blister, fever, headache, and vesicular eruption. This disease is common among children.

**Causative agent**: Virus.

**Mode of infection**: As in small-pox.

**Location in the host**: Respiratory tract.

**Incubation period**: 14 - 16 days

**Symptoms**: High temperature, headache, fever [illegible] spots (rash) with blister.

**Control**: Isolation of patient and disinfection of [illegible] room and his belongings. Once a patient has recovered from chicken-pox, immunity is usually conferred on the person for life.

### Infective Hepatitis (Jaundice)

Hepatitis is a disease of the liver caused by virus.

**Causative agent**: Virus

**Mode of infection**: By breathing air infected with the virus. Drinking infected water and milk. Eating an infected food.

**Location in the host**: Liver

**Incubation period**: 10 - 40 days

**Symptoms**: Headache, high fever, vomiting, abdominal pain, jaundice. Liver enlarges, presence of bile in urine, loss of appetite.

**Control**:

1. Isolation of patient
2. Disinfection of stool
3. Strict sanitation is very important.
4. Hepatitis patient must not be allowed to donate blood for at least one year.

### Measles

This is a serious disease in young children.

**Causative agent**: Virus
**Mode of infection**: By breathing infected air. Close contact with infected person.

**Location in the host**: Blood and the lining of the nose.

**Incubation period**: 10 - 11 days

**Symptoms:** Catarrh, sneezing, fever, cough, rash on the face at first and spreads all over the body later.

**Control:**

1. Avoid contact with an infected person and his belongings.
2. Use handkerchief when coughing.
3. Mass vaccination especially in children.

## Acquired Immune Deficiency Syndrome (AIDS)

**Causative agent:** Human immuno-deficiency Virus (HIV).

**Mode of infection**

1. By sexual intercourse.
2. Anal sex as practised by homosexuals.
3. By transfusion of blood of an HIV infected person to an uninfected person.
4. By oral sex.
5. Using unsterilized infected needles.
6. From infected mother to her baby in the womb or during birth.

**Location in the host:** Blood, semen, vaginal secretions and breast milk.

**Symptoms**

1. Weight loss greater than 10%.
2. Fever longer than one month.
3. Chronic diarrhoea longer than one month.
4. Persistent severe fatigue.
5. Persistent cough longer than one month.
6. General skin irritation.
7. Swelling of the glands.
8. Rashes all over the body.

**Control**

1. National mass campaigns to educate everyone of the danger of **HIV**, how it is spread and how to avoid it.
2. Keep to one faithful partner.
3. Use a condom when having sexual intercourse (Note: This is not 100% safe as it may burst during intercourse).
4. Sharing of injection needles, razor blades, ear piecers must be avoided.
5. Blood must be screened to avoid transfusing blood infected with **HIV** to a patient.
6. Before marriage, both partners should test their blood to make sure that they are both free from **HIV**.
7. Avoid anal and oral sex.
8. Avoid kissing.
9. A woman infected with **HIV**, should avoid pregnancy as she may stand the risk of infecting her unborn baby.
10. Abstain from sexual intercourse until you are married.
11. Foreigners who are to stay in the country more than three months should produce a medical certificate declaring them free of **HIV** infection.

**AID VIRUS** belongs to a group of RNA (Ribonucleic acid) **viruses** referred to **retro-viruses.** They are capable of converting their RNA to DNA (Deoxyribonucleic acid) utilizing an enzyme called **reverse transcriptase.** AIDS (Acquired Immune Deficiency Syndrome) is now one of the most deadly and dreaded diseases ever faced mankind. No known cure has been discovered since this disease was discovered in Los Angeles, U.S.A. in 1981. AIDS has infected over 40 million people all over the world and is fast spreading. Millions of the victims have died. It has been shown that in every second, one person is infected in the world. It is therefore of great interest to know its life cycle.

**AIDS virus** attacks, infects and destroys certain cells of the white blood cells called **helper T cells** or **lymphocytes** which are responsible for the immune system of the body.

HIV is deadly because it attacks, infects and destroys the white blood cells called **helper T cells** which play very important role in the immune system of the human body. HIV can remain dormant in the cells of the host (human) for years and replicating as the cells of the host divide. Eventually, HIV becomes active, producing many viruses causing the bursting and killing of the **helper T cells.** As the **helper T cells** are killed, the body immune system is greatly destroyed leading way to opportunistic diseases such as pneumonia, tuberculosis, skin cancer (Kaposi's sarcoma) and herpes.

## Life cycle of Human Immune Deficiency Virus (HIV)

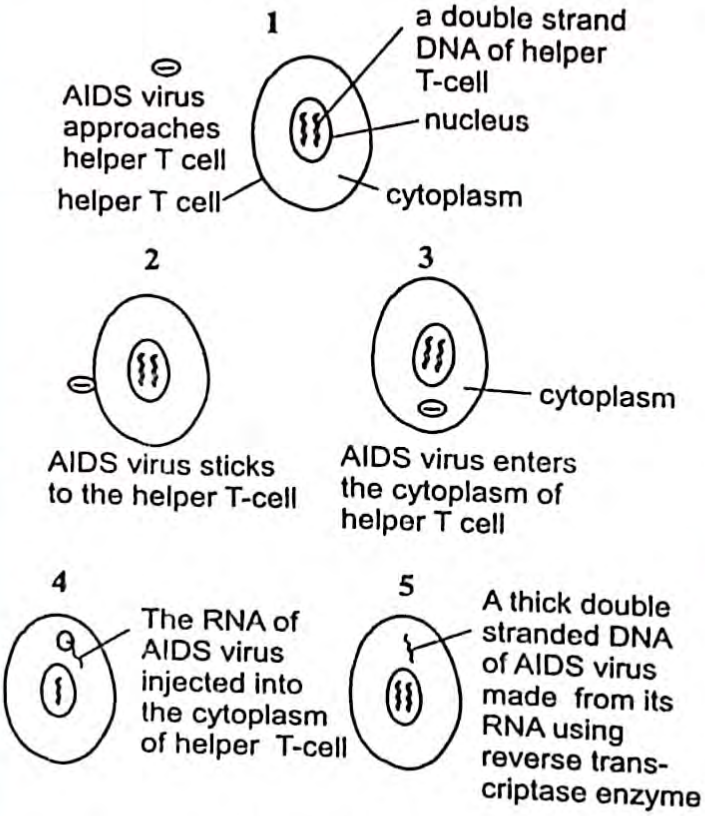



**Figure 21.5. Life cycle of (HIV)**

## Reasons why HIV is an uncompromising enemy to conquer

1. HIV kills the helper T cells, the very cells that defend the body against it.
2. HIV can remain inactive and hidden in the cells for many months or years. At this stage of inactivity, it can not be destroyed.
3. HIV antigens change shapes often making it difficult to be detected by the cells of the body defence system.

## Some other viral diseases of man

1. Influenza
2. Mumps
3. Common cold
4. Cow pox
5. Shingles
6. Dengue fever.

# Bacteria

Bacteria are unicellular organisms of microscopic size; the largest being about 12 microns (1 micron = 0.001 millimetre) long and about 1.5 microns in width. Bacteria can be seen with light microscope. Van Leeuwenhoek first discovered bacteria in 1683.

## Structure of bacterial cell

A bacterial cell consists of a mass of protoplasm surrounded by a cell wall. The cell wall is covered outside with a slimy substance in some types of bacteria. This slimy layer (capsule) helps to protect the bacterial cell from dehydration and also helps the cell to stick to the surface of its host or food.

**Cytoplasm:** There is a definite cytoplasm. The cytoplasm is bounded inside by plasma membrane (cell membrane) and outside by the cell wall. The cell membrane is thrown into folds called mesosomes. Mesosomes contain various enzymes. The cytoplasm is filled with dense fluid. Inside the cytoplasmic fluid are granules and ribosomes.

**Nucleoid:** Bacteria have no well organized nucleus. They have nuclear material without a nuclear membrane. The **DNA** (Deoxyribose Nucleic Acid) is concentrated in an area called **nucleoid**. The nucleoid is not bounded by a membrane. Some bacterial cells have flagella while some have food granules. Yet few have vacuoles of water and dissolved materials.

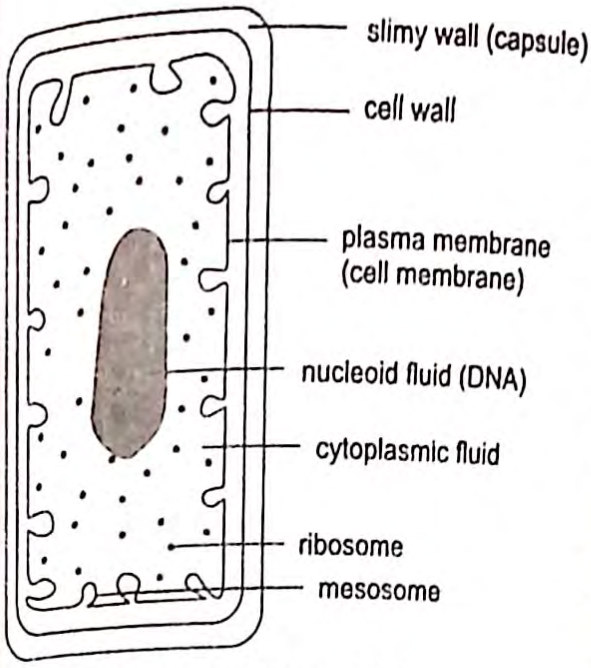



**Figure 21.6. Structure of a bacterial cell**

## Different shapes of bacteria

Bacteria have different forms. These are:

1. **Cocci** (singular, coccus). The cells are spherical or rounded.
2. **Bacilli** (singular, bacillus). The cells are rod-shaped. Some have flagella.
3. **Spirilla** (singular, spirillum). The cells are spirally twisted or corkscrew like. Some have flagella. Example is *Treponema*.
4. ***Vibrio***: The cells are comma-shaped. Example is *Vibrio cholera*.

## Aerobic and anaerobic bacteria

Aerobic bacteria use oxygen for respiration while anaerobic bacteria do not need oxygen for respiration.

Examples of aerobic bacteria are *Mycobacterium tuberculosis* and *Vibrio cholera*.

$C_6H_{12}O_6 + 6O_2 \text{-----}> 6CO_2 + 6H_2O + \text{Energy}$

Examples of anaerobic bacteria are *Clostridium tetani* and *Clostridium botulinum*.

$C_6H_{12}O_6 \text{---}> 2C_2H_5OH + 2CO_2 + \text{Energy}$.

## Diseases caused by bacteria

### Gonorrhoea

Gonorrhoea is a venereal disease caused by bacterial infection.

**Causative organism**: It is caused by *Neisseria gonorrhoea* (gonococcus).

**Mode of infection**: Usually by sexual intercourse with an infected person of the opposite sex or the same sex. Newborn babies occasionally become infected during birth if the mother is infected.

**Location in the host**: Urino-genital tract mostly. Other locations may be mouth, throat and rectum.

**Incubation period**: 3 - 7 days.

**Symptoms:**

**In males**: After 3 to 7 days of infection, there is a creamy discharge of pus from the penis. Burning pain when passing urine. Frequent passing of urine.

**In females**: Over 90 percent of females have no symptoms. Symptoms which may appear separately or together are an increase in discharge from the vagina, burning pain during urination, pain in the lower abdomen. In both male and female, sterility may occur at advanced stage.

**"If one has some of these symptoms, does it mean that one has gonorrhoea?"**

No, there are many other possible causes for these symptoms. It is important to have the appropriate laboratory tests done for correct diagnosis and adequate treatment.

**Control**

1. Commercialized prostitution must be discouraged. Prostitutes spread this disease at a fast rate.
2. An infected person should report as early as possible to a medical doctor for treatment.
3. An infected person should stop sexual intercourse with previous partner(s) and others until he or she has received full treatment and declared cured by medical doctor.

4. Your previous partner(s) must be reported to the doctor for treatment
5. Sex education is necessary to bring the evil effects to the public especially the youths.

**Other points of interest:**

1. **"Can one get treatment without going to a doctor or clinic ?"**

All self-treatment is not adequate. Symptoms may be relieved while one remains infected and able to spread the infection and develop compli-cations.

2. **"How long can gonorrhoea be passed along if one is not treated ?"**

Indefinitely.

3. **"What treatment is effective ?"**

Penicillin (by injection only) or other antibiotics. The dosage and number of injections required may differ depending on the doctor's prescription and response to treatment.

4. **"How soon after treatment can one resume sexual intercourse ?"**

This can only be determined by a follow-up examination and laboratory tests. Some infections do not clear up readily.

5. **"If one has had gonorrhoea once, is one immune ?"**

No. One can get it repeatedly and will need treatment for each infection.

6. **"What happens if one does not get treated ?"**

One will spread the disease. One may develop serious complications such as pain in the sex organs, sterility and even death.

## Syphilis

Syphilis is a venereal disease caused by the *Treponema pallidum.*

**Causative organisms:** *Treponema pallidum.* Treponema belongs to **Spirochaetaceae**

**Mode of infection:** Usually by sexual intercourse with an infected person of the opposite sex or the same sex. Occasionally through a break in the skin.

**Incubation period:** 10 - 90 days.

**Symptoms:** After 10 - 90 days, an open, usually painless sore (chancre) appears at the place of the original infection (penis, labia, vagina, mouth, rectum). It could be inside and not visible. A contagious skin rash may appear six weeks to six months after initial infection. In some cases the rash may not appear or may be so slight that it goes unnoticed. After this, there will usually be a period of **no** symptoms. The sore disappears. This is the **primary stage.**

**Secondary stage:** Fever, headache, sore throat, loss of appetite and skin rash of varied appearance.

**Tertiary stage:** Insanity, paralysis, blindness, deformity of bones, and deafness.

**Control:** As in gonorrhoea

## Cholera

Cholera is a disease caused by the *Vibrio cholera*, characterized by severe watery diarrhoea and vomiting. Fatality is very high 40 - 80 percent).

**Causative organism:** *Vibrio cholera* (a comma-shaped bacterium)

**Mode of infection:**

1. By drinking water or milk infected with cholera. *Vibrio cholera* can survive in water for two weeks or more.
2. By eating food and vegetables infected with cholera.
3. Houseflies carry the germs to our food.

**Location in the host:** Small intestine.

**Incubation period:** 2 - 3 days.

**Symptoms:** Severe watery diarrhoea and vomiting. Abdominal pain. Dehydration. Unconsciousness and death eventually.

**Prevention and control:**

1. Immediate report of any suspect to the nearest hospital.
2. Complete isolation of patient in fly-proofed room.

3. Water must be boiled properly before use.
4. Public water must be purified and workers must be inoculated.
5. Strict observation of laws of hygiene (sanitation).
6. Foodstuffs must be protected from flies.
7. All vegetables and meat must be cooked properly.
8. Hands are to be washed in boiled water before eating and after defaecation. The faeces of the patient must be disinfected and buried.
9. Mass cholera inoculation.
10. Strict observations of immigration rules for people entering the country especially from countries where there is cholera outbreak.
11. Treatment - See a medical doctor.

## Tuberculosis

Tuberculosis is a disease caused by *Mycobacterium tuberculosis* (tubercle bacteria) characterized by the formation of tubercles causing the destruction of the lungs.

**Causative organism**: *Mycobacterium tuberculosis* (tubercle bacteria)

**Mode of infection:**

1. Breathing in an infected air or dust.
2. Drinking infected water or eating an infected food such as meat or milk of an infected cow.
3. Personal contact with an infected person.
4. Flies also carry the germs to our food.

**Location:** Lungs

**Symptoms**: Slight persistent cough at first and tiredness. Later, severe cough with blood in sputum. Loss of appetite, indigestion and loss of weight. High temperature and sweating at night.

### Prevention and control

1. Strict sanitation.
2. Eating nourishing food to increase body resistance.
3. Living in well ventilated house and avoiding overcrowding.
4. Patient to occupy a separate room and sputum buried deeply or burnt.
5. During coughing, patient must use handkerchief to cover his mouth.
6. Articles and patient's room must be disinfected.
7. Patient must not kiss any person.
8. People are to be protected by vaccination with B.C.G. (Bacillus calmette guerin).
9. Treatment: X-ray the chest and receive treatment from a medical doctor.

## Dysentery

**Causative organism**: Dysentery bacillus.

**Mode of infection**: By drinking infected water or eating an infected food. Flies spread the germs by carrying them from infected faeces to our food.

**Location in the host**: Large intestine.
**Incubation period**: 1 - 2 days

**Symptoms**: Abdominal discomfort and diarrhoea. In chronic cases, diarrhoea with blood and mucus are passed.

**Control**:

1. Careful disposal of human faeces. Good toilet such as water system types are excellent.
2. Public water supplies are to be protected to avoid contamination with human faeces by flies and human faeces. Boiling of drinking water is highly recommended.
3. Hands must be washed thoroughly before preparing, serving and eating food. Hands must be washed thoroughly after attending toilet.
4. Vegetables, fruits are to be washed thoroughly before consumption.
5. Screen houses, foodstuffs in market or put food in glass cases. This prevents flies from coming in contact with the food.
6. See a medical doctor for treatment.

**Table 82. Some other diseases caused by bacteria are:**

| Disease | Causative organism | Mode of transmission | Symptoms | Control |
|---|---|---|---|---|
| 1.**Tetanus (lockjaw)** | 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.<br>2. Broken bottles, nails or any sharp objects must not be thrown to the floor, compound and streets but buried.<br>3. Immunise yourself. |
| 2.**Leprosy** | Bacteria (*Mycobacterium leprae*) | Long contact with a sufferer of leprosy. | 1. Swelling of the limbs<br>2. Fingers and toes are gradually being eaten up by the germs.<br>3. Blotches on the skin.<br>4. Skin becomes insensitive to pain. | 1. Infected person should be isolated.<br>2. See medical doctor. |
| 3. **Whooping cough** | Bacteria (*Haemophilus pertussis*) | By inhaling droplets from an infected person. | Cold, high fever, cough with prolong sound and vomiting. Pneumonia may result. | 1. Isolation of infected person.<br>2. Babies should be immunised early in life.<br>3. Sputum of an infected person must be burnt or buried. |

## Economic importance of bacteria

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

## 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.

## Beneficial activities of bacteria

### (1) Soil Bacteria

(a) Soil bacteria bring about the decay of dead organic matters such as dead plants and animals.

(b) During the decaying process, chemical substances locked up in the dead organic matters, are released to the soil, thereby, making the soil fertile. Fertile soil promotes

the healthy growth of plants hence production of more food.

(c) Nitrogen-fixing bacteria are capable of converting the atmospheric nitrogen into nitrates which are used by plants.

## (2) Bacteria in industry

(a) **Vinegar-making**: Yeasts and bacteria are used in producing vinegar. The yeasts first ferment the sugar in the fruit juice to alcohol and carbon (IV) oxide. Acetic acid bacteria then oxidize the alcohol to acetic acid. Vinegars contain about 4 percent acetic acid.

(b) **Tanning of leather**: The hair of the hide is removed either by the action of bacteria or chemical process. The tanning of the hide takes place in large tanks in which there are bacteria and other organisms which attack the hide and render it pliable.

(c) **The retting of flax:** Bacteria are used in the retting of flax. The bacteria decompose the pectin that holds the fibres together. The free fibres are processed into linen.

(d) **Curing of tobacco**: The carbohydrates in the fresh leaves are fermented by bacteria to produce special flavour. This is called curing of tobacco.

## (3) Bacteria in dairy industry

(a) **Butter making**: The cream is first separated from milk solids. The cream is then pasteurized to reduce the population of bacteria. **"Starter" bacteria** are introduced to the pasteurized cream to produce lactic acid and other ingredients which produce good flavour. After bacteria activity, the cream is cooled and churned. Tiny particles of butter fats stick together to form **butter**.

(b) **Cheese-making**: Cheese is prepared from whole or skimmed cow's milk. **"Starter" bacteria** are added to the whole milk to produce **lactic acid**. This brings about the separation of the **milk solids** or **curdling** of the milk. The curd (milk solid) produced from whole milk consists of milk protein **(caesin)**, fats and minerals. If the curd is skimmed, it is mostly caesin. The separation of the curd from the liquid is carried out. **Cream cheese** is produced by the addition of butter. Other types of cheese are made by salting the curd and pressing to remove water. Time of 'ripening' is required. During ripening, micro-organisms (bacteria and molds) are grown on the surface of the cheese to produce required flavour. Temperature and time required for a type of cheese differ.

## (4) Synthesis of vitamin B complex and vitamin K in man

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

(5) Bacteria help to digest the cellulose found in the vegetable diet of ruminants.

(6) **Sewage**: In sewage, the solid matter is acted upon by bacteria converting it into material which can be dried and used as fertilizer.

(7) **In medicine**: Some kinds of bacteria are weakened to a point of being harmless and introduced into human beings. The body then produces antitoxins and antibodies which help to fight against the invading and harmful bacteria. The introduction of weakened bacteria into the human body is called **Immunisation or vaccination.**

# Fungi

Fungi are non-green simple plants. They are mostly parasitic or saphrophic in nutrition. Parasitic fungi live in or on the tissues of their hosts while the saprophytic forms obtain their food from dead and decaying materials. Few form associations with algae (as in lichens). Reproduction is mostly by **spores**, (asexual reproduction). In some conditions, sexual reproduction takes place. Majority of fungi are microscopic while some are large enough to be seen with the naked eye (e.g. mushroom). Examples of fungi are *Mucor, Penicillium*, **Streptomyces, Aureomyces,** *Tinia* and **yeast.**

## Some diseases caused by fungi

### Ringworm

**Causative organism:** *Tinia*

**Location in the host:** Between outer and inner layers of the skin more especially on the belly, thigh, back, face, scalp and hair.

**Mode of infection:** Contact with infected person or belongings of the sufferer such as clothes and chairs, hair brush, hat and towel where the infectious spores are deposited.

**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 the hairs causes hair to fall off.

**Control**

1. Good personal hygiene.
2. Avoid wearing wet shoes and clothes.
3. Avoid contact with an infected person and his belongings.
4. Spray infected materials with fungicides.
5. See a medical doctor for medical advice and treatment.

### Athlete's foot

**Causative organism:** *Tinia pedis*

**Location:** Skin between toes.

**Mode of infection:** Walking with bare-foot on infected grounds such as swimming pool ground and in changing-room of sports hall. Wearing shoes of an infected person.

**Symptoms:** Skin between toes becomes whitish. At advanced stage, pains and itching result.

**Control**

1. Keep feet clean and dry all the time after bathing. Rub dusting powder in between toes.
2. Wear open sandals or loose shoes. This keeps the feet dry and cool.

## 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 dysentry.

Penicillin is made from *Penicillium notatum*, Streptomycin is made from *Streptomyces* and Aureomycin from *Aureomyces*.

### 2. In industry

(a) **Alcoholic industry**

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

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2C_2H_5OH + 2CO_2 + 28\text{Kcal}.$$

To brew beer or spirits (such as brandy or whisky) barley is germinated. The germinated barley which has converted starch to sugar is then crushed and water added. It is then filtered. Yeast is added to the filtered solution and fermentation of sugar to alcohol and carbon (IV) oxide takes place. To make beer, hops are added to the alcohol to give it the characteristic bitter taste. To make brandy or whisky, fermentation is prolonged. The fermented solution is distilled and the spirit is collected.

(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 and also for the retting of flax to obtain linen fibres.

(d) *Penicillium* is used in the ripening of cheese.

3. **Fungi** cause decay of organic materials. Decay leads to the formation of humus. Humus adds fertility to the soil. Fertile soil helps plant crops to produce more food for man. Decay also helps to remove dead organic matter from the habitat.

4. **Sewage:** Fungi are used in the treatment of sewage. Fungi help to decompose and purify sewage.

## Protozoa

Protozoans are microscopic and unicellular animals found in both marine and fresh water and in damp soil. Some are free-living (e.g. *Amoeba proteus*, *Paramecium caudatum*) while others are parasitic (e.g. *Plasmodium*, *Entamoeba histolytica* and *Trypanosomes*).

### Diseases caused by protozoans

### Malaria

Malaria is a disease caused by a protozoan blood parasite (*Plasmodium*) which is transmitted by the bite of a female anopheles mosquito, characterized by occurrence of fever, chill, headache and vomiting.

**Causative agent:** *Plasmodium* species (*P. vivax*, *P. falciparum* and *P. malariae*).

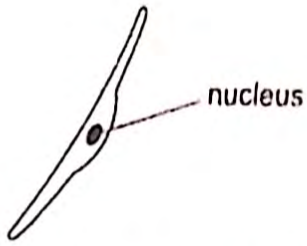
### Life cycle

**The life cycle of *Plasmodium* is in two stages, one in man and the other in the female anopheles mosquito.**

### Life cycle in man

*Plasmodium* is injected in *sporozoite* form by the bite of an infected female anopheles mosquito into the blood.

A



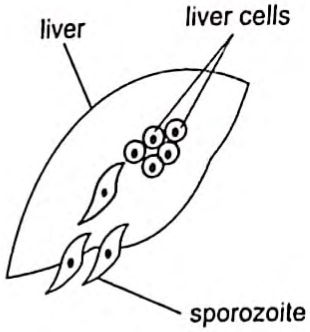

**Sporozoite injected into the blood**

After about 30 minutes of injection into the blood, the sporozoites disappear from the blood and enter the cells of the liver. On reaching the liver, they *reproduce asexually* to form another type of *Plasmodium* called ***merozoite***. Each sporozoite reproduces about one thousand of merozoites in the liver. These merozoites then leave the liver and enter the blood stream again. The merozoites then attack and feed on the red blood corpuscles. This feeding form inside the red blood corpuscles is called ***trophozoite***. The trophozoite grows and reproduces asexually to form more merozoites inside the red blood cell. Eventually, the red blood corpuscle bursts liberating more merozoites into the blood. At this stage, signs of malaria begin to show up. The new merozoites attack more red blood corpuscles again.

**Initiation of sexual reproduction**

Some of the merozoites on entering the red blood corpuscles, do not divide asexually again, instead they develop into female and male **sexual forms** or gametocytes. These grow in the red

B




Blood corpuscles, causing the bursting of the red blood corpuscles. The gametocytes now circulate freely in the blood stream. This is the last stage in man.

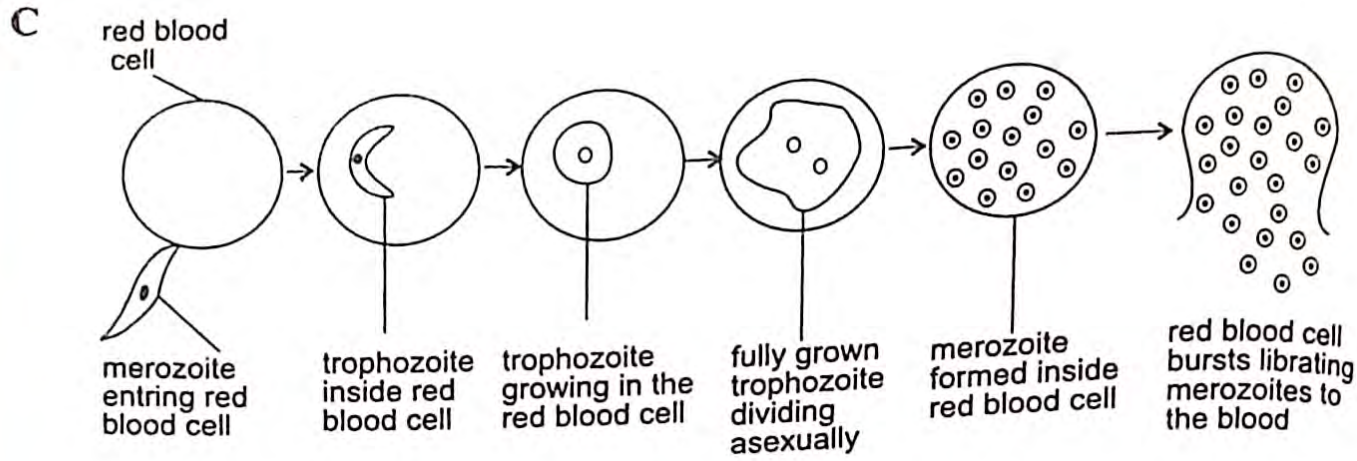



**Figure 21.7. Stages of developement of *Plasmodium* in man**

## Life cycle in the anopheles mosquito

If a female anopheles mosquito bites a man with the gametocytes, the gametocytes are ingested with the blood meal. The male gametocyte develops to male gametes while the female gametocyte develops into the female gametes.

**Fertilization** takes place forming a **zygote** in the stomach of the mosquito.

The zygote moves to rest between the tissues of the alimentary canal. The zygote forms a cyst around itself. The zygote divides asexually to sporozoites. When the cyst bursts, the sporozoites are liberated over the tissues. Some sporozoites migrate to the salivary glands of the mosquito.

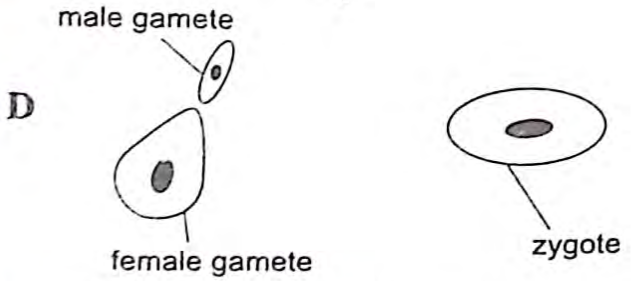



**Figure 21.7. A to D. Stages in the development of *Plasmodium*.**

## Symptoms of malaria

The symptoms could be classified into three stages initially: (1) **chill**, (2) **high fever** and (3) **Sweating**.

These stages may occur at regular intervals.

Later stages result in anaemia, general weakness, pains in the joints, headache and profuse sweatin Spleen and liver become enlarged. Brain becom affected.

**Control**: Control measures could be applied in thre ways:

A. Against the **vector** (Anopheles mosquito).
B. Measures to reduce contact with the **vector.**
C. Against **parasites** in man.

A. **Against the vector**: These measures are agains the adult mosquitoes and larvae.

**Adult mosquito control**: Spray houses and surroundings with insecticides to kill the mosquitoes. Kill all mosquitoes physically when sighted.

**Larva control**

(1) All breeding places are to be eliminated by filling. All broken vessels which can retain water should be turned upside down.
(2) Where drainage is not applicable, kerosine or oil should be poured on the water to kill the larvae and pupae since the oil layer will prevent respiration.
(3) Paris green is used also to kill the larvae of anopheles. Consumption of Paris green by the larvae kills them.
(4) Introduction of fish such as *Tilapia, Alestes* and *Epiplatys* into the water to feed on the larvae and pupae. This is a biological control.

B. **Reduction of contact with the vector (mosquito)**

1. When siting houses, avoid marshy areas. Prevent mosquitoes from entering.
2. Screening of houses.
3. Using mosquito nets over the sleeping beds.
4. Wearing of anti-mosquito clothes.
5. Using insect repellants.

C. **Against parasites in man**

Using preventive drugs such as Daraprin. Taking one tablet every week will help to prepare your body against the infection and prevents malaria attack.

## Sleeping sickness (Trypanosomiasis)

**Causative organism**: Trypanosomes

**Mode of infection**: By the bite of an infected tse-tsefly

**Location in the host**: Blood

**Incubation period**: 1-6 weeks.

**Symptoms**: Fever, headache, weakness, dosing and sleeping all the time. Loss of weight, diarrhoea, restlessness, swelling of lymph glands, oedema, and anaemia.

**Control**

1. Clearing vegetation around the banks of lakes and rivers. This deprives them of breeding grounds.
2. Spray the bushes with insecticides to kill the tse-tse flies.
3. Animals such as antelopes are carriers. Elimination of such animals may be undertaken.

## Dysentery (Entamoebic dysentery)

Dysentery is a disease caused by a protozoan. Dysentery is characterized by severe diarrhoea with blood and mucus in faeces.

**Causative agent**: *Entamoeba histolytica* (a protozoan).

**Mode of infection**: By drinking infected water or eating an infected food.

**Location in the host**: Large intestine.

**Incubation period**: Variable, may take months.

**Symptoms**: Abdominal discomfort and diarrhoea. In chronic cases, diarrhoea with blood and mucus are passed.

**Control**:

1. Careful disposal of human faeces. Good toilet such as water system types are excellent.
2. Public water supplies are to be protected to avoid contamination with human faeces by flies. Boiling of drinking water is highly recommended.
3. Hands must be washed thoroughly before preparing, serving and eating food and also hand washing after attending toilet.
4. Vegetables, fruits are to be washed thoroughly before consumption.
5. Screen houses, foodstuffs in market or put food in glass cases. This prevents flies from coming in contact with the food.

## River blindness (Onchocercaisis)

River blindness is a disease caused by a **filarial worm**. ***Onchocerca*** is transmitted by an infected blood-sucking blackfly (*Simulium*).

**Causative agent**: (microfilarial worm). Onchocerca. (Phylum Nematoda: Round and unsegmented worms).

**Vector**: Blackfly (*Simulium*)

**Location in man**: Under the skin, and eyes.

**Life cycle of the blackfly**

When the blackfly bites an infected person for blood meal, the microfilariae under the skin, are ingested. The microfilariae develop rapidly in the thoracic muscles of the insect, and within 6 to 14 days, infective larvae are produced. These infective larvae migrate to the salivary glands of the blackfly.

When the blackfly bites a man, the infective microfilariae are transmitted into the blood. The microfilariae then move to settle under the skin where they form **nodules**. Some years later, they invade the tissues of the eyes eating up the cornea thereby causing **blindness**. This blindness is classified as river blindness because of the breeding habitat of the causative agent.

**Symptoms**: Development of fibrous nodules enclosing the worms under the skin particularly around the waist, head and shoulder. Skin surrounding the nodules becomes inflamed. Blindness.

**Control and prevention**:

1. Complete avoidance of bites of blackflies. The head and body should be covered.
2. Use insect repellant to rub the whole body when you are in an endemic area.
3. The destruction of the blackflies by insecticides.
4. Infected persons migrating into the country must not be allowed until they are treated.
5. Treatment of infected persons promptly by a medical doctor.

# Flukes

## Bilharziasis (Schistosomiasis),blood fluke of man

Bilharziasis is a disease caused by a blood fluke called **bilharzia** or **schistosoma**. The disease is characterized by the presence of blood in the faeces and urine of the sufferer.

**Causative agent**: Bilharzia (schistosoma).

**Location in man**: Veins close to small intestine (mesenteric vein) or veins of the bladder.

**Life cycle of bilharzia**: Male and female worms copulate. Fertilized eggs are laid. The egg has a sharp spine at one end. The sharp spine of the egg enables it to find its way from the vein to the small intestine or bladder. This is the only instance in which egg moves in the animal world.

If an infected person passes faeces or urine into fresh water, the eggs hatch into free living ciliated larvae called *miracidia*. These free-living forms (miracidia) are not capable of infecting man. They swim about in the water and when they come in contact with an appropriate water snail (*Bulinus* or *Biomphalaria* spp), they move into the snail. Development takes place inside the snail for about 4 to 7 weeks to become flukes with tails, called ***cercareae***. The cercareae move out of the water snail. They use their tails to swim about in the water. Human skin attracts the flukes. On coming in contact with human skin or other animal like cow, they pierce it and find their way into the veins. These flukes die within 1 to 2 days if they fail to find an appropriate host usually man. They feed and grow in the blood stream and become sexually mature. Finally, they move to the ***veins (mesenteric)*** near the **small intestine or bladder** to settle.

Copulation takes place again and the cycle is repeated.

**Incubation period**: 10 to 12 weeks.

**Symptoms**: Skin irritation at the point of entry after few hours. Fever, headache, sweating and backache occur. Blood is found in urine or in faeces. Enlargement of liver and spleen. Anaemia results.

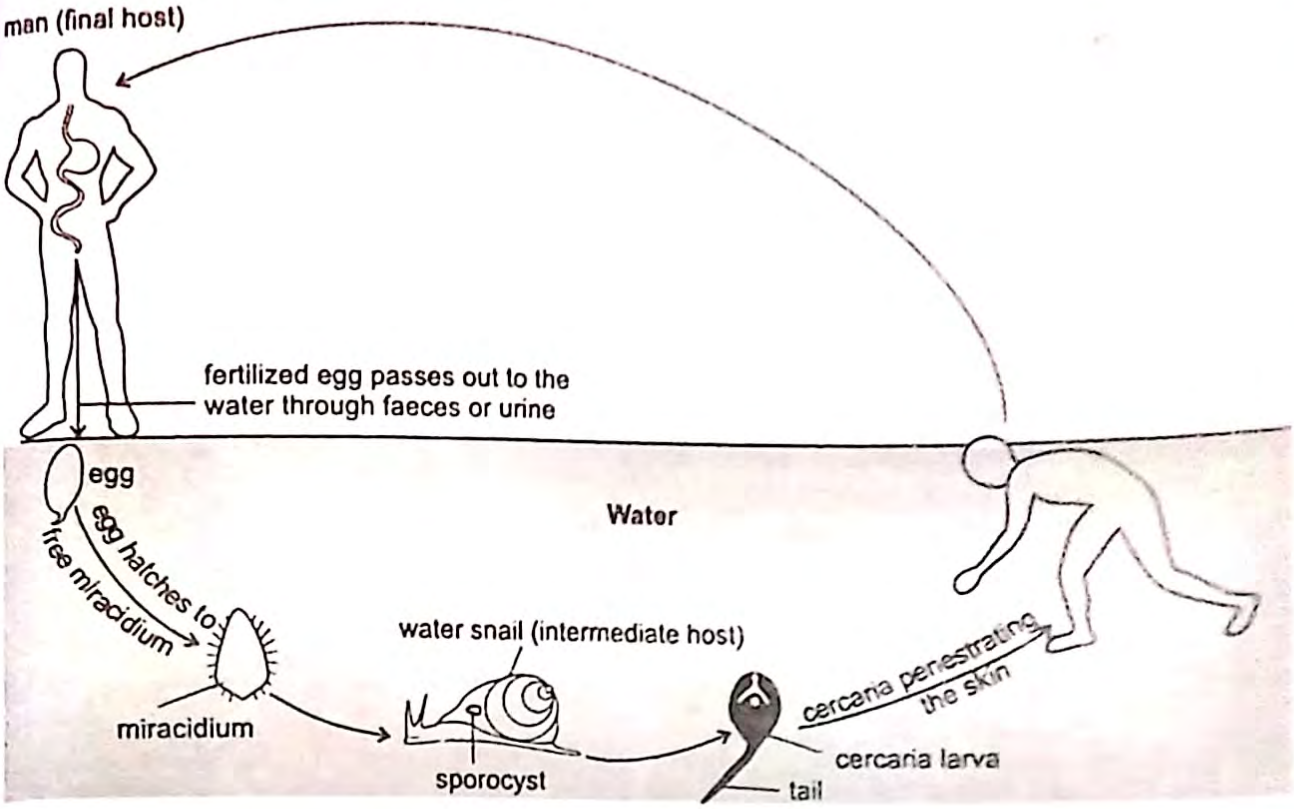



**Figure 21.8. Life cycle of Bilharzia**

## Control and prevention

1. Faeces and urine should not be passed into water. People should be educated to construct good latrines. People must be educated on the danger of bathing or waddling in water infected with the fluke larvae.
2. **Copper sulphate or lime:** Infected water can be poisoned with copper sulphate or lime to destroy the snails.
3. **Clearing of vegetation:** Clearing of vegetation from standing water will reduce the population of snails as this will tamper with their breeding grounds.
4. After bathing, clean the body with towel immediately. It has been discovered that the flukes pierce the skin when the water on the body has evaporated.

## How pathogenic organisms enter the body

1. **Abrasion of skin**: When there is any cut or abrasion on the skin, germs gain entrance into the body. Example is *Bacillus tetani* that causes tetanus.
2. **Mouth**: Pathogenic organisms for cholera, tuberculosis, and dysentery enter the body either by drinking or eating infected water or food respectively.
3. **Nose**. Micro-organisms that cause influenza, pneumonia, mumps and tuberculosis are inhaled into the body through the nostrils.
4. **Umbilical cord** If infected instruments are used to cut the cord or dirty materials used for dressing it, germs gain entrance into the body. Example is *Bacillus tetani* that causes tetanus.
5. **Placenta**. Micro-organisms that cause **syphilis** and **measles** enter the foetus through the placenta, if the mother is infected.

6. **Urinogenital tract**: Micro-organisms that cause gonorrhoea, syphilis, AIDS enter the body through urinogenital tract during sexual intercourse.
7. **Moist unbroken skin**: Hookworm for example can enter the body through moist skin.
8. **Insect bites**. **Malaria, yellow fever, sleeping sickness, river blindness** are introduced to the body through the bites of infected insects.
9. **Mammalian bite**: Micro-organisms that cause **plague, rabies** and **lassa fever** are introduced into the body by the bites of infected rats and dogs respectively.

## How disease - producing organisms spread

Disease-producing organisms spread from the body through the following:

1. **Urine**
2. **Sputum**
3. **Faeces**
4. **Oral cavity's secretion** (saliva)
5. **Nasal secretion**
6. **Blood** (blood transfusion)
7. **Milk** (sucking)

## How micro-organisms cause diseases:

### Tissue damage

Some micro-organisms cause the damage of he tissue. For example when bacteria causing tuberculosis enter the lungs, they damage the blood capillaries of the lungs causing bleeding (haemorrhages). Bacteria causing typhoid fever, damage the cells of the intestinal walls causing lesions. Red blood cells are destroyed by malaria parasites (*Plasmodium*).

### Soluble toxins (exotoxins)

Some bacteria produce certain toxic substances (toxins) that diffuse from the bacteria cells into the human tissues. These toxins may be carried by the blood stream to other parts of the body. For example, toxins of bacteria causing **tetanus** are carried from the infected area on the skin to jaw muscles where it causes **rigid paralysis** and **muscle spasms.** Hence the disease is called
**"Lockjaw."**

If the toxins are formed in food stuffs, and such food stuffs are eaten, **food poisoning** results.

### Endotoxins

Certain bacteria are able to produce poisons within their cells. On their death, the poisons are released to the tissues. Examples are cholera, typhoid fever, bacteria causing **bacterial dysentery** and **bubonic plague**.

### How human body fights against diseases

1. **Skin**: The skin covers the external parts of he body. The skin prevents disease causing micro-organisms from entering the body tissues. Some substances (salts and fatty acids) found in he sweat and sebaceous glands kill bacteria.
2. **Mucous membrane**: The mucous membranes covering the mouth, digestive tract, genital tract, and respiratory tract perform function of the skin in preventing micro-organisms from entering the body tissues. The secretion of mucus by the mucous membrane also covers the delicate membranes thereby preventing bacteria from entering the membranes. Majority of the cells of the mucous membranes have cilia which keep off bacteria. Mucous membranes also contain some substances harmful to bacteria.
3. **Tears**: Tears wash off bacteria and

other foreign bodies. Some enzymes (lysozymes) present in the tears destroy the bacterial cell walls.

4. **Chemical defence**: Some parts of the body secrete acid or alkaline. The gastric glands in the stomach for example, secrete gastric juice containing dilute hydrochloric acid and the secretion of bile (alkaline solution) from the liver which is stored in the gall bladder. These substances kill bacteria in the **food in the stomach and duodenum.**
5. **White blood corpuscles and lymph:** The white blood corpuscles (phagocytes) and the lymph cells engulf and digest bacteria.
6. **Liver, lungs, spleen**: The linings of the small blood vessels in the liver, lungs and spleen help to destroy micro-organisms. The phagocytes making up the **reticuloendo- thelial system** capture, engulf and digest bacteria.
7. **Fever**: This is an increase in the normal body temperature. When micro-organisms invade the body, the body temperature increases. During the body invasion, **toxins** are released into the body by bacteria. The increase in body temperature is to inhibit the population of bacteria and stimulate the white blood corpuscles into action of engulfing the bacteria. Fever is useful if it is not high and long.
8. **Antibodies**: The blood produces antibodies which kill bacteria. The anti-bodies also neutralize the toxins produced by bacteria.
9. **Inflammation**: An injured tissue is inflamed. More blood flows to the injured area. The injured area becomes acidic and leads to an increase in temperature, swelling and pains. These are ways of making the injured area inhabitable to micro- organisms.
10. **Immunity**: This is the ability of an animal or plant to resist infections of parasitic organisms.

There are two types of immunity, these are **Natural immunity** and **acquired immunity**

**Natural immunity**: This is the type of immunity inherited from parents.

**Acquired immunity**: Acquired immunity is either **passive** or **active.**

**Passive immunity**

This is acquired artificially. When there is an epidemic outbreak, **small doses of antibodies** from an animal are given to people to provide an urgent temporary immunity to the body. After this, the body can develop a resistance against that particular disease. This type is called **passive artificial immunity.**

Prior to birth, the mother transfers antibodies to the foetus through the placenta.

**Active immunity**

This is divided into active natural and artificial immunities.

**Active natural immunity**

When the body recovers from an infection the body has many anti-bodies in the blood to protect it from further infection of the same disease for a long time.

**Active artificial immunity**

This is by injecting vaccines such as weakened or killed bacteria products into the body. In this way the body can produce its own antibodies.

## *Questions*

1. (a) *By reference to three mammals and three named crop plants, mention:*
   (i) *three diseases caused by bacteria.*
   (ii) *three diseases caused by viruses.*
   (b) *State briefly the various methods that can be adopted in the prevention of viral diseases in:*
   (i) *animals*
   (ii) *plants.*
   (c) *Mention five beneficial uses of bacteria.*
   (d) *State three places each, where (i) viruses and (ii) bacteria may be found.*

2. (a) *Describe briefly the structure of a virus.*
   (b) *What is a disease?*
   *Name five diseases caused by (i) bacteria (ii) viruses.*
   (c) *Briefly describe five ways in which the activities of bacteria are beneficial to man.*
   (d) *Mention two methods of preserving food from spoilage by bacteria and describe each briefly.*

3. (a) *What are bacteria?*
   (b) *Describe the structure of a bacterial cell*
   (c) *How do they cause disease in a human body?*
   (d) *Write an account of the ways in which the human body combats bacterial diseases.*
   (e) *Briefly describe three ways in which bacteria are of benefit to man.*

4. *State the causes, symptoms and prevention or control of the following diseases:*
   (a) *Malaria*
   (b) *Small-pox*
   (c) *Dysentery*
   (d) *River blindness*
   (e) *List eight methods of preventing or controlling germs to maintain healthy life.*

5. (a) *In a well organized tabular form write the answers from any of the following diseases below, under these headings:*
   *Exactly how man becomes infected; Causative organism; Location in the host; symptom and control.*
   1. *Gonorrhoea*
   2. *Small pox*
   3. *Cholera*
   4. *Tuberculosis*
   5. *Acquired Immune Deficiency Syndrome (AIDS)*

   (b) *How would you show experimentally that micro-organisms are present under the fingernail or in our food?*

# 22

# TOWARDS BETTER HEALTH

**Methods of controlling harmful micro-organisms to maintain good health.**

Micro-organisms which cause ill-health (pathogens) could be controlled by the following methods:

1. **High and low temperature**

(a) **Boiling or heating**

A high temperature kills bacteria and their spores. Frying or cooking of food with fire helps to kill bacteria. Boiling and filtering of drinking water helps to kill and remove germs.

(b) **Sterilization** of medical instruments and dresses by boiling, autoclaving or radiation destroys germs. This ensures that germs are not passed from the instruments or dresses to the patient.

(c) **Freezing**

Food items can be preserved in a freezer. At a low temperature, the activities of micro- organisms are reduced to the barest minimum.

2. **Covering of food**

Covering of food prevents **vectors** (germ carriers) such as houseflies, rats and cockroaches from coming in contact with our food. Cover- ing of food also prevents pathogens in the air from reaching our food.

3. **Antibiotics**

Antibiotics are used to kill germs. Antibiotics such as amphiclox, ampicillin, penicillin, tetracycline, auriomycin, streptomycin and erythromycin are used to kill many bacteria causing diseases.

4. **Antiseptics**

Dettol, milton, chlorine water, medicated soap and hydrogen peroxide are examples of antiseptics. Some antiseptics destroy micro-organisms while others prevent the multiplication of the micro-organisms.

5. **Disinfectants**

Disinfectants are stronger antiseptics. Examples are sanitas, lysol and izal (carbonic acid). They are used to disinfect hospitals, warehouses and public buildings. They are also used for bathing, cleaning woods and treating clothes. Antiseptics and disinfectants have to be diluted to render them gentle or mild to the skin.

6. **High salinity (Salting)**

Salt is used to preserve food. When salt is applied to food items like fresh fish or meat, the micro-organisms are destroyed. The bacterial cells are plasmolysed due to the movement of water from the cells of the bacteria.

7. **Dehydration**

When foodstuffs such as meat and fish are dried, micro-organisms can not thrive on them. Bacteria need water to survive. So dehydration prevents the survival of micro-organisms.

8. **Sanitation**

Good sanitation is essential to good health. Keeping the body clean, brushing the mouth always, wearing clean clothes, living in a clean house, washing hands after toilet, before and after eating all help to promote good health.

9. **Clearing bushes**

Clearing bushes where vectors of pathogenic organisms stay helps to prevent the spread of diseases. Clearing of bushes destroys their habitats and they therefore move far away from our surrounding.

Health education is very important. People must be educated about the importance of diseases They should know how to control or treat diseases and what to do when there is an outbreak of any infectious disease.

10. **Isolation of infected persons**

Persons suffering from infectious diseases such as **tuberculosis** and **cholera** must be isolated so as to prevent the spread of such diseases to other members of the community or family.

11. **Balanced diet**

Eating balanced diet everyday helps to promote good health. Good food promotes high body resistance to diseases.

## Methods of food preservation

1. **Salt curing or high salinity**

When salt is used in curing fish, pork and other meat, it causes the plasmolysis of the bacterial cells resulting in the destruction of bacteria, food can then be persevered for days. This method has been used for centuries.

2. **Canning**

Properly canned food is free from bacterial actions. Food is properly cleaned and processed and then sealed up in cans. The can food is heated to a selected temperature and then cooled. The cooled canned food can be preserved for many months.

3. **Refrigeration**

This process retards the growth and multiplication of bacteria and fungi. The metabolic activities of bacterial enzymes are also reduced. Food can therefore be preserved for long time.

4. **Dehydration or drying of foods**

This is a process whereby moisture or water is removed from the food to a level that bacteria are unable to grow or secrete enzymes and fungi. Smoking of fish or meat is a good example. Also fresh food items such as vegetables, okro, tomatoes and pepper can be dried in the sun for some days to remove water from them to a level in which bacterial and fungi will not destroy them.

5. **Quick-freezing**

When food is still fresh and given quick- freeze, it can be preserved for many years without destroying the vitamins and nourishment. At temperature of O°C to minus, the activity of bacteria is almost ceased.

6. **Pasteurization**

Pasteurization is the process of killing or retarding the growth of bacteria in milk, alcohol and beverages by heating to a selected temperature of about 60°C for 30 minutes or 80°C for 30 seconds and cooled immediately. This kills pathogens, while the flavor is retained.

7. **Preservation in vinegar**

Foodstuffs such as fruits and vegetables could be preserved in vinegar. The acidity of vinegar prevents the growth and multiplication of bacteria.

## Ways of controlling the vectors

***A vector is an animal that carries pathogenic organisms.*** Most vectors are arthropods (especially insects). For example, house-fly is the vector of *Entamoeba histolytica* (a protozoan) that causes entamoebic dysentry while female anopheles mosquito is the vector of *Plasmodium* (a protozoan) that causes malaria fever.

### Rodents

Black rats *(Rattus rattus)* and mice are common rodents. They are vectors of diseases such as typhus and plaque. They spread these diseases by contaminating our food and drinking water with their urine and faeces.

**Habits of black rat *(Rattus rattus)***

1. Rats are omnivorous in diet, eating grains (rice, millet, wheat, guinea corn, bean), meat, fish, clothes and papers.
2. They prefer to stay in places where foodstuffs are kept.
3. They are nocturnal in habits.
4. They stay in holes, roofs and in between places where many things are packed in our houses. Packed wood, holes, roofs, rubbish dumps provide breeding places for them.

### Control of rats

1. Foodstuffs must be safely kept to prevent rats from reaching them. Grains should be kept in rat-proof stores to prevent rats from reaching them.
2. All vegetation and rubbish dumps near our houses must be cleared off.
3. Dwelling houses must be kept clean always.
4. House refuse must be kept in dust bins and properly covered.

### Biological control

5. Cats which are predators of rats should be kept as pets.

### Chemical control

6. Rat poisons mixed with food such as pieces of bread, crayfish, meat and fish as baits are used to kill rats

### Traps

7. Traps using baits are used to catch rats.

## REFUSE

1. **Refuse is the dry or wet solid waste collected from markets, homes, hospitals, offices and factories.** Waste papers, food, cans, cobs of maize, yam and cassava peelings are examples of refuse.

**Refuse** provides breeding grounds for insects and animal pests such as rats which are vectors of many germs. Refuse dumps are ugly sight and odour from them causes discomfort and some irritation. It also contains germs which may be picked up by visiting insects such as housefly and carried to our food.

### Disposal of refuse

1. **Burning**

In urban towns, refuse is collected from markets, factories, schools, offices and homes and burnt in an **incinerator.** Dust bins are usually used to collect refuse in homes, schools and offices.

2. **Burying**

Pits and trenches are dug far away from living surroundings. Refuse is put into pits or trenches and arranged in layers. Each layer is covered with earth of 30 cm thick. This causes faster decomposition of the refuse due to rise in temperature and prevents rodents and insects from turning the place into a breeding ground.

3. **Dumping**

Refuse collected from town or village is carried in barges far into the sea where it is dumped. Dumping of the refuse should be far away so that the sea does not wash back the refuse. Refuse can also be collected from town and carried with lorries far away into the bush. Usually, a site is chosen for the dumping.

## SEWAGE

Sewage is the wet waste resulting from the following:

1. Faeces and urine
2. Bath water
3. Waste water from houses and street
4. Waste from factories
5. Agricultural waste

Sewage contains over 99 % water while the remaining 1 % contains impurities and micro-organisms. It is very important to dispose of sewage to avoid an outbreak and spread of diseases.

### Methods of sewage disposal

1. **Bucket Latrine**

Faeces and urine are passed into the bucket and when the bucket is full, it is emptied by **night soil men.** The faeces and urine are dumped into a **dug trench** of about a half kilometre away from the town. The buckets containing faeces and urine are carried to the trench. This method is unhygienic and unsatisfactory and should be discouraged.

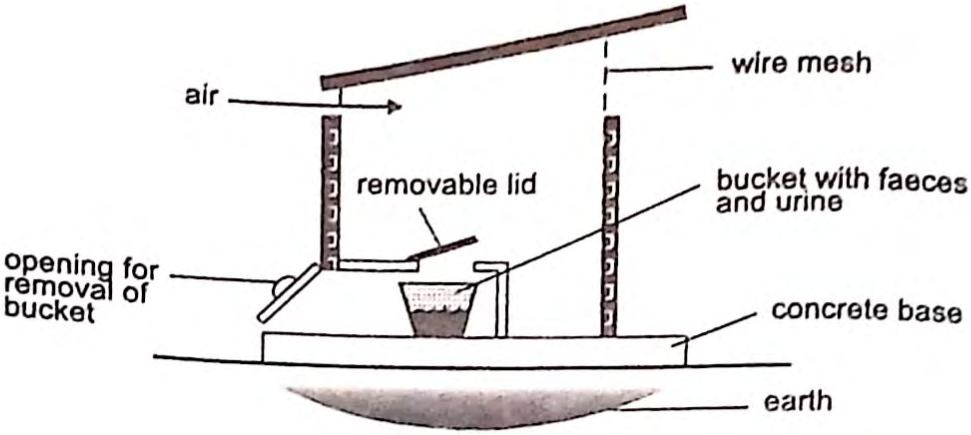



**Figure 22.1. A bucket laterine.**

## 2. Pit Latrine

This is a very cheap method of disposing faeces and it serves well for a family. This is simply digging a pit or hole of about 240cm deep. The hole has a lid to keep away flies and reduce odour. Flies do not like deep pit latrines

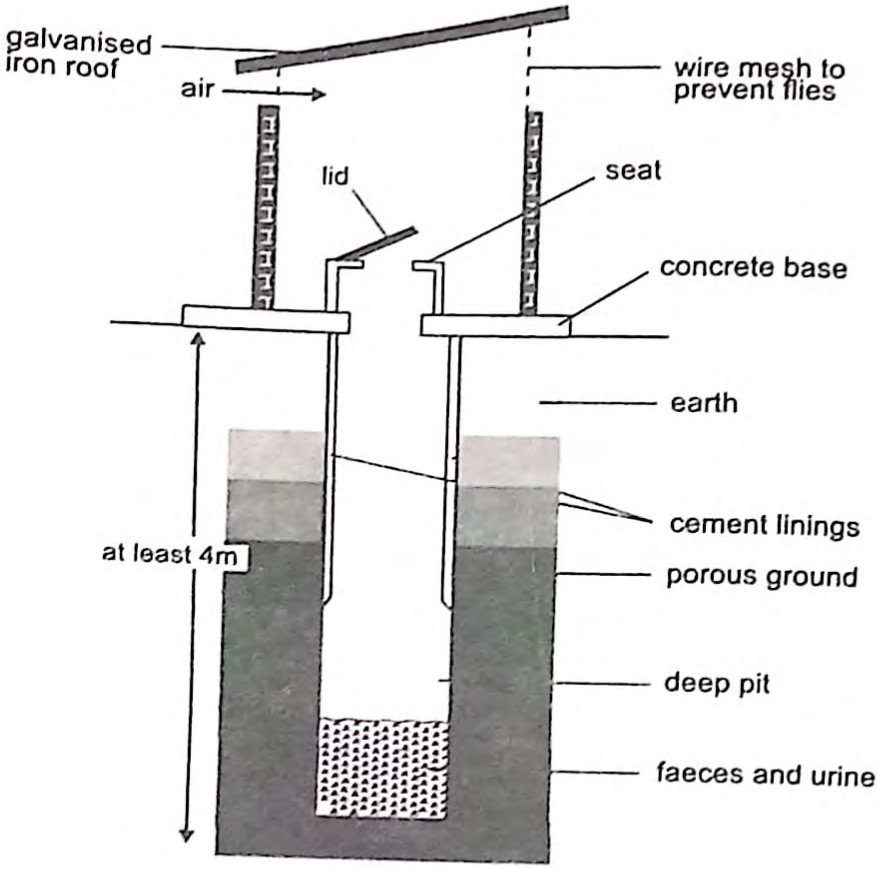



**Figure 22.2. A pit laterine.**

3. **Septic Tank Latrine (Water-borne system)** This is the most hygienic and safest way of disposing sewage. Pipes are constructed from the house to large tank sunk about 16 meters from the house. Faeces and urine are passed into a ceramic bowl containing water and by means of water from the system, the waste is flushed into an underground septic tank. The liquid waste drains into a soakaway pit made of loosely packed stones. The sewage is decomposed by **anaerobic bacteria**.

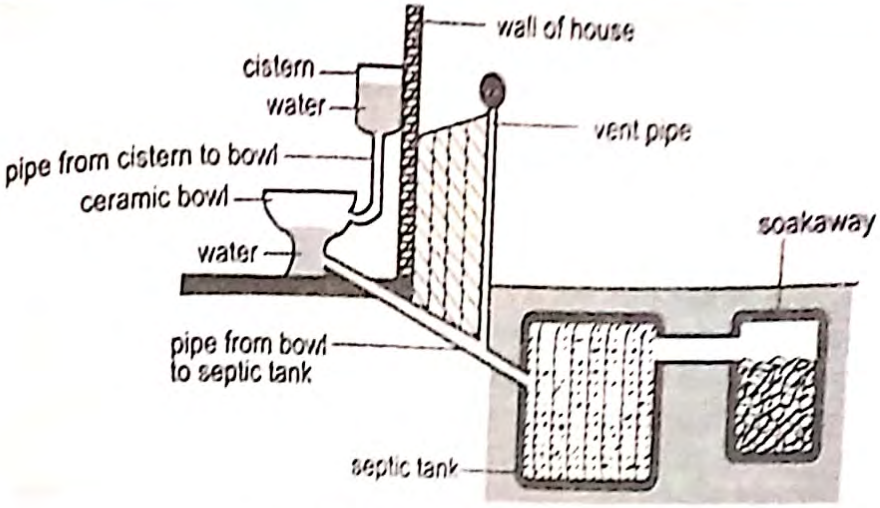



Figure 22.3. A septic tank laterine.

Some diseases associated with sewage are (1) **Cholera** (2) **typhoid** (3) **dysentry** and (4) **bilharziasis.**

## Protection of water

The water we drink and bathe with must be protected from diseases. The sources in which we get our drinking and bathing water are usually contaminated with germs.

Sources of water supply are:

1. **wells** 2. **streams** 3. **rivers** 4. **Lakes** 5. **reservoirs** 6. **rainfall.**

## Purification of water

### Large-scale purification of water

**Purification of water means the removal of suspended solid matter and bacteria from water by sedimentation, filtration and sterilization with chemicals.**

There are three main processes for treating water supplied to town. These are **sedimentation, filtration** and **sterilization.**

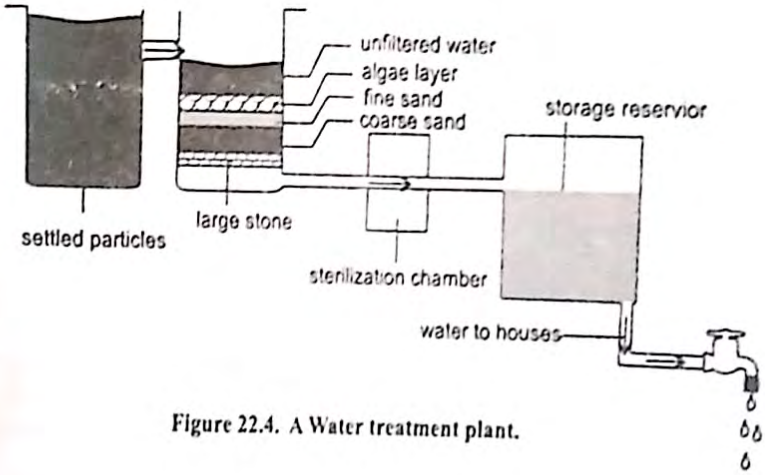



Figure 22.4. A Water treatment plant.

**Sedimentation:** The water is pumped into large tanks and left to remain in the tanks for several days. The large and heavy particles such as silt settle to the bottom of the tanks. **Alum** is added to aid **sedimentation**. The alum helps the large and heavy particles to stick together and settle to the bottom.

The exposure of the water to sunlight and air helps to destroy many bacteria.

**Filtration:** The water is passed through a **filtration tank** containing layers of algae, fine sand, coarse sand and large stones. The layer of algae forms gelatinous layer on the top of the fine sand. This layer removes suspended particles including bacteria. This method is called **slow-filtration.**

Another filtration method is called **pressure filtration.** This is operated in closed concrete tanks. Instead of algae being used, chemicals such as aluminium silicate is used. The **aluminium silicate** forms a film of jelly-like layer over the sand and helps to retain impurities and bacteria in water.

**Sterilization:** The filtered water is passed over a chamber where chlorine gas is bubbled into the water to kill any germs. This process is called **chlorination** of water. After chlorination, the water is then distributed to houses and industries.

## Small-scale purification:

**Boiling:** Boiling of water is a good way to destroy germs. Boiling should continue vigorously for five minutes. To improve the taste of water after boiling, pour it back and forth from one clean container to another after it has cooled, thus allowing oxygen to dissolve in the water.

**Iodine:** Ordinary tincture of iodine may be used to purify small quantities of water. Add 20 drops to 4 litres of clean water or 40 drops for cloudy water. Mix and allow to stand for 30 minutes before use.

**Filtering:** Filter the water with commercial filter then add alum and followed by chlorine or iodine.

**Distillation:** Impure water is heated and the steam produced is passed through a glass-tube and allowed to condense into water which is then collected as distilled water. Oxygen is then added for tasted as described above.

**Bleaching powder:** Small amount of bleaching powder is added into water and allowed to stand for thirty minutes to one hour. The bleaching kills all the micro-organisms present in the water.

# Protection of food

The food we eat is very important. Food gives good health and as such, must be protected from germs all the time. Kitchen where food is prepared must be kept clean always. The floor, windows and frames must be washed with soap and water always. Kitchen should be well lighted so that insects and dirts are easily seen. Food must be protected during storage, preparation and serving.

## Storage of food

Stored food attracts flies, cockroaches and rats which are **vectors** of many pathogenic organisms. Soft food such as meat, fresh fish should be stored in refrigerator, while dry food should be stored in clean ovens, meat safes, cupboards or big tins with lids. All these prevent vectors from reaching the food.

## During food preparation

Hands must be thoroughly washed. Dirty hands and finger-nails are inhabited by bacteria and viruses which can easily be introduced to food if not properly washed. Vegetables, meat, fish, cooking ingredients are to be washed properly. Cooking utensils must be washed with soap and clean water to remove all possible dirt and left over food particles. All food items used for the food preparation should be covered to prevent flies. Food must be properly cooked to destroy all germs.

## Serving of food

Cooked food should be eaten immediately. If left over for a long time, it will attract flies. Food should be served in clean plates. Spoons, forks and table knives must be kept dry and clean. The table-ware and dish-cloths must be kept dry and clean. Damp cloths harbor millions of germs.

It is important to observe **table manners** such as not laughing, sneezing and blowing nose when eating. These bad manners can spread diseases.

# HEALTH ORGANIZATIONS

Different organizations have been established to maintain good public health both at the national and international levels. Some of the organizations are **Red Cross, United Nations International Children's Emergency Fund (UNICEF), World Health Organization (WHO), Food and Agricultural Organization (F.A.O.),** Public Health Authority and Nigerian Medical Association.

## A. Red Cross

The **Red Cross Society** is a world-wide organization concerned with alleviating human suffering and misery in time of war and disaster such as earthquakes, flood, and drought. It has its headquarters in **Geneva**.

**Functions:**

1. It gives aid to ex-servicemen (veterans).
2. In time of war (civil or international), the organization provides food, medicine, clothes for the wounded people. It establishes hospitals and clinics for their treatment.
3. It campaigns for **blood donation** for those in need of blood.
4. It prepares **first aid books** for people and teaches people how to give first aid and first aid courses such as swimming, life-saving (e.g. taking "cover" during war).
5. Pays visits to the prisoners of war and present them with gifts to make them happy.
6. Evacuates people especially during the war from unsafe to safe zones.
7. During disaster such as floods or earthquakes, it provides relief work, food, medicine, clothing, vaccines and resettles the affected people.
8. It renders first aid during sports meetings.
9. It initiates and supervises the exchanges of prisoners of war.
10. It helps to provide information for missing person(s).

## B. The United Nations International Children's Emergency Fund (UNICEF).

1. It provides dried milk, vitamins and other protein-rich foods to needy children to improve their nutrition.
2. It assists greatly in setting up welfare services, nutrition and health programme for children.
3. It helps to supply equipment, drugs and transport to combat major diseases such as malaria, yaws, tuberculosis and typhus which often attack children and mothers.
4. It helps to train doctors, nurses, midwives, nutritionists and sanitary officials to improve health services.
5. UNICEF provides scientific equipment for processing milk, beans and fish to communities of developing countries.
6. It encourages and provides equipment to schools for poultry and other animal farming and fish culture.
7. It carries out teaching campaigns to the local communities on the various methods of improving their nutrition, those of the children and how best to make use of the locally available food.
8. A small portion of its fund is given out annually for emergency relief.
9. It co-operates with the **International Labour Organization (I.L.O.)** in improving occupational health.

## C. The Functions of the World Health Organization (W.H.O.)

1. It is primarily concerned with improving the knowledge and standards of health all over the world.
2. It assists by sending medical personnel to countries, upon request to advise on the best methods of improving their health services.
3. It assists in the training of medical personnel.
4. Promoting the nutritional and sanitary products.
5. It helps in waging war against major diseases.

such as **tuberculosis, cholera, malaria, yellow fever, small pox** and **AIDS.**

6. Assists in pre-natal and post-natal health care.
7. Assists in finding solution to mental problems.
8. It publishes literatures on health which are circulated all over the world.
9. It controls the distributions of dangerous drugs.
10. It helps to stop the spread of infectious diseases, such as cholera and small pox from one country to another.
11. Quarantine and innoculation regulations are set by it.
12. Reports the outbreaks of infectious diseases in one country to other countries.
13. It helps in standardizing the quality and dosages of drugs.
14. Prepares international health statistics.

## D. Food and Agricultural Organization (FAO)

F.A.O. was created on 16th October 1945 with its headquarters in **Rome.**

**Functions:**

1. To promote the common welfare through separate and collective action to raise the level of nutrition and standards of living.
2. To improve the efficiency of production and distribution of all food and agricultural products.
3. To better the conditions of rural population, thus ensuring human freedom from hunger.
4. Is charged with collecting, evaluating and giving out information relating to nutrition, food and agriculture, fisheries, forestry and marine products.
5. Promotes scientific, technological, social and economic research relating to nutrition, food and agriculture.
6. Helps on the improvement of education and administration relating to nutrition, food and agriculture.
7. Helps to spread to the public the knowledge of nutritional and agricultural science and practice.
8. Helps in the conservation of natural resources and adoption of improved methods of agricultural production.
9. Helps in the improvement of the processing, marketing and distribution of food and agricultural products.
10. Donates free samples of improved varieties of plant and animal species to member countries so as to improve food yield.

## E. The Public Health Authority

The **Public Health Authority** is a body responsible for the health of the community.

**Functions**

1. It makes sure public places such as markets, play grounds, and food manufacturing places are clean.
2. It is concerned with the proper disposal of refuse.
3. It provides maternity clinics.
4. It provides child welfare services and medical inspection of schools.
5. It registers births and deaths.
6. It prevents and controls infectious diseases by administering vaccination, immunisation and inoculation.
7. It informs **W.H.O.**of out-breaks of infectious diseases.
8. Makes sure that clean water is supplied to the public.
9. It provides **Ambulance Services.**
10. It provides quarantine services.
11. It gives health certificates to travellers.
12. It inspects and registers nursing homes.
13. It helps to educate the public about the importance of health.
14. It carries out supervision of clinics, hospitals and welfare centres.

## Personal Hygiene
## Care of the skin and teeth

### Care of the skin

The skin performs very important functions and as such it needs proper care.

1. **Cleaning**
In the tropics, loss of water by evaporation is much. After evaporation, oil, dead cells, salt, dust and bacteria are left on the surface of the skin. If they are not cleared, they will decompose to give body odour and irritation of the skin. Water and soap are very good in removing dirt from the skin. Taking bath twice a day is good for tropical people.

2. **Warm water bath**
Is very efficient in removing dirt and is therefore encouraged. Warm water stimulates the sweat glands to be more active, causes the dilation of the blood vessels supplying the skin. Taking a cool shower immediately gives a mild shock to the body, the blood vessels contract and readjust to the quick change in temperature. Giving the body this mild shock habit, helps the body to readjust to a sudden change in temperature.

3. **Hot water bath**
Should be discouraged. It can cause sudden dilation of the blood vessels of the skin resulting in sweating. Blood rushes to the surface of the skin from the brain and digestive organs causing drowsiness. It is important to have clean water for bathing and clean the body with a clean and dry towel. Dirty and wet towel may harbor germs. Another person's towel should not be used.

4. **Air**
The skin needs air. Light clothes that allow free flow of air to the body are best in the tropical countries. Heat may cause the blockage of some sweatducts thus causing trapping of sweat in the body. This condition may lead to leaking of sweat in the skin causing **itching** and **inflammation**.

5. **Clothes**
Clothes are to be washed with clean water and soap to remove dirt. Proper rinsing with clean water ensures complete removal of any trace of soap. Traces of soap on clothes cause skin irritation.

6. **Ironing**
Ironing clothes before wearing kill germs that cause skin diseases.

7. **Borrowing of clothes**
It is a bad habit to borrow and wear clothes of another person. Wearing another person's clothes could spread skin diseases. For this reason **second-hand** clothes acquired for use should be properly disinfected.

8. **Brushing and combing**
Brushing and combing the hair always remove dirty. It also exercises the skin around the root hair, facilitating blood circulation.

## Care of teeth

### During pregnancy

Strong and healthy teeth start before birth. Even though the teeth do not appear on the surface, they are within the jaw bones. The pregnant mother should therefore take plenty of vitamins A, C and D, calcium and phosphates to build strong teeth for the baby.

**Temporary teeth** need great care to prevent decay which may affect **permanent teeth**. Children are to be educated on how to clean their teeth especially after eating or drinking sweet drinks.

### Cleaning

1. Brushing the teeth after each meal is important. This helps to remove food particles from the teeth that would eventually cause decay of teeth and make the mouth to smell.
2. Cleaning the teeth or drinking water after eating sweets prevents the teeth from decay. Bacteria like sweets.
3. The toothbrush needs proper care such as rinsing and putting it in the sun to dry.
4. Chewing stick is good and should be used regularly for strong and white teeth aiso.
5. Eating hard food such as hard biscuits, fruits, nuts and moderately hard bones help to increase flow of blood to the gums and helps to hold the teeth strongly.

6. Small amount of **fluorine** in **public water** protects the enamel from decay.
7. Sharp objects such as needles and pins should not be used to clean the teeth. They may injure the gums and cause infection. The use of tooth picks is better.
8. Regular dental inspection by a qualified dentist is encouraged. School children especially, need dental inspection more often.
9. Food like milk, fruits, vegetables, eggs, fish and meat help to build strong teeth.

## Sanitation

Sanitation is an arrangement to protect individual or public health by the efficient removal of dirt and sewage.

### Care of the kitchen

Kitchen is where food is prepared and as such must be the cleanest section in the house.

The kitchen is kept clean in these ways:

1. The floor should be made of smooth and waterproof materials. This will ensure clean sweeping and washing efficiency.
2. The kitchen should be constructed in such a way that sufficient light enters it. This will help us to see dirts and insects which are to be removed.
3. Screening the windows with wire gauze helps to keep flies away. The door of the kitchen should be shut all the time.
4. The store-room should be rat proof.
5. Tables and cup-boards are to be washed with water and soap and kept clean regularly.
6. The sink or any place for washing in the kitchen should be kept clean and properly drained. Improper kitchen drainage harbors germs.
7. Cooking utensils are to be kept clean by washing them with clean water and soap to ensure that no food particle sticks to the utensils because food particles may decay and encourage bacterial growth. Cracked cooking utensils should not be used for preparing food. Food particles stick to the cracks and disease causing organisms cannot easily be removed.
8. Any person handling or preparing food in the kitchen must be clean. Washing of hands with soap before handling food is important. Do not laugh, shout, or cough when preparing food. You may contaminate the food with the germs from your mouth.
10. Dish and table cloths should be kept clean and dry. They should be washed regularly and kept dry. Wet cloth harbors germs.
11. Water should not be left in containers for days in the kitchen for mosquitoes will breed in them.

## Care of dwelling places

A dwelling place consists of house and its surroundings.

### Care of the house

A house is an important place to keep clean. A dirty house harbors all sorts of germs and their vectors.

1. The windows are to be screened with wire gauze to prevent insects and rats from coming to the house. The doors should be shut always.
2. Cob-webs on the ceiling and walls of the house should be removed when they exist.
3. Scrubbing or washing the floor with soap and clean water helps to make the house clean and healthy to live in.
4. Sweeping the house with a clean broom when the house is dirty is vital. It is important to wash the broom when it is dirty. Dirty broom can keep germs.
5. The furniture need a proper arrangement for healthy and comfortable living. Polishing the furniture when they are dirty is important. If there is a carpet, constant dusting is necessary to keep it clean.
6. The house should be well ventilated. Unventilated house is dangerous to health as it can cause suffocation.
7. The toilet is an important place in the house that needs a close attention. It needs to be kept clean all the time. Flies must be discouraged from entering into the toilet. The toilet should be covered after use.

8. It is unhealthy to spit in any part of the house. pitting can spread germs.
   Apart from this, it is an unpleasant manner.
9. Bed-bugs and cockroaches should not be allowed to live in the house. Bed-bugs disturb sleep and are known to transmit diseases. Cockroaches are a nuisance to the house and destroy valuable things.

## Care of the surroundings

It is equally important to keep the surroundings of the house clean. Dirty surroundings constitute health problems to the occupants of the house.

All standing vegetation that may likely harbor insects such as mosquitoes and house-flies should be cleared off. Refuse should not be dumped on the surroundings as this will attract houseflies and rapid growth of bacteria population.

Pits that may contain water when it rains are to be filled up. All broken vessels that may store water should be removed. Pits and broken vessels are good breeding grounds for mosquitoes. Broken vessels are also injurious to people.

Planting of ornamental plants around the house is good provided they are properly maintained. Plants that secrete alkaloids are poisonous and should not be planted in the surrounding. Sweeping the surrounding is vital.

## *Questions*

1. ***What are the effects of:***
   ***(a) smoking and***
   ***(b) alcohol on human health?***
   ***(c) What are the functions of the World Health Organization (W.H.O.)?***

2. ***What are the functions of the following organizations or bodies:***
   ***(1) The Red Cross Society.***
   ***(2) The Public Health Authority.***
   ***(3) The United Nations International Children's Emergency Fund (UNICEF).***
   ***(4) Food and Agricultural Organization (F.A.O.)?***

3. ***(a) Briefly describe eight ways of controlling harmful micro-organisms to maintain good health.***
   ***(b) What is (i) refuse and (ii) sewage? Describe how refuse and sewage are disposed off.***
   ***(c) Name four disease associated with sewage.***

4. ***(a) State five importance of water to living organisms.***
   ***(b) (i) Define water purification.***
   ***(ii) How can you purify (i) a domestic water supply (ii) a town water supply.***
   ***(c) State seven ways of how to take care of your kitchen or house.***

# 23

# BASIC ECOLOGICAL CONCEPTS

## Ecology

The term **ecology** is derived from the Greek word ***Okios*** meaning **Household** and **Logus** meaning study. So in practical sense, **ecology is the study of interactions of organisms with their physical environment and with each other.** No plant or animal is independent of its environment. If organisms must survive, then the environment must provide suitable conditions for their existence.

Ecological concepts include the following:

**Environment, biosphere, lithosphere, hydrosphere, atmosphere, habitats, niche, population, biotic community and ecosystem.**

## Environment

The environment is the surrounding of an organism. The environment consists of two parts namely **abiotic** (physical or non-living) part and **biotic** (living) part. The **abiotic part** consists of things like light, temperature, wind, humidity, pH, water and soil. The **biotic part** is the living part of the environment which includes animals and plants.

There are three major environments namely, (a) **marine,** (b) **freshwater** and (c) **terrestrial.** These environments have numerous habitats.

## Biosphere

**Biosphere** is the part of the earth in which life exists. The biosphere forms a thin film at the surface of the earth extending about 12 - 17 km above the surface of the earth and about the same distance into the depth of the sea. This thin layer is made up of **lithosphere, atmosphere** and **hydrosphere.**

Many factors are responsible in producing the changing patterns of life on the surface of the earth. The biosphere has different large geographical regions each with particular kind of physical Climate and a characteristic set of organisms. These geographical regions are called **biomes** e.g. ocean, desert, seashore, savannah and forest. These biomes are generally characterized and identified by their abundant and dominant biological species.

## Lithosphere

Is the solid crust of the earth.

## Atmosphere

This is the region that lies between the earth and outer space and is composed of four main divi-sions. These are **troposphere, stratosphere,** mesophere and **thermosphere.** The boundaries between them are determined by abrupt changes in average temperature. The atmosphere is made of the air around us. The air consists of nitrogen (78.1%), oxygen (20.9%), carbon dioxide (0.03%) and other gases (0.97%).

## Troposphere

This is the first and lowest layer, closest to the earth. It is 16 kilometres thick above. It covers all points on the earth surface. About 75% of all the molecules in the atmosphere are concentrated in this layer. At its outer boundary, the temperature is below 50°C.

## Stratosphere

Is the second layer which extends to up to light of 75km. In the stratosphere, the temperature increases with hight. The major warming of the stratosphere is due to layer of ozone ($O_3$). Ozone molecules absorb most of the ultraviolet rays of the sun, which would have been lethal to most forms of life should they reach the earth's surface.

## Mesosphere

Is the third layer. In this layer there is a gradual decrease in temperature as the concentration of ozone decreases in the steadily thinning atmosphere.

## Thermosphere

Is the fourth layer. The temperature in the thermosphere increases. At the outer boundary of this layer, the thin atmosphere blends with the hydrogen and helium atoms in the space between the stars.

## Hydrosphere

This is the aquatic portion of the biosphere comprising the oceans, seas, lakes, rivers, streams, and ponds. It occupies three quarters of the earth's surface.

In nature, the movements of inorganic sub-stances are called **biogeochemical cycles** because they involve **geological** as well as **biological** components of the ecosystem. The **geological components** are the atmosphere which is made up largely of gases including water vapour, dust and other particles of the lithosphere. The **biological components comprise the producers, consumers and decomposers.**

## Habitat and Niche

### Habitat

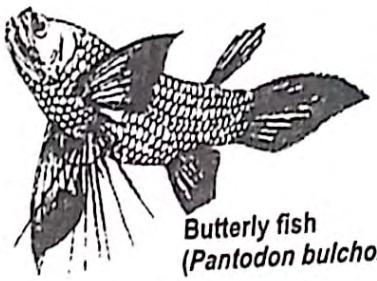
Every organism in any ecosystem lives in a particular place (**home**) or region called its **habitat.** A habitat may be as large as an ocean, forest or desert, or as small as a leaf of a plant or the intestine of an insect. Such small and localised areas are known as **microhabitat.**

### Niche

Within its habitat and ecosystem, every organism also plays a variety of roles. It feeds on some organisms and serves as food for others. It extracts some nutrients from its habitat and returns some to it. It is primarily either a producer or a consumer. The sum total of all these roles for any organism is referred to as its **ecological niche.** In other words, the ecological **niche** of a species refers to its life style, how it lives, what it does, how it interacts with other members of its habitat.

**African river pike** (*Hespetus odoe*) and **Butterfly fish** (*Pantodon bucholzi*) for example, are aquatic freshwater fish inhabiting surface waters of either ponds, streams, rivers or lakes. African river pike is a predator (piscivore = fish feeder) feeding on small fish and occupies open water surface while **Butterfly fish** feeds on aquatic insects and plant materials and occupies the surface or aquatic vegetation and shady places. The two species therefore occupy different **niches** in the same habitat. It is the niche of African river pike to feed on fish while the niche of **Butterfly fish** is to feed on **aquatic insects and plant materials.**

African river pike (*Hepsetus odoe*)



Butterly fish (*Pantodon bulchozi*)

**Figure 23.1. African river pike and Butterfly fish.**

*Tilapia zilli*, and *Oreochromis niloticus*, (*Tilapia niloticus*) are cichlids living together in stream, river or lake. ***Tilapia zilli*** is a planktivore (feeds on plankton) while ***Oreochromis niloticus*** is an omnivore. It is the niche of *Tilapia zilli* to feed on plankton while it is the niche of the *Oreochromis niloticus* to feed omnivorously but both live in the same habitat. The savanna scaly anteater called Pangolin (*Manis sp*) and the Cutting grass (*Thryonomis swinderianus*) are both mammals living in savanna. The scaly anteater, Pangolin (*Manis sp*) is an insectivore feeding on ants and termites while the Cutting grass (*Thryonomis swinderianus*) is a herbivore feeding on grasses.

These two species of mammals occupy different niches in the same habitat (savanna). It is the niche of the scaly anteater, Pangolin (*Manis sp*) to feed on ants and termites while the niche of the Cutting grass (*Thryonomis swinderianus*) is to feed on grasses.

In social insects such as honeybees, it is the niche of the drone (males) to mate with the queen, while the niche of the queen is to reproduce and that of the worker is to bring food, feed the queen and larvae and clean and protect the hive.

Every environment offers a large number of niches and habitats. Although two species can occupy the same habitat but they cannot occupy the same niche for long. Either one would become extinct or one or both have to separate into different niches.

In some cases, individuals of the same species may have different niches as in case of animals with complete metamorphosis. For example, it is the niche of the larva (caterpilar) of butterfly to feed on green leaves with its powerful mandibles (jaws) while it is the niche of the adult butterfly to feed on nectar of flowers.

In order to know the status of an organism in the community, one has to determine the following aspects of its existence:

a. Nutrition and source of energy
b. Rate of metabolism and growth
c. Effect on other organisms.

## Population

**Population is the total number of organisms of the same species which live at a given time in a particular habitat.** For example human population in a state or country for ten years. The population is the structural component of an ecosystem and it develops and maintains itself by reproduction. It is a self regulating system and is considered as an evolutionary unit. Some individuals of a population which are more adapted to the range of environmental condition, increase in numbers. The relationship between them is expressed as **social behaviour.** The basic characteristic of a population is its natality (birth rate), mortality (death rate), immigration (dispersal), emigration and growth rate. These parameters are inter-related as follows:

## Biotic community

It is a group of interacting populations in a particular habitat. It is an assemblage of both plants and animals living in the same habitat and under the same environmental factors and mutually inter-dependent.

A biotic community has a diversity of species reflecting the nature of habitat and environmental factors. The diversity is greatest in small organisms. It is also the greatest in the tropics and as one moves to the north or south of it, the numbers decrease on a latitudinal gradient.

Communities usually exhibit stratification both on a vertical and horizontal plane, for example, a tropical rain forest, shows the following layers, from above downwards of trees (Fig. 23.26).

(A) Crowns only here and there in contact laterally, wider than deep 37 - 46m tall, isolated crowns are still taller and known as emergents.
(b) More continuous crowns with occasional gaps. Deeper than wide, 15 - 37m tall.
(c) Crowns very dense and almost without gaps, much deeper.
(d) Shrub stratum is very definite.
(e) Seedlings of trees, herbs, ferns etc.

The stratification of a forest has an effect on the variety of animal populations. The bird popula-tions inhabit the canopies of the emergents, never go below. **Lemurs, monkeys, squirrels** etc. feed in the middle layers while the herbivores feed on the forest floor (Fig. 20).

Aquatic ecosystems have the strata development based on light penetration as well as temperature and oxygen factors. The usual strata in lakes are **hypolimnion, metalimnion** and **epilimnion. Horizontal stratification** is caused primarily by the climate and local conditions, like edaphic conditions. It is noticeable around ponds and pools. There is no sharp transition between the communities, but rather they blend into one another in such a way that it is not easy to locate the ending of one and the beginning of the other community. Such a transition between two diverse biotic communities is known as **ecotone.** This zone contains individuals of both communities. The species diversity in the ecotone is known as **edge effect.** The examples of ecotone are between forest and grassland or a sea-shore which is ecotone between terrestrial and marine communities.

Scanned with CamScanner

## Ecosystem

Consists of interdependent communities of species and their **physical environment.** The extent of an ecosystem is imprecise; a single ecosystem may cover thousands of hectares or just a few. They include major natural systems such as grasslands, mangroves, coral reefs, wetlands, and tropical forests as well as agricultural lands. The ecosystem would be more stable if there is a greater species diversity. Some of the important features of the ecosystem are as follow:

1. **Population** is the major functional unit of an ecosystem. Exploitation of ecosystem leads to a decline of its maturity.
2. The ecosystem passes from a less complex to a more complex state. In a mature ecosystem the energy flows through more diverse channels.
3. The total energy flowing through the ecosystem depends upon the amount fixed by producers.
4. A considerable portion of energy is lost in each transfer from **one trophic level** to another.
5. The productivity of an ecosystem is the rate at which solar energy is fixed by the producers. The total stored energy content is known as **biomass**. It is in fact the total cumulative net productivity over a certain period. The ecosystem deteriorates when gross productivity is less than the respiratory rate. In a tropical ecosystem with no cold season, the gross productivity is 15 grams/sq m/day.

## Components of the ecosystem

There are two components of an ecosystem i.e. **abiotic** and **biotic**.

**Abiotic components** include inorganic elements and compounds such as water, carbon (IV) oxide oxygen, nitrogen, salts, heat, energy, light, winds, currents, pressure and moisture.

**Biotic environment** of an organism consists of other living organisms that are important in its life. Some of these are members of its own species. It is in the **abiotic matrix** that the biotic components (plants, animals and prokaryotes) interact.

## Aquatic habitat

It is an environment consisting of water, e.g. ponds, rivers, lakes, seas and oceans, mangrove swamps, lagoons and flooded rice fields.

Broadly speaking, aquatic habitats are divided into fresh and salt waters. Ponds, rivers, streams, and most lakes contain fresh water while seas and oceans contain salt water. There are three main conditions which distinguish freshwater habitat from marine habitat. These are:

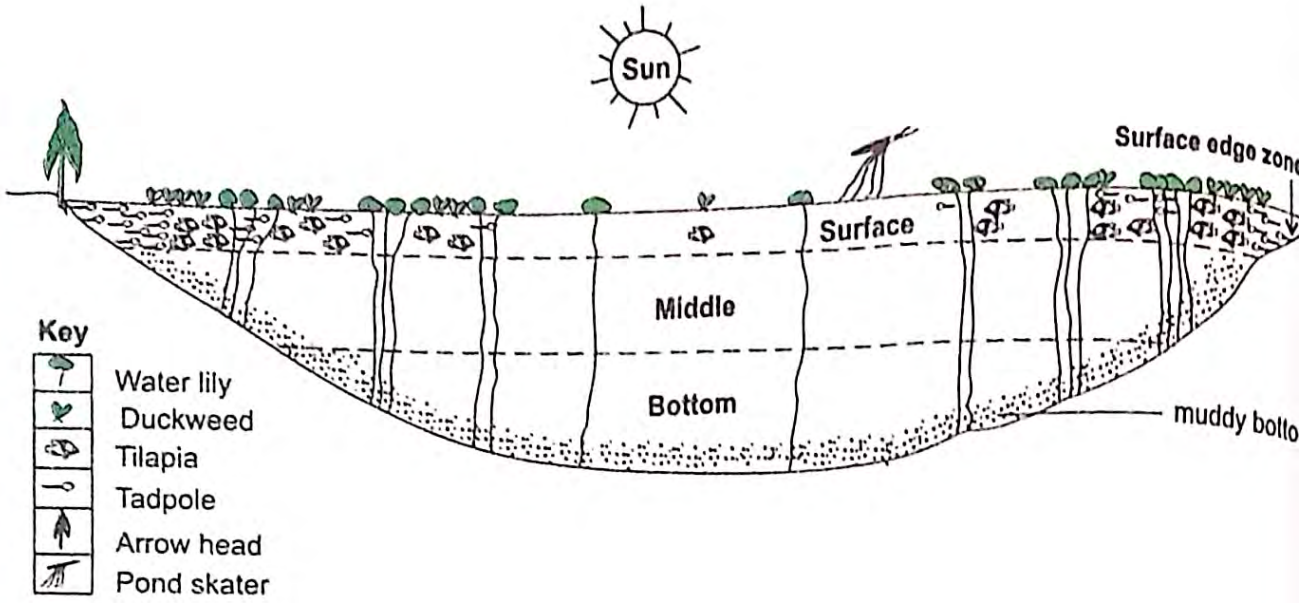
1. The salt content of fresh water is very low and that of marine is substantially high.
2. Strong, swift currents (except ponds, and large lakes) are common features of fresh water habitat hence fresh water plants are strongly rooted. Generally, marine habitat does not experience strong and swift current.
3. Climate and weather often affect fresh water habitats (except very large lakes) much more easily than marine habitat. For example, some bodies of fresh water dry up during the dry season. The temperature changes daily to a great extent.

## Fresh water habitats

### Ponds

Pond is used as an example of an aquatic habitat.

**Ponds:** ***Ponds are small bodies of shallow water having no or feeble currents.*** Ponds vary in size depending upon age and location. Many ponds have a great deal of vegetation increasing as the pond gets older. There is hardly an open water in the centre as the centre has been occupied by float-ing and rooted plants. The depth of ponds varies from few centimetres to 2.50 metres. The bottoms may be sandy or muddy depending upon the loca-tion. In a pond, four zones are recognized. These are: surface edge zone, surface zone, middle zone, and bottom zone.




## Zones in fresh water pond

### Surface edge zone

This is the marshy area around the pond. The water fluctuates, that is, it is subject to flooding and dryness: The organisms may be hydrated during the rainy season and in dry season, water may not be available. The organisms are therefore **amphibious** in character.

Plants such as **Sagittaria or arrow head, sedges** and **grasses, bamboo, white crinum lily** and *Ceratopteris* (fern) are found.

### Plants' adaptations e.g. arrow head

1. Well developed numerous fibrous root system for firm anchorage into the soft mud.
2. Numerous root hairs for absorption of nutrients from the soil.
3. Long petiole which raises the leaf above water so that the stomata are not blocked by water hence photosynthesis is not hindered.
4. The petiole has many air spaces which are used for efficient diffusion of oxygen to the underground stem and roots.
5. Reproduction is vegetative and by means of sucker.
6. There are numerous spines on the long petiole. These spines are protective in function.

   Animals usually found are water snakes, tree frogs, dragon flies and birds.

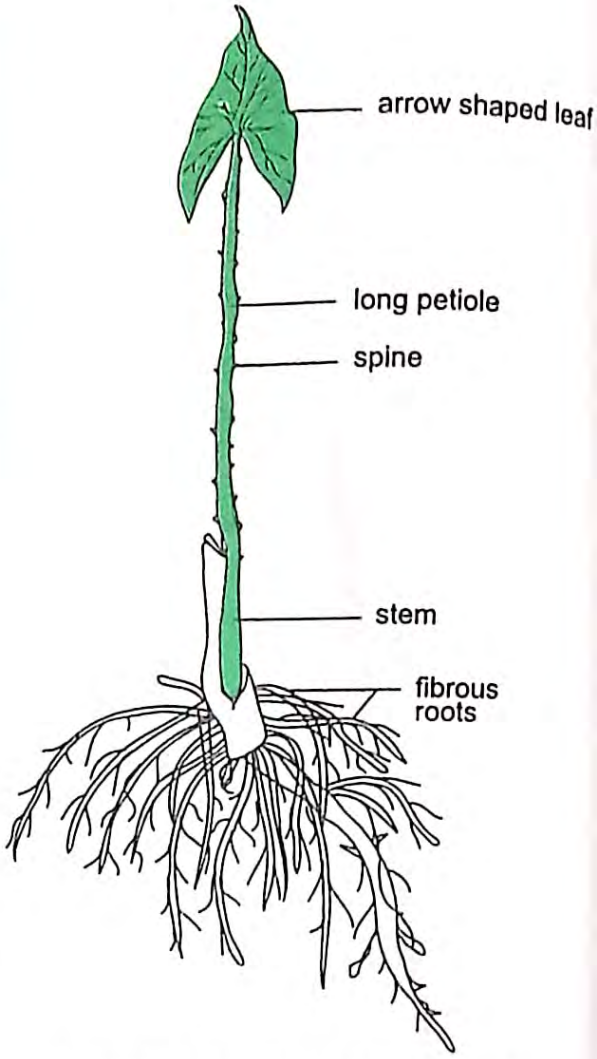



**Figure 23.3. Arrow head (*Sagittaria* sp)**

## Adaptations of animals

### e.g. water snake and tree frog.

### Water snake (Smith's water snake)

1. The two nostrils (for breathing) are placed on the head so that the nostrils are raised above water when the rest of the body is submerged in water.
2. The mouth is terminally placed for the capture of preys. The teeth are sharp for the same purpose.
3. The body is long and flexible, which helps for locomotion.
4. Protective coloration - The dark colour above and white below - gives a complete camouflage.
5. The scales are smooth and water repellent for easy locomotion in water.

### Surface zone

The surface zone of the pond is about 20cm deep. This zone receives sufficient light and is rich in oxygen and nutrients. The temperature is relatively high. Plants found in this zone are mostly the floating types such as: *Pistia* (Water lettuce), *Salvinia* (Water fern), *Lemna* (Duck weed) and water lily.

### Pistia (Water lettuce)

### Adaptations

1. There are hairs on the surface of the leaves which prevent water from staying on the surface of the leaves thereby preventing the blocking of the stomata, hence photosynthesis and respiration are not hindered. The hairs on the undersurface of the leaves reduce the density of the leaves thereby increasing buoyancy.
2. The air spaces found all over the plant (roots, stem and leaves) are for effective buoyancy.
3. The numerous adventitious roots and root hairs are used for absorption of water and mineral salts.
4. Reproduction is vegetative, by means of stolon.

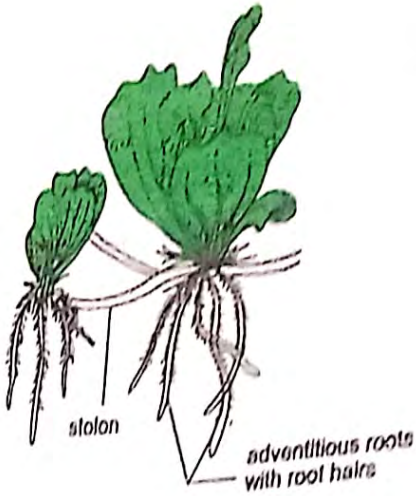



Figure 23.4. *Pistia stratiotes* (water lettuce).

### *Salvinia* (Water fern)

### Adaptations

1. The small size of the plant makes it light. The lightness helps it to float in water.
2. Reproduction is vegetative and is by means of fragmentation of the bud.
3. The numerous roots with root hairs are effective for absorption of water and mineral salts.
4. The hairs under the surface of the leaves reduce the density of the leaves thereby increasing buoyancy.
5. The air spaces present in the stem and roots aid buoyancy.
6. The leaves are green thus effective to carry out photosynthesis.

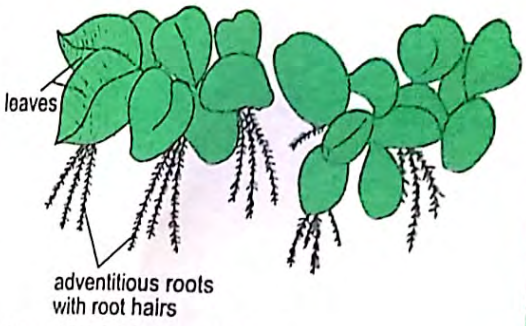



Figure 23.5. *Salvinia* (water fern).

### *Lemna* (Duckweed)

1. It is a small, light and flat floating plant. These features make it buoyant in water.
2. The leaves are adapted for absorbing water

and mineral salts hence the roots are poorly developed.

3. The upper surface of the leaf is waxy. This makes it water repellent thus preventing the clogging of the stomata with water hence photosynthesis and respiration are not prevented.
4. Reproduction is vegetative, by means of buds.
5. The green leaves are for photosynthesis.

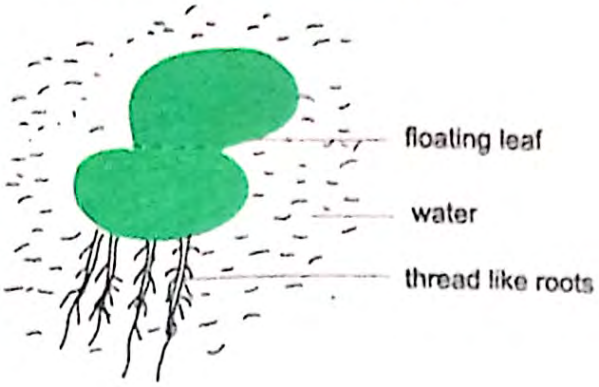



Figure 23.6. *Lemna* (Duckweed).

**Water lily (*Nymphaea lotus*)**

1. It has a long petiole which supports the broad lamina on the surface of the water for photosynthesis.
2. The long flexible petiole enables it to withstand the small wave action of the pond which may be caused by wind.
3. The upper surface of the leaf is waxy. This make it water repellent thus preventing the clogging of the stomata hence photosynthesis and respiration are not prevented.
4. The plant is firmly anchored by well developed and numerous adventitious roots. The roots have many root hairs for effective absorption of mineral salts and water.
5. The flowers are raised above the water surface by long flower stalk for the purpose of pollination by insects.

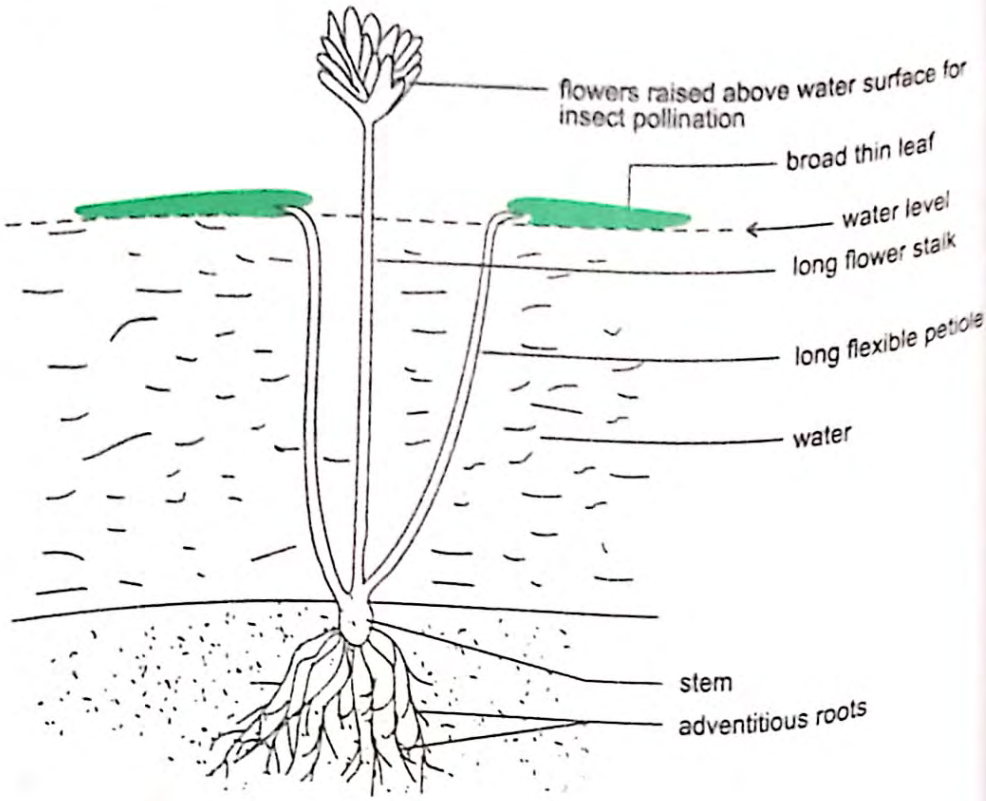



Figure 23.7. Water lily.

## Animals

Animals such as tilapia, tadpoles, pond skaters, zooplanktons, water bugs and mosquito larvae inhabit this zone.

## Adaptations

### Tadpoles

1. The body is streamlined for easy swimming in water.
2. The broad muscular tail is used for swimming and steering.
3. There are external or internal gills (depending upon the stage of development) used for respiration.
4. The skin is moist and is used for respiration.
5. The intestine is long, an adaptation for herbivorous feeding. At later development, the intestine becomes shortened. This is an adaptation for carnivorous feeding and preparation for terrestrial life.
6. The dorsal and ventral surfaces of the body are dark and silvery white respectively thus concealing the animal from predators above and below.

### Pond skater

1. The body is slender and very light. These features make it possible to stay on the thin surface of water without breaking it.
2. The middle and hind legs are thin and long. The front pair of legs are short and modified for holding food.
3. The middle pair of legs has terminal pads used for skating (sliding movement) on the thin surface of water. The hind legs are used for steering.
4. There are tracheae and spiracles for utilising atmospheric oxygen.
5. To avoid breaking the thin, long leg, the anal segments rest on water when the animal is motionless. This helps to reduce the weight of the insect which the thin legs would have carried.
6. The body is covered with exoskeleton which helps to prevent dessication.

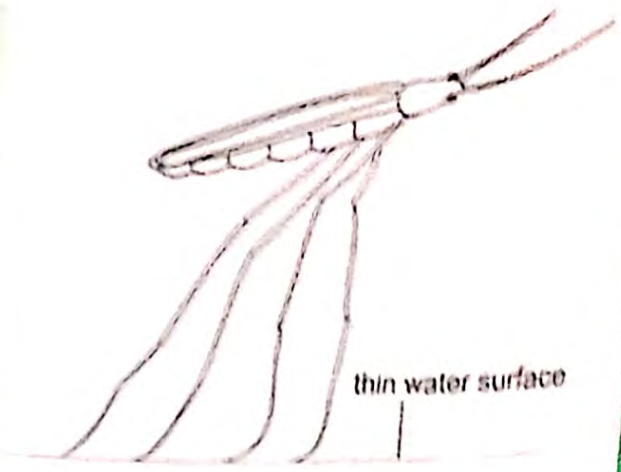



**Figure 23.8. Pond skater (*Gerris*).**

### Water bug

1. The body is slender and streamlined for easy locomotion in water.
2. The mesothoracic and metathoracic legs have bristles for swimming.
3. The prothoracic legs have claws for grasping.
4. It has a long siphon for breathing atmospheric air.
5. The body is light. This makes it easy for the insect to come to the surface to breathe atmospheric air.

**Figure 23.9. Water bug.**

### Mosquito larva

1. The worm-like body enables it to carry out wriggling movement to the surface of water to absorb atmospheric air with its siphon.
2. When its siphon has not been developed, the young larva absorbs oxygen from the water through the body.
3. There are mouth brushes for feeding on microscopic organisms.
4. The anal papillae absorb salt from the fresh water, thus helping in osmoregulation.

## Middle zone

The amount of sunlight reaching this zone is reduced. This is because the rays of light first pass through the surface zone and the organisms inhabiting this surface zone absorb much of the light. The temperature is relatively uniform. Water movement is highly reduced. The concen-tration of dissolved oxygen is lower and that of carbon (IV) oxide is higher than in the surface zone. Plants inhabiting this zone are *Cerato-phyllum (hornwort)*, *Utricularia*. (*Bladderwort*) and *Cratopteris*. These are completely submerged plants.

Animals inhabitants include fishes such as *Parachanna obscura* (snakehead), *Heterotis niloticus* (African bony tongue).

***Ceratophyllum* (Hornwort)**

1. It has many tiny, dissected green leaves to increase the surface area for efficient absorption of the low light for photosynthesis and oxygen for respiration.
2. The air spaces present in the stem are for buoyancy and storage of air.

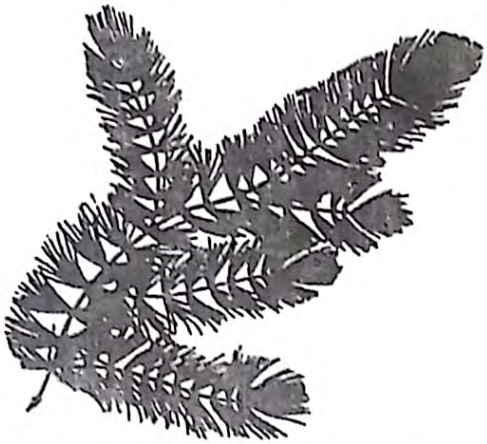


**Figure 23.10.** ***Ceratophyllum* sp. (Hornwort)**

***Utricularia* (Bladderwort)**

Adaptation are as in *Ceratophyllum* but, in addition, *Utricularia* has many floats to increase buoyancy. Flowers are raised above water surface for pollination.

Animal inhabitants include fishes (such as Tilapia), fresh water snails (on vegetation), insect larvae and hydroids (such as *Hydra)*.

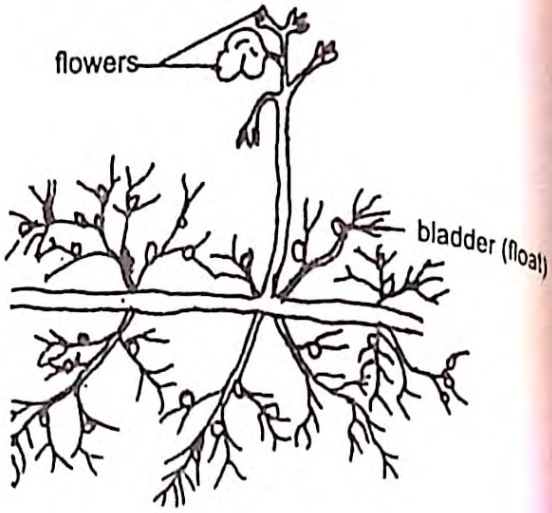



**Figure 23.11.** ***Utricularia.***

## Adaptations of animals

**Freshwater snails** (*Limnaea* and *Planorbis*)

1. The fleshy bodies are encased in conically and spirally twisted shells which protect them from being attacked by predators and parasites.
2. They have muscular feet for holding fast to vegetation and for creeping.
3. They have lungs for respiration.
4. The teeth-like structures in the mouth are used for rasping the aquatic vegetation.
5. They have eyes on the tentacles for seeing.

## Bottom zone

The light intensity is very low and not enough for photosynthesis. The zone is constantly dark.

Plenty of nutrients are accumulated as the water is relatively stagnant. The greatest concentration of carbon (IV) oxide and lowest concentration of oxygen occur here.

### Plant inhabitants

Roots of floating plants occur here.

### Animal inhabitants

Animals found here are leeches, worms, larvae (such as ***Eristalis* larva**) and fish such as *Clarias*, water snails such *Limnaea* sp. These animals are usually detritus feeders.

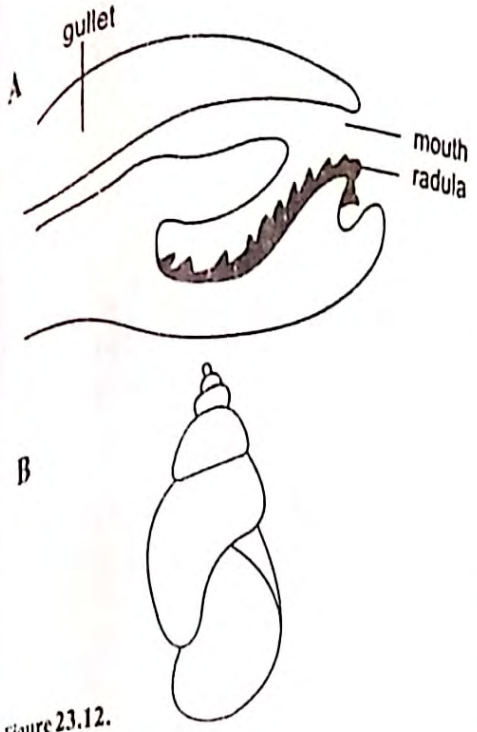



Figure 23.12.
A = Limnaea
B = Section through the head and mouth.

## Adaptations

### Leech

(1) Leech has anterior and posterior suckers. The anterior sucker is for blood sucking from its host while the posterior sucker is for firm attachment to the host.

(2) The skin is thin and oxygen can diffuse in for respiration.

(3) The dark and dark brown bands coloration are for camouflage.

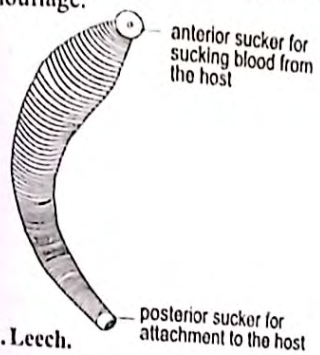



Figure 23.13. Leech.

## Swamps

Swamps are found in sheltered regions of lakes, rivers, at the edges of standing water and in hollows. The vegetation consists of erect monocotyledonous plants such as, species of *Phragmites* and *Cyperus*, *Typha* and *Vossis*. The roots of these plants are submerged while the shoots stand well above the water. The roots shoots that are covered with water have air spaces to aid aeration. Large trees are less common. The common trees of swamp region are *Raphia spp* and *Anthocleista vogelic*.

## Characteristics of swamp

Characteristics of Swamps

1. The land is low lying and forms a belt along coast line of big rivers.
2. The soil is always wet with some parts permanently water-logged
3. The soil is poorly drained
4. The soil is poorly aerated
5. The environment of swamps has very high relative humility.
6. Swamps are found in areas of heavy and frequent rainfall.
7. Swamps are flooded periodically
8. The soil along swamps is very unstable/shifting mud banks and can only support plant with special adaptive feature.
9. The Swamps environment is acidic
10. Light penetration in swamps is very low
11. Low diversity of species in swamp
12. Plants have still roots.
13. Plants have breathing roots.
14. Decomposition of plant litter/organic matter is rapid

## Types of swamp

There are two types if swamps. These are salt water and freshwater swamps.

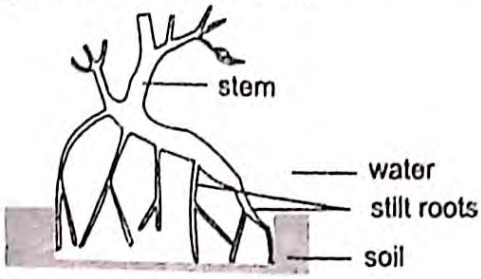
### 1. Saltwater swamp

The water in this swamp is saltwater from the sea. The soil is salty as well. Salt water swamp forms a belt along the coast of Nigeria stretching from Lagos State through **Ondo, Edo, Delta, Rivers, Cross River** to **Akwa Ibom** States. The salt water swamp lies in the rain forest zone where there is heavy rainfall and many large rivers. During the rainy season, the rain water and river floods dilute the salt water from the sea. In the dry season, salt water swamp becomes very salty again as sea water flows into it during high tide.

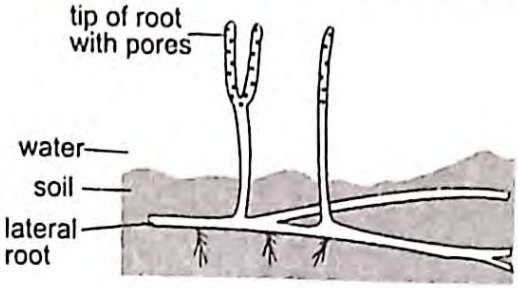
## Plants living in the saltwater swamp

The common trees of the saltwater swamp include coconut palms and white mangrove *(Avicenia nitida)* towards the sea shore and the red mangrove *(Rhizophora racemosa)* away from the shores. The white mangrove develop numerous

breathing roots *(pneumatophores)* about 30cm high above the soil level. The red mangrove develops many stilt roots from the main stem and branches. Breathing roots and stilt roots make it difficult to walk through saltwater swamp forest.




**Red mangrove** *(Rhizophora racemosa)*




**White mangrove** *(Avicennia nitida)*

**Figure 23:14. Some common plants inhabiting mangrove swamp forest.**

## Animals that live in the saltwater swamp

Animals found in the saltwater swamp are *Tilapia guineensis, Tilapia melanopleura, oysters* attached to the stilt roots of the red mangrove, barnacles crabs, birds (e.g. heron) and mosquitoes.

## Adaptive features of plants

1. Coconut palm develops fibrous roots for firm anchorage and absorption of water. Fibrous roots prevent flood from washing away the palms.
2. White mangrove develops breathing roots out of the waterlogged soil to absorb atmospheric air to solve oxygen shortage in wet soil.
3. Red mangrove develops stilt roots for firm anchorage to the soil to prevent it being washed away by tidal waves.
4. Saltwater swamp plants store water in succulent stems and leaves to dilute the salts that enter their bodies.
5. Seeds of the mangrove germinate on the branches (viviparous) before they drop to the water-logged soil. This helps to avoid failure to germinate in the water-logged soil.

## Adaptive features of animals

1. The fish drink the salt water and secrete the excess salts through the gills and pass plentiful urine to maintain body fluid close to surrounding salt water.
2. The crustacea such as the crabs and barnacles secrete excess salts with their antennal glands.
3. Animals that cannot tolerate wide ranges of salt concentration are restricted to the lagoons and higher up the creeks.

## Freshwater swamp

Freshwater swamp is formed by flood from rivers and rainfall. It occurs in inland beyond the influence of tides of the sea. It is inhabited by plants and animals adapted to life in freshwater habitat. It lies in the zone of heavy rainfall with very high relative humidity.

## Plants in the freshwater swamp.

Shrubs and climbers form thick bush here and there. Trees scattered among the bushes are oil palm trees, raphia palm trees, *Alstonia* and *Spondiathus*. The stagnant water contains floating and submerged plants such as algae, *Salvinia*, duck weed, water lettuce, bladderwort *(Utricularia)* and *Hydrilla*.

## Animals that live in the freshwater swamp.

Some animals found in the freshwater swamp include water birds, water snakes, aquatic insects, toad and frogs, fish, water snails, crabs, earthworms, leeches, mosquitoes, insect larvae and pupae.

## Adaptive features of plants and animals in the freshwater swamp.

1. Swamp plants develop large interconnecting air cavities which store air that enter the bodies through the leaves and stems. This enables them to live in the oxygen deficient medium.

2. Excess water in the bodies of the plants is excreted through hydathode on the lips of their leaves at night. This process is known as guttation.

## Marsh

The marsh is a low, flat land completely or partly covered by shallow water with silt frequently deposited. The water is about knee deep in most parts while it is less in many other places. Marsh is thickly covered by stiff water grasses. Trees are almost absent. Water birds and insects are common in the marsh.

## Characteristics of the marsh.

1. The soil is always covered with water (water-logged).
2. The water and soil are poorly aerated as the dissolved oxygen is constantly being used by micro-organisms (bacteria and fungi) for decay processes.
3. The land is low lying and flat.
4. The vegetation is mainly stiff water grasses and other low herbs.
5. The fauna is dominated by water birds, water insects and water snakes.
6. The water is usually shallow about 60 - 70cm deep.
7. Light penetration is low because of decaying organic matter in suspension.

## Types of marshes

There are two types of marshes based on their life span. They are **temporary** and **permanent marshes.**

**1. Temporary marshes**

Temporary marshes are seasonal, occurring during the rainy season and drying up in the dry season.

**2. Permanent marshes**

Permanent marshes contain water throughout the year. They are close to the rivers or seas which serve as permanent water source.

## Formation of marshes

Marshes are formed by water flowing into a flat lowland from a flooded river. The clay soil holds the water while the vegetation cover of grasses and lilies help to reduce evaporation.

Marshes may also be formed by debris uniformly filling the bottom of ponds or lakes thereby introducing grasses and lilies into them, with water birds, aquatic insects and water snakes migrating into them later.

## Plants that live in marshes

The plants that live in the marshes are mainly *rooted grasses, lilies* and *floating ferns*. There are usually no trees in the marshes. The grass growing right in the marsh is *Vossia cuspidata* on which the water birds build their nests. The floating plants are duckweed, water lily, water lettuce, *Salvinia, Azolla* and algae.

## Animals that live in marshes

Animals that live in marshes include water birds, aquatic insects, water snakes, worms (such as earthworms), leeches, frogs, tadpoles, crabs and larvae of insects.

### Adaptive feature of plants

1. The grasses grow in large bunches or tussocks to avoid being washed away by water movement.
2. Their leaves are long, narrow and held high above water for atmospheric gaseous exchange to compensate for poor aeration of the water-logged soil.
3. The algae, *Salvinia, Azolla* and duckweed are on the surface to receive both atomospheric and dissolved oxygen to meet their oxygen requirements.

### Adaptive features of animals

1. Worms, crabs and bivalves burrow into the soft mud to avoid high temperatures and drying up.
2. Insect larvae, beetles and frogs come near the surface from time to time to gulp atmospheric air to survive the low oxygen content in the water.

## Characteristics of marshes

1. Low and habitat covered with water (if permanent) but dry up during the dry season (if temporary).

2. Soil is soft making difficult for big animals to move.
3. The vegetation is mostly dominated by grasses.
4. Dissolved oxygen content is low due to decay of organic materials, by aerobic micro-organisms (bacteria and fungi) using the oxygen in the process.
5. The contents of mineral salts is high.

## Mangroove swamp forests

They are found in tidal lands. The vegetation consists of evergreen trees and shrubs. The common trees are **Rhizophora** sp. (red Mangroove), *Avicennia* spp., *Conocarpus* and *Laguncularia*. The fern *Acrosticum aureum* is predominant on the landward margin of the mangroove. In relatively dry climates the *Aerostichum* patches may be replaced by a moist saline meadow community of *Paspalum, Kyllinga* and *Sesuvium spp.*

## Estuary

Estuary is an example of local biotic community of biomes. It is the point where a big river enters the ocean. Here salt water from the ocean mixes with fresh water from the river to form an **intermediate water known as brackish water**. The salinity of estuary fluctuates with distance from the ocean with high and low tides and with dry and rainy season.

## Characteristics of an estuary

1. Broad mouth of the river making the coast line to push inland form a bay.
2. It is shallow as the river brings in sediments that pile up yearly.
3. The bottom is made up of soft mud.
4. The water is brackish, that is the salinity is intermediate between the fresh and salt water.
5. The volume of water rises with high tide and falls with low tide.
6. There is usually no wave action.
7. Estuary has restricted number of organisms because of the strong zonation as follows.
   (a) The zone near the sea is marine and is inhabited by marine organisms only.
   (b) The inland zone is freshwater and is inhabited by freshwater organisms as well.
   (C) The zone in-between is the true estuary made up of brackish water and inhabited by estuarine organisms.
8. The habitat is flooded and exposed as the tide rises and falls.

## Plants and animals living in an estuary.

The plants are phytoplankton, mud-flat algae, marsh vegetation and the epiphytic plants. Algae are mostly of marine origin, the marsh vegetation consists mainly of *Spartina, Salicornia, Scripus* and *Thalassia*. The animals are oysters, clams, crabs, lobster, crustacea, anemones, annelids, shrimps and fish.

In Nigeria, swamps/estuaries are found in coastal zones of Lagos, Ondo, Ogun, Edo, Delta, Rivers, Akwa-Ibom and Cross River States.

water lettuce

Hairy mangrove crab (*Sesarma huzardii*)

*Egeria paradoxa*

*Tilapia guineensis*

Mudskipper (*Periopthalmus koelreuteri*)

# Marine habitats

The oceans or seas and their shores constitute a **marine habitat**. Marine habitat contains only salt water. However, salt water lakes are also classified as marine habitat. Oceans and seas occupy more than **two thirds** of the earth's surface.

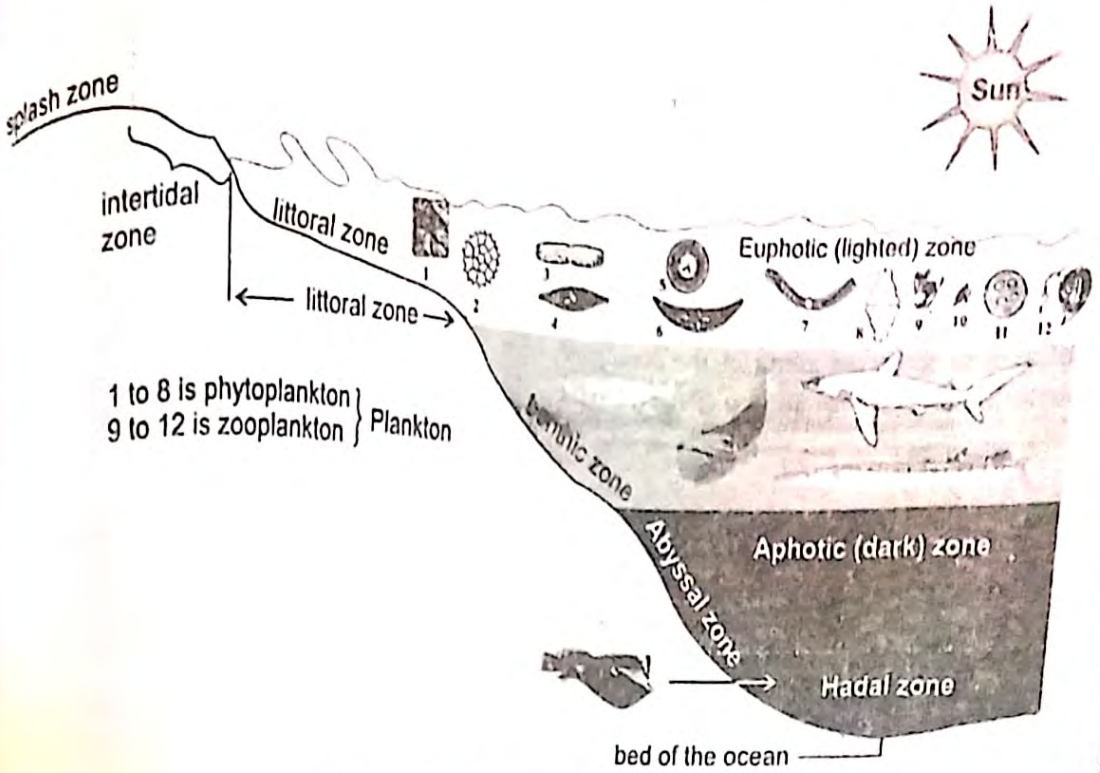



Figure 23.16. The zones of the ocean.

## Characteristics of the marine habitat

### Temperature

The surface temperature of the ocean in the tropics ranges from 29 to 31°C while at the bottom (about 16 000m) the temperature is about 4°C.

### Salinity

The salinity of the ocean water is high. The average salinity is 35 parts of salt by weight per thousand parts of water (usually abbreviated as 35°/00). The most abundant salt is sodium chlo-ride. Other salts are those of calcium, magnesium, potassium, phosphorus and manganese.

### Pressure

Water pressure increases at 1 atmosphere at the surface to **1000 atmospheres** at the bottom.

### Turbidity and light penetration

The turbidity of the ocean water is high due to the suspended particles washed into it from land and rivers. Due to the high turbidity, light can only penetrate to about 200 metres.

### Density

The density of the ocean water is **1.028** while that of pure freshwater is **1**.

### Dissolved gases

Oxygen and carbon dioxide are the common dissolved gases. More oxygen is dissolved at the surface water due to the wave action at the surface and green plants (phytoplankton) which carry out photosynthesis leading to the release oxygen to the water. At the bottom of the ocean, oxygen is absent.

### pH (Hydrogen-ion concentration)

The pH of the surface water ranges from 8.0 to 8.5.

### Currents

Oceanwater is always moving towards a parti-cular direction. This directional movement is called **current.** Current is caused by winds, rotation of the earth and differences in water density between one part of the ocean and another.

### Waves

The ocean is often subjected to wave action. Waves are undirectional movements of water caused by the blowing of winds against the water surface. Waves help to mix up the surface water with oxygen and circulate it to the other zones of the ocean and nutrients from **hadal zone** are also circulated to the surface.

### Tides

The rise and fall of the ocean water twice a day is called **tide.** Tides are caused by the **gravita-tional pull** on the earth. During high tide, lagoons and estuaries are filled with water while in low tides the water levels fall drastically. Tides have effects on the lives of organisms living in lagoon and estuaries.

## The major ecological zones of marine habitat and their characteristics

An ocean is divided into distinct ecological zones, namely:

1. **Splash** (supratidal) zone;
2. **Intertidal** (euphotic or neritic) zone;
3. **Littoral** (euphotic, subtidal) zone;
4. **Benthic** (diphotic or bathyal) zone;
5. **Abyssal** (aphotic) zone and
6. **Hadal** (aphotic) zone.

### Splash zone

Splash zone is not a part of marine habitat instead it is a land habitat. As the strong waves of the ocean hit the shores, water splashes to the land and wets the splash zone. It is exposed and usually moistened by the splashed water.

### Plants in splash zone

***Sesuvium portulacastrum***

*Sesuvium portulacastrum* is a halophyte. It is a succulent plant with reduced thick leaves for water conservation. As a plant living in a salty soil, the surplus water contained in its body helps in dilu-ting the excess salt entering the plant. *Sesuvium* and many other halophytes are found growing in the margin of splash zone. It also possesses chloroplasts for photosynthesis.

### Animals in splash zone

Crabs such as ghost crab and sand crabs are the common animals.

**Adaptive features of crabs**

1. They dig holes (burrows) into water level which they stay and this helps to prevent them from being preyed upon by predators. Staying in the burrows also protects them against strong waves.
2. Possession of gills help them to absorb oxygen when covered with water.
3. Possession of lung-like tissue helps them to absorb atmospheric oxygen when on land.
4. They possess powerful chelipeds for seizing food.
5. The body is covered with exoskeleton that prevents dessication on land.
6. The body fluid is isotomic to the sea water, that is, the body fluid has the same concentra-tion as the ocean water so that the body fluid does not lose or gain water by osmosis.

**Figure 23.17. Crab (Courtesy F.A.O).**

### Intertidal zone

Intertidal zone is exposed to drying conditions of the air at low tides and covered by water at high tides. This zone receives abundant sunlight and photosynthetic activity by green plants is high hence high food production. Water temperature fluctuates greatly. It is about 150-190 metres deep.

### Plants

Plants that inhabit this zone are algae (e.g. Kelp and Sargassum).

**Adaptive features of Kelp**

*Kelp*: This is a giant algae.

1. Possesses holdfast for anchorage into the soil.
2. The thallus contains bladder filled with air that functions as floats and gives it buoyancy.
3. Possesses chloroplasts for photosynthesis.

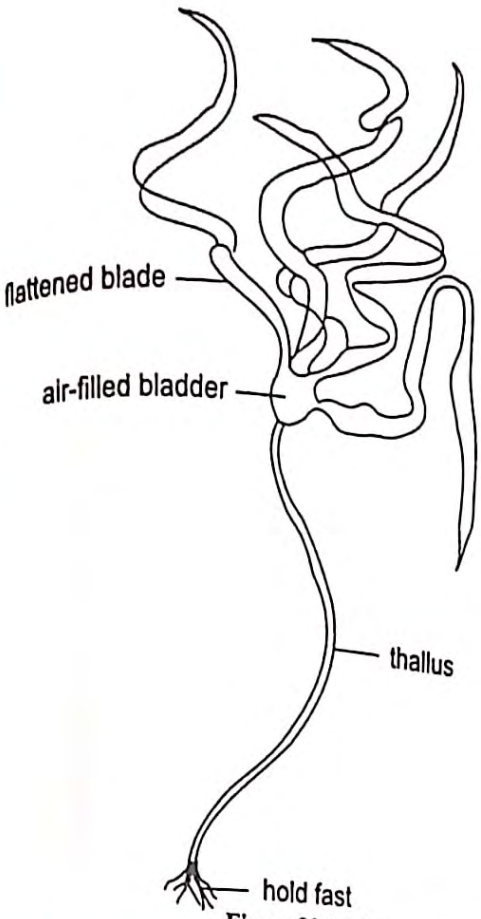
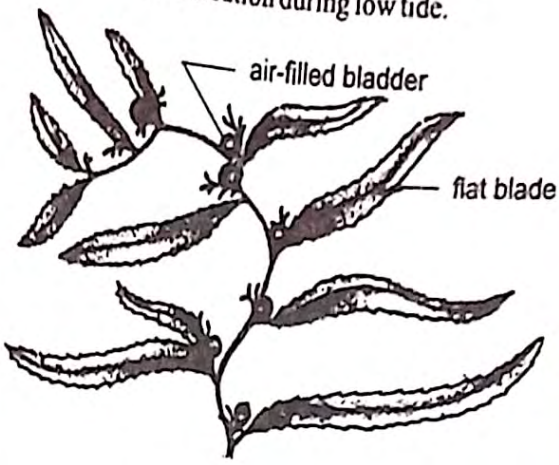
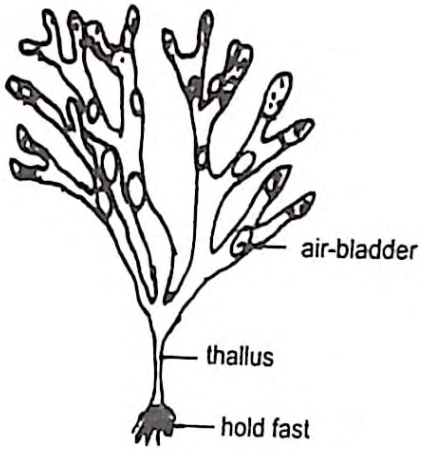



**Figure 23. 18. Brown algae.**

**Sargassum and *Fucus***

1. Possesses chloroplasts for photosynthesis.
2. Air bladders are present for buoyancy and drifting.
3. Possesses hold fasts for firm attachment to the substratum.
4. The body is covered with mucilage which reduces dessication during low tide.




## Animals

Animals such as barnacles, crabs, sea anemones, periwinkles and starfish inhabit this zone.

**Adaptive features**

**Barnacle**

1. Possession of basal disc for strong attachment to substratum such as rock during low tide.
2. Its shell prevents dessication during low tide.
3. During low tide, the mantle clamps down tightly to a substratum in such a way that water is retained in the mantle for respiratory activity and to prevent dessication.
4. It possesses cilia for filter feeding.

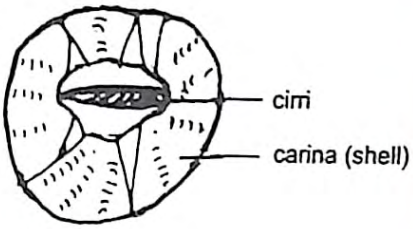



**Figure 23.19. Barnacle (*Balamus*).**

## Crab

Same as adaptive features already described for crabs of splash zone.

**Sea anemone**

1. It has a holdfast for attachment to substratum such as rock.
2. Its body is covered with tough leathery skin that can bend by waves without being broken.
3. Mouth is equipped with tentacles containing nematocysts for capturing prey.

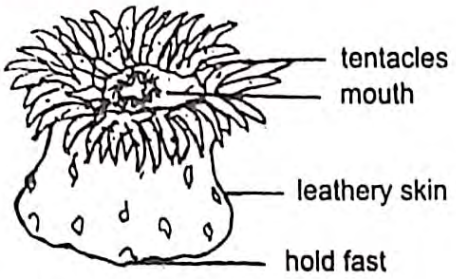



**Figure 23.20. Sea anemone.**

**Periwinkle**

1. It possesses lungs for breathing atmospheric air at low tide.
2. It uses its foot for attachment to substratum at low tide.
3. Its shell prevents dessication at low tide.

**Figure 23.21. Periwinkle.**

**Littoral zone (euphotic zone: receives direct light)**

This area of the ocean covers the continental shelf. It is about 200 metres deep. It is always covered with water. It receives sufficient light. Photosynthetic activity by green plants is high.

**Benthic zone (diphotic zone: receives dim light)**

This zone starts from the end of continental shelf to about 2000 metres. This zone receives **dim light**. This is the beginning of the deep ocean and water movement is slight. Photosynthetic activity is low and restricted to the upper level.

**Abyssal zone (aphotic zone: receives no light)**

This zone starts from the end of benthic zone to about 2500 metres. The water is uniformly cold and Quiet, with high pressure and no light penetration. Primary food production is by chemosynthesis.

**Hadal zone (aphotic zone: receives no light)**

This zone is the bed of the deep ocean. It may be about 3000 to 4000 metres deep. Light penetration is zero. The water is uniformly very cold, quiet with high pressure and little dissolved oxygen brought in by wave action.

**Adaptions of animals**

9. **Wide mouths:** Fishes have wide mouths fully equipped with long and sharp teeth. When the mouth is opened, prey can unknowingly swim into it and easily captured and tightly held by the sharp and long teeth without escaping. Many of these fishes can swallow fish bigger than themselves.
10. **Large stomachs:** The fishes usually have large stomachs to store as much food as possible when available since food is scarce in this zone.
11. **Bioluminescence:** Since the animals living in this zone are blind, some of them possess light-producing organs (luminescent organs) of different sizes and shapes in different species. These light-producing organs produce light of different colours depending upon the species. The colours may perform the following functions:
    (i) Recognition of their own species for mating purposes.
    (ii) Luring of prey into the mouth for food. For example, an angler fish (*Melanocoetus johnsoni*) carries a lantern-like bioluminescent organ on top of its snout. An inquisitive prey attracted by the light is captured.
    (iii) Warning intruders or enemies of the danger of coming near.
12. **High pressure:** Due to high pressure in this zone, animals have developed high pressure sense to help them recognise turbulence created by other animals possibly prey. The turbulence created by prey helps to locate its direction for capture.

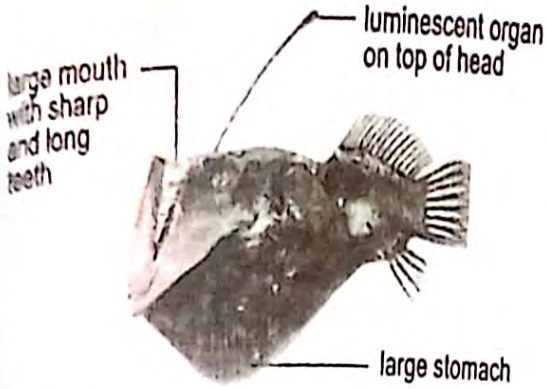



Figure 23.22. Angler fish (Courtesy American Museum of Natural History).

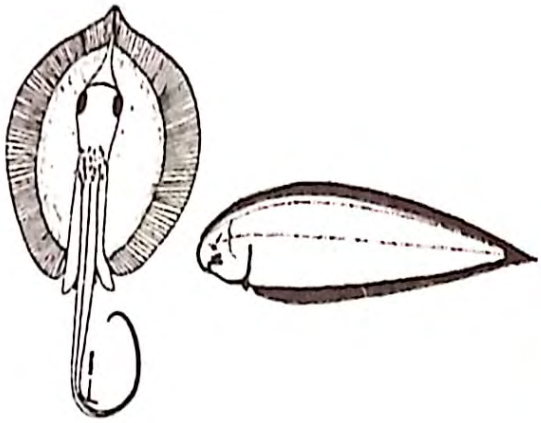


Figure 23.23. Cartilaginous fish.

## Fish

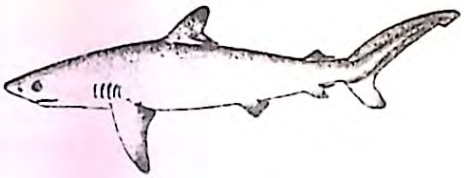
Apart from the general adaptations of fish to aquatic environment already stated in this book, both **cartilaginous** and **bony** fish have the follow-ing additional adaptations to cope with the high salinity of the ocean.

### Cartilaginous fish

Dog fish, sharks and sting rays are examples of cartilaginous fish.

**Adaptations**

1. The blood of cartilaginous fish contains **urea**. Urea raises the osmotic concentration of the blood slightly higher than that of marine water. Therefore water is not lost from the blood of the fish by osmosis.
2. There are glandular cells at the **rectum** that excrete excess salts from the blood so as not to over increase the salinity of the blood than that of the marine water.



### Bony fish

**African brown snapper, sardine** and **baracuda** are examples of bony fish.

The marine water has higher salinity than the blood of bony fish. Therefore fish constantly lose water through the gills to the marine water by osmosis. Excess salts resulting from drinking of the ocean water accumulate in the blood of the fish.

**Adaptations**

1. They drink the ocean water almost continuously to replace the water they are losing by osmosis.
2. Excess salts ingested with ocean water and food are eliminated through special cells called **chloride cells** located in the gills.

Figure 23.24. African brown snapper.

## The biomes (local biotic communities) of Nigeria.

### Terrestrial habitats

This is an environment consisting of the ground on earth such as **forest, grassland, uncultivated land** and a **fallow farmland.**

## Tropical rain forest

1. This is a type of vegetation consisting primarily of **woody plants** (trees, shrubs, herbs and climbers) and **grasses** are conspicuously absent.
2. In a forest, tree crowns touch and cast a deep shade upon the ground.
3. Tropical rain forest zone receives abundant rainfall (2000 - 4000 mm annually), dry season is never less than three months.
4. Temperatures are high (26 - 28°C) with an average humidity of 80%.
5. Tropical rain forests are rich in species diversity.
6. The trees in tropical rain forest have straight slender trunks with branches mostly near the top. At the base, the trunks of some of the trees have buttresses.
7. The trees often have thin, smooth barks without conspicuous fissures or lenticels.
8. Leaves tend to be large, leathery and dark green with entire or nearly entire margins, and are simple with extended drip tips. Occasionally young leaves are brightly coloured, being either reddish or whitish in colour.
9. The flowers are often small, inconspicuous and of greenish or whitish in colour. It is rare to find large and strikingly coloured flowers on tropical forest trees.
10. Tropical rain forest trees show great variation in height which is reflected in the layering of their crowns into three or occasionally two layers, apart from the shrub and herb layers (fig....). The **climbers** and **epiphytes** are abundant in rainforest (Fig.). The climbers consist of a high proportion of woody varieties (lianes), whose stems can attain as great a size as that of the thigh of man, and can be extremely long, and may either hang down in festoons on the trees or climb to the canopy. Among the **epiphytes** are **mosses, orchids** and **ferns** like *Phymatodes, Platycerium.* Among the tree top epiphytes are the semi-parastic ***mistletoes*** (*Loranthus spp*) as well as the **stranglers**, most of which are species of *Ficus.*
11. The structure of the tropical rain-forest is made up of five layers, with each layer having its unique plants and animals. The five layers are:- **upper layer** (emergents), **middle layer** (canopy), **lower layer** (canopy), **shrub layer** and **forest floor**.

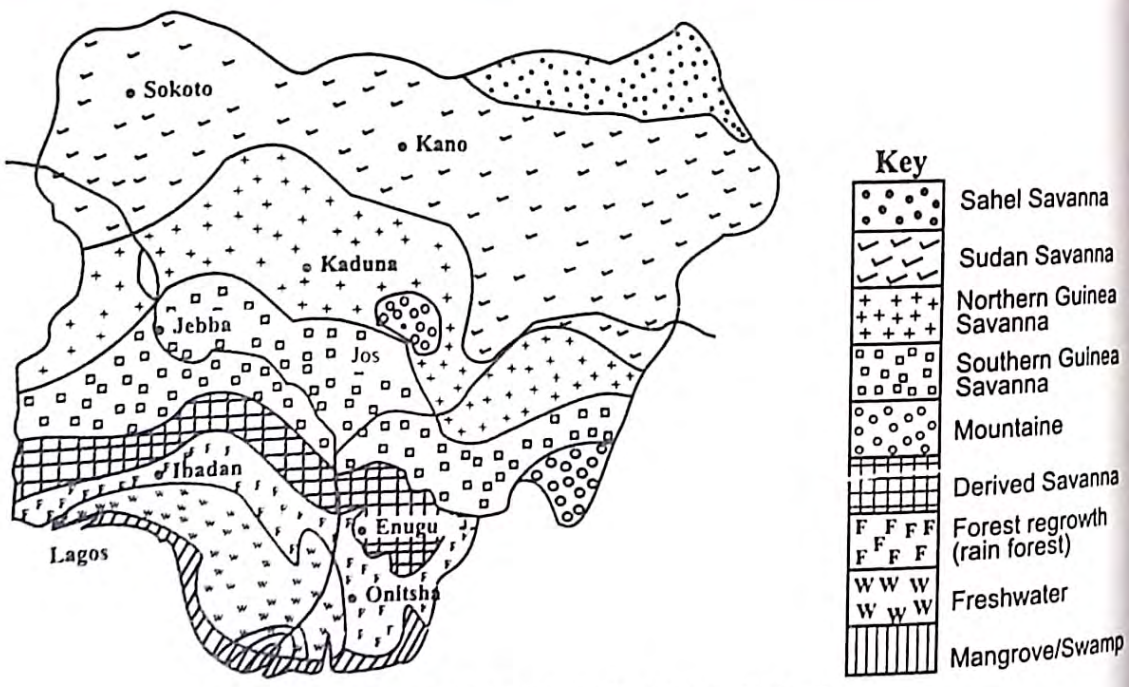



Figure 23. 25. The major biomes of Nigeria

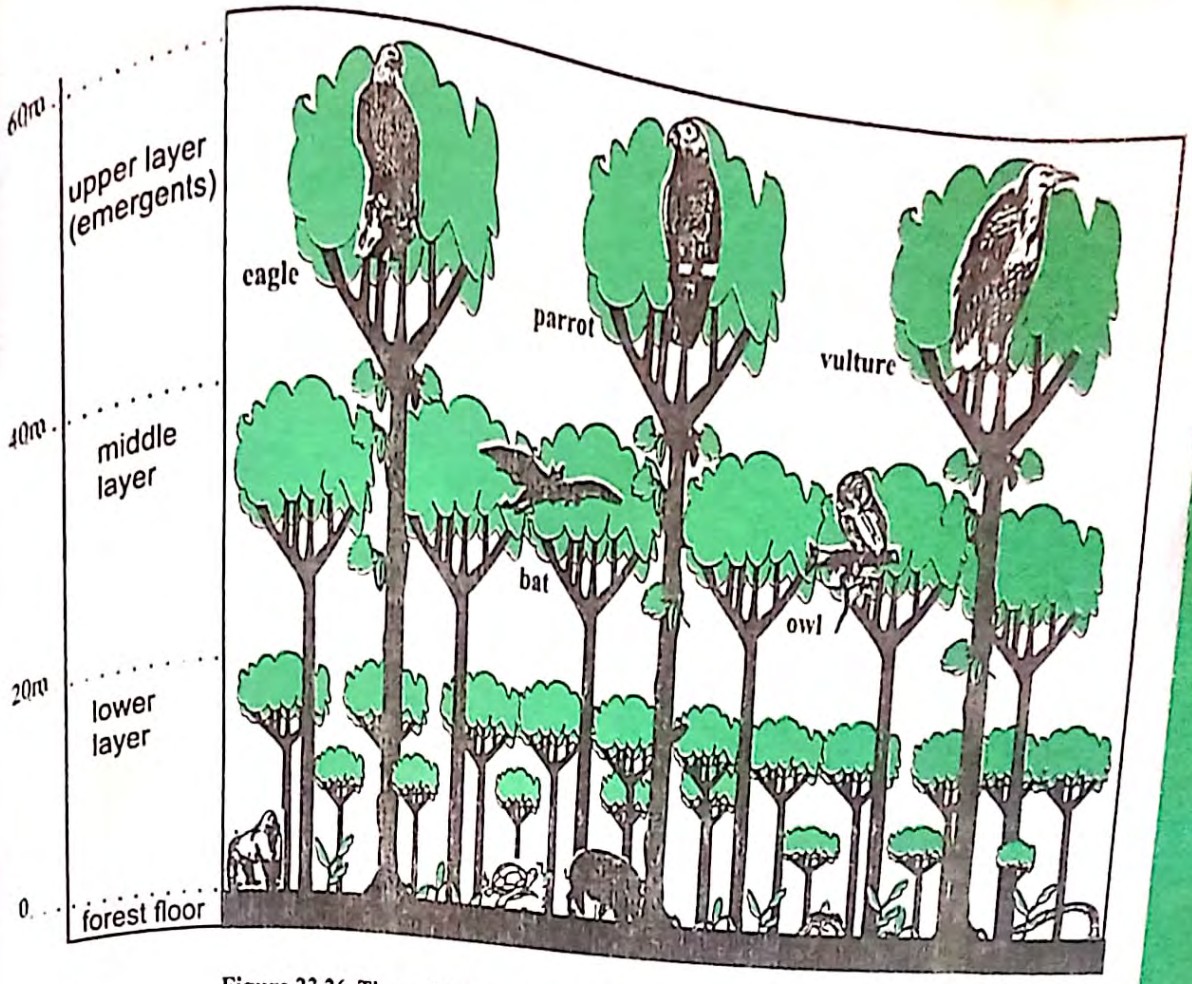



**Figure 23.26. The profile of tropical rain forest showing stratified vegetation.**

(a). **Upper layer (emergents)**

This layer is made of giant and tall trees (from 40m - 60m) which push up through the middle canopy forming a **discontinous layer.** The trees enjoy the best of sunlight. Mahogany is an example of a giant tree in this layer. High flying birds such as eagles, parrots and vultures are found here.

(b). **Middle layer (canopy)**

This consists of tall trees of about 33 metres forming a **continuous canopy**. These trees forming canopy have long slender **trunks** and **rounded crowns**. The trees are bound together by large **climbing plants** and creepers. Forest birds (hornbills, parrots and owls), monkeys, bats and butterflies abound here.

(c). **Lower layer (canopy)**

Short trees reaching the height of 10 - 15 metres inhabit this layer. Their crowns are narrow in proportion to their height, an adaptation which enable them to take the maximum advantage of the sunlight that penetrates the canopy. Light penetration is little as the dense canopy prevents much of the sunlight. Due to keen competition for light, this layer is **discontinuous**. It becomes dense except for some breaks in the canopy either due to the death of a big tall tree or when such a tall tree is felled. Monkeys, civets, bats, snakes, lizards, treefrogs abound here.

(d). **Shrub layer.**

The plants in this layer are shade-loving. They are small but fully-grown. Their leaves are large with colourful flowers.

(e). **Forest floor.** This layer consists of **herbs, ferns** and **fungi**. Ferns like *Pteridium aquilinium* (**bracken fern**) and tree fern (*Cyathium*) are common. There are numerous woody climbers or lianes. Many lianes reach up to the canopy and grow from tree to tree reaching the length of several metres. Epiphytes are numerous and attached to trees, among the epiphytes are mosses, orchids and ferns like Phymatodes and *Platycerium*. Many

epiphytes are adapted to life in this layer by having **spongy roots** and **cup-shaped leaves** to trap **moisture** and **fallen debris**.

The soils are composed of red clay called **laterites**. In many cases, when laterite soils are cleared, they either erode rapidly or form thick, impenetrable crusts which cannot be cultivated after a season or two. Tropical soils are generally deficient in minerals and those minerals that are present are leached out by heavy rainfall. As a consequence, soils where tropical forests have stood are very poor agriculturally. There are three formations of tropical evergreen forest: the **American**, the **African** and the **Indo-Malayan formations**. The American formation covers the Central American mainland and the wetter parts of West Indies. The African formation covers a lowland basin of Congo and extends as a belt along the coast of West Africa. The Indo-Malayan formation occurs over the East Indies, Malayan and Vietnam.

Some animals that inhabit forest floor are the **ants, millepedes, tortoise, ant-eating pangolin, bush cows, red river hogs( bush pigs) elephants, baboons** and **gorillas**.

In Nigeria, the tropical rain forests are found in **Edo, Delta, Ondo, Ogun, Imo, Rivers, Bayelsa, Akwa Ibom and Cross River States**.

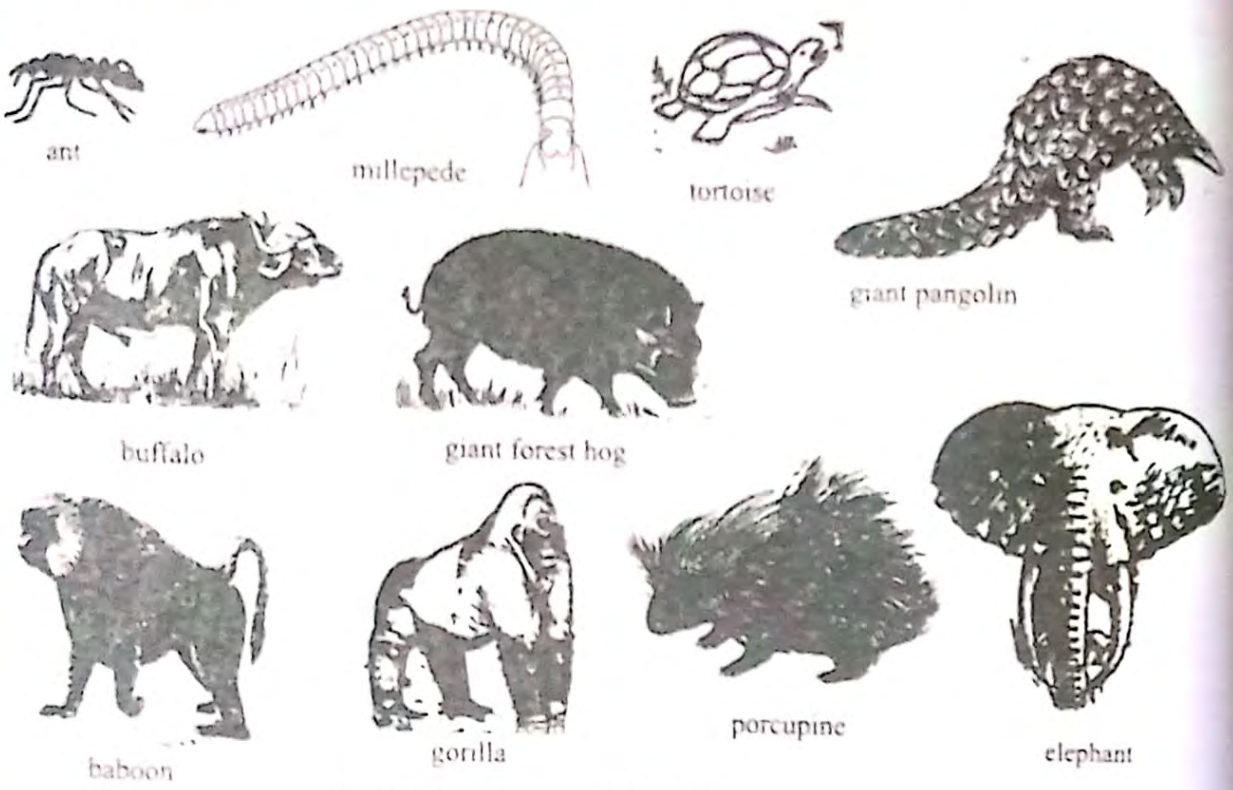



**Figure 23.27. Some animals that inhabit the forest floor.**

## Adaptations of some tropical rain-forest plants

*Ceiba pentandra* (**Silk cotton tree**)

1. It has well developed buttress roots to support the large and tall trunk.
2. There are spines on the trunk and branches which help to protect the tree from being browsed by animals. The spines are injurious to climbers and stranglers.
3. The leaves are small and many. The smallness of the leaves helps the leaves from being damaged by the strong action of the wind above. Many leaves give it large surface area to receive more light for photosynthesis.
4. The seeds are small and light and covered with mass of white cotton called floss. The floss helps the seeds to be dispersed by wind.

**Phymatodes (epiphytic fern)**

1. There are numerous roots for absorption of water and attachment to its host.
2. The succulent stem helps as water storage organ.
3. The leaves are leathery and deeply serrated, an adaptation to reduce the force of the wind. The waxy nature of the upper cuticle of the leaves helps to reduce loss of water by transpiration.

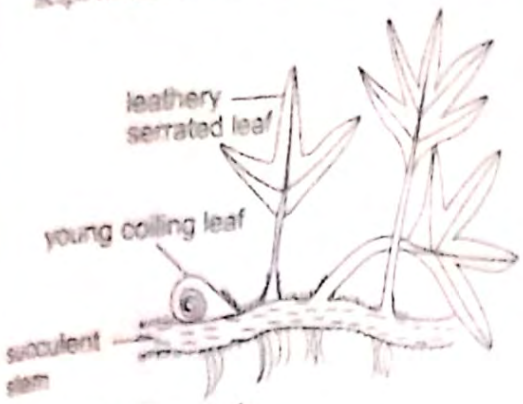



**Figure 23.28. Phymatodes.**

**Adaptations of some rainforest animals**

**Millipede**

1. The body is covered with hard calcareous exoskeleton which is protective in nature and for conservation of water.
2. There are many walking legs, two pairs per segment for locomotion.
3. A pair of sensory antennae is used for finding its way.
4. The mouth parts are adapted for herbivorous feeding.
5. When the animal is disturbed, it coils up. This is a protective behaviour.
6. In each segment, there is a pair of stinking glands, the secretion has an offensive odour and contains iodine and hydrocyanic acid poisonous to predators.
7. Respiration is by profuse tracheal system.

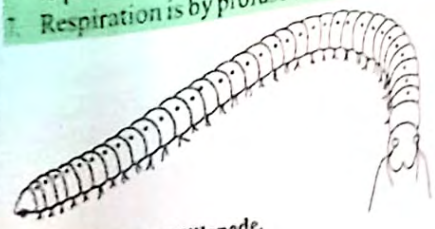


**Figure 23.29. Millepede.**

**Monkey**

**Adaptations**

1. The big eyes are placed on the front of the head giving the animal a wide binocular vision.
2. It has a long tail which is used for balancing.
3. Both the hindlimbs and the forelimbs are well-developed. The hindlimbs are used for take o f f and the forelimbs are used for landing.
   The digits are elongated and opposable for efficient grasping of the branches of the trees.
4. The chest is well developed - an adaptation for landing.
5. The body is elongated and slenderly built, an adaptation for an efficient jumping.
6. The dorsal part of the body is covered with dark brown hairs while the ventral side (belly) is covered with white hairs. This colouration conceals the animal from enemies above and below.

**Figure 23.30. Monkey.**

# Grassland

## Southern Guinea Savannah

Savannah is a type of vegetation comprising predominantly of grasses which are burnt annually. Trees and other woody shrubs are also present. The vegetation is more open with wide spaced trees. The trees have broad leaves. Xerophilous shrubs are conspicuous. Epiphytes and climbers are poorly developed. The common species are ***Daniellia***, ***Isobalina dorcas***, ***Lophira spp.***, ***Butryospermum parkil*** and **Black plum** (***Virtex doniana***)

**Southern Guinea savannah** type of vegetation is found in **Kogi, Niger, Kwara, part of Enugu, Benue, Taraba and Cross River States of Nigeria.**

## Northern Guinea Savannah

In many respects the vegetation of northern guinea savanna looks similar to the vegetation of southern guinea savanna.

1. The trees are 10 - 15m tall, with the tree crowns more or less touching.
2. The trees are mostly broad-leaved and in some places the tree cast shade deep enough to suppress grasses.
3. Wherever the canopy is open, grass is dominant, though usually distinctly shorter than the southern guinea zone.
4. The dominant species in northern guinea savanna are ***Isoberlina dorcas***, ***Isoberlina dalzelii*** and ***Montoes kerstingii*** **shrubs** like ***Gardenia*** **spp.**, ***Protea elliottii*** are frequent and woody climbers like ***Uvaria chamae*** are only locally present.

The state of Nigeria which have northern guinea savanna type of vegetation are **Kaduna, Plateau, Bauchi, Niger, Adamawa, part of Kwara** and **Cross River States.** Almost all the savanna is secondary due to the effect of previous cultivation.

## Montane/submantane

These types of savanna occur about 1,200m above the sea level. These are rare due to the scarcity of the high land. The largest and most important area is on the **Jos Plateau.**

## Sudan Savanna

The vegetation and climate of sudan savanna zone are very distinct.

**Characteristic**

1. The mean annual rain fall is 50 cm. Seven to eight months from (October to May) have less than 2.5cm of rainfall on the average
2. Trees are usually 8 - 15m high, with wide spreading crowns
3. The dominant tree species are *Acacia spp.*, ***Amogeissus leiocaspus***, ***Sclerocarya birrea***, ***Balanites aegyptica*** and ***Proropis africana*** Erect shrubs are *Xeromphis nilotica* and woody shrubs e.g. *Combretum micranthum* and *Capparis corymbosa* are abundant in more open savanna type

The Nigerian States which have Sudan Savanna type of vegetation are **Sokoto, Kebbi, Kaduna, Katsina, Kano, Yobe, Taraba and Borno.** Since all the sudan zone of Nigeria has been inhabited for many centuries and in consequence practically all the vegetation has been greatly modified by cultivation, cutting, bushfire and cattle grazing.

## Sahelian zone

**Characteristics**

1. The vegetation is of open thorn savanna with trees 5 to 10 m tall.
2. The trees have tiny leaves.
3. There are short, thorny and sparsely distributed grasses. The typical species are *Acacia radidiana*, *A. senegal*, *A. laeta* and *Commiphora africana*. The shrubs are *Salvadora persica*, *Leptadenia pyroteshnica*.
4. The date palm *(Phoenix dactylifera)* is commonly planted. In Nigeria, sahel zone is only in Borno State near Lake Chad.

**Adaptations of some plants to savannah**

1. Grasses (Elephant grass *Pennisetum spp Andropogon, and Monocymbium*)

a. They have **tussocks** which protect the buds during burning. The term "**tussocks**" is used to describe a cluster of shoots which originate from buds very close together on the same plant and close to the ground.
b. The marginal part of the tussocks protects the dormant buds in the centre during burning.
c. They are perennial.

d. The underground parts are not destroyed by fire thus enabling them to grow up during the rainy season.

2. **Woody plants** (e.g. *Mahogany bean, Afzelia africana, Shea butter, and Acrican balsam).*

a. They have a thick fire resistant bark which protects the living tissues inside.

b. Growth is continued by dormant buds lower down which is protected from fire.

c. They produce foliage only during the wet season.

In addition to the above adaptive features, **Shea butter's** leaves have water storing tissues.

3. **Baobabs**

a. The trunk has a large water storing tissue.

b. The stem is thick and the bark is corky. This feature reduces transpiration to the minimum.

c. It has a long tap root for water absorption.

4. ***Acacia***

a. The leaves are very small and thick. This helps to reduce transpiration.

b. The tap root is very long for absorbing water which is deep in the soil.

c. There are spines on the body of the plant. The spines protect the plant from being damaged by animals.

## Adaptations of some animals in savannah

### Grasshopper

a. The body is covered with exoskeleton made of chitin which helps to protect the internal organs, provide places for attachment of muscles and to prevent water from entering and leaving the body.

b. The hind limbs are well developed and muscular for effective hopping. Wings are used for short flight.

c. The appendages (fore- and hind-limbs) are jointed for easy locomotion.

d. The mouth parts are well developed for feed ing on the vegetation.

e. There is an efficient tracheal system of air tubes which ensure direct delivery of oxygen to the tissues.

f. The compound eyes ensure keen sense of sight.

g. The body is coloured green or brown to camouflage the insect in the vegetation.

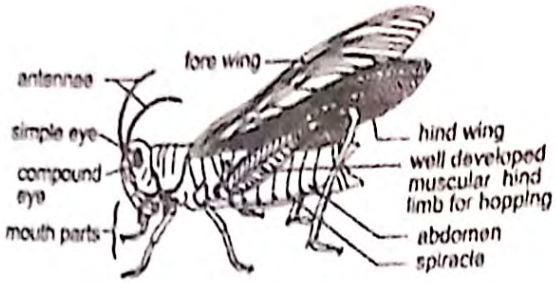



**Figure 23.31. Grasshopper.**

## Amphibians

### Adaptations

a. The toad is capable of camouflaging. The pigments (chromatophores) in the skin can change the colour of the toad to suit its background. This prevents it from being seen by its enemies.

b. The glands in the skin produce a distasteful and poisonous secretion when attacked by an enemy. Thereby preventing its predator from further attack.

c. The skin is sensitive to both chemical and mechanical stimuli.

d. The attachment of the thick sticky tongue to the front of the lower jaw makes it an effective organ for catching insects.

e. The vomerine teeth and the teeth on the roof of the mouth help to hold the prey tightly.

f. The large bulging eyes give the toad a keen and wide range of vision since it depends on good sight to see its enemies and hunt for food. The eyes are placed in a position where they are above water when the animal is submerged in water.

***Thryonomys swinderianus*** **(Cane rat or cutting grass)**

**Adaptations**

a. The incisors are long, curved and chisel-like. They are used for gnawing on the tender stems and root tubers. The molars are broad and ridged used for grinding.
b. The **monocular** eyes are placed at the sides of the head to increase wide range of vision.
c. They have keen sense of hearing. With the slightest noise they are at alert and ready to escape.
d. They have long whiskers for finding their way in darkness.
e. The body is covered with thick brown hairs which camouflage it.
f. They move in large groups thereby facilitating the detection of predators or food.
g. They are nocturnal animals and this makes it possible to avoid daylight predators. In the day, they hide in thick dense vegetation.
h. During the dry season, they hide in the bur-rows of other animals.

**Figure 23.32.** ***Thryonomys swinderianus.***

## Desert

Desert is an area with less than 25mm of rainfall per year.

**Characteristics of desert areas**

1. Rainfall is less than 25mm per year.
2. Very high temperatures (about 80°C) during the day and very low during the night.
3. Sunshine is direct to the ground.
4. The soil is sandy.
5. Winds are very strong as there are no trees to act as breaks.
6. Life depends on scattered **cloud bursts (rain)** and ability of plants and animals to store water.
7. Vegetation is sparse, characterized by cactus, **sedge bush, cresote bush** and other small shrubs. Vegetation which is adapted to dry environmental conditions is called **xerophytic** and such plants are called **xerophytes.**
8. Plants are widely spaced, an adaptation that allows each plant a maximum area from which to draw available water.
9. In desert biome, during the brief rainy season the ground becomes carpeted with numerous plants and most of these complete their life cycles from seeds to plants in a few weeks.
10. In **desert oases,** ground water may occur close enough to the surface for deep rooted plants to draw from it. This water is normally saline. The date palm (*Phoenix dactylifera*) is a common plant in such habitat.
11. The animals that live in the desert have special adaptations to this extreme climate. Reptiles and insects, for example, have water-proof outer coverings and excrete **dry uric acid**, thus conserving valuable water. The few mammals of the desert are small and nocturnal in habits. Most desert mammals such as **desert rats** live in burrows during the day to conserve water and come out to feed at night. Some rodents (e.g. desert rat) depend upon the water of seeds and fruits they eat. The **Kangaroo rat** and the **Jerboa rat** for example, need never drink water. They rarely urinate, essentially all metabolic water that is produced in respiration is conserved. In absolute deserts like the **Sahara,** where no rain falls, life is sparse indeed.

## Major biomes of the world

The major tropical biomes (tropical rain forest, savannah and desert) have been discussed under local biotic communities.

The **biomes** of the **temperate** regions are different from the tropical biomes for two major reasons:

1. **Rainfall** is the main ecological factor in the tropical biomes while **temperature** is the main ecological factor in the temperate biomes.
2. There are two seasons (**dry** and **wet**) influencing the tropical biomes while there are four seasons namely **summer, autumn** (fall), **winter** and **spring** influencing the temperate biomes.

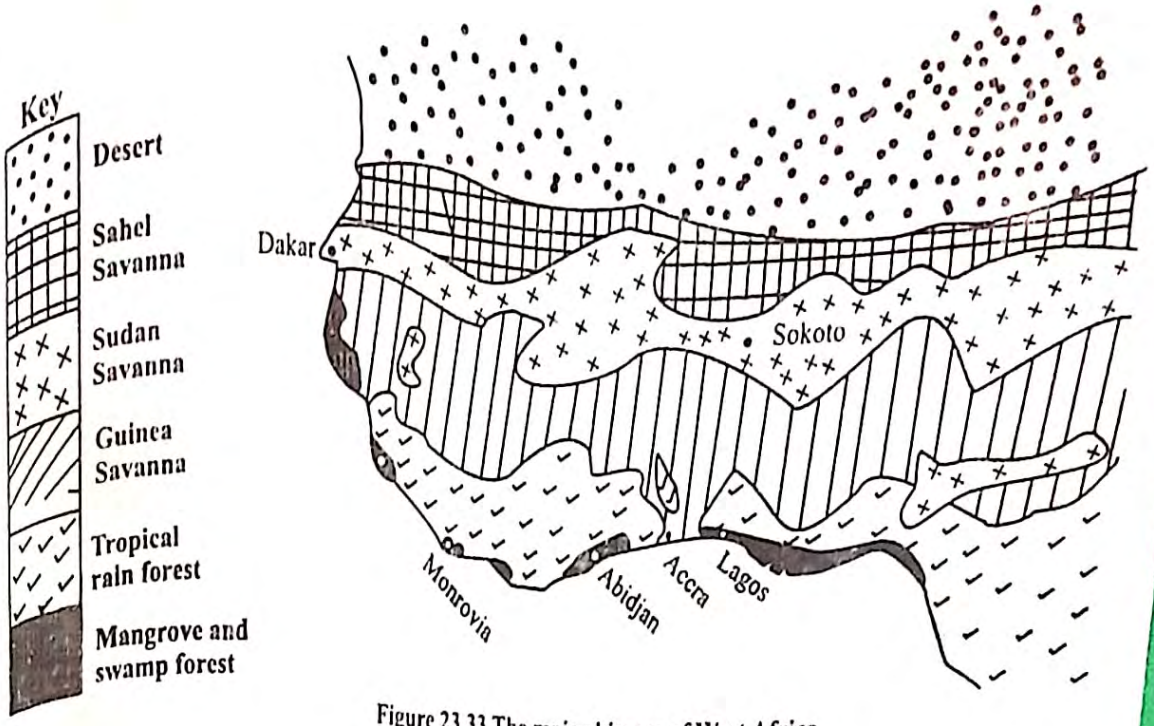



Figure 23.33 The major biomes of West Africa

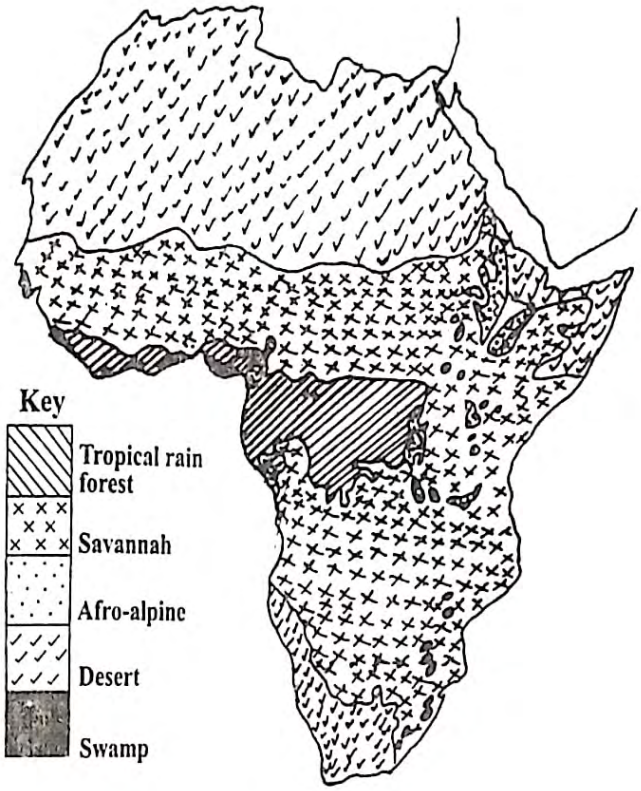



Figure 23.34. The major biomes of Africa.

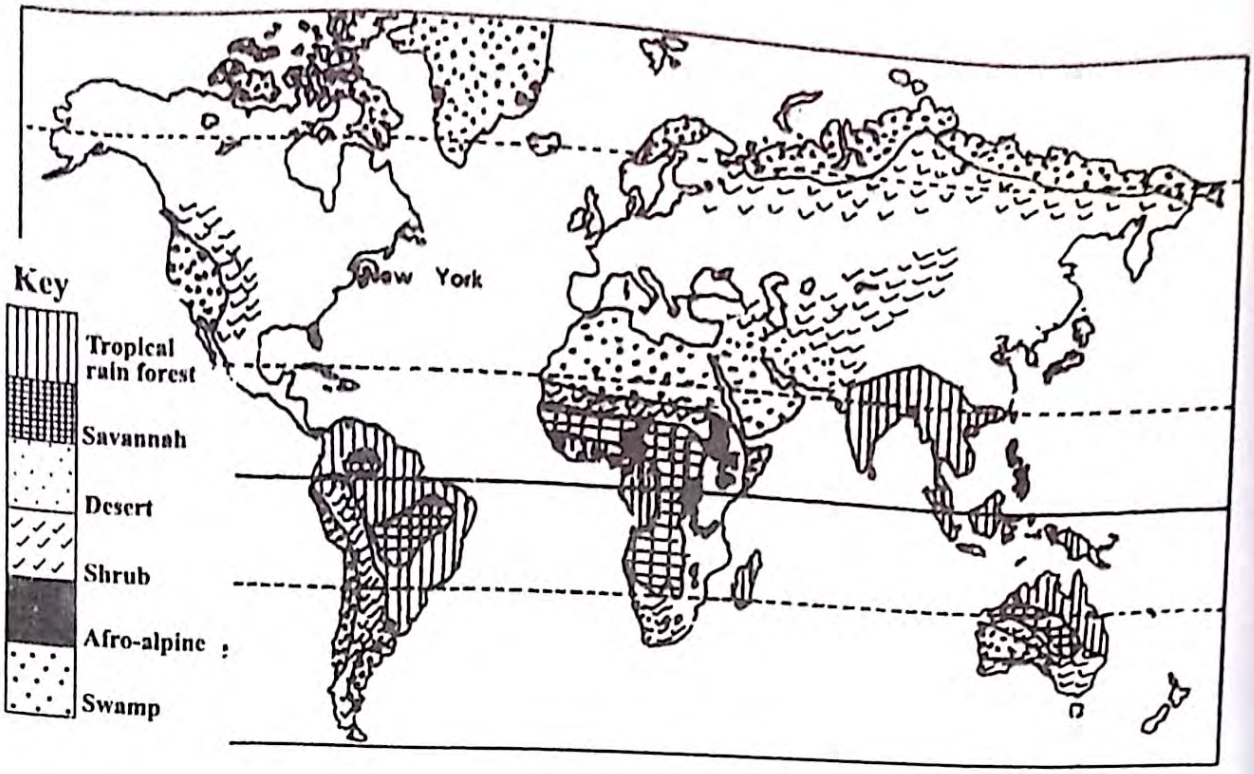



**Figure 23.35. The major biomes of the World.**

## a. Tropical rain forest

The richest of all the biomes is the tropical rain forest where neither shortage of water nor extreme temperature limits growth of plants during any period of the year. The mean annual rainfall is in the range of 1500 -2500mm; the dry season is never more than three months. The temperature is 25° - 27°C. The structure of the tropical rain forest consists of five layers, the three highest of which are formed of trees. The **first layer** is a very discontinuous layer of emergents, trees that rise above the general level of the forest. The **second layer** consists of tall trees forming a continuous canopy, the top of which is typically at a height of about 33mm. The canopy trees have long slender trunks and rounded crowns, and the **third layer** is formed of shorter trees, reaching the height of 10 - 15m; these have crowns that are narrow in proportion to their height, and adaptation that enables them to take the maximum advantage of sun light that penetrates the canopy. Due to competition for sunlight, the third layer is discontinuous becoming dense only where there are breaks in the canopy. The **fourth layer** is the shrub layer, which is sparse. The **fifth layer** consists of herbs and ferns like *Pteridium aquilinium* (a bracken fern). Tree fern *(Cyathium)* is common in many tropical forests. There are numerous woody climbers or lianes. Many lianes (woody climbers) reach up to the canopy and grow from tree to tree, attaining lengths of several metre. There are numerous **epiphytes** which grow attached to the branches of other trees. Many epiphytes have adaptations such as **spongy roots** (orchids) and **cup-shaped leaves,** to trap moisture and falling debris. The soils of tropical

rain forests are relatively infertile. Many of the soils are composed of red clay; these red soils are called **laterites**. In many cases, when laterite soils are cleared, they either erode rapidly or form thick, impenetrable crusts which cannot be cultivated after a season or two. Tropical soils are generally deficient in minerals and those minerals that are present are leached out by heavy rainfall. As a consequence, soils where tropical forests have stood are very poor agriculturally. There are three formations of tropical evergreen forest. The **American**, the **African** and the **Indo-Malayan formations**. The American formation covers the Amazon Basin; coastal lowlands of Columbia, the central American mainland and the wetter parts of West Indies. The African formation covers a lowland basin of Congo and extends as a belt along the coast of West Africa. The Indo-Malayan formation occurs over the East Indies, Malayan and Vietnam.

b. **Savanna**

The savannas are the tropical grassland with tall tufted grasses and sparsely scattered shrubs and trees. The savanna occupies areas lying between the tropical rain forest and semi-desert vegetation. Savanna occurs in the zone lying between 5 and 20 latitude north and south of the equator. The climate of most savanna is the same as in the tropical and semi-humid regions with a rainy season in summer and a long dry season during the winter months. Most trees in savanna are deciduous, shedding their leaves during the dry season, species of *Brachystegia* and *Julbernardia* are common in Africa savanna. Their new leaves appear several weeks before the rain, during the hottest weather and when soil is at its driest. The young leaves of some species are yellow or dark red; after a few weeks they change to green. Shrubs are often Y-shaped, branch a few metres above the ground and spreading out to an umbrella shaped crown. Most savanna trees have thick corky bark, enabling the mature trees to survive occasional fires which under natural conditions may be caused by lightning. When trees and shrubs are absent from tropical grasslands, the vegetation is called **savanna grassland**. Straight trunks are uncommon. The other common trees are *Spathodea campanulate* and *Adansonia digitata* (the baobab tree). These are very slow growing trees.

**Grasses of savannah**

The grasses of the savanna have their grow-ing period during the wet season and cease towards the end of it. In the early dry season their part above the ground die. As the dry season progresses, these parts dry out and turn brown and at the end of it they burn easily.

c. **Desert** **(read it under local biomes)**

d. **Shrub**

On the equatorial margins of the subtropical and tropical deserts there is a climatic zone with a short rainy season in summer and a long winter dry season. The vegetation of this area is dominated by **thorny trees or shrubs** and is called **thorn shrub.** It usually occurs under a mean annual rainfall of 250mm to 475m; all of which falls in a short wet season of 2 - 3 months. The effectiveness of the rainfall is lessened because it occurs in summer, when temperature is high and evaporation is rapid. Such thorn shrubs are common in **Tanzania, Brasil** and **Southern Coast of California.** Plants such as *Acacia spirocarpa* and *Mimosa* species are common and are characterized by having hard, thick evergree leaves and witish thorns. A thorn shrub formation also covers large parts of the continental interior of **Australia.** It occurs on soils with a sandy or gravelly texture, both on hillside and on stabilized sand dunes. In some areas the thorn shrub grows as a close formation of bushes and short trees, giving a

dense thickest as in the **floor of African Rift Valley.** In some areas thorn shrub has replaced savanna as a result of overgrazing by cattle; the grasses and most palatable bushes and trees have been destroyed and replaced by thorny species of little value for pasture.

### e. Afro-Alpine

Land over 3,100m is restricted to a few more or less isolated peaks, mainly in the **East African** and **Ethiopian regions.** These peaks are the home of **Afro-Alpine** flora. Majority of the plants are perennials with their perennating bulbs close to the ground. In some plants these bulbs rest on or just beneath the surface of the soil; in other they are found within 25mm of the ground. These budding feature as well as the absence of tall plants, are a response to the harsh climatic conditions. The ground remains snow covered or frozen for four to five months of the year. After the snow has melted in the spring, the ground begins to be warmed by the sun; this stimulates growth from the perennating bulbs. The growing season is short and the mean temperature of the warmest month is usually less than 15°C . The most dominant species in Afro-Alpine region is the giant *Lobelia (Lobelia bequarti)* and giant granidsels *(Senecio johnstonii).* The tufted grasslands at such high land is colonised by species from the lowland savanna and by migrants from other mountain system.

### f. Swamps

Areas that are permanently flooded are called swamps and areas on which silt is frequently deposited are **marshes.** The species of monocot e.g. *Phragmites* (reed), *Cyperus papyrus* (papyrus), *Typha* and *Vossia* dominate the vegetation. Mangroove swamps are found on parts of tidal lands in the tropics and are often termed as tidal forests, forming an almost impenetrable thicket with their mass of prop roots (Fig. 14). Mangroves species can tolerate the salinity of oceanic region. Many mangroves have viviparous seedlings which arise from the seed germinating into fruits. The presence of pneumatophores serves for the gaseous exchange between the atmosphere and the intertidal tissue of the plant.

## Ecological factors

*Ecological factors are the factors that affect living things in the habitats.* These factors influence the distribution of plants and animals and their mode of life in the different habitats. For instance, ecological factors account for **seasonal migration, aestivation** and **hibernation.** These factors are many and varied but can be broadly examined under two categories. These are **biotic** and **abiotic ecological factors.**

### 5. Biotic ecological factors

These are factors due to the **presence** or **absence** of **living things** in the **habitat** which can influence the distribution and way of life of plants and animals in the habitat.

### 6. Abiotic ecological factors

These are factors due to the **presence** or **absence** of **non-living things** in the **habitat** which can influence the distribution and way of life of plants and animals in the habitat.

Ecological factors common to all habitats.

The factors common to all habitats include **oxygen, light, temperature, wind, pressure** and **hydrogen ion concentration (pH).**

The ecological factors found only in aquatic habitats include **salinity, dissolved oxygen, transparency** or **turbidity** and **current** (tides and waves).

The ecological factors found only in terrestrial habitats include relative **humidity, edaphic** and **topographic factors.**

## Oxygen

Most organisms are **aerobic**, that is they require oxygen for respiration for the release of energy for vital **activities**. A few organisms are **anaerobic** in their respiratory requirement and so are not disadvantaged by oxygen deficiency wherever they are found. Oxygen is well distributed on land and therefore living things on land have no problem getting it for respiration. The amount of oxygen that dissolves in water is **low** compared to the amount present in the air. As the depth of the water increases the amount of dissolved oxygen decreases. Also as the temperature of the water increases, less oxygen is dissolved in it.

Low oxygen content in water restricts the distribution of aerobic organisms in aquatic habitat. The number of aerobic organisms therefore decreases from the surface to the bottom with decreasing oxygen content. Some organisms have therefore developed some adaptive features such as **air cavities** to store oxygen to survive in areas where oxygen is low. Other organisms come to the surface from time to time to gulp atmosphere oxygen.

The percentage of oxygen available in a habitat is measured with **oxygen meter** or by **titrimetic method.**

## Light

Sunlight is necessary for green plants to carry out photosynthesis and for most animals to see and carry out vital activities for their well being.

The **duration** and **intensity** of light are very important for **photosynthesis out put** of green plants, the flowering of plants and the hatching of eggs.

In the tropics, there are about **12 hours** of day light (7.00 am to 6.00 pm). In Nigeria the sun rises at about 7.00 am with **mild intensity** and increases in intensity with time up to 4.00 pm and starts to decrease in intensity till 6.00 pm.

**Photosynthetic activity, evaporation of water from exposed surfaces** and **transpiration rates** are directly proportional to light intensity. With this, there is an abundant photosynthetic products and plenty of activities for **diurnal** (day light) **animals**. Light seems to be available and accessible to all diurnal organisms. In aquatic habitat, light penetration is restricted by depth and turbidity. These account for the abundance and distribution of organisms in aquatic habitats. Green plants flourish in **euphotic zone** (area of sufficient light intensity for photosynthesis) thinning out through the **disphotic zone** (area of dim light) and totally absent in the **aphotic zone** (area of total darkness).

Animals are distributed along the same pattern to the extent that very few animals are in the **aphotic zone**. Some animals in the aphotic zone develop light producing organs in their bodies to find food and locate mates in the dark zone. Some plants such as the *sunflower* and *Mimosa pudica* (sleeping plant) open their flowers and leaves respectively when there is sunlight and close their flowers, and leaves when there is no light. Although light is important to green plants for photosynthesis, very high light intensity reduces the rate of photosynthesis.

### Measurement of light intensity.

**Measurement of light intensity** is carried out by a **light meter** or **photometer** in terrestrial habitats and by a **hydrophotometer** in aquatic habitats. The unit of measurement is expressed in **candela.**

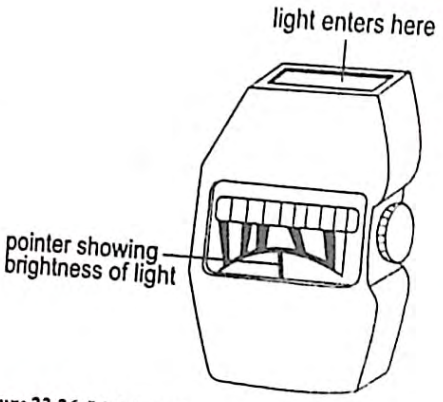



**Figure 23.36. Light meter.**

## Rainfall

Rainfall is the main source of water in all habitats. When rain falls, water soaks the soil and the excess in the form of run off water flows into pools, ponds, rivers, lakes, seas and oceans.

In the tropics, rainy season is separate from the dry season Most water bodies dry up during the dry season. Only big rivers, lakes, seas and oceans will have water available to their organisms all the time. Water is very important to all living things. It forms an important constituent of protoplasm, a universal solvent in which certain substances are dissolved. It is necessary by all enzymes to carry out their activities. It is also the medium of transportation of materials, manufactured food of green plants and dissolved salts, male gametes to eggs and dispersal of some seeds and fruits.

With rainfall, seeds germinate while plants grow luxuriantly and abundantly forming vegetation. Vegetation in turn forms protective habitats for animals and food for them.

Rainfall determines the pattern and distri-bution of vegetation. In the southern Nigeria and along the coast where there is a long period of heavy and frequent rainfall, the vegetation is an **evergreen forest**. The vegetation towards the north runs through the deciduous forest, Guinea savanna, Sahel savanna to semi desert as the rainy season becomes shorter and rainfall scanty. Seeds in dry soil may remain dormant and will not germinate until water (rainfall) returns.

In the dry season the aerial parts of grasses, water leaf, Arum and cocoyam die down their roots or rhizomes remain alive in the soil. They grow new aerial parts in the next rainy season.

Rainfall is not a critical factor in marine habitats except for increased salinity in prolonged absence of rainfall. Most marine organisms can tolerate wide ranges of salinity and so no problems for them. While a few migrate to estuaries or perish.

## Measurement of rainfall

The amount of rainfall is measured with a **rain gauge**. Rain water is collected into the cylinder through a funnel. Every morning the cylinder is emptied into a measuring cylinder to measure the amount of rain in millimetres for the day.

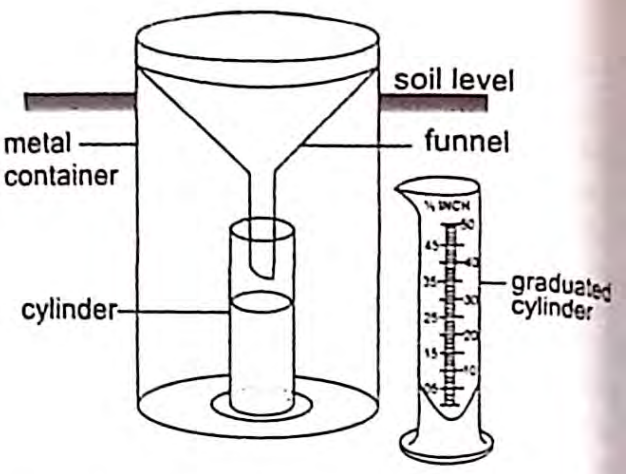



**Figure 23.37. Rain guage.**

## Temperature

Temperature is the measurement of the **hotness** and **coldness** of the habitat or body. It is influenced by sunlight throughout the biosphere and the condition of the body of organisms. This is why temperature varies from time to time, place to place and among different organisms. Temperature is low in the morning and high in the noon and afternoon and low again in the evening. Hence higher temperatures are recorded in the dry season while low temperatures are recorded in the rainy season. In all aquatic habitats, temperature decreases with depth.

Temperature variations have effect on the distribution of organisms, their mode of life and their rate of physiological activities. Animals that cannot survive the high temperatures of the day hide and come out during the night when the temperature is low. Other animals migrate to cooler regions of the world at the onset of dry season in the tropics to avoid high temperatures. Small animals live in burrows to avoid high temperatures. Cold-blooded animals such as lizards hide in crevices or shades of trees when temperature is high and remain inactive when the temperature is low.

Grasses and maize plants roll up their leaves at high temperatures. All these measures are taken by the organisms to prevent losing too much water from their bodies because high temperature promotes desiccation.

Living things require suitable temperatures for the efficient working of enzymes in their bodies. High temperature denatures (destroys) proteins and enzymes. Living things do all they can to avoid the two extremes of temperatures. In aquatic habitats, organisms make vertical migration to make the necessary adjustments.

Only birds and mammals have **constant body temperatures** (homoiothermic). They use the heat energy of respiration to keep their body temperatures constant. Secondly, they use their skin to regulate their body temperature.

In addition, they avoid direct heat by going into cool shelters, and by drinking water to replenish water lost by sweating.

Very low temperatures result in poor growth of plants leading to poor food production. At high temperature, plants wither, leading to poor food production.

Aquatic organisms may have little oxygen to utilize since the solubility of oxygen in water is low with increase in temperature.

## Measurement of temperature

Temperature is measured with a thermometer and expressed in degrees **celsius** or **centigrade** (°C).

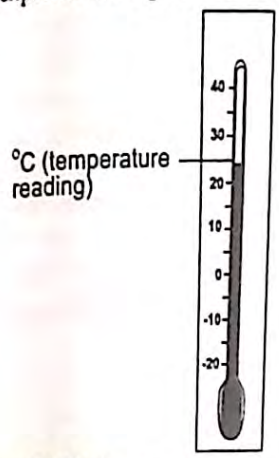



**Figure 23.38. Thermometer.**

## Wind

**Wind is air in motion.** This is an instance of movement in a non-living thing. The **direction** and **velocity** of wind is very important to living things in terrestrial and aquatic habitats. The southwest winds bring rain while the northeast trade winds bring harmattan to Nigeria. The windward side of the mountain has rain while the leeward side is without rain. The windward side therefore supports dense populations of plant and animal species due to rain it receives while the Leeward side has scanty plant and animal species. The plants and animals found on the wind ward side are different from those on the lee ward side.

High wind speed (velocity) sets up waves and current, evaporation in aquatic habitats, increases rate of transportation, pollination and dispersal of seeds and fruits in plants.

Strong wind causes waves and dissolves more oxygen in aquatic habitats making more oxygen available to plants and animal for respiration.

Strong wind speed causes **rill erosion** and **weathering** of parent rocks for the formation of soil.

Strong wind also causes **lodging** of plants or totally knocking down some plants and **shelter** of animals including those of man.

## Determination of wind direction and the measurement of wind velocity.

The direction of the wind is determined with a **wind vane** while the velocity or speed of wind is measured with **anemometer**.

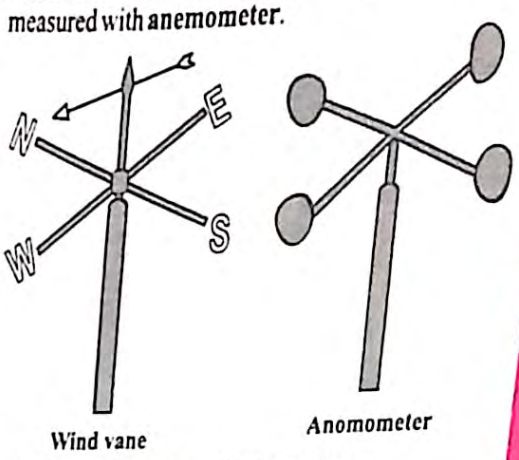



**Figure 23.39. Wind vane and anemometer.**

## Hydrogen ion concentration (pH)

Hydrogen ion concentration gives a measure of the **acidity** or **alkalinity** of the water in aquatic habitats or soil in terrestrial habitats. **pH** is influenced by the **amounts of carbonates** present and act as **buffer** neutralizing any acidity. **pH** value is expressed on a **logarithm Table** 1 to 14 with **pH** 7 being **neutral** while less than 7 is **acidic** and more than 7 is **alkaline**.

The chemical nature of the parent rock of the soil plus the water, organic and inorganic content of

the soil contribute to the acid or alkaline nature of the soil. **Most soils** tend to be **acidic** because of the organic and inorganic substances present in them. **Freshwater** tends to be **neutral** while **sea water** is fairly **alkaline.** Alkaline medium supports more vegetation. Acid medium supports very little vegetation.

Animals are equally sensitive to **pH** variations. Most animals prefer **neutral to alkaline medium** and avoid acid medium. The **pH** of water and soil can be measured with a **pH** paper which works on colour reaction which is later transfered to a colour chart to read off the value.

## Measurement of pH

The **pH** of water and soils can be measured by the **colorimetric method**. In this method, a **universal indicator** is used to determine the approximate range of **pH**. More accurate measurement can be obtained by using more specific indicators such as **cresol red** or **bromothymol blue**.

An easier and faster method is by the use of a **portable battery-operated pH meter** which can be used directly on the field.

The **pH** can also be determined with the help of **pH paper**. The **pH** paper is dipped into water or soil solution. The colour change of the **pH** paper is matched with a coloured chart to obtain the **pH** value.

## Pressure

Pressure affects the distribution of plants and animals in both terrestrial and aquatic habitats. Pressure is very low at the tops of very high mountains while it is very high at the floor of very deep aquatic habitats. Pressure increases with increase in the depth in aquatic habitat. Only very few organisms are found at these extremes of pressure and they are highly adapted to meet the respiratory hazards in them. The pressure of air (atmospheric pressure) of the terrestrial habitat is measured with a **barometer** and expressed in **atmosphere** (Atm).

**A mercury barometer works in this way:**

If the atmospheric pressure increases, the mercury column in the glass tube rises. On the other hand, if the pressure falls, the mercury column in the glass tube falls.

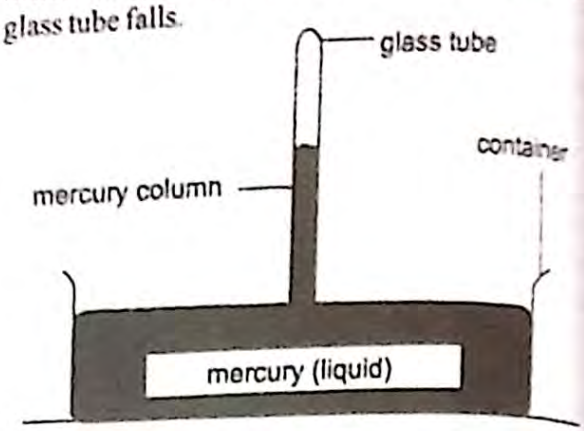



**Figure 23.40. A mercury barometer.**

## Ecological factors affecting aquatic habitats

### Salinity

This is the measurement of the amount of **mineral salts** dissolved in water. Salinity is lowest in freshwater habitats while it is moderate in brackish waters (lagoons, swamps and estuaries) and highest in marine habitats such as seas, oceans and inland drainage lakes. Organisms living in **freshwater habitats have adaptations for removing excess water entering their bodies while those in the sea develop salt secreting devices to maintain osmotic balance between their body fluid and their aquatic surroundings.** Organisms in the brackish water have body tissues that can tolerate wide ranges of salinity in their habitat.

## Measurement of salinity

Measurement of salinity or mineral salt concentration of water is carried out by **titrating 10cc of water with silver nitrate solution**, using some drops of **potassium chromate** as indicator. The volume of silver nitrate used to change the colour from **yellow** to **red** is expressed as the salinity of the water in **parts per thousand** (‰).

## Turbidity or transparency of water

**Turbidity or transparency** is an expression of how **clear or cloudy** the water is in aquatic habitats. The clearness, cloudness or muddiness depends on the amounts of debris or silt suspended in the water. The amounts of materials in suspen-sion in water is affected by rainfall which gives rise to erosion and flooding of aquatic habitats.

Generally water transparency is reduced during the rainy season while in the dry season water transparency increases. The **organic materials** in suspension serve as food for **detritus feeders**. Silt reduces light penetration and therefore phytoplankton tend to make upward migration. As phytoplankton migrate, the zooplankton that feed on them tend to move as well.

## Measurement of transparency of water

The transparency of water is measured using a **secchi disc** which is lowered into water with a graduated cord. The **depth** at which the disc **disappears** from **sight** is recorded, and the depth at which it **reappears** is also recorded. The average of the two depths in centimetres is recorded as the **water transparency**.

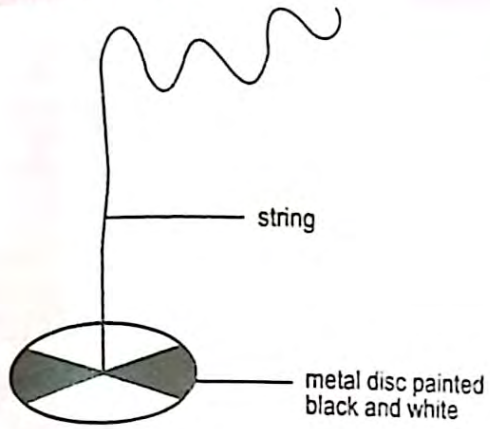



**Figure 23.41. A Secchi disc.**

## Ecological factors peculiar to terrestrial habitats.

### Humidity

**Humidity is the amount of water vapour that is present in the air at the time of its measurement.** Atmospheric humidity is important as the rate of water loss from both plants and animals depends on it. The rate of water loss from plant and animal bodies is lowest when the air is most humid and highest when air is less humid. When humidity is low, the adaptation in plants may take the form of restriction of water loss through closing of the stomata.

### Measurement of relative humidity.

Relative humidity is best measured using a **whirling hygrometer** which consists of **wet** and **dry bulb thermometers**. The instrument is whirled at the standard rate of 80 - 100 whirlings per minute to get a standard air flow. The whirlings are done until two readings are constant. The wet thermometer reading is subtracted from the dry one. The difference obtained in the depression and the relative humidity in percent is read from the psychometric tables purchased with the hygrometer. The value gives the % humidity relative to saturated air at that temperature.

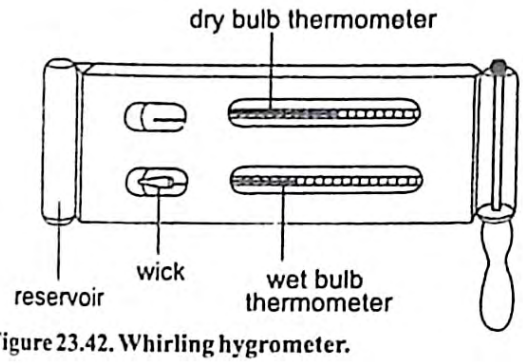



**Figure 23.42. Whirling hygrometer.**

## Topography

Topography relates to the structures of the earth's surface. It includes such features as altitude, slopes

and low lands. On mountain tops, temperatures and air are low and the habitat is exposed, so that only plants and animals that can withstand these conditions are found there. Little water sinks in the slope as much of the water flows fast downstream. Gentle slopes generally support more plants than steep slopes where plants not firmly attached are easily washed off.

Low lands generally support tall trees, shrubs and climbers with little under growth due to poor drainage and the attendant poor aeration.

## Soil factors (edaphic factors)

Soil factors have been treated on chapter 19.

## *Biotic factors.

These include

1. Green plants or animals
2. Interaction between organisms
   a. predation
   b. scavenging
   c. symbiosis
   d. parasitism
3. Animals or plants
4. Man

## Ecology of population studies

## Population density

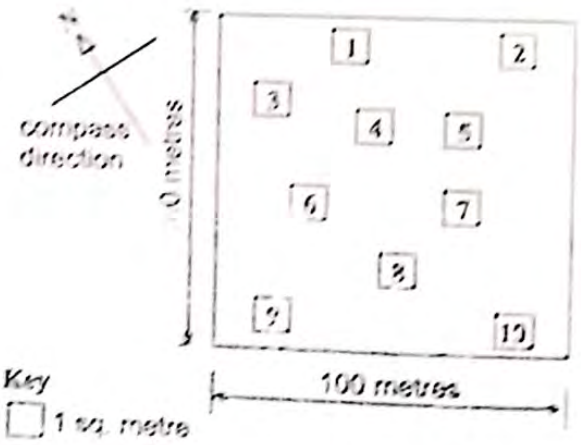
**This is the number of individuals per unit area or volume at a particular time.** For example, number of human inhabitants per square kilometre, number of trees per square hectre in a forest, millions of diatoms per cubic metre of sea water. If there are 20 lions in a grassland measuring 1000 m by 1000 m, the density of the lions' population is 20 lions per 1 000 000m3 that is 1 lion per 50 000 m². Population density can be estimated by (1) **direct counting** (2) **tagging** and (3) **quadrat sampling.**

1. **Direct counting:** This involves counting a particular species of organisms in a particular area. The complete counting of individuals in an area is called **census.**
2. **Tagging: Capture, release and recapture method)** This is a method of capturing a known number of a particular species of animals in a particular area. The captured animals are tagged or marked. The tagged animals are then released. After a known period, the same number of these animals are captured again from that area. For clarity a hypothetical number will be considered.

Suppose 200 *Tilapia zilli* are captured in a pond. The 200 *Tilapia zilli* are then tagged or marked and released. After two days, another 200 *T zilli* are captured. If the 200 *T zilli* captured after two days include 40 tagged ones, the total population tagged and untagged in the area is 1000, that is, the proportion of tagged animals to untagged animals is 1 : 5. Therefore total number of *T zilli* population is

$$\frac{200}{40} \times \frac{200}{1} = 1000$$

3. **Quadrat sampling: A quadrat** is a sampling area of any shape, viz. **square, circular or rectangular.** Several quadrats of a particular size and shape based on the nature of study are thrown at random and all the enclosed individuals are counted. For example, estimating the number of earthworms and goat weeds using 1 metre square quadrat.




| Samplings | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Goat weeds per quadrat area | 15 | 19 | 12 | 20 | 5 | 18 | 19 | 24 | 2 | 13 | 127 |
| Earth worms per quadrat area | 2 | 4 | 1 | 4 | 3 | 7 | 5 | 2 | 6 | 1 | 35 |

**Population estimation of Goat weeds**

| | |
|---|---|
| Area of abandoned farmland | = 10m² |
| Area of a quadrat | = 1m² |
| Number of unit area tossed | = 10 |
| Total unit area tossed 10 x 1 | = 10m² |
| No. of goat weeds in 10m² | = 127 |
| Average frequency (i.e. the number of goat weeds per square metre quadrat) | = 127/10 |
| | = 12.7 |
| Area of habitat studied | = 10m² |
| Estimated population of goat weeds in the 10m² | = 1270 |

**Population density**

**Density is the number of individuals per unit area.**

| | |
|---|---|
| Estimated population of goat weeds | = 1270 |
| Size of area studied | = 10m² |
| Density of goat weeds | = 12.70 per m² |

**Earth worms**

| | |
|---|---|
| Area of abandoned farmland | = 10m² |
| Area of quadrat | = 1m² |
| No. of unit area tossed | = 10 |
| Total unit area tossed = 10 x 1 | = 10m² x 1 |
| No. of earth worms in 10m² | = 35 |
| Average frequency | = 35/10 |
| | = 3.5 |
| Area of habitat studied | = 10m² |
| Therefore estimated population of earth worms in 10m² is | = 100 x 3.5 |
| | = 350 |

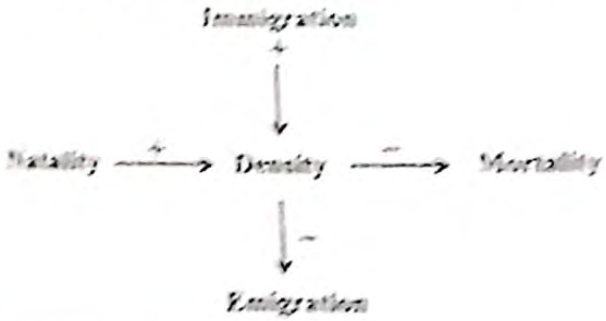
**Population density**

| | |
|---|---|
| Estimated population of earthworms | = 350 |
| Size of area studied | = 10m² |
| Therefore density of earthworms | = 350/100 |
| | = 3.50 per m² |

## Population size

Many factors are responsible for population sizes. These are:-

1. **Natality**: Is a broad term referring to the production of new individuals by **birth, hatching or germination**. It is expressed as a rate by dividing the number of individuals born by time.
2. **Mortality**: Is the rate of removal of individuals from a population by **death**. It is expressed as a rate by dividing the number of individuals dead per time.
3. **Immigration**: Is the movement of individuals into a population.
4. **Emigration**: Is the movement of organisms out of the population. But these phenomena are responsible for considerable modification of population number in a given area.
5. **Dispersion**: Dispersion is the manner in which individuals in the population are spread in particular area.
6. **Growth rate**: This is the net result of **natality, mortality and dispersion**. Fluctuation in population in a given area at a given time is brought about by **natality, mortality, immigration, emigration, over-crowding, cannibalism, competition, migrations and diseases**. All these reduce the number of individuals in the population.




## Dominance

Those species that have a **major controlling** influence on the nature of the community are called **dominant**. The dominants in a community may be the most **numerous**, have the **highest biomass**, use the most available space, make the largest contribution to **energy flow**, control or influence the rest of the community. The main portion of the energy transfer is carried out through them. The dominance of the species can be felt in terms of **changes** that occur throughout the ecosystem if the dominant species are removed completely. To determine the dominance of a species in a community, one has to first calculate the **importance value index (IVI)** of the species and which is the **sum of relative frequency, relative density and relative cover**. Any species having the highest Important Value Index, **IVI** is considered to be dominant. The population fluctuation is most obvious in locusts. In the arid or semi arid regions these insects are non-migratory in most years but occasionally their number increases enormously and they consume everything in their migratory route.



Scanned with CamScanner

The rate of population change can be calculated by the following formula.

Natality rate - Mortality rate + Net migration rate.

The **population display** is an age structure which can be represented in the form of **age pyramid.** A pyramid with a broad base indicates a high percentage of young individuals. In a rapidly growing population, there is higher proportion of young individuals and a reverse is the case of a declining population. The age structure of a population is a useful indicator for the future population trends.

## Ecological factors

There are various common physical and biological factors which normally operate in both aquatic and terrestrial communities.

## Factors affecting population

1. **Space and food**: There is a maximum number or density of individuals that can occupy a particular amount of space. This is called the **carrying capacity** of the environment. If there is overcrowding when the space has reached its carrying capacity, food shortage results leading to intensive competition, increase in death rate and migration. These forces operate until the population regulates itself to the **carrying capacity** of the environment. In any new environment, population growth curve is S-shaped, beginning with a slow rate of growth followed by **rapid exponential growth** and finally levelling off when the **equilibrium** is reached.

2. **Predators:** Predators regulate the population of preys. As the population of preys increases, greater percentage is preyed upon by the predators as the preys become easier to find. As there is an abundant population of the preys, the population of the predators increases. Conversely, as the popu-lation of the prey decreases the population of the predators decreases.

3. **Parasitism and disease**: As the population of the host increases, higher percentage of the hosts is victimised by diseases thereby checking the population growth.

4. **Competition** is a biological interaction between organisms of the same species or different species for the same resources which are in **limited supply** such as food, water, space, light, suitable **temperature** or mates.

As the population density of the organisms increases, competition for the limited **resources** becomes more intense and the competing organisms (**competitors**) are harmed. As a result of competition, the weaker individuals are eventually eliminated while the stronger individuals (fittest) survive. Plants mainly compete for light, water, soil nutrients and space while animals mainly compete for food, water, space and mates.

Competition helps to keep down overpopulation of organisms.

## Types of competition

There are two types of competition namely: **intraspecific competition** and **interspecific competitions.**

## Intraspecific competition

Intraspecific com-petition is a type of competition which involves organisms of the **same species**. For example, if flowers are planted too close together in a flower bed, the plants will compete for space, light, water and soil nutrients resulting in stunted growth and poor flower or production of few flowers. If some of the plants are removed artificially, healthy growth resumes and many flowers will be produced.

## Experiment to demonstrate intraspecific competition in maize plants

**Aim**: To demonstrate intra-specific competition in maize plants.

**Method**: Two boxes of one metre square are filled with humus soil. The two boxes are labelled **A** and **B**. In box **A**, 11 healthy maize grains are planted, each at a distance of 30cm. In box **B**, 100 healthy maize grains are planted, each at a distance of 5cm. Both boxes are exposed to source of light and **regularly**

watered for 21 days. **Results:** The maize seedlings in box A look healthy with green leaves while in box B the seedlings look weak with thin stems and yellow leaves.

**Conclusion:** Since the seedlings in boxes A and B receive adequate water and sunlight, the seedlings in box B compete for space and same nutrients in the soil which are in limited supply.

**Intraspecific competition** is harmful to living organisms. To avoid intraspecific competition plants disperse their **spores, seeds** and **fruits** by various mechanisms while animals emigrate. Birth control is another way of reducing intraspecific competition among human beings.

For example, in **aphids,** when conditions are favourable, many **wingless females** are reproduced parthenogenically but when conditions become unfavourable **intraspecific competition** becomes more intense and winged females develop and fly out **(emigrate)** of their birth place.

## Interspecific (interspecies) competition

This is a type of competition involving two or more organisms of **different species** using the same limited resource such as food, water, space, shelter, light or nesting sites. Interspecific competition becomes more intense as the number of individuals compe-ting for the limited resource increase. As more and more similar the needs of the **competitors** are, the more intense the competition or in the words of ecologists, the more the **niches** of different species overlap, the more intense the interspecific competition. Sometimes one of the competing species may adjust by changing its food habits. It is an **ecological axiom** that ***two species cannot occupy the same niche permanently.***

In interspecific competition, the **stronger competitor** may drive the **weaker competitor** into an **extinction**.

The possible outcomes of interspecific competition are:

a. The stronger competitor may drive the weaker competitor into an extinction.

b. **One species may enjoy competitive superiority in some regions** while the other may be competitively superior in other regions with different environmental **conditions**, as a result the **superior competing species** may eliminate the **inferior competing species** from those regions it **enjoys** superiority. Therefore both species survive in their different regions. This is one of the reasons while some plant or animal species are found in one region and absent in the other.

A well studied example of interspecific (interspecies) competition is that of two closely related species of genus *Paramecium* namely *Paramecium caudatum* and *Paramecium aurelia.* When the *P. caudatum* and *P. aurelia* are cultured separately in the laboratory, there is a steady increase in population of both species until a stable population is attained. But when the two species are cultured together with fixed food supply, *P. caudatum* fails to survive, that is, it is eliminated by *P. aurelia* but the growth rate of *P. aurelia* is slower than when cultured alone.

Since *P. aurelia* does not prey on *P. caudatum*, the disappearance of *P. caudatum* from the mixed culture is as a result of interspecific competition. The slower growth rate of *P. aurelia* in the mixed culture also results from the **interspecific competition.** This confirms that in interspecific competition, competing species are **harmed** in one way or the other.

In the mixed culture, both species compete for food, mineral salts and space.

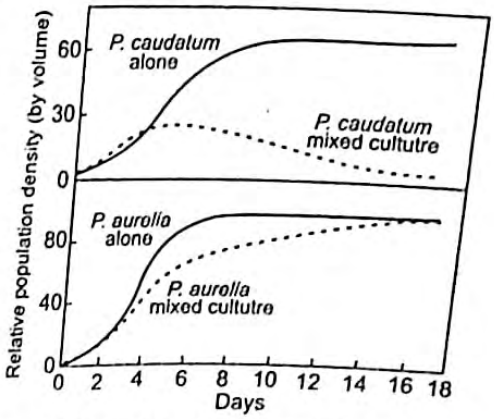



**Figure 24.43. Effect of interspecific competition between two species of *Paramecium***

Another example is found in two species of duckweeds, *Lemma gibba* and *Lemma polyrrhiza* which grow equally when alone, but *L. gibba* always replaces *L. polyrrhiza* when they are grown together.

This is due to the fact that plant body of *L. gibba* has **air filled sacs** that elevate it and it forms a mass over the other species, cutting off the light, thus the *L. polyrrhiza* in the shade dies out.

5. **Changes in the physical environment** such as **temperature, humidity, rainfall, wind** and **light** help to regulate the population of certain individuals. The physical and biological factors mentioned above which prevent a species from reproducing at its maximum rate is called **environmental resistance**. The **environmental resistance** factors may be **extrinsic** affecting a population from outside or **intrinsic** affecting a population from within. The extrinsic factors may be climatic, predation, food supply and disease, while the intrinsic factors include territoriality and social stress.

## Investigating plant life

Vegetation is the total assemblage of plants inhabiting a given area. The first step in any vegetational survey is to prepare a **check list** of all the plants inhabiting in an area. It can be done by collections carried out along several lines in the area under investigation. It is nice to visit the area for collections in every season. After the collec-tion, plants should be pressed, dried and properly identified. In order to know the importance of any plant in the area, certain aspects like its **freq-uency, density** and **cover** and **importance value index** are determined. This can be done with the a quadrat The **size, shape, number** and arrange- ment of the quadrat varies depending on the nature of vegetation and the aim of study. The quadrat is laid down at random with the help of random number tables.

**Frequency:** This expresses the distribution of various species in a community. Lay the required number of quadrats of appropriate size and record the presence or absence of each species by + or - a respectively.

$$\textbf{Frequency} = \frac{\text{Total no. of quadrat occurence}}{\text{Total no. of quadrat studied}} \times 100$$

**Density (D):** It is determined by estimating the abundance of individuals of a species in a unit sample plot and dividing by the area sampled.

$$D = \frac{\text{Abundance}}{\text{Area}}$$

**Cover:** It shows the area of ground covered by the parts of plants, when viewed from above. For trees, the diameter at breast height (1.3m) gives an idea of cover since the diameter varies directly with the total cover. For shrubs the length of the measuring tape intercepted by the individual plants indicates cover. For herbs and grasses cover can be estimated by stem diameters of at least 100 stems measured with calipers. It is average and converted to basal area ($Ar^2$), which is then multiplied by density and expressed as sq. cm per sq. meter ($Ar^2$).

**Importance value index:** It is determined by adding values of frequency, density and cover and dividing the sum by 3, i.e.

$$I.V.I = \frac{\text{Frequency} + \text{Density} + \text{Cover}}{3}$$

## Investigating animal life

Sampling of animals is slightly difficult due to their movement. **Traps, pooter, butterfly net,** and **plankton net** are some instruments that are used for investigating animal life.

**Traps:** Many nocturnal animals are best captured by trapping. Commercial traps are available for catching small mammals alive or dead. Attractive baits for small rodents include **porridge oats** and **bread**. In the live trap, nesting material should be provided. Many night flying insects and birds are attracted by lights. Pit-fall traps are useful for collecting crawling or running insects. It is constructed by sinking a jam jar so that its mouth is level with the beaten soil of a path or run made by small mammals. The mouth should be protected by a roof of stone to prevent rain and large animals like toads which might eat the insects. Pit-fall traps should be arranged so that the ground falls away from them and there is no danger of flooding by drainage water. Decaying meat is placed in the jar as bait. The traps should be visited regularly and insects should be noted at every visit.

**Pooter:** A pooter is an instrument used for sucking in of tiny invertebrates such as insects and spiders from leaves, tree trunks, rock and wall surfaces.

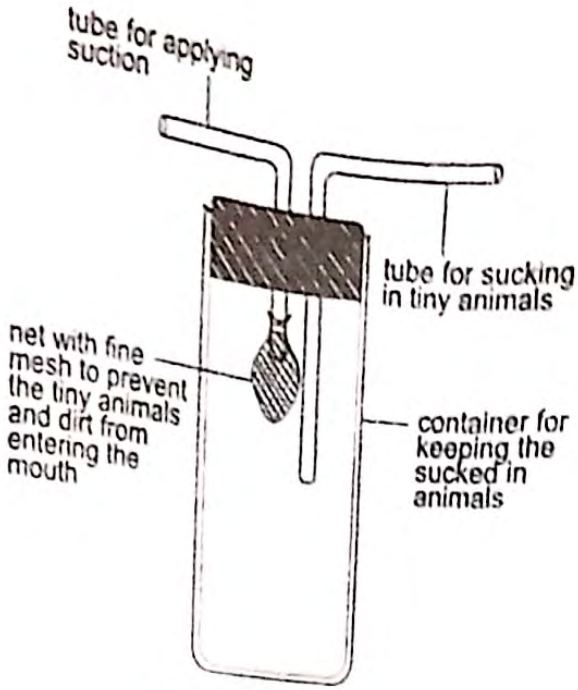



Figure 23.44. A pooter.

**Butterfly net (insect net or sweep net)** Flying insects such as butterflies can be captured by butterfly (insect or sweep nets.)

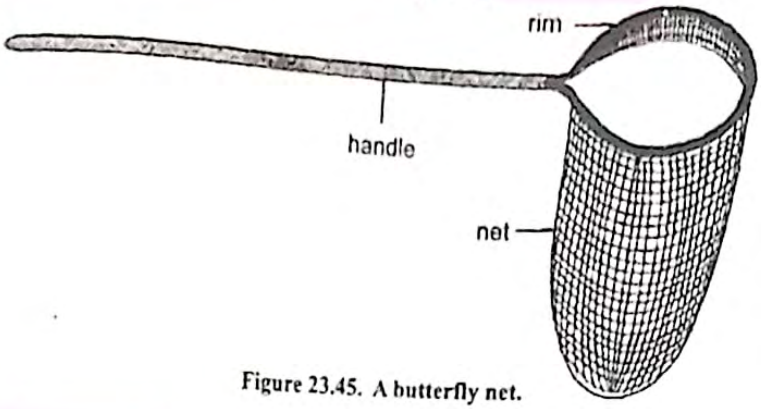



Figure 23.45. A butterfly net.

**Fish traps**: Some common fish traps are basket trap and hook and line.

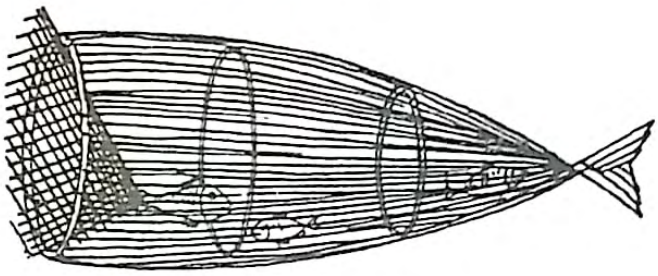


Figure 23.46. A basket trap.

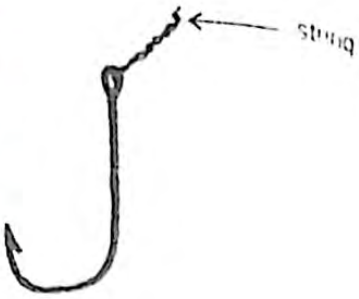



Figure 23.47. A man fishing with rod and line.

**Fishing nets**: Some common fish nets are castnet and gillnet

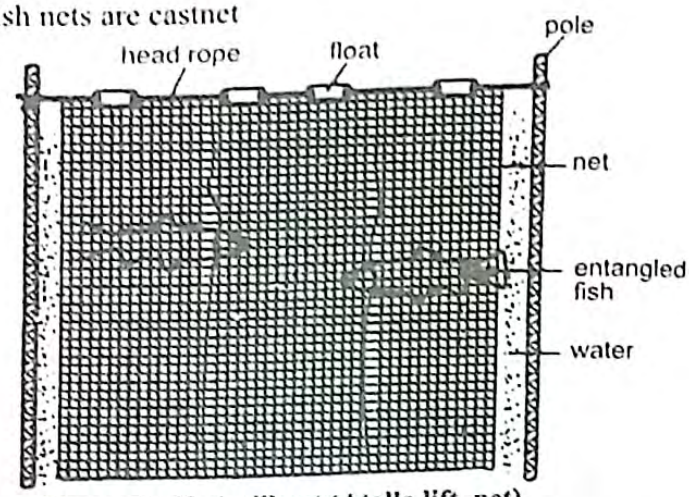



Figure 23.48. A gill net (Atalla lift net).

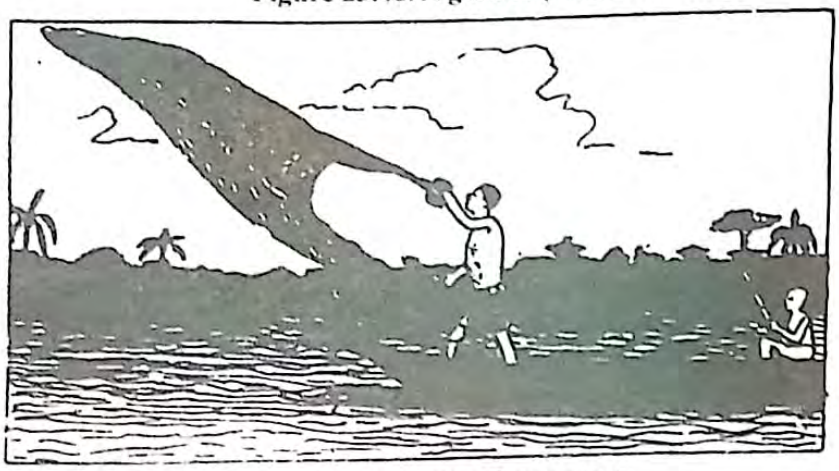


Figure 23.49. Man using castnet.

**Plankton net:** A plankton net is an instrument for collecting plankton from aquatic habitats such as **pools, ponds, lakes, streams, rivers** and **seas.** It is a conical net fitted with a detachable metal or plastic container.

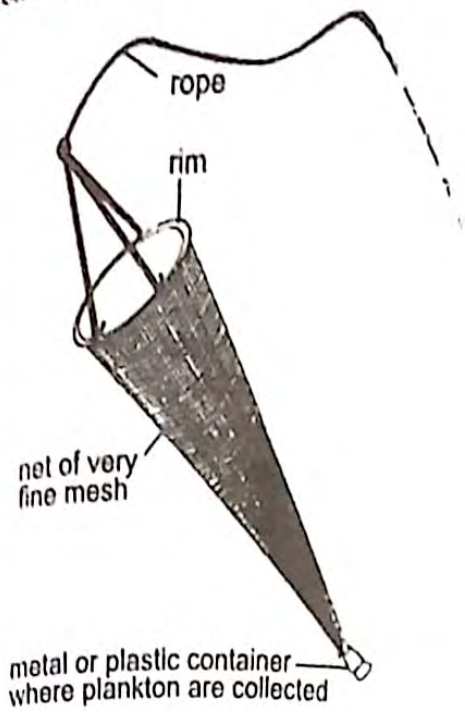



**Figure 23.50. A plankton net.**

**Net:** Flying insects can be collected by the use of aerial nets. Aquatic throw nets or dip nets or bottom nets are useful in the collection of aquatic organisms.

## Ecological succession

**Ecological succession is the orderly changes that occur in plant and animal community of a given area over a period of time until a climax (stable) community is established.**

The communities of plants at any place modify the environment because of their activities and making the environment less stable to the existing community and so a better suited community of plants replaces it. This new community again modifies the environment in such a way as to make conditions less suitable to itself. Thus, changes take place continuously in the community structure, **organization, physiognomy,** the associated animals and the environment at a place in the course of time and this phenomenon is called **ecological succession.** Ecological succession is based on three main things. These are:

1. Availability of colonizing material.
2. Selection of colonizing material in the environment.
3. Modification of the environment by colonizing plants i.e. soil formation.

The rate of successional changes is rapid at the beginning and gradually it slows down. The pioneers and early seral species are hardy species such as lichens and species which have short life cycles. Their remains build up an organic content in the form of a humus. The decay of the latter begins to supply mineral salts and improves the aeration and the water-holding capacity of the sub-strate. **Algae, liverworts** and **mosses** are also among the early colonizers. The substrate undergoes a gradual change and finally the soil is formed.[1]

## Characteristics of succession

Followings are the major characteristics of succession:

1. **Ecological succession** takes place in a newly formed open habitat e.g. sea shore, sand dunes, lakes and cleared ground and bare rock surface.
2. **Successional changes** are orderly and develop in a certain sequence. For instance, if a mature forest is cleared, it is likely that a fresh forest community will eventually develop there but not straight away. It develops through succession of several types of seral communities which are different from the forest community.
3. The **pioneer colonizers** are hardy plants with short life cycle which get replaced by small herbaceous plants with low nutrient requirements.
4. The **rate of successional changes** is rapid initially and gradually it slows down until a climax community (final) is reached.
5. **Seral communities** are large in number depending on minor differences in edaphic, topographic and other local conditions. Seral communities are therefore short lived and quick in development. The **Sere** is the entire

sequence of temporary communities from the pioneers stage to the final stage or **climax community**.

9. **Climax communities** are formed after a long period of time and once formed they maintain their structure and composition.

## Primary succession

**The occupation by plants of an area not previously covered by vegetation is known as primary succession.** Bare rocks and cliffs are common sites of **primary succession**. The first stage in such area is the **formation of soil**. The solid rocks are broken down by weathering processes such as freezing and thawing or heating and cooling, which cause substance in the rocks to expand and contract, thus splitting the rock apart. Water and wind help in breaking the fragmented rocks into smaller particles. Water enters between the particles and soluble materials such as rock salts dissolve in water. Water in combination with carbon (IV) oxide from the air forms a mild acid which dissolves substances by chemical reactions. Ultimately rocks disintegrate and soil is formed. Bacteria, fungi, algae and lichen inhabit the soil. These organisms are called **pioneers**. The death of the pioneers adds some organic matter to the soil. Algae and mosses now inhabit the land. **Mosses** and **algae** die adding more humus to the soil. Ferns and grasses now inhabit the soil. These ferns and grasses further breakdown the rock and more humus added. Shrubs move in and eventually trees. At this stage a dominant species of tree takes over the population making the environment for itself and unsuitable for other species. Tall trees for example cast shade for smaller plants. Those plants which are shade loving thrive well while those that do not like shade die off. The stage of tall and shady trees is regarded as **climax community**.

Another example of primary succession is an **estuary** with a high salt content and is flooded twice daily. The pioneer colonizers of an estuary are the red mangrove (*Rhizophora spp*). They can tolerate high salinity level, have seeds which germ-inate on the parent plants before landing on the mud and continue to grow there. They fix them-selves in the mud and grow to tall trees with stilt roots. The roots form a raft which accumulates soil particles from the water and thus raise the banks. This red mangrove is followed towards land side by white mangrove, (*Avicennia spp*) which grow on more stable and high land. Along with these are some herbaceous plants such as *Drepanocarpus punatus*, *Hibiscus* species and *Acrasticum aureus*. With the death and decay of these plants, and accumulation of organic matter, more stable soil is formed on which a normal forest flora will soon develop and thus giving a **climax community**. The first set of animals which will colonize the mangrove swamps are species of insects, mud skippers, *Pila leopoldvillensis*, *Pila glauca*, *Lymnaea peregra* and crabs. In the region of white mangroves, animals such as squirrels, rats, snakes and their predators are commonly found.

## Primary succession in aquatic habitat (e.g pond)

### Pond succession

At first, the pond is only a basin of water. Microscopic plants and animals such as bacteria, algae and protozoa soon inhabit the water. These are the pioneers. Seeds of plants and eggs of aquatic animals are brought to the pond by the feet of visiting birds. Some insects fly to the pond and some animals travel to the water. The pond starts supporting hydroids, molluscs, fish, amphibians and aquatic reptiles.

Submerged plants and floating plants begin to grow in the pond. The edge of the pond is inha-bited by plants. This is **submerged and floating vegetation stage**. The death of some plants and animals starts building up organic matter in the bottom of the pond and around the edges of the pond. The pond now gets smaller and shallower. Terrestrial plants begin to grow towards the centre of the pond as organic matter builds up. Various mammals and birds visit the edges of the pond. This is the **temporary pond stage**.

Finally the whole pond is filled with organic matter. **Shrubs** and **trees** appear and eventually, a **forest stage (climax stage)** is reached.

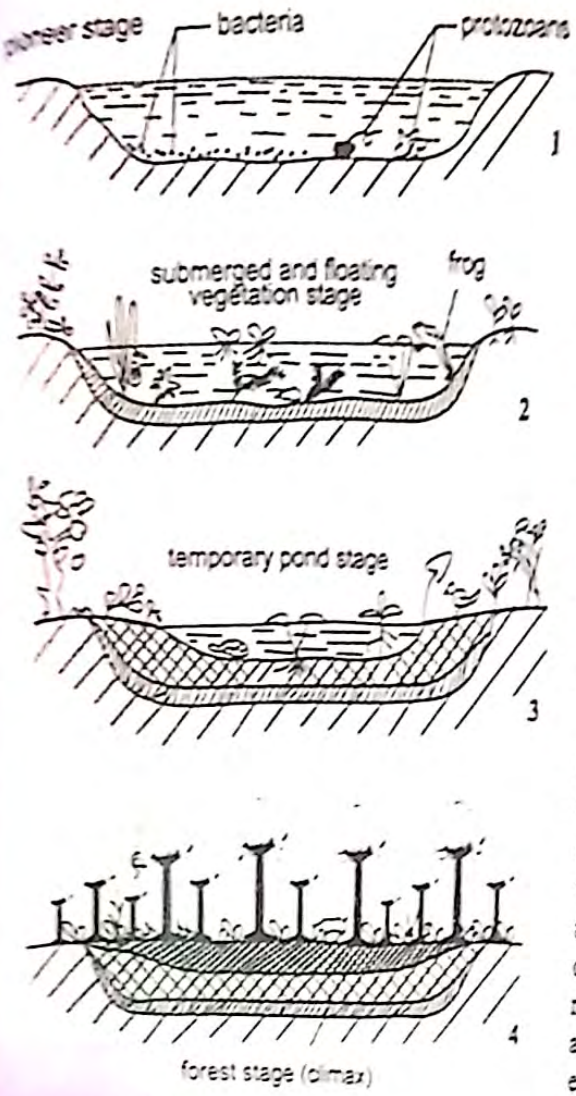



Figure 23.51. Different stages in pond succession.

## Primary succession in terrestrial habitat (e.g. abandoned farmland)

### First stage

In an abandoned farmland, the pioneers (first colonizers) are weeds, underground stems, seeds of plants, eggs and larvae of insects and worms. These pioneers derive their food from the left over nutrients of the old farm. Animals such as mice, rats and cane rats can now visit this vegetation to feed on grasses. Snakes and lizards are also found.

### Second stage

In the second stage, seeds start to germinate, underground stems such as cocoyams grow up, grasses and weeds (shrubs) increase in population. Eggs and larvae of insects hatch and grow into adult insects. Worms increase in population. The vegetation can now provide a suitable habitat for rodents (mice, rabbits, cane rats).

### Third Stage

In the third stage, weeds and grasses (herbs) are gradually being replaced by shrubs. More animals visit the habitat.

### Fourth Stage

Trees now grow to replace the shrubs. Creeping plants increase. Birds, reptiles (such as snakes and lizards) and various mammals inhabit the various strata of the habitat. Species diversity is thus increased.

### Climax stage (stable community)

Trees grow to very tall heights in an attempt to get light forming a forest canopy. Small trees die off due to lack of light resulting from the canopy. Plant climbers increase. A lot of leaves fall to the ground which decay and form food for detritus fee-ders such as snails and millipedes. Therefore, the activities of detritus feeders increase. The animal community now includes herbivorous, carnivorous, omnivorous and detritus feeders. A complex food web is now established.

## Secondary succession

When succession occurs on a site previously occupied by a vegetation, it is called a **secondary succession**. Secondary succession occurs on areas laid bare by man such as abandoned farmland, and strip mines and road sides. Such an open area is bombarded by the seeds of numerous plants and is captured by those that can germinate most rapidly. The example of this type of succession has been discussed under terrestrial succession which is that of an abandoned farmland **Climax of succession**. A **climax community** is the end product of the succession of several seral communities over a long period at one place. Once the climax community is established it may remain indefinitely. The climax community is regarded as **steady state** which has restored the community structure towards steady state.

## Types of climax communities

1. The **edaphic climax** results from soil characteristics, as in salt marshes, hill tops, ridge summits, sea coast and sand dunes.
2. The **fire climax** as a consequence of periodic burning, for example savanna in Africa.
3. The **biotic climax** is due to the activities of living things. It is infact an example of retrogressive succession . For example grasslands which are frequently grazed by animals are likely to remain grassland climax unless grazing is prevented and grassland allowed to mature to a climax community.
4. **Topographic climax** is due to local topography like slope, exposure to dry winds etc.

## Characteristics of a stable ecosystem

1. It is generally believed that once the **climax** is attained, the community does not change at all, but this is not exactly so. Climax community changes due to aging. The climax community is heterogeneous.
2. The climax community depends on the broad climate of the region and thus in a state of **dynamic equilibrium** with the climate and is self sustaining. Example of climaxes are the tropical rain forest, the woodland, savannas and deserts.
3. Climax ecosystem has numerous microhabitats which are inhabited by different types of organisms.
4. Climax community does contain many sub-communities. For example, in a low land rain forest, the typical mature forest shows 4-5 layered or stratification of trees each layer supporting different types of epiphytes and animals. –

**Table 83. Differences between competition and succession**

| Competition | Succession |
|---|---|
| 1. Starts when resources are in short supply in a habitat. | Usually starts with new habitats. |
| 2. Occures in all places inhabited by organisms. | Occurs only in a particular area. |
| 3. The replacement of an old population by a new population is due to interspecific competition | Old polpulation is gradually being replaced with new dorminant polpulation. |
| 4. Competition has no end, it continues in a stable or climax community. | Succession ends when a stable or climax community has been attained. |
| 5. Competition speeds up succession. No competition, no succession. | Succession provides basis for competition. |
| 6. The replacement of one population by another in a given environment in competition is due to survival of the fittest. | In succession, the replacement of one population by another in a particular area is transitory and it leads to climax or stable community. |

## Problems of survival

A community consists of all the plants, animals and other organisms that live in a particular region. A **population is a group of organisms of the same species occupying a particular area at the same time.** Interactions among populations within a community are major factors in determining the numbers and kinds of organisms found there. The size of a population is the end result of a number of different forces. Whether or not a population decreases or increases in size is determined by three basic factors (1) natality (birth rate), (2) mortality (death rate) and (3) immigration and emigration, movement of organisms in and out of a particular community.

**Over crowding**: Simply means too many organisms. For example, a room which is initially meant for two inhabitants, now occupied by five inhabitants can be said to be overcrowded. Many hostels of higher institutions are overcrowded as six to eight students are occupying a single room meant for two students. The classrooms in secondary schools are said to be overcrowded as too many students are in the class. **Factors responsible for overcrowding are as follows:**

1. Limited space

$$\text{Space} = \frac{\text{Area of habitat}}{\text{Number of individuals}}$$

2. Increase in birth rate.
3. Limited food supply.
4. Flux of immigrants.
5. Less emigration.
6. Decrease in mortality rate.
7. Increase in survival rate.
8. Barriers.

### Effects of overcrowding

Crowding speeds up the depletion of available resources (food, water, and health facilities, etc). This ultimately results in malnutrition and high cost of living due to increase in demand and incr-ease in supply. This may also lead to infectious diseases leading to an epidemic situation. In lower animals, it may lead to fighting as well as reduced natality. In human beings overcrowding such as urban centres may lead to the development of anti-social activities such as robberies, begging, prostitution and rape.

### Means to overcome overcrowding

Biological organisms have developed various adaptations to prevent overcrowding at one place. The most obvious methods are **territorial behaviour in animals** as in birds, fish, insects and mammals and dispersal of seeds and fruits in plants. The roots and leaves of many plants release to the environment **some chemicals** which are **toxic to the** germination and growth of other plants. This phenomenon of suppressing the growth of some plants by others is called **allelopathy**. Examples are *Salvia nemorosa* which secretes **terpene** which does not allow the growth of any plant in a radius of one meter. *Juglans regia* leaves secrete **juglene** - an alkaloid, which when washed down to the ground by rain water does not allow other plants to grow underneath it. The local example is of **siam weed (*Eupatorium odorata*)**. The leaves contain **allelochemicals** which inhibit the seed germination and growth of cowpeas.

Many plants have different methods of dispersal of seeds and fruits. These agents of dispersal include **wind, water and explosive mechanisms.** Most wind dispersed plants have light seeds with parachute mechanisms, e.g. *Tridax procumbens*. Some plants have seeds, with tiny barbed hooks, so that these get stuck to the body of passing animals and man e.g. *Boerhavia diffusa*. Many fruit trees and crop plants are dispersed by man. Spores of fungi, bryophytes and ferns are extremely light and are therefore dispersed by wind.

Animals have different means to prevent overcrowding. They move from one place to another. For example, birds fly away over long distance for feeding and breeding purposes. Fish do the same. Only man tends to overcrowd himself by moving from rural area to urban centres. This is one of the major concerns to sociologists, economists and demographers.

## Territorial behaviour

**Territory refers to an area that an organism defends against intruders.** Most vertebrates stay close to their birth places, occupying a home range that is likely to be the same home range occupied by their parents. Even in the case of migratory birds that travel great distances, they are likely to return year after year to the same areas; often these home ranges are defended, either by **individuals**

(normally males), by mating pairs or by groups against other individuals or groups of the same species. **Territoriality** has been widely recognized in animals e.g. monkeys, fur seals, dragonflies, red deer, beaver, many types of lizard, birds and fish. This behaviour of territoriality ensures the defending animals have adequate food supply, space for nests, mating partners and parental care. This behaviour of these animals also eliminates overcrowding.

Territory varies greatly in size. The **golden eagle,** for instance defends a territory of abouts 93 square kilometres, the **European robin,** a territory of about 6 square kilometers and the **king penguin,** a territory of only 1 square metre. Individuals of the same species often have territories of some what different size, depending partly upon the density of food and shelter in a given territory, partly upon population pressure and partly upon the aggressiveness of the individual.

## Territories and population Regulation

Animals that do not gain possession of territories or that are excluded from the home range or breeding area do not produce young. As older animals die, younger ones will contend for their places, keeping the breeding population stabilized. If conditions are particularly favoura- ble,or if the range is enlarged more animals can gain access to the breeding community. Limita- tion of the reproductive capacity/rate as by social dominance or territoriality,is sometimes referred to as **self regulation** of animals population. Within the limits imposed by the environment, **dominance** and **territoriality** determine and regulate the **reproductive capacity** of dominant animals.

### Food shortage

No other problem facing mankind today is so crucial as the **food** and **population** problems. These two problems are the roots of many others international unrest; the widening gap between the haves and the have **nots** and the lags in economic development of the lesser developed countries and of underprivileged segments of many developed countries. Unless these problems of food supplies and population growth can be solved all other efforts to build a better world will be an illusion. Also one cannot ignore the fact that an increasing percentage of humanity is dependent on the grain exports of a few coun- tries.

### The causes of food shortage

1. Overpopulation.
2. Primitive methods of land cultivation.
3. Underdeveloped land potential.
4. Use of low yielding seeding materials.
5. Infertility of soil.
6. Non-availability of good fertilizers.
7. Lack of irrigation facilities.
8. Soil erosion.
9. Floods.
10. Plant diseases.
11. Lack of interest in farming by young generation.
12. Poor transportation of agricultural products.
13. Poor methods of preserving and storing food.
14. Subsistence farming.
15. Lack of crop insurance and credit facilities.
16. Inconsistency of Government agricultural policies in many underdeveloped countries.

### Effects of food shortage

Scarcity of available food to organisms leads to malnutrition among organisms,which reduces their reproductive capacity. Even the offspring produced under such scarcity of food would be weak, inactive and may not reach the reproduc- tive stage. Food shortage in a community affects various population of organisms. The entire food **chain** and food **web** is disrupted and this ultima- tely affects the nutrient cycle in nature. Food shortage also affects the size of a population in the following ways: **emigration, competition, and increase in natality rate.**

### The size of population

This is the end result of a number of different forces. **Natality** varies enormously from one

species to another. For example, an oyster lays more than a million eggs a season, a large mammal can produce and care for only one infant every two or three years. A single female housefly producing an average of 120 eggs per laying, with half developing into females and with seven generations per year per female could produce 6,182,442,727,320 house-flies in one year. However, on the other end of the reproduction scale is a pair of elephants, which have a long gestation time and usually give birth to only one offspring, which in turn survives and reproduces. This pair of elephants could have 19 million descendants at the end of 750 years.

Human beings in many developed countries tend to **avoid marriage** or **marry at late age**. Most couples use contraceptives and like to have one or two children. Education and economic status of an individual also to a large extent affect the size of population. Many birds avoid mating when food is scarce. The rate of increase or decrease of a population is the difference between the birth rate and the death rate. Death rate is high in natural populations. Mortality rate increases as food supply gets depleted. Different organs of the body become weak which leads to low resistance to diseases. Prolonged malnutrition leads to death as has been recently seen in **Somalia** and **Ethiopia**.

Food shortage in any ecosystem also leads to **emigration**, that is departure of individuals from a population. For example, when a locust population increases in number, hormonal changes begin to take place among members of the new generations. These changes result in longer wings, more slender bodies and darker colours. The locust swarms are made up of these individuals. The stimuli that cause emigration differ from species to species, but the result is always the same, a drastic reduction in the size of population.

## Competition

Between the members of the same species for the food and other resources appears to limit the size of the population. Competition results in exclusion or **extinction** of some weaker individuals leading to survival of the **fittest**. The feeding habits of organisms also affect the size of population. Absence of particular type of food may lead the consuming organism either to emigrate or stay there and starve to death. Omnivorous animals which feed on a variety of food materials, are better adapted to such situation of scarcity of particular food and their population size tends to remain stable.

## Balance in nature

### Factors affecting a population

Many factors may limit the growth, decrease the natality or increase the mortality or emigration rate of population. These factors are sometimes grouped under the term **environ- mental resistance** and are divided into **density independent** and **density dependent** factors. The **density** of the population is simply the number of individuals in a given unit of an area at a particular time. These are the **biotic** and **abiotic factors**. Abiotic factors include light, temperature, heat, edaphic, precipitation, fire, altitude and **latitude**. Biotic factors are the presence or absence of other species, their death, birth rate, competition, dispersal, emigration and immigration. Temperature is, for example, a **density independent factor**. Extreme cold or extreme heat may destroy large numbers of organisms in a population. The number destroyed is not depen-dent upon the size of the population in the area. Forest fires, floods, etc. are all density independent factors. The most density-dependent factor is food supply. The per capita food supply decreases as the number of organisms in the population increases. If there is abundant food supply, the members of the population would be well fed and have a higher reproductive capacity. The population size will increase. On the other hand, if there is scarcity of food, the members of the population will be underfed and have a lower reproductive capacity and thus there would be a decrease in population.

### Dynamic equilibrium

Both **biotic** and **abiotic factors** play a role in the natural regulation of the abundance of organisms. The net result of these factors on population in any ecosystem is that the population size of organisms reaches a **dynamic equilibrium (balance in nature)** at any given time. It is also influenced by interactions among the various populations. Among the types of interactions is **competition** which may result in the **elimination of one species** or **its restriction to a non-competitive position.** Plants sometimes compete with one another by producing **toxic chemicals** that inhibit the growth of neighbouring species.

The trophic levels of an ecosystem are linked by predator-prey associations. These associations exert a regulating force on the size of populations and also have a profound effect on population to achieve its **dynamic equilibrium**.

# THE FUNCTIONING ECOSYSTEM

The **sun** releases a tremendous continuous flow of energy of which a small fraction reaches the earth's surface as **sunlight**. This fraction is called **solar flux**. About half of this is absorbed by the upper atmosphere or is reflected back to space. Most of the energy that actually strikes the earth,s surface is converted into **heat energy**. Only a fraction or **1 percent** is absorbed by green plants and used in photosynthesis. Thus **primary producers** in a community are the green plants and all living things in any ecosystem, are sustained by this energy derived from the sun. The process of converting light energy through photosynthesis by green plants into organic matter is called **energy fixation.** All green plants are called **producers.** All producers are **autotrophic.** All other organisms like man and animals are **heterotrophic** (feeding on others) and are therefore called **consumers.** Animals that derive their nutrition from eating plants directly are **herbivores** or **primary consumers** (e.g. goat, cow): **Carnivores are secondary consumers** (e.g. cat, and lion) as they eat herbivores and thus derive their energy indirectly from the producers. This transfer of energy from one organism to another in a series of trophic levels of eating and being eaten is called a **food chain.** In a community, there are a series of food-consumer relationships and several food chains are interconnected to form a complex series called **food web.** In a food chain each successive level is known as a **trophic level.** The various trophic levels may be as in **Figure 23.52.**

**Trophic Level**

**Trophic level (energy level) in an ecosystem involves several different organism with energy transfer usually from smallest numerous organisms to largest and few organisms. There is decrease in energy at every level. Energy is used progressively at each trophic level through respiration**

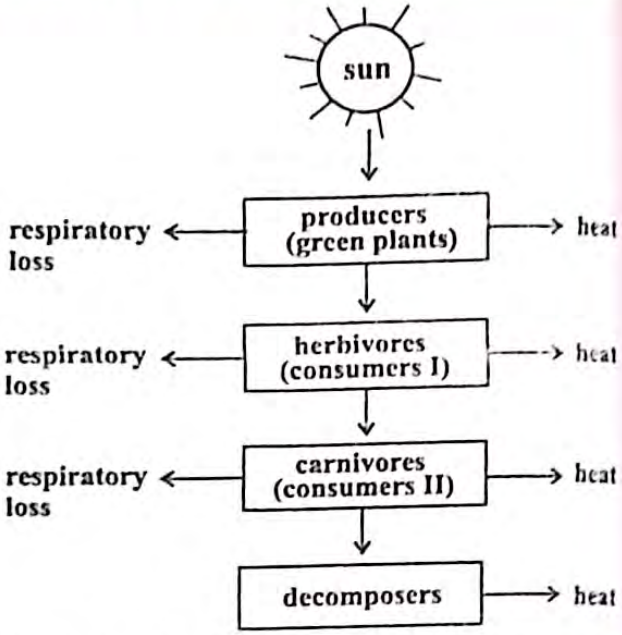



**Figure 23.52. The flow of energy in the food chain of a typical ecosystem.**

## Energy flow

Energy through a food chain from one trophic level to another is utilized in either of the following manners.(a) Production of material is called **biomass** or is the weight of producers, consumers and decomposers that exist in an ecosystem at a particular time.

(b) A part of energy is lost due to **respiration** It is this process by which energy is utilized for various metabolic activities.

(c) The rest of the energy is lost as heat which is released during various activities.

**Energy** that is utilized by producers (green plants) is **radiant energy**, which is converted into **chemical energy** by green plants which is the energy required by all living organisms. The chemical energy is

concentrated in food which is synthesized by the producers. This energy is converted into potential energy by a rearrangement of the atoms of food and is released as **kinetic energy** by a rearrangement of the atoms. During work, there results a random movement of molecules producing **heat energy**. The unit of heat energy is the calorie (cal.) A larger unit is kilocaloric (Kcal) composed of 1000 cal. About 500,000 Kcal/m/yr radiant energy is received on the earth's surface depending on the location and season. Only 1 or 2 percent of the total radiant energy received by the earth is converted into chemical energy by producers. In general, in the transformation of energy through the ecosystem, the energy in magnitude of 10 is lost from one trophic level to another. Thus, about 100 kcal would be converted to herbivore tissue and 10 kcal to first carnivores, if 1000 kcal of plant energy were consumed by herbivores.

The **ecological efficiency** is the ratio of the energy used by **one step** in a food chain in **unit time** to the energy made available to the **next step**. The ecological efficiency for the plants is about 1 percent. Due to complexity of food chains, it is rather difficult to study food chains in nature. A generalized food chain in an abandoned old field involving mice and foxes can be represented as in Figure 23.53.

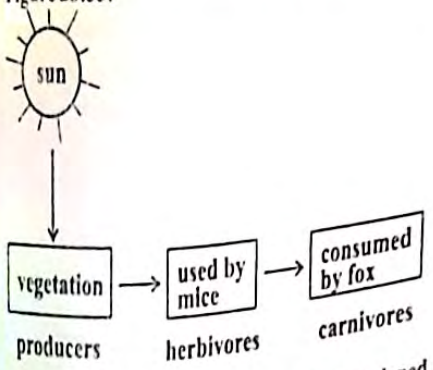



**Figure 23.53. A generalized food chain in abandoned old field.**

The vegetation converts about 1% of the solar energy into plant tissue. The mice consume about 2% of the available plant food while the foxes about 31% of the mice. About 75% of the stored energy in ungrazed vegetation is returned to the soil as dead plant material. Similarly, out of the quantity consumed by herbivores, about half goes to soil as **faeces**.

## Types of food chains

There are two types of food chains.

### 1. Predator (grazing) food chain:

This is made up of predator species and their prey or food species which are usually alive or freshly killed when they are eaten.

Grass ⟶ Sheep ⟶ Wolves ⟶ Lion

In predator (grazing) food chain, the energy source is the sun and the green plants use the solar energy to make food for the ecosystem. Usually, food chains consist of many links. For example, in aquatic habitat, microscopic floating plants called **phytoplankton** are primarily responsible for the production of organic matter by photosynthesis. These tiny autotrophic plants are consumed by acellular and multicellular animals called **zoo plankton.** These zooplankton are eaten by shrimps, lobsters, crabs, small fish and so on. The shrimps, lobsters and crabs may be eaten by small fish and small fish eaten by larger fish. The larger fish then serve as food for various reptiles, birds or mammals whose final death and subsequent decomposition by microorganisms of decay terminate the food chain. This food chain is drawn in **Figure 23.54.**

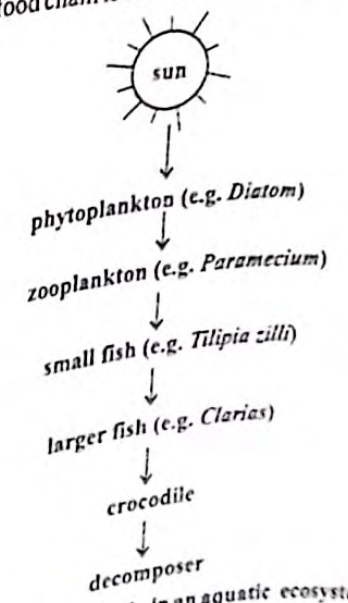



**Figure 23.54. Food chain in an aquatic ecosystem.**

**Food chain that starts with dead organisms.**

For simplicity reason, the food chains are indicated as straight pathways. In fact, these are more complex and are often accompanied by various branching and parallel sequences. In Fig. 3 herbivorous plankton may also be directly eaten by fish, which eventually perish and decay thus contributing short branching food chain, connected to the larger one. Thus **food web** occurs, with all sorts of short circuits and connections occurring in a system.

## 2 Detritus (decomposer) food chain

In this food chain the starting material is dead and unused organic material. The feeding species attack only dead organisms or non-living fragments of organisms. It is also called **decomposer food chain.** Bacteria and fungi feed on the faeces of animals, the cellulose of fallen trees, dead bodies of mammals etc. As bacterial cells of a decom- poser species exhaust their supply of food, most of the members of the bacterial population also die and their organic remains are decomposed by yet another set of microbial cells. This microbial waste also serves as food for other microbes. Thus the end products produced by the whole complex of detritus food chains are carbon (IV) oxide, and inorganic compounds such as phos- phates, nitrates, sulphates etc. After the com- pletion of the detritus cycle, no combustible organic matter is left.

Humus → Earthworm → Domestic fowl → Human being → Decomposers

Sewage treatment facilities are designed to provide detritus feeders with an optimal environ- ment, so that they degrade sewage as rapidly as possible.

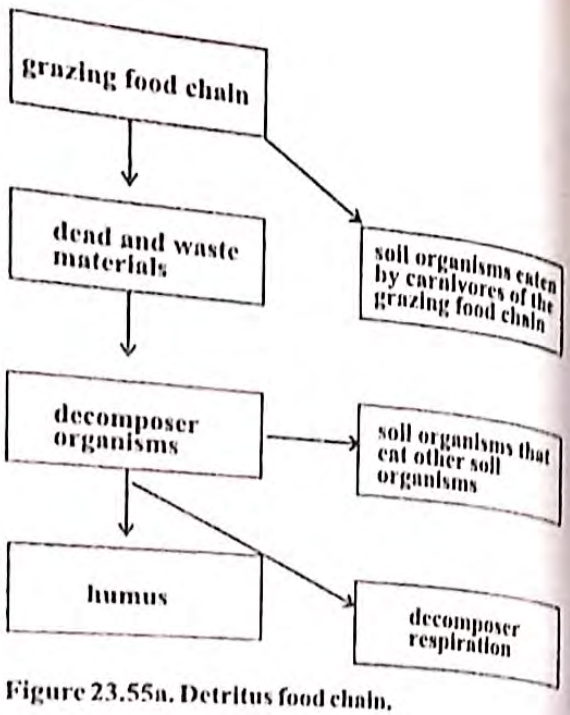



**Figure 23.55a. Detritus food chain.**

**Food web**

The great varieties of producers and consumers allow animals to select food items from a broad range of food source Normally, an animal feeds on two or more organism and in turn is eaten by many others.

Therefore, **food web** *(net) is the complex inter-connections of food chains in an ecosystem. Here is an example of a food web in a terrestrial ecosystem.*

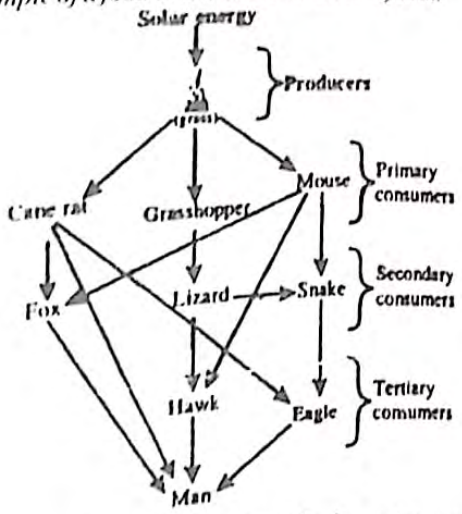



*Figure 23.55b.food web in a terrestrial ecosystem.*

## Transformation of energy by autotrophs

As discussed earlier only 1% of the radiant energy is converted into chemical energy. The rate at which energy is incorporated into a parti- cular component of a community is called the **pro- ductivity of that component**.

**Gross Primary Productivity (GPP)** is the rate at which light energy is transformed into chemical bond energy by all the producers in a **unit area of a biotic community.** Also some energy is lost along a food chain at every trophic level e.g. 100 kgs of grass does not produce 100 kgs of meat, as autotrophs themselves use some of the energy to carry out their life processes. The rate at which the energy is transformed by photosynthesis (GPP) minus the respiration rate (RA) of the producers is called the **Net Primary Productivity (NPP).**

**So, NPP = GPP - RA.**

NPP is positive when GPP exceeds RA and it is negative when RA exceeds GPP. The energy input and output of an individual producer is outlined as follows:- Energy enters autotrophs as light and leaves as heat or as the chemical bonds of the molecules that make up the **Biomass.**

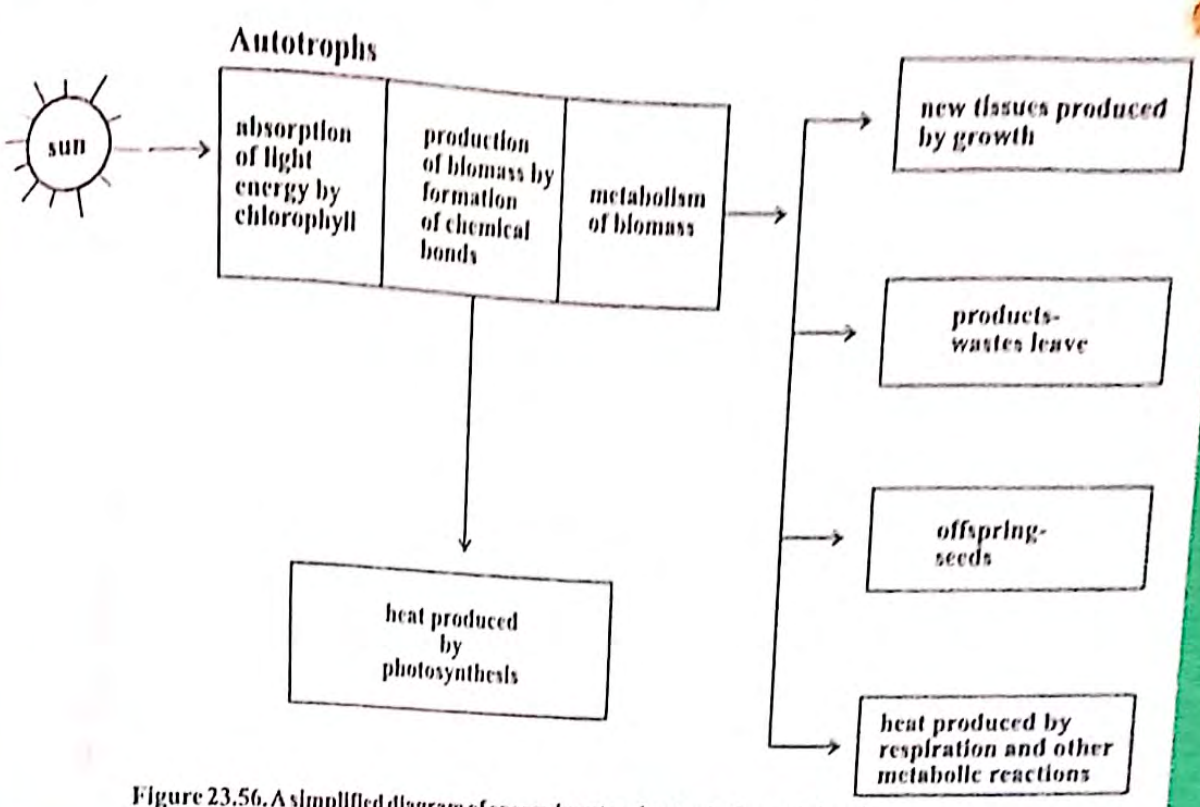



**Figure 23.56. A simplified diagram of energy input and output of an autotroph.**

### Ecological pyramids and laws of thermodynamics

The flow of energy through a community can be represented by a **pyramid of energy.** The energy flow across different trophic levels is governed by **second law of thermodynamics** which states that *in any conversion of energy from one form to another, there is always a decrease in the amount of useful energy.*

A good example is in **food chain. The transfer of energy** between trophic levels is not 100%, that is, **successive levels have less energy and support fewer animals.** The primary producers **(plants) have the highest energy.**

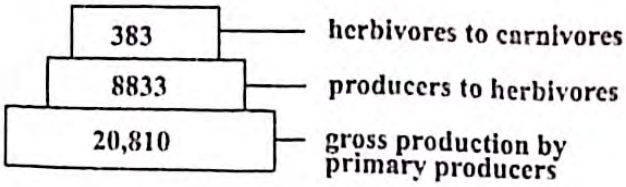



**Figure 23.57. Pyramid and energy**

When herbivores consume plants, the energy level is reduced and when carnivores consume herbivores the energy level is further reduced.

This conforms with the second law of thermodynamics.

**The first law of thermodynanics states** *that energy can neither be created nor destroyed.* In order words, one can say that the total amount of energy resulting from any conversion is the same as the initial amount of energy.

A good example is the transformation of **solar energy** to **chemical energy** by plants during photosynthesis.

| Solar Energy absorbed by plants | = Chemical (stored as food) | + Heat energy (energy of respiration) |
|---|---|---|

For example, in Silver Springs river in Florida, the plants absorbed 20,810 kcal per square metre per year. 11,977 kcal per square metre were used up for respiration leaving 8833 kcal/m$^2$/yr.

Solar energy absorbed by plant = 20,810 kcal/m$^2$/yr and 11,977 kcal/m$^2$/yr were used for respiration leaving 8833 kcal/m$^2$/yr. stored in the plants.

20,810 kcal/m$^2$/yr. = 8833 + 11,977 kcal/m$^2$/yr

(Solar energy absorbed) kcal/m$^2$/yr (stored in plants)

Adding 8833 to 11,977 will give 20,810. This conforms with the first law of thermodynamics.

The chemical energy can be converted into different forms of energy. For example, in the muscle tissue, the chemical energy in the food is converted into mechanical energy for work.

**In an ecological pyramid**, the first level or producer level forms the base and successive trophic levels as the upper tiers. Each successive level can support fewer organisms **than the previous**. This is due to the inefficiency of energy transfer from one trophic level to another. The pyramid's original energy is progressively reduced from plants to herbivores to carnivores. Also there is a reduction of biomass (weight of living organisms) along the food chain.

## Types of pyramids

There are three types of ecological pyramids.

1. Pyramid of **numbers**
2. Pyramid of **biomass**
3. Pyramid of **energy.**

These pyramids are graphically represented based on numbers of individuals,total dry weight and energy. These ecological pyramids do not include decomposers, whose number is too large but weight is too small as it becomes inconvenient to be measured or graphed.

### 1. Pyramid of numbers

In this pyramid, the number of individuals at each trophic level is arranged in a graphic system. It gives a quick idea of the relative abundance of the organisms that constitute each trophic level. The organisms at the base (**producers**) are the most abundant,and other higher successive trophic levels decrease rapidly and finally there are very few carnivores at the top.

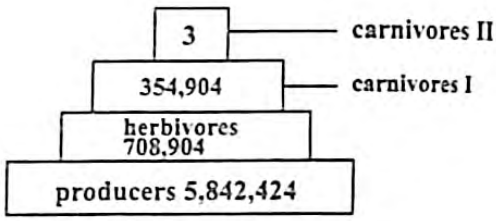



**Figure 23.58. The pyramid of numbers (from Odum 1959).**

The pyramid of numbers over emphasizes the importance of small organisms. The number of organisms decreases at each trophic level since many producers are needed to support fewer herbivores and fewer herbivores are needed to support fewer carnivores (primary, secondary and Tertiary consumers).

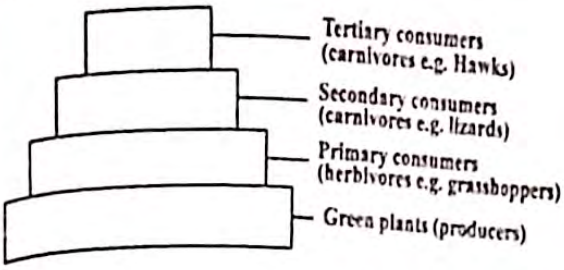



**Figure 23.59. The pyramid of numbers.**

However, if the primary producers are very large in size for example trees, fewer numbers will feed a higher number of herbivores. Many caterpillars or grasshoppers (herbivores) can feed on the leaves of one tree.

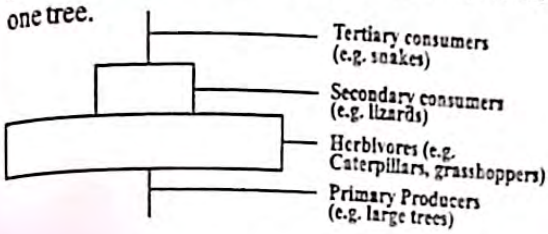



**Figure 23.60. The pyramid of numbers with the producers being very large.**

## 2. Pyramid of biomass (increasing size)

Pyramid of biomass emphasizes the importance of large organisms that have heavy weight. The organisms at the higher level are usually larger in size.

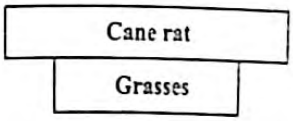



**Figure 23.61. Pyramid of biomass (after Odum 1957).**

## 3. Pyramid of energy

It indicates the amount of energy flow at each level and the role which the organisms play in the transfer of energy. There is a decrease in energy from one trophic level to another along the food chain. The pyramid of energy gives an overall picture of the functional nature of communities and throws light on the rate at which food material passes through the food chain. It also indicates how efficiently the energy can be transferred between trophic levels and the potential number of levels that can be maintained in a system on the assumption that there is a minimum energy requirement to support a trophic level. Energy flow pyramid provides a more suitable index for comparing any and all components of an ecosystem.

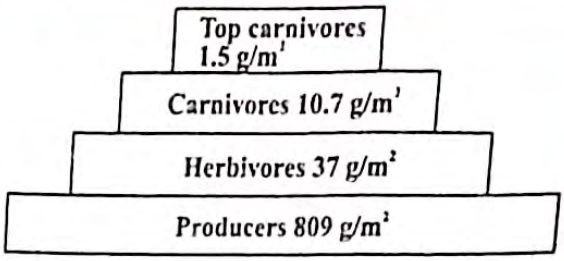



**Figure 23.62. Pyramid of energy (kcal/m² yr after Odum 1957)**

## Major sources and forms of energy

**What is energy?**

*Energy is defined as ability to do work.* Energy supports life and in all life activities, energy is involved. When you walk, speak, eat, laugh, sleep, write, etc. energy is expended.

**Major sources of energy**

The sun is the ultimate source of energy on earth. Chloroplasts in green plants are capable of trapping the sun's energy and converting it into chemical energy stored in organic compounds during the process of photosynthesis. The stored energy released is used for work.

## Forms of energy

Basically, energy exists as either **potential energy** or **kinetic energy**.

## Potential energy

Is a stored form of energy which is released when the need arises. For example, food in the body is stored as potential energy. When an energy to do work (e.g. running) is required, the stored potential energy is converted into kinetic energy through cellular respiration. Kinetic energy is an energy at work. The released chemical energy from glucose can be converted into different forms of energy. These are:

1. **Electrical energy**

This is used for the conduction of nerve impulses. Nerve cells change **chemical energy to electrical energy.**

2. **Mechanical energy**

This is used for the contraction of muscles change which brings about movement of different parts. The cells of the muscles change **chemical energy** to **mechanical energy.**

3. **Light energy**

The light energy is derived from chemical energy during **cellular respiration** (bioluminescence)

4. **Heat energy**

This is used for the regulation of the body temperature. The heat energy is derived from chemical energy during cellular respiration.

5. **Sound energy**

This is an energy in form of waves which causes the eardrum to vibrate and interpreted as sound by the **brain.**

### Energy containing food

The amount of energy contained in different types of food is expressed in kilojoules (KJ).

Fat: 1 gramme contains 38.9 kj.

Protein: 1 gramme contains 18.2 kj

Carbohydrate: 1 gramme contains 17.1 kj

**Table 84. The daily energy requirement of different ages of people**

| | Age | KJ per day |
|---|---|---|
| 1. | New-born baby | 1885 |
| 2. | One year child | 3352 |
| 3. | Child 2-3 years | 5866 |
| 4. | Child 5-7 years | 7542 |
| 5. | Girl 12-15 years | 9637 |
| 6. | Boy 12-15 years | 117732 |
| 7. | Office worker | 11313 |
| 8. | Factory worker | 12570 |
| 9. | Coal miner | 15084 |
| 10. | Pregnant woman | 10054 |
| 11. | Woman breast feeding | 11313 |

## Eating too much

Eating more than the body requires to produce energy results in the excess food being converted into fats and stored under the skin. The person gains weight and if the habit of eating excess food continues, obesity results.

On the other hand, when a person is starving or sick, he derives energy from the stored fats. He now loses weight. When all the stored fats are used up, the tissue proteins are also used for supplying energy. Under this condition, the person becomes very lean and weak.

### BMI (BODY MASS INDEX)

A person can know whether he or she is overweight or obese by calculating BODY MASS INDEX.

**Calculation of Body Mass Index (BMI)**

1. Multiply the weight of the person in pounds by 703 (Wt X 703)
2. Divide the answer by the height of the person in inches.
3. Divide again the answer from (2) by the height of the person in inches.
4. The resulting number is the Body Mass Index (BMI) of the person.

**Interpretation**

(a) Overweight person has BMI value of 25-29.

(b) An obese person has value of 30 and above.

(c) A person with value below 25 is not overweight.

## Nutrient cycles

Except for the radiant energy used in photosynthesis, energy does not move through the biosphere in pure form. It flows through the food chain **unindirectionally** and is coupled with matter in the form of chemical bonds. The matter remains within the biosphere,being constantly recycled between living and non-living components. The pathway that matters follows as it moves from the non-living environment through the food chains of the biotic community and back to the non-living (abiotic) environments form closed loops called **biogeochemical cycles.**

There are more than 100 chemical elements on earth and only six of the 16 lightest elements, that is, hydrogen, carbon, nitrogen, oxygen, phosphorus and sulphur play major role in the metabolism of living organisms. Furthermore, oxygen, hydrogen, and nitrogen dominate the chemistry of biosphere and make about 99% of world biomass. There are a number of biogeochemical cycles,but only three are discussed here.

## Carbon cycle

The carbon cycle involves the atmosphere and the ocean. The atmospheric carbon in the presence of sunlight is converted into chemical bond energy during the process of photosynthesis which is shown in the following equation.

$$6CO_2 + 6H_2O \xrightarrow[\text{sunlight energy}]{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

Here carbon (IV) oxide and water are used and organic compound and oxygen are produced, whereas **respiration** has the opposite effect. The carbon (IV) oxide is found in the atmosphere and dissolved in the water of the earth. The amount of carbon (IV) oxide in the atmosphere is 0,03 %. The bulk of the carbon is locked up in the rocky crust as limestone and their rocks. Another source of carbon is **fossil** fuel (crude oil).

**The absorption of carbon (IV) oxide from the atmosphere and water:** The carbon (IV) oxide ($CO_2$) in the air and that dissolved in water constitute the **reservoir** of inorganic carbon. During photosynthesis, green aquatic and terrestrial plants make use of the carbon (IV) oxide to manufacture carbohydrates and other foods. Animals obtain the carbon by feeding on the food of plants containing carbon.

**Returning of carbon to the atmosphere and water:** Terrestrial When terrestrial plants and animals **respire**, carbon (IV) oxide is produced from the break down of the food containing carbon

Glucose + oxygen ⟶ Carbon (IV) oxide + Water + Energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + H_2O + \text{Energy}$$

The fermentation of sugar by yeasts also gives alcohol and carbon (IV) oxide.

$$\text{Sugar} \xrightarrow[\text{by yeasts}]{\text{fermentation}} \text{Alcohol} + \text{carbon (IV) oxide}$$

$$C_6H_{12}O_6 \xrightarrow{\text{yeasts}} 2C_2H_5OH + 2CO_2 + \text{Energy}$$

### Decay

When plants and animals die, bacteria and fungi cause the decay of the dead plants and animals thereby releasing the locked up carbon as carbon (IV) oxide to the atmosphere.

### Combustion

During the combustion of organic materials such as coal, wood and petroleum, the carbon is oxidized to carbon (IV) oxide.

### Decomposition in nature

When plants and animals die, their bodies decay Bacteria and fungi feed on the decaying bodies of these organisms and break them into simpler molecules These micro organisms are called **decomposers** and constitute the final major trophic group in the ecosystem The other **macro-decomposers** are earthworms, ter- mites, mites, beetles and other small arthropods **Fire** in savanna areas also helps as decomposers The primary function of these decomposers in an ecosystem is to decompose the organic compounds locked up in the bodies of producers and consumers and in their waste matter, such as the faeces of animals, and fallen leaves and twigs of plants.

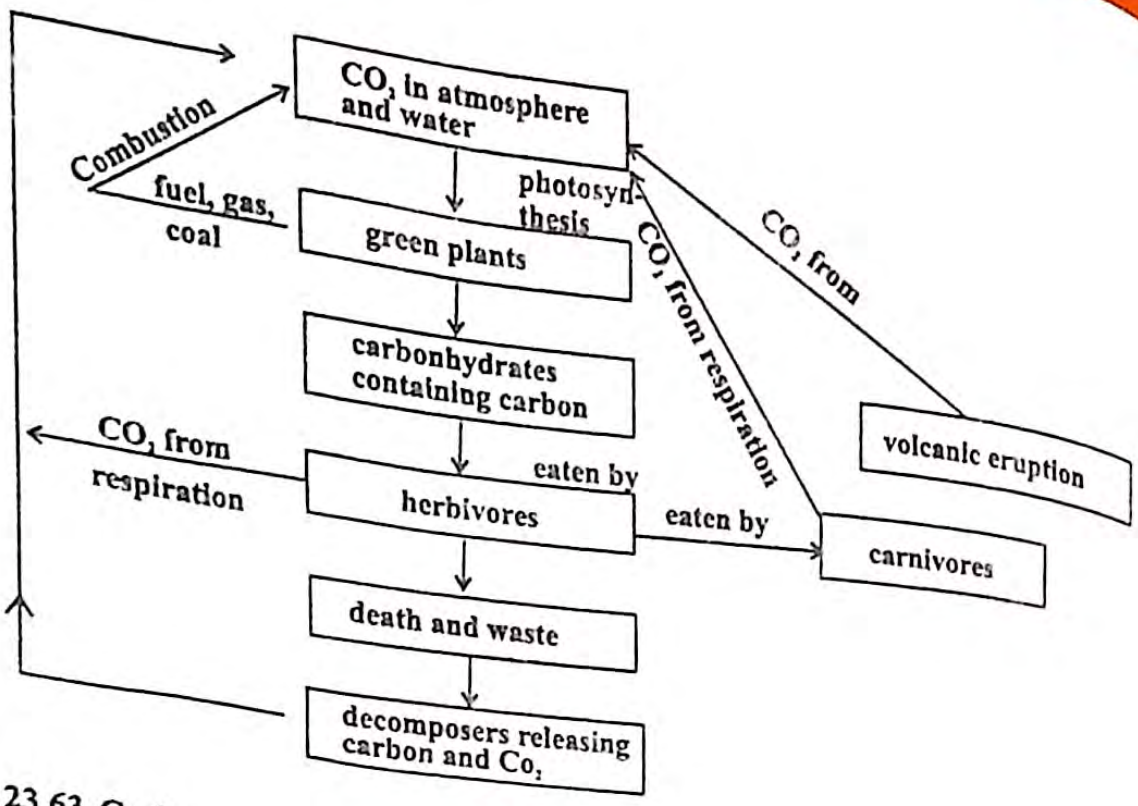



**Figure 23.63. Carbon cycle.**

## Oxygen cycle

The oxygen of the atmosphere is in a dynamic equilibrium. Its 20% concentration is essentially the result of an equal rate of its removal from the atmosphere by respiratory activities of living organisms, balanced by an equal rate of replacement by photosynthesis. It is estimated that if the atmospheric oxygen were suddenly depleted, it would take about 3000 years to restore the oxygen concentration to its original level by photosynthesis.

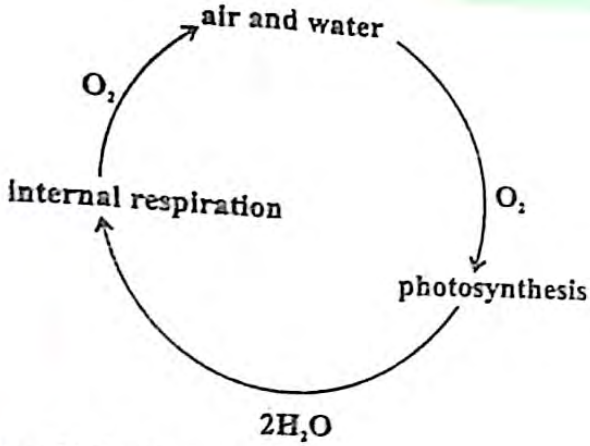



**Figure 23.64. Oxygen cycle.**

## Water cycle

Water cycle is the continuous movement of water from the earth to the atmosphere by evaporation and back from atmosphere to the earth by preci- pitation.

The solar energy causes water to evaporate from the hydrosphere into the atmosphere. When the water vapour cools, it condenses. At high altitude, the condensed water forms clouds. The clouds precipitate as rain returning to the hydrosphere.

Plants and animals contribute to the cycle. Aquatic organisms absorb water from their envi- ronment. They excrete some of the water back and after death the remaining water returns during decay.

Terrestrial plants absorb water from the soil and some of the water is given to the atmosphere dur-ing transpiration.

Terrestrial animals drink water for metabolic activities. Some of this water is returned to the hydrosphere through excretion, respiration and perspiration. The remaining water is returned to the hydrosphere by decay when the organisms die.

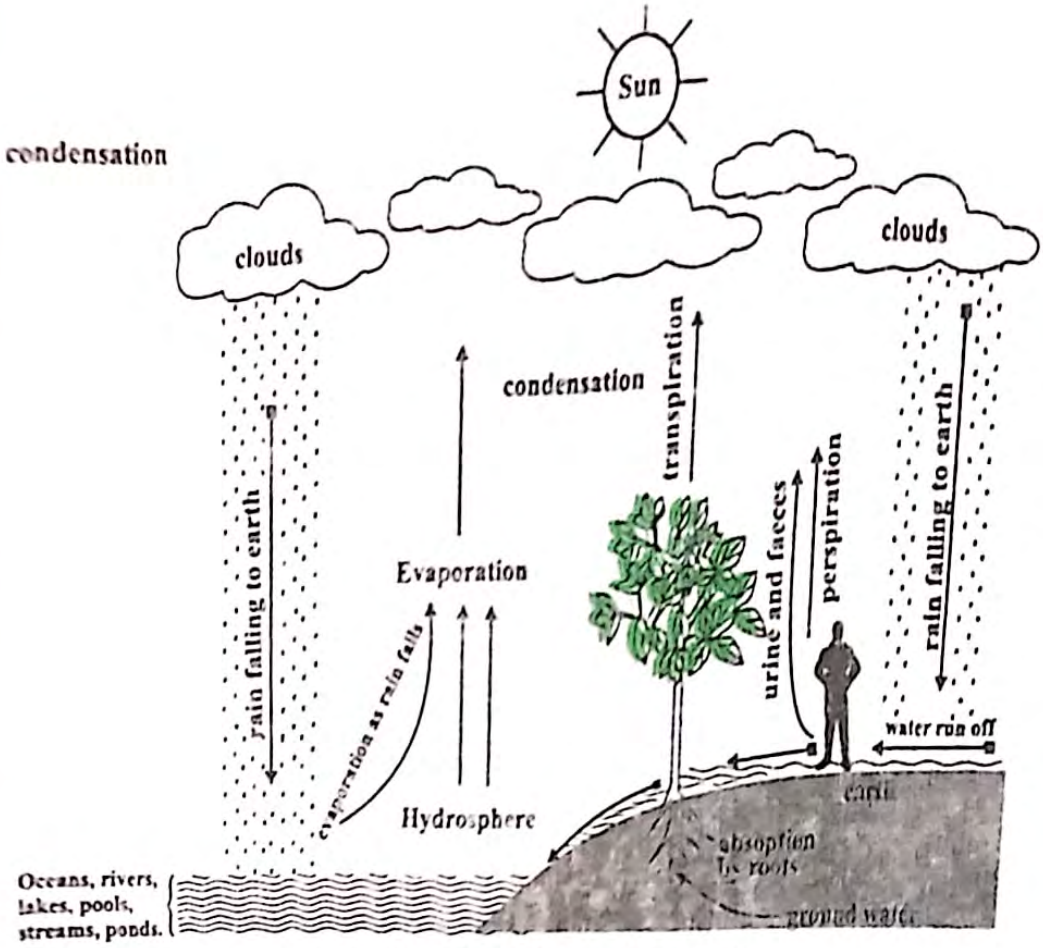



Figure 23.65. Water cycle in nature.

## Nitrogen cycle

Nitrogen is one of the essential elements. It is utilised by plants for making proteins and chlorophyll. The earth's atmosphere contains about 78% of nitrogen. Organisms cannot use gaseous nitro- gen except some few species of bacteria and blue green algae that are capable of utilising the gaseous nitrogen from the soil. Gaseous nitrogen is converted into nitrates in the following ways.

### 1. Nitrogen fixation

Free nitrogen bacteria called *Azotobacter*, *Clostridium* and *Rhodospirillum* living in the soil are able to produce nitrates from the free nitrogen in soil.

### 2. Nitrogen fixing bacteria (symbiotic bacteria)

The species of *Rhizobium* such as *R.leguminosarium* have symbiotic association with roots of some leguminous plants such as groundnuts, beans and crotalaria. These symbiotic bacteria enter the root hair walls of the legumes and multiply thus causing swellings or nodules in the infected cells. They absorb the atmospheric nitrogen in the soil and build up into nitrates which the roots of the plants absorb to form proteins.

The *Rhizobium* bacteria are not capable of fixing nitrogen if they are free from leguminous roots.

### 3. Blue green algae (*Anabaena and Nostoc*)

These species are also capable of fixing the atmospheric nitrogen into nitrates.

### 4. Thunder storms

During thunderstorms, the lightning produced, causes the atmospheric nitrogen to combine with oxygen to form nitrogen (II) oxide (nitrous oxide, NO).

$N_2 + O_2 \text{-------->} 2NO$

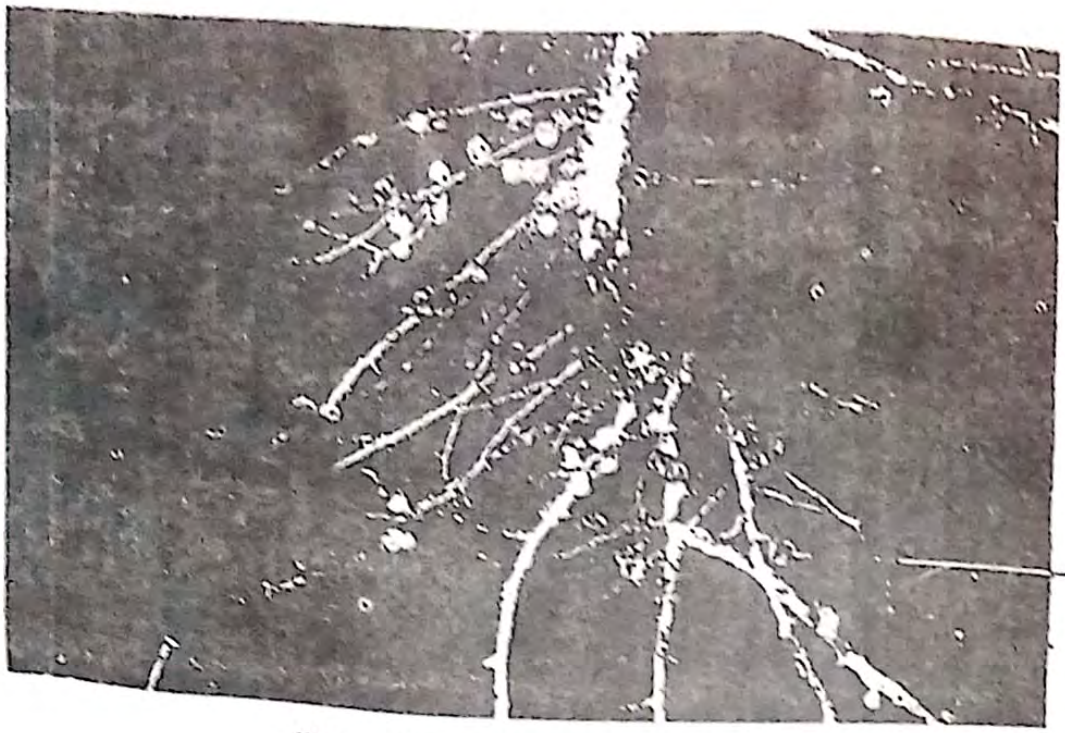



**Figure 23.66. Roots of leguminous plant with nodules.**

The nitrogen (II) oxide reacts with oxygen to form nitrogen (IV) oxide (nitrogen dioxide, $NO_2$).

$$2NO + O_2 \longrightarrow 2NO_2$$

The nitrogen (IV) oxide reacts with rain water to form a weak solution of trioxonitrate (V) acid (nitrous acid, $HNO_2$) and dioxonitrate (III) acid (nitric acid, $HNO_3$)

$$2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$$

When this weak solution of dioxonitrate (III) acid reaches the soil, it combines with mineral salts in the soil to form nitrates which the plants absorb.

5. **Decay**

When plants and animals die, they undergo decay. The protein is decomposed by the bacteria of decay (**putrefying bacteria**) into ammonia, carbon (IV) oxide and water. **Nitrifying bacteria** (*Nitrosomonas*) oxidize **ammonia** to **nitrites** and another variety of nitrifying bacteria (**nitrobacter**) converts nitrites to nitrates which are absorbed by the roots of the flowering plants.

The process of converting ammonia into nitrate is known as **nitrification**.

**Return of nitrogen to the atmosphere**

The process of returning nitrogen into the atmosphere is called **denitrification**. Some bacteria such as *Pseudomonas denitrificans* can convert ammonia, nitrites or nitrates into free nitrogen which escapes into the atmosphere.

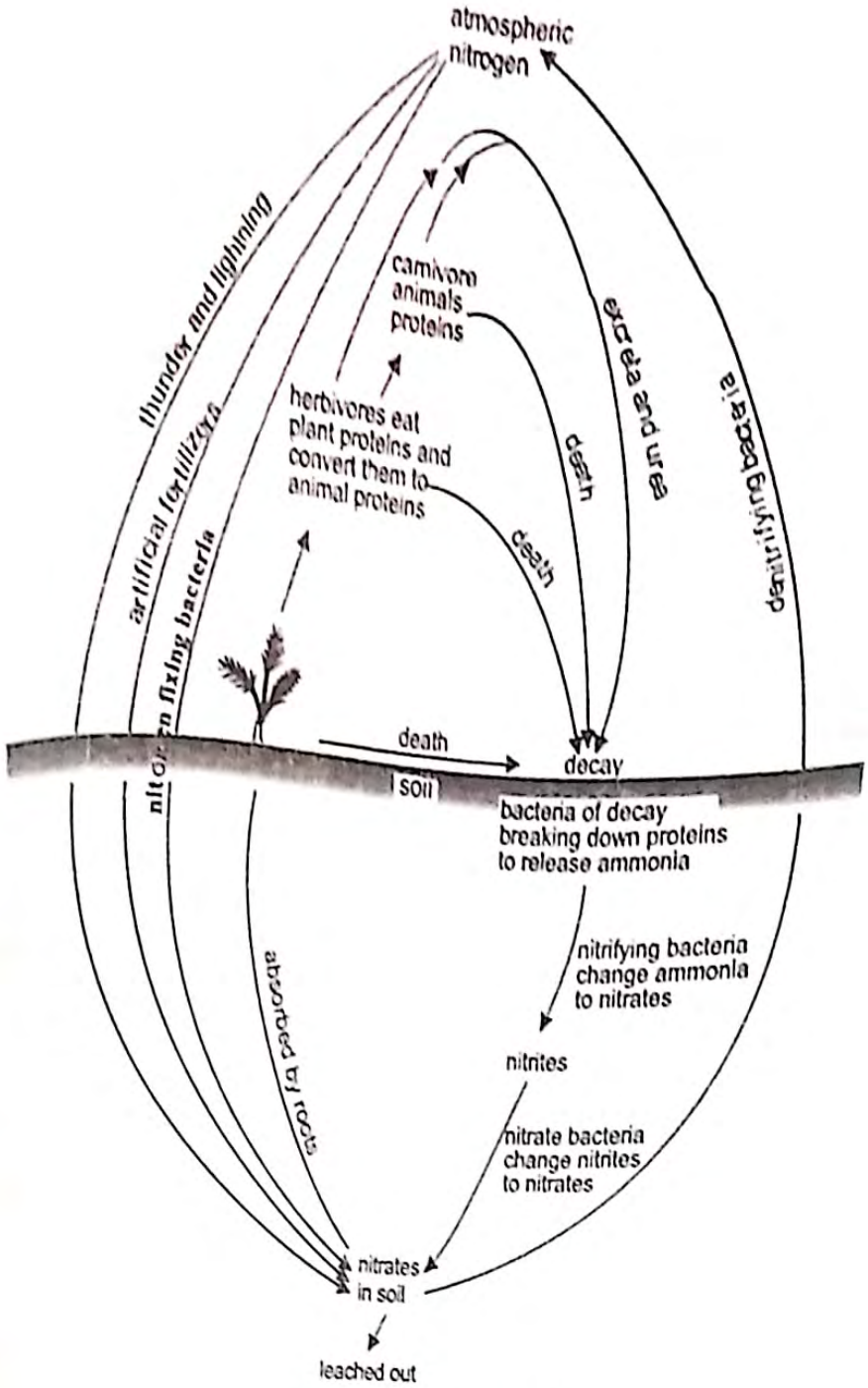



**Figure 23.67. Nitrogen cycle**

The role of **decomposers** is very essential because without decomposers, the supply of materials to the producers and the consumers can-not be maintained. By their action, the minerals originally absorbed by green plants from the soil and later locked up in their bodies or in the bodies of consumers (animals) once again become avail-able to the soil and in turn to green plants (producers). In modern cities,sewage treatment facilities are designed to provide decomposers with an optimal environment, so that they degrade sewage as rapidly as possible.

## Gaseous products

The end products produced by decomposers (detritus food chain) are carbon (IV) oxide, water and such inorganic compounds as phosphates, nitrates and sulphates. When decom- position process is complete, there is no metabolic or combustible organic matter left.

## ECOLOGICAL MANAGEMENT

All the members of a single species living in the same area and interacting with each other are referred to as a **population**. The species of any biotic community live in a state of symbiosis (**Greek: sym = together, bios = life**). If the species of a community are studied two at a time, there are only three possible effects that each member of a pair can have on the **population growth** of the other:
**Positive** (+) means **benefit**.
**Neutral** (o) means no significant **benefit or harm**.
**Negative** (-) means **harm**.

### Types of associations

1. **Neutralism (o/o)**, is neither beneficial nor detrimental to either population. For example, the **direct interactions** between a squirrel and a bird appear to be of this type. Neither ser-ves as food for the other nor do they compete for the same food supply, yet they are part of the same forest community.

2. **Interspecific competition: (-/- and -/o):**
It reduces the availability of a resource, such as food, water, sunlight, space, to the members or at least one of the competing species. The **competitive interaction** between **rice plants** and **weeds** (broad- leaved) is an example of interspecific competition.

3. **Mutualism or Symbiosis:** (+/+). When both populations benefit and at least one of them is so dependent upon the other for some critical resource or function that it cannot survive in the given environment without the other species is referred to as **mutualism** or **symbiosis**. The example of symbiosis is the association between the **alga** and **fungus** (lichens). The alga carries out **photo- synthesis** while the fungus absorbs **rain water** through its tangled network of mycelia, which the alga uses to photosynthesize its food. The fungus gets ready-made food from the alga. Both of them are mutually beneficial to each other.

   The relationship between insect pollinated flowers and insect pollinator (e.g butterfly) is mutualistic. The flowers supply the **nectar** which the insects feed upon and in return the flowers gain by being pollinated.

   The association between human being and the bacteria in his intestine is also mutualistic. The bacteria make vitamin $B_{12}$ and carry out some mi-crobial digestion for him. The bacteria benefit by having nutrients and shelter from human being.

   Another example of mutualism occurs in herbivorous animals (such as goats, sheep and cows) and cellulose digesting bacteria living in the ceacum and colon of herbivores. These bacteria are able to digest the cellulose of leaves and convert the digested cellulose to sugar which is absorbed by the herbivores. The bacteria gain by being provided with shelter and abundant nutrients in ceacum and colon.

4. **Saprophytism**
**Saprophytism** are those organisms which derive their **food** from the **dead decaying organisms** by **secreting enzymes** on the dead matter and absorbing the nutrient by **diffusion**. They digest their **food externally**, that is, outside the body of the saprophyte. The examples are fungi (*Mucor* and yeasts) and bacteria. Saprophytes play an important role in detritus food chain.

   ***Mucor:*** It is a saprophyte that grows on organic matter like bread, cheese, leather or dead wood. It produces hyphae which penetrate the host or substratum and absorb already digested food from the substratum.

   **Bacteria:** They are microscopic organisms which are either **parasites** or **saprophytes**. The sapro- phytic bacteria lack chlorophyll. They are found in water and soil containing organic compounds of plant or animal origin, or dead bodies of plants and animals. They secrete enzymes to bring about the digestion of the carbohydrates, proteins and fats and absorb the digested products.

## Table 85. Differences between parasitism and saphrophytism

| Parasitism | Saprophytism |
|---|---|
| 1. Feed on living organisms | Feed on dead organisms |
| 2. Causes harm to its host which may lead to death of the host. | The host is already dead. |
| 3. Absorbs food which is already digested. | Food has to be digested before absorption. |
| 4. No enzyme is secreted extracellularly to the food. | Enzymes are secreted externally to the food. |

### Predation (— —)

Predation is an interaction in which a free living organism kills another free living organism and eat it as food. The killed organism is the **prey** while the killer is the **predator**. For example, domestic cat kills rat for food. Rat is the **prey** while cat is the **predator**.

### The effects of predation on prey

1. Sometimes limits severely the number and distribution of its prey often below what the environmental resources can support.
2. The prey may become extinct (disappear).
3. The predator helps to cut down the prey population. This is beneficial to the prey (of course not the individual eaten) as it helps to regulate the population size of the prey and prevents it from out-running its resources such as food.

### Parasitism (— —)

Parasitism is an **intimate association** between two living organisms of different species in which one organism obtains **food** and **shelter**. The other is **harmed** and does not receive **any benefit**. The organism obtaining food and shelter without contributing anything in return is termed as the **parasite** while the other organism providing food and shelter and being harmed is known as the **host**.

When the host is parasitised upon, the host may lose vitality. An efficient parasite does not kill its host since the death of the host would deprive the parasite of food and shelter.

Parasites which live inside the body of the host are called **endoparasites**. Examples are *Plasmo- dium* (causing malaria fever) a protozoan living in the red blood corpuscles, *Ascaris lumbricoides* (common round worm) and tapeworm both live in the small intestine of a man. Parasites which live on the surface of their hosts are known as **ectoparasites**. Examples are **head lice**, **ticks**, **fleas**, **lampreys** (a fish parasite), **dodder** (plant) and **mistletoe** (plant).

**Mistletoe**: Is a semi-parasite on the stem of many trees in the forest. It grows on the stem of its host and absorbs the nutrients from the host using their specially developed roots called **haustoria**. It is green and carries out photosynthesis. The host tree is harmed.

## Table 86. The characteristic differences between a predator and a parasite

| Predator | Parasite |
|---|---|
| 1. Usually larger than its prey. | Always much smaller than its host. |
| 2. Kills and eats its prey and then goes on its way. | Passes much of its life on or in the body of a living host deriving food in a harmful manner |
| 3. Less prey specific, lion can eat an antelope, goat, deer and many other mammals. | More host specific. For example, the common round worm (*Ascaris lumbricoides*) parasitises only on human beings. |

**Co-operation**: It benefits both populations, but is not necessary for the survival of either. For example, the flight (running away) of many animal

species of possible dangers (e.g. Predators).

**Commensalism (+/-):** **Commensalism** (*com=together; mensa=table*) is a rela-tionship in which one of the partners (**commensal**) benefits while the other (**host**) is neither benefitted nor harmed. The advantage derived by commensal species from its host frequently involves shelter, support, food or several of these.

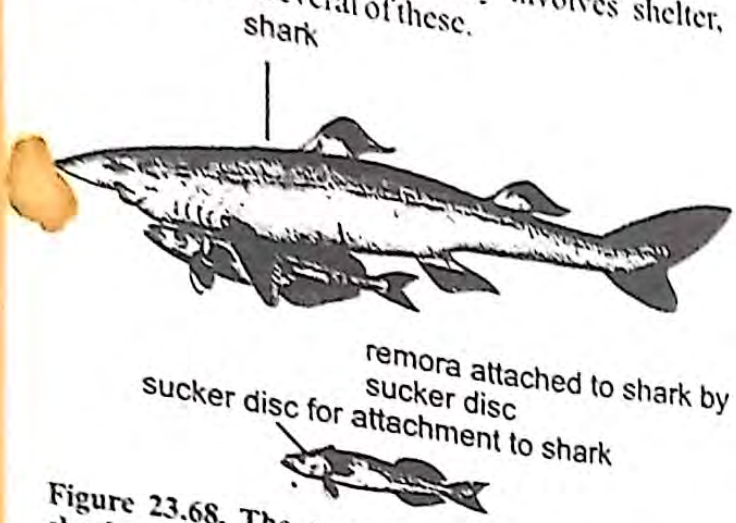



**Figure 23.68. The commensal relationship between shark and remora**

A good example of commensal relationship is found between a small fish called **remora** and **shark**. The remora has a suction pad on top of its head. By means of this pad it attaches itself to the underside of a shark and feeds on scraps of shark's food. Remora also gains wide geographical distribution and protection. The shark neither **benefits** nor **suffers** in any respect.

Another example is the use of trees by birds for shelter and nesting. A Kite for instance builds its nest on the branches of big trees like Iroko. It rests and sleeps on the top of the Iroko. Apparent-ly the Kite does no harm to the Iroko tree and the tree does not gain anything from the Kite.

The dispersal of the fruits of some plants by animals is another example of commensalism. For example, the fruit of ***Triumfetta*** is dispersed by passing animals such as sheep, goats, or cattle. The fruit of ***Triumfetta*** has hooked hair-like outgrowths from the pericarp which cling to the hairs of passing animals mentioned above. *Triumfetta* plant gains by having its fruits dispersed to a new environment while the animals (hosts) are not harmed.

## Hermit crab and bristle worm

**Hermit crab** and **bristle worm** from another example. The bristle worm lives in the shell of a hermit crab. The bristle worm feeds on the scraps of the crabs's food. The worm also enjoys shelter and protection. The hermit crab neither gains nor is harmed.

A small tropical fish, **Fierasfer** (about 11cm long) lives in the rectum of a particular species of sea cucumber. The fish comes out periodically to feed and returns to the rectum by poking the fish's anus, and enters with its tail. The fish gains shelter and the sea cucumber does not gain nor is it harmed.

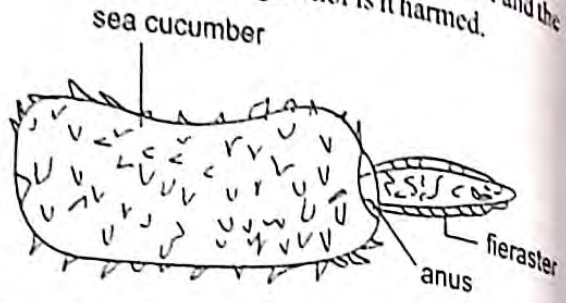



**Figure 23.69. The commensal relationship between sea cucumber and Fierasfer.**

**Allelopathy (+/-):** This is an interaction in which one organism releases a chemical substance(s) into an environment causing a harmful effect on other organisms. For example, the release of chemical substances from the roots and fallen leaves of sunflower plant inhibit the germination of the seeds of other plants near that area while the seed germination of sunflower is not affected. The sunflower plant benefits by eliminating competitions for space, light and nutrients from other plants.

## Adaptation to environmental factors

**Adaptation** is the ability of an organism to survive in any given environment or habitat. The living organisms show different adaptations in aquatic and terrestrial habitats.

### Adaptations of plants to aquatic environment

1. **Spongy tissues:** In most of the aquatic plants (hydrophytes) there are large inter-cellular

spaces and cavities which contain gases used for buoyancy. Examples are *Nuphar, Eichornia* (water hyacinth) and *Pistia* (fig.13abc).

2. Submerged plants lack cuticle
3. Mechanical and water conducting tissues are considerably reduced.
4. Roots are shorter and less branched. Rootlets are devoid of root hairs.
5. Some plants like red mangrove (***Rhizophora racemosa***), white mangrove *Avicennia* spp. and **Raphia** palm possess **breathing roots** or **pneumatophores**. (fig 14)
6. Presence of chloroplasts even in the epidermal cells of leaves and stems of submerged plants is meant to meet the reduced light conditions.
7. Presence of waxy cuticle to prevent wetting of leaves, such as those of *Pistia*, *Lotus* (water lettuce).
8. Vegetative reproduction is highly developed. Fragmentation of the plant body is followed by regeneration from any small part bearing a bud and colonisation by means of rhizomes, stolons and runners is widespread. *Lemna*, *Wolfia* and *Elodea* are examples.
9. Flowers are raised above water for the purpose of pollination.
10. Variable leaf shapes. The submerged leaves are dissected to provide a minimum resistance to water currents and increase the surface area for water and mineral absorption, while the aerial leaves are entire. *Potamogeton* is an example.

## Adaptation of plants to terrestrial environment

1. Many plants have twisted trunks with thick bark as an adaptation for fire tolerance.
2. Possession of thick waxy cuticle and hairs on leaves to reduce water loss by transpiration.
3. Presence of sunken stomata or lower number of stomata to reduce water loss.
4. Modifications of leaves into thorns (*Acacia*) or reduced to scale-like structure such as whistling pine (*Casuarina*) where photosynthe-tic function of the leaves is taken over by green branches.
5. Presence of succulent stems for water storage in many dry land plants, e.g *Cacti, Euphorbia* and ***Opuntia.***
6. Presence of succulent leaves e.g. ***Bryophyllum pinnata.***
7. Possession of deep tap root with extensive lateral roots.
8. Better developed pallisade tissue which frequently occurs on both sides of the leaf blade.
9. Smaller intercellular spaces.
10. Decrease in acidity of cell sap.

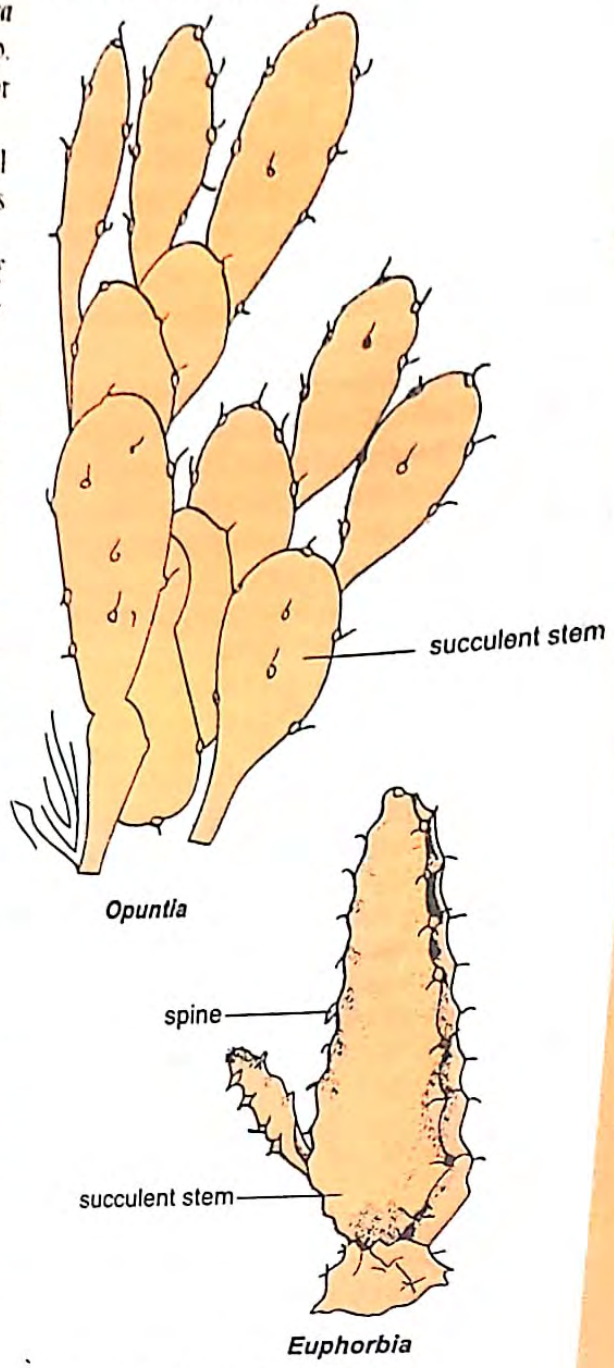



Figure 23.70. *Opuntia* and *Euphorbia.*

## Morphological adaptation of fish to aquatic environment

1. Stream-lined shape of the body enables it to swim easily in water.
2. Absence of neck allows for efficient movements in water.
3. Presence of vascularized gills which absorb dissolved oxygen in water for respiration.
4. Mouth which opens and close alternately, thus allowing water to flow constantly over the surface of the gills and dissolved oxygen diffuses into the thin blood capillaries of the gills and carbon (IV) oxide diffuse out into the water. Oxygen is transported by the blood stream into all cells for aerobic respiration.
5. Presence of lateral line helps to detect vibrations in water.
6. Powerful muscular tail for movement.
7. The pectoral and pelvic fins are used for slow movement and act as brakes. They also help to bring fresh oxygenated water to the gills.
8. The anal fin acts as stabilizer and helps to maintain a straight course.
9. The dorsal and anal fins are used for balancing.
10. The tail fin is used for steering.
11. **Cryptic colouration** (dorsal side is dark while the ventral side is silvery white) which makes fish difficult to be seen by predators above and below.
12. **Mucus** which secreted by the glands in the skin forms covering over the body and helps to lubricate the fish. The slimy body makes swimming easy and helps the fish to escape from enemies. It protects the fish from being attacked by parasites.
13. Presence of overlapping tapering body scales to facilitate water to pass smoothly over its body.

## Adaptation of tadpole to aquatic habitat

1. Streamlined body for easy movement in water.
2. Possession of tail and fin for balancing and swimming in water.
3. Presence of gills for breathing. The skin can also be used for gaseous exchange.
4. Dorsal surface is dark-grey while the ventral surface is silvery white. This camouflages it against predators above and below.
5. Presence of long coiled intestine which is an adaptation for its herbivorous diet.
6. Possession of a pair of horny jaws without teeth enables it to nibble phytoplankton.
7. Two large eyes to see prey and predator.

## Adaptation of animals to aquatic environment

1. Possession of a streamlined body. Such a shape offers minimum resistance to water flowing over them e.g. Fish, insect larvae and tadpoles have streamlined shape.
2. Occurrence of gills (fish) and siphon-like tubes (Mosquito larva) for breathing.
3. Presence of air bladder for bouyancy in water e.g. bony fish.
4. Occurrence of air bubbles on their body surface as in insects.
5. Presence of lungs which are filled periodically with air at the surface e.g. ***Limnaea*** and ***Planorbis*** (water snails).
6. Occurrence of fins (e.g. fish) and webbed toes (e.g. toad) to facilitate swimming movement.
7. The ventral surface of some animals e.g. flatworm and snails are sticky for attachment and occurrence of suckers for attachment to plants or animals.
8. Dorsal side is dark and ventral side is silvery white for camouflage against predator e.g. fish.
9. Presence of lateral line to detect vibrations in water e.g. fish.

## Adaptation of animals to terrestrial environment

1. For the regulation of body temperature, species of mammals (including man) possess hairs, birds have feathers and reptile possess scales.
2. Presence of lungs for respiration (as in bird, toad and man).

3. Presence of sweat glands for excretion and lowering the body temperature.
4. Presence of skin (e.g. mammals) and exoskeleton (cuticle) in insects for protection against injury and desiccation.

## Colour change in chameleon

In order to protect itself from predators, the chameleon has developed a defensive adaptation which enables it to change its skin colour rapidly to match with the colour of its environment thereby making it difficult to be seen by predator(s). The exact mechanism is not fully understood, but it is believed to be physiological.

**Figure 23.71. Chameleon.**

## Tolerance

If the performance of a biological organism is examined along some environmental factors such as moisture, temperature, light, cold, alkalinity or acidity, certain ecological phenomenon can be observed. Most significantly, within a given environment, all organisms will have limits of tolerance beyond which they will not grow. The upper and lower limits of any factor have been termed as the **tolerance limits** of the species and the intervening range is called **range of tolerance.** Under natural conditions, a species must be capable of completing all phases of its life cycle in a given area, if it is to persist there for a prolonged period. However, not all phases of a species life cycle have similar environmental requirements. For example individual phases, such as **vegetative growth** of a plant may have a far wider tolerance range than all phases in combination.

## Geographic range

A particular species can only occupy those parts of the earth's surface where environmental conditions are within its range of tolerance. The geographical limits of the area within which a particular species actually occurs is known as its **range.** The maximum possible area it could occupy is its **potential range.** The potential range of organisms is determined by climatic conditions. Few types of organisms are cosmopolitan, that is, widely distributed throughout the world and they can exist in every type of climate. Temperature factor alone limits the distribution of many organisms to arctic temperate or tropical regions. A particular species, however, rarely occupies the whole of its potential climatic range. Factors of soil and competition tend to restrict its distribution even further.

## *Questions*

1. *(a) Define the following terms: (i) Ecology (ii) Environment (iii) Habitat (iv) Food chains (v) Population and (vi) Ecosystem.*
   *(b) Give an example of food chain in a named habitat.*
   *(c) In what ways does temperature influence the ecology of a place.*
   *(d) Give the name and size of a habitat you have studied.*
   *(e) What did you do to estimate the population of one named animal and one named plant in the habitat?*
   *(f) In what ways are the populations of plants in a habitat influenced by the presence of animals in the same habitat?*

2. *(a) What is (i) a community (ii) an ecosystem?*
*(b) Name two animals and three plants in a named habitat that you have studied.*
*(c) (i) How does each of the named organisms obtain its energy?*
*(ii) How do human beings benefits from the activities of the organisms in that habitat?*

3. *Give a brief description of one named natural habitat you have studied including in your answer.*
*(i) four named animals;*
*(ii) four named plants;*
*(iii) a map or any other suitable diagram showing by means of symbols, the frequency and distribution of two of the organisms named in (i) and (ii).*
*(iv) show how two of th e animals and two of the plants named are adapted for life in this habitat.*

4. *Name <u>one</u> plant and <u>one</u> animal that are found in each of the following habitats:*
*(a) Freshwater pond (b) Tropical rain forest and (c) Savanna.*
*State how the named plant and animal are adapted to each habitat. (Diagram optional). Using arrows only to give an example of food chain in each habitat.*

5. *(a) (i) Define the term population.*
*(ii) List two biotic and abiotic factors each that affect population growth.*
*(b) What are the effects of food shortage on a population?.*
*(c) Describe three methods each for:*
*(i) improving crop yield.*
*(ii) preserving and storing food. Explain the principle involved in each of the methods described for preserving and storing food. (SSC, 1989)*

6. *What do you understand by the following terms?*
*(a) Commensalism (b) Mutualism (c) Predation (d) What are the effects of predatory organism on its prey?*
*Give three characteristic differences between a predator and a parasite.*

7. *(a) Write short notes on any two of the following:*
*(i) Territoriality*
*(ii) Parasitism and*
*(iii) Competition.*

*(b) State four differences between competition and succession.*

8. *(a) What is meant by competition?*
*(b) Explain briefly the term:*
*(i) interspecies competition;*
*(ii) intra species competition.*
*(c) Explain two ways each, by which the toad/rog is structurally adopted to the following:*
*(i) obtaining food;*
*(ii) protection;*
*(iii) movement. (S.S.C.E. 1996).*

9. *(a) List the components of an ecosystem.*
*(b) Describe briefly the interaction among the components named in (a).*
*(c) List major steps taken in studying plants or animals in a community.*
*(d) Distinguish between parasitism and saprophytism*

(e) *Give five examples each of parasites and saprophytes.*

10. (a) *State the approximate percentage composition of air in the atmosphere.*
*Name the gases of the atmosphere which are used directly by:*
*(i) plants and*
*(ii) animals and name the processes in which the gases are used.*
(b) *Describe the nitrogen cycle in nature.*

11. (a) *Why is nitrogen important to flowering plants?*
(b) *How does nitrogen become available to flowering plants?*

12. (a) *How is the percentage of carbon dioxide [carbon (IV) oxide] in the air kept fairly constant? (Diagram of carbon cycle essential)*
(b) *Define the word succession. Describe a succession in a pond or an abandoned farmland.*

13. (a) *What is a climax community?*
(b) *Discuss briefly the various stages starting with a bare rock to a climax community.*

14. (a) *Explain the following terms: (i) food chains (ii) pyramids and (iii) food web.*
(b) *Trace the energy flow through (i) aquatic habitat (ii) abandoned farm land.*
(c) *What do you understand by biogeochemical cycles?*

15. (a) *Define (i) tolerance (ii) geographical range (iii) range of tolerance.*
(b) *Briefly explain the role of decomposers in nature.*
(c) *Draw a map of your country and outline the major biotic communities.*

16. (a) *State the characteristics of a stable ecosystem.*
(b) *Giving suitable example, discuss the changes in the flora and fauna as you move from equator to poles.*

17. (a) *What is the importance of water to a living organism?*
(b) *Define water purification. How can you*
*(i) purify a domestic water supply;*
*(ii) purify a town water supply?*

18. (a) *Describe water cycle in nature.*
(b) *What is the importance of water to living organisms.*
(c) *List seven causes of food shortage.*

19. (a) *Describe overcrowding and state the means to overcome it.*
(b) *How does territory regulate repopulation size?*

20. (a) *Define dynamic equilibrium.*

(b) What do you understand by balance in nature?
(c) Describe pyramid of number and pyramid of biomass. Which one of these do you think is more adequate in a terrestrial habitat?

21. (a) List three major zones in the marine habitat stating one characteristic feature of each zone.
(b) (i) Give one example of plants and animals in the marine habitat.
(ii) Explain how each of the plant and animal is adapted to the habitat
(c) State three behavioural adaptations of animals to seasonal changes in terrestrial habitat.
(d) State three characteristics each of the plant community in the tropical rain forest and savannah (S.S.C.E. 1993).

22. (a) With reference to food chain, explain the role of each the following: (i) green plants; (ii) herbivores; (iii) carnivores and (iv) decomposers.
(b) With the aid of a diagram, describe the carbon cycle (S.S.C.E. 1995).

23. (a) Give a brief description of the characteristics of the Northern Guinea savannah.
(b) Describe how you can estimate the density of a plant species using a quadrat. (S.S.C.E. 1993).
OR
Describe how you can estimate the population of a named fish species in a named fresh water habitat.

24. (a) Describe the characteristic features of the vegetation of the tropical rainforest.
(b) Name two types of savanna found in your country giving one example in each case of a town where they are found.
(c) Describe four ways in which animals in an arid habitat are adapted to (i) drought (ii) high temperatures. (SSCE 2007)

# 24

# POLLUTION

***Pollution** is the unfavourable alteration of the environment due to the addition of impurities by man to constitute danger to either his health or natural resources. It must be realised that pollution results from the by-products of human activities. Pollution impairs the usefulness of the environment*

***Pollutant** is any substance introduced into any environment by man which causes the destruction or impairs the purity of the environment and causing harm to living organisms including man*

**Major types of pollution are:**

1. Water pollution
2. Air pollution
3. Noise pollution
4. Land (soil) pollution

## Water pollution

*Water pollution is the discharge into water body of any substance (usually by man) which may become harmful to plants and animals in the water and make them unfit for human consumption.*

## Causes of water pollution

**Some of the major causes of water pollution are the discharge or dumping of the following into water bodies.**

1. Petroleum hydrocarbons (crude or refined)
2. Poisonous chemicals 3. Human waste
4. Phosphate detergents
5. Fertilizers. 6. Cleared vegetation
7. Heat (thermal).

### 1. Oils (Petroleum hydrocarbons)

**Causes of oil pollution in water**

Crude or refined oil (petroleum hydrocarbons) is one of the poisonous chemicals in water bodies. It has been treated separately from other poisonous chemicals because of its frequent occurrence and destructive effects on the aquatic environment.

(a) Oil spillage (leakage) from oil pipelines.
(2) Rig activities with possible oil spill blowouts and effluents.
(3) Effluents from industries especially oil related industries.
(4) Oil discharge from ships, engine boats and motor tankers.
(5) Urban water run-off containing refined oils such as desiel, petrol and kerosine.
(6) Gas flaring into the atmosphere emitting volatile aromatic hydrocarbons and heavy metals which later fall back into water bodies.

**Effects of oil pollution in water**

Crude and refined oils are some of the poisonous chemicals in water bodies.

i. Deoxygenation causes death of fish species especially lacking accessory breathing organs as the surface water is covered with oil preventing oxygen from dissolving in water and also reduces the amount of light entering the water, hence less photosynthetic activities by green aquatic plants.
ii Gills of fish are damaged thereby impairing respiration.
iii. Aquatic vegetation are killed leading to loss of fish habitats and food.
iv Increase in petroleum hydrocarbons in water and sediments increases zinc concentration in sediments which is toxic to benthic (bottom) organisms decreasing their population.
v. Total petroleum hydrocarbons (TPH) in water above *10mg/l* is harmful to aquatic organisms and human.
vi. Aromatic hydrocarbons of crude oil in water and sediments are extremely harzadous and dangerous to human health. Aromatic hydro-carbons are bioaccumulated by shrimps and fish through drinking of water or feeding from the bottom sediments. Drinking water or eating fish contaminated with

aromatic hydro-carbons will lead to the bioaccumulation of aromatic hydrocarbons in human body.

Aromatic hydrocarbons cause cancer and mutation.

## 2. Poisonous chemicals

There are many poisonous chemicals in our water bodies today due to the discharge of wastes from factories, hospitals and abottoirs. Some poisonous chemicals discharged with wastes into the water bodies include heavy metals such as zinc (Zn), cadmium (Cd), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), iron (Fe), cobalt (Co), mercury (Hg) and petroleum hydrocarbons (oil). Some local fishermen in desperate effort to increase their fish catch even use very poisonous chemicals like gammaline 20 to kill fish without knowing the ecological consequences of their action.

### Effects of poisonous chemicals

Drinking water or eating fish contaminated with the heavy metals will lead to the bioaccumulation (storage) of the metals in human=s organs leading to serious health problems, even death. Exceeding the recommended maximum limits of metals in water and fish are toxic to human's body.

**Table 87. Poisonous chemicals and their harmful effects**

| Heavy metals | World Health Organization (WHO) recommended maximum acceptable limits in water (*mg/l*) | World Health Organisation (WHO) recommended maximum acceptable limits in food (*mg/kg*) | Harmful effects |
|---|---|---|---|
| Zinc | 15 | 10-75 | 1. Depress the immune system leading to the invasion of the body by diseases.<br>2. Accelerates the growth of prostrate cancer and contributes to colon cancer.<br>3. Nausea, vomitting, diarrhoea, stomach ache, poor muscle co-ordination, fatigue and possible kidney failure.<br>4. Toxic to plants at higher level. |
| Cadmium | 0.05 | 2 | 1. High blood pressure<br>2. Kidney and liver damage.<br>3. Destruction of testicular tissue and red blood cells<br>4. Bronchitis<br>5. Cancer<br>6. Inactivated enzymes.<br>7. Abnormal swelling of the lungs<br>8. Abdominal pains.<br>9. Nausea, anaemia, vomiting, dizziness and diarrhoea. |
| Copper | 1 | 1-3 | 1. Stomach and intestinal distress resulting in vomiting, diarrhoea, stomach cramps.<br>2. Liver disorder.<br>3. Water polluted with copper kills water plants and fish. |
| Lead | 0.05 | 2 | 1. Loss of appetite, nausea, abdominal cramps, anaemia and weakness.<br>2. Kidney infection (nephritis).<br>3. Brain damage, mental deficiency leading to abnormal behaviour.<br>4. Lead in water combines with the mucus of the gill covers resulting in the interference with normal respiration causing the death of fish by asphyxiation (suffocation). |

| Heavy metals | World Health Organisation recommended maximum limits in water *(mg/l)* | World Health Organization (WHO) limit for food *(mg/kg)* | Effects |
|---|---|---|---|
| Nickel | Less than 1 | 0.5 - 0.6 | 1 Liver cancer<br>2 Kidney damage.<br>3. Ashma. |
| Iron | 1 | 1 - 3 | 1 Excessive accumulation in the human body promotes bacterial growth as iron is needed in their growth.<br>2 Cancer. |
| Manganes | 0.05 | 0.1 - 0.5 | 1. High levels of manganese causes gene mutation.<br>2 It may also cause Parkinson disease. |
| Chromium | 0.05 | 0.05 - 0.15 | 1 Inhalation of dust containing chromium (IV) and (VI) can cause cancer of respiratory tract.<br>2 Perforation of nasal septum. |
| Cobalt | | 2 | Asthma, pneumonia, nausea, vomiting and cancer |
| Mercury | 0.001 | 0.001 | Mercury is the most toxic metal.<br>1. It causes Minamata disease leading to neurological illness, muscle weakness, loss of vision, mental retardation and paralysis.<br>2 Respiratory fatigue.<br>3. Emotional instability. |
| Nitrate | 45 | - | 1. Leads to children mortality and toxic to adults.<br>2. Nitrate methemoglobinemia in infants (blue babies) of three weeks old. The nitrate $No_3$ in the intestinal tract is reduced to nitrite $No_2$ because of the absence of oxygen. The haemoglobin of the blood prefers nitrite to oxygen and therefore combines with nitrite instead of oxygen resulting in bluish colouration of the infants hence the name Ablue babies@. Death may result from asphyxiation. |

**3.Human wastes**

As industries and population continue to grow, more and more human wastes are produced and dumped into water. Nature's own purification system cannot handle this and as a result, the water is over-loaded with impurities. Most streams, rivers, lakes have been fouled with human and animal wastes and debris of all kinds. The human waste such as faeces and urine may contain disease-causing organisms.

**Effects**

(a). **Diseases**

Untreated human and other animal wastes may harbour viruses, bacteria and eggs of worms that cause diseases such as dysentery, cholera, typhoid, hepatitis (jaundice) and bilharziasis.

(b). **Destruction of aquatic life**

The immediate effect of aquatic pollution is the destruction of aquatic organisms. Sewage and other organic substances dumped into water bodies encourage rapid growth of bacteria and algae. The

bacteria require oxygen for the break down of the organic substances and the required oxygen comes from the water hence the dissolved oxygen in the water is reduced to a level that cannot support aquatic organisms. Fish and all other aquatic organisms die of **asphyxiation**. Fish is a source of animal protein. The death of algae from algal bloom and other aquatic plants in fresh and marine waters may lead to shortage of oxygen in the atmosphere. About 65% of the atmospheric oxygen comes from the sea through photosynthesis. Man will therefore die of asphyxiation if water pollution continues unchecked.

**4. Phosphate detergents**

Phosphate detergents increase the quantity of phosphorus in the water and help to stimulate excess growth of algae leading to **algal bloom** making the water turbid and foamy. The trade names of a few detergents in Nigeria are Omo, Surf and Elephant.

**5. Fertilizers**

Fertilizers (nitrates and phosphates) washed from the farmlands cause overgrowth of algae causing algal bloom and aquatic vegetation.

**Effects:** As explained in item 3.

**6. Cleared vegetation**

Some farmers dump their cleared vegetation into water. The decay of the vegetation causes the shortage of oxygen in water.

**Effects:** As explained in item 3.

**7. Heat (thermal)**

When heat is added to a stream, river, lake or sea it is called **thermal** pollution of water. Some machines in factories use water as coolant. When the used hot water is returned into a stream, river or lake, the temperature of the water rises making it unsuitable for aquatic plants and animals. High temperature leads to less oxygen dissolution in water

**8. Chemical (Cadmium; Cd. - a heavy metal)**

(1) Cd displaces Fe in the blood leading to anaemia.
(2) Bronchial irritation.
(3) Pulmonary oedema.
(4) Headache, chills, muscle aches, nausea, vomiting and diarrhoea.
(5) Damage to olfactory nerve.
(6) Osteoporosis (weakness of the bones).
(7) Itai-itai disease (crippling condition).
(8) Back and joint pains.
(9) Rickets in adults (osteomalacia), and bone fractures.
(10) Lung cancer.
(11) Renal failure.
(12) Alteration of genetic materials particularly chromosomes.

## Air pollution

Air pollution is the addition of air-borne substances such as dust, smoke, soot, nitrogen dioxide, chlorofluorocarbons and hydrocarbons sulphur dioxide into the air which alter the composition of the atmosphere causing harm to both plants and animals.

**Causes of air pollution**

1. Carbon (IV) oxide produced from burning of firewood, coal, oil and natural gases. Carbon (II) oxide (carbon monoxide) is produced from exhaust of automobiles.

**2. Sulphur dioxide, sulphur trioxide and sulphuric acid.**

Sulphur dioxide ($SO_2$) is produced when sulphur or sulphur containing substances such as coal and oil are burnt.

$$S+O_2 \text{-----}> SO_2$$

Sulphur trioxide is produced by the oxidation of sulphur dioxide with the help of sunlight.

$$2SO_2+O_2 \text{-----}> 2SO_3$$

Sulphuric acid is produced when sulphur trioxide reacts with the moisture or rain water in the atmosphere.

$$SO_3 + H_2O \text{-----}> H_2SO_4$$

**3. Nitrogen monoxide (N0) and nitrogen dioxide**

Both gases are produced by automobile. Nitric acid is produced when nitrogen dioxide reacts with water.

4. Production of organic substance such as alco-hol and organic acids to the atmosphere by the incomplete combustion of carbon containing fuels. Evaporation of gasoline, alcohol and acids to the atmosphere also causes air pollution.

5. **Dusts** resulting from construction and wear and tear of roads from automobiles. Lead dust from the fume of petrol

6. Microscopic organisms such as bacteria, fungi, parts of insects: such as wings, hairs and legs all pollute the air.

7. **Chlorofluorocarbons (CFC)**

Chlorofluorocarbons are important gaseous chemicals used as coolants in air conditioners and refrigerators. They are also used as propellants in aerosol spray cans and in making polyurethane foams. When chlorofluorocarbons escape into the stratosphere they destroy the ozone in the stratosphere. Recent reports have shown that big holes have been formed in the ozone layer. This means that the ultraviolet rays of the sun are striking the surface of the earth direct. The ozone layer prevents much of the ultraviolet rays from reaching the earth's surface.

## The effects of air pollution

### 1. On atmosphere

Air pollution reduces visibility of the atmos-phere. Smoke, soot and fog for example reduce the amount of light reaching the earth. This can reduce atmospheric visibility and can cause plane crash and motor accidents.

### 2. On vegetation

**Sulphur dioxide** causes damage to trees, fruits, vegetables and flowers. Ethylene destroys the petals of various flowers. It also interferes with the action of auxins. The destruction of plants will lead to shortage of food.

The **dust particles** in the atmosphere reduce the amount of light reaching the earth. The reduction of light reduces the rate of photosyn-thesis in green plants. Dust particles, smoke, soot may block the stomata of the leaves, affec-ting adversely photosynthesis, respiration and transpiration.

### 3. On soil

The sulphuric and nitric acids reaching the soil make the soil acidic. This affects the fertility of the soil.

### 4. Effects on man

(a) Acute illness possibly leading to death.

(b) Chronic diseases such as asthma, lung cancer and bronchitis.

(c) Irritations, nervous disturbances, eye and nose irritations and offensive odours.

(d) General discomfort and unhappiness.

### 5. The effects of destroying the ozone layer

When the ozone layer is destroyed or depleted more ultraviolet rays reach the earth's surface and thus cause the following:

(a) Ultraviolet rays cause skin cancer, cataracts of the eyes and sunburns in humans. For example, in Australia, where a large amount of the ozone layer is depleted majority of the citizens have or have had cancer problems due to exposure to harmful ultraviolet rays that have leaked through the ozone layer.

(b) Direct ultraviolet rays from the sun is very harmful to living things on the earth surface because they (ultraviolet rays) damage the DNA (deoxyribonucleic acids)- the genetic material.

(c) It produces clouding in humans, thus impairing vision and other visual disorders.

(d) Ultraviolet rays suppress the efficiency of immune system, thus causing the risk of tumor formation, growth and spread

(e) Plankton which form the basis of food chains in all aquatic habitats are destroyed by ultraviolet rays.

(f) In green plants, photosynthesis will be hindered as too much ultraviolet rays destroy the chloroplasts, thus food production is lowered and consequently all animals will face starvation.

(g) Beneficial micro-organisms in the environment are killed.

(h) Complete depletion of ozone layer will allow ultraviolet rays to reach the surface of the earth causing an increase in temperature.

### Control

The ozone layer must be preserved. All chemicals that react with ozone to decrease the ozone layer should be banned internationally.

### 6. On materials

Acids corrode metals and destroy papers, textiles and marble. Inhaling lead fumes causes lead poisoning and consequently death may result.

## Noise pollution

Noise pollution is an impairment of the environmental quality of the air by noise. Towns and cities are becoming noisier.

## Causes of noise pollution

Aeroplane, automobiles, guns of various types, bombs (especially atomic bombs), musical sets and television sets usually tuned to the highest volume, singing and drumming.

## The effects of noise pollution

### 1. Loss of hearing

Loud noise may lead to temporary or in some cases permanent deafness. The noise from towns and cities is high enough to cause deterioration of hearing as we grow older.

2. Emotional disturbance.
3. Causes high blood pressure.
4. Anxiety and fright.
5. General irritation, tension and tiredness.
6. Atherosclerosis (the hardening of the arteries).
7. Causes short temper.
8. Brings about changes in behaviour.

## Land pollution

Land pollution is the dumping of rubbish and chemicals on land by man which makes the land infertile and causing harm to both plants and animals.

**Table 88: Land pollutants, their sources, effects and control**

| Pollutant | Source | Effect | Control |
|---|---|---|---|
| Refuse | Industries, markets, institutions, offices and homes. | 1. Provides breeding grounds for insect and animal pests such as houseflies and rats which cause harm to man.<br>2. Harbours germs which are harmful to man.<br>3. Ugly to sight and causes discomfort due to its offensive odour.<br>4. Occupies a space which would have been used for farming. | 1. Indiscriminate dumping of refuse on the soil must be discontinued.<br>2. Refuse must be burnt or buried in proper places.<br>3. All refuse should be deposited at a dustbin. |
| Poisonous chemicals | Industrial effluents and wastes, domestic sewage, laboratory and hospital dumps, gas flaring. | 1. Eating fish, meat, fruits, drinking water contaminated with metals such as lead, cadmium, nickel, chromium, zinc, copper, manganese, cobalt and mercury is very harmful to man when absorbed directly or indirectly. For example, eating fish from rivers which absorb cadmium from soil is harmful.<br>2. Toxic waste dumps may contain radioactive elements which can cause gene destruction or mutation and possible death in man and animals. For example, strontium-90 can be absorbed from the soil by plants. If animals eat such plants, strontium-90 may be deposited in the flesh, milk or bones. If a man eats such animals, strontium-90 is deposited in his bones. Certain level of strontium-90 can destroy tissues and cause cancer and possible death.<br>3. The site containing toxic waste may not be used for farming again.<br>4. Poisonous chemicals may be dissolved in ground water which will eventually find its way to drinking water bodies such as wells, lakes and rivers. Drinking water from such bodies may be harmful to man. | 1. Dumping of any poisonous chemicals on land must not be allowed. Governments should enact laws to this effect.<br>2. All solid wastes, industrial effluents and domestic sewage must be thoroughly treated before disposal. |

| Pollutant | Source | Effect | Control |
|---|---|---|---|
| Broken bottles, glasses, plastics | Bottle and glass manufacturing factories, breweries, hotels, plastic manufacturing industries, homes and offices | 1. Can cause serious bodily injuries if mishandled or ignored case.<br>2. May render the land difficult to cultivate.<br>3. Occupy farming space.<br>4. May contain water where mosquitoes breed. | 1. Broken glasses and bottles should be gathered together and recycled by glass manufacturing companies.<br>2. Broken glasses and bottles at home must be gathered at a special place and sent to glass manufacturing companies for recycling.<br>3. Waste plastics should be gathered and recycled. |
| Sewage (human faeces, urine and food the changes from household and factories) | Homes, offices, schools and factories | 1. May contain harmful chemicals such as mercury and radioactive elements which when washed to water bodies such as rivers and dams may be consumed by fish and stored in their muscles. Consumption of such fish by man can cause ill health.<br>2. Sewage washed from and to source of drinking water may contain harmful organisms such as protozoans and bacteria that cause diseases such as dysentery, cholera and typhoid fever.<br>3. Sewage may contain the eggs or worms such as those of hookworms. May necessitate collected on mixing food contaminated with infected soil.<br>4. The emitting noxious smelling from open sewers discomfort and cause irritation. | 1. Using deep pit latrines or septic tank latrines.<br>2. Sewage should be properly treated before disposal or recycling.<br>3. Indiscriminate passing of excreta must be avoided. |
| Pesticides and herbicides | From the spraying of crops and vegetation to kill insects | 1. May kill both harmful and useful insects in the air.<br>2. May sink into the soil and kill useful organisms which feed on air-raw and fertilize the soil.<br>3. May be washed to water bodies such as streams, rivers and lakes causing the death of aquatic lives such as fish, crabs and turtles which man hunts to food. Drinking of such water may lead to ill health. | Over or indiscriminate use of pesticides and herbicides must be discouraged. |
| Crude oil | Spillage from oil pipes | 1. Burns the vegetation.<br>2. Poisons the soil minerals.<br>3. Kills the useful organisms in the soil.<br>4. May seep to wells and other bodies thereby contaminating them. Drinking such water may cause ill-health to man. | 1. Oil companies must as a matter of policy check and maintain their pipelines always. In case of oil spillage immediate arrangements must be made to clean up the affected area.<br>2. Governments should enact laws against oil pollution. |

## General control of pollution

1. The Government must develop more stringent regulations to control pollution of water, soil and air and also the existing laws must be enforced at all levels.
2. All industrial effluents must be properly treated and discharged into pits instead of water bodies. All industries must have adequate means of treating and disposing industrial effluents arising from the industries.
3. Solid wastes must be treated and deeply buried to avoid being eroded into water bodies.
4. Vandalization of oil pipelines which leads to oil spillage must be prevented.
5. Old oil pipes must be replaced with new ones to avoid linkages resulting from rusting.
6. Gas flaring which pollutes the air, soil and water bodies must stop.
7. Environmental Impact Assessments must be carried out for any new industry before a new industry is established. Results of such assessment will be used to monitor increase or decrease in pollution levels in future.
8. Frequent environmental monitoring, at least twice a year must be carried out to know the levels of environmental contamination.

## *Questions*

1. (a) *What is pollution?*
   (b) *State five ways in which air pollution and water pollution are each important to man.*
   (c) *Give seven functions of the W.H.O. as the keeper of the world's health.*
   (d) *Name three different types of cells found in the mammalian blood. State their functions.*

2. (a) *Define water pollution and air pollution. Mention two organisms which cause water pollution and outline how these organisms reach our water.*
   (b) *What are the effects of water pollution?*

3. (a) *What are the major causes of air and water pollution?*
   (b) *How can the pollution of air and water affect man's health.*

4. (a) *What are the effects of the following pollution on man:*
   (i) *dust*
   (ii) *carbon (II) oxide (carbon monoxide)*
   (iii) *sewage*
   (iv) *refuse?*

   (b) *What is the importance of sanitation to man?*
   (c) *State five functions of the local Public Health Authority in the maintenance of environmental sanitation.*

# 25

# CONSERVATION OF NATURAL RESOURCES

**Conservation of natural resources** is the wise use and safe keeping of natural resources for the good of mankind, to ensure their continuous avail- ability and to preserve the original nature of the environment.

For many years now, natural resources have been wasted. Much of the wildlife has been destroyed due to ignorance and carelessness. Growth of towns and agricultural developments which are a **must** for our existence have also contributed to the destruction of forests and consequently the destruction of the habitats of wildlife.

If the natural resources are **misused** or **poorly managed,** the resources become less useful or destroyed entirely. For example, if water that is so essential to man's existence is misused due to pollution, its usefulness is reduced and the organisms living in the water such as fish, crabs and turtles etc., may be killed. Such polluted water may be harmful to man's health if drunk and the death of fish, crabs, turtles etc., means shortage of food for man.

Also if forests are set on fire there is the destruction of timber, young trees of future forest, and fertile soil (humus).

## Natural resources

Natural resources are useful things provided by nature. Soil, water, wildlife, forest, minerals, sunlight and air are some examples of natural resources. Natural resources are classified into two categories namely: replaceable and irreplaceable.

## Replaceable (renewable) resources

**Replaceable resources** are those which can only be replaced by offspring that is by reproduction. Trees and animals are examples.

## Irreplaceable (Non-renewable) resources

**Irreplaceable resources** are those resources which cannot be replaced when the initial stock is used up. Examples are petroleum, coal, gold, diamond, copper and iron. Therefore those resources must be carefully managed to avoid their shortage until acceptable substitutes are found.

## Conservation of soil

The soil needs to be conserved if we are to avoid shortage of food, and famine. Mismanagement of soil results in loss of its fertility. For example, overgrazing and burning of the land promote soil infertility and erosion.

The following practices help to conserve soil:

1. **The erosion of the soil** must be checked by planting grasses and legumes to prevent the washing away of the fertile top soil. Crops should be planted on ridges across slopes to prevent the top soil from being eroded.

2. **Practising shifting cultivation** and **crop rotation** helps to conserve soil fertility.
3. **Bush burning** should be avoided as burning destroys timber, young trees, seeds and the rich humus on the floor of the forest.
4. **Manure** should be added to the top soil to make it fertile.

5. **Use of cover crops**

   Leguminous creeping plants such as *Centrosema*, and *Mucuna*, ground nut and *Pueraria* sp are often planted in fallow pieces of land in an attempt to conserve the soil. The

spreading of foliage and extensive root systems of these plants effectively check erosion.

6. **Mulching**
This involves the spreading of a layer of vegetable material on cultivated farmland. The mulching prevents rain drops from directly striking the soil, an action which loosens soil particles. It also prevents loose particles from being carried off by wind or running water.

7. **The "fallow method"**
If a piece of land is left fallow, it is gradually covered with plants. These plants help to conserve the soil of such fallow farm-lands in similar way as cover crops do.

8. **Planting of grass and trees**
Trees and grasses serve as wind brakes thus checking wind erosion.

9. **Speed brakes**
Where farmlands with gentle slopes are cultivated, it is necessary to check the speed of run-off water which results in erosion. This is done by constructing ridges across the slope of the land or large bunds at intervals.

## Benefits of soil conservation

1. It ensures preservation of soil nutrients, hence healthy growth of plants and therefore increase in food for man.
2. It provides healthy habitats for soil organisms which help to aerate and fertilize the soil.
3. It provides raw materials for some industries (for example, clay is an essential raw material for ceramic and brick industries).
4. Preservation of soil fertility is ensured.
5. It prevents desertification.
6. It prevents soil erosion.

## Conservation of water

Water is so essential to life that its conservation is very necessary for a normal existence of life. Water is conserved in the following ways:

1. Burst water pipes must be repaired immediately to prevent wastage of drinking water.
2. Taps must be locked if they are not in use.
3. Dumping of poisonous chemicals, refuse and sewage must not be allowed. Laws forbid-ding dumping should be established.

## Benefits of water conservation

1. It ensures good water supply for agriculture.
2. It ensures the preservation of the natural, habitats of fish and other aquatic animals thus promoting high yield of fish for man's food.
3. It provides water for domestic use.
4. It provides source for hydroelectric power.
5. It provides medium for transportation.
6. It provides recreation such as swimming and sport fishing.

## Conservation of wildlife

Wildlife means animals in their natural habitat. These include fish, frogs, reptiles, birds and mammals.

Wildlife can be conserved in the following ways:

1. Indiscriminate killing of wildlife should be discouraged.
2. Establishment of game reserve to protect the animals from being hunted. Hunting in amereserves is not allowed by law unless permitted.
3. Water bodies such as rivers, streams and lakes should be devoid of poisonous chemicals, (such as gammalin 20 and mercury) sewage and garbage. These kill fish, the food of the fish and other aquatic animals.
4. Killing of young animals should not be allowed. In fishing, mesh size of net that can only catch adult fish should be used.
5. Clearing of aquatic vegetation provides enough space for fish and allows oxygen to circulate freely for the benefit of fish and other aquatic animals. Fish and other aquatic animals will increase in productivity.
6. Constructing dams across rivers should only be allowed when it is of high economic value to the country. Dams disturb fish migration. However, if a dam is constructed, fish ladders (channels around the dam that allow fish to move upstream) should be provided.

7. **Deforestation** destroys the habitats of animals including birds. Therefore, cutting down of trees and burning of bush indiscriminately should be discouraged. Good conservation of forests also helps in the conservation of the wildlife.

8. **Game reserves:** A government acquires a particular area and establishes laws protecting the animals from being hunted and the forest from deforestation.

## Benefits of wildlife conservation

1. It provides continuous source of food.
2. It provides continuous source of raw materials for industries such as fur, hide and skin.
3. It provides recreation for man. Man derives great pleasure from hunting and fishing and hence it promotes tourism. Foreign tourists spend their hard currencies in the country thereby increasing the foreign exchange earn-ings of the country.
4. Scavengers such as vultures help to eat off the dead animals which would have littered around our environment and cause discomfort or ill-health to man.
5. Conservation of wildlife will ensure that ani-mals species are protected from extinction.
6. They will be easily available for study in their own natural environment.

## Conservation of forests

Forests are fast dwindling due to indiscriminate felling of trees for various uses such as firewood and furniture. Bush burning is a major disaster in forests. Air and soil pollution are also contributors to the dwindling forests.

Therefore to prevent loss of our forests and to have continuous maximum benefits from them, conservative methods are necessary,

The following are the ways of conserving forests:

1. **Laws**

   There are established laws that regulate the felling (cutting down) of timber trees. Before any timber is felled, permission must be obtained from the Ministry of Agriculture and Natural Resources.

2. **Forest guards**

   Forest guards who are usually civil servants must guard and protect the forest against mis-use.

3. **Selective cutting of trees**

   Only mature trees are allowed to be felled for timber. Young trees are left to grow to replace the felled trees.

4. **Planting of new trees (Afforestation)**

   It is now a common practice to plant trees. The slogan is that where you remove one tree, plant two. If trees are not planted, there will be shortage of trees in future.

5. **Forest reserves**

   Various governments have acquired forests known as forest reserves. Nobody is allowed to cut down trees, farm and hunt in the reserves except by permission.

6. **No bush burning**

   Burning of forests is forbidden by law. Anybody caught is severely punished.

7. **Government** should bring the cost of coal, cooking gas and electricity to a level which the poor can afford. This will prevent the excessive use of firewood which is one of the causes of deforestation.

## Benefits of forest conservation

1. They ensure preservation and continuous availability of timber and other economic trees.
2. They help to preserve the fertility of the top soil by preventing soil erosion.
3. They prevent desert encroachment that is de-sertification.
4. They preserve the natural habitats of animals hence increase in animal population. With in-crease in animal populations, animal proteins (meat) will be more available for man.
5. They encourage rainfall which plants need to grow well. Healthy growth of plants leads to abundant food supply.
6. Forests act as wind brakes to strong winds hence prevent strong winds from destroying man's properties.
7. Some plants are used for medicines. Their conservation will ensure continuous availability and therefore promote good health.

## Conservation of minerals

Minerals are some of the irreplaceable resources. Therefore careful management is needed to avoid running short of them.

Only Federal Government agencies are authorized to mine minerals in Nigeria. Few individuals or private companies may be allowed to mine minerals.

The quantity to be mined is regulated. For example, the number of barrels of crude oil pumped daily is limited. This practice ensures that we do not run short of oil on time.

## Benefits of mineral conservation

1. They provide continuous source of energy. For example, coal is used for cooking and driving of locomotives such as trains while petrol is used for driving motor vehicles.
2. They provide raw materials for industries. For example, iron ore and coal are used in iron industry.
3. It ensures continuous availability of common salt (sodium chloride) used for food and industries.
4. When sold to foreign countries, earning is in foreign exchange.

## Problems and difficulties of natural resources conservation

Problems abound in attempts to conserve natural resources. Some of the problems are:

1. **Limited source of energy**

   Sources of energy for cooking are few and limited to fairly and highly rich people of the society who can afford to buy them. Coal, cooking gas and electricity are sources of energy which are too costly for the poor people to use as sources of energy for cooking. The poor people who are in majority in the society resort to destruction of forests for firewood for cooking. It is difficult to stop people especially the poor from using firewood when it is the cheapest and most abundant.

2. **Bush burning**

   Bush burning is a major destroyer of natural resources. Some farmers who are too lazy to clear the bush for their farming resort to setting fire on the bush in order to make clearing much easier for them. Some people set fire on the bush to kill animals.

   **Smokers** who throw lighted cigarettes to the bush also cause bush burning. Road makers and campers are not left out in bush burning. The fire used for cooking is often left on the road side or camp site causing bush burning of massive scale. It is very difficult to stop these destructive practices of the people.

   Bush burning as earlier stated destroys timber, young trees, seeds and the humus rich soil. The natural habitats of animals especially mammals and birds are destroyed. This may lead to death of animals in large scale and even extinction of some (such as land snails, tortoises and snakes).

3. **Limited land area for development**

   The human population is fast growing and the demand for land is equally increasing. For some years now buildings, industries and agricultural developments have enjoyed an uninterrupted increase. Many towns have obtained urban status. These have led to clearing of forests and ploughing of fields thereby dwindling the forest area. It will be outrageous to stop developments in preference to forest conservation.

4. **Over fishing**

   Fish population has decreased considerably due to over fishing. All sorts of fish gear have been used indiscriminately including poisonous chemicals such as gammalin 20. Fish nets of various mesh sizes capable of catching the young and adult fish are in use. Many fish species have gone into extinction. The problem here is that the fishermen do not know the after effect of over fishing as most of them are uneducated. Most of them are migrant fishermen and it is difficult to assemble and educate them. Those who take to fishing as their sole occupation, believe that fishing everyday, will give them more money and therefore they will not obey the advice of Government officers.

5. **Over hunting of animals** Hunting is a profession. Animals especially reptiles, birds and mammals have been over hunted by man for food and commercial purposes. Some of these animals are already rare or have gone into extinction.

6. **Overgrazing**

   When domestic animals graze repeatedly on a piece of land, there will be little vegetation to cover the soil. The animals also trample on the soil thereby

compacting it. The structure of the soil is destroyed and water may not infiltrate sufficiently into the soil. The water may collect and flow out as run-off, carrying along soil particles. Also since the soil does not receive sufficient water, it soon dries up and the top soil can be blown away easily.

It is difficult to stop domestic animals from grazing since there is not enough green pastures for them throughout the year. Also the economic value of the animals is assumed to outweigh the over-grazing of the land.

7. **Poaching**

**This is a practice of illegally killing animals for commercial purposes.** For example, elephants are illegally killed in thousands for their tusks (ivory). This unholy practice has led to drastic reduction in elephant population in West and East Africa. Possession of an elephant tusk is a symbol of wealth.

The tusks are in high demand in Japan, North and South Korea, China and Hongkong where they are used in making cutlery, necklace and aphrodisia etc. However, there is now an international ban on ivory trade.

8. **Inadequate guards**

There are many natural resources to protect. Government officials to guard and protect the resources are few. It is not easy for the few forest guards to guard all forests day and night. Neither will the few fisheries officers guard and protect rivers, lakes, streams and sea all the time. It is also difficult for the police to guard against the abuse of all minerals in the country.

9. **Insufficient money and equipment**

To enforce the policy of conservation, enough money and equipment must be available. Lack of sufficient money and equipment to execute the policy of conservation have adversely affected the efforts of conservationist. Publicity in radio, television, handouts, posters to educate people and create the awareness all need money.

## The effects of man's excessive use of natural resources

1. Excessive use of natural resources will lead to poverty in future. For example, over 85% of Nigeria income comes from petroleum. Excessive use of the petroleum will lead to its shortage and this will lead to national poverty.
2. Over use of the forests leads to shortage of trees. Shortage of trees will lead to the closure of furniture and timber industries. Such closure will force us to import furniture at a higher cost from other countries. This will deplete our foreign exchange earnings.
3. The excessive use of forests will deprive wild-life of their natural habitats and their food. Wildlife will eventually die due to lack of habitats and food. The death or reduction of wildlife will result in food shortage for man. Over hunting of wild life will reduce their population and this will also lead to food shortage for man.

   Over fishing of our waters will lead to reduction in fish population hence shortage of fish protein.
4. Pollution of the land, air and water results in decrease of plant and animal's population. Death may result if the toxicity of the pollutant is above tolerable level.
5. Tourism resulting from wildlife will collapse. This will lead to great loss of revenue both in local and foreign currencies.

## Ways of ensuring conservation

1. **Agencies**

   Different agencies to conserve natural resources have been established by various governments. In Nigeria, the agencies are:

a. Nigerian Conservation Foundation.

b. Forestry and Fisheries Divisions of the Federal and State Ministries of Agriculture and Natural Resources.c.Game Reserve Authorities e.g. Yankari Game Reserve in Bauchi State, Borgu Game Reserve in Kwara State and Okomu Sanctuary in Edo State.

d. Energy Commissions.

e. Zoological gardens e.g. Zoological gardens of the Universities of Ibadan, Ibadan and Obafemi Awolowo, Ife.

2. **Conservation education**

People need to be educated about the usefulness of conservation of natural resources. Federal, State and Local governments have launched campaigns through the radio, television, cinemas, newspa-pers, mobile vehicles equipped with loud speakers, handbills and posters about the evils of destroying the natural resources and the usefulness of preserving the natural resources. People are educated to plant two trees where one tree is felled.

A day has been officially set aside every year as a **"tree planting day"** by Federal Government in which the Minister, Commissioners and Supervisory Councillors of Agriculture and Natural Resources in well publicized ceremonies are to plant trees.

Conservation education is now in the syllabus of primary schools throughout Nigeria. This is the best place to start conservation education as it will create awareness in them as they grow.

3. **Conservation laws**

Various conservation laws have been passed by different governments to protect and regulate usage of natural resources. In Nigeria, laws against bush burning, exploration of minerals (e.g. petroleum, coal, gold, diamond and bauxite) by individuals, killing of fish with poisonous chemicals (e.g. gammalin 20) and killing of endangered species.

The above laws regulate and protect the exploration of the natural resources.

## *Questions*

(a) ***What is conservation of natural resources?***

(b) ***List various natural resources that need to be conserved. State briefly the benefits of conservation of each case.***

(c) ***List the problems often encountered in ensuring conservation of natural resources.***

(d) ***What are the efforts being employed in your country to ensure conservation of natural resources? (SSC 1989).***

# 26

# EVOLUTION (HISTORY OF LIFE)

The world is occupied by millions of different kinds of plants and animals. These plants and animals are adapted to different kinds of **habitats** and **niches**. How did these different organisms come to exist in the world? This is the question scientists have been battling to answer for hundred of years now.

There are two theories of history of life. These are **divine creation** (creationism) and **organic evolution.**

## Theory of divine creation (Creationism)

This theory states **that all living organisms were created by God (Divine creation) as described in Genesis in Christian Bible. or a Supernatural being.** Each living organism was given life and necessary features to enable it adapt to its environment. The **Bible** and **Koran** believe that divine creation lasted for **six days** while others believe that creation happened several times with each population dying away and is being replaced with another population and all different organism (species) have remained unchanged since they were created like that by God.

## Theory of organic evolution

1. The **first living organism** is believed to have come from certain molecules (**methane, ammonia, hydrogen** and **water vapour**). These molecules combined together under particular **ultraviolet radiation** from the sun and **electrical lightning** of the hot atmosphere to form the **first living thing** about two billion years ago.

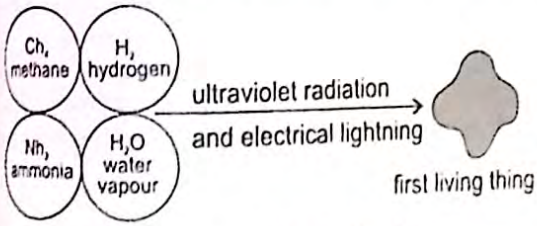



**Figure 26.1. Formation of the first living thing.**

2. The various simple organisms present in the world today evolved from the first living organism.
3. The complex organisms evolved from the simple organisms.
4. All living organisms change from generation to generation, producing descendants with new modifications.
5. The process has been operating since the beginning of life resulting in different groups and varieties of living organisms we have today, those that once lived have become extinct (died away).
6. These different living organisms are related to each other in one way or the other.

***Organic evolution is therefore, the series of gradual changes which living organisms had undergone in response to changes in environment, since the beginning of life.***

## Lamarck's theory of organic evolution

**Jean Baptist Lamarck**, a French biologist was one of the first biologists to put forward the theory of organic evolution in 1801. His idea of organic evolution was hinged on three theories.

**1. The theory of need**

This states that the development of a new part or organ by an organism (plant or animal) results from the need of that part or organ to the organism. For example, the early ancestors of snake had short bodies and legs. As the land was changing during its formation, many narrow places and dense vegetation were formed. For snakes to walk through narrow places and dense vegetation they started stretching their bodies to become elongated so that they could easily crawl through the narrow places and dense vegetation instead of

walking which would be rather difficult.

2. **The theory of use and disuse**

This theory states that **organ become well developed and active when being used but slowly degenerate, become functionless or disappear with disuse**. For example, each generation of snakes continued to stretch their bodies resulting in the strengthening of their bodies. Their legs became useless and strengthless and finally disappeared since they would hinder crawling through narrow places and dense vegetation.

3. **Theory of acquired characteristics by inheritance**

This theory states that all characteristics (structures) or variations acquired by organisms during their life time are transmitted to the next generation by inheritance. For example, the snakes of today inherited their legless and elongated bodies from the ancestors that had lost the legs and short bodies through disuse.

The modern giraffe, **Lamarck** believed, evolved from a giraffe with **short neck** and **short legs**. When competitions for low grasses among the herbivorous animals became too keen, the short-necked and short-legged giraffe started to stretch its neck and forelegs so as to reach the leaves of trees. These characteristics of long neck and long forelegs were inherited by subsequent generations including the modern giraffe.

Some other beliefs of Lamarck were the development of webs between the toes of ducks and frogs. Lamarck believed that ducks and frog originally had no webs between their toes but as they continued to visit water frequently for food, therefore the need to develop webs for swimming became as necessity. The toes and the surrounding skin became stretched and more blood was supplied to the toes leading to the formation of webs for swimming. The webbed toes were then inherited by their offspring.

## Testing Lamarck theory of evolution

Not all scientists at that time supported the Lamarck theory. Many biologists did carry out experiments to disapprove Lamarck's **theory of acquired inheritance**. The most credible work was that of August Weissmann, a German zoologist. He wanted to investigate whether acquired characteristics (traits) were inherited. In his experiment, Weissmann, cut off the tails of mice (males and females) and allowed them to mate. The offspring of all the tailless mice had **normal tails**. He again cut off tails of the **second generation** and allowed them to mate again and the offspring of the **second generation** of the tailless mice had normal tails. Weissmann carried out his experiment for 21 generations. The offspring of the 21st generation had normal tails as the first generation. Non of the offspring had a cut tail throughout the 21 generations.

Weissmann then explained that the body of a living organism consists of two parts namely: **somatoplasm (somatic part)** and **germplasm (reproductive part)**. The germplasm is developed in special organs which produces reproductive cells that bring about variations in organisms that are inherited by offspring. Germplasm is subject to no destruction or alteration and is outside the influence of the environmental factors.

The somatoplasm is responsible for all production of all the somatic (body) cells of an organism. The somatic cells are influenced by environmental factors resulting into **acquired variations** which are never inherited by offspring since such variations are never transferred to germplasm for inheritance. Therefore, Lamarck theory of acquired inheritance was set outside.

However, Lamarck theory of **use** and **disuse** is still plausible. Gradual changes take place from time to time due to **use** and **disuse**. For example, a weight lifter develops strong hand and chest muscles due to use and those muscles become weak and thin if put in cast of POP (Plaster of Paris) when there is bone fracture, thus preventing the use of the hand during the healing period. The wings of ostrich are small and weak and cannot be used for flight due to disuse.

## Darwin's theory of organic evolution by natural selection

**Charles Darwin**, a British biologist, in 1859 propounded a theory of organic evolution by **Natural Selection** leading to the origin of species.

His theory of natural selection is as follows:

1. **Overproduction**

All living organisms produce more offspring than can survive.

2. **Struggle for existence**

Due to overproduction of offspring, there is a constant struggle (competition) for existence among the offspring.

3. **Offspring show variations.**

No two individuals are exactly the same.

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4. **Adaptive characteristics**

Some of the offspring are well adapted (fitted) to survive the competition than others.

5. **Inheritance of adaptive characteristics**

The well adapted ones (or the fittest) will transmit such variations to their offspring. Those with poor adaptations will die off.

6. **Development of new species**

An accumulation of favourable variations will in a long time lead to a **divergence** (spread) from the original stock resulting in the formation of **new species.**

Figure 26.2. Charles Darwin (1809 - 1882).

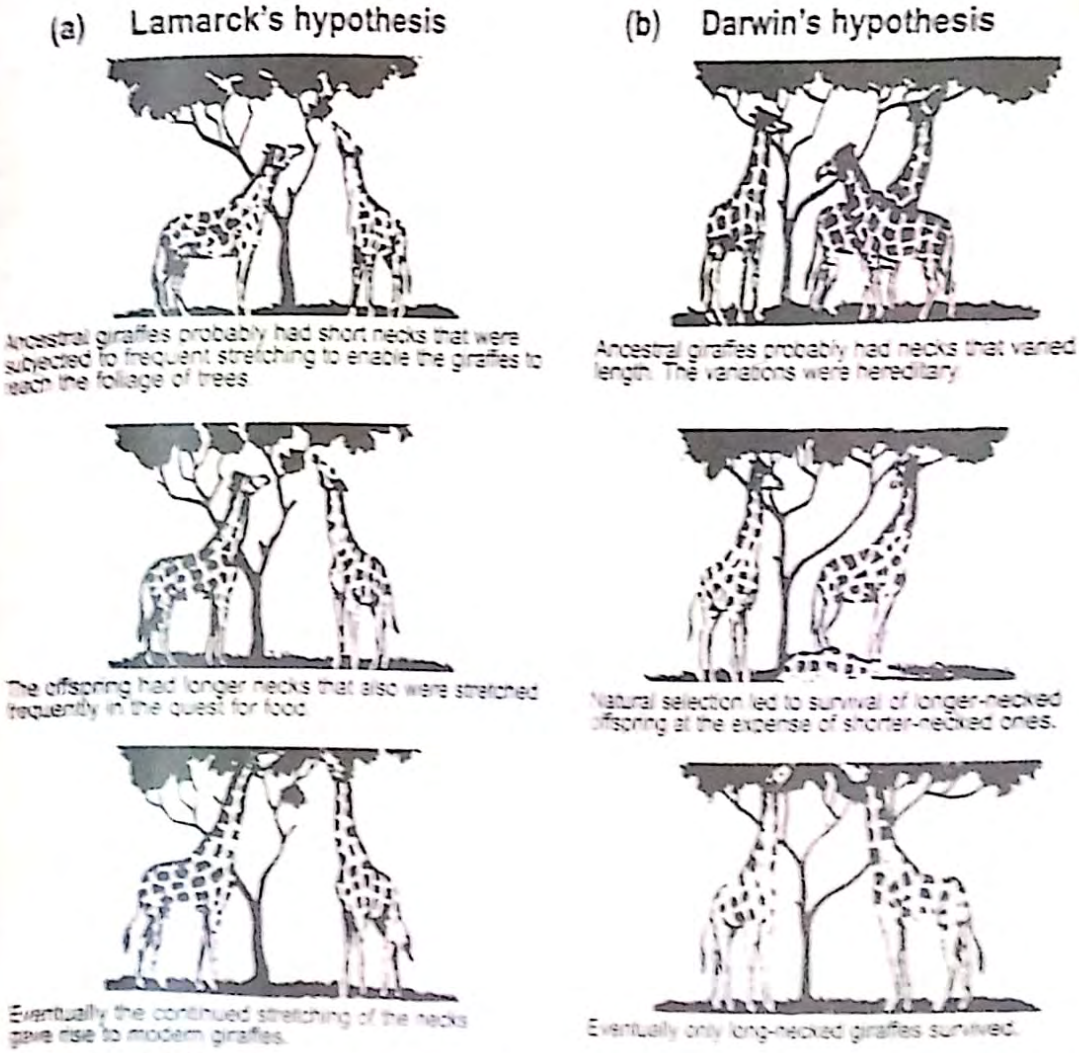


Figure 26.3. A comparison of Lamarckian and Darwinian hypothesis - the evolution of giraffes (Courtesy. Biological Sciences Curriculum Study).

## Modern theories of organic evolution

The theory of organic evolution as stated by Darwin has been modified. The modern theories are now based on **genetics, ecology, cytology, palaeontology, physiology, anatomy and embryology**.

## Evolution of new species by mutation and isolation

## Mutation theory of organic evolution

**Mutation** is a change in genetic material resulting in a new stable characteristic which can be inherited by offspring. **Hugo De Vries**, a Dutch botanist propounded the **mutation theory** of organic evolution in 1901 after many years of scientific work with **evening primrose** plants. He discovered that out of 50,000 evening primrose, that 800 of these plants showed traits (variations) not present in their parent plants. He concluded that mutation occurred in the 800 **primrose plants** and the new traits (variations) found in the 800 plants were transmitted to the offspring.

From this study **Hugo De Vries** further con-cluded that mutations similar to primrose plants are frequently occurring in other **organisms** too and that change by mutation forms the basis for evolution.

## Mutation

Mutation is the sudden changes in genetic makeup (DNA) either in gene or chromosome resulting in a new characteristic or trait that can be inherited. Mutation occurs during meiosis when the sperm and eggs (ova) are being formed. When mutation occurs, it will lead to the production of offspring with marked differences in appearance from other members of the population of the species. An organism arising from mutation is called **mutant**. Mutations provides raw materials for organic evolution through natural selection of new species.

**A mutation** which provides an organism with **beneficial trait (variation)** for adaptation to its environment will **survive the struggle for existence.** This **trait is inherited** by the organism's offspring and gradually the trait will spread through the entire population leading to formation of new species.

### Types of mutation

There are two types of mutations namely: **gene mutations (points mutations)** and **chromosome mutations.**

**Gene (point) mutations** are sudden changes in the structure of DNA (gene code) at a **particular point** or **area** of the chromosome. Gene mutations occurring in the **reproductive cells** are inherited by all the cells of the offspring while **somatic (body) mutations** occur only in the **somatic cells** and are only inherited by the cells produced by **mutant cells by mitosis**. Somatic mutations are not transmitted to offspring since reproductive cells are not involved. Somatic mutations are transmitted in plants with vegetative reproduction, hence there are many new varieties of plants.

**Somatic mutant cells** may give rise to tumour which may become **benign** without affecting other cells or become **malignant** and may invade healthy cells, a condition referred to as **cancer**.

**Chromosome mutations** are caused either by **breaking off** or **fragmentation** of chromosomes during meiosis. The following may happen to the break off or fragmented part. It may

(i) be lost **(deletion)**

(ii) be attracted to another end of another chromosome **(translocation)**.

(iii) be fused to another chromosome resulting in **duplication.**

(iv) turn through an angle of 180° and rejoin the chromosome **(inversion)**.

**Causes of mutation**

Mutation may be caused by frequent exposure to

(i) X-rays

(ii) ultra-violet sun light

(iii) cosmic radiation.

(iv) chemical mutagens usually present in cigarettes. **Minor gene mutations** occur frequently with **no** or **little** characteristics (traits) expressed on the organism. Mutant genes are generally recessive

heterozygous offspring in which other gene is normal. For example, if one gene in a pair of genes AA mutates to **a**, the mutant characteristic will not appear in the heterozygous offspring (**Aa**). However, if mutant gene continues to increase in the population, a situation will arise in which two recessive mutant genes (**aa**) will pair, resulting in the production of a homozygous offspring with a new characteristic.

If the mutant recessive genes in the homozygous offspring are **lethal**, then organism stands a chance of possible elimination.

**Major mutations** are usually **lethal (harmful)** to the organism even leading to its death or serious deformity. For example, the gene mutation responsible for the **production of chlorophyll** in green plant is harmful since it will make the plant unable to manufacture food through photosynthesis and consequently it will lead to the death of the plant.

## Evolution of new species by isolation

If members of the same species in populations are isolated or separated by natural barriers and prevented from interbreeding for a long period (thousands of years), new species will evolve as their genes may undergo mutation. The isolated species would not share the mutant genes with the species of other populations. Distinct variations would occur in the species of each separated population.

Possible natural barriers are mountain ranges, deserts, oceans, seas, lakes and rivers. With sea or ocean as a natural barrier, there is little or no chance of plants and animals of the species to interbreed.

## Some similarities between Divine creation and organic evolution

1. Both **Divine creation** and **organic evolution** believe that man came last of all living things.
2. Both also believe that snakes once had legs (Lamarck's theory of **use and disuse** and the **curse of snakes** (serpent) to crawl on its belly by **God** after deceiving **Eve** to eat the forbidden fruit in the **Garden of Eden** (Genesis Chapter 3, verse 14).

## Evidences in support of organic evolution

### 1. Evidence from comparative anatomy

**Homologous structures** can be used to explain the evidence of comparative anatomy. Homologous structures are those structures which are built in the **same common plan** but yet modified to perform **different functions**. For example the fore-limbs of frog, bird, horse, whale and man are in the **pentadactyl plan** but yet perform different functions. Thus, the fore limb of frog is modified for landing; that of the birds is modified as wing for flying, the fore limb of horse has only one digit (finger) for fast running, that of whale is used for swimming while in man, the fore limb could be rotated and has five fingers for holding and grasping. These different functions are brought about due to differences in environment. The only reasonable explanation to this common plan of the forelimbs of the vertebrates indicate a genetic relationship and common ancestor.

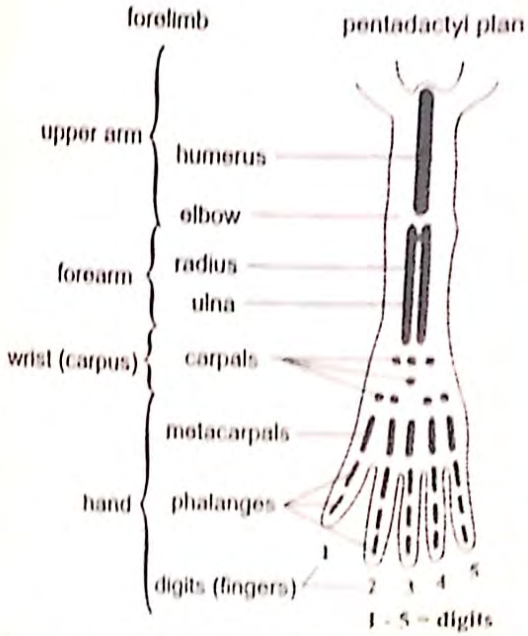


**Figure 26.4. Homologous structures of different vertebrates.**

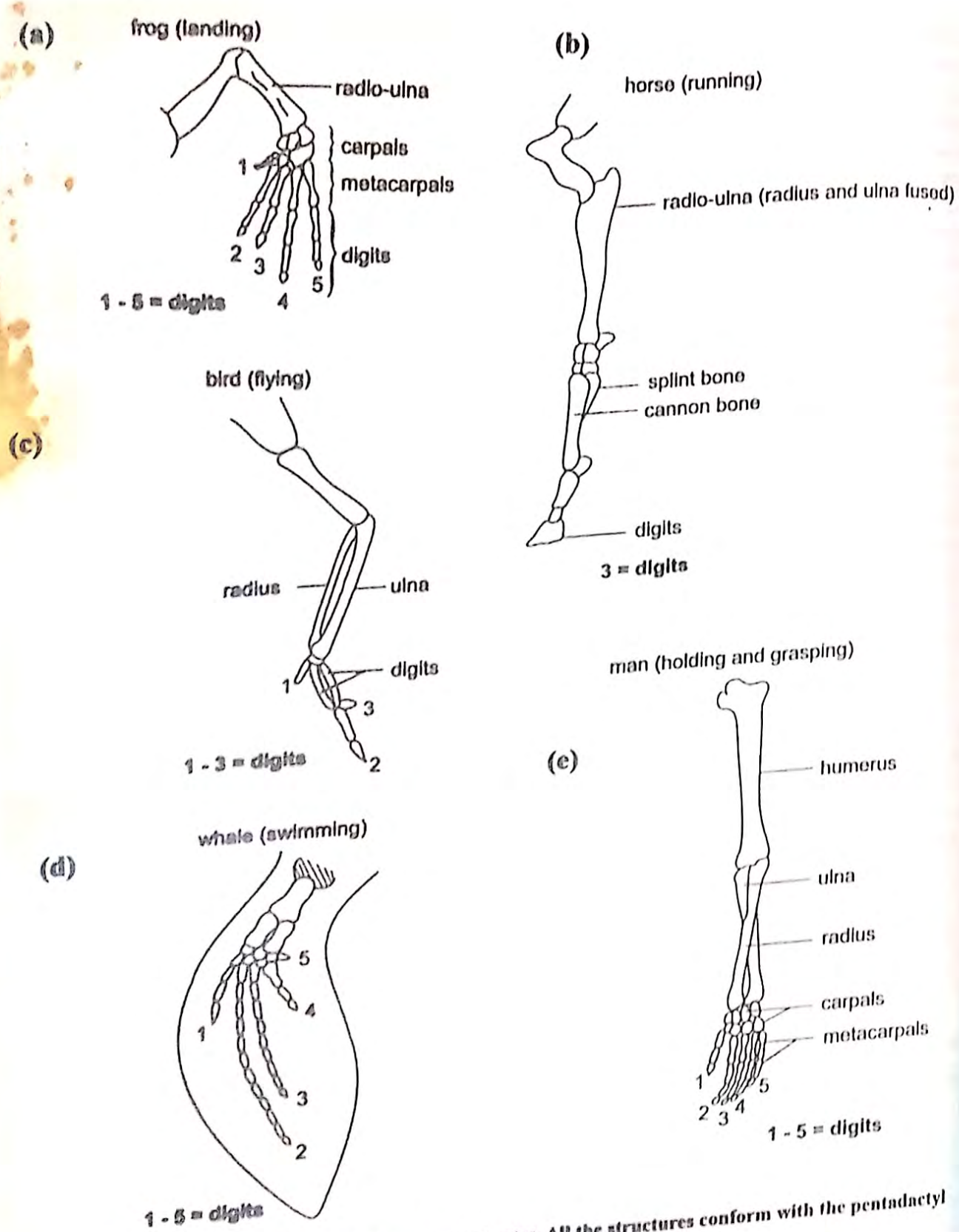


**Figure 26.5. The homologous structure of different vertebrates. All the structures conform with the pentadactyl plan but modified to carry out different functions.**

### Evidence from vestigial organs

Other convincing aspects of comparative anatomy are the **vestigial organs**. These are the rudimentary or useless organs still found in animals and plants. A good example is the **appendix** of man. This organ has no function in man but it is notorious as seat of disease. In herbivorous mammals such as cow and goat, this organ is large and performs useful job. Bacteria are present in it which help to break down cellulose of cell walls found in a vegetable diet. The appendix of these mammals also allows extra time for food digestion. Thus, the appendix of man can only be explained as a degenerative organ inherited from his ancestor with a functioning appendix and vegetable diet, if not, it is very hard to explain why such a functionless and useless organ should be created to be a source of disease to man.

The **caudal vertebrae (coccyx)** of a man have become vestigial. They have become fused together and reduced to small sized bones called **coccyx**. The caudal vertebrae have no function in man but in other mammals they perform useful function. The caudal vertebrae have developed into tails in most mammals. In monkeys the tail is used for balancing. In goats, sheep and cattle, the tails are used for driving insect pests away from the posterior part. Again the only possible explanation to the possession of a tail by man is that man and mammals possessing tails descended from a common ancestor that once used tail. Some other vestigial organs of man are **pyramidalis nasi muscle of the forehead**, and **posterior auricular muscles of the ear.**

The **pyramidalis nasi** (extrinsic) muscles in man is functionless but other mammals use it in moving the scalp to drive away insect pests.

The **posterior auricular muscle** in man is functionless but used by other mammals in moving the pinnae (outer ears) towards the direction of sound and driving away insect pests.

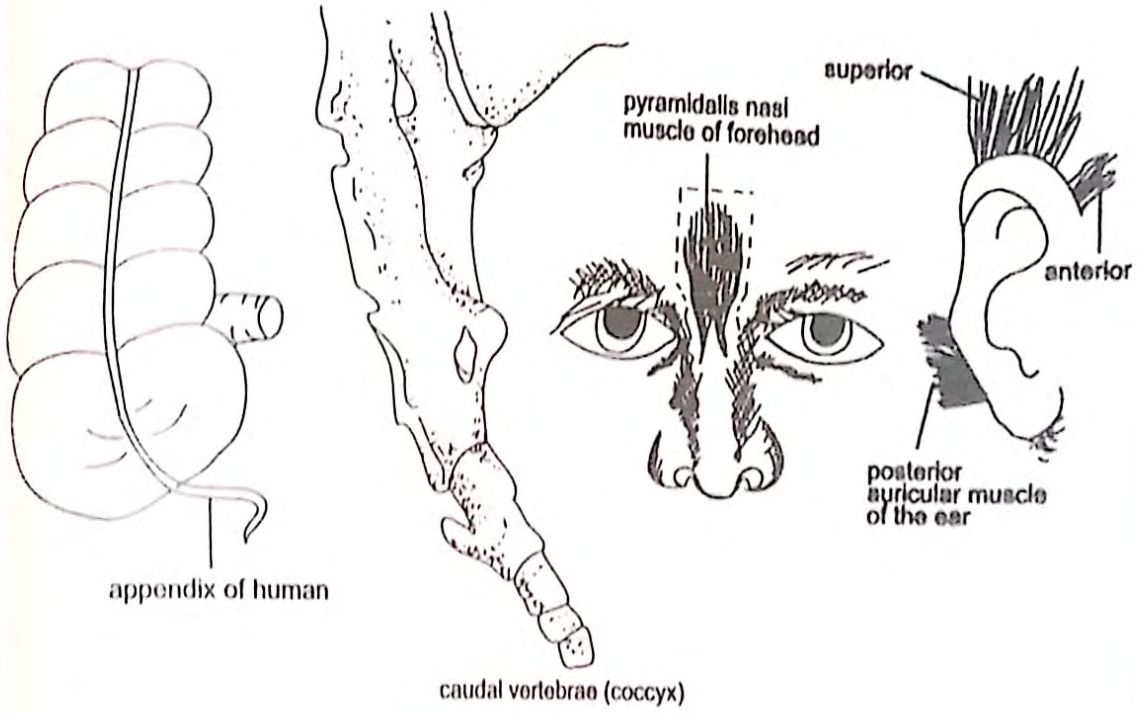


**Figure 26.6. Vestigial organs of man.**

### 3. Evidence from physiology

**Enzymes** and **hormones** are similar in many groups of animals. **Trypsin** is present right from protozoa to man. **Amylase** is also found in the majority of animals. The actions of these two enzymes are similar in all animals. Thyroid hormone is present in all vertebrates. It has been proved that

the thyroid hormone of vertebrates is exchangeable amongst them. For example, the thyroid hormone from cattle has been used successfully to treat human thyroid deficiencies. This proves that all vertebrates descended from a common ancestor.

**5. Evidence from fossils**

Fossils are long-preserved remains or imprints of organisms that once lived.

Those ancestors of the modern horse can be traced through fossil evidence.

The most ancient horse called *Eohippus* lived during the Eocene period about 55 000 000 years ago. The *Eohippus* was about a medium sized dog. Its teeth were short-crowned. The forelimbs had four functional toes with the rudiment of the fifth while the hindlimbs had four toes. In this Eocene period, the *Eohippus* lived on abundant vegetation bordering streams. Therefore the short-crowned teeth were used for browsing than grazing. The forelimbs and hindlimbs were suitable for support on the soft ground. Height was about 5 feet.

In Oligocene period about 35 000 000 years ago, another horse called *Mesohippus* evolved. *Mesohippus* had three toes in both fore and hind limbs and long-crowned teeth. In Oligocene period, there were fewer streams and the land was becoming drier. Grasslands and forests were becoming dominant. Under this condition, the need to escape from enemies became important hence the reduction of toes to three for speed. The third toe was enlarged. The high crowned teeth were adapted for grazing than browsing. Height was 5 feet.

In Miocene about 26 million years ago, *Merychippus* evolved. The weather was very dry. Grass lands were dominant. The need for speed to escape from predators became very important. The second and fourth toes became reduced and the third toe enlarged. Teeth became longer with cemented crown. Height was 1m.

In Pliocene period about 7 million years ago, *Pliohippus* evolved. There was still greater need for speed to escape from predators as the weather was still very dry. The second and fourth toes became highly reduced and third toe enlarged with hoof. High crowned teeth for eating grass became prominent. Height was 1m.

In Pleistocene about 1 million years ago, the modern horse called *Equus* evolved. The second and fourth toes disappeared. The third toe became enlarged with hoof. Teeth now have large surface area. Only molar teeth were present.

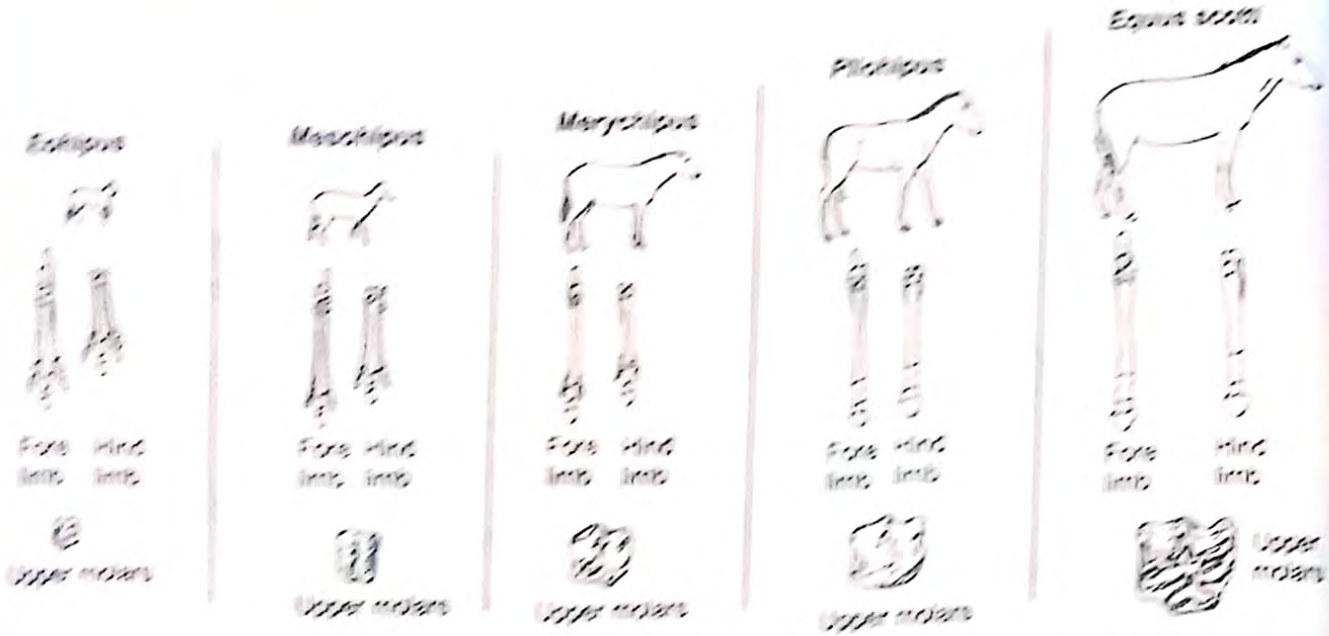


Figure 26.7. Evolutionary tree of the horse. (Diagrams after C.W. Hunter and P.R. Hunter).

### a. Evidence from embryology

The developments of vertebrate embryos are similar. The **law of biogenesis** states that during the development of an individual, it passes through many embryonic stages that its ancestor underwent earlier because the mechanism of development was inherited from a common ancestor. In other words, ontogeny recapitulates phylogeny.

In the development of human embryo many primitive features appear and disappear. The appearance of **gill slits** like those of fish, **two chambered heart** like those of amphibians, appearance of **tail** like those of reptiles and **coat of hair** like those of monkeys are obvious facts to show that human being evolved through the fish, amphibian, reptile and mammalian line.

The **whalebone whales** have no teeth in the adult stage. They feed on minute organisms of the sea. But it is surprising to note that their embryos have **teeth buds** which are absorbed as development continues. Birds have no teeth, yet their embryos are teeth buds.

Thus, the presence of **teeth buds** in whales and birds prove that they have descended from ancestors that had teeth.

### b. Evidence from cytology

The electron microscope has revealed that the cell structures (membranes, mitochondria, Golgi apparatus, ribosomes, lysosomes etc.) are all similar in all living organisms. This shows that all living organisms evolved from a common ancestor with similar cell structures.

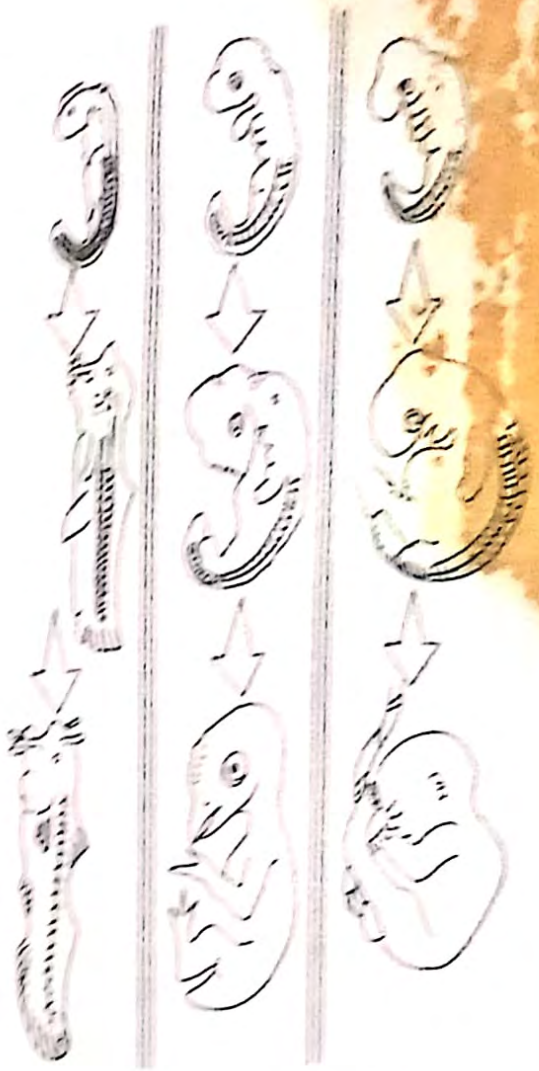

Figure 26.2. Different stages in the development of three vertebrate animals. Note their similarities in the very early stages and their differences in the later stages.

## Table 89: Geologic Time Table

| Era | Period | Epoch | Time from Beginning of Period to Present (millions of Years) | Geologic Conditions | Plant Life | Animal Life |
|---|---|---|---|---|---|---|
| CENOZOIC (AGE OF MAMMALS) | Quaternary | Recent | 0.011 | End of last ice age; climate warmer | Decline of woody plants; rise of herbaceous one | Age of man |
| | | Pleistocene | 1 | Repeated glaciation, 4 ice ages | Great extinction of species | Extinction of great mammals; first human social life |
| | Tertiary | Pliocene | 13 | Continued rise of mountains of Western North America; volcanic activity | Decline of forest; spread of grasslands; flowering plants; monocotyledons developed | Man evolved from manlike apes; elephants, horses, camels almost like modern species |
| | | Miocene | 25 | Sierra and Cascade mountains formed; volcanic activity in northwest U.S.; climate cooler | | Mammals at height of evolution; first manlike apes |
| | | Oligocene | 36 | Lands lower; climate warmer | Maximum spread of forests; rise of monocotyledons; flowering plants | Archaic mammals extinct; rise of anthropoids; first runners of most living genera of mammals |
| | | Eocene | 58 | Mountains eroded; no continental seas; climate warmer | | Placental mammals diversified and specialized; hoofed mammals and carnivores established |
| | | Paleocene | 63 | | | Spread of archaic mammals |

Rocky Mountain Revolution (Little Destruction of Fossils)

| | | | | | | |
|---|---|---|---|---|---|---|
| MESOZOIC (AGE OF REPTILES) | Cretaceous | | 135 | Andes, Alps, Himalayas, Rockies formed late; earlier inland seas and swamps; chalk, shale deposited | First monocotyledons; first oak and maple forests; gymnosperms declined | Dinosaurs reached peak, became extinct; toothed birds became extinct; first modern birds; archaic mammals common |
| | Jurassic | | 181 | Continents fairly high; shallow seas over some of Europe and western U.S. | Increase of dicotyledons; cycads and conifers common | First toothed birds; dinosaurs larger and specialized; marsupials |
| | Triassic | | 230 | Continents exposed; widespread desert conditions; many land deposits | Gymnosperms dominant; declining toward end; extinction of seed ferns | First dinosaurs, pterosaurs and egg laying mammals; extinction of primitive amphibians |

Appalachian Revolution (Some Loss of Possi

ly)

| Era | Period | Epoch | Time from Beginning of Period to Present (millions of Years) | Geologic Conditions | Plant Life | Animal Life |
|---|---|---|---|---|---|---|
| PALEOZOIC (AGE OF ANCIENT LIFE) | Permian | | 280 | Continents rose; Appalachians formed; increasing glaciation and aridity | Decline of lycopods and horsetails | Many ancient animals died out; mammal-like reptiles became more great |
| | Pennsylvanian (Late carboniferous) | | 320 | Lands at first low; great coal swamps | Great forests of seed ferns and gymnosperms | First reptiles; insects common; spread of ancient amphibians |
| | Mississippian (Early Carboniferous) | | 345 | Climate warm and humid at first, cooler later as land rose | Lycopods and horsetails dominant; gymnosperms increasingly widespread | Amphibians at height; spread of ancient sharks |
| | Devonian | | 405 | Smaller inland seas; land higher, more arid; glaciation | First forest; land plants well established; first gymnosperms | First amphibians; lungfishes, sharks abundant |
| | Silurian | | 425 | Extensive continental seas; lowlands increasingly arid as land rose | First definite evidence of land plants; algae dominant | Marine arachnids dominant; first (wingless) insects; rise of fishes |
| | Ordovician | | 500 | Great submergence of land; warm climates even in Arctic | Land plants probably first appeared; marine algae abundant | First fishes, probably freshwater; corals, trilobites abundant; diversified mollusks |
| | Cambrian | | 600 | Lands low, climate mild; earliest rocks with abundant fossils | Marine algae | Trilobites, brachiopods dominant; most modern phyla established |
| Second Great Revolution (Considerable Loss of Fossils) | | | | | | |
| PROTEROZOIC | | | 1400 | Great sedimentation; volcanic activity later; extensive erosion, repeated glaciations | Primitive aquatic plants algae, fungi | Various marine protozoa; towards end, molluscs, worms, other marine invertebrates |
| First Great Revolution (Considerable Loss of Fossils) | | | | | | |
| ARCHEOZOIC | | | 3600 | Great volcanic activity some sedimentary deposition, extensive erosion | No recognizable fossils; indirect evidence of living things from deposits of organic material in rock | |

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## Questions

1. *What do you understand by the theory of evolution? Give three evidences to prove that evolution has occurred.*
2. (a) *Describe briefly what you understand by the terms: (i) evolution; (ii) variation and (iii) natural selection.*
   (b) *What are the contributions of Lamarck and Darwin to the development of the theory of organic evolution?*
   (c) *Define fossil. Use a fossil evidence to show that evolution has occurred.*
3. (a) i. *Mention two theories of evolution.*
   ii. *State four major ideas of Darwin's theory of evolution.*
   (b) *Briefly explain how comparative anatomy and vestigial organs could be used to explain that evolution has occurred.*

# 27

# THE OUTCOME OF ORGANIC EVOLUTION

The outcome of organic evolution is the **adaptation** of living organisms to their various environments.

## ADAPTATION

The summary of life processes is that every living thing wants something to eat and at the same time prevents itself from being eaten by other organisms. The living things use their structures and behaviours to carry out a lot of manouvres to obtain food of their choice and to avoid being eaten by other organisms. This ensures survival for the individual organisms and the species as a whole. The organisms are then able to reproduce their kinds and leave offspring behind them.

An adaptation is therefore any **genetically controlled characteristic that enhances the fitness of a living organism to survive and successfully reproduce its kind in its living environment.** Any living organism that is unable to adapt to its environment is not fit to live and stands eliminated by nature. An organism must be adapted in such a way that it can obtain food, compete favourably for space and mates. It must be able to respond quickly and efficiently to the ever changing conditions in its environment, defend itself from attack by other organisms. It must be able to maintain a fairly constant internal chemical and physical environment to be able to function efficiently all the time. It is now clear why the structures of organisms and their component parts are closely related to the functions they perform.

**Adaptation may be structural (morpholo-gical), physiological or behavioural.**

### Structural adaptation

This is a type of adaptation in which an organism possesses special structures which enhance its chances of surviving successfully in its environment.

**Structural adaptation to obtain food**

For the structural adaptation to obtain food by some insects such as housefly, mosquito and butterfly have been discussed in **chapter 6.**

### Beak

There is a great deal of structural adaptation of beaks and feet of birds to obtain food. This makes the birds to exploit different foods and this cuts down on interspecific competition for food and ensures survival. Some examples of the adaptation of the beaks and feet to obtain food are:

1. **Short, strong and straight beak** for picking seeds and insects. It is also used for pecking small pieces of food from large lumps of food. It is found in the domestic fowl, guinea fowl, turkey and other fruit eating birds.

**Figure 27.1. The beak of a domestic fowl *(Gallus).***

2. **Powerful, sharp and curved or hooked beak** for killing preys. It is further used for tearing flesh apart and away from bones. Birds such as hawk, kite, eagle and owl have this type of beak.

Figure 27.2. The beak of an eagle.

3. **Blunt, short and strong beak** for cracking open seeds and nipping off buds for food. Weaver bird is an example.

Figure 27.3. The beak of a weaverbird *(Ploceus cucullatus)*

4. **Long, narrow and tubular beak** which is slightly curved is used for sucking fluid food from corolla tubes. The fluid food is mostly nectar from nectary at the base of corolla tubes in flowers as seen in *Allamanda*, *Neuboldia leavis*, *Thevetia peruviana*, plantain and pawpaw flowers. This type of beak is seen in sunbird.

Figure 27.4. The beak of a sunbird

5. **Hard and strongly built beak.** Upper beak is larger, longer and hooked over the smaller, shorter lower one. This type of beak is used for cracking hard nuts while it is held with the toes. This type of beak is possessed by the parrot.

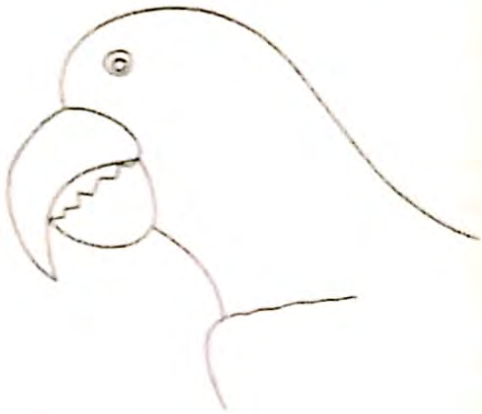


Figure 27.5. The beak of a parrot

6. **Flattened and broad beak with grooved sides** for sifting out food from water and mud. This is found in the duck.

Figure 27.6. The beak of a duck.

## Bird's feet

Feet of birds are diverse in shape and number of toes. It is also another evidence of structural adaptation to obtain food from different habitats such as water, mud, top of floating vegetation, soil, land and top of trees. A few familiar forms found in birds include:-

(a) **Three toes of unequal length directed forward and one backward.** The toes are strongly clawed. The claws are blunt and slightly curved. These feet

...used for walking, running and scratching the soil to expose seeds, roots of plants, insects and other small animals used as food. Examples are domestic fowl, bush fowl and guinea fowl.

Figure 27.7. The foot of a demestic fowl *(Gallus)*

b) **Three toes of about the same length and equally spaced** are directed forwards while the fourth greatly reduced toe is directed backward. The three toes are strongly webbed. These feet are best suited for swimming. They can also be used for walking and running. Example is duck.

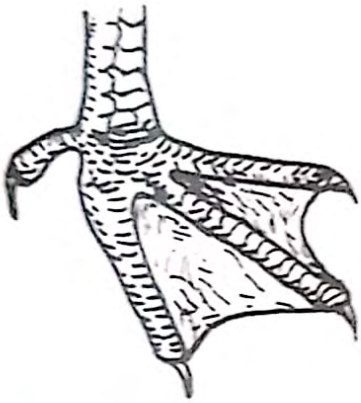


Figure 27.8. The foot of a duck

c) **Three toes directed forward and one backward.** The toes are strongly clawed. Claws are curved and sharp(talons) used for killing and catching prey. The toes can be bent to meet, thereby closing on the prey. Examples are eagle, hawk, kite and owl.

Figure 27.9. The foot of a kite.

## Claws in mammals

Some mammals develop sharp curved claws which adapt them to certain kinds of food. The **scaly anteaters** *(Pangolin)* have large sharp and curved claws on the digits of their fore limbs for digging deep into termitarium to reach the dwelling chambers of the termites and feed on them. Carnivorous mammals such as the cat and lion have long and sharp claws used for catching and killing other animals for food. Their claws are different from other animals in that they retract into the paws when not in use. When these animals walk or run, their foot prints do not leave marks of claws.

Figure 27.10. The claws of a cat.

## Table 90: FEEDING ADAPTATION OF SOME INSECTS

| | Insects | Nature of mouth parts | Type of food | Feeding mechanism |
|---|---|---|---|---|
| 1. | Termites, cricket grass | Mandibulate. (Possess well developed mandibles and maxillae). | Plant material (herbivorous) | Biting and chewing |
| 2. | Cockroach | Mandibulate | Omnivorous (any dry plant and animal material | Biting and chewing |
| 3. | Praying mantis | Mandibulate | Carnivorous (feed on insects and small animals) | Biting and chewing (Prothoracic legs are raptorial for holding prey against the mouth). |
| 4. | Yam beetle, Longhorn beetle | Mandibulate | Herbivorous | Biting and chewing |
| 5. | Dragonfly | Mandibulate | Carnivorous | Seizing and swallowing preys whole. (feeds on wings, meaning feeding during flight). |
| 6. | Larva of butterfly (Caterpillar) | Mandibulate | Herbivorous (feed on fresh leaves of plant) | Biting and chewing |
| 7. | Ants | Mandibulate | Omnivorous | Biting and chewing |
| 8. | Mosquito, tsetsefly human louse | Proboscis | Fluid [blood from animals] | Piercing and sucking |
| 9. | Housefly louse | Proboscis | Fluid from plants and animals source (omnivorous) | Sucking |
| 10. | Butterfly, moth, cotton stainer. | Proboscis | Herbivorous plant fluid such as nectar, sap and fruit juices. | Piercing and sucking |
| 11. | Honey bees | Proboscis | Omnivorous (juice from plants and animals sources) | Sucking |
| 12. | Corn weevil, Palm weevil, Rice weevil. | Rostrum | Herbivorous (mainly grains and seeds in storage | Boring |
| 13. | Mosquito larva, Blackfly larva. | Ring of cilia around the mouth (mouth brushes). | Omnivorous (microscopic plants and animals in water). | Filter feeding (filtering and swallowing). |

## Structural adaptation for protection and defence

There is a direct relationship between the structure of certain animals and their chances of survival in their biotic environment, as will be seen in the following selected examples.

**Body shape:** Stick insect had evolved a body shape which is slender and stick-like. When stick insect is at rest it looks like a piece of dry stick. This adaptive feature conceals it from predator.

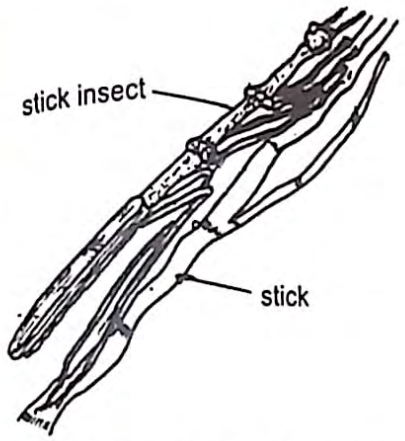



**Figure 27.11. Structural adaptation of the stick insect for protection.**

**Bony plates:** In tortoise and turtle, bony plates are joined together to form a **carapace** into which the animals retract their heads and limbs, thereby protecting them from being eaten by predators. Predators that catch up with tortoise wait for a long time and go away disappointed as the retracted animal refuses to come out and move. Bony plates also protect the possessors from harsh environment factors such as severe cold (harmattan) and heat.

**Carnassial teeth:** Carnassial teeth are characteristic of carnivorous mammals. Carnassial teeth consist of the last upper premolar cutting against the first lower molar in the dentition of carnivorous mammals. These teeth are large and have sharp cusps. The carnivores use them for clearing flesh from bones or for crushing bones in their diet. They are also weapons of defence and offence e.g. dog.

## Stinging cells

**Coelenterates** *(Hydra*, jelly fish, *Physolia*, sea anemone) discharge stinging cells **(nematocysts)** which contain poisons capable of paralysing preys and causing lesion or rash on the skin of man. The stinging cells are weapons of offence and defence.

The **Phylum Arthropoda** is full of members that **sting** and **bite** painfully and introduce various form of **irritating poisons** into their victims. Among them are the savanna spider *Tarantula*, **scorpion, centipede** and various insects such as the **honey bees, soldier ants, termites, wasps**. Stinging and biting are for defence.

In the vertebrates, the toads are avoided by all predators because of the poisonous secretion from the skin. Toads are hardly preyed upon by predators. The snakes are known to be very poisonous and so avoided by all other carnivorous animals except the **Mongoose** that has a flare for eating snakes. This is natural control on the population of snakes. Their poisons had been very good weapon of defence.

**Exoskeleton in insects:** Insects have very hard chitinous externally located skeleton, called **exoskeleton** around their bodies. This exoskeleton protects the insect against high and low temperatures. It also prevents water loss from the internal tissues and serves as hydrofuge for the aquatic insects. This adapts the insects to life in the savannah, semi-desert and desert where they are exposed to high temperature, severe cold and dry air.

**Spines and scales:** The long spines of porcupine and the wide overlapping scales of the scaly-anteater (*Pangolin)* are fused hairs. They are epidermal structures that are used for defence against predators and severe water loss from the body. The possession of these spines and scales protect these animals from predators.

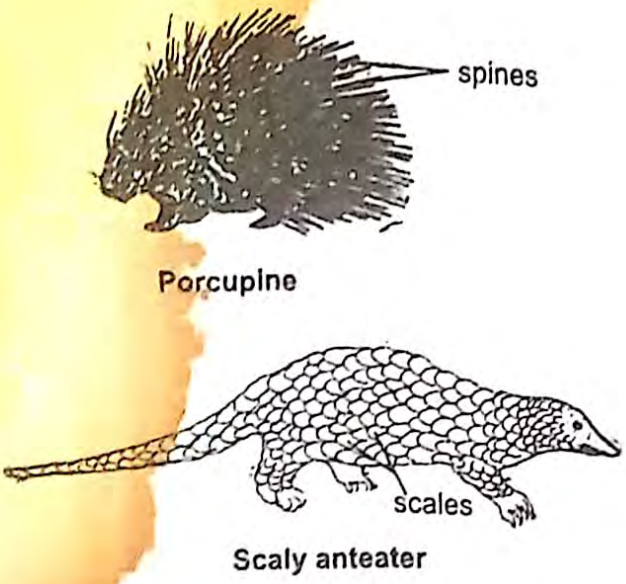
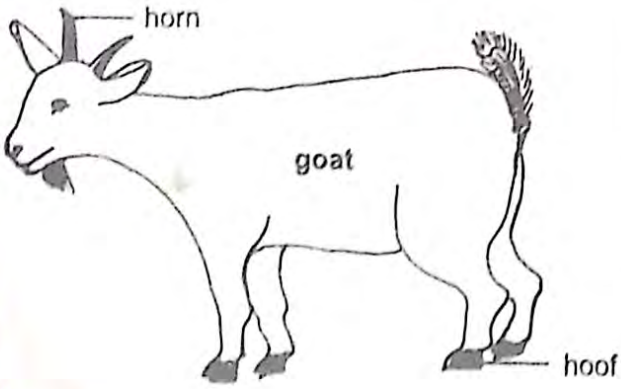



**Figure 27.12. Porcupine and the Scaly anteater showing spines and scales respectively for protection.**

**Horns and hoofs in ungulates:** Animals such as goats, cows, horses, antelopes, deer and buffaloes have horns and hoofs. Hoofs are horny materials which are hard and strong. They protect the toes of these animals in hot and cold weather and enable them to run fast in any type of ground without difficulty. This enables the animals to graze and escape from predators such as lions and leopards. Horns are also horny structures supported by bones. They are of various sizes and forms. They are used as weapons of offence and defence. The male rams use their horns to charge and fight off other male intruders in their territory.



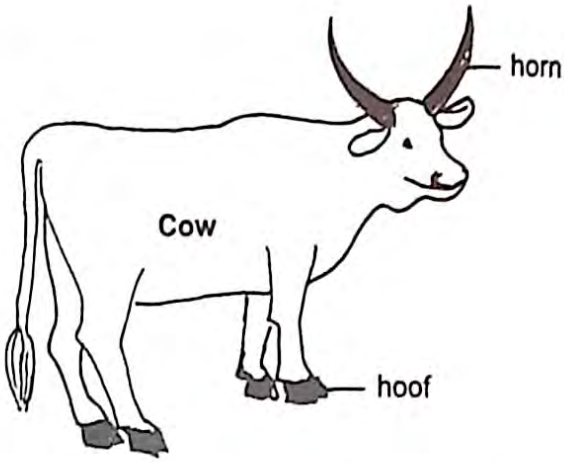




**Figure 27.13. Goat and cow showing horns and hoofs for offence and defence.**

## Structural adaptation for securing mates for reproduction

Generally, in living things, the male and female individuals are usually rarely identical in appearance. Some basic structural differences occur among them. Such structural differences create attractions between the male and female individuals which lead to mating for reproduction.

In the insects, the bright colours are used for securing the opposite sex for mating. The more brightly coloured males of certain grasshoppers and butterflies are easily spotted by the dull coloured females and pair up for mating. Male ladybird beetles spot their more brightly coloured females and pair up with them for mating.

The horn on the thorax of the male **rhinocerous beetle** serves as a sex signal by which the female is attracted to pair with the male for mating.

In fish like *Chromidotilapia pulcher,* the belly of the female becomes **bright red** during the breeding season. This **bright red colour** attracts the male for mating. The male of *Tilapia zilli* acquires a beautiful colour to attract the female for mating during breeding.

Male toads and frogs develop **nuptial pads** on the first digits of their fore limbs for griping the female firmly during breeding.

The male of the rainbow lizard *(Agama agama)*, has brightly coloured head, neck, portions of the tails, prominent gular folds, nuchai crest, and tail to attract the female for mating.

The male domestic fowl has beautifully coloured long tail feathers and brightly coloured body feathers, combs and wattles which attract the less brightly coloured females for pairing and mating.

Some flowering plants such as the flame of the forest *(Delonix regia)* and okro *(Hibiscus esculentus)* have brightly coloured flowers which attract insects and some birds to pollinate their flowers.

## Structural adaptation for regulating body temperature

Organisms in the biosphere are bound to gain or lose heat depending on the presence and intensity of sunlight. Some organisms develop certain structures to regulate their body temperatures to protect them from the effects of too low or too high temperatures.

All other animals apart from the birds and the mammals have variable body temperature, and so they use the following structures to overcome the problems of the extremes of temperatures of their surrounding.

**Shells:** Crustaceans, snails, tortoises and turtles have shells which help in regulating their body temperature.

The lizards and snakes have dry scales which protect them from cold and heat within the tolerable limits before they withdraw into hiding at the extremes of temperatures.

**Basking:** The body temperature of the lizards, snakes and crocodiles falls correspondingly low with that of the surrounding habitat at night with the result that they become inactive and sluggish in the morning. They remain in this state of stupor until the sun rises, shines and warms them before they become active for the day. This practice of warming the body in the sunlight to gain heat and be able to move about is called **basking** in the sun. The lizards, snakes and crocodiles bask in the early morning sun to warm up their bodies before they are able to move about in search of food and mates.

**Skin, feathers and scales:** The birds have feathers on their bodies and scales on their feet for regulating their body temperature at a fairly constant level irrespective of the temperature of their surrounding.

How the mammalian skin is adapted to regulate the body temperature has been discussed in **chapter 9**.

The plants have an external covering of cuticle for shielding their body from the excessive heat of the sunlight in their habitat.

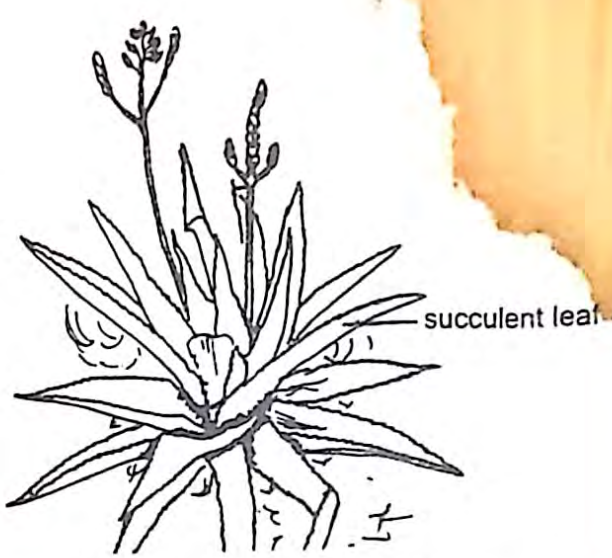


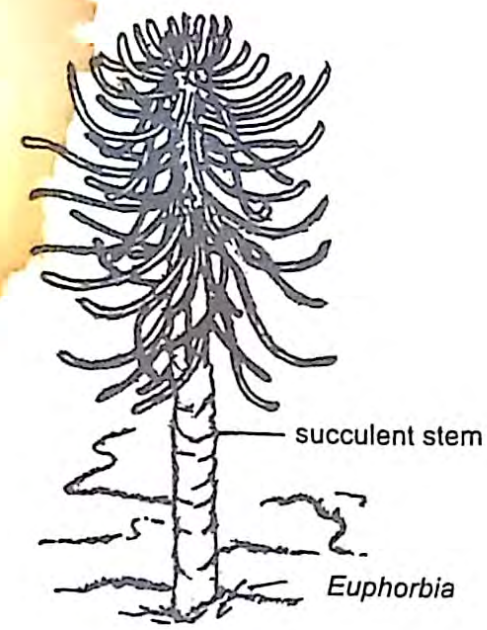

**Figure 27.14. Succulent leaves of *Aloe sp.* as an adaptation for surviving high temperatures and drought.**

## Structural adaptation for water conservation

Plants growing in dry or arid land are called **xerophytes.** These plants have adopted various methods of conserving water to survive period of drought. Some of these adaptive methods are:

1. **Thick succulent stems for storing water:** Plants such **cactus**, *Euphorbia* and **baobab** *(Adansonia)* are examples of plants that store water in their stems. The **baobab** tree (also called bottle-tree) has wide stem where water is stored. The leaves and branches of baobab are very small so as to conserve water.
2. **Succulent leaves for water storage:** *Bryophyllum, Portulaca* and *Aloe* have thick and succulent leaves for water storage.

3. **Reduction of leaves to spines or scale leaves:** *Acacia* and *Opuntia* have their leaves greatly reduced to spines to cut down water loss during transpiration through the leaves. They therefore have enough water to use during drought.



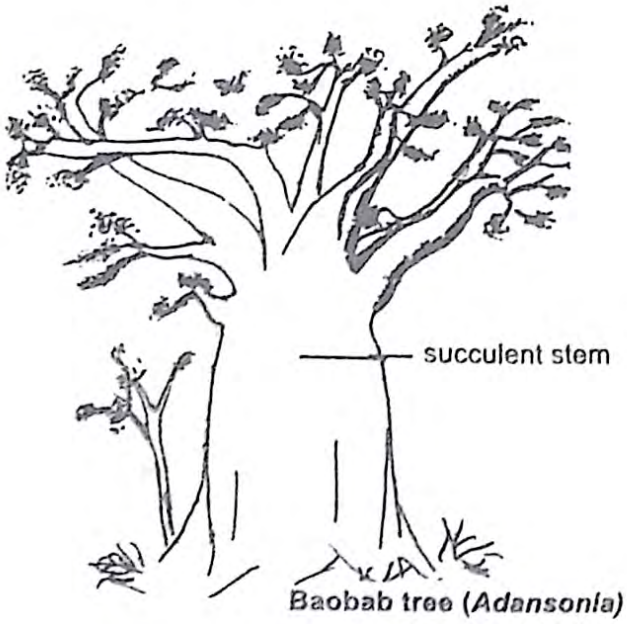




**Figure 27.15.** ***Euphorbia*** **and Baobab tree showing succulent stems and reduced leaves for surviving in regions of the world.**

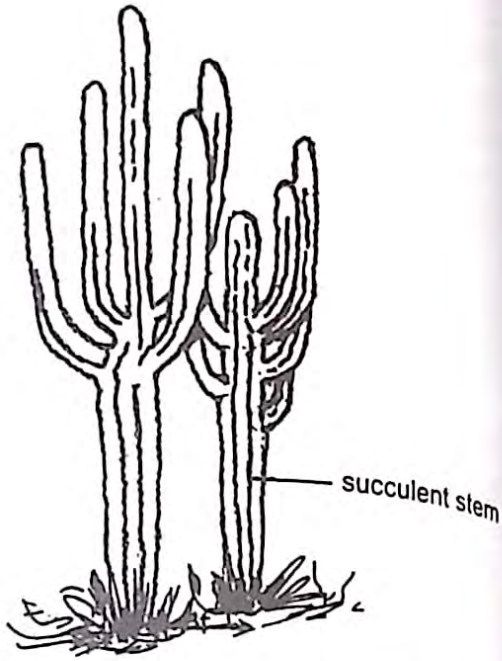



**Figure 27.16. Cactus** ***(Carnegiea)*** **showing succulent stems and branches as adaptations conserving much needed water in regions with prolonged drought.**

**The whistling pine** *(Casuarina)* **bears tiny scale leaves on needle-like branches to reduce water loss by transpiration thereby conserving enough water for use in the long dry period.**

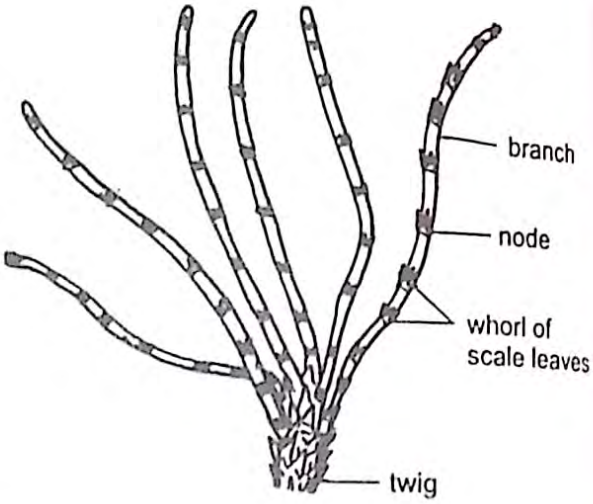



**Figure 27.17.** ***Casuarina*** **showing tiny scale leaves on needle-like branches as an adaptation to reduce water loss.**

Animals living in dry places develop scales on their skin to prevent water loss from their bodies to the surrounding dry air. Many reptiles (snakes, lizards and tortoises) develop scales all over their bodies to prevent them from losing water from their bodies to the surrounding air. The birds develop scales on their feet only for the same purpose. The **scaly anteater Pangolin** (*Manis*) is a good example of a mammal that develops epidermal scales to protect its body from water loss under dry condition.

## Adaptive colouration

Adaptations for survival are seen in the colours and structures of plants and animals as well as in the physiological processes. Biologists recognize three types of colour adaptations, these are:

(1) cryptic (concealing) or protective colouration
(2) warning or aposematic colouration and
(3) mimicry.

1. **Cryptic (concealing/camouflage) protective colouration:** This type of colouration enables the organisms to blend with its back ground and be less visible to predators.

(a) **Colour blending with the environment:** The **green leaf-like mantis** resembles green leaves in such a way that predators find it difficult to differentiate between the green leaves and the praying mantis.

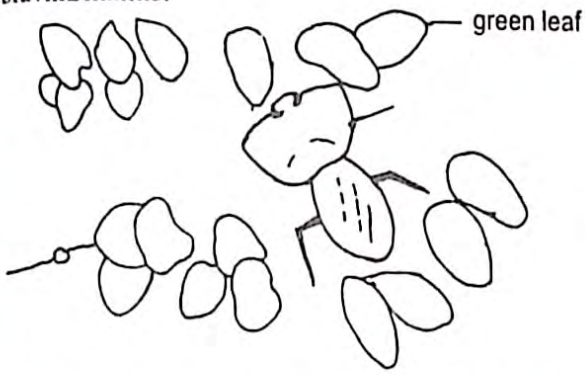



**Figure 27.18. The green leaf-like praying mantis among green leaves.**

(b) **Countershading:** In the countershading, colouration of one part of the animal's body has a different colour from the other part. A common example is the dark colour on the dorsal side and silvery white colour on the ventral side of most fish. This protects the fish from predators looking at them from above and below the water.

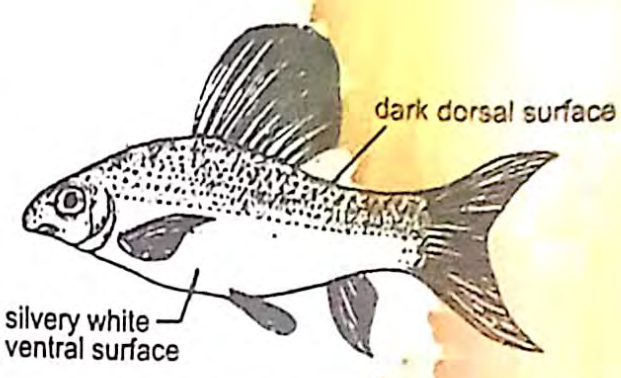



**Figure 27.19. Countershading in African carp** *(Labeo pseudocoubie)*

(c) **Breaking the body outline:** The alternating bands of black and white colours and the black dots on white or yellow background break up the outline of the body of the animal thus concealing it and obscuring it from the predators. This is another way of achieving cryptic colouration by animals for survival in their habitat. Examples of animals that have this type of colouration include: (1) the zebra *(Equus zebra)* having alternating parallel bands of black and white colours arranged vertically on the trunk and horizontally on the limbs. (2) the African weasel **(Poecilogale)** with the alternating parallel bands of black and white colours arranged horizontally on the main body. (3) the ladybird beetle has round dots of black colour on a yellow background on the general body surface.

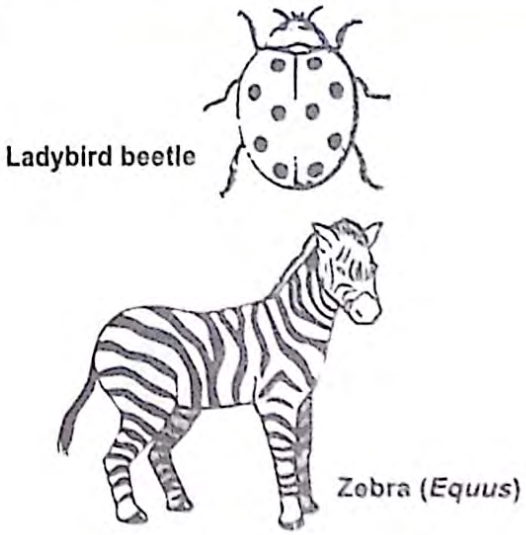



**Figure 27.20. Striped and spotted colouration for protection from predators.**

(d) **Changing the colour pattern of the body:** Some animals have the ability of changing the colour pattern of their body to blend with that of the general surrounding. This reduces the chances of the predators in spotting them and catching them for food. The chances of these animals for survival are thus enhanced. As colour change in these animals is induced by the colour of their general surrounding they therefore have a wide range within which to look for food, mates and shelter. The colour pattern to which the animals change is somehow limited and restricted to the natural background. The most remarkable ability of colour change and of the widest range of colour pattern is possessed by the reptilian chameleon. Colour change can be fast as in the chameleon, slow as in the squid, loligo and octopus and seasonal in toad and frog, snake and grasshoppers. Some animals change the colour pattern of their skin in their breeding season for securing mates for reproduction, the fish and birds are good examples.

Figure 27.21. A chameleon.

2. **Warning or aposematic colouration:** Warning or aposematic colouration consists of bright and conspicuous colours possessed by some animals advertising themselves as poisonous and distasteful. Many of these brightly coloured animals may taste bad, sting or secrete poisonous substances which may harm unsuspecting predators. Any predator that has one or two of such unpleasant encounters with these brightly coloured animals learn to avoid them later on. For example the bright coloured grasshopper *(Zonocerus variegatus)* is avoided by predators because it smells bad. Also the brightly coloured wasp *(Vespa sp)* is avoided by predators because of its painful sting.

3. **Mimicry:** Mimicry is the resemblance of an organism to another different organism as a means of enhancing its chances of survival in its habitat.

Figure 27.22. Arum. *(Amorphophallus dracontioides)*

In plants for example, the large spathed plant arum lily *(Amorphophallus dracontioides)* mimics the **poisonous hooded cobra**. During the dry season a **spathe (bract)** grows out of the ground from the short stalk. The spathe is a mixture of **grey, olive and purple** on the outside and **reddish purple** with **white vertical lines** towards the base on the inside. This colouration resembles the poisonous cobra of Africa. This appearance of the arum lily scares away the grazing animal from eating it.

Mimicry is again seen in a species of an orchid flower *(Trichroceros antennifera)* which mimics some female flies. Its flower resemble the female flies so much that male flies are attracted to land on the flowers. The male flies are therefore dusted with pollen grains which are carried to other flowers for pollination.

**Figure 27.23. An orchid flower that resembles a fly (Modified from Keeton).**

A species of a moth *(Phalera bucephala)* resembles a broken twig so closely that it is difficult to be seen by its predators

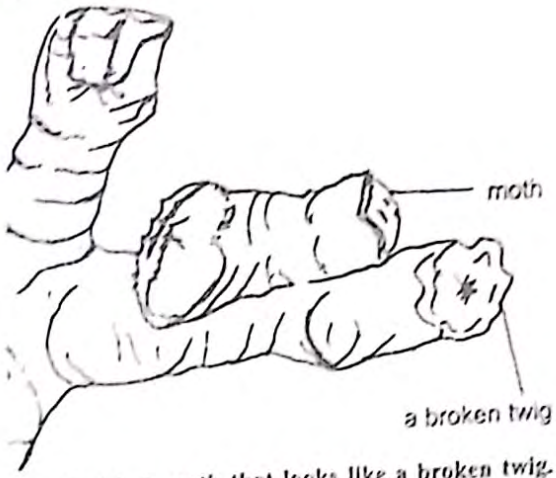



**Figure 27.24. A moth that looks like a broken twig. (Modified from Keeton)**

## Behavioural adaptations in social animals

Social animals live and co-operate together in groups for their survival. The cooperation among some animals may be so intimate that each individual's life rest on the functions of others. Examples are the social insects honey bee, termites and ants. Baboons, ape and human being are example of social mammals.

## Social life has its advantages and disadvantages.

**Advantages**

1. Social life affords better protection against predators by improved group detection, enhancing their escape from predators in group by confusing them (predators) by their zig zag escape.
2. Social life provides an efficient management and defence of scarce resources such as food.
3. Offspring are better protected and well fed leading to increased survival.
4. Group feeding increases appetite leading to efficient feeding and high rate of survival.
5. Reproductive efficiency is enhanced. For example, the queen honeybee is well fed with royal jelly by the workers enhancing her reproductive efficiency.
6. Group parental care ensures higher survival of offspring.
7. Staying close together generates heat during the cold weather thereby promoting their well-being.

**Disadvantages**

1. Frequent intra-specific competitions for scarce resources such as food, water, space and including mates will reduce quality of life
2. Increased disease infections leading to poor health and death.
3. Increased predation of offspring by neighbouring predators leads to reduction in population
4. The danger of being captured in large numbers by man is high.
5. Increased cannibalism of the young by the adults.

## Behavioural adaptation of honeybees.

The system of communication developed in honeybees is strikes. It involves visual, chemical, mechanical (contact) stimuli and sound as signals and behavioural responses. With these, the field bees pass information among themselves in their daily duty of food gathering

**Visual stimuli:** The honey bees use the direction of sunlight to find their way back to the hive after going far and wide in search of food and also to make as many repeated trips to particular source of food.

**Chemical stimuli:** The queen honey bee secrets a

chemical called **pheromone** which is picked and shared among the workers. A pheromone is a chemical scent secreted by an organisms that induces a behavioural response in another individual of the same species. The behavioural response from this chemical stimulus is for the workers to stop constructing more royal brood cells for the brooding of more queens. Pheromone enables the bees to trail their track from a food source back to the hive. It also makes them recognize members of their colony anywhere.

**Mechanical (contact) stimuli:** The field bees return with nectar and pollen grains which they share with the other workers and make body contact with them informing them about source and richness of the food. This is followed by a **waggle dance** in two **semi-circles** forming a figure of 8 to indicate the location of the food. The **abdomen waggle dance** follows a straight line in between the two semi-circles and this indicates the distance. The other bees watch the dancing bee in close contact receiving messages through the eyes and **antennae.** From this method of communication, all the field bees in the hive soon converge at the food source gathering more food to the hive and thus presenting food shortage.

**Food storage behaviour:**

The workers not only gather food for members of the hive but also store enough food in the cells of the hive to prevent food shortage during unfavourable season such as harmattan period.

**Defence:** Worker bees aggressively defend the hive by stinging any intruder that comes near, thus ensuring the protection and survival of the population.

**Clustering together**: During harmattan period when the weather is cold, honey bees have the behaviour of clustering togther to generate heat to warm the hive and the queen. This behaviour ensures that the bees including the queen do not die of cold.

**Selective feeding:** The selective feeding behaviour with different food items by the workers ensures that all the castes are present in the colony.

**Nuptial flight** (*mating flight*)**:** Same as in termites.

**High production of young:** Same as in termites.

## Behavioural adaptations of termites

1. **Feeding:** They feed on wide variety of food substances such as dead wood and leaves, living plants and dead members of the nest. This ensures that food is always available for them.
2. **Group movement:** They move in a group. This enables them to ward off their enemies.
3. **Burrowing:** Their ability to burrow into wood and soil gives them protection against their enemies and to escape from adverse weather conditions.
4. **Tunneling or ant nest:** Their ability to dig tunnels provides aeration in the nest. Living in warm, dark, humid environment, well constructed tunnels or ant nest (termitarium) protect them from dehydration which essential for their survival.
5. **Feed on dead members:** Their feeding behaviour on their dead members helps to keep the nest clean and healthy.
6. **Selective feeding:** The selective feeding of nymphs by the workers determines the type of caste a nymph will become. This selective feeding ensures that all the castes are present in the nest.
7. **Nuptial flight (mating flight):** A behaviour of carrying out a nuptial flight when a nest is becoming over crowded leads to reduce over-crowding.
8. **Communication:** The ability to communicate effectively among themselves ensures proper co-ordination within the nest thus promoting survival.
9. **High production of young**: The ability of the queen to reproduce many young ones ensures continued survival of the animal.

## Adaptive communication in animals

Animals have evolved various methods of communicating information among themselves especially in time of danger. **Contact notes** and **warning calls** are examples of communications among animals.

### Contact notes

This is a type of communication between the **offspring** and the **parents.** When the offspring are uncomfortable or in danger, they produce **distress calls.** For examples, the **wails** (cries) of a **newborn**

human's child, or a young monkey, the mew of kittens. The parents respond to the **distress calls** by moving to them either to comfort them or protect them against any form of danger. Apart from **distress calls**, **pleasure signs or sounds** are produced by offspring to notify parents of **their happines.** The **smile** and **laughter** of human's babies and the **purr** of kittens of cats are examples of **pleasure signs or sounds.**

## Warning calls

**Warning calls** are produced by many animals especially the social animals to alert their members or offspring when danger threatens. When a **warning call** is heard, members of the group or offspring will either hide or run away for protection. For example when monkeys give **warning call**, nearly all members of the group jump away and hide. The parent domestic fowl (hen) gives **warning call** to her chicks when enemies threaten. The chicks will either run to the mother or hide immediately.

## Behavioural adaptations under unfavourable conditions.

### Hibernation

**Hibernation** is a **behavioural adaptation** in which some small mammals such as **shrews, monotremes** and **bats** spend **cold season (winter)** in **inactive condition** or **deep sleep** in a **warm** and **safe place.** These small mammals are unable to produce and conserve sufficient heat to carry them throughout the winter season. During hibernation, the rate of metabolism of the body drops greatly. The heart beat and respiration decrease greatly and energy requirement also decreases to the minimum.

During hibernation, no food is eaten, instead the animal uses up its stored body fats.

The hibernating animal wakes up as the temperature of the environment rises and the metabolic activities speed up.

### Aestivation

**Aestivation** is a behavioural adaptation in which some animals such as African lungfish, (*Protopterus*), **snails** and **frogs** spend hot weather (drought) in **inactive condition.**

## Aestavation in African lungfish (*Protopterus annectens*)

**Figure 27.29. African lungfish.**

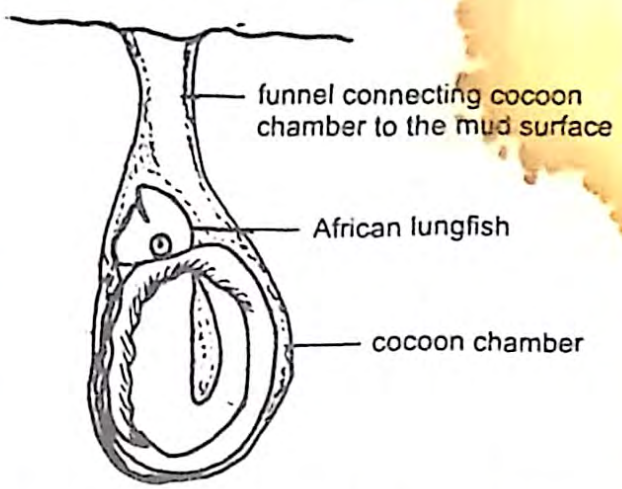



**Figure 27.30. Diagram of African lung fish in a cocoon.**

During the dry season, African lungfish burrows into the mud up to the depth of 30 - 40cm and constructs a **cocoon.** The cocoon is constructed with the surrounding mud and the slim **(mucus)** secreted from its skin. The cocoon consists of a chamber where the fish stays and a **funnel** that connects the **chamber** to the **mud surface**. Through the funnel the fish obtains oxygen for respiration. The fish now aestivates for the rest of the dry season. During aestivation, African lungfish excretes **urea** inside the cocoon instead of **high toxic ammonia** from the breakdown of amino acids, no food is eaten and the rate of respiration drops greatly.

Normal life resumes during the rainy season when the cocoon dissolves.

## Questions

1. (a) Briefly explain the term adaptation.

   (b) Outline how flightless animals are adapted for

   (i) escaping enemies for reproduction

   (ii) obtaining food

   (iii) defence and protection

   (iv) temperature regulation.

2. State three behavioural adaptations of animals to seasonal changes in terrestrial habitat. Give good examples to support your answer.

3. (a) What do you understand by the term adaptive colouration? Give examples to support your answer.

   (b) Give briefly the importance of (i) contact notes and (ii) warning calls in three named vertebrates.

4. (a) State reasons why termites are regarded as social insects.

   (b) Name the different castes making up the termite nest and mention the function of each caste.

   (c) (i) Describe how termites are adapted to their environment behaviourally.

   (ii) Name one social animal other than insects. (SSC,1993).



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# 28

# DRUGS AND DRUG ABUSE

***A drug is any substance used as a medicine or used in making medicines for internal or external use, altering the body's actions***

When the normal functioning of the cells of body is interfered with, illness results. When the body's defence system is over powered by germs, drugs are prescribed by doctor to aid quick recovery. When there is a wound, doctor prescribes drugs for the healing. When a medical doctor prescribes any drug, he knows the effects of the drug on the body. He has to prescribe the right doses. Therefore any drug prescribed by a medical doctor for use is not a drug abuse.

## Drug Abuse and Drug Addiction

### (Dependence)- Way to self-destruction

**Drug abuse** is the use of a drug by a person **without medical purpose** to influence his behaviour or endanger his life and lives of other people.

Drugs are abused because users derive temporary happiness, emotional excitement, relaxation or relief from problems.

### Drug Addiction (Dependence)

**Drug addiction (dependence)** is a situation in which a person has taken or abused a drug for a long period of time resulting in a great need for the drug and the person **cannot do without** the drug.

Drug addiction is a brain disease because the abuse of drugs leads to change in the structure and function of the brain. Although it is true that for most people the initial decision to take drugs is voluntary, over time the changes in the brain caused by repeated drug abuse can affect a person's self control and ability to make sound decisions.

There are two types of drug addiction, namely **psychological** and **physical**.

**Psychological addition** is the mental or an emotional dependence on a drug. The person craves for the drugs. He can do anything, including stealing to make sure he obtains the drug he needs to satisfy his need.

**Physical addiction** is a physical dependence on drug. That is the body needs a continuing supply of the drug. A physical addicted person becomes ill if he stops taking the drug. Symptoms include **withdrawal, sleeplessness, breathlessness, palpitations, irregular heart beat, and depression.**

**Drug abuse** starts when a person first begins to derive happiness, relaxation or sound from worries.

### Why people take drugs and become addicts

People take drugs and become addicts in many ways.

1. Close association with drug dealers who in one way or the other influence people with their money to test them.
2. Some people take drugs to cope with anxiety, fear, frustration, problems and loneliness.
3. Many people take drugs to overcome the effects of overwork and poor nutrition.
4. Many young people take drugs because they see their friends or peers take them.
5. Some people take drugs out of curiosity or experimental basis without knowing the danger ahead.
6. Other people may become addicted after an illness in which a doctor prescribed a drug to relieve pain.
7. Some pharmacists, nurses and doctors who have access to drugs may be tempted to use drugs and so become addicted.
8. Lack of sufficient education by the government on the evils of drug abuse.

## Commonly abused drugs

Commonly abused drugs are classified as follows: **stimulants, narcotics, sleeping drugs** and **psychodelic drugs**.

### A. Stimulants

*Cocaine and amphetamines are the stimulants of the central nervous system, that is they increase the activity of the central nervous system.* Some lorry drivers, students and night workers use these drugs to stay awake.

Cocain and Indian hemp have a similar chemical structure to chemical messengers of the brain called neurotransmitters which are produced by the brain. Because of this similarity, Indian hemp is able to "fool" the brains receptors and activities the nerve cells to send abnormal messages.

### Effects

1. Sense of judgment is reduced.
2. Vision is impaired.
3. Lorry drivers and factory workers under the influence of these drugs will constitute serious hazards on the highways and in the factories respectively.
4. Students who take these drugs to cram for examinations stand the risk of being nervous and confused during examination leading to failure, letdown and misery.
5. Cocaine or amphetamine dependence leads to sleeplessness at night leading to emotional distress, nervous disorder and mental depression.
6. Poor health due to lack of sleep and appetite.
7. Use of cocaine changes the mood of the user and causes drowsiness and nausea. It causes social irresponsibility, erratic behaviour and economic wastage. It increases blood pressure and energy leading to powerful excitement. These over activities lead to confusion and crimes.
8. Sniffing may cause nose damage while smoking causes respiratory problems.

### B. Narcotics (Pain killers)

*A narcotics are drugs which cause sleep, stupor and relief of pains. Narcotics reduce the activity in the pain centers of the brain.* They are very dangerous and additive. The sale and use of narcotics are illegal except prescribed by medical doctors. Possession of narcotics no matter how small will lead to an arrest and prosecution by law enforcement agencies. **Opium, morphine** and **heroin** are examples of narcotics.

**Opium** is produced from the juice of white poppy plant.

**Morphine** is produced from opium.

**Heroin** is a synthetic compound produced from opium.

**Cocaine** is also a narcotic drug produced from coca leaves.

**Effects:** Are similar to cocaine.

### C. Sleep-inducing drugs (tranquilizers or sedatives)

**A sleep-inducing drug** is a drug used by medical doctors to induce sleep in order to reduce emotional stress. Sleep-drugs slow down the action of the central nervous system. Barbiturates are examples.

### Effects

1. Constant use of these drugs can lead to psychological dependence.
2. When used together with alcohol, each one can double the effect of the other which may lead to death.
3. Memory is impaired.
4. Speech is slowed.

### D. Psychedelic or Hallucination drugs

These drugs affect the mind by changing the rate and content of thought. The reality of the moment is lost. They cause hallucinations (seeing and hearing strange things). Indian hemp *(Cannabis sativa)* is one of the psychedelic drugs.

### Effects of Indian hemp

1. Smoking of Indian hemp damages the brain leading to lack of concentration, loss of memory. Depression and madness are common.
2. Some users lose self restraint and become violent and commit all sorts of crimes such as raping, stealing and murder. Fighting is also common.
3. Driving under the influence of Indian hemp

endangers the life of the driver and other road users. Over speeding and inability to judge distances by the driver under the influence of India hemp pose danger on the road.

## Prevention of drug abuse

1. Mass education of the general public on the dangers of drug abuse by Government through news media (radio, television and newspapers) and seminars. Religious organizations should also preach the evils of drug abuse in churches and mosques.
2. The use of sleeping inducing drugs by parents must stop so that children do not learn from them.
3. Teachers have a great role to play in drug abuse. Young people are the target as they can easily be influenced and recruited. Teachers, therefore, have to educate the children on the dangers of drug abuse.
4. The practice of teachers in **day care centres** inducing the young innocent children with sleeping drugs to enable them (teachers) have freedom to carry out their own personal activities must be discouraged at all cost. Government should send School Inspectors to inspect all **nursery schools** and **day care centres** and any teacher caught in such an act should be prosecuted under the laws of the land.
5. Thorough checking at boarders and ports must be carried out to make such that drugs are not illegally brought to the country.
6. Experts are needed to identify drugs. Therefore, Government must train people to carry out the duty of identifying drugs.
7. Trained dogs capable of detecting hidden drugs in luggage must be stationed at strategic places such as air and sea ports.
8. No country can fight drug trafficking alone. To eradicate drug trafficking, the Government must cooperate with other governments and international organizations assigned with the responsibilities of fighting against drug abuse and trafficking.

## ALCOHOLISM

**Alcohol** is a **depressant,** (sedative) that is, it has a depressant effect on the nervous system especially the brain. **Alcoholism is a disease resulting from chronic dependence on alcohol.** It starts by drinking little in social gatherings. As some temporary problems arise and life is not so pleasant, the person takes alcohol to overcome or escape from his problems. Yet the problems remain. He has to take more alcohol and the road to **self-destruction** has started. With loss of sound judgment and self control, solutions to the problems are further reduced. As he continues to take more alcohol, **alcoholism** gradually graduates to **alcohol psychosis**, a serious state of **mental illness**. At this stage, the person needs medical attention. A patient of **alcohol psychosis** is unable to recognise his family's members. He trembles. There is a loss of memory. He tells stories which are not real and he may even think that every body is his enemy.

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### Effects of alcohol on the user and society

1. **On the nervous system:** When alcohol is taken, the nerve cells of the cortex of the brain are affected resulting in loss of self control, will and judgment. As the alcohol goes more into the brain, the person behaves foolishly and characterized by foolish laughter or sadness and open weeping. The person becomes very talkative and quarrelsome and commits all sorts of crimes. He starts seeing double vision.
   As the alcohol goes into the cerebellum, the muscles become affected leading to dizziness and staggering walk. Later the person becomes unconscious and death may result.
2. **On digestive system:** The salivary glands are affected resulting in the production of weak saliva. Therefore, starch digestion in the mouth becomes slow and delayed. The walls of the stomach are destroyed and become inflamed. Due to an increase in stomach secretion, gastritis (a painful inflammation of the stomach's linings) results.
3. **On liver:** Alcohol destroys the cells of the liver leading to a disease called **liver cirrhosis.**
4. **On tissues:** Tissues become dehydrated because the oxidation of alcohol produces water which is excreted from the body by the skin in large quantity from the body.

Loss of water from the body results in high concentration of nitrogenous wastes in the kidneys and hinders the removals of waste materials.

5. **Alcohol and the length of life:** Those who drink alcohol have lower body resistance to diseases and therefore, stand the risk of dying by infectious diseases such as tuberculosis. Chances of alcohol drinkers dying by accident are higher than non-drinkers.
6. **Crimes:** Heavy drinking leads to committing all sorts of crimes.
7. Family neglect, divorce, loss of jobs are common with alcoholic people.
8. **Malnutrition:** Alcoholic people often starve themselves resulting to malnutrition and vitamin deficiency.
9. **Alcohol and national economy:** The national economy is affected. Alcohol dependent drinkers often absent themselves from duty. A lot of money is spent in treating them. Their high nuisance values are offensive to other citizens. Innocent people die by accidents caused by alcoholic people. Many alcoholic people become aggressive and hostile, resulting in fights. Some people take alcohol to give them high courage to commit crimes such as burglary, robbery, murder and rapes.

## Prevention of alcohol drinking habit

1. Government and religious organizations should educate the people especially the youths the evils of drinking alcohol.
2. Government should ban the advertisement of alcohol on radio, television and in newspapers.
3. As a deliberate Government policy, every bottle of alcoholic drink must **carry a warning** of the danger of the drinking Of alcohol.
4. Young people of **less than 18 years** should not be allowed to buy alcoholic drinks.
5. Government should not grant license for the establishment of new alcoholic breweries. Heavy tax should be imposed on the existing alcohol breweries in order to increase the price of alcoholic drinks, thereby discoura-ging people from alcoholic drinks.
6. Teachers and parents who have formed the habit of drinking alcohol should stop such habit so that the young children should not learn from them. They (teachers and parents) should educate the children early in life the dangers of alcoholic drinks.
7. Unlicensed people must not be allowed to produce or sell alcoholic drinks.

## SMOKING

Smoking is dangerous to health. Tobacco contains a poisonous substance called **nicotine.** Once a smoker develops a **physical dependence** on nicotine, a **road to self-destruction** has opened.

Young people feel that once they start smoking they have gained a place in the society and social life. This is a deceptive heaven. Yet if you seek the advice of an older smoker, his sincere advice would be **Don't start it.**

## Dangers of smoking

Twelve thousand (12,000) people die everyday of smoking related diseases.

**1. Tissue damage:** Aveoli are enlarged and become reptured. Arterioles of the lungs become thickened. The cilia and the protective cells of the mucosa in the trachea and bronchi are destroyed by the heat and chemicals in the smoke. These are the structures that cleanse and lubricate the respiratory tract and help to prevent infection.

2. Respiratory trachea is often irritated leading to coughing. It aggrevates asthma.

Figure 28.1 Non-Smoker (normal lungs) Lungs of a Smoker - enlarged and reptured

3. Smoking causes lip, tongue, lung and bladder cancer.
4. Chronic bronchitis, peptic ulcer, diseases of the heart and blood vessels are often associated with smoking.
5. Smoking causes loss of appetite resulting in malnutrition and deficient disease.
6. It causes stomach discomfort, headache, and nervousness. Leads to memory loss.
7. Smoking is a dirty habit. Fingers and teeth are stained. Breath has an unpleasant smell.
8. It cause discomfort to non-smokers.
9. It is an expensive habit involving spending of money. The money which the smoker would have used for the feeding and education of his family is being wasted on smoking.

## Prevention of smoking

1. Anti-smoking campaign must be carried out using the news media (radio, television and newspapers) by various Governments (Local, State and Federal) on the harmful effects of smoking.
2. Government as matter of deliberate policy should ban cigarette and tobacco advertisements in all news media and public places.
3. Smoking should not be allowed in working places.
4. Teachers should not be allowed to smoke in school compound as children easily imitate habits.
6. Parents who smoke should stop the habit so that children should not learn smoking habit from them.
7. Establishment of new cigarette industries should not be encouraged by Government. Imposition of heavy tax on cigarette is necessary to increase the price of cigarette thereby discourage people from smoking.
8. People below the **age of 18 years** should not be allowed to buy cigarette.
9. Every packet of cigarette must carry a warning sign that **cigarette is dangerous** to your health.

## COFFEE, TEA AND KOLANUT

Coffee, tea and kolanut contain caffeine. Caffeine is a highly stimulating drug that stimulates the **central nervous system** making caffeine a **psycho trophic** (mind altering) drug. Even though, coffee and tea are good beverages, too much intake is very dangerous to human health.

*Taking a small dose of caffeine regularly over a long period of time may lead to caffeine addiction.*

***How to know that you are addicted to caffeine***

*Stop taking all caffeine containing diet for a few days. If you observe the following systems, then you have become addicted to caffeine.*

1. *Headache ranging from mild to severe.*
2. *Loss of appetite and exhaustion.*
3. *Lack of sleep (insomnia).*
4. *Anxiety and nausea.*

***Effects of caffeine***

1. *Stomach irritation leading to interference with proper digestion of food.*
2. *Constriction of blood vessels leading to high blood pressure (hypertension).*
3. *Sleeplessness (insomnia)*
4. *Caffeine stimulates the stomach to excrete excessive acid (hydrochloric acid) which may cause stomach or intestinal ulcers.*
5. *Caffeine irritates the kidneys and thus acting as a diuretic leading to an increase in urine output which will cause dehydration (loss of water) from the body.*
6. *It causes irregular heart beat.*
7. *It causes acute mental confusion (delirium) and visual disturbance.*
8. *Caffeine causes chronic fatigue.*

## *Questions*

*1. (a) Explain the meaning of the following terms (i) alcoholism (ii) drug abuse (iii) drug dependence.*
*(b) What are the effects of smoking*
*(i) cigarette*
*(ii) Indian hemp on the smoker and the society.*
*(c) What measures are being taken by your country to prevent smoking?*

*2. (a) (i) Define the following*
*(ii) drug and (ii) drug abuse*
*(iii) of commonly abused drugs.*
*(iii) State three reasons why people are involved in drug abuse.*
*(b) (i) State four effects of alcohol on the consumer and two effects on the society.*
*(ii) State three ways of preventing alcohol abuse.*

# 29

# FIRST AID

**First aid** is the immediate and correct help rendered to a victim (person) of **accident, sudden illness, war** using materials available at the time before he or she is rushed to an hospital for treatment by a qualified medical doctor.

## Objectives of First Aid

The main objectives of first aid are:

1. To save life or regain consciousness.
2. To relieve pains or discomfort.
3. To prevent worsening of the victim's condition.
4. To sustain life.
5. To protect the victim from cold or wet.
6. To prevent the wounds of the victim from disease infection.
7. To reassure the victim of life and that nothing is lost from his/her life.

## What not to do

1. Do not scold or talk harshly to the victim as this may irritate and worsen his condition.
2. Do not place the victim into a source of danger such as near fire or on the middle of the road in order to prevent another accident.
3. Do not block the victim's nostrils as this will hinder the intake of oxygen.
4. Do not give any discomfort such as forceful carrying of the victim or doing things that may frighten or irritate him as this may worsening his health.

## SNAKE BITE

When a person is bitten by a snake, it injects **venom (poison)** into the blood stream.

## First aid

1. Locate the point bitten.
2. The victim must remain quiet. Movement must be prevented so that the venom does not spread rapidly through the body.
3. Restrict the flow of blood from that area to the heart by applying **tourniquet** so that the heart does not pump the venom to other parts of the body.

**Application of tourniquet:** *This is tying of a narrow bandage or strap tightly above a wound so that the blood vessels especially arteries are pressed against a bone or near a pressure point*

At interval of about 20 minutes, the tourniquet must be **relaxed** and tied again. In carrying out tourniquet, the position of the arteries must be known.

***Tourniquet warning***

A tourniquet is only applied as a **last resort** when all other methods have failed and the life of the victim is in serious danger. It should only to be applied to hand or leg. It is dangerous to apply, to leave on and to remove. It may result to tissue damage and cut off blood supply to the affected part below causing **gangrene** and **loss of limb**.

The victim should be rushed to the nearest hospital or a medical doctor be invited immediately.

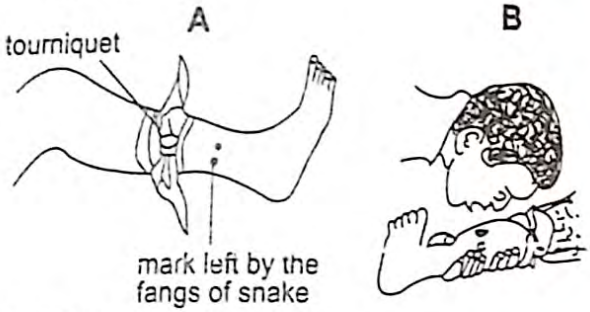


Figure 29.1.

A = Application of a tourniquet in the treatment of a snake bite

B = About to suck the poisonous blood from the cut of the victim

4. Bleeding must be encouraged by making a **cut** of about **1cm (10mm) long** and **5mm deep** over the bite so that the venom can flow freely with blood away from the body. The wound is bathed with warm water to encourage blood flow.
5. If bleeding is sluggish, squeeze the wound or suck it and spit out the poisonous blood. *(Warning:* A person with wounds in the mouth or lips must not suck the wound as the poison may enter into victim's blood circulation)
6. Dress and bandage the wound to support the injured area.
7. Quickly take the victim to the nearest hospital or clinic for medical treatment.

   ***It is desirable to kill and identify the snake if it is possible so as to know whether the snake is poisonous or non-poisonous.***

## BLEEDING

Refer to **First Aid** for haemorhage (bleeding) on page 157. Some major pressure points for stopping bleeding in the body.

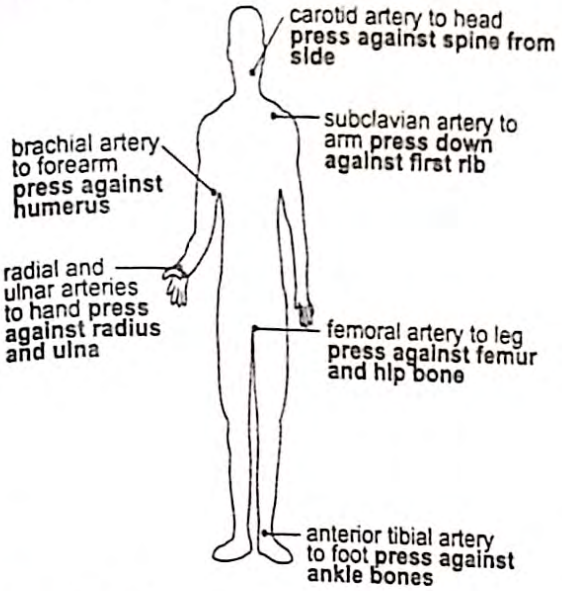


**Figure 29.2. Some major pressure points in the body.**

## BURNS AND SCALDS

A **burn** is an injury caused by **dry heat** such as fire, hot metal, hot charcoal, electric shock etc. A **scald** is an injury caused by **moist heat** such as steam, hot water, hot oil or hot coal tar.

## Degrees of burns

**Burns** are classified as **first, second** and **third degree** depending upon the seriousness of the **burn** on the body surface and destruction of tissues.

**First degree burns:** The skin is only **reddened.**

**Second degree burns:** The injury is **deeper** and **blisters** develop on the skin.

**Third degree burns:** The injury is **deepest;** the burned area may be appear **white** or **charred.**

**Figure 29.3.**
**A = First degree burn reddens the skin only.**
**B = Second degree burn.**
**C = Third degree burn.**

The objectives of first aid for burns and scalds are to treat for shock, relieve pains and to prevent infection.

## First aid

1. Keep the victim flat and quiet to prevent more injuries.
2. Wash the area with clean water to prevent infection.
3. Cover the burn or scald with a sterile dressing or clean handkerchief before bandage. Pains are caused by air coming in contact with burns or scalds. The even pressure of a bandage helps to reduce pains.
4. Give pain relieving tablets.
5. The victim needs alot of liquid and salt. Add **half teaspoonful of common salt** and **two teaspoonful of sugar** or **honey** to **one litre** of clean water and give him **half glass** of this solution **every 10 minutes** for **2 to 3 hours** to replace the fluid lost due to sweating. Do not force him to drink as his own thirst is the best guide.
6. Send for medical doctor or take the victim immediately to nearby hospital or clinic.

### What not to do

1. Do not remove clothes over burned or scalded area.
2. Do not remove the pieces of cloth that stick to burn or scald.
3. Do not burst blisters.
4. Do not use grease, ointment, petroleum jelly on severe burn or scald.
5. Do not use iodine or antiseptic on burns or scald.
6. Do not touch burn with anything except sterile or clean dressing.
7. Do not change the dressings that were initially used until 5 - 7 days.
8. Do not keep victim in a warm place.

## FAINTING

**Fainting** is a temporary loss of consciousness due to shortage of oxygenated blood to the brain owing to low beat of the heart.

Fright, fatigue, pain, emotional problems, poor ventilation may cause fainting.

### Symptoms

1. Pale face
2. Sweating
3. Weakness.
4. Weak pulse
5. Dizziness and unconsciousness.
6. Irregular breathing.

### First aid

1. Let the victim lie or sit down and support him at the back to prevent further fatigue.
2. Let the victim receive sufficient supply of fresh air so that sufficient oxygenated blood is carried to the brain. Fanning him is necessary.
3. Loosen his clothes at the neck, chest and waist so that he can receive sufficient air and to prevent over heating of the body.
4. Let him bend his head between his legs if he is sitting down so that blood flows to the brain for quick recovery. But if he is lying down, his legs should be raised above is head in order to increase blood flow to the brain.
5. When signs of recovery appear, give him fluid to drink so as to replenish the lost fluid due to sweating. Allow him to rest sufficiently.

## EPILEPSY

**Epilepsy** *is a sudden and brief loss of consciousness as a result of temporary disturbance of the cerebrum of the brain.* Consciousness is regained after.

### Sign of epilepsy

1. Jerking of limbs, neck and head.
2. Fronting (foaming) at the mouth.
3. The tongue may be bitten.

### First aid

1. The patient should be removed from a place of danger such as fire place and water body, hard and **sharp objects** such woody chair, stone, knife, cutlass which may cause him body injuries.
2. The patient should lie on the ground and his head turned to one side and supported so that the tongue may not fall backwards.
3. Gently open his mouth and place a clean object such as folded handkerchief or a piece of rubber between his teeth to prevent his tongue and cheek from being bitten. If his teeth are closed together, do not force them open as injuries may occur.
4. Do not **disturb him** during the **period of unconsciousness** as disturbance may delay recovery.
5. Allow the patient to inhale plenty of fresh air so that sufficient oxygenated blood flows to the brain for quick recovery.
6. The patient should be allowed to sleep as long as he wishes in order to regain strength in time.

## FITS (CONVULSIONS)

*A fit is sudden loss of consciousness due to a problem in the brain.* The common causes of fits are high fever, severe dehydration, malaria of the brain, poisoning or meningitis. In children, the common causes are high fever and dehydration.

### First aid

1. Keep the patient from injuring himself if he falls to the floor or ground by removing dangerous objects on the floor.
2. Wrap his legs loosely with a blanket to control his legs from being thrown about. The restricted movement of the legs will reduce weakness.
3. If the **fit** is due to high **fever**, pour cold water over the body or allow him to sit under a fan to reduce his body temperature.
4. Put dresses soaked in cold water on his chest
1. and forehead to continue to reduce the temp-

erature. High body temperature is harmful to enzymes in the body.

5. Prevent the bitten of his tongue and cheek as described in epilepsy.

## DROWNING

***Drowning** is death due to **suffocation** in water or any other liquid.* Death does not occur imme-diately. A person who has stopped breathing has only 4 to 6 **minutes** to live, therefore, first aid must be fast.

A drowned person's lungs are filled with water resulting in suffocation. The drowned person can be revived if the water can be removed from his lungs and his natural breathing is restored by artificial respiration.

### Artificial respiration

**Artificial respiration** *is an emergency method of supplying air to the lungs of a person who has stopped breathing.*

Artificial respiration is more effectively carried out by **mouth-to-mouth** method of breathing.

### Mouth-to-mouth of artificial respiration

The following steps are employed:

**Step 1:** Lay the victim on his side with his head lower than his rest body as in diagram. With the heel of your hand on his belly between the ribs and navel, make a **quick upward push** to force water from his lungs and stomach.

**Step 2:** Then turn the victim to lie on his back. All tight clothing must be loosened to allow free passage of fresh air to the lungs.

**Step 3:** Pull his lower jaw forward to open the mouth and remove any obstacle such as mucus, weeds or mud that may likely block his air passage (throat) to the lungs.

**Step 4:** Close his nostrils with your fingers and open his mouth wide and cover his mouth with your mouth tightly. Take a deep breath and gently blow in air into his lungs.

**Step 5:** Remove your mouth so that the person breathes out while you wait to take another deep breath. Repeat this procedure for about **15 times** per minute.

**Step 6:** Repeat **mouth-to-mouth respiration** until the person is able to breathe by himself or until there is no hope for his living. Sometimes it may take you upto one hour.

**Figure 29.4. Mouth-to-mouth artificial respiration**

## ELECTRIC SHOCK

When a person unknowingly touches or marches a **live electric wire**, the person receives **severe electric shock**. The victim may either receive burns at the point of contact with live wire, stuck to the live wire or stop breathing.

### First aid

1. Turn (switch) off the electrical current if it is within your reach to stop further current passing to victim's body. ***(Warning:*** you must wear rubber shoes to protect yourself from being shocked in the process).
2. Remove the victim from the live wire. In doing so, you must wear **rubber gloves** or use **dry wood** to push him off. This self precaution is to protect you from electric shock.
3. Quickly remove his clothes if they are wet as they must still conduct current; clean his body with dry towel or clothes.
4. **Artificial respiration** is applied if the

victim has stopped breathing.

5. Where only burns have occurred apply first aid for burns as already discussed.

## DISLOCATION

A **dislocation** is the **displacement** of a bone at a joint and more often with the tearing of tendons and ligaments around the joint. Most dislocations occur are at the ankle, hip, shoulder, elbow, fingers and lower jaw.

### Signs and symptoms of dislocation

1. Severe pains at the affected joint.
2. Swelling around the affected joint.
3. The limb cannot move at the affected joint.
4. The length of the limb may not be the same as other limb.
5. Deformity at the affected joint.
6. There is no power in the affected limb.

### First aid

1. Bind the affected joint with a bandage or handkerchief or piece of cloth so as to give support to the limb. The bandage should not be too tight so that it may not interfere with blood circulation.
2. Apply cold water or ice water to the bandage frequently to reduce pains.
3. Rest the patient in bed.
4. Apply embrocation gently to the affected joint to reduce pains.

**Figure 29:5 Treatment of dislocation of limb bone.**

## FRACTURE

A **fracture** is any **break** in a bone. There are two kinds of fracture namely **simple (closed)** and **compound (open)**

### Simple or closed fracture

If the broken bone does not come out through the skin and injury to the surrounding tissue is slight, it is called a **simple** or **closed fracture**.

### Causes of fractures are:

(a) A heavy hard object falling on the body.
(b) By colliding with another bigger and heavier object violently.
(c) By automobile accidents.
(d) Falling from a height and landing on a hard object.
(e) By gun shot.

### Sign of fracture

1. Pain at the part fractured.
2. Fractured part swells.
3. Internal bleeding as broken bones puncture blood vessels.
4. Fractured part becomes disfigured at the part lengthens or shortens or left in unnatural position.
5. Inability to move fractured part.

### Types of fracture

**1. Simple** or **closed fracture:** The bone breaks neatly inside the body without causing wound on the flesh and skin over the area. A good example is simple fracture of the upper arm.

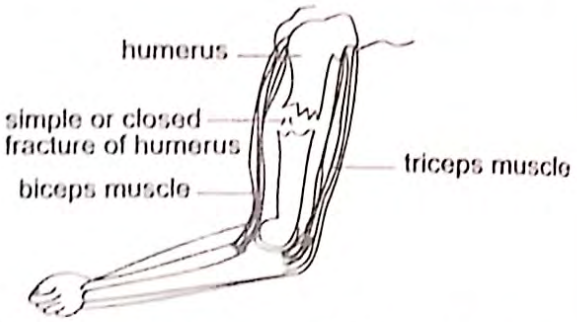


**Figure 29.6. Simple fracture of the upper arm**

**2. Compound** or **open fracture:** The fractured bone pieces the muscle and skin leading to an open wound. There is the attendant risk of infection of the wound, an example is compound or open fracture of the thing bone.

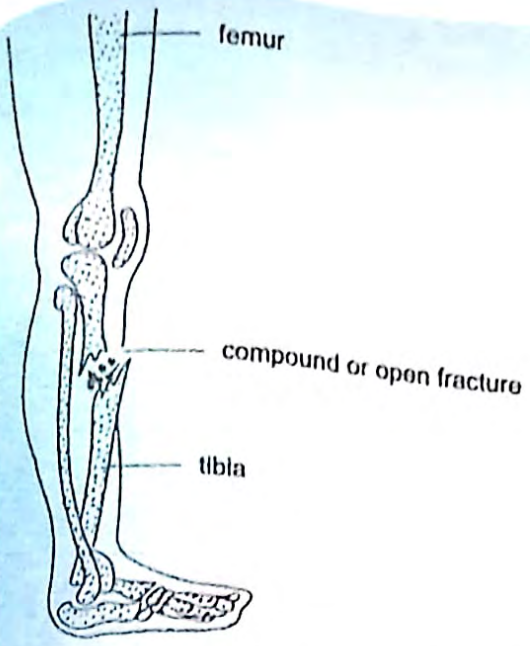


**Figure 29.7 Compound or open fracture of the tibia of right leg of a man.**

**3. Complicated fractures:** Below are forms of complicated fractures.

(1) **Multiple fracture:** In this type of fracture, the bone is broken into several pieces or crushed.

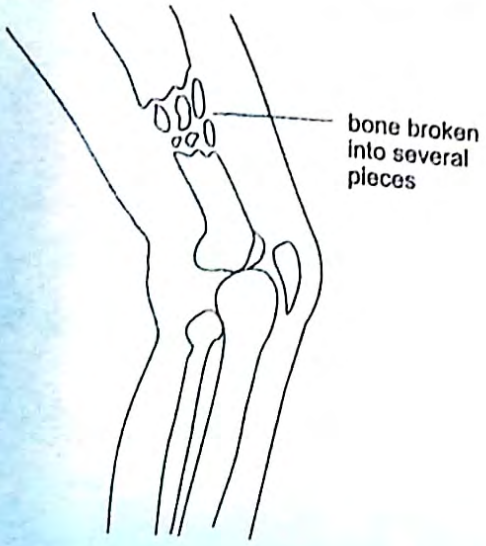


**Figure 29.8. Multiple fracture**

(2) **Impacted fracture:** The fractured ends of the bone are driven into each other.

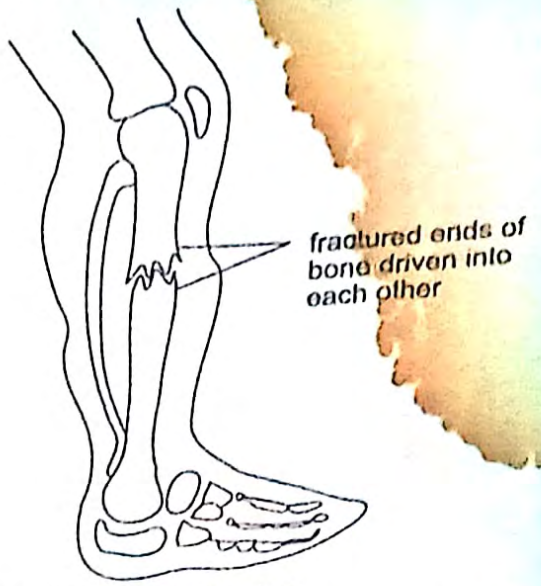


**Figure 29.9. Impacted fracture**

(3) **Green stick:** The bone is partly broken or cracked. This type is experienced by children with soft tissue bones.

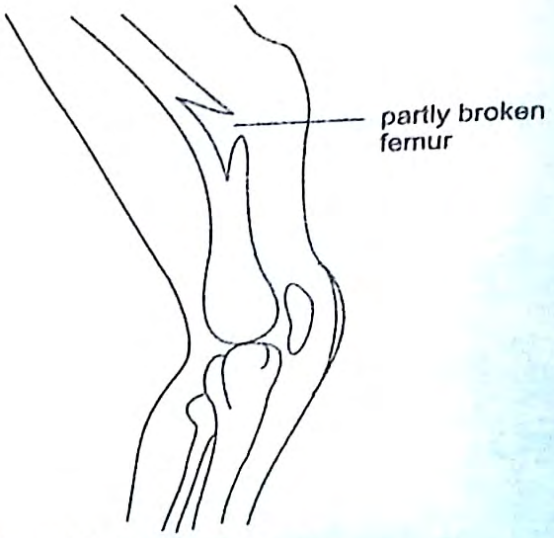


**Figure 29.10. Green stick fracture.**

(4) **Depressed fracture:** In this type, the broken part is driven inwards e.g. fractured skull.

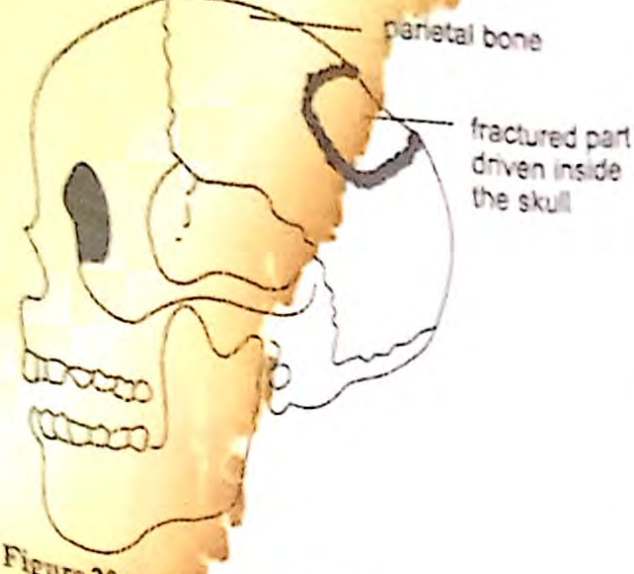


Figure 29.11. Depressed fracture.

## General first aid measures of fractured bones

**First aid measures of some fractured bones**

**Humerus (armbone)**

1. Place splints in front and back of the fractured bone from the shoulder to the elbow and bandage well (one bandage above and one below) to immobilize the limb, and to keep the bones in place to prevent more damage to the bone and surrounding tissues. (Note: In absence of bandage, handkerchief, necktie, belt or scarf can be used).

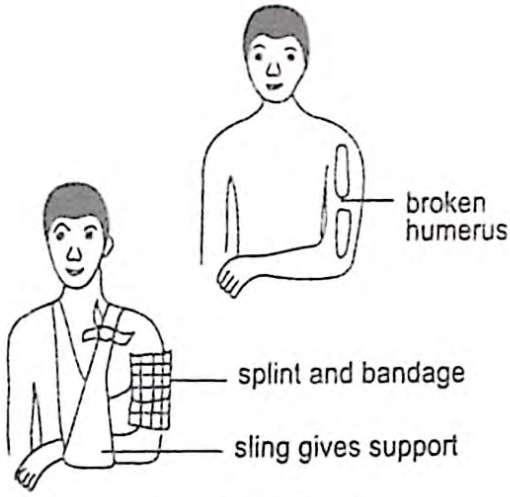


**Figure 29.12. First aid for broken humerus**

2. Place the fractured hand inside the sling with the fingers coming out of the sling as in diagram. This makes the hand to be at a right angle position.

   A sling can be made by folding a large piece of cloth or towel diagonally. The two ends of the cloth or towel are then tied around the neck. Sling helps to immobilize the entire arm and gives support.
3. The victim should be carried on a stretcher to avoid holding the fractured area so as to prevent more injuries.
4. If there is bleeding, this must be treated first before the fracture is tied with splints in order to avoid infection and loss of blood that may lead to fainting.

### Thigh (femur)

1. Hold the ankle and foot and as much as possible straighten the limb slightly.
2. Splint the body from the chest to the feet.
3. Bandage the chest, waist, ankles, legs and knees.
4. In absence of splint, tie the two legs together as several places.

**Figure 29.14. Victim of a fractured thigh bandage from chest to feet.**

## FIRST AID AGENCIES

The following are the agencies that carry out the functions of first aid:

1. Red Cross
2. Saint John's Ambulance Brigade.
3. Boys' Brigade
4. Boy Scouts.
5. Girls' Brigade
6. Girls' Guides.
7. Baptist Royal Ambassadors.
8. Nigerian Aid Group (Muslim organization).

## Questions

1 (a) Explain the term artificial respiration. Describe step by step method of mouth-to-mouth respiration to a drowned victim.

(b) Explain the term fainting and what first aid would you give to a victim of fainting.

(c) Name four agencies involved with First Aid in your country.

2 (a) Briefly explain the meaning of the following terms:

(i) bleeding (haemorhage)

(ii) first aid

(iii) fit

(iv) dislocation

(b) (i) State the symptoms of dislocation

(ii) State three differences between a simple and a compound fracture.

(iii) Name the step you would take when administering first aid to victim of a poisonous snake bite and explain the importance of each method employed.

(c) Describe three methods of stopping bleeding from an open wound and state the importance of each method.

3 (a) (i) State five objectives of first aid.

(ii) If a footballer has a dislocation at the head of the humerus when playing a football march for your school, what first aid procedure will you take?

(b) What first aid would render to a victim of:

(i) epilepsy

(ii) electric shock

(iii) burns and scalds.

(iv) In each case explain the importance of the method employed.

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# 30 BUILDINGS

## Domestic Buildings

It is a life desire of every person to own a house but in doing so some basic requirements must be considered to make such a house good for healthy living.

## Requirements for good housing

These are:-

1. Good site
2. Orientation
3. Site surroundings
4. Building design
5. Ventilation
6. Sanitation

## Good site

The site chosen for building a house should not be water-logged or marshy as such area will provide breeding grounds for mosquitoes and other insects. Water-logged or marshy area is usually damp and helps to promote growth of bacteria some of which cause diseases. Also such an area stands the risk of being flooded during the rainy season leading to the collapse of the house.

A good site should, therefore, have a porous soil with a mixture of sand, gravels and chalk to drain off rain water easily from the surface soil. Clay or granite soil is not good as it retains water and promotes flooding.

A house site is better on a gentle slope as it allows drainage of rainwater from the house and its surrounding. A higher ground is better for building a house than a lower ground because such a house receives drier and cooler wind.

## Orientation

A well planned house must have a correct orientation. It is better to locate the bed rooms to the **east** or **south** side of the house and not to the west side. This orientation reduces the heat of the sun since the effect of morning eastern sun is mild and also ensures more breeze of the south-west cool winds to the rooms.

If located to the west, the bedrooms will be heated by the afternoon=s sun and makes the interior of the house hot even after sun set.

## Site surroundings

The building should be surrounded by an open space for the movement of air around and through the house. Low vegetation must be kept away from the house so that movement of air is not prevented. Breeze across a trimmed lawn is desirable. Large trees should not be allowed to overhang the house because they can constitute a serious danger to life if felled by stormy weather on the roof of the house. They can also hinder air movement around the house.

Trees are desirable but they should be planted some metres way from the house. Trees act as strong Abrakes@ against strong wind which often destroy roofs of houses. Trees also purify the surrounding air by absorbing carbon (IV) oxide (carbon dioxide) and give out oxygen for respiration. If the surrounding trees have holes in which rain water collects, such holes should be filled with concrete to prevent the breeding of mosquitoes around the house.

## Building design

For a building to be comfortable it must fulfil functional and physical requirements.

## The functional requirements

The basic housing units should be made up of a living room, bedrooms, kitchen, store, bathroom and toilet. The physical requirements comprise **roof, walls, floor, windows and doors**. Windows and doors ensure that ventilation, lighting, cooling, warming and safety of the occupants of the house. It is also necessary that the building structure be made

of any of the following materials, mud, burnt bricks, concrete blocks and cement blocks, glass, steel and wood.

## Layout plan

Planning authorities in town must ensure that only designs that conform with regulations are approved. The minimum requirements for a house must consist of the following:

1. Bedroom for sleeping
2. Sitting room for social interactions
3. Shaded front verandah for out door social life
4. Covered back verandah for cooking and house work.
5. Small kitchen
6. Small lock-up store near the kitchen for storage of food and cooking utensils
7. Toilet
8. Bathroom
9. An incinerator for burning refuse after dust bin collection.

## Bed room

The bed rooms should have the minimum size 3.3 x 3.3 metres with enough windows placed at adjacent sides of the wall to let in plenty of light. The room should be painted with light colour to reduce the heat absorbed since light colours reflect more heat than dark.

## Sitting room

The sitting room should be big to accommodate enough inhabitants and have large windows for cross-ventilation of the interior. The windows should be placed opposite to each other to increase speed of breeze across them.

Bed room and sitting room should have plastic or aluminum netting to prevent entry of flies such as mosquitoes and houseflies.

## Front verandah

A front verandah with a roof covering should be at least 1.05 metres wide. Front verandah should be located before or beside the sitting room to trap the southwest cooling breeze. It can also be located in west size to provide shade for the walls to prevent overheating of interior.

## Back verandah

This should be close to the kitchen for an outdoor cooking. All verandahs should have floors raised at least 150mm above the natural ground level to prevent flooding during the rainy season.

## Kitchen

The kitchen should have a floor area of not less than 5.6 square metres in length and not less than 2 metres in width and 3 metres in height to give sufficient space for cooking activities which include preparation, serving and storage. A kitchen should have a sink usually made of aluminum for washing cooking utensils and a storage cupboard for keeping cooking utensils. The floor of the kitchen should be non-slippery and be made of cement-sand screed or terrazzo to enhance regular cleaning to prevent disease organisms such bacteria and fungi and to prevent accident due slippery. Windows should be adjacent or opposite to encourage free air movement. Gas cookers should be placed adjacent to windows to ensure proper lighting while cooking and to prevent fire hazzard due to air movement.

## Store

The store if it is separated from the kitchen should be adjacent and directly to the kitchen. It should have a floor area of not less than 1.5 metres and a height of not less than 3 metres. It should have non-slippery washable floor and a window of moderate size to allow sufficient sunshine and fresh air to warm up and ventilate it. A store must have shelves for keeping of food stuffs such as beans, yams, plantain and rice. The store must be regularly cleared to get rid of rats and cockroaches which spread diseases.

## Toilet

A well planned building must have a toilet and bathroom per bedroom or a combination of a toilet and bathroom at the rate of one unit for every three rooms. The toilet should have floor area of not less than 2 square metres or if in combination with the bathroom should not be less than 3 square metres with ceiling height not less than 2.4 metres. The floor of the toilet and bathroom should either be plastered with cement or made of some water tight, non-absorbent and non-slippery material like rough ceramic tiles or terrazzo.

The walls should be finished with water-resistant material like ceramic tiles.

The toilet should contain water-closet for disposal of human waste and a wash-hand basin for washing hands after toilet use.The water closet is connected to an underground septic rank through a man-hole and separates from solid effluence and is channelled to the undergro-und soak-away pit.

cooking space. No room used for storage, shall open directly into space by a door or other to prevent spread of air-born diseases and offensive odour.

## Bath room

The floor and walls of bath room should be made of non-slippery and non-absorbent materials like terrazzo, cement mixed with sand and rough ceramic tiles. When a bath room has only a standpipe or shower, the floor should be made of concrete with a cement-sand screed or other non-absorbent material sloped towards and outlet. The outlet is connected through a manhole and sloped pipes to a soak-away pit. All bath rooms and toilets should have high-level windows with a maximum height of 900mm for privacy and good lighting. Every such room should have a door completely closing the entrance to it.

## Sanitation:

Read the care of dwelling places on pages 474 - 475 in addition to incinerator described below.

## Incinerators

House refuse consists of damp decaying vegetable matter and food remnants. There are several methods of house refuse disposal after collection, the commonest being (a) **burning** and (b) **dumping**. Dust-bins of covered metal drums are recommended as they are fly-proof and rat-proof.

**Burning:** This is the best known method because the refuse is made harmless. However, house refuse in tropical countries usually contains a lot of wet vegetable matter. It can only be burnt in properly designed incinerators or destructors. These are usually made of steel and located in strategic and accessible locations by sanitary officials. It is sometimes necessary to dry refuse for a few hours before burning.

**Dumping:** House refuse is sometimes used to fill up hollows and for raising the level of low land. Great care should be taken here because of



offensive smells that may arise, while rubbish dump attracts rats and becomes breeding-places for diseases-carrying flies and rodents such as rats and mice; hence refuse should never be dumped near houses.

# SCHOOL BUILDINGS

There are three basic school types and they are: **primary, secondary** and **tertiary**. Primary schools comprise nursery and elementary school, secondary schools include junior and senior high schools and vocational training schools while tertiary includes universities, polytechnics, colleges of education and schools of technology.

The focus here is on secondary school buildings. The treatment of this topic shall be subdivided as follows:

(1) Site
(2) Building design
(iii) Building materials
(iv) Orientation
(v) Surroundings
(vi) Ventilation

## Site

Every school is built in a locality governed by town planning regulations which determine land use and minimum standards to ensure comfort of the building users.

The site chosen for school buildings may be in the urban or rural area depending upon the availability of land. Planing regulating bodies stipulate that the minimum site are for a secondary school should not be less than **two hectares (or 20,000 square metres)** to adequately accommodate classrooms, assembly hall, lecture halls, dormitories, teachers quarters, offices, laboratories and a football field for recreation.

Access to the school site should be through good road to ensure convenience of movement to and from it. The school compound should be fenced round with sanderete block wall at least 2m high with two entrance gates to ensure security within and close monitoring of students' movement. A school site should be in quiet residential area or in the outskirts of the town to reduce noise pollution to the barest minimum. On no account should a school be built in an industrial area to avoid noise and air pollution from factories. A good school site shall be gently sloped and well drained to ensure adequate run-off of rainwater towards community's drainage system.

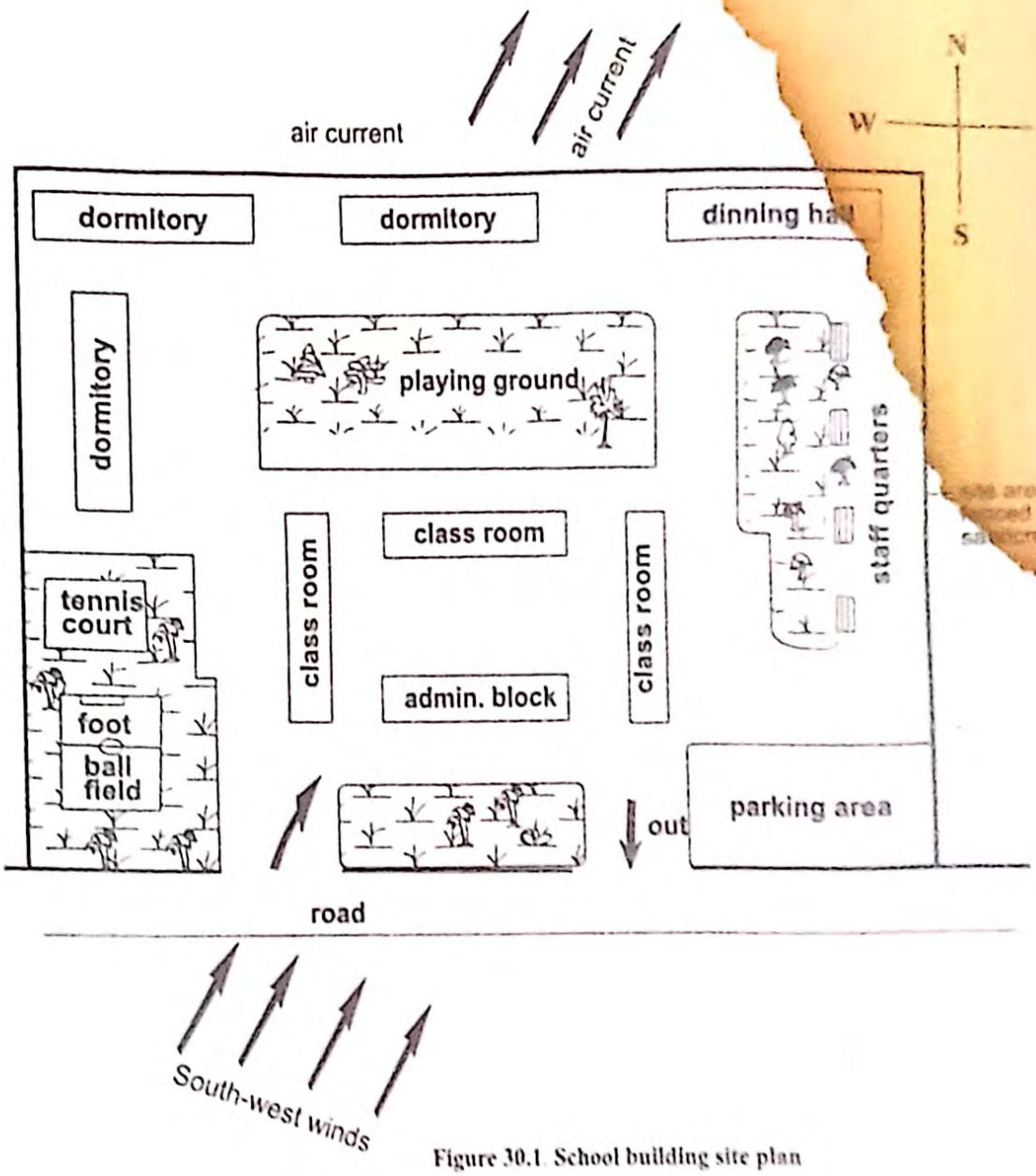



Figure 30.1. School building site plan

## Building design

**(a) Plan layout:** The aim in school building design is to ensure individuals and small groups in various rooms retain a sense of identity and independence. This is achieved by planning to ensure independent building blocks. However, to prevent being wet by rain during movement from one building to another, covered verandahs of 1200mm width open at both ends should be provided between buildings. Educational planning policies stipulate that for effective teaching, the ratio of teacher to students shall not exceed 1:40. A class should therefore contain a maximum of 40 students. The minimum classroom size should be 7.3m x 9.1m in floor area and 3m high. Doors should be at least two per class and open outwards to enhance ease of exit in emergency situations like fire out-breaks. Laboratories should be a minimum size of 7.3m x 14.6m and height of 3m.

Toilets consisting of water closets and wash

shall be designed to ently accommodate the entire school population during indoor assemblies. It shall be provided with sufficient exit ways for free movement.

**(b) Lighting and ventilation of interior spaces:** Student toilets must be far from classrooms. Every habitable and occupiable room or space like classrooms, offices, laboratories and assembly halls in school buildings shall be provided with windows, ventilators, skylights, glazed doors or other light and air transmitting media, opening to the air-space, yard or courtyard or sky. This should preferably face north or south, since light from this direction is brightest. The total area of the windows in any space shall not be less than ⅛ (one eighth) of the floor are served. For maximum natural cooling of interior and comfort of building users, sufficient space for breeze is important. By using an arrangement with facing windows on opposite walls the speediest air movement, and maximum cooling effect is achieved. This should be the situation in classrooms, assembly halls and laboratories.

In the administrative building with internal wall divisions in offices, breeze speed can be enhanced by placing internal partitions to encourage air movement.

**Plan of classroom showing cross ventilation through opposite windows.**

To improve the ventilation of the interior an overhang above the air inlet window would be preferred. An overhang, of concrete slabs or plastic waffles, at ceiling height, intercepts and diverts air toward inlet and improves ventilation within. A horizontally pivoted window, like glass louvre or hardwood louvre windows, with blades turning downwards produces a satisfactory air flow.

## Building materials

A building is made up of the following: (a) foundation (b) floor (c) walls and (d) roof.

**Foundation:** The materials for foundation are cement, sand, gravels, rocks and metal rods. These materials are mixed together in right proportion to form concrete foundation.

**Floor:** The floor can be made of timber, mud or concrete depending upon the financial resources of

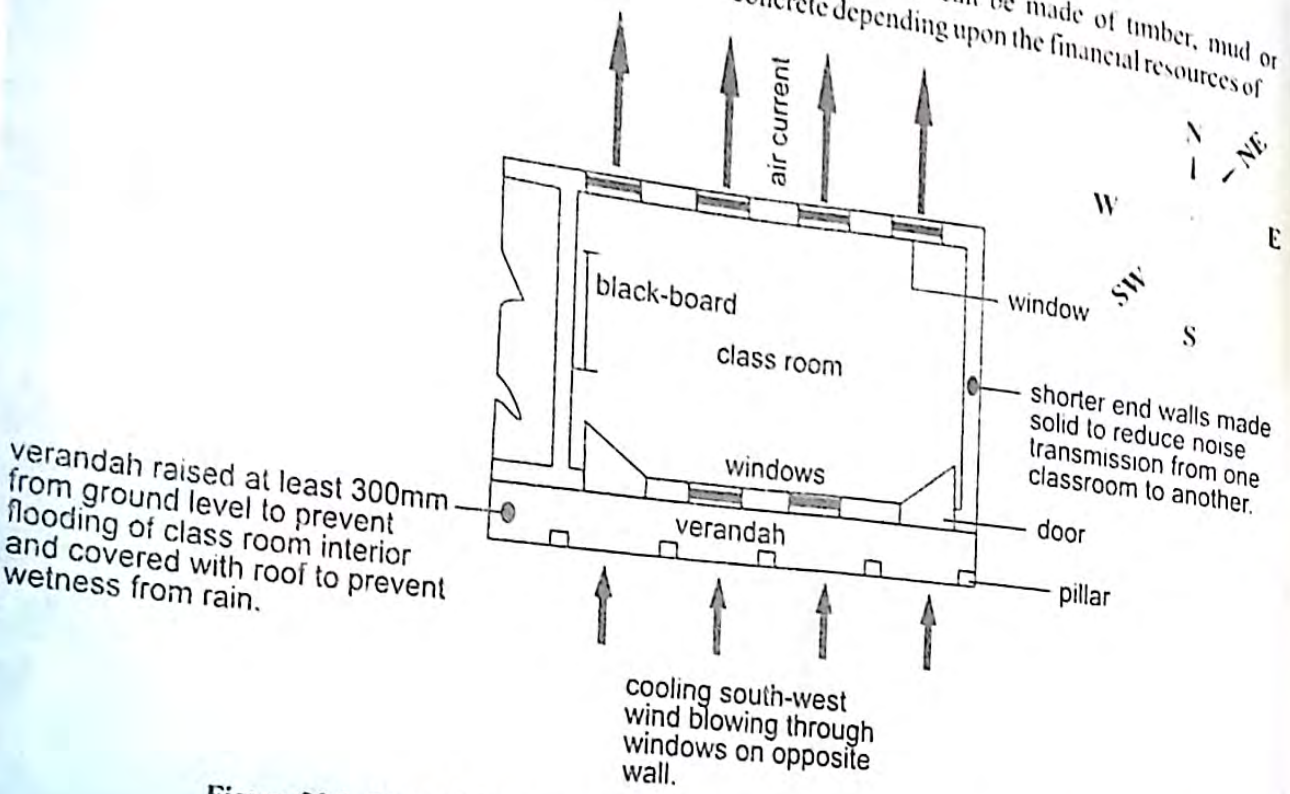



**Figure 30.2. Plan of classroom showing cross ventilation through opposite windows.**

the corner. If the floor is to be made of concrete, it must be screeded with cement and sand mixed in right proportion.

**Walls:** Walls may be made of mud, sandcrete blocks, sandcrete blocks burnt bricks, mud/clay/laterite blocks.

Mud, concrete blocks, and burnt bricks and fireproof while wood is not. Walls made of mud are not durable as they are easily destroyed by floods and therefore not recommended for school.

Concrete blocks and burnt bricks are preferable for the durability and safety.

**Roofs:** Roof is made up of **roof structure** and **roof-covering**.

**Roof structure** is made up of either **timber, steel** or **aluminium.** If timber is to be used it must be the hard type such as **Apa** and it must be treated with pesticides such as sologrum to prevent attacked of insects rats.

**Roof covering** is either made up of clay-tiles, concrete tiles corrugated sheets (e.g. galvanized metal or aluminium). Galvanized aluminium sheets are preferable because of their high heat reflection and durability.

## Orientation

The site selected should as mush as possible have the longer axis along the east - west direction. This will ensure a minimum exposure of site and building to the east and west directions and more to the north and south. By this orientation, the intense heat from the western setting sun will be reduced, the brighter light from the north and south will be optimally used for educational activities and the cooling south-west winds will be encouraged to blow through the building interiors to give users comfortable environments within.

## Surroundings:

Refer to surroundings on housing page 599.

## Ventilation

An ideal classroom must be well ventilated. Wide low levelled windows should be placed at opposite side of the walls to encourage free movement of air. The windows can be made glass or wood louvre. The blade of the louvre windows should be able to turn downwards to produce satisfactory air flow. It is reasonable to have two wide doors per class room placed at different for easy exit possibly during an emergency.

Vegetation around classrooms should be of low shrubs or lawns so that air movement is not disturbed.

Ceiling fans can be instored to increase air circulation.

## *Questions*

*(a) What consideration would you give to*
- *(i) building materials*
- *(ii) orientation*
- *(iii) sanitation*
- *(iv) ventilation when you want to build a secondary school.*

*(b) What are the disadvantages of siting a school building in marshy area?*

# 31

# GLOBAL WARMING AND CLIMATE CHANGE

## GLOBAL WARMING

*Global warming refers to an average increase in the earth's surface temperature due to release of greenhouse gases from industrial activities, deforestation and depletion of the ozone layer.*

## Greenhouse effect

Naturally, the Earth warms and cools itself. The temperature of the sun is about 5000°C and about 50% of the solar energy penetrates to the Earth's atmosphere and warms the Earth's surface. About 30% of the solar energy is reflected back to space to prevent overheating of the Earth's surface. While the Earth retains some of the heat energy referred to as "long wave infra-red" essential for the evolution of life on Earth. It has been calculated that without this heat, the average temperature would have been between -17°C and -23°C. The actual average temperature of the Earth's surface is 15°C. The retention of this heat is caused by oxides of carbon, sulphur and nitrogen, methane, ozone, and water vapour (not a gas). These gases form a blanket of gases referred to as "greenhouse gases" which surround the Earth. These gases absorb and retain heat (long-wave infra-red) and reflect the heat back to Earth's surface.

*The greenhouse effect is, therefore, a natural feature of warming the Earth's surface to keep the average temperature of the Earth at 15°C but when there is a rise in temperature it results to global warming leading to climate change.*

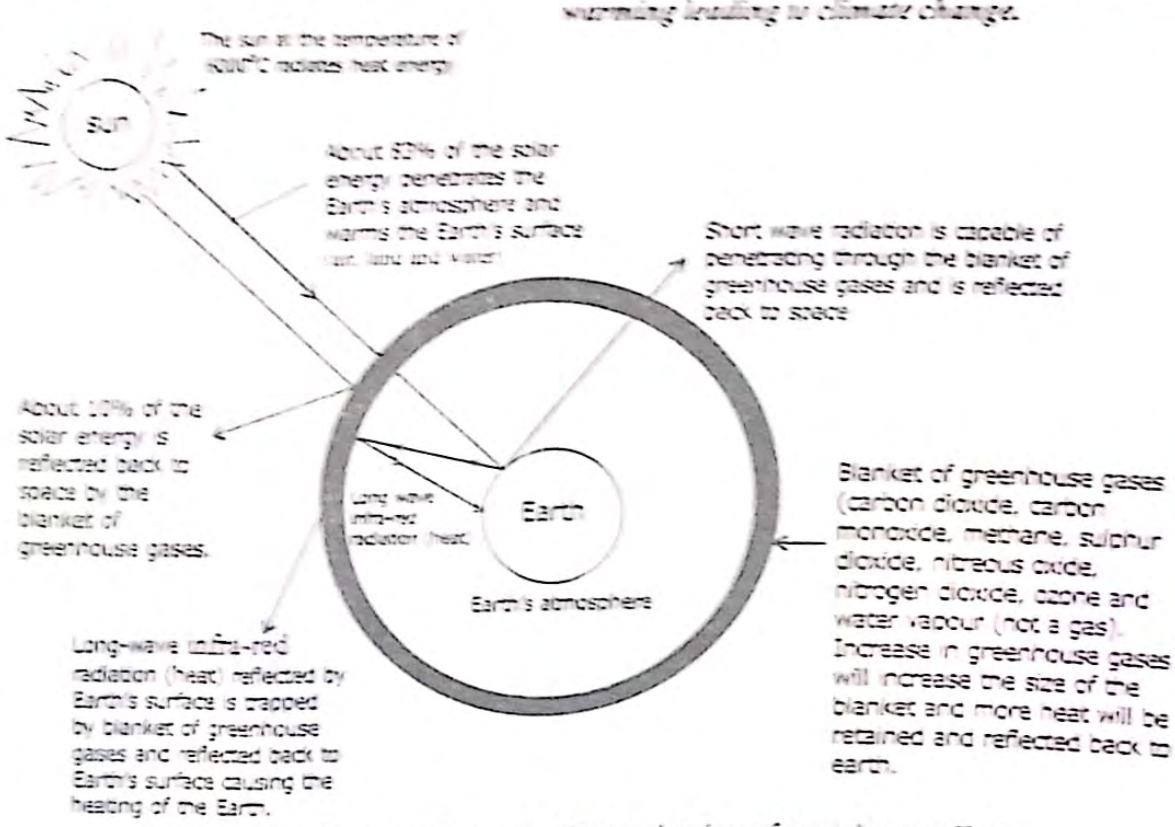



Figure 31.1. Diagram illustrating the mechanism of greenhouse effect.

## Causes of global warming

It all started from the industrial revolution of 18th when the establishment of industries took a more stage. Rapid rise in industrialization has led to an increase in motor vehicles and aeroplanes for transportation, different machines for various purposes, massive construction of roads and railway lines, large scale farming (leading to deforestation), bush burning, crude oil exploration and exploration, combustion of fossil fuels (coal, oil and natural gas) etc. Each year 120,000 sq km of forest are lost as follows: 45% to shifting cultivation, 5% commercial farming and grazing, 10-15% to road construction and dams and 10% to timber products (such as mahogany, massina or furniture) and bush burning just to mention few are major contributors to greenhouse gases.

## Greenhouse gases

On Earth, the major natural greenhouse gases that lead to global warming are carbon dioxide ($CO_2$), carbon monoxide (CO), methane ($CH_4$), ozone ($O_3$), sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), nitreous oxide (NO), and water vapour (not a gas).

Chlorofluorocarbons (CFCs) are organic molecules manufactured by scientists.

## Carbon dioxide ($CO_2$) and carbon monoxide (CO)

Burning of fossil fuels, firewood, bush burning and methane (cooking gas) releases large amounts of carbon dioxide into the atmosphere while incomplete combustion of above results in the formation of carbon monoxide.

About 5 million metric tonnes of carbon dioxide exist in the atmosphere today. Carbon dioxide contributes about 50% of the greenhouse effect (global warming). Before the wide spread industrialization, the concentration of carbon dioxide in the atmosphere was 0.03% by volume. Since the excessive burning of fossil fuels, the amount of carbon dioxide in the atmosphere has increased steadily. The concentration of carbon dioxide has increased from 0.03 to 0.034%. The recent study of U.S National Research Council estimated that the concentration of carbon dioxide in the atmosphere would pass [illegible]% by 2025 and might even exceed that level. If these concentrations are reached, the earth's surface temperature would increase between 1.5 to 4.5 [illegible]. China, United States of America (U.S.A), India and Brazil are the greatest carbon emission into the atmosphere.

Aeroplanes emit about 200,000,000 tonnes of carbon into the atmosphere annually.

## Methane ($CH_4$)

The concentration of methane has increased to 149% since 1750. Methane causes about [illegible]% of greenhouse effect. The activities of petroleum industries which have resulted to gas flaring has contributed greatly to the released of large quantity methane gas into the atmosphere.

Methane is also produced by anaerobic bacteria living symbiotically in the guts of ruminants (e.g. goats, sheep, cattle and camels). These bacteria break down the vegetable diet of the ruminants resulting in the production of methane. Methane is also produced from landfill sites, swamps, paddy fields by anaerobic fermentation of anaerobic bacteria. Therefore human activities such as cattle ranching have increased the release of methane into the atmosphere. For example, a single cow can produce 200dm$^3$ of methane per a day.

## Ozone($O_3$)

Ozone which has three oxygen atoms (triatomic) occurs naturally in the atmosphere mainly by a chemical process involving the action of solar radiation on oxygen gas. At a high altitude, about 20-50km above the Earth's surface, ozone forms a layer (ozone layer) making it a greenhouse gas.

Depletion of ozone layer results in direct heating of the earth's surface thereby increasing the temperature of the earth.

## Sulphur dioxide ($SO_2$), nitrogen dioxide and nitreous oxide.

Burning of fossil fuels or gas flaring containing sulphur leads to the formation of sulphur dioxide in the atmosphere.

$$S + O_2 \xrightarrow{\text{heat from gas flaring}} SO_2$$

sulphur oxygen sulphur dioxide

The heat also converts the atmospheric nitrogen into nitrous oxide and nitrogen dioxide.

$$2N_2 + O_2 \xrightarrow{\text{heat from gas flaring}} 2N_2O$$

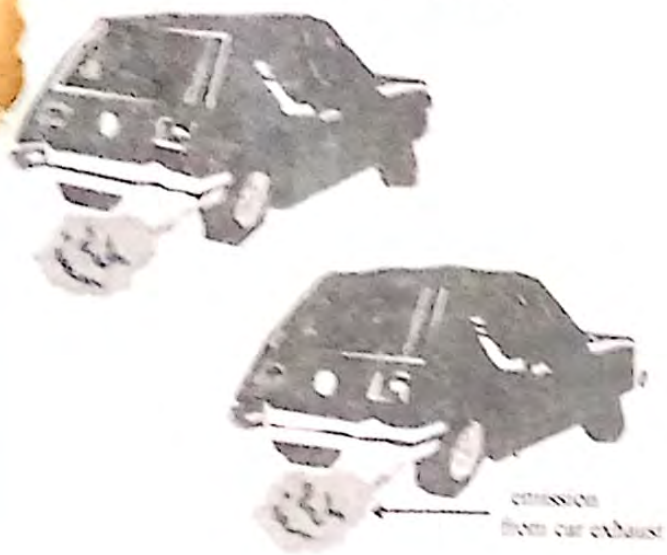
Nitrous oxide

$$N_2 + 2O_2 \xrightarrow{\text{heat from gas flaring}} 2NO_2$$

nitrogen oxygen (nitrogen dioxide)

**Exhaust emissions from vehicles and aircrafts**

Exhaust emissions from vehicles contain much carbon dioxide and carbon monoxide which are released to the atmosphere.




Aircrafts emit large quantities of greenhouse gases. For examples, Britain produces more carbon emission from flying aircrafts than any other country in the world. The average carbon emission for each British flyer is 603kg (951lb) a year, Ireland is second accounting for 434kg while that of U.S.A is 275kg. The low cost of traveling by air in Britain has increased the number of people traveling by air and consequently more aircrafts flying thereby increasing greenhouse gases in the atmosphere.

## Water vapour

Water vapour causes about 36% - 70% of the greenhouse effect (excluding clouds). Water vapour acts as a powerful long-wave heat absorber. Therefore, increased water vapour in the atmosphere increases the surface temperature of the Earth leading to more water vapourising into the atmosphere.

## Effects of global warming

Greenhouse gases restrict the heat from the surface of the Earth from reflecting back to space thus causing global warming. Since 1901, the global temperature has arisen by 0.5°C. Rise in global temperature leads to the following consequences.

**(a) Rise in sea level**

Melting of the polar ice caps will cause flooding of the low coastal areas of the world or four million square kilometres of land which provide home for 3% of the world population same the risk of being flooded and may be lost forever. For example, the Arctic glaciers will be melting at the rate of 15metres every year due to global warming. All settlements along the coast will be lost forever. Also one quarter of the plant and animal species will go into extinction. If the global warming increases, the polar ice caps may melt completely and sea levels would rise by more than 150 metres leading to the flooding of the entire Atlantic coast of North America which covers an average distance of several hundred kilometres inland. Niger Delta region of Nigeria and the entire West African coast will be covered. By the middle of this century, 200 million people will be permanently displaced due to rise in water level. Billion of dollars will be spent on coastal protection. Caribbean and Pacific Islands and coastal towns such as Lagos, Port Harcourt, Warri, Tokyo, Hong Kong, New York, Miami, Calcutta, London and Bangladesh will be flooded if not protected.

**(b) Salt water intrusion**

Salt water intrusion from the oceans and sea into fresh water bodies such as rivers, streams and lakes will destroy fresh water organisms including fish.

**(c) Heavy rains and flooding**

Since 1880, the average temperature of the earth surface has increased by 0.5°C (0.9°F). It is predicted that by 2010, the temperature will rise by 1°C (1.8°F) and by the end of this century, global temperature will increase by 4°C. global warming causes rise in temperature which in turn causes more water to evaporate into the atmosphere. Since **water vapour acts** as a **greenhouse gas**, global warming will increase. More water vapour will lead to heavy rainfall and thus causing flooding of low land areas.

**(e) Melting of ice caps (Glaciers)**

As the ice caps melts, even water bodies will be flooded. Water reflects less heat than ice. Therefore, water bodies will absorb more solar radiation (heat) and thus causing more warming which in turn causes more melting of ice caps. Melting of **seabed ice** will lead to decay of **buried** organisms causing the release of carbon dioxide and methane into the atmosphere, and thus increasing the global warming.

The temperate regions of the world will experience more heavy rainfalls than the tropical regions. The tropical region will experience drought which will lead to poor crop harvest. Hunger and poverty will be common.

**(d) Hurricanes (Cyclones and Typhoons)**

When the temperature of the sea is above 27°C, hurricanes (storms in Atlantic ocean, cyclones in Indian ocean and typhoon in Pacific ocean) start to build up. **Hurricane is caused by rising hot air with cooler air rushing beneath it.** Hurricanes destroy trees, crops and buildings. Huge waves caused by hurricanes lead to flooding of the coastal areas.

**(e) Ill-health in humans**

(i) High temperature and dry weather and the spread of diseases such as meningitis and measles. Dry weather and heat make these germs more active and spread faster with dust particles.

(ii) Prolonged [illegible] dehydration.

(iii) Also heat stroke [illegible] unable to withstand [illegible] heat.

(iv) General discomfort [illegible] lead to poor health.

**(f) Crop losses**

Dry weather will cause [illegible] soil to become infertile leading to low [illegible] of simple crops. Hunger will be common. He[illegible] of millions of people will starve to death.

**(g) Species migration**

With rise in water level, pests a[illegible] diseased vectors may extend their habitat ranges. [illegible] example, it has been recently reported that a [illegible] land area in Kenya which has been malaria free [illegible] started experiencing malaria out-break as a [illegible] of flooding that has now extended to the area.

The land surface will be reduced in size due to flooding. Terrestrial animals will congregate into the remaining areas leading to over population which will in turn promote predation and cannibalism.

**(i) Thermal inversion**

Thermal inversion will occur as a result of warm air trapping cool air containing dust particles and smoke close to the earth causing smog which does not rise to the surface. Smog causes invisibility which may cause plane crash and motor accidents. Photosynthesis will be reduced leading to food shortage and less oxygen in the atmosphere.

**(j) Desertification and its effects**

High temperature causes evaporation of soil water leading to dry soil which is unable to support plant life. Death of plants exposes the soil surface to wind erosion leading to desertification. Many animal species living in forests may be heading for extinction. Many plant species of medicinal values may become extinct. It has been predicted that by 2050, about 1,103 plant and animal species would be extinct. As plants die so also the herbivores and the death of herbivores will equally cause the death of carnivores and omnivores.

**Drying up of inland water bodies**

Increase in temperature will lead to drying up of inland water bodies that are not connected to oceans and seas e.g. Lake Chad that was as large as 25,000 squ kilometers in size is today only 1000 squ kilometers due to excessive evaporation as a result of global warming.

**Control of global warming**

1. Since the global warming is a global issue, international co-operation is essential. The Kyoto Protocol in 1997 was an attempt to get all countries to agree to limit their production of greenhouse gases. However, for various economic reasons some of the big countries like USA, India and China have not signed the agreement to limit the production of greenhouse gases.

2. The practice of burning bush during the dry season must stop. Various government agencies must enforce the laws against bush burning to the letter.

3 Gas flaring by oil companies which is an environmental disaster must stop. Government must sanction any oil company flaring gas. Oil money must not be allowed to destroy our environment and lives.

4. Production of chloroflouorocarbons mainly responsible for the destruction of the ozone layer must stop. In 1987, an international agreement (Montreal Protocol) was reached. All the major industrialized countries agreed to limit their production and the uses of CFCs. Sad enough, CFCs stay in the atmosphere for a long time (about 60years or above) and the hole in the ozone layer (as big as the size of U S A) is still there.

5. Fossil fuel burning must be limited. There must be an alternative to fossil fuel burning such as the use of solar and wind power.

6. Increasing the taxation on fuels will reduce fossil fuel burning.

7. Limiting the use of land fill sites will reduce methane production to the atmosphere.

8. Deforestation must be limited and planting of trees should be encouraged. Plants absorb carbon dioxide during photosynthesis and cool the environment. Amazon rain forest in Brazil absorbs about 600,000,000 million tonnes of carbon dioxide from the atmosphere annually.

9. Manufacture of electric vehicles to replace fuel vehicles. This will eliminate carbon-dioxide emission from vehicles.

10. The number of vehicles in use should be reduced. This will reduce the quantity of carbon-dioxide emission into the atmosphere. Modern technology can make vehicles that go farther per litre of fuel, as this will reduce the amount of carbon dioxide that would be released into the atmosphere by vehicles.

11. Mount a local campaign against the evils of global warming.

12. The use of firewood as source of energy must be discouraged as burning of firewood adds carbon dioxide to the atmosphere and also leads to deforestation.

**13. Birth Control:** Human population as a matter of deliberate policy must be controlled. Increase in human population leads to an increase in carbon dioxide release to the atmosphere through respiration.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{respiration}} 6CO_2 + 6H_2O + \text{Energy}$$

# OZONE LAYER (OZONOSPHERE)

**Ozone ($O_3$) layer is a layer of the earth's surface in which most of the atmosphere's ozone (90%) is concentrated.** It is concentrated in the stratosphere of the earth's surface. The remaining 10% of the ozone occurs in the upper surface of the troposphere. Troposphere is about 20km above the earth's surface. In the stratosphere, most of the ultraviolet radiation is absorbed by the ozone layer molecules, causing temperature rise in the stratosphere. By absorbing most of the sun's radiation, the ozone layer protects living organisms on earth. At the equator, ozone layer is thinnest while at the poles, it is largest and thickest.

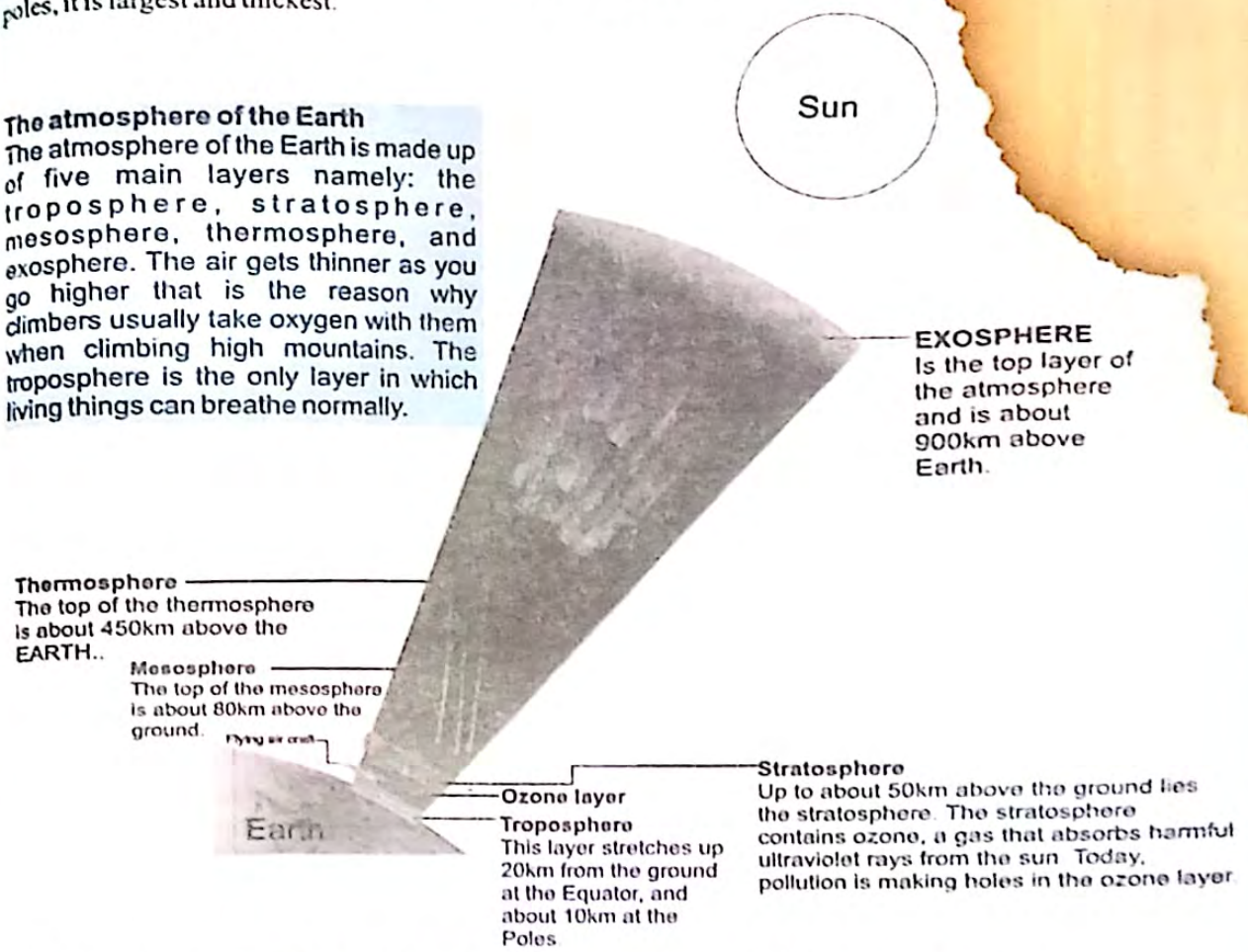



Fig: 31.3 Atmosphere of the Earth Modified from Dorling Kindersley Science Encyclopaedia with courtesy

### Formation of ozone

Ozone is formed by the action of ultraviolet radiation on oxygen. Ozone is formed when oxygen molecules absorb ultraviolet photons and undergo a chemical reaction called **photo dissociation or photolysis** where a single molecule of oxygen breaks down into two oxygen atoms. The free oxygen atom (O) then combines with an oxygen molecule ($O_2$) to form a molecule of ozone ($O_3$)

The ozone ($O_3$) molecules in turn absorb ultraviolet rays to prevent the harmful radiations of the sun from entering the earths surface. In the process, ozone ($O_3$) molecules split up into a molecule of oxygen ($O_2$) and an oxygen atom (O) the oxygen atom (O) combines with the oxygen molecule ($O_2$) to regenerate an ozone ($O_3$) molecule. Therefore, the total amount of ozone ($O_3$) in the atmosphere is maintained by this process of destruction and regeneration.

### Importance of ozone layer

The ozone layer filters out the harmful ultraviolet rays from the sun thereby protecting life on earth. Ultraviolet of the sun are associated with a number of health related environmental issues.

### Causes of ozone layer's depletion

The depletion of ozone occurs when the natural production of ozone and the destruction of ozone in the stratosphere is shifted in favour of destruction. The natural destruction of ozone is a temporary loss as the ozone can be regenerate the lost amount.

## Depletion of ozone layer Chlorofluorocarbons (CFCs).

Chlorofluorocarbons (organic molecules) manufactured by scientists in the 1930s mainly as refrigerator coolants and for the manufacture of plastic materials are some of the causes of the greenhouse gases and are responsible for the depletion of the ozone layer. Their uses increased till 1970s due to their use as propellants in aerosols. In the 1970s, it was discovered that CFCs damaged the ozone layer due to its reaction with ozone.

CFCs accounts for about 80% of the total depletion of ozone in the stratosphere. CFCs are very stable in the lower atmosphere of the Earth but in the stratosphere, they break down to release a free chlorine atom due to ultraviolet radiation. A free chlorine atom now reacts with an ozone molecule ($O_3$) and forms chlorine monoxide (ClO) and a molecule of oxygen. The chlorine monoxide reacts with an ozone molecule to form a chlorine atom and two molecules of oxygen. The free chlorine molecule again reacts with ozone to form chlorine monoxide. The process continues upto 100,000 times resulting in a reduced level of ozone.

$$2Cl_2 + 2O_3 \longrightarrow 4ClO + O_2$$
$$4ClO + O_2 \longrightarrow 2Cl_2 + 3O_2$$

Chlorofluorocarbons are not easily broken down in the atmosphere, staying up to 60years hence they contribute to greenhouse warming in the atmosphere.

Compounds containing chlorine, fluorine, bromine, carbon and hydrogen from man made compounds are known as industrial halocarbons. These compounds also contribute to the destruction of ozone layer.

## The effects of destroying the ozone layer

When the ozone layer is destroyed or depleted more ultraviolet rays reach the earth's surface and thus cause the following:

(a) Ultraviolet rays cause skin cancer, cataracts of the eyes and sunburns in humans. For example, in Australia, where a large amount of the ozone layer is depleted majority of the citizens have or have had cancer problems due to exposure to harmful ultraviolet rays that have leaked through the ozone layer.

(b) Direct ultraviolet rays from the sun is very harmful to living things on the earth surface because they (ultraviolet rays) damage the DNA (deoxyribonucleic acids)- the genetic material.

(c) It produces clouding in humans, thus impairing vision and other visual disorders.

(d) Ultraviolet rays suppress the efficiency of immune system, thus causing the risk of tumor formation, growth and spread.

(e) Plankton which form the basis of food chains in all aquatic habitats are destroyed by ultraviolet rays.

(f) In green plants, photosynthesis will be hindered as too much ultraviolet rays destroy the chloroplasts, thus food production is lowered and consequently all animals will face starvation.

(g) Beneficial micro-organisms in the environment are killed.

(h) Complete depletion of ozone layer will allow ultraviolet rays to reach the surface of the earth causing an increase in temperature.

### Control of ozone layer depletion

1. Ban international production and release of ozone layer depletion chemical such as chlorofloron carbons (CFCs) halons and halocarbons.
2. Minimize high altitude aircraft flights and rockets flights that emit large quantities of green house gases to the atmosphere which contribute to the depletion of ozone layer.
3. Use products which are labeled "ozone friendly".
4. Ensure technicians reparing your refrigerators or air conditioners recover and recycle the old CFCs so that they are not released into atmosphere again.
5. Vehicle air conditioners units should be checked regularly for leads into the atmosphere.
6. Replace helon fire extinguishers with alternatives such as carbon dioxide or foam.
7. Awareness campaign in schools and towns and villages about the hazards of ozone depletion.

### *Questions*

*1 (a) State four ways in which human activities are adding carbon to the atmosphere.*
*(b) i. What is global warming?*
*ii. With the aid of diagram, explain how the surface of the Earth is getting warmer than it was 200 years ago.*

*2 (a) Name four greenhouse gases and describe how they are contributing to climate change.*
*(b) i. State five effects of global warming.*
*ii. State six measures your country is adopting to control global warming.*

*3. (a) state the location of ozone layer in the atmosphere.*
*(b) mention the importance of ozone layer*

*4. mention four hazards of ozone layer depletion to the environment.*

*5. state four control measures to save the ozone layer from depletion.*

*6. name two chemicals made by scientist that are contributing to the depletion of ozone layer.*

**Abiotic environment** The non-living component of the environment such as soil, water, temperature, air which influences the living organisms.

**Absorption** The diffusion of digested food molecules into the cells.

**Accommodation** The ability of the eye to focus objects of varying distances on the retina.

**Adaptation** Any feature of an organism which makes it to adjust and survive in an environment.

**ADP (adenosine diphosphate)** A low chemical energy compound in the cells of living organisms performing the function of energy storage and transfer.

**Adventitious roots** Roots formed from parts other than the radicle of a seed of plants, such as nodes of creeping stems or internodes of stem cutting buried in the soil.

**Aerobic respiration** A type of respiration requiring oxygen to oxidize the food molecules to release energy in the cell.

**Aestivation** A behavioural adaptation in which some animals (e.g. African lungfish, snails and frogs), spend hot weather in inactive condition.

**Aggregate fruit** A fruit formed from a single flower in which the gynoecium consists of many free carpels.

**Agriculture** The cultivation of the soil for crops and the rearing of various of types of domestic animals and fishes for food.

**Air pollution** The addition of air-borne substances such as dust, smoke, soot, radioactive materials and sulphur dioxide into the air which alters the composition of the atmosphere causing harm to both plants and animals including man.

**Albinism** An inheritable diseases due to lack of melanin pigments in the malpighian layer of the skin epidermis.

**Alcoholism** A disease resulting from chronic dependence on alcohol.

**Alleles (Allelomorphs)** A pair of genes located on the same place of homologous chromosomes and are responsible for contrasting characters. e.g. Tt are two genes responsible for tallness (T) and shortness (t).

**Allelopathy** An interaction in which one organism releases a chemical substance(s) into an environment causing a harmful effect on the other organisms.

**Allometric growth** A type of growth in which the different parts of the plant grow at different rates.

**Alternation of generations** A form of life cycle in which the asexual reproductive form alternates with the sexual reproductive form. Both forms are different in physical appearance, habit and reproduction.

**Anabolism** Building up of simple molecules of food into complex molecules by living things, with the use of energy leading to an increase in size and complexity (growth).

**Anaerobic respiration** The breakdown of sugar in the absence of oxygen with a release of energy, alcohol and carbon (IV) oxide (carbon dioxide) in the cell.

**Annual** A plant that completes its life cycle in one year during which it germinates, grows to maturity, flowers, produces seeds and eventually dies. Marigold and sunflowers are examples

**Antibody** An immune substance in the blood which fights against bacteria, toxins and other foreign bodies.

**Antitoxin** A substance present in the blood that counteracts the harmful effect produced by the disease producing organisms.

**Arable farming** A type of farming in which the main aim is to produce crops for consumption.

**Arteriole** A tiny artery that has branches which form capillaries in vertebrates.

**Artery** A thick-walled vessel that carries blood away from the heart in vertebrates.

**Asexual reproduction** A reproduction without gametes.

**Assimilation** The incorporation of the absorbed food molecules into the protoplasm.

**Atmosphere** The region which lies between the earth and outer space.

**ATP (adenosine triphosphate)** A high chemical energy compound in all cells of living organisms performing the function of energy storage and transfer.

**Autonomic (involuntary) system** The unit of the peripheral nervous system comprising sympathetic and parasympathetic systems which helps to regulate the vital internal organs of the body such as heart, eyes, lungs, kidneys, penis thus maintaining a system of "checks and balances".

**Auxin** A plant hormone that regulates plant's growth.

B

**Bacteria** Group of microscopic one-celled (unicellular) organisms surrounded by slimy layer with some useful and others harmful to organisms.

**Bacteriophage** A kind of virus capable of destroying bacteria.

**Balance diet** A diet containing carbohydrates, proteins, fats, mineral salts, vitamins, fibres and water in right proportion and insufficient quantities.

**Behaviour** The manner in which a living organism responds to a stimulus

**Biennial** A plant that completes its life cycle in two years (two growing seasons) using the first year to build up food reserves which it uses (food reserve) in the second year to produce flowers and seeds and eventually dies. Carrot is an example.

**Bile** An alkaline secretion of the liver which is sent to the duodenum emulsify, digest, and absorb fats

**Binary fission** A form of asexual reproduction in unicellar organisms by which the parent cell divides into approximately equal daughters. If the division produces two equal daughters, it is called **binary fission** while more than two, it is called **multiple fission.**

**Biology** The study of living things.

**Biomass** The total mass of all organisms (plants and animals) that exist in an ecosystem at a particular time.

**Biosphere** Part of the earth in which life exists.

**Biotic community** A group of interacting populations in a particular habitat.

**Biotic environment** The living things that exits in an ecosystem.

**Blood pressure** The force exerted by the flow of blood against the arterial wall. Blood pressure is greatest when the ventricles of the heart contract to force blood to the arteries **(systolic pressure)** while blood pressure falls to lowest when the heart is being filled with blood from the veins **(diastolic pressure).**

**Blood** A fluid tissue consisting of plasma, red cells, white cells and platelets that circulates in blood vessels and arteries to and from the heart.

...ective
...ly made
...erial.
...dy of plants.
...g. The mechanical process of getting air (containing oxygen) into the lungs (inspiration) and air (containing waste gases such as carbon IV oxide) out of the lungs (expiration).

**Budding** A type of asexual reproduction in which a small new individual splits off from the body of the parent to develop into a new individual.

**Bulb** A short, thick and conically shaped underground stem surrounded by many layers of thick fleshy leaves covered with a layer of dried scale-leaves and bearing a cluster of adventitious roots at the base, e.g. Onion and harmattan lily.

## C

**Capillary** A tiny blood vessel with one layer thick receiving blood from arteries and carrying it to veins for exchange of substances between blood and tissues.

**Carbohydrates** Organic compounds that contain carbon, hydrogen and oxygen generally with a ration of 2:1 of hydrogen to oxygen atoms.

**Carnivore** A flesh-eating animal e.g. cat, dog, and lion.

**Carrier** A normal heterozygous organism which has or carries an abnormal recessive gene, or a person infected with a disease but does not show signs of the diseases in his body. e.g. AA x As will give AA, As, AA, As,. Person having As is a carrier of sickle cell anaemia but he does not suffer from sickle cell anaemia.

**Cartilage** A tough elastic and semi-transparent tissue devoid of blood vessels and nerves.

**Catabolism** The break down of complex food molecules into simple molecules by living things with liberation of energy for work.

**Cell** A structural and functional unit of protoplasm bounded by a membrane and containing nuclear and cytoplasmic materials.

**Chemosynthesis (chemoautotrophic nutrition)** Type of nutrition in some bacteria in which energy for the manufacture of carbohydrates is obtained from inorganic chemical reactions of the environment instead of sunlight.

**Chemotropism** Response of plant parts to chemical stimulus.

**Chitin** A non-living and non-cellular structure (made from protein-carbohydrate compound) secreted by an underlying epidermis. chlorophyll II

**Chromosome** A rod-shaped body found in the nucleus of a cell and in which genes are located.

**Class** A group of organisms having similar or closely related orders.

**Closed blood circulatory system** A type of circulation in which blood is pumped from the heart into blood vessels and capillaries and circulates round the body and returns to the heart without being exposed.

**Cold blooded (Poikilothermic) animal** An animal in which its temperature varies with the environmental temperature e.g. Amphibians, fish and reptiles.

**Commensalisms** The relationship between two organisms in which one of the oranisms is benefited while the other is neither benefited nor harmed.

**Community** A large group of natural population of plants, animals and micro-organisms that live together in a given area and directly or indirectly depend on each other for their survival.

**Compensation point** The point at which respiration rate is equal to that of photosynthesis in plants.

**Competition (or Struggle for existence)** An interaction between a number of organisms of the same or different species for resources in limited supply such as food, water, space and light.

**Conditioned reflex (conditional response)** A behaviour acquired through learning such as walking, running, swimming, typing, and driving a car

**Conjugation** A form of sexual reproduction in which two equal reproductive cells of the same species such as *Spirogyra, bacteria (e g. Escherichia coli and Ciliates e g. Paramecium)* fuse temporarily to exchange genetic materials.

**Conservation of natural resources** The wise use and safe keeping of natural resources for the good of mankind to ensure their continuous availability and to preserve the original nature of the environment.

**Consumer** An organism (animal) that feeds on other organisms below it in the food chain.

**Contact note** The communication between parents and offspring.

**Continuous cropping** Growing of crops continuously on the same piece of land for two or more years.

**Corm** A compressed and fleshy underground stem swollen with food reserve and growing vertically upwards in association with a few daughter corms developing from lateral bud, e.g. coco yam.

**Courtship behaviour** A type of behaviour in animals that plays an important role in attracting a mate of the same species for copulation.

**Crop rotation** A system in which a piece of land is continuously cultivated with different crops which are best suitable to such an environment.

**Crop** A plant grown by man for the purpose of harvesting it at some stage of the crop development for use.

**Cross pollination** The transfer of pollen grains from the anther of a flower to the stigma of another flower on a different plant of the same species.

**Cross-fertilization** The fusion of male and female gametes to form zygote from different parents of the same species.

**Cyclosis** The rotational streaming (movement) of the cytoplasm and its contents in cells with vacuoles.

**Cytokinin (Kinin)** A plant hormone (restricted only to the tissue where it is secreted) that stimulates mitosis (cell division) in plants.

**Cytoplasm** The protoplasmic materials surrounding the nucleus and is itself surrounded by cell membrane.

## D

**Dairy farming** Rearing of animals for milk and milk products such as cheese and butter.

**Decomposer** An organism that breaks down dead organisms or wastes of plants and animals into simpler substances and obtaining energy in the process.

**Defaecation** The discharge of undigested food material (faeces) from the alimentary canal through the anus.

**Deficiency diseases** Diseases caused by lack of or inadequate supply of certain food substances in the diet. For example, lack of vitamins A, B, C, and D cause night blindness, Beri-beri, scurvy, and rickets respectively.

**Deforestation:** The extensive cutting down of trees for the purpose of either farming or firewood or mining thereby exposing the top soil to agents of erosion (wind and water).

**Dental formula** A formula that shows the number and kind of teeth in the upper and lower jaws in a particular species of mammals in order of **incisors, canines, premolars and molars,** e.g. the dental formula of rabbit and man are:

$$i\frac{2}{1}.\ c\frac{0}{0}.\ pm\frac{0}{0}.\ m\frac{3}{3} = 28 \text{ rabbit}$$

$$i\frac{2}{2}.\ c\frac{1}{1}.\ pm\frac{2}{2}.\ m\frac{3}{3} = 32 \text{ man}$$

**Dichogamy** The maturation stamens and stigmas of a bisexual flower at different times.

**Digestion** The breakdown of large food molecules into simpler molecules by enzymes which can then be absorbed and assimilated into the protoplasm (body)

**Dihybrid inheritance** Offspring possessing genes for two contrasting (different) characters.

**Dioecious plants** Plants with female and male flowers on separate plants.

**Diploid** is a full set of homologous pairs of chromosomes found in the body cells. (For example, after fertilization in man, the zygote contains 23 pairs that is 46 chromosomes. It is therefore a diploid product of sperm and egg.

**Disease** Any disturbance in the body of a living organism which interferes with the normal functioning of one part or more of its parts.

**Dislocation** The displacement of a bone at a joint often with the tearing of tendons and ligaments around the joint.

**Dispersal** The scattering of fruits and seeds to different directions from the parent plants.

**Display behaviour** A type of reproductive behaviour or activity that an animal exhibits to attract an opposite sex into mating.

**Dominant character** A character from one parent which is noticed in the offspring when a recessive gene is present or a character which suppresses the other character in a heterozygous phenotype.

**Dormancy** An inactive period of an organism leading to cessation of growth or insignificant growth.

**Drug** Any substance that alters the body's actions of a living organisms when used.

E

**Ecological pyramid** An illustration of food chain in which the producers form the base, the herbivores form the middle while the carnivores form the apex.

**Ecology** The study of the relationship of living things to their environment and to each other.

**Ecosystem** A stable environment, regardless of size, in which living and non-living organisms interact and in which materials and energy are used and recirculated e.g. pond, lake, and forest are large ecosystems.

**Ecotone** The transition between two habitats (biotic communities). The transition zone contains individuals of both communities. Examples of ecotone are the transition between forest and grassland and between river and ocean.

**Effector** A structure that is sensitive to a stimulus which causes an organism or part of it to react to the stimulus.

**Endocrine gland** A ductless gland which releases its secretion (hormone) directly into the blood or lymph.

**Endoskeleton** The hard parts found inside the bodies of all vertebrates and few invertebrates (as in octopus) that give supporting framework to the external soft parts.

**Environment** All the external forces (such as temperature, light, wind, humidity, soil, competition) acting on the living organisms.

**Enzymes** Enzymes are organic catalysts of protein origin produced by living cels which help to speed up or slow down the rate of chemical reactions but remain chemically unchanged at the end of the reaction.

**Epigeal germination** A type of germination in which the cotyledons of the seed are raised above the soil level, e.g. broad bean seed and cow pea seed.

**Epiphyte** A non-parasitic plant that attaches itself to another plant and uses it as a support e.g. fern *(Platycerium)*.

**Eukaryote** An organism having its genetic material (DNA) enclosed with nuclear membrane, that is DNA is restricted to nucleus.

**Excretion** The elimination of waste substances of metabolism formed within the organism.

**Exocrine gland** A gland which releases its secretion through a duct to the blood or lymph.

**Exoskeleton** The hard outer cover of certain animals mainly the arthropods in which muscles are attached internally.

**External respiration** The intake of oxygen from the environment and output of carbon dioxide from the organism.

## F

**Faeces** The intestinal solid waste material which are eliminated through the anus.

**Family planning** A method adopted by a couple (husband and wife) to control the number of children they can adequately cater for and the right time to have them.

**Family** Grouping of organisms having one or closely related genera.

**Fats** Organic compounds that contain **high proportion** of carbon and hydrogen with **low** proportion of oxygen.

**Fertilization (Syngamy)** The fusion of a haploid male gamete with a female gamete to form a diploid zygote. If fertilization occurs outside the body of the female parent, it is called external fertilization (as in case of aquatic organisms) while if it occurs in the body of the female parent it is called internal fertilization (as in case of terrestrial organisms).

**Fertilization** The union of the male and female gametes.

**Fibrinogen** A blood protein involved in the clotting of blood.

**First aid** The immediate and correct help rendered to a victim (person) of an accident, sudden illness, war using materials available at the time before he or she is rushed to an hospital for treatment by a qualified medical doctor.

**Food chain** The transfer of the sunlight energy from producers (green plants) to consumers (animals) as organisms feed on one another.

**Food pyramid (Pyramid of number)** A quantitative representation of a food chain with the producers (green plants) at the base and the carnivores at the apex. (Note: Many producers are required to support the fewer herbivores which in turn support the fewer carnivores).

**Food web (Food cycle)** A complex feeding interrelationship among plants and animals in an ecosystem.

**Food** Any substance taking into the body, digested, absorbed and assimilated into the cells to give materials for growth, energy and repairs of tissues and regulation of life processes without doing harm to the organism.

**Fossil** The persevered remains or imprint of organisms that lived in the geological past.

...y break in a bone.

**...agmentation** A type of asexual reproduction is which an organism brakes into several parts with each part developing into a new individual.

**Fruits** A structure which develops from the ovary of a flower after the fertilization of the ovules.

## G

**Gamete** A male or female reproductive cell.

**Gene** A unit of inheritance composed of DNA and located in chromosome.

**Genetics** The study of inheritance.

**Genotype** The genetic constitution of an organism. For example a man who has AA or As in his blood has a genotype of AA or As.

**Genus** A Grouping of organisms consisting of number of closely related or similar species.

**Geotropism ( Gravitropism)** Response of plant parts to the stimulus of gravity.

**Germination** The growth of a viable seed into a photosynthesizing plant under favourable conditions such as suitable temperature, oxygen and water.

**Gestation period** is the period of the fertilization of the egg (conception) till the birth of foetus.

**Gibberellin** A plant substance that promotes stem elongation in plants.

**Gland** A structure which produces a substance essential and vital to the life of the organism, e.g. ductless glands, silvary glands, pancreatic glands.

**Global warming** An average increase in the earth's temperature which in turn causes changes in climate.

**Growth** An internal increase in size of an organism through cell division and cell enlargement.

**Growth** An irreversible increase in size or length of an organism due to an increase in protoplasm.

**Guttation** Loss of liquid water in certain plants through specialized pores (hydathodes) in the margins of leaves when transpiration is inhibited (e.g very humid atmosphere).

## H

**Habitat** The physical place **(home)** where an organism lives e.g. pond, lake, river, abandoned farmland, forest and desert.

**Haemoglobin** A protein containing iron found in the red blood cell which gives it red colour.

**Haemolysis** The bursting of red blood cells in the plasma.

**Halophyte** A plant that survives in high salt contents. Estuary plants are halophytes.

**Heart** A large hollow muscular pumping organ of the circulating system in vertebrates.

**Heavy metal** A metal with atomic mass exceeding the atomic mass of calcium or density of the metal is greater than $5g/cm^3$.

**Herbivore** A plant-eating animal, e.g. goat, sheep, rabbit and elephant.

**Heredity** The transmission of characteristics from parent to offspring.

**Hermaphrodite** An organism having both male and female gonads e.g. mango tree, *Hydra and tapeworm.*

**Heterodnt** Having teeth that are different in shape and size and differentiated into **incisors, canines, premolars and molars** e.g. man.

**Heterozygous** is an offspring obtained from parents in which paired genes for a particular character are different.

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**Hibernation** A behavioural adaptation in some animals (e.g. bats, shrews and monotremes) in which they spend cold season in inactive condition or deep sleep in a warm and safe place.

**Holophytic (autotrophic) nutrition** A type of nutrition in green plants in which inorganic materials such as water and carbon (IV) oxide are used to make organic materials with the aid of sunlight energy and chlorophyll.

$$6CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

**Holozoic (Heterortrophic) nutrition** A type of nutrition in animals which are not capable of making their own food but depend upon already made food which must be digested, absorbed, assimilated and egested. This is typical of animal nutrition which is characterized by ingestion, digestion, absorption, assimilation and egestion.

**Homeostasis** The maintenance of the internal environment of an organism in constant form despite changes in the external environment.

**Homodont** Having the same kind of teeth e.g. fish and reptiles.

**Homologous chromosomes** The inheritance of similar chromosomes from male and female parents, or **homologous chromosomes** have identical genes and possess the same characteristics arranged in the same place on the chromosomes.

**Homozygous offspring** An offspring obtained from parents which have like genes for the same character.

**Hormone** A chemical substance produced by the cells in certain parts of the body and carried to all or some parts by body fluids where it produces some physiological effect.

**Host** An organism that provides food and shelter to a parasite.

**Humus** A dark coloured substance made from decayed organic matter.

**Hybrid** An offspring from a cross between parents differing in one or more characters (traits).

**Hydrosphere** The aquatic portion on the surface of the earth.

**Hydrotropism** Response of roots to the stimulus of water in the soil.

**Hypertonic solution** Solution containing higher concentration of solutes and lower concentration of water molecules than another solution.

**Hypogeal germination** A type of germination in which the cotyledons of the seed remain in the soil e.g. African yam bean seed and maize grain

**Hypotonic solution** A solution containing lower concentration of solutes and a higher concentration of water molecules than another solution.

**Hyrophte** A plant that lives in water or very wet place e.g. water-lettuce, duckweed and *Salvinia*.

## I

**Imbibition** The absorption of water molecules by substances that do not dissolve in water resulting in the swelling of the substances. Dry seeds for example do not dissolve in water but absorb water to swell before germination

**Immunity** The ability of an animal or plant to resist infections of disease-producing organisms.

**Ingestion** An intake of complex organic food into the body.

**...on (Tissue, Cellular)** The oxidation of food molecules usually glucose within the cell with release of energy.

**Interphase** The period of growth of a cell that occurs between mitotic divisions.

**Interspecific competition** A competition between organisms of different species.

**Intraspecific competition** A competition between organisms of the same species.

**Irreplaceable (Non-renewable)** Are resources which cannot be replaced when the initial stock is used up

**Irrigation** The artificial means of supplying water to plants and animals during dry seasons or in drought affected areas.

**Irritability (sensitivity)** The ability of a living organism to detect, interpret and respond to stimulus in the environment

**Islets of Langerhans (pancreatic islets)** Groups of cells in the pancreas that secrete insulin

**Isometric growth (equal growth)** A type of growth in which all the parts of the body grow side by side at the same time.

**Isotonic solution** Having the same osmotic pressure, that is, when two solutions are separated by a semi-permeable membrane, there is no loss or gain of water molecules by osmosis to the other.

J

**Joint** A place where two bones are joined together

K

**Kinesis** The change in rate of movement of an organism in response to the intensity of stimulus e.g. the speed of movement depends on the intensity of stimulus

L

**Lenticel** A small opening in the epidermis or bark of a young woody stem through which gases are exchanged between the internal tissues and the atmosphere

**Limiting factor** Anything that is needed by an organism for its survival and productivity but when in short supply, there is competition for it in the environment

**Lymph** The colourless fluid which is derived from blood by filtration through capillary walls that circulates in tissue spaces and lymph vessels.

M

**Manure** Decayed plant and animal material which are added to soil to supply nutrients needed for plant growth.

**Meiosis** A kind of cell division during **spermatogenesis** (sperm formation) **and oogenesis** (egg formation) in which there is a reduction of chromosomes to half of the original number of chromosomes. During spermatogenesis or oogenesis in human, the 46 chromosomes are reduced to 23. Therefore each sperm or egg now has 23 chromosomes. The fusion of the sperm and egg gives 46 chromosomes which every human being has.

**Mendel's first law (law of segregation)** states that **a pair of genes** (factor) is separated or segregated during gamete formation (spores in lower plants) and only one gene of a pair can be represented in a single gamete.

**Mendel's second law (law ofindependent assortment)** states that when two or more pairs of genes of contrasting characters are present, each pair is independently inherited.

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**Menstrual (oestrous) cycle** The series of monthly changes that occur in the reproductive organs of a mature female human (including some primates) to release an egg on the average of every 28 days under the influence of hormones.

**Mesophyte** A plant that lives in a moderate condition of water supply (i.e. neither too dry or too wet) e.g. mango tree and oil palm tree.

**Metabolism** The physical and chemical processes by which simple molecules of food are built up into complex molecules (assimilation, anabolism) and complex molecules are broken down into simple molecules (respiration) with liberation of energy for work by the organism (Note. Metabolism = Anabolism + Catabolism).

**Metamorphosis** The series of gradual changes that occur during the development of an animal from the zygote to the adult stage.

**Metaphase** The stage of mitosis in which the chromosomes migrate to the opposite poles.

**Migration** The periodic and directional journeys of some entire animals population from their natural habitats to different habitats for the purpose of breeding in favourable conditions or avoiding unfavourable climate or due to shortage of food supply and later return to their original habitats.

**Mimicry** The resemblance of an organism to another different organism that has protective features in order to enhance its survival in its habitat.

**Mitosis** A process of cell division during which each chromosome in the nucleus duplicates itself and two new cells are formed with equal number of chromosomes.

**Mixed cropping** The cultivation of different crops on the same piece of land at the same time.

**Mixed farming** The cultivation of crops and rearing of domestic animals by farmer.

**Monoecious plants** Plants with male and female flowers on separate plants.

**Motor neurons** A nervous cell which carries impulses from the brain or spinal cord to a muscle or gland.

**Moulting (ecdysis)** The periodic shedding of the outer layer of the exoskeleton of arthropods or the scale layer of reptiles in order to allow growth.

**Multiple fruit** A fruit formed from many flowers whose ovaries unite together with other parts of the flower after fertilization.

**Mutation** A sudden structural change in a gene or chromosome resulting in a new characteristic that is inheritable.

## N

**Narcotics** Drugs that kill pains and also cause sleep and stupor.

**Nephron (Malphigian body)** One of the numerous excretory structures in the kidney having Bowman's capsule, glomerulus and tubules

**Nerve impulse** A wave of electrical activity passing along a nerve fibre.

**Neurone (nerve cell)** A specialized cell that transmits impulse (message) around the body in form of electrical charge.

**Niche** The particular role played by an organism **(that is how it lives or what it does)** in relation to other organisms in an environment. For example, *Synodontis schall* and *Synodontis batendosa* are catfish that live in river but *S. schall* is an omnivore while *S. batendosa* is a planktivore (feeds on plankton). It is also that niche of an antelope to feed on grass while it is the niche of lion to feed on antelope in

grassland. In social insects such as honeybees, it is the niche of the **drone** (male) to mate with the queen, while the niche of the **queen** is to reproduce and the niche of the worker is to bring food, feed the queen and larvae and clean and protect the hive.

**Noise pollution** The impairment of the environmental quality of air by noise. (Noise from aircraft, radios, machines, high disco music all pollute the air and impair hearing).

**Nucleus** The denser part of the cell that is surrounded by nuclear membrane and containing chromosomes. (hereditary units).

**Nymph** The immature stage of an insect which undergoes an incomplete metarmorphis.

O

**Omnivore** An animal that eats all types of food e.g. man and pig.

**Opened blood circulatory system** A type of circulation in which blood is pumped into the body cavity (coelom), bathing the internal suspended organs.

**Organ** A collection of different tissues grouped together to perform a common function or functions e.g. the lungs consists of epithelium, cartilage, red blood cells and smooth muscles that function together for the purpose of gas exchange. Eye, ear, stomach, nose are examples of organs.

**Organelle** A minute specialized structure in a cell capable of performing a particular function. Nucleus, lysosome, mitochondrion and ribosome are examples of organelles.

**Organic evolution** The series of gradual changes which living organisms had undergone in response to changes in environment since the beginning of life.

**Organism** A complete individual living thing consisting of either one cell or many cells e.g. *Amoeba*, housefly, and man.

**Orgasm** The peak of sexual excitement in human beings coinciding with the release of sperm (ejaculation) in males.

**Osmoregulation** The process by which an animal balances the amount of water to mineral salts in its body fluid.

**Osmosis** The movement of greater concentration of water molecules to a region of lower concentration of water molecules through a semi-permeable membrane.

**Osmotic pressure** The pressure developed by a more concentrated solution to prevent the flow of sugar or salt solution when water molecules move into it through semi-permeable membrane.

**Oviparous reproduction (oviparity)** Laying eggs in which the embryos hatch externally, e.g. amphibians, most fish and birds.

**Ovoviviparous reproduction (ovoviviparity)** The production of eggs that have been developed and nourished internally without placenta and hatch before or soon after extrusion of the eggs e.g. tsetse fly, snakes, lizards, and snails.

**Ovulation** The release of one or more eggs from the ovary.

P

**Pairing behaviour** A reproductive behaviour in which a mature male and female leave their home or homes and establish a new home elsewhere.

**Parasite** A small organism living in or on another larger organism (the host) from which it derives its food and causing harm to the host and without contributing anything in return.

**Parasitism** An intimate association between two living organisms of different specie in which one organism (parasite) obtains food and shelter from the host without contributing anything in return and the host is harmed.

**Parasitism** An intimate association between two living organisms of different species in which one organism (parasite) obtains food and shelter while the other (host) is harmed and does not receive any benefit in return.

**Parasympathetic nervous system** A division of autonomic nervous system that helps the body to function in non-threaning situations thereby keeps the body in relaxed, unstressed and easy-going condition.

**Parental care** A type of an inherited behaviour in which a parent or parents spend useful time and energy in feeding, caring and protecting their offspring right from conception and after birth, until they are of age to care and protect themselves.

**Parthenogenesis (parthenos = virgin, genes = born)** The development of an organism from an unfertilized egg.

**Parturition (birth)** The process of expelling the foetus, placenta and foetal membranes from uterus at the end of the gestation period.

**Pastoral farming** A type of farming involving only animal husbandry e.g. the Fulanis only rear cattle, sheep and goat, therefore are pastoral farmers.

**Perennial** A plant that lives for more two growing seasons or number of years. Trees and shrubs are examples.

which communicate with the central nervous system (brain and spinal cord) and remaining parts of the body.

**Phenotype** An observable outwards appearance or feature of an organism due to gene action e.g. colour, size and body structure

**Photolysis** The splitting of water molecule into hydrogen ($H^+$) and hydroxyl ($OH^-$) by energized chlorophyll (having absorbed sunlight energy during light reaction in photosynthesis).

**Photosynthesis** The process by which carbohydrates or sugars are synthesized in the green parts of plants containing chlorophyll by combination of carbon (IV) oxide and water with the aid of sunlight energy.

**Photropism (Heliotropism)** Response of plants parts to the stimulus of light.

**Phylum** A group of organism having similar or closely related classes.

**Phytoplankton** Minute surface water floating photosynthezing plants (usually microscopic) that serve as food for larger aquatic animals.

**Plankton** Minute surface water floating organisms (usually microscopic plants and animals) that serve as food for lager aquatic animals.

**Plasma** The liquid portion of the blood or lymph.

**Plasmolysis** The shrinking of a plant cell due to loss of water by osmosis.

**Platelet (thrombocyte)** The smallest of the blood cells without nuclei and which releases enzyme called thrombokinase in clotting of blood.

**Pollination** The transfer of pollen grains from the anthers to the stigma.

**Pollutant** Anything that causes the destruction or impairs the purity of the environment.

**Pollution** The unfavourable alteration of the environment due the addition of impurities by man causing danger to either his health or natural resources.

**Population density** The number of individuals per unit area or volume at a particular time.

**Population** A group of organisms of the same species living at a given time in a particular area.

**Predation** The feeding relationship between prey and predator in which the predator hunts, captures and kills the prey for food.

**Predator** A free living organism that hunts and kills another free organism for food. e.g. cat is a predator of a rat.

**Prey** An organism that is hunted for food. e.g a cat hunts rat for food. rat is therefore a prey.

**Primary producers** Organisms (usually green plants) that manufacture their own food from simple inorganic materials using the sunlight energy. They are the starters of food chains.

**Primary succession** The occupation by plants of an area not previously covered by vegetation such as bare rocks and cliffs.

**Prokaryote** An organism having its genetic material (DNA) not enclosed with nuclear membrane, that is DNA floats freely in the cytoplasm.

**Prophase** The stage of mitosis in which chromosomes shorten and appear clearly double and the nuclear membrane disappears.

**Proteins** Organic compounds that are made up of **carbon, oxygen, hydrogen and nitrogen** but with some proteins containing **sulphur** and **phosphorous.**

**Protoplasm** The organized complex materials of which living cells are made (cytoplasm + nucleus).

**Psychedelic (Hallucination) drugs** Drugs that affect the mind by changing the rate and content of thought.

**Puberty** The age at which reproductive organs start to function in human beings (boys and girls) and is associated with the appearance of secondary sex characters.

**Pulmonary circulation** A type of blood circulation in mammals and birds that transports deoxygenated blood from the right atrium through right ventricles to the lungs and transports oxygenated blood in the left atrium for onward transport to the rest body (Heart ⟶ lungs ⟶ heart).

## R

**Receptor** A cell or group of cells that receive a stimulus and capable of changing such stimulus into an electrical impulse.

**Recessive character** A character from one parent which is masked (hidden) in the offspring when a dominant gene is present.

**Red blood corpuscle (erythrocyte)** A disc-shaped blood cell with haemoglobin and containing nucleus at maturity in mammals.

**Reflex action** An involuntary response to a stimulus.

**Refuse** The dry or wet solid waste collected from markets, homes, hospitals, offices and factories.

**Regeneration** The ability of an organism to grow new tissues or organs to replace lost or damaged ones.

**Relex arc** The nerve pathway traced from receptor to effector in a reflex action.

**Replaceable (renewable) resources** Resources which can only be replaced by offspring (that is by reproduction).

**Reproduction** A process by which a living organism produces offspring.

**Respiration** The exchange of oxygen and carbon (IV) oxide (carbon dioxide) between living cells and their environments, followed by liberation of energy due to oxidation of food molecules.

**Respiratory quotient (RQ)** The ratio of carbon dioxide produced by an organism during respiration to the volume of oxygen consumed.

**Response** A reaction to external or internal stimulus.

**Rhizome** Thickened part of a stem lying horizontally under the ground and swollen with food materials on which the plant survives during unfavourable seasons, e.g. ginger, lemon grass and canal lily.

**Root Pressure** The pressure gathered by the roots which forces absorbed water from the soil to move through the roots up to the stem.

**Root tubers** Tap roots, lateral roots or adventitious roots which become swollen as a result of storage of food (mostly carbohydrates) in them, e.g. cassava and carrot.

## S

**Saprophyte (saprotroph, saprobe, saprobiont)** An organism that feeds on dead organic matter. Fungi are examples.

**Scavenger** An animal that feeds on dead or decaying flesh of other animals e.g. vulture.

**Secondary producers** Herbivores (plant eaters) that derive their energy from green plants.

**Secondary succession** The occupation by plants of an area previously covered by vegetation such as abandoned farmland and road sides.

**Secretion** The production of essential chemical substances by cells or glands

**Seed** A structure which develops from the ovule of a flower after fertilization of the ovule.

**Selective reabsorption** The reabsorption of all remaining glucose and amino acid molecules together with some salts and water from the renal tubules back to the blood stream.

**Self sterility** (self-incompatibility) pollen grains of a flower or of another flower of the same plant. Will not result in fertilization even if the pollen grains reach the stigmas. In such flowers, the pollen grains and stigmas are not compatible. Examples are *crotalaria* and tobacco plant.

**Self pollination** The transfer of pollen grains from the anther to the stigma of a flower or of another flower on the same plant.

**Sense organ** An organ which receives a particular stimulus and converts the stimulus into an impulse (sensation) and transmits the impulse into the central nervous system (brain or spinal cord).

**Sensory neurons** A nervous cell which carries impulses from the sense organ to the brain or spinal cord.

**Sere** The entire sequence of temporary plant communities from the pioneer organisms to the final stage or climax community.

**Sewage** The waste matter from homes (faeces, urine) or industries dissolved or suspended in water.

**Sex ratio** The ratio of the number of males to number of females in a population.

**Sexual intercourse (coitus, mating, copulation)** The process in which a male introduces sperm into a female reproductive organ.

**Sexual reproduction** The fusion of male gamete (or sperm) and female gamete (or egg).

...gain ...ow for ...being

**...haemia** An inheritable disease in which some red blood cells are sickle or crescent shaped with abnormal haemoglobin.

**Simple fruit** A fruit formed from a single flower in which the gynoecium is made of either a single carpet or many united carpets.

**Skeleton** The hard framework on which the body is built.

**Sleep-inducing, (tranquilizer or sedative) drugs** Drugs used by medical doctors to induce sleep in order to reduce emotional stress.

**Soil erosion** The detachment of the topsoil and its transfer to another area by waer or wind.

**Soil fertility** The ability of the soil to support healthy growth, development and production of crops.

**Soil pollution** The discharge into soil of any substance (usually by man) which may become harmful to plants and animals and makes the soil infertile.

**Soil** The outer layer of the earth's crust capable of supporting vegetation.

**Sound behaviour** A type of reproductive behaviour which some animals produce sound to locate the position of a mating partner or to attract a mate for copulation.

**Species** A population of related organisms that can interbreed within themselves to produce fertile offspring.

**Stem tuber** An underground stem whose branches become swollen at their ends with storage of carbohydrates, bearing numerous 'eyes' which represent terminal and lateral buds from which new plants can develop, e.g. yam and potato.

**Stimulus** A factor which produces a temporary change in the activity of an organism against which it must react.

**Succession** The orderly changes that occur in plant and animal community of a given area over a period of time until a stable (climax) community is formed.

**Sucker** A lateral underground stem which later grows vertically upwards into a new independent plant as a form of vegetative reproduction, e.g. plantain and banana.

**Suction pressure** The pressure required to force water into the cell.

**Sweat** The salty fluid secreted by sweat glands of the skin.

**Swim bladder (Air bladder, gas bladder)** An air-filled organ (sac) lying above the digestive system in bony fish which aids in varying the buoyancy of density of the fish.

**Symbiosis** A type of relationship in which two different kinds of organisms live together to the benefit of each other.

**Sympathetic nervous system** A division of autonomic nervous system that brings responses to threatening or frightening situations ("fight or flight" responses) that prepares the body for emergencies.

**Synapse** A gap between two nerve endings.

**System** A group of organs performing a particular function e.g. digestive system, respiratory system, circulatory system and excretory system.

**Systemic circulation** A type of blood circulation in mammals and birds that transports oxygenated blood and nutrients to all tissues and returns deoxygenated blood from tissues to the right atrium.

(Heart ⟶ body ⟶ heart).

## T

**Taxis** The movement of a whole organism or cell to the direction of stimulus.

**Telophase** The last stage of mitosis, during which two daughter cells are formed.

**Territory** A specific area acquired by an animal and such an area is advertised and defended against intruders particularly of its own species.

**Tertiary consumers** Animals that feed on secondary producers deriving energy from them.

**Thermal pollution** The addition of heat to water body.

**Thigmotropism (Haptotropism)** Response of the aerial parts of some plants to touch.

**Tissue** A collection of cells that are similar in structure which perform similar functions e.g. blood, bones, muscles, phloem and xylem are examples of tissues.

**Tolerance** The ability of a living thing to successfully cope with the extreme variations (upper and lower) limits of an environment.

**Toxin** A poisonous substance produced by diseases producing bacteria, or other organisms which affect the body.

**Translocation** The movement of water, mineral salts and dissolved food from one part of the plant to another.

**Transpiration** The process whereby the water absorbed by the plant is lost to atmosphere as water vapour through stomata, cuticle and lenticel.

**Tropism** A growth response (movement) in plants or parts of plants towards the direction of the stimulus.

## U

**Ultra-filtration** The passage of small molecules (e.g. water, glucose, amino acids, urea, salt) through the capillaries of the glomerulus under the influence of high blood pressure within the glomerulus.

**Unconditioned (inherited) reflex** A reflex action a person is born with such as withdrawing hand on touching a hot object.

**Urea** A nitrogenous waste substance found in urine.

**Urine** The liquid waste filtered from the blood by the kidneys and removed by the bladder.

## V

**Vaccination** An inoculation of viral or bacterial organisms or antigens into the body in order to produce immunity.

**Variation** The differences which exist within a given species of plants or animals.

**Vector** An organism (usually insect or other arthropods) which transmits an infectious disease from one organism to another e.g. female anopheline mosquito is a vector of malaria parasite (*Plasmodium*).

**Vegetative reproduction (propagation)** A type of asexual reproduction in plants in which a part of the plant is detached and externally develops into a complete plant.

**Venation** The arrangement of veins in a leaf.

**Venule** A small branch of vein in vertebrates.

**Viruses** Sub-microscopic particles which lack cytoplasm, nucleus and a surrounding membrane which reproduce only in living tissues of their hosts usually causing diseases.
causing diseases.

**Vitamins** Organic substances needed in small quantities in the body for healthy growth and development and prevention of deficiency diseases, e.g. vitamins A, B, C, D, E, and K.

**Viviparous reproduction (viviparity)** Bringing forth the young alive that have been nourished internally through placenta e.g. all placenta mammals (man, goat, sheep, cat, etc.).

**Voluntary action** An action initiated and controlled by the conscious part of the brain.

W

**Warms blooded animal (Homeothermic)** An animal that has its body temperature constant irrespective of the environmental temperature changes e.g. birds, and mammals.

**Warning (aposematic) colouration** The possession of bright and conspicuous colours by some animals, which advertise them to predators that they are poisonous, distasteful and dangerous.

**Warning calls** are calls produced by many social animals to alert members or offspring when danger threatens.

**Water cycle** Continuous movement of water from the earth to the atmosphere by evaporation and back from atmosphere to the earth by precipitation (rainfall)

**Water pollution** The discharge into water of any substance (usually by man) which may become harmful to aquatic organisms (plants and animals) and unfit for human use.

**White blood corpuscle (leucoyte)** A colourless and shapeless blood cell with nucleus and no haemoglobin., which helps to defend the body against diseases.

X

**X-chromosome** A sex chromosome present in many animals with the male animal having one (X) while the female animal has two (XX).

**Xerophte** A plant that needs very small amount of water to live e.g. desert plants such cactus and *Portulaca*

Y

**Y-chromosome** A sex chromosome only present in male organisms.

Z

**Zoology** The study of animals.

**Zooplankton** Minute surface water floating animals (usually microscopic but some can be visible to naked eye) that feed on phytoplankton and also serve as food for other larger aquatic animals.

**Zygote** The product of the fusion of male and female gametes.

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