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BIOLOGY

Standard 11

(Semester II)

PLEDGE

India is my country.
All Indians are my brothers and sisters.
I love my country and I am proud of its rich and varied heritage.
I shall always strive to be worthy of it.
I shall respect my parents, teachers and all my elders and treat everyone with courtesy.
I pledge my devotion to my country and its people.
My happiness lies in their well-being and prosperity.

રાજ્ય સરકારની વિનામૂલ્યે યોજના હેઠળનું પુસ્તક

Gujarat State Board of School Textbooks
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PREFACE

The Gujarat State Secondary and Higher Secondary Education Board has prepared new syllabi in accordance with the new national syllabi prepared by the NCERT based on NCF-2005 and core-curriculum. These syllabi are sanctioned by the Government of Gujarat.

It is a pleasure for the Gujarat State Board of School Textbooks to place before the students this textbook of **Biology, Standard 11, (Semester II)** prepared according to the new syllabus.

Before publishing the textbook, its manuscript has been fully reviewed by experts and teachers teaching at this level. Following suggestions given by teachers and experts. We have made necessary changes in the manuscript before publishing the textbook.

The board has taken special care to ensure that this textbook is interesting, useful and free from errors. However, we welcome any suggestion, from people interested in education, to improve the quality of the textbook.

Dr. Bharat Pandit
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FUNDAMENTAL DUTIES

It shall be the duty of every citizen of India

(A) **to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;**

(B) **to cherish and follow the noble ideals which inspired our national struggle for freedom;**

(C) **to uphold and protect the sovereignty, unity and integrity of India;**

(D) **to defend the country and render national service when called upon to do so;**

(E) **to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;**

(F) **to value and preserve the rich heritage of our composite culture;**

(G) **to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;**

(H) **to develop the scientific temper, humanism and the spirit of inquiry and reform;**

(I) **to safeguard public property and to abjure violence;**

(J) **to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;**

(K) **to provide opportunities for education by the parent or the guardian, to his child or a ward between the age of 6-14 years as the case may be.**

* Constitution of India : Section 51-A

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About this book...

This book of Biology promises to be a feast for those students who are passionate about the subject and are ready to explore ever expanding vistas of knowledge. The book is aimed at providing what is latest in the study of living beings. It offers an opportunity for the learner to undertake the in-depth study of the subject satisfying his dual needs – scoring marks in the exam and nurturing his love for the subject as well. Besides if the theory is understood keeping in mind all important practicals, it will surely turn his learning into a most enjoyable experience.

The syllabus of Biology is treated as a long continuum for the students of higher secondary for both 11^{th} and 12^{th} standard. The chapters are designed and carefully crafted in order to present the sequential development of the kingdom of living beings on the earth. The books of Biology in Semester I and Semester II are like two rings in a chain properly linked and bonded together thereby displaying the image of a complete whole. What is learnt in Semester I complements the advanced studies in Semester II. There are different chapters dealing with various disciplines of Biology. Starting from biochemistry and ultra-structure of cells, there are various chapters on plant anatomy and animal tissue along with the function of their components. There are chapters illuminating the different facets of plant organs like roots, stems, leaves, flowers, fruits and seeds. The detailed study of the anatomy and morphology of plants leads to the study of 'families' and the families are explained in detail by the description of three plant species.

Just as the animal cell was the focus of study in semester I, tissue organization by cells is the highlight of the present book. This will surely stimulate the learner with burning curiosity. There will be new found inquisitiveness among our learners. There will be questions galore : how is the organ system made up of tissues ? What are the different types of patterns in lower and higher groups of animals ? For the satisfactory answers to all these questions, morphology and anatomy of three different types of animals have been selected. Ceolomic earthworm gives an idea how it exists without appendages and restricted organ system. Unlike Ceolomic earthworm, Cockroach is slightly developed with appendages. Both these animals represent invertebrates while a frog is a typical example of vertebrates. There is a separate chapter dwelling on its organ system.

The intricacies and various nuances of the animal kingdom along with the complexities of varied world of plants have fascinated the humanbeings for centuries. It is really challenging to fully understand and probe the mind-boggling mysteries of all living beings. This book is an attempt to unravel some of those secrets of existence. Here is an opportunity for the learners to challenge the limits of knowledge and follow the path of some of the great geniuses of life sciences.

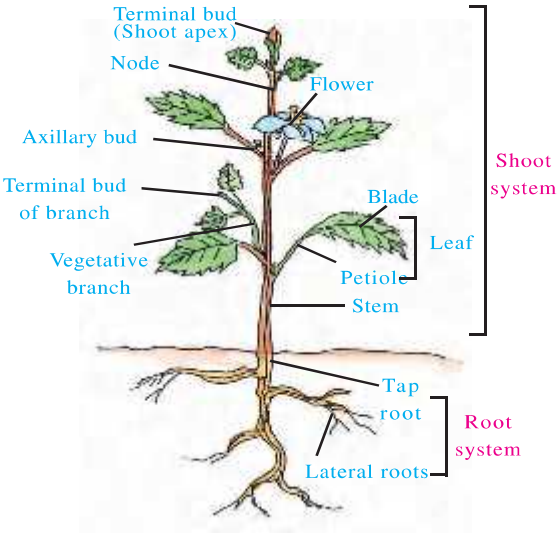
1

Plant Morphology-1
(Root, Stem and Leaf)

The flowering plants are the most dominant plants on the earth today. About 3 lac species of this group exist. They exhibit great variations in their size, form, structure, etc. *Lemna* is a very small aquatic plant. *Sequoia* and *Eucalyptus* are very tall plants. Some are herbs, some are shrubs. Some are trees and some are climbers. Some are annuals whereas some are perennials old. In their lifestyles, they may be xerophytic hydrophytic, epiphytic or parasitic.

The plants can be studied through their external as well as their internal characters.

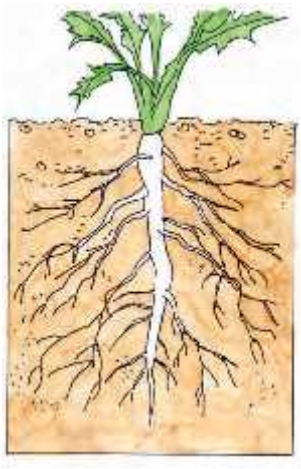
A typical flowering plant possesses an unbranched or branched axis. From this axis, lateral appendages are produced. The main axis is generally divided into two parts – an underground part root and an above ground part shoot. They are also called a root system and a shoot system. The root system develops from the radicle and the shoot system develops from the plumule. The shoot system consists of stem, leaves, flowers, etc. The flowers produce fruits and seeds. Seeds produce new plants.



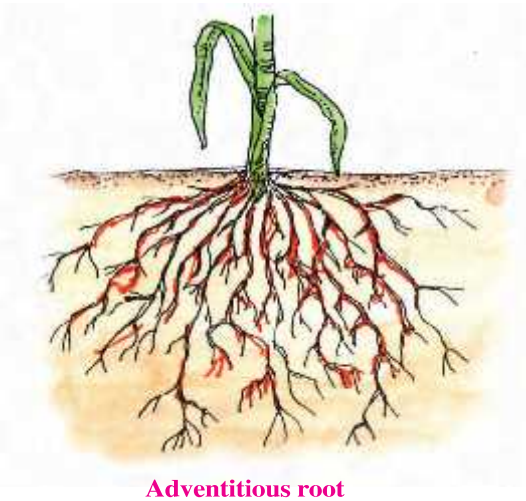
Typical plant

(I) Root : Root is the underground part of the plant axis. It develops from the radicle. It is positively geotropic and hydrotropic and negatively phototropic. It lacks chlorophyll.

The primary structure developing from the radicle is called primary root. From its secondary and tertiary branches arise. If the primary root develops longer and stronger than its branches then it is called a tap root.



Tap root



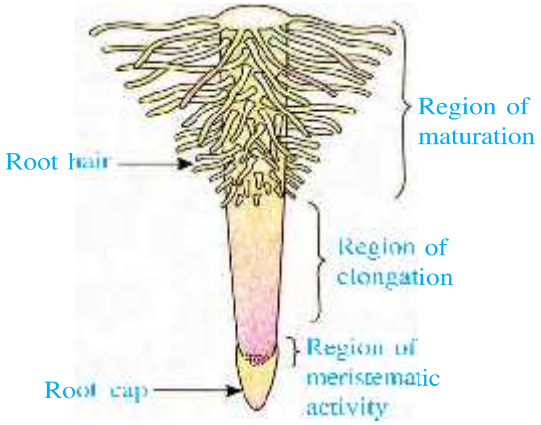
Adventitious root

The root system developing from a tap root is called tap root system. In dicotyledonous plants tap root system occurs.

A root developing from a radicle is called a normal root. A root developing from any part other than the radicle is called an adventitious root. Such roots may develop from hypocotyl, stem or leaf parts. In monocot plants, the primary root is shortlived. Later on thin fibrous roots develop from the hypocotyl and the basal region of stem. Such roots are called fibrous roots and the root system formed by them is called fibrous root system.

Regions of the Root

Regions of root include the apical meristematic region surrounded by protective rootcap, the elongation region and the maturation region.



Regions of root

- **Root cap :** It surrounds the meristematic region of the root apex e.g : *Pandanus*. In aquatic plants like *Pistia*, it occurs as a loose covering which is called root pocket.
- **Meristematic region :** The cells of this region undergo constant cell divisions and add new cells. These cells are small with thin walled and filled with protoplasm.
- **Region of Elongation :** The cells of this region increase rapidly in size and length and induce growth in length and width.
- **Region of Maturation :** The cells of this region differentiates and form tissue structure. From this region then delicate fibrous root hairs are produced. This region is also known as root hair region. The new branches are produced from the permanent region located after this region.

Normal Functions of Root

(1) Fixation : To fix the plant properly in the soil and to develop a proper hole in soil.

(2) Absorption : To absorb water and various minerals from soil and to conduct them to the base of stem axis.

Special functions of Root :

Special adaptations are essential for performing special functions. Such adaptations cause modification in the concerned organs.

Modifications of roots for special functions

(1) Storage of food : Sometimes, the extra food prepared by leaves is stored in roots. Such roots are underground, fleshy and of various shapes. The stored food helps the plant in tiding over the dormancy.

(A) Modifications of tap roots : In Carrot, Radish and Beet, tap root stores food and becomes fleshy. **In carrot,** the food storing root becomes conical. It is called conical tap root. In **Radish,** it becomes fusiform in shape and hence it is called fusiform tap root. In **Beet,** entire food is stored in the basal part of the root. Hence the root suddenly tapers into a thin thread-like structure. Such a root is called napiform tap root.

Beet

Carrot

Radish

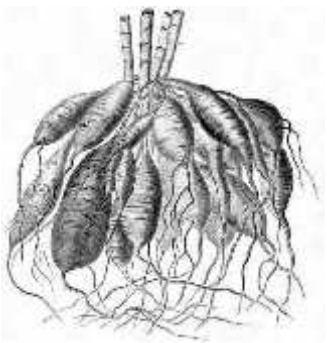
Root : Modifications of tap roots for storage of food

(B) Modifications of adventitious fibrous roots : When a fibrous root stores food and becomes fleshy, it is called a **tuberous root.**

In **Sweet Potato,** a creeper plant, isolated adventitious fibrous roots, developing from the stem, become tuberous in shape. These roots have irregular shapes and are called simple, tuberous, roots.

In ***Asparagus*** and ***Dahlia*,** tuberous roots occur in a cluster. Such clusters are called fasciculated tuberous roots.

Sweet Potato - Simple tuberous root



Dahlia - fasciculated tuberous root

Root- Modification for storage of food

(2) Mechanical Support :

(A) Stilt roots : In Maize and ***Pandanus*** adventitious roots arise from node of the stem nearer to the ground. These roots grow obliquely downwards, enter the soil and provide mechanical support. The need for additional support arises because the underground root systems are superficial. These roots are called stilt roots.

Maize Pandanus

Stilt roots

Banyan Tree - Prop root

(B) Prop Roots : The root system of **Banyan** tree possesses a strong hold in the soil. Its aerial branches grow horizontally. Gradually they become thick and heavy. They may snap under their own weight. To prevent this, prop roots develop. Prop roots are rope-like and develop in groups. They grow downwards, enter the soil and develop prop roots. Later, they become thick and pillar-like.

(3) Climbing : Plants growing as twinners and climbers possess weak stems. They possess modified structures for climbing. In ***Pothos***, long branched or unbranched, brown adventitious roots develop from nodes and internodes of the stem. They are called **climbing** or **clinging** roots. They secrete a sticky material which helps them to stick to the support, and helps them in climbing.

Pothos Root-Modification for climbing

(4) Photosynthesis : ***Tinospora*** is a twinner and grows very rapidly. The leaves on the stem are few and small. They cannot fulfill the food requirement of plant. Thin, smooth, green and thread like adventitious roots develop suspended from the stem. These roots are called **assimilatory roots.** They carry out photosynthesis.

Tinospora Root – Modification for photosynthesis

(5) Breathing : The specialized groups of plants which inhabit the saline, waterlogged soil of creeks near coastal regions are called Mangroves. ***Rhizophora*** and ***Avicennia*** are such

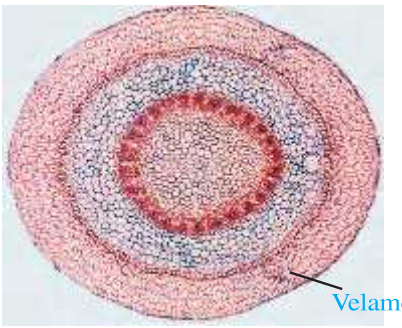
Mangroves

Pneumatophore

plants. They produce negatively geotropic and positively phototropic aerial roots from their underground roots. These roots are spongy, long and possess a large number of lenticels. They may be branched or unbranched. Sufficient oxygen reaches the underground root system through these lenticels and the exchange of gases becomes easy. These roots are called pneumatophores.

(6) Absorption of Moisture : Some **Orchids** live as epiphytes on the branches of trees in forests. They obtain only a habitat from the host. They do not obtain water, salts or prepared food from the host. They have no contact with soil. They produce some adventitious roots which remain suspended in air. These roots are spongy, thick, long and greenish. A specialized velamen tissue occurs on their outer surface. The cells of this tissue are polygonal, thick walled and arranged in many layers and absorb moisture from atmosphere. They are called epiphytic roots.

Orchid



T. S. of epiphytic root

(7) Parasitism : Some plants are dependent on other plants for their nutrition. They are called parasitic plants.

Cuscuta

Loranthus

Parasitism

Cuscuta is a nongreen, leafless plant. Its stem is yellow and twining. It is a total parasite. It develops suckers or haustoria at places of close contact with the host plant. Through these haustoria it establishes direct contact between its own conducting tissues and the conducting tissues of the host. These haustoria suck water, minerals and prepared food from the host. Such 'suckers' act as parasitic roots. Cuscuta is a total parasite.

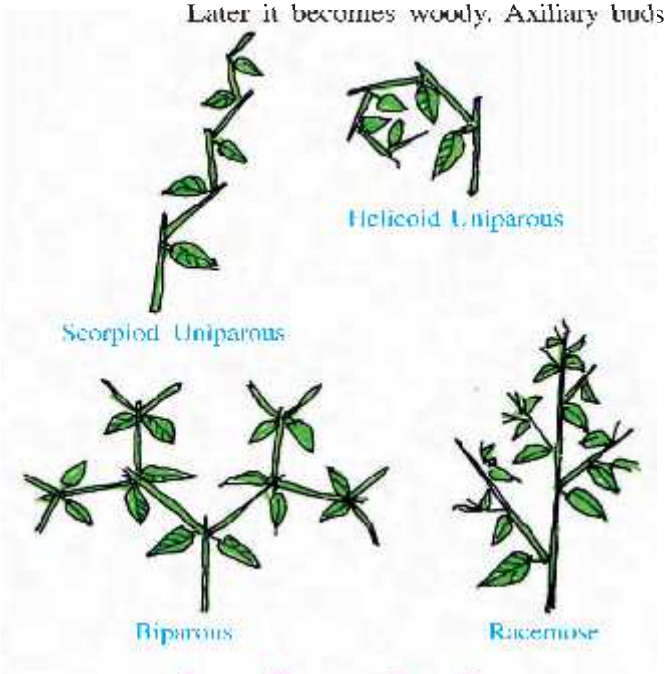
Loranthus lives on the branches of trees like mango. It absorbs only water and minerals from host through its haustoria. As it possesses green leaves, it prepares its food using them. Thus *Loranthus* is a partial parasite.

Symbiosis-Root nodules

(8) Symbiosis : The leguminous plants like **Bean, Groundnut** and others possess small or large nodules on their root systems. These are called root nodules. Nitrogen-fixing *Rhizobium* bacteria live in these root nodules. These bacteria convert atmospheric nitrogen into absorbable salts through nitrogen fixation. These salts are available to the plants. In return, the bacteria obtain a habitat and nutrition. Such a mutually beneficial relationship is called symbiosis and the roots are called symbiotic roots.

(9) Vegetative Propagation : Adventitious buds occur on tuberous roots of plants like sweet potato take part in reproduction.

(II) Stem : It is the aerial part of plant axis. It develops from plumule. It is negatively geotropic and hydrotropic and positively Phototropic. It is distinguished into nodes and internodes. Leaves arise from nodes. The region between two successive nodes is called internode. An apical bud occurs at the tip of stem. It causes growth in elongation of main axis. An axillary bud occurs in the axil of a leaf. An axil is the angle formed by a leaf with the stem at the node. In the beginning, the stem is green. Later it becomes woody. Axiliary buds develop new branches.



Cymose/Racemose branching

Branching

The development and arrangement of branches on stem is called branching. Two main types of branching occur :

(1) Dichotomous branching : The apical bud continuously divides into two branches, which also continue to do the same, e. g : Hyphaene (palm)

(2) Lateral branching : The branches are produced on lateral sides. There are two types of lateral branching — Racemose and Cymose.

In racemose type of branching, the axillary buds on the main axis produce new branches continuously in an acropetal fashion.

Hyphaene

Polyalthea

Vitis

These branches develop and also do the same. As a result the plant develops a conical or a pyramidal shape. e.g. *Polyalthea; Cassuarina.* As all the branches arise from a single main axis, such an axis is called monopodial axis. In cymose type of branching, the apical bud of the main axis becomes inactive after sometime. A branch develops from the axillary bud located in the axil of the leaf just under it. If a single branch develops in this way, it is called uniparous cymose branching. If all such branches are formed only on one side, either right or left, it is called helicoid, uniparous branching, e. g: *Ashoka*. If the branches are formed alternately both sides, it is called scorpioid, uniparous branching. e.g : *Vitis.* If two branches develop, the branching is called biparous, cymose branching. e.g : *Mirabilis, Carissa.* If more than two branches develop in this way, the branching is called multiparous, cymose branching, e.g. **:** *Red oleander, Croton***.** If the axis of the stem is formed by union of many lateral branches, it is called a sympodial axis. e.g. *Vitis.*

Stem may be aerial or underground. Aerial stem in most plants is erect, strong and woody. In some cases, the stems are delicate, threadlike and weak. Such plants either live prostrate on ground or they live as climbers or twinners. They develop special structures for climbing.

Underground stems occur inside the soil. They are devoid of chlorophyll, and generally possess small scaly leaves. They sometimes store food. In favourable season, they produce aerial leaves. They also carry out vegetative propagation. The food stored in them provides nourishment during dormancy period.

Normal Functions of Stem

(1) To arrange the leaves in such a way that they obtain sufficient light.

(2) To arrange reproductive organs like flowers, fruits and seeds in such a way that pollination, fertilization and dispersal of seeds can be properly carried out.

(3) To conduct water and minerals, absorbed by the roots, towards leaves and to transport food prepared by leaves to other organs of the plant.

Special Functions of stem

Under specific condition, the stem performs special functions. They are as follow.

(1) Storage of food : Underground stems are modified for storage of food. In **Ginger,** the underground stem grows parallel to the ground surface. It becomes fleshy

through storage of food. It possesses nodes, internodes, scaly leaves and adventitious roots. Such a modified stem is called rhizome or rootstock. Another example of this kind is Turmeric. In the axils of the underground scaly leaves of Potato plant branches develop. They store food in their apical regions which become round or oval. These are called tubers. Buds with scaly leaves occur in the pits on tubers. These are called 'eyes'. with the help of eyes they can carry out vegetative propagation. In *Amorphophallus*, a condensed form of rhizome occurs which is called corm. It is a food-storing structure made up of only one internode.

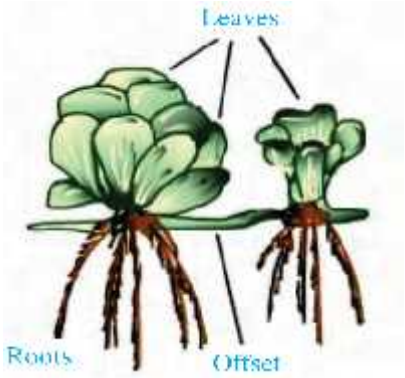
Ginger

Potato

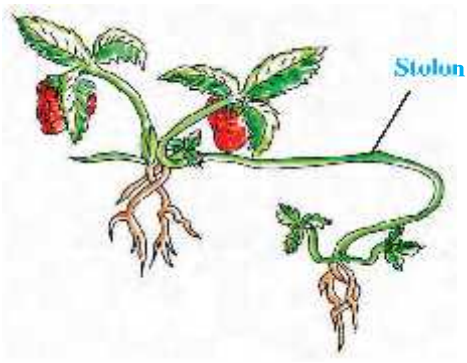
Amorphophallus

Food storage stem

(2) Vegetative Propagation : These modifications are of subaerial stems. A part of the stem is underground and a remaining part is above ground. In Grass, *Oxalis* and *Hydrocotyl*, thin long branches develop. They possess internodes and run parallel to the ground. From the nodes which come in contact with ground, new plants are produced. This modification is called runner. In aquatic plants, *Pistia* and *Eichhornia*, short, thick and horizontal branches develop. Such branches are called offsets. In *Nephrolepis* and *Strawberry,* branches arising from basal regions grow obliquely like arches, come in contact with ground and produce new plants. These branches are called stolons. In Mint vegetative propogation takes place by suckers.



Pistia - Offset



Strawberry - Stolon

Vegetative Propagation

(3) Protection : In some plants, the apical or the axillary bud develops into a sharp pointed structure. It is called thorn. They are protective. In ***Carissa,*** the apical bud is transformed into a bifid, leafless thorn. In ***Lawsonia*** and ***Pomegranate*,** an axillary bud is transformed into thorn. Sometimes leaves and flowers are borne on thorns. The pointed, curved sharp structures

produced on the surface of stem in rose plant are called prickles. They are not modifications of stem. They are outgrowths from surface.

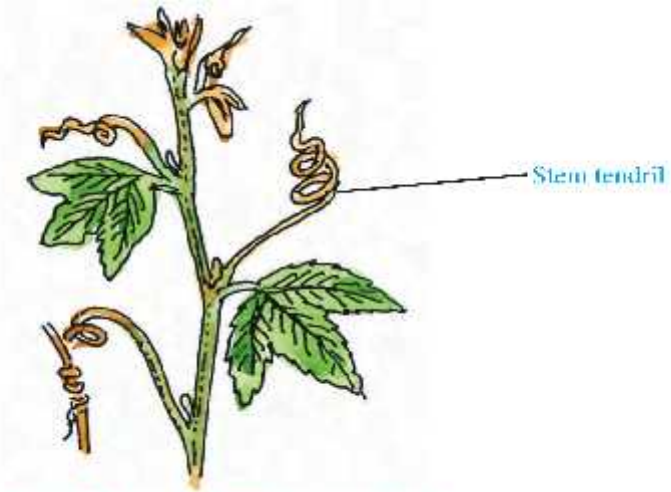
Carissa - Thorn

Lawsonia - Thron

Rose - Prickles

Modification for protection

(4) Climbing : In Passion flower, Cucurbita, Bittergourd, etc. the axillary buds modified into thin, long, threadlike structures. These are called Stem tendrils. They twine around the support and help the plant in climbing.



Passion flower-Modification for climbing

(5) Photosynthesis : Plants like *Muehlenbeckia* and *Opuntia* live in dry habitats. They shed their leaves to reduce transpiration. Their stems become green, possess chloroplasts and are generally flat. Such stems which carry out photosynthesis are called phylloclades.

Muehlenbeckia - Stem modification

Opuntia - Stem modification

Modification for photosynthesis

(6) Storage of food and reproduction : In ***Dioscorea*** and ***Agave*** plants, axiliary buds and floral buds respectively store food and become fleshy. Later on they separate from the parental plant and produce new plants. Such a modified bud is called bulbil.

Dioscorea bulbil

Agave floral bud

(III) Leaf : A leaf is a flat, green and broad lateral appandage developing from the node of a stem or its branch. It possesses an axillary bud in its axil. It has determinate growth.

Typical leaf

There are three parts in a typical leaf leaf base, petiole and lamina. The leaf remains attached to the stem at node through the leafbase. Sometimes a pair of lateral outgrowths develops from the leaf base. They are small and leaf-like. These are called stipules. In plants like Maize, the leafbase expands into a sheath which covers the nodal region. It is called sheathing leaf base. A stalk-like region connecting the leafbase and the lamina is called petiole. It supports the lamina and arranges it for securing proper light. If a petiole occurs, the leaf is called petiolate. If the petiole is absent, the leaf is called sessile. Generally the petiole is round and cylindrical. Lamina is the main part of the leaf. It is broad, flat and green. Veins are distributed in it. There is a great variation in size, shape, margin incision, etc. of lamina. The arrangement of veins and veinlets in lamina is called venation.

Reticulate venation

Parallel venation

Two main types of venation occur - Reticulate venation and Parallel venation. Reticulate venation is observed in dicotyledon leaves. Monocotyledon leaves possess parallel venation. Conducting tissues occur in veins. Both these types of venation are further divided into

two types - unicostate and multicostate. Multicostate venation can be either converging or diverging. The veins transport water, soluble minerals and prepared food. They also form a skeletal network in the lamina.

Simple leaf and compound leaf

If a single lamina occurs in a leaf, it is called a simple leaf. It has an axillary bud in its axil. Sometimes, the lamina appears dissected from the margin. Such incisions divide the lamina to a lesser or a greater degree. However, this incision is not complete. If this incision reaches the midrib or the tip of the petiole, the lamina is divided into independent leaflets. Such a leaf is called a compound leaf. The leaflets of a compound leaf do not possess axillary buds.

A compound leaf may be pinnate or palmate. In a pinnate compound leaf, the leaflets are arranged on both lateral sides of the main vein or midrib. In a palmate compound leaf, the leaflets are arranged on the tip of the petiole. If a single leaflet is so arranged, the leaf is called unifoliate palmate compound leaf (e.g : Lemon). If two leaflets occur, it is called bifoliate, palmate compound leaf (e.g : Balanites) and if many leaflets are thus arranged, it is called multifoliate palmate compound leaf (e.g : *Bombax, Aegle*). In a pinnate compound leaf, if the leaflets are arranged directly on the main midrib, it is called unipinnate compound leaf (e.g. *Cassia)*. If the midrib branches and the leaflets are arranged on these secondary branches, the leaf is called bipinnate compound leaf (e.g. : *Caesalpinia, Acacia*) and if the leaflets are arranged on tertiary or higher order branches, the leaf is called multipinnate compound leaf (e.g. *Moringa*).

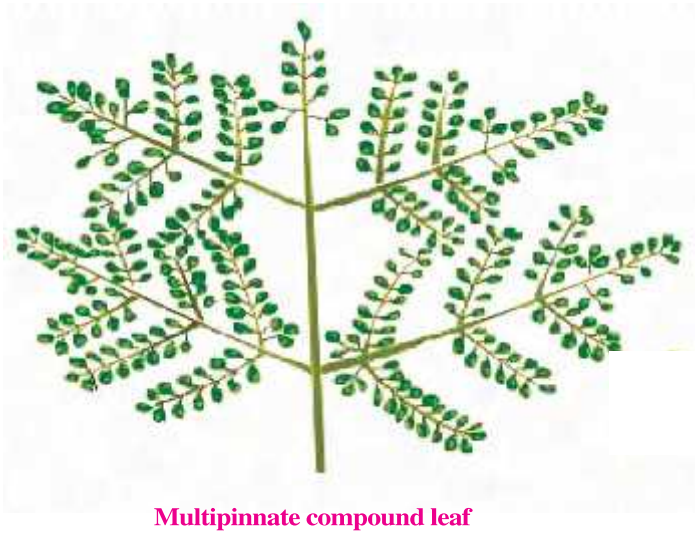
There are some other types of leaves also. The leaf included within a seed is called cotyledon or seedleaf; very small, reduced and papery leaf is called scaly leaf; the leaf from the axil of which a flower develops is called bract. Stamen and carpel are called sporophylls.

Pinnate compound leaf

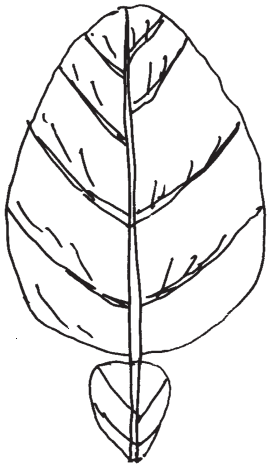
Palmate compound leaf

Unipinnate compound leaf

Bipinnate compound leaf

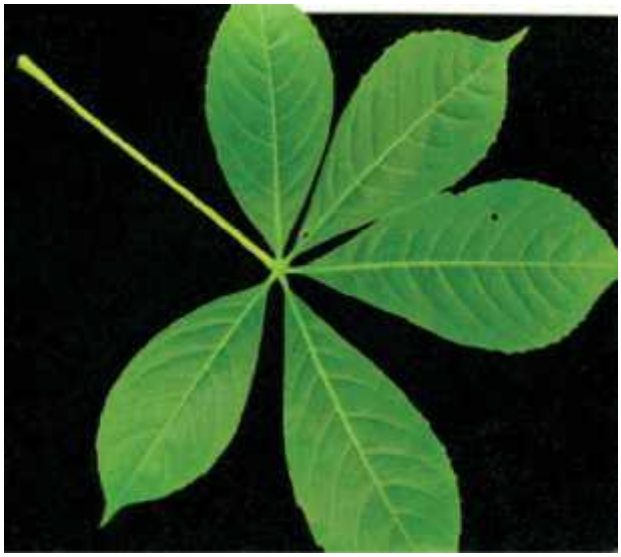


Multipinnate compound leaf



Unifoliate palmate compound leaf

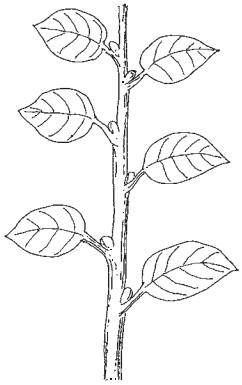
Bifoliate palmate compound leaf



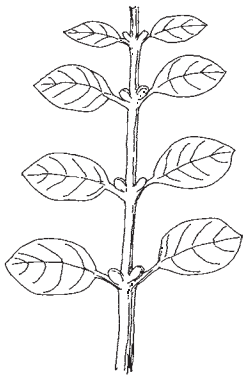
Multifoliate palmate compound leaf

Phyllotaxy

The arrangement of leaves on stem or on its branches is called phyllotaxy. If a single leaf arises from a node, the phyllotaxy is called alternate e.g., Mustard, Sunflower, Hibiscus. In some plants, two leaves arise opposite to each other from a node. This phyllotaxy is called opposite. When the pairs of leaves on successive nodes are arranged at right angle to each other, the phyllotaxy is called opposite decussate, e.g. ***Calotropis*.** If the pair of leaves on successive nodes are arranged overlapping one another, the phyllotaxy is called opposite superimposed, e.g. ***Quisqualis,*** Guava. If more than two leaves are arranged at each node, the phyllotaxy is called whorled, e.g. Red oleander, ***Alstonia***.



Alternate



Opposite superimposed

Opposite decussate

Whorled

Normal Functions of Leaf

(1) To prepare food by carrying out photosynthesis.

(2) To arrange gaseous exchange for respiration.

(3) The loss of water in the form of water vapour (transpiration) occurs through leaves.

Special Functions of Leaf

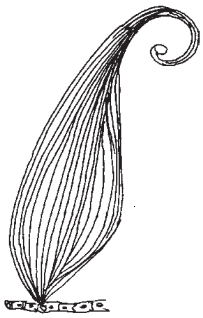
In addition to their normal functions, leaves perform special functions in some plants. They possess modified structures for these functions.

(1) Storage of food : In Onion, the stem is condensed, underground and disc-like. Leaves are arranged concentrically. The main part of leaf is aerial and green. It prepares food. The food is stored in the leaf base. The leaf bases of inner leaves become fleshy. The peripheral leaf bases remain dry and papery. Such a food storing structure is called a tunicated bulb.

(2) Support and climbing : In some plants which possess weak stems, the entire leaf or its part is utilised for climbing.

In *Gloriosa*, the leaf apex becomes tendrillar. In ***Smilax*,** the stipules become tendrillar. In Pea, the terminal leaflets of a compound leaf become tendrillar. In *Bignonia*, three terminal leaflets become hook-like or clawed. Tendrils twine around a support and help the plant in climbing.

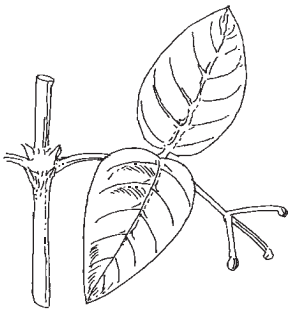
Gloriosa plant



Gloriosa leaf

Pea

Smilax



Bignonia

Leaf-Modification for climbing

(3) Protection : In some plants leaf or some part of the leaf is transformed into a sharp pointed structure which provides protection against grazing animals. In *Acacia* and *Zizyphus*. the stipules become spiny. In *Agave*, the leaf apex becomes spiny. In *Opuntia*, the entire leaf becomes a spine.

Acacia

Zizyphus

Agave

Opuntia

Leaf Modification for protection

(4) Photosynthesis : Photosynthesis is a normal function of leaf. However, it is carried out mainly by the lamina. In Pea, stipules become leaflike and carry out photosynthesis. They are called foliaceous stipules. In Australian *acacia*, the petiole becomes green and flat and prepares food. It is called phyllode.

Phyllode in Australian acacia

Phyllode

Foliaceous stipules in pea

(5) Insectivory : In the insectivorous plant, **Nepenthes,** the leaf is modified into a pitcher. In ***Utricularia***, the leaf is modified into a bladder. These structures are useful in capturing insects.

Nepenthes

Summary

The flowering plants are most dominant plants on the earth today. They exhibit great variation in their external morphology. They have well developed shoot and root systems. Root system is positively geotropic and hydrotropic and negatively phototropic. It develops from the radical. Root systems may be either tap root or fibrous root. Generally dicot plants have tap root system and monocot plants have fibrous root system. Root possesses root cap, meristematics region, region of elongation and region of maturation. The main functions of the root system are fixation of plant in the soil and absorption of water and mineral from the soil.

Roots are modified for various functions like storage of food, mechanical support, climbing, photosynthesis, respiration, absorption of moisture, parasitism and symbiosis and reproduction.

The shoot system is developed from plumule. It is negatively geotropic, positively phototropic and negatively hydrotropic. The shoot system is diffentiated into stem, leaves, flowers and fruits. Stem possesses nodes, internodes, leaves, hairs and axillary and apical

buds. Under specific condition the stem performs diverse functions such as storage of food, reproduction, protection, climbing, and photosynthesis.

A leaf is a flat, green and broad lateral appendage developing from the node of stem or its branches. A typical leaf possesses three parts namely leaf base, petiole and lamina. The arrangement of veins and veinlets in lamina is called venation. Two main types of venations are found – reticulate and parallel. Leaves are also divided into simple and compound leaf. The compound leaf may be of two types: pinnately compound and palmately compound. The arrangement of leaves on stem is called phyllotaxy. This is usually of three types: alternate, opposite and whorled. Leaves are often modified to perform various functions like storage of food, support, climbing and protection.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Root is....

(A) Positively phototropic ◯ (B) Positively geotropic ◯

(C) Negatively hydrotropic ◯ (D) None of this ◯

(2) Root pocket is found in which of the following plants ?

(A) Pandanus ◯ (B) Pistia ◯

(C) Maize ◯ (D) Radish ◯

(3) Example of fusiform tap root is.....

(A) Radish ◯ (B) Beet ◯

(C) Carrot ◯ (D) Sweet potato ◯

(4) Fasciculated tuberous root is found in.....

(A) Dahlia ◯ (B) Beet ◯

(C) Sweet potato ◯ (D) Maize ◯

(5) Function of prop root is.....

(A) Reproduction ◯ (B) Climbing ◯

(C) Support ◯ (D) Food storage ◯

(6) Which of the following plants is an incomplete parasite ?

(A) Rhizophora ◯ (B) Tinospora ◯

(C) Loranthus ◯ (D) Cuscuta ◯

(7) In which type of branching, apical bud becomes inactive after sometimes ?

(A) Racemose ◯ (B) Cymose ◯

(C) Monopodial ◯ (D) Sympodial ◯

(8) Function of turmeric is .....

(A) Protection ◯ (B) Reproduction ◯

(C) Food storage ◯ (D) Climbing ◯

(9) Which of the following plants possesses *Rhizobium* bacteria ?

(A) Orchid ◯ (B) Bean ◯

(C) Tinospora ◯ (D) Cuscuta ◯

(10) Which of the following plants possesses photosynthetic root ?

(A) Banyan ◯ (B) Rhizophora ◯

(C) Tinospora ◯ (D) Pandanus ◯

2. Answer in short :

(1) Which parts produce root system and shoot system ?

(2) Mention the regions of root.

(3) What are Mangroves ? Give examples.

(4) Give the examples of insectivorous plants.

3. Define with suitable example :

Tuberous root, Adventitious root, Epiphytic root, Rhizome, Tuber, Runner, Offset, Stolon, Stem tendril, Bulbil, Stipule.

4. Describe the special modifications of root, stem and leaf with examples for following functions :

(1) Storage of food (2) Climbing

(3) Photosynthesis

5. Explain the following terms :

Root pocket, Epiphyte, Symbiosis, Branching, Thorn, Spine, Prickle, Stolon, Bulbil, Phylloclade, Stipules, Compound leaf, Phyllotaxy, Phyllode.

6. Write short notes on :

Normal functions of Root, Symbiotic Root, Stilt roots, Normal functions of Stem, Clinging roots, Venation, Photosynthetic roots, Phyllotaxy, Pneumatophores, Normal functions of leaf, Parasitic root, Insectivory, Typical leaf

7. Draw labelled diagrams of :

(1) Various regions of root. (2) Typical Leaf

(3) Typical angiosperm plant

8. Distinguish between :

(1) Tap root system - Fibrous root system

(2) Roots of Cuscuta and Orchid OR Parasitic root and Hygroscopic root.

(3) Simple leaf and Compound leaf

(4) Pinnate compound leaf and Palmate compound leaf

2

Plant Morphology-2
(Flower, Fruit, Seed and Family)

We have so far discussed the vegetative organs of the plant in Chapter 1; now we study the reproductive parts of flowers in this chapter.

As the young plants grow and the vegetative parts mature, flowers make their appearances in order to produce seeds and thus, pave way for the next generation. The vegetative growth leads to the development of branches and foliages. Some of these mature shoots start bearing flowers and are known as reproductive shoots.

Inflorescence

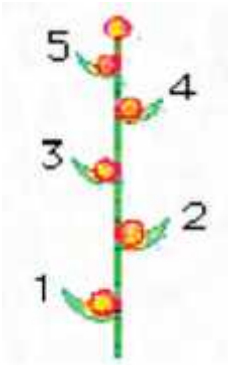
The axis of a plant which bears flowers is called peduncle or rachis. The arrangement of flowers on the rachis is called inflorescence. It is also termed as Anthotaxy. An inflorescence may be apical or axillary. There are two main types of inflorescence (A) Racemose and (B) Cymose.

(A) Racemose Inflorescence : In this type of inflorescence the apical bud is not transformed into a flower. It goes on producing new flowers in an acropetal succession on the rachis. The flowers towards the base develop earlier and are larger. Then the process gradually progresses towards the apex.

Raceme - Caesalpinia

Racemose Inflorescence is of different types. Some common types are as follow :

(1) Raceme : When peduncle or rachis is normally elongated and flowers are stalked, the inflorescence is called a raceme. e.g. Mustard, Caesalpinia



Spike - Achyranthus

(2) Spike : When peduncle or rachis is normally elongated but flowers are sessile, the inflorescence is called a spike e.g. *Achyranthus.*

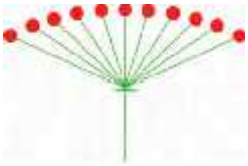
Spadix - Colocasia

(3) Spadix : In this type the peduncle is thick and fleshy and bears unisexual, sessile flowers at its lower end. The male flowers are borne above the female flowers. Sometimes sterile flowers are present between male and female flowers. The peduncle is protected by a large foliage bract known as spathe e.g. *Colocasia, Musa.*

(4) Catkin : If the axis of a spike is weak and does not stand erect but is pendulous and all the flowers in an inflorescence are unisexual, the inflorescence is called Catkin e.g. Mulberry, Acalypha.

Catkin - Acalypha

(5) Umbel : In an umbel type of inflorescence, the rachis becomes condensed and stalked, flowers are arranged on its tip like the spokes in an umbrella. The flowers are usually bracteate. Thus the bracts form a whorl or a cluster at the base of flowers. This group of bracts is called involucre e.g. Onion.



Umbel - Onion

(6) Capitulum : In a capitulum type of inflorescence, the peduncle becomes flat and disk like. It is called receptacle. Small, sessile flowers are arranged in a centripetal order. Peripheral flowers are called ray florets and central flowers are called disc florets. The receptacle is surrounded by a whorl of bracts known as an involucre e.g. Sunflower, Tagetes.

Capitulum - Sunflower

Hibiscus

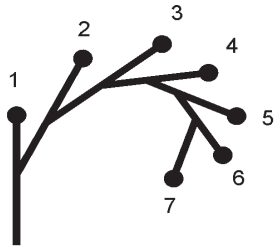
(B) Cymose inflorescence : In this type of inflorescence, the apical bud is transformed into a flower. Thus, the development of inflorescence axis becomes arrested. It may be divided into the following types:

(1) Cymose solitary : In this type only one pedicellate flower is borne terminally by the peduncle. A joint some where in the stalk demarcates the extent of peduncle and pedicel. e.g. *Hibiscus*, *Argemone*

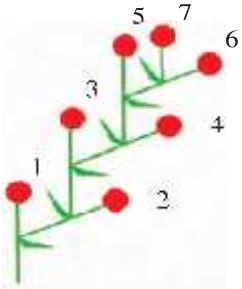
(2) Uniparous (Monochasial) : The main axis ends in a flower and the growth is continued by a single lateral branch. It may be:

(A) Helicoid : In monochasial cyme, the apical bud gives rise to a single lateral branch before being transformed into a flower. The apical bud of this branch also does the same. This order continues. If the new branches are formed sequentially on one side of the axis only. The inflorescence is called unilateral, monochasial cyme or helicoid. e.g. *Hamelia*

Hamelia



Helicoid



Scorpioid - Heliotropium

(B) Scorpioid : In this case the lateral branches arise alternately on left and right sides e.g. *Heliotropium*

Jasmine

(3) Biparous (Dichasial) : A determinate inflorescence in which the main axis ends in a flower after producing two daughter axis in flowers. e.g. *Jasmine, Nyctanthus*

(4) Multiparous (Polychasial) : A determinate inflorescence in which the main axis ends in a flower after producing more than two branches e.g. *Calotropis*, Red oleander

Calotropis

A typical flower

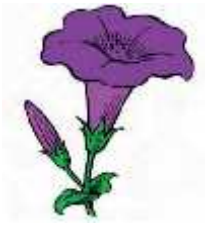
Flower : The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. It consists of a middle axis, called as Floral axis. The expanded and swollen tip of the floral axis is called a thalamus or receptacle while stalk like lower portion is called Pedicel. A typical flower consists of four whorls – calyx, corolla, androecium and gynoecium. The components of all these whorls are concentrically arranged on a thalamus. The calyx and corolla are accessory organs, while androecium and gynoecium are reproductive organs.

(1) Calyx : The calyx is the outermost whorl of the flower and its individual unit is called sepal. Sepals are green, leaf-like and protect the flower in the bud stage. If the sepals are free from one another, the calyx is called polysepalous and if they are united through their margins to form a tube-like structure, the calyx is called gamosepalous

Polysepalous

Gamosepalous

Polypetalous



Gamopetalous

(2) Corolla : The next whorl is of corolla. Corolla is composed of petals. Petals are of various shapes and colors. Corolla may be tubular, bell-shaped, funnel-shaped, wheel-shaped or butterfly-shaped. Petals are usually brightly colored to attract insects for pollination. They protect the floral whorls arranged on their inside. They can also be of polypetalous and gamopetalous types.

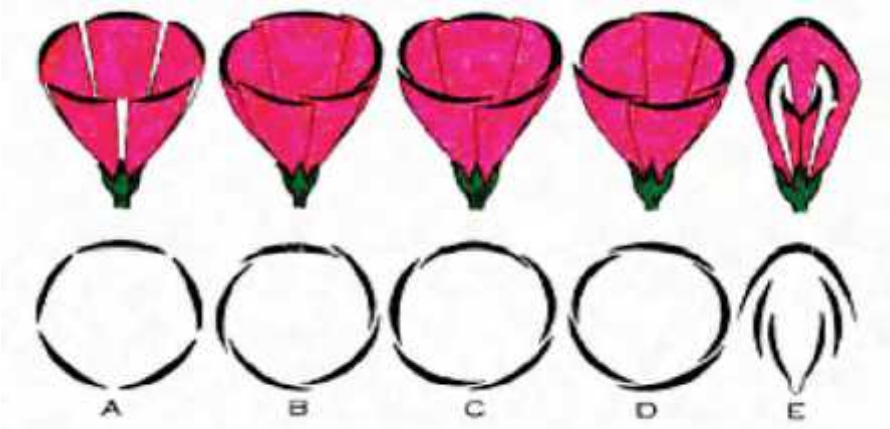
Sometimes, both these whorls appear similar, then, jointly they are called perianth, e.g. *Crinum*, *Bougainvillea*

Aestivation

Aestivation is the arrangements of sepals or petals in the bud condition of a flower. It may be of the following types.

(A) Valvate : If the sepals and petals touch only along their margins and do not overlap one another, then the aestivation is called valvate. e.g. *Calotropis*, Mustard

(B) Twisted : If the component members have their one margin overlapped by the margin of another component, and the other margin overlapping the margin of another component, the aestivation is called twisted. e.g. China Rose, Cotton



Types of Aestivation

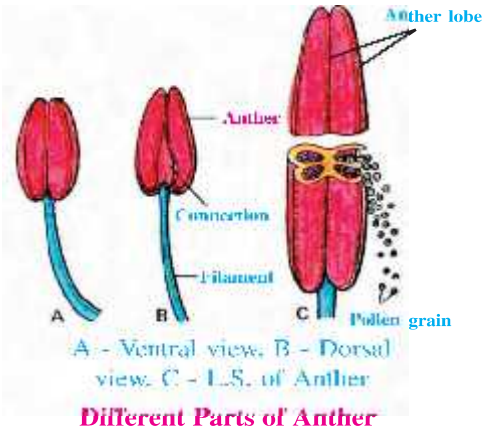
A – Valvate B – Twisted C – Imbricate D – Quincuncial E – Vexillary

(C) Imbricate : One member is completely outside and one member is completely inside. While other three members have one end outer and another one inner. This aestivation is called imbricate. e.g. Cassia, Delonix (Gulmoher).

(D) Quincuncial : It is a special type of imbricate aestivation where there are five components, two components are outer, two are inner and in one component one margin is inner and another margin is outer. e.g. Cucurbita, Melia

(E) Vexillary : This type of aestivation is seen in flowers having vexillary corolla. Out of the five petals, the largest (standard) overlaps the two lateral petals (alae) which in turn overlap the two smallest anterior petals (keel). This type of aestivation is known as vexillary. e.g. Pea and Bean

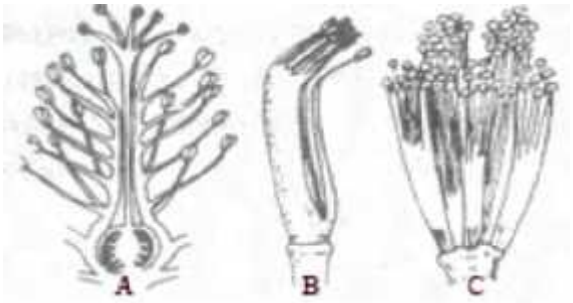
(3) Androecium : This whorl which is arranged inner to corolla is made up of stamens. Each stamen is made up of a filament, connective and anther. Pollen grains are produced within anther. Pollen grains can be smooth or spiny and of various shapes. A sterile stamen is called staminode. The mature anther is bilobed, hollow and sac-like. Anthers dehisce in various ways and liberate the pollen grains. The filament and the anther are joined through a connective. This union can be of various types.



A - Ventral view, B - Dorsal view, C - L.S. of Anther

Different Parts of Anther

The number of stamens varies. If all stamens are free from one another, they are called free. If all stamens are jointly through their filaments, they are called monodelphous e.g. China Rose. Sometimes, two groups are formed. They are called diadelphous. e.g. pea or when they are in more than two bundles, they are called polydelphous e.g. Citrus



Monodelphous Diadelphous Polydelphous

Cohesion of stamens

(4) Gynoecium : This whorl is arranged on the innermost side and it is made up of carpels. Each carpel possesses, at its base a hollow bag like ovary, from its tip a tubular style occurs. The tip of the style is called stigma and is the receptive surface for pollen grains. Each ovary bears one or more ovules attached to a flattened cushion-like placenta.

Apocarpous

If a singal carpel occurs in the gynoecium it is called monocarpellary. e.g. Pea. If more carpels occur, it is called polycarpellary. In a polycarpellary gynoecium, if all carpels remains free from one another it is called apocarpous. e.g. Rose, Lotus. If all carpel's are united with one another, it is called syncarpous. In such case only one ovary occurs. e.g. *Datura, Hibiscus*

Syncarpous

Placentaion : The region from where an ovule develops inside the ovary is called placenta. The arrangement of ovules within an ovary is called placentation. The placentation is of the following types.

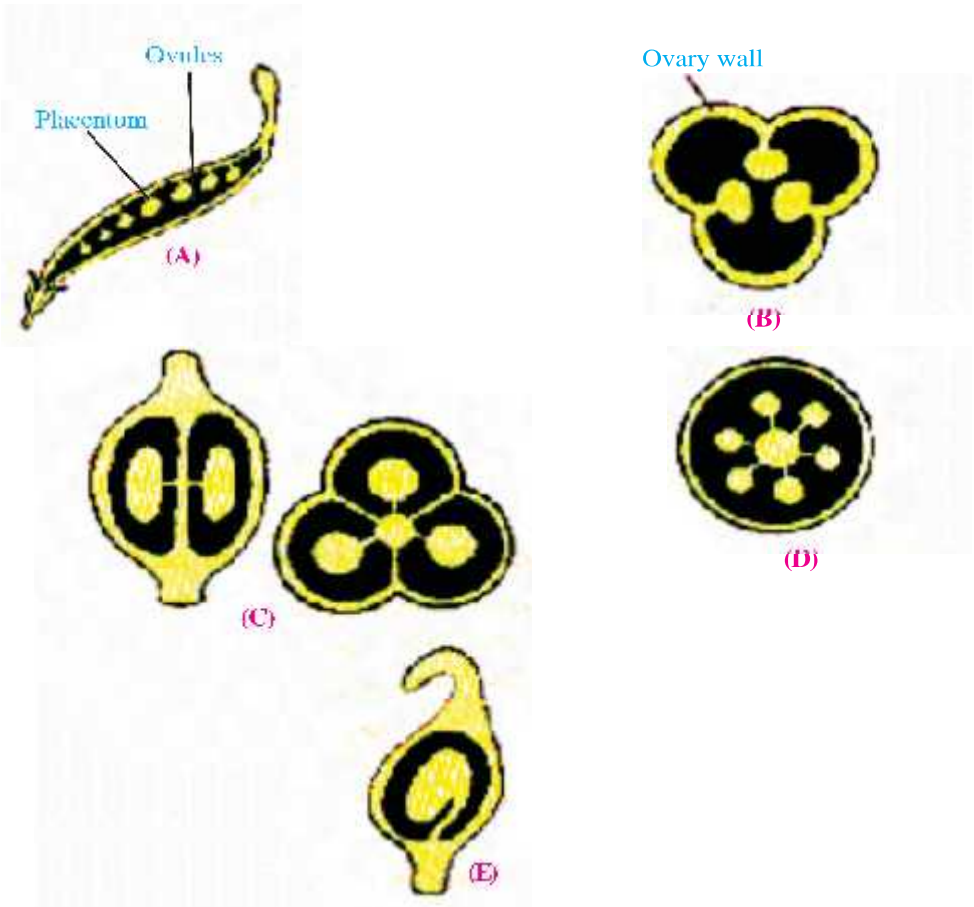
(A) Marginal : In marginal placentation, the ovary is unilocular and the ovules are borne on the inner folds of the ovary wall e.g. Pea, Bean

(B) Parietal : In parietal placentation, the ovules develop on the inner wall in the periphery of the ovary . Ovary is one chambered but it becomes two chambered due to the formation of the false septum e.g. Mustard and *Argemone*

(C) Axile : In axile placentation, ovules are arranged on a central axis in the ovary. The ovary is divided into locules. The number of these locules is based on the number of carpels e.g. Tomato, Hibiscus

(D) Free central : In free central placentation the ovules are borne on a central axis, which arises from the base of the ovary and is not connected by partitions with the wall of the ovary e.g. *Dianthus*

(E) Basal : If a placenta develop at the base of the ovary-chamber and bears a single ovule, the placentation is called basal placentation e.g. Sunflower



A – Marginal B – Parietal C – Axile
D – Free central E – Basal

Types of Placentations


Complete flower


Incomplete flower

Types of Flowers : Types of flowers can be described from various view points.

If all four whorls are present in a flower, it is called a complete flower. But if any one of the whorls is absent, then it is called an incomplete flower.

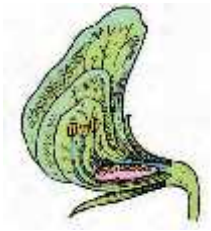
When a flower has both androecium and gynoecium, the flower is called bisexual. A flower having either stamens (male flower) or carpels (female flower) is called unisexual flower.


Unisexual flower


Bisexual flower

In symmetry, If a flower can be divided into equal halves along any longitudinal plane then it is called actinomorphic (radial symmetry) e.g. *Hibiscus, Datura*. If it can be so divided in one plane only then it is called zygomorphic (bilateral symmetry). e.g. Bean, *Caesalpinia*


Actinomorphic


Zygomorphic

Types of Flowers

A flower is called **isomerous**, when the number of component members in all whorls are the same. A isomerous flower may be trimerous, tetramerous or pentamerous, when the floral appendages are in multiple of 3, 4, or 5 respectively. Flowers can also be heteromerous


Trimerous flower


Tetramerous flower

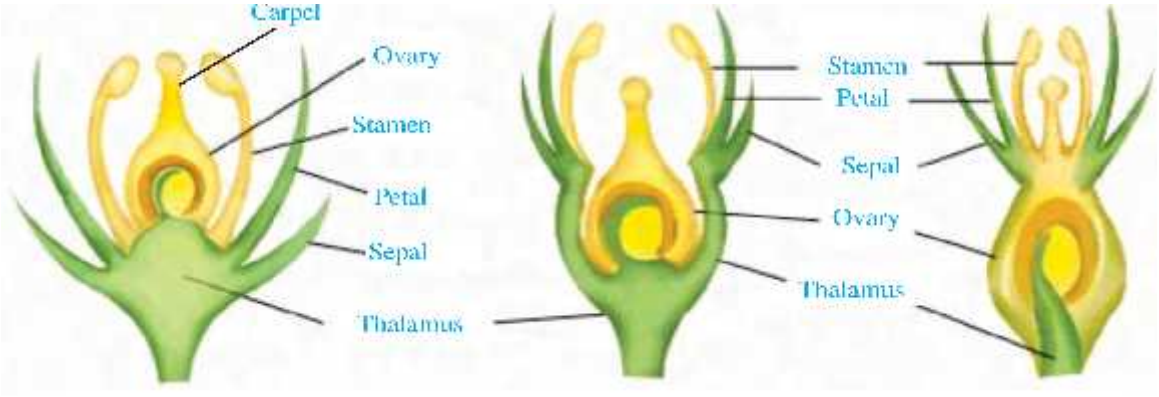

Pentamerous flower

The leaf, from the axis of which a flower develops is called a bract. The flower with a bract is called bracteate flower. Ebracteate flower lacks a bract.


Bracteate flower


Ebracteate flower

Three kinds of flowers occur on the basis of the position of the ovary. In a hypogynous flower, the thalamus becomes conical so that the ovary occupies the highest position. Such an ovary is called superior. e.g. Mustard, China rose and Datura. In a perigynous flower, the thalamus becomes flat, disc-like. The ovary placed in the centre is semi-inferior. Other floral whorls are arranged on the rim of the thalamus. e.g. Rose, Caesalpinia. In a Epigynous flower, the thalamus envelops the ovary. Here, the ovary is inferior. The other three whorls are arranged above the ovary e.g. Sunflower, Cucumber



A **B** **C**

Hypogynous (Superior ovary) **Perigynous (Semi-inferior ovary)** **Epigynous (Inferior ovary)**

(Position of ovary - kinds of flowers)

Fruit : The fruit is defined as fertilized and ripened ovary. If a fruit is formed without fertilization of the ovary, it is called parthenocarpic fruit. Generally, the fruit consists of a wall or pericarp and seeds. The seeds are covered by a pericarp in a fruit. The pericarp may be dry or fleshy. A fruit which develops only from an ovary is called true fruit. In some cases fruit develops from the thalamus or some other parts of the flowers. Such type of fruit is called false fruit. In apple, the thalamus is involved and in cashew nut fruit, the peduncle is involved, these are false fruits.

Kinds of fruits : Based on their origin and development, three kinds of fruits occur – simple, aggregate and composite.

(A) Simple fruit : Simple fruit develops from monocarpellary ovary or multicarpellary syncarpous ovary. It may be dry or fleshy. In dry simple fruit the pericarp is dry. Simple fruits are of two types – dehiscent and indehiscent.

Dry Dehiscent Fruit : When fruits ripen, their fruit walls dehisce in various ways and liberate the seeds. According to kind of dehiscence, they are classified into: follicles, legumes and capsules. The follicles type of fruit dehisces by one suture only. e.g. *Calotropis, Vinca*. The legume fruit dehisces along two suture. e.g. Pea, Bean. The capsule dehisces along more than two sutures. e.g. Cotton, Datura. In siliqua fruit dehiscence starts from lower part and proceeds upward by the sutures. e.g. Mustard.


Calotropis


Bean


Pea


Cotton


Datura

Indehiscent dry fruit : The wall of the ripened fruit does not dehisce. The pericarp decomposes in a natural way and releases the seeds. They develop from monocarpellary to polycarpellary syncarpous with one chamber and one ovule. Caryopsis, Achene, Cypsela Nut, Samara are the types of indehiscent fruit. In **caryopsis** the pericarp and the seed coat are fused and form a 'hull'. There is a single seed in the fruit. e.g. Maize, Wheat. In achene fruit pericarp and seedcoat are free from one another. e.g. *Naravelia, Ocimum*. In **nut** fruit, the pericarp is very hard and stony. e.g. Cashewnut, Trapa. In **cypsela** fruit, the pericarp and the seed coat remain free from each other. e.g. *Tridax, Vernonia.* In this fruit persistent hairy calyx are found at the apex of the fruit. In **samara,** the pericarp became flat like wings. e.g. Holoptelea, Hiptage.

Fleshy Fruit : In fleshy fruits, pericarp is succulent and fleshy. They may be of three types, drupe, berry and pome.

(1) Drupe : In drupe fruit, the pericarp is differentiated into three regions, outer thin and skinny epicarp, middle succulent or juicy mesocarp and an inner hard stony endocarp which encloses a seed. e.g. Mango, Coconut


Mango


Coconut

(2) Berry : In berry, epicarp and mesocarp are similar to those seen in drupe fruit but the endocarp is fleshy. e.g. Tomato, Orange.


Tomato


Orange

(3) Pome : The fruit is false as it is surrounded by the fleshy thalamus. It is an edible part. True fruit remains inside the swollen thalamus. The ovary enclosing seeds forms the central core of the fruit. e.g. Apple.

Apple

(B) Aggregate Fruit : This fruit develops from an apocarpous, polycarpellary gynoecium. Each carpel forms a fruitlet and thus, a cluster of fruitlets known as etaerios develops from one flower. On the basis of the kinds of the fruitlets, the aggregate fruits are named. Their chief types are as follows.

(1) Etaerio of berries - e.g. Custard Apple.

(2) Etaerio of follicles - e.g. *Calotropis*.

(3) Etaerio of drupes - e.g. Raspberry.

Custard Apple

Calotropis

Raspberry

(C) Composite Fruits : A composite fruit develops from all the flowers of a whole inflorescence forming one body at maturity. There are two types of multiple fruits namely sorosis and syconus.

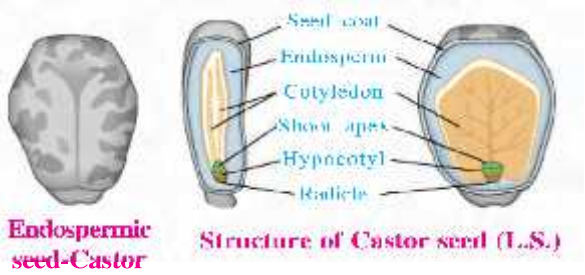
Pineapple

Ficus (Fig fruit)

Sorosis : In pineapple, fruit develops from spike inflorescence. The rachis and the flowers along with bracts unite together into fleshy compound fruit. Flowers are usually sterile and seeds are rarely formed.

Syconus : It is derived from a special type of inflorescence known as hypanthodium, which has a fleshy receptacle. It has large number of unisexual flowers. On ripening, the receptacle becomes fleshy and juicy and forms the edible portion. e.g. Banyan fruit or Fig fruit.

Seed : The fertilized ovule is called a seed. A seed contains seed coat and embryo. Embryo possesses cotyledons, plumule and radicle. The plumule is responsible for development of shoot system and the radicle is responsible for development of root system. Food may be stored either in the cotyledons or in a separate region. Such a region is called endosperm, which is formed as a result of double fertilization.



Endospermic seed-Castor

Structure of Castor seed (L.S.)

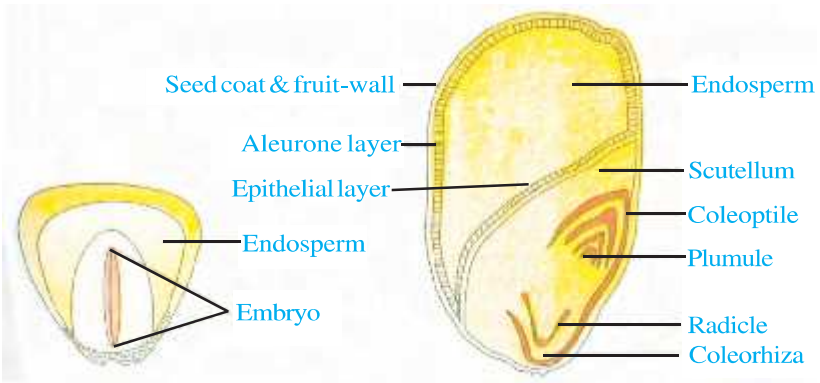
On the basis of the number of cotyledons, there are two types of seeds - Dicotyledonous and Monocotyledonous. If two cotyledons occur, the seed is called dicotyledonous seed. e.g. Bean, Gram. If a single cotyledon occurs, the seed is called monocotyledonous seed e.g. Maize, Wheat. If the food is stored in a separate endosperm region, the seed is called Endospermic seed e.g. Maize, Castor. If the food is stored in cotyledons and a region called endosperm does not occur, the seed is called Non-endospermic seed e.g. Bean, Pea, Gram.

Structure of a Dicotyledonous Seed : Bean is a typical example of dicotyledonous seed. The bean seed is flat, kidney-shaped and yellowish white in colour. A seed coat occurs on the outside. The seed coat has two layers. The outer one is tough and yellowish is called testa and inner one is thin and transparent. It is called tegmen. The hilum is a scar on the seed coat through which the developing seeds were attached to the fruit. Above the hilum is a small pore called the micropyle.

In the structure of the embryo, two large, fleshy and white cotyledons found attached to the embryonic axis. They are often full of reserve food materials. Plumule occurs at one end of this axis and radicle occurs at the other end. Plumule is protected by two minute leaves. During germination it develops into the shoot while due to growth and development, the primary tap root system is organized from radicle. The region of embryonic axis between plumule and cotyledons is called epicotyl and that between radicle and cotyledons is called hypocotyl. Bean seed is dicotyledonous, nonendospermic seed.

Structure of dicotyledonous seed Bean
(Non-endospermic seed)

Structure of Monocotyledonous seed : Maize is a typical example of monocotyledon seed. Maize grain is flat, yellow, narrow at one end and broad at the other end. If the seed is cut longitudinally into two parts and the cut face stained with iodine, the endosperm part (deep blue because of starch) and the embryo part (yellowish) can be easily demarcated. Usually the embryonic region is located in the narrow flat region. The remaining part is the endospermic region. The structure of maize grain can be studied in its longitudinal section.



Maize seed

Structure of monocot seed - Maize
(Endospermic seed)

On the outermost side a hull occurs. It is a tough covering formed through fusion of pericarp and seed coat. An aleurone layer occurs under the hull. This is made up of big square or rectangular cells. Grains of proteins are stored in these cells.

A single, thin and shield-shaped cotyledon occurs in the embryonic region. It is called scutellum. The outer layer of scutellum which remains in contact with endosperm is called epithelial layer. The endospermic region is large. It stores food mainly in the form of starch.

At the narrow end of scutellum, the embryonic axis remains attached. At one end of this axis, occurs plumule and its protective covering is called coleoptile. At the other end of this axis, occurs radicle and its protective covering is called coleorhiza.

The maize grain is a representative of monocotyledonous, endospermic seed.

Floral Formula : Before the construction of floral diagram and floral formula, various morphological features are used to describe a flowering plant. Such a description has to be brief, in a simple and scientific language and presented in a proper sequence.

First of all, there should be a mention of the habitat of the plant. Then the plant is described beginning with its habit, vegetative characters- stem, leaves and then inflorescence, floral characters and floral parts. After describing various parts of a plant, a floral diagram and a floral formula can be structured.

In construction of the floral formula, the number of members in the floral whorls, their union with one another, their insertion on thalamus, their association with other whorls, etc. are taken into account. Various symbols used in a floral formula and their meanings can be explained as under :

1. Bracts

Br = Bracteate

Ebr = Ebracteate

Brl = Bracteolate

2. Symmetry

⊕ = Actinomorphic or Regular flower

◑ or % = Zygomorphic or irregular flower

3. Sex

♂ = Staminate flower

♀ = Pistillate flower

⚥ = Bisexual flower

4. Calyx

K = Calyx

K_4 = Four free sepals

$K_{(4)}$ = Four fused sepals

5. Corolla

C = Corolla

C_4 = Four free petals

$C_{(4)}$ = Four fused petals

6. Perianth

P = Perianth

P_6 = Six free tepals

$P_{(6)}$ = Six fused tepals

P_{3+3} = Six tepals in two whorls of three each

7. Androecium

A = Androecium

A_5 = five free stamens

$A_{(5)}$ = Five fused stamens

A_{5+5} = Ten stamens in two whorls of five each

A_0 = Stamens absent

A_α = Stamens indefinite in number

$\overline{C\ \ A}$ = Stamens epipetalus

$\overline{P\ \ A}$ = Stamens epiphyllous

8. Gynoecium

G = Gynoecium

G_2 = Two free carpels

$G_{(2)}$ = Two fused carpels

G_0 = Carpels absent

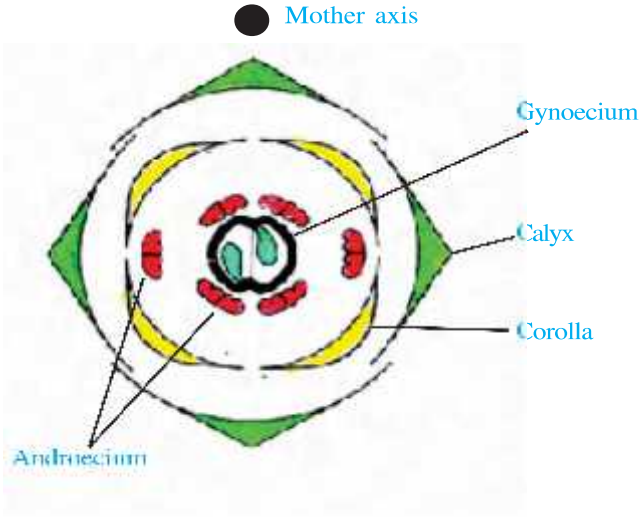
$\underline{G}_{(2)}$ = Bicarpellary, syncarpous superior ovary

$G_{(2)}$ – = Bicarpellary, syncarpous semi-inferior ovary

$\overline{G}_{(2)}$ = Bicarpellary, syncarpous inferior ovary

In constructing the formula, after the symbol of concerned floral whorl, the number of members in that whorl is written. The following floral formula and floral diagram in figure represent the Mustard plant :

Floral formula of Mustard plant : ⊕, ♀, K_{2+2}, C_4, A_{2+4} $\underline{G}_{(2)}$



Floral diagram

Floral diagram : A Floral diagram provides information about the number of parts of a flower, their arrangement, their adhesion and cohesion with other whorl and their relation to the mother axis. The position of the mother axis with respect to the flower is represented by a dot on the top of the floral diagram. On the outermost side calyx is shown. Then sequentially, inside, corolla, androecium and gynoecium are shown. If possible placentation is also shown. Extrose anthers are to be faced toward the petals and the introse ones towards the gynoecium. Staminodes are represented either by a cross (x) or asterisk (*). If a bract is present, it is shown under the floral diagram.

Description of families

To understand the method of discription of flowering plants, we shall discribe families an illustration, discription of three family is given.

Fabaceae

Classification :

Class	–	Dicotyledons
Subclass	–	Polypetalae
Series	–	Caliciflorae
Order	–	Rosales
Family	–	Fabaceae

This family was earlier called Papilonoideae, a sub-family of family Leguminosae.

Vegetative characters :

Habitat : It is distributed all over the world.

Habit : Mostly trees, shrubs and herbs. Some of them are climbers. Root is with root nodules. Often spiny outgrowth present on stem.

Leaf : Pinnately compound or simple, alternate, leaf base pulinate, stipulate stipules spiny, venation reticulate.

Floral characters : Inflorescence racemose.

Flower : Complete, zygomorphic, bisexual, pedicellate, bracteate, hypogynous

Calyx : Sepal five gamosepalous, imbricate aestivation.

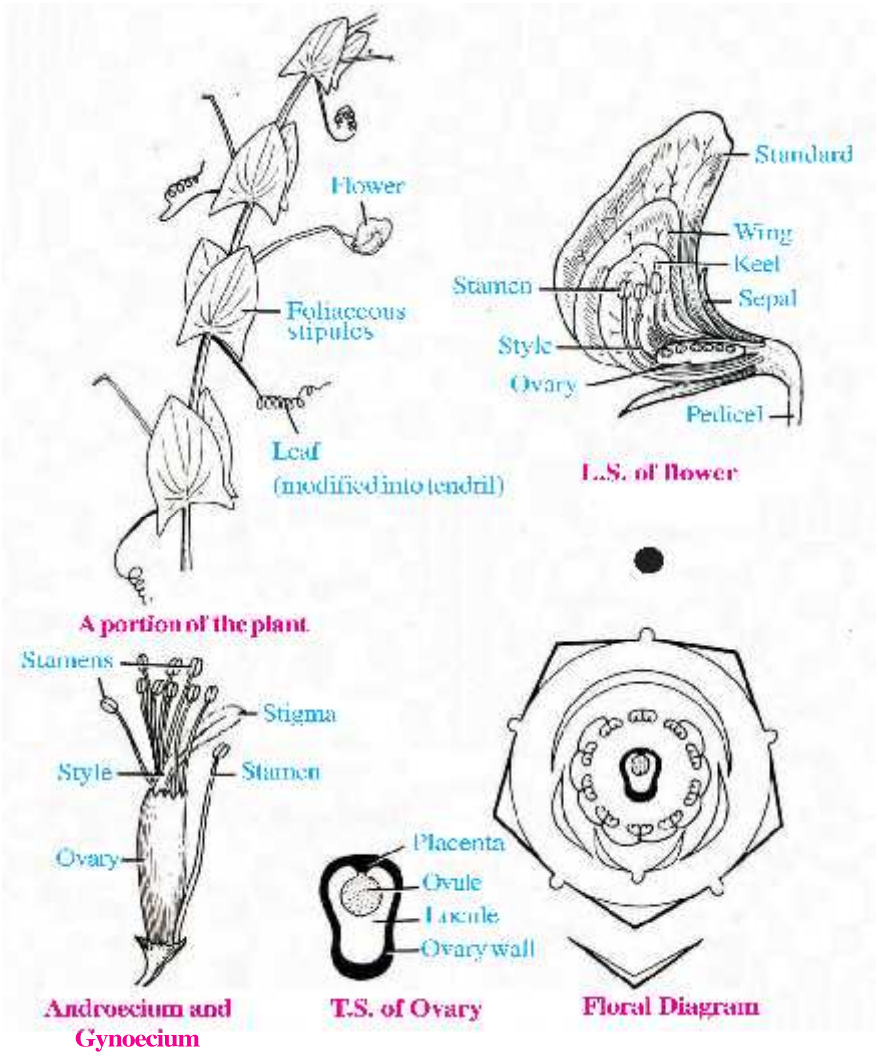
Corolla : Petals five, coloured variously, polypetalous, papillionaceous, consisting of one posterior standard, two lateral wings and two anterior ones forming a keel (enclosing stamens and pistil), vexillary aestivation.

Androecium : Ten, diadelphous ((9)+1) anther dithecous.

Gynoecium : Monocarpellary, ovary superior, unilocular with many ovules, style single with capitate stigma, marginal placentation.

Fruit : Legume, seed one to many, non-endospermic.

Floral formula : Br, $\oplus$, $\male\female$, $K_{(5)}\ C_{1+2+(2)}\ A_{1+(9)}\ \underline{G}_1$



Fabaceae : Lathyrus aphaca (Pea)

Scientific name

(1) *Phaseolus mungo* (Green gram)
(2) *Cajanus cajan* (Pegion pea)
(3) *Cicer arietinum* (Chana)
(4) *Deris indica* (Karanja)

Economic importance

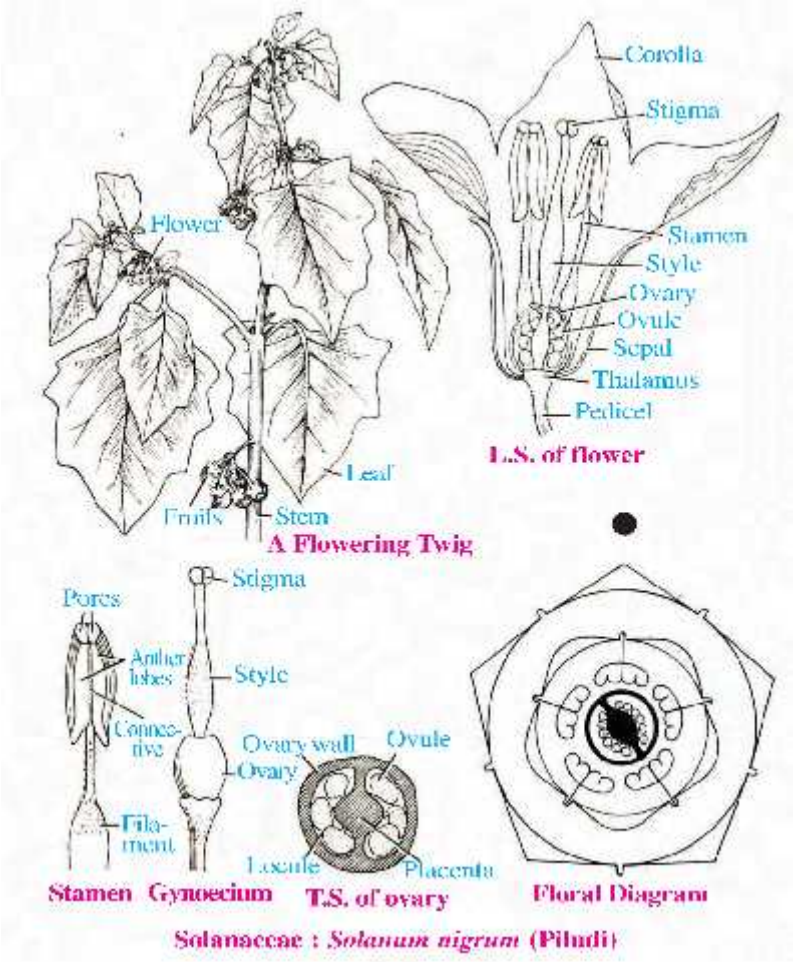
Many plants belonging to this family are the sources of pulses (Black gram, Green gram, Bean, Pea, Lentil) edible oil (Groundnut, Soyabean), dyes (*Indigofera*), fibres (Sun hemp), fodder (*Crotolaria, Sesbania*) and medicines (Muliathi).

Solanaceae

Classification :

Class – Dicotyledons
Subclass – Gamopetalae
Series – Bicarpellatae
Order – Polymoniales
Family – Solanaceae

It is a large family, normally called as the potato family.



Solanaceae : *Solanum nigrum* (Pilndi)

Vegetative Characters

Habitat : It is widely distributed in tropical and temperate regions.

Habit : Plants mostly herb, rarely climber, shrubs and small trees.

Stem : herbaceous, aerial, cylindrical, hairy, underground stem in potato.

Leaf : Simple, alternate, hairy, exstipulate, pinnately dissected, Venation reticulate.

Floral characters

Inflorescence : Solitary cyme or monochasial, helicold cyme, apical or axillary.

Flower : Complete, actinomorphic, bisexual, hypogynous.

Calyx : Sepals five, gamosepalous, tubular, valvate, persistent.

Corolla : Petals five, gamopetalous, valvate, variously shaped.

Androecium : Stamens five, epipetalous, introse.

Gynoecium : Bicarpellary, Syncarpous, ovary superior, many ovules in each locule, Placentation axile.

Fruit : Capsule or berry, seed endospermic.

Floral formula : Ebr, $\oplus$, φ, $K_{(5)}\ \overline{C_{(5)}\ A_5}\ \underline{G}_{(2)}$

Scientific name

(1) *Datura fastuosa* (Datura)

(2) *Solanum melongena* (Brinjal)

(3) *Solanum tuberosum* (Potato)

(4) *Solanum nigrum* (Piludi)

Economic importance

Many plants belonging to this family are the sources of food (Potato, Tomato, Brinjal), medicines (Ashwagandha) and spices (Chilli). Many plants are ornamental (Petunia).

Liliaceae

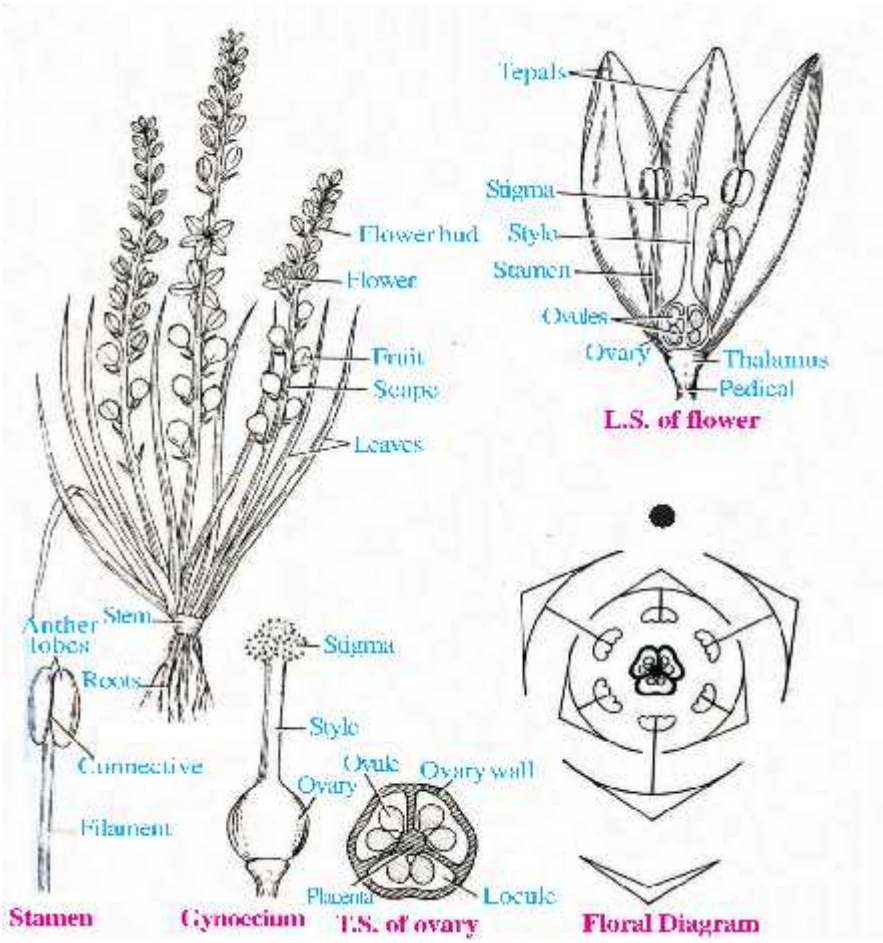
Classification :

Class – Monocotyledons

Series – Coronariae

Family – Liliaceae

Commonly called the lily family.



Asphodelus tenuifolius (Dungro)

Vegetative characters :

Habitat : It is distributed in the major parts of the world.

Habit : Mostly herbaceous, some are climbers (Asparagus) some are xerophyles (Agave). Vegetative reproduction mainly by bulb and rhizome.

Leaf : Simple alternate, opposite or whorled, exstipulate, mostly basal, venation parallel.

Floral characters :

Inflorescence : Solitary, axillary, cymose often umbellate clusters.

Flower : Complete actinomorphic, bisexual, bracteate, hypogynous.

Perianth : Perianth sepaloid or petaloid (3+3), free, valvate, aestivation.

Androecium : Stamen six (3+3), free or periphyllous, filament long, introse or extrose.

Gynaecium : Tricarpellary, syncarpus, ovary superior, trilocular with many ovules, axile placentation.

Fruit : Capsule rarely berry, seed endospermic.

Floral formula : Br, $\oplus$, $\male$, $\overline{P_{3+3}\ A_{3+3}}\ \underline{G}_{(3)}$

Scientific name

(1) *Allium cepa* (Onion)

(2) *Aloe vera* (Kunwarpathu)

(3) *Asparagus racemosus* (Satavari)

(4) *Gloriosa superba* (Vachhnag)

Economic importance :

Many plants belonging to the family are good sources of medicines e.g. Aloe and Asparagus. Many plants are ornamental (Tulip).

Summary

When the young plants grow and the vegetative parts mature, flowers make their appearance. The arrangement of flowers on the rachis is called inflorescence. There are two main types of inflorescence – racemose and cymose. The flowers are arranged in different types of inflorescence. A typical flower consists of four whorls – calyx, corolla, androecium and gynoecium. The arrangement of sepals or petals in the bud condition of the flower is called aestivation. The main types of aestivations are valvate, twisted, imbricate, quincuncial and vexillary. Androecium is composed of stamens. Stamens of flowers may be free or united with other members such as petals or among themselves. Gynoecium is the inner most female reproductive part of the flower and is made up of one or more carpels. A carpel consists of three parts namely stigma, style and ovary. When more than one carpel is present, they may be free of fused. The arrangement of ovules within the ovary is called placentation. The placentations are of different types namely marginal, axile, parietal, basal and free central. Types of flowers can be described from the various points of view such as presence of four whorls, presence of bracts and position of ovary in relation to other parts. After fertilization, the ovary is converted into fruit and ovules into seeds. Based on origin and development, three kinds of fruits occur – simple, aggregate and composite. Simple fruit may

be dry or fleshy. Dry fruits are dehiscence or indehiscence. Fleshy fruits may be of three types - drupe, berry and pome . On the basis of the kinds of the fruitlets, the aggregate fruits are named. A composite fruit develops from all the flowers of a whole inflorescence. Seeds may possess either two cotyledons or one cotyledon and may be endospermic or non-endospermic. The floral characteristics form the basis of classification and identification of flowering plants. This can be illustrated through semi-technical description of families. Hence, a flowering plant is described in a definite sequence by using scientific terms. The floral features are represented in the summarized form as floral diagram and floral formula.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Which of the following plants shows spike inflorescence ?

(A) Mustard ◯ (B) Caesalpinia ◯

(C) Achyranthus ◯ (D) Mulberry ◯

(2) Onion is the example of which type of inflorescence ?

(A) Capitulum ◯ (B) Catkin ◯

(C) Spadix ◯ (D) Umbel ◯

(3) _____ is the example of scorpioid type of inflorescence.

(A) Hamelia ◯ (B) Heliotropium ◯

(C) Hibiscus ◯ (D) Argemone ◯

(4) The expanded and swollen tip of the pedicel is called _____

(A) Rachis ◯ (B) Thalamnus ◯

(C) Peduncle ◯ (D) Receptacle ◯

(5) Which of the following are accessory floral organs ?

(A) Calyx and gynoecium ◯ (B) Androecium and Corolla ◯

(C) Calyx and Corolla ◯ (D) Gynoecium and Corolla ◯

(6) Of the following which is an example of perianth ?

(A) Hibiscus ◯ (B) Sunflower ◯

(C) Crinum ◯ (D) Datura ◯

(7) Which of the following is an example of vexillary placentation ?

(A) Cassia ◯ (B) Cotton ◯

(C) Pea ◯ (D) Melia ◯

(8) Of the following which is an example of imbricate placentation ?

(A) Gulmoher ◯ (B) Cucurbita ◯

(C) China Rose ◯ (D) Bean ◯

(9) What is true for Sunflower ?

(A) Superior ovary ◯ (B) Epigynous flower ◯

(C) Axial placentation ◯ (D) Umbel inflorescence ◯

(10) Semi-inferior ovary is observed in _____ flower.

(A) Epigynous ◯ (B) Perigynous ◯

(C) Hypogynous ◯ (D) None of above ◯

(11) Which of the following is called fertilized and ripened ovary ?

(A) Seed ◯ (B) Ovule ◯

(C) Fruit ◯ (D) Placenta ◯

(12) Maize is an example of _____ type of fruit.

(A) Cypsela ◯ (B) Achene ◯

(C) Caryopsis ◯ (D) Nut ◯

(13) Which of the following is an example of follicles fruit ?

(A) Calotropis ◯ (B) Cotton ◯

(C) Maize ◯ (D) Apple ◯

(14) Which type of the fruit is pineapple ?

(A) Capsule ◯ (B) Etaerio of follicle ◯

(C) Composite ◯ (D) Etaerio of berries ◯

(15) _____ is an example of endospermic seed.

(A) Gram ◯ (B) Pea ◯

(C) Bean ◯ (D) Maize ◯

(16) Which of the following is sign for bisexual flower ?

(A) ⚥ ◯ (B) ♀ ◯

(C) ♂ ◯ (D) % ◯

(17) _____ is an example of family solanaceae.

(A) Karanja ◯ (B) Potato ◯

(C) Gram ◯ (D) Satavari ◯

2. Explain/Define the following terms :

Anthotaxy, Catkin, Spike, Involucre, Aestivation, Gamopetalous, Placentation, Actinomorphic flower, Perianth, Hypogynous flower, Fruit, Seed, Caryopsis, Drupe,

3. State the example of the following :

Umbel inflorescene, Helicoid, monochasial cyme, Perianth, syncarpous carpel, Diadelphous, Polypetalous, Hypogynous, Actinomorphic, Imbricate aestivation, Basal placentation, True fruit, Caryopsis, Parthenocarpic fruit, Hull, Berry, Etaerio of berries, Aggregate fruit, Non-endospermic seed, Liliaceae family, Solanaceae family

4. Write notes on :

(1) Capitulum inflorescence

(2) Uniparous cyme inflorescence

(3) Corolla

(4) Aestivation

(5) Gynoecium

(6) Types of flower on the basis of position

(7) Indehiscent dry fruit

(8) Fleshy fruit

(9) Aggregate fruit

(10) Embryonic region in dicot seed

(11) Floral diagram

(12) Placentation of ovary

5. Distinguish between :

(1) Racemose inflorescence – Cymose Inflorescence

(2) Uniparous inflorescence – Biparous Inflorescence

(3) Hypogynous flower – Epigynous flower

(4) Regular flower – Irregular flower

(5) Androecium – Gynoecium

(6) Axile placentation – Parietal placentation

(7) Simple fruit – Fleshy fruit

(8) Simple fruit – Aggregate fruit

(9) Bean Seed – Maize Seed

(10) Papilionaceae – Liliaceae

6. Draw labeled diagram of :

(1) L.S. of typical flower

(2) Spadix inflorescence

(3) Vexillary aestivation

(4) L.S. of dicot seed

(5) L.S. of Monocot seed

7. What is inflorescence ? Describe Racemose types of inflorescence with figure.

8. Describe various types of flowers.

9. What is aestivation ? Describe various types of aestivation.

10. What is placentation ? Describe various types of placentation with figure.

11. Describe various types of fleshy fruits.

12. Describe structure of dicotyledonous seed.

13. Describe structure of Maize seed.

14. Give general character of Papilionaceae family. Give scientific names of two plants from the family.

15. Give classification of Solanaceae family. Describe it with diagram of floral characters.

16. How is the floral diagram of family Liliaceae constructed ?

3

Anatomy of Flowering Plants

The plant body is made up of cells. The cells are organized into tissues and in turn various tissues are organized together and form tissue system. Tissue systems form organs. Different organs in a plant show differences in their internal structures. Study of internal structure of plant is called plant anatomy. Within angiosperms, the monocots and dicots are also seen to be anatomically different. In previous chapter we have studied external morphology of plants. Now we shall study the internal structure of plant organs.

The Tissue

A tissue is a group of cells having a common origin and performing specific functions. A plant is made up of different kinds of tissues. Plant tissues can be divided mainly into two groups.

(1) Meristematic tissues (2) Permanent tissues

(1) Meristematic tissues : Meristematic tissues consist of actively dividing cells. A group of actively dividing cells is known as meristem. Plants have different kinds of meristems.

The meristems which are found at the tips of shoots and roots and produce primary tissues are called apical meristems. These meristems are responsible for the linear growth of the plants. During elongation of stem, some cells are left behind the apical meristem of shoot and they constitute the axillary bud. Such buds are present in the axils of leaves and are responsible for the formation of flower or a branch.

The meristem which is located in between permanent tissues is called intercalary meristem. Such meristems occur in grasses and regenerate parts eaten up by the grazing herbivores.

Both apical meristems and intercalary meristems are primary meristems because they appear early in the life of plant and contribute to the formation of primary plant body.

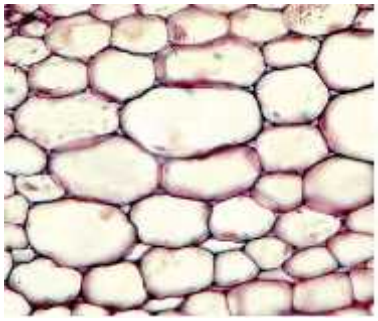
The meristem that occurs in the mature regions of shoots and roots of many plants and appear later than primary meristem is called secondary or lateral meristem. Lateral

meristem usually occurs beneath the bark of the tree in the form of cork cambium and in the vascular bundles of dicots in the form of vascular cambium. The activity of this meristem results in the formation of secondary growth.

(2) Permanent tissues : Following divisions of the cells in both primary and secondary meristems, the newly formed cells become structurally and functionally specialized and lose the ability to divide. Such cells are known as permanent cells and constitute permanent tissues. There are two types of permanent tissues : i) Simple permanent tissue and ii) Complex permanent tissue.

Simple tissue consists of a single type of cell, while the complex tissue is formed of different types of cells having different structural and functional peculiarities. However, such different types of cells together contribute to the functioning of the complex tissue they form.

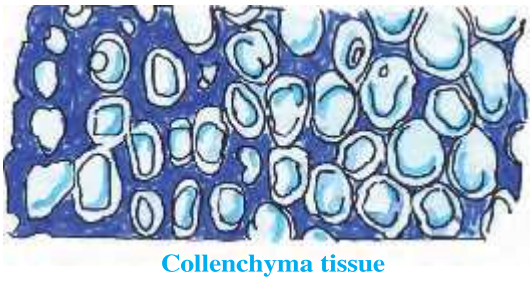
Simple tissues : These tissues are called simple because they are composed of similar types of cells which have common origin and function. They are named and classified on the basis of their structural and functional characteristics as follows :



Parenchyma tissue

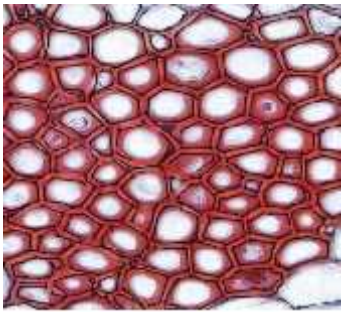
Parenchyma : This simple permanent tissue mainly consists of thin walled cells which are either closely packed or have intercellular spaces. The cell wall is made up of cellulose. Each parenchymatous cell is isodimetric, spherical or oval in shape. This tissue is widely distributed in various plant organs like root, stem leaf, flowers and fruits. The parenchyma performs various functions like photosynthesis, storage, secretion etc.

Collenchyma : The cells of this simple permanent tissue are living. The cell wall is made up of cellulose and the inner walls show the deposition of pectin. Such thickening is more prominent in the angular walls where number of cells join together. This tissue renders elasticity and flexibility to the organs and hence, it is found in tender stem and petiole. The cells are compactly arranged and do not have intercellular spaces. It occurs chiefly in hypodermis of stems and leaves but is absent in monocots and underground parts of the plants. The cells being alive do not arrest the growth of the organ in which they are located but protect the organ by rendering flexibility and elasticity.



Collenchyma tissue

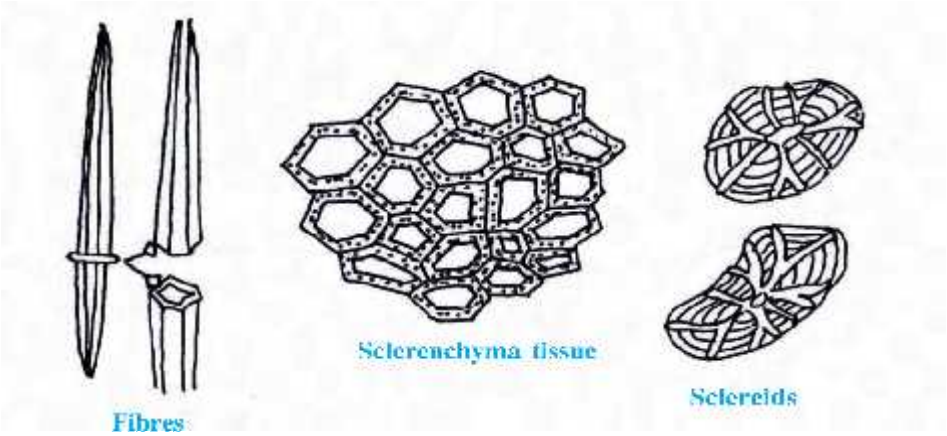
Sclerenchyma : This tissue consists of thick walled, dead cells. These cells have hard and extremely thick secondary walls due to uniform deposition of lignin. Lignin deposition is so thick that the cell walls become strong, rigid and impermeable to water. Cells do not have intercellular spaces between them. This tissue mainly occurs in hypodermis, pericycle, secondary xylem and phloem and provides mechanical support to the organs. On the basis of variations in form, structure, origin and development, sclerenchyma are of two types :



Sclerenchyma tissue

(1) Fibres : thick walled, elongated and pointed cells found in various parts of the plants

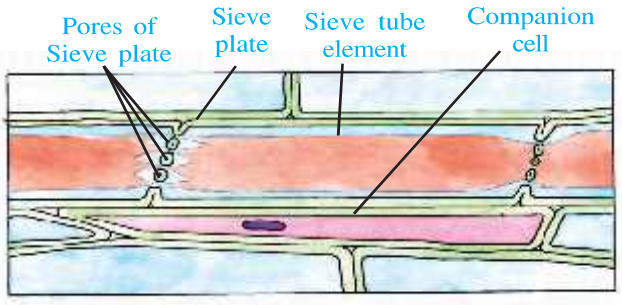
(2) Sclereids : spherical, oval or cylindrical thickened dead cells with very narrow lumen. These are commonly found in the fruit walls of nuts, pulp of fruits like guava, pear and sapota; seed coats of legumes and leaves of tea.



Complex tissue : A complex permanent tissue is a group of more than one type of tissues having a common origin and working together as a unit to perform a function. These tissues are concerned with transportation of water, mineral, nutrients and organic substances and, hence, they are also called conducting tissues. Xylem and phloem are the examples of complex permanent tissues.

Xylem : The xylem transports water and mineral ions from the root to the rest of the plant. Structurally it consists of tracheids, vessels, xylem parenchyma and xylem fibres. Tracheids and vessels have secondary wall thickening and lose their cytoplasm at maturity; hence they are dead yet functional. Tracheids have pointed ends and overlap each other, whereas vessel elements have open end walls and are arranged end to end to form a larger unit called vessel. Tracheids are found in pteridophytes and gymnosperms, while vessels are present in angiosperms. Tracheids and vessels are the main water transporting elements. Xylem parenchyma are living cells and they store starch, lipid, tannin and crystalline substances. Xylem fibres have highly thickened walls and provide mechanical support.

Phloem : The phloem transports the products of photosynthesis throughout the plant. In angiosperms phloem consists of sieve tube elements, companion cells, phloem parenchyma and phloem fibres. Gymnosperms are in lack of sieve tube elements and companion cells but they have albuminous cells and sieve cells. Sieve tubes are long, tubular structures. They are made up of many cells arranged longitudinally one above the other. The transverse wall separating them become perforated and form sieve plate. Sieve tubes are associated with companion cells. Phloem parenchyma is made up of elongated, tapering cylindrical cells which have dense cytoplasm and nucleus. The parenchymatous cells store food materials and other substances like mucilage, resin, latex etc. Phloem fibres are sclerenchymatous cells. They are much elongated, unbranched and have pointed needle like apices. They provide mechanical support.



Phloem

The Tissue System

A tissue system is formed by organization of tissues. Tissue systems organize to form an organ. There are three types of tissue systems found in plant organs like root, stem and leaf.

(1) Epidermal tissue system (2) Ground tissue system (3) Vascular tissue system

Epidermal tissue system : It is represented by the epidermis and the associated structures. The epidermis is the outer most layer of the plant organs. It is usually a single layer of compactly arranged barrel shaped parenchymatous cells. In the stem and leaf, the epidermis cells are thick walled and are meant for protection. The epidermis of stem and leaf is usually surrounded by a thin covering called cuticle which prevent the loss of water. In root the epidermal cells are thin walled, since they are mainly involved in the absorption of water and mineral salts. Hence, the epidermis of root is described as epiblema or pilliferous layer. In epiphytic roots of orchid, it is multilayered. Cuticle is absent in root.

The epidermis usually forms projections known as epidermal hairs. In the root, the epidermal hairs are unicellular and are called as root hairs. The root hairs penetrate between the soil particles to absorb water. In the stem and the leaf, the epidermal hairs are multicellular and are known as trichomes. The trichomes help in preventing water loss due to transpiration and they may be secretory.

The epidermis of leaf and herbaceous stem contains numerous minute opening called stomata. Each stoma is surrounded by two bean shaped cells known as guard cells. In grasses, the guard cells are dumb-bell shaped. The guard cells possess chloroplast and regulate the opening and closing of stomata. Sometimes along with guard cells subsidiary cells are also present. The stomatal aperture, guard cells, and surrounding subsidiary cells are together called stomatal apparatus.

Ground tissue system : All structures except the epidermis and the conducting tissues are included in ground tissue system. It consists of simple tissues such as parenchyma, collenchyma and sclerenchyma. In a typical condition, following regions can be seen in the ground tissue :

Hypodermis is found below the epidermis. It is made up of few layers of collenchyma or sclerenchyma. It provides protection and mechanical support. Cortex is a major component of ground tissue represented by many layers of loosely arranged parenchyma cells. Endodermis is the innermost layer of cortex and made up of compactly arranged barrel shaped parenchyma cells. Pericycle is a region that lies immediately below the endodermis. In the stem it is represented by a few layers of sclerenchyma cells while in root, it is represented by a single layer of parenchyma cells.

Pith is the innermost part of the stem or root indicating the axis. It is formed by the loosely arranged parenchyma cells.

In leaves the ground tissue consists of thin walled chloroplast containing cells and is called mesophyll.

Vascular tissue system : Vascular tissue system is formed by the organization of conducting tissues. Normally, constituents of xylem and phloem jointly form vascular bundles. Thus a vascular bundle can be considered a unit of vascular tissue system.

The vascular bundles may sometimes possess cambium (Meristematic tissue) between xylem and phloem. When cambium is present, the vascular bundle is described as open and when the cambium is absent, the vascular bundle is described as closed.

A vascular bundle may contain either only phloem or only xylem or both. Accordingly, based on the relative position of xylem and phloem the bundles can be distinguished into following types :

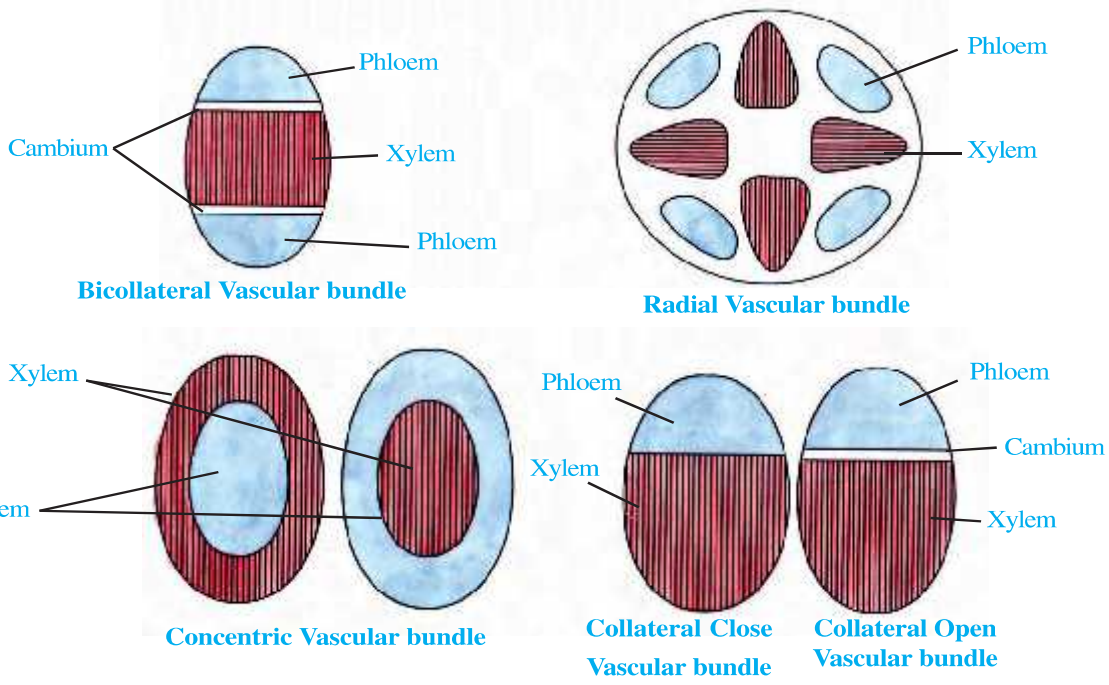
(1) Radial : These vascular bundles are made up of only xylem or only phloem. They are arranged alternately on different radii. Such bundles are found in roots.

(2) Conjoint : The vascular bundles in which xylem and phloem occur together are called conjoint vascular bundles. They are of three types :

(a) Concentric : In such type of vascular bundle, one conducting tissue completely surrounds another one.

(b) Collateral : When phloem occurs radially outside the xylem on the same radius, the vascular bundle is called collateral.

(c) Bicollateral : In this type, phloem occurs radially on both the sides of xylem on the same radius.



Anatomy of Dicotyledonous and monocotyledonous plants

The various organs of higher organisms are made up of several different tissues. The various plant organs like root, stem and leaf show different tissue organization in their anatomy which can be observed in stain preparations in transverse and longitudinal sections. Let us see some examples.

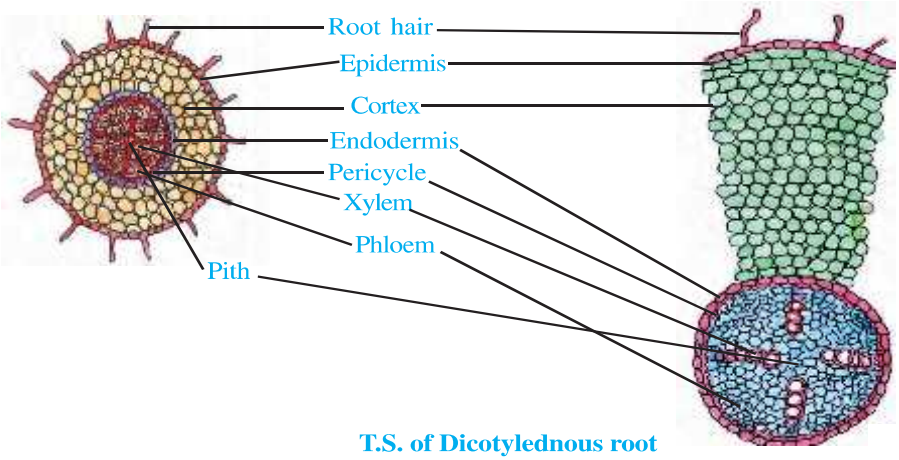
Dicotyledonous Root : A very thin transverse section of young root of sunflower stained with very dilute solution of safranine, show the structure under the microscope as follows :

Epidermis, also called epiblema, forms an outermost single layer of parenchymatous cells. Many of the epidermal cells protrude in the form of unicellular root hairs. Root hairs increase the absorptive surface of epidermis for the absorption of water and dissolved mineral salts. The cortex, present below the epidermis, consists of many layers of thin walled parenchyma cells with intercellular spaces. The endodermis is the innermost layer of cortex made up of barrel shaped compactly arranged cells.

The radial walls of the barrel shaped cells of endodermis show thickening of water impermeable wax like suberin as well as lignin in the form of strips called Casparian strips. Next to endodermis a few layers of parenchyma cells are present which referred to as pericycle. The lateral or secondary roots originate from the pericycle.

The medulla or pith forms the parenchymatous central core of the root. The parenchymatous cells present between xylem and phloem are called conjuctive tissue.

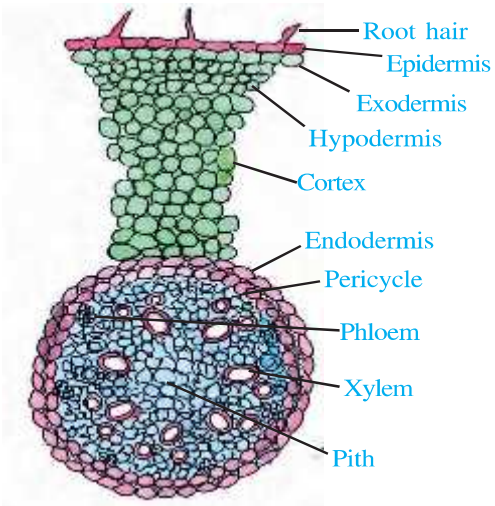
There are usually two to four xylem and phloem patches. All tissues on the inner side of endodermis such as pericycle, vascular bundles and pith constitute stele. Thus the stele in sunflower root is radial, alternate and tetrarch.



T.S. of Dicotylednous root

Monocotyledonous Root : The anatomy of monocot root is similar to the dicot root in many respects. It has epidermis, cortex, endodermis, pericycle, vascular bundles and pith.

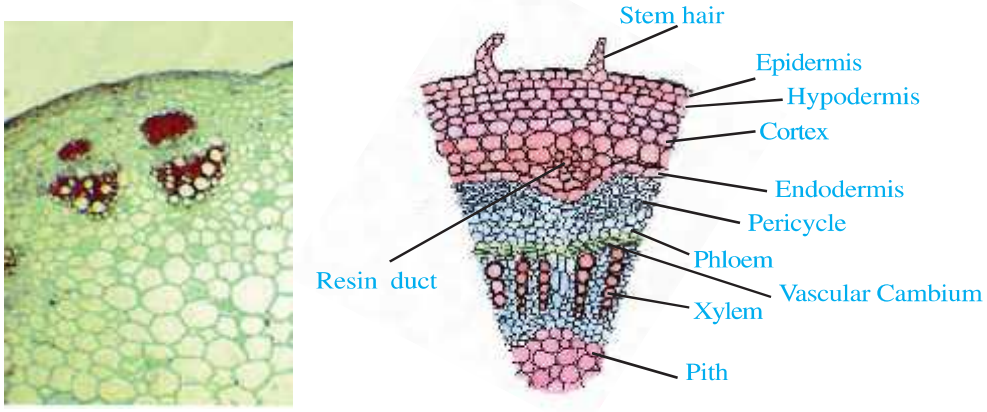
In maize root below the epidermis, a single layer of thick walled parenchyma cells is present which is called as exodermis. When the epidermis is destroyed, the exodermis becomes protective in function. A few layers of sclerenchyma cells present below the exodermis as hypodermis. It provides mechanical support.



T.S. of Monocotylednous root

As compared to dicot root which have fewer xylem bundles, there are usually more than six exarch xylem bundles (polyarch) in monocot root. The protoxylem lies towards the peripheral side and metaxylem lies towards the pith, the condition is called exarch. Pith is larger and well developed. Stele is radial, alternate and polyarch.

Dicotyledonous Stem : The epidermis of the stem is single layered and parenchymatous. The outer surface of these cells is covered by cuticle. The epidermis has several multicellular hairs called trichomes. Scattered stomata may be seen among the epidermal cells.



T.S. of Dicotyledonous stem

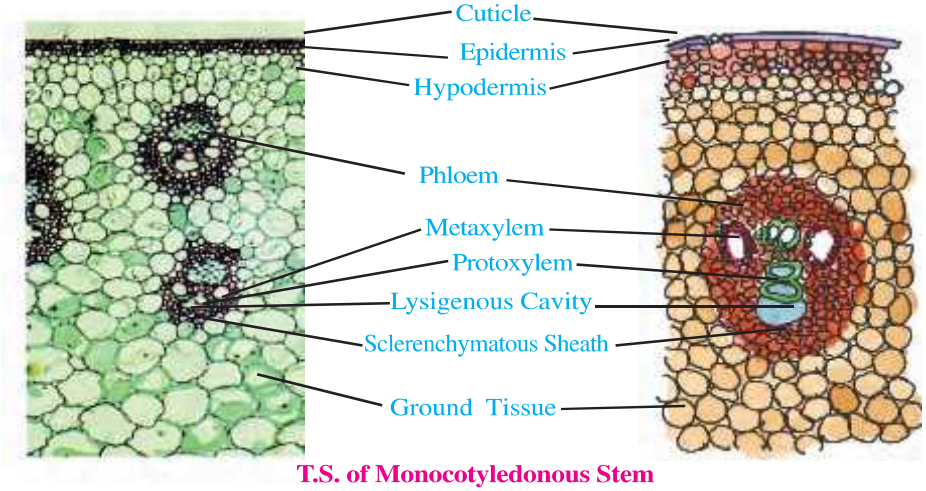
The cells arranged in multiple layers between epidermis and pericycle constitute the cortex. It consists of three sub-zones. The outer few layers of collenchyma cells form hypodermis beneath the epidermis. Hypodermis is followed by multilayered parenchymatous cortex having distinct intercellular spaces. The inner most layer of cortex is called endodermis. The parenchyma cells of endodermis contain starch grains and therefore it is also known as starch sheath.

Pericycle is present on the inner side of the endodermis and above the phloem in the form of semi-lunar patches of sclerenchyma.

A large number of vascular bundles are arranged in a ring. Ring arrangement of vascular bundles is a characteristic of dicot stem. In between the vascular bundles a few layers of radially arranged parenchyma cells are present which constitute **medullary rays.**

Each vascular bundle is **conjoint, collateral and open**. As the protoxylem lies on the inner side towards the medulla and metaxylem lies towards the periphery the xylem is described as endarch.A large size of parenchyma cells with intercellular spaces occupy the central position and form **pith.**

Monocotyledonous Stem : In the monocot stem, beneath the epidermis a sclerenchymatous hypodermis made up of 2 to 4 layers is present.

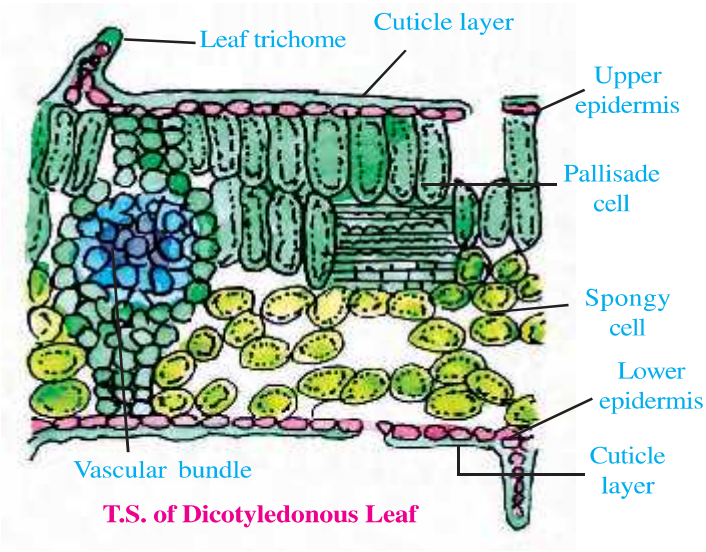


T.S. of Monocotyledonous Stem

Ground tissue is not differentiated into various regions such as cortex, endodermis, pericycle, medulla and medullary rays but is formed of round and oval thin walled parenchymatous cells having intercellular spaces.

A large number of vascular bundles, each surrounded by sclerenchymatous sheath are scattered in the ground tissue. Peripheral vascular bundles are generally smaller than the centrally located ones. Vascular bundles are conjoint (collateral) and closed. The phloem parenchyma is absent and water containing lysigenous cavities are present within the vascular bundles.

Dorsiventral (Dicotyledonous) Leaf : The transverse section of dorsiventral leaf shows three main parts namely epidermis, mesophyll and vascular system.



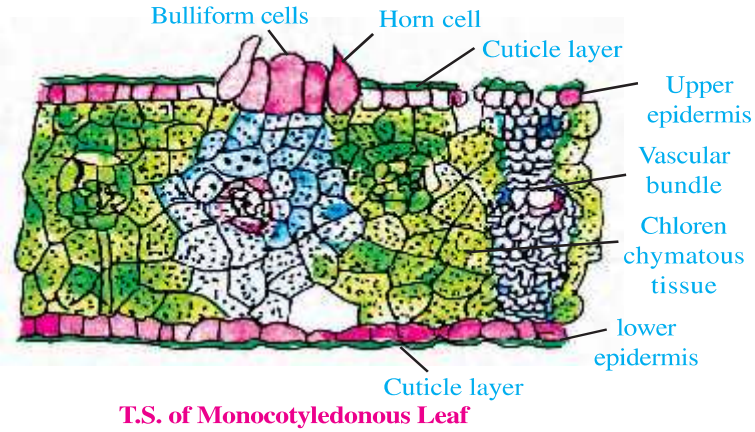
T.S. of Dicotyledonous Leaf

The parenchymatous epidermis which covers both the upper surface (upper epidermis) and lower surface (lower epidermis) is highly cutinized and possesses multicellular trichomes and stomata. The number of stomata is larger in lower epidermis than in the upper epidermis.

Ground tissue system consists of chlorenchyma. It has two regions. The region present below the upper epidermis is made up of elongated and compactly arranged cells, known as palisade. The spongy type of chlorenchyma made up of loosely arranged cells occupy the remaining region up to the lower epidermis. Large air spaces occur in this region.

As two different types of mesophyll tissues occur towards upper and lower epidermis, the dicot leaf is called a bilateral dorsoventral leaf.

Vascular system includes vascular bundles which can be seen in the veins and the midrib. Vascular bundles are conjoint, collateral and closed. The xylem points towards the upper epidermis while phloem points towards lower epidermis. Vascular bundles are surrounded by parenchymatous bundle sheath.



T.S. of Monocotyledonous Leaf

Isobilateral (Monocotyledonous) Leaf : The anatomy of isobilateral leaf is similar to that of the dorsiventral leaf in many ways. However, it shows the following characteristic differences:

In monocot leaf, the stomata are present on both the surfaces of epidermis. Mesophyll is not differentiated into palisade and spongy chlorenchyma. In the upper epidermis of grass leaf, bulliform cells occur

at regular intervals. They occur in groups of five to seven cells. They lack cuticle and chloroplasts. Curved trichomes occur on their lateral sides. In dry condition, they lose water and shrink. Thus they cause rolling of leaf blade. As a result transpiration is reduced. In humid condition, they absorb water, swell and cause unrolling of leaf. As these cells cause movement of leaf, they are also called motor cells. As entire mesophyll is made up of spongy type of chlorenchyma, the leaf is called isobilateral leaf. The sclerenchymatous sheath surrounds the large vascular bundles and a parenchymatous sheath surrounds the smaller ones.

Secondary Growth

The lengthwise growth of roots and stems is due to apical meristem and this type of growth is known as primary growth. In most of dicotyledons, after the completion of primary growth further increase in girth takes place due to the formation of secondary tissues. This increase is called secondary growth. The secondary growth involves lateral meristems like vascular cambium and cork cambium.

(1) Vascular cambium : The meristem producing the secondary xylem and phloem is called the vascular cambium. In young stem it is present in patches as a single layer between xylem and phloem. Later it forms a complete ring.

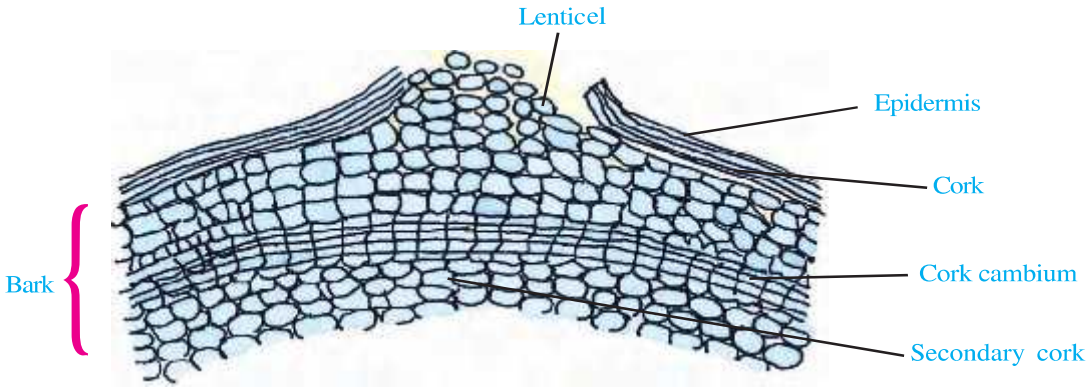
Formation of cambium ring : The cambium present between primary xylem and primary phloem is known as intrafascicular cambium. At the time of secondary growth, the cells of medullary rays, in a line with intrafascicular cambium become meristematic and form interfascicular cambium. Intrafascicular and interfascicular cambium joined to form a continuous ring, known as cambium ring.

Formation of Secondary tissues : The cambium ring becomes active and starts dividing producing new cells, both towards the inner and outer sides. The cells produced towards inner side mature into secondary xylem while the cells produced outer side differentiate into secondary phloem. The cambium is more active towards pith and hence, more amount of secondary xylem as compared to that of secondary phloem is produced. At maturity, this secondary xylem forms the main bulk of the stem. By its pressure primary and secondary phloems get crushed. The primary xylem, however, does not lose its identity for considerable time period. At some places, the cambium forms narrow bands of radially elongated, parenchymatous cells both on the outer and inner sides instead of phloem and xylem. These form the secondary medullary rays. In temperate region, the climatic conditions are not uniform throughout the year. In spring season, cambium is very active producing large number of xylary elements. This wood is called spring wood or early wood. In winter, cambium is less active and produces fewer xylary elements. This wood is known as autumn wood or late wood.

Heart Wood and Sap Wood : In older stem, where sufficient amount of secondary growth has taken place, the secondary wood loses the power of conduction and its cells are filled with tannin and other substances. It becomes hard and durable and is blackish in color. This region is known as heart wood or duramen and its function is to give mechanical support to the plant. The outer region of secondary wood, which consists of younger xylem cells, is yellow in color and is known as sap wood or alburnum. It does the function of water conduction.

(2) Cork Cambium : Due to activity of vascular cambium stem increases in girth. This increase makes pressure on outer cortical and epidermal layers resulting the break down of these layers. Hence, sooner or later another meristematic tissue called cork cambium or phallogen develops, usually in the cortical region. Phellogen cuts off cells on both the sides. The outer cells differentiate into cork or phellem while the inner cells differentiate into secondary cortex or phelloderm. Phellogen, phellem and phelloderm are collectively known as periderm. The new cells formed on the outside of the cork cambium lose their contents, become filled with air and are arranged in rows at right angle to the surface forming dead impervious layer. This layer is called cork. The cork cells being suberized check the outward passage of water. The outer tissue become dead and acts as the bark. Thus, the bark includes all the dead tissues lying outside the cork cambium. Bark that is formed early in the season is called early or soft bark. Towards the end of season late or hard bark is formed.

By the formation of periderm the stomata are closed and also the cuticular respiration is checked. To replace this, some aerating pores are formed in the bark which are called lenticels. Through these pores exchange of gases and evaporation of water can take place.



The lenticel

Secondary growth in roots : In dicot root vascular cambium originates in the form of strips from the tissue located just below the phloem bundles. The number of strips depends upon the number of phloem bundles. These strips extend both ways in between xylem and phloem and ultimately unites with each other to form a continuous ring. Further events are similar to those already describe above for a dicotyledon stem.

Summary

A tissue is a group of cells having a common origin and performing specific functions. In plants, two types of tissues are found i.e. meristematic tissue and permanent tissue.

Meristematic tissues consist of actively dividing cells. On the basis of their locations they are classified into three types (1) apical meristem, (2) intercalary meristem and (3) lateral meristem. Apical meristem and intercalary meristem are primary meristems because they appear early in the life of plant and contribute to the formation of primary plant body. As the lateral meristem appears later than primary meristem, it is called secondary meristem.

Cells of permanent tissues do not possess the property of cell division and these tissues are structurally and functionally specialized. Permanent tissues may be simple or complex.

Simple permanent tissues consist of similar types of cells. They are classified into parenchyma, collenchyma and sclerenchyma. A complex permanent tissue is a group of more than one type of tissues having common origin and working together as a unit to perform a function. These tissues are concerned with transportation of water, minerals and nutritions. Xylem and phloem are complex permanent tissues.

Three types of tissue systems are found in plant organs like root, stem and leaf. Epidermal tissue system is represented by the epidermis and the associated organs like cuticle, hairs, stomata etc. Ground tissue system is made up of hypodermis, cortex, endodermis, pericycle, and pith while vascular tissue system consists of xylem and phloem.

In most of the dicotyledons, after completion of the primary growth, further increase in girth takes place due to formation of secondary tissues. The secondary growth involves lateral meristems like vascular cambium and cork cambium.

The lengthwise growth of roots and stems is due to apical meristem and this type of growth is known as primary growth. The secondary growth involves lateral meristem like vascular cambium and cork cambium. These are the secondary tissues responsible for growth in breadth or girth.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) The tissue in which cells are having property of cell divisions is known as :

(A) Permanent tissue ◯ (B) Meristematic tissue ◯

(C) Xylem ◯ (D) Phloem ◯

(2) The meristem which is responsible for the linear growth in the plant is :

(A) Lateral meristem ◯ (B) Apical meristem ◯

(C) Vascular cambium ◯ (D) Cork cambium ◯

(3) Which of the following is primary meristem ?

(A) Intercalary meristem ◯ (B) Lateral meristem ◯

(C) Vascular cambium ◯ (D) Cork cambium ◯

(4) Which of the following tissues possesses dead thick walled cells ?

(A) Parenchyma tissue ◯ (B) Collenchyma tissue ◯

(C) Sclerenchyma tissue ◯ (D) Meristematic tissue ◯

(5) In which type of tissue the inner wall of cell shows the deposition of pectin ?

(A) Parenchyma tissue ◯ (B) Collenchyma tissue ◯

(C) Sclerenchyma tissue ◯ (D) Meristematic tissue ◯

(6) Which of the following tissues provides elasticity and flexibility to the organs ?

(A) Parenchyma tissue ◯ (B) Collenchyma tissue ◯

(C) Sclerenchyma tissue ◯ (D) Meristematic tissue ◯

(7) Which of the following is the living component of xylem ?

(A) Tracheid ◯ (B) Xylem Vessel ◯

(C) Xylem parenchyma ◯ (D) Xylem fibre ◯

(8) Which of the following is the dead component of phloem ?

(A) Sieve cell ◯ (B) Companion cell ◯

(C) Phloem parenchyma ◯ (D) Phloem fibre ◯

(9) Casparian strips can be seen in the endodermis of

(A) Dicot root ◯ (B) Monocot stem ◯

(C) Monocot leaf ◯ (D) Dicot stem ◯

(10) The collenchymatous hypodermis can be seen in

(A) Monocot root ◯ (B) Monocot stem ◯

(C) Dicot stem ◯ (D) Dicot leaf ◯

(11) The sclerenchymatous hypodermis can be seen in

(A) Dicot stem ◯ (B) Monocot stem ◯

(C) Dicot root ◯ (D) Dicot leaf ◯

(12) In which plant organ stele is radial, alternate and polyarch ?

(A) Monocot stem ◯ (B) Monocot root ◯

(C) Dicot stem ◯ (D) Dicot root ◯

(13) In which plant organ stele is radial, alternate and tetrach?

(A) Monocot stem ◯ (B) Monocot root ◯

(C) Dicot stem ◯ (D) Dicot root ◯

(14) Bulliform cells are found in

(A) Dicot leaf ◯ (B) Monocot leaf ◯

(C) Dicot stem ◯ (D) Monocot stem ◯

2. Answer in short :

(1) Define meristematic tissue

(2) Define complex permanent tissue

(3) What is spring wood ?

(4) Why dicot leaf is known as dorsiventral leaf ?

(5) Define : Radial and collateral types of vascular bundles.

3. Do as directed :

(1) Differentiate between collenchyma and Sclerenchyma

(2) Differentiate between Heart wood and Sap wood

(3) Give reason : Bulliform cells are present in the maize leaf

(4) Give reason : Collenchyma tissue is considered as living mechanical tissue

(5) Differentiate between isobilateral leaf and dorsiventral leaf

(6) Write properties of meristematic tissues

(7) Name the regions which form ground tissue system

(8) Give location and functions of Casperian Strips.

(9) Give location and functions of vascular cambium

(10) Give location and functions of lateral meristem

4. Long answer questions :

(1) Describe the structure and functions of various components of xylem.

(2) Describe the types of simple permanent tissues

(3) Explain the structure and functions of various components of phloem.

(4) Explain the different types of tissue systems found in the various organs of plants.

(5) How the vascular cambium is responsible for secondary growth ? Explain.

(6) Explain the internal structure of monocot root.

(7) Describe the internal structure of dicot stem with the help of labelled diagram.

(8) Explain the internal structure of monocot leaf.

(9) Describe the internal structure of dicot leaf.

(10) Explain, with labelled diagram, the stele of dicot root.

Naturalist Jaikrishan Indraji

Naturalist Jaikrishan was born in Girnara Brahmin caste in Lakhapat village of Kachcch on the day of Aso sudh dasham (Vijayadashmi) in Sanwat 1905. His father's name was Indraji Thakar. During his childhood he had an abnormal interest in physical exercise which was proved worth during his frequent visits to jungle. He spent his adolescence in Mathura.

In his Dec. 22, 1929 issue of "Navjivan" Pujya Gandhiji wrote about Jaikrishan Indraji that "many times he wandered in Barda Dungar for the search of plants. He made herbaria of many plant specimens in his own house. He was having tremendous interest in the identification of plants and hence, I always considered him as an ideal student".

Shri Jaikrishan didn't receive any degree in Science from any university but he worshipped science. He was an avid follower of science and inspired the generation of students to follow the path of science. Day and night he worshipped Botany. In a real sense he was the Linnaeus of Gujarat. He was also a great lover of nature and books.

Under the guidance of Pandit Bhagwanlalbhai he first started identifying flowering plants and as per his direction he read the book of botany written by Hucker and came to know the scientific names of plants. After that he came in contact with Dr. Sakharm Arjun (Botanist) who introduced Jaikrishan to Dr. Mc Donald (Botany Teacher). Many other European friends have appreciated his amazing knowledge of Botany and helped him. He learnt the properties of dynamism and regularities from them. In the beginning he was writing about the plants in monthly magazine "Vaidh Kalpataru". Later on he wrote books like "Vanspatishastra" and "Kachchh Ni Jadi Butti".

Many rare books of English literature were in his home library and some of those books were gifted to him by his British friends. The Volumes of the Hucker were his most favourite. The life of Jaikrishan was for the people. The early half of his life was spent in the study of botany while the later half was spent in worshipping god . Lotus was his favourite flower.

This great soul breathed his last in Bhuj on Magsar Sudh Bij of Sanwat 1968.

4

Animal Tissue

As you have studied that body organization process remains dynamic where multicellularity resulted with complexity due to which there was need for division of labour and coordination. As a result, group of cells structurally and functionally became similar and organised into tissues. Its sequential formation is as follows :

Complex body
↑
Organ Systems
↑
Organs
↑
Tissues
↑
Cells

The present chapter is aimed to understand various types of tissues in animals in general. Animals contain four basic types of tissues. Each basic tissue has its own characteristics and distinguished appearance. These basic tissues are :

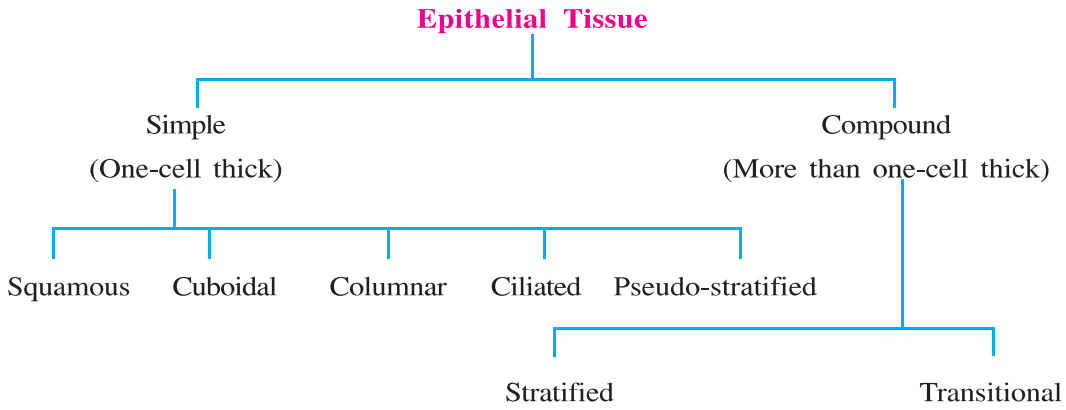
(1) Epithelial tissue (2) Connective tissue (3) Muscular tissue (4) Nervous tissue

(1) Epithelial tissue : The epithelial tissue is highly specialised to perform the functions of protection, absorption and secretion. It covers the external surface of the body and internal free surfaces of many organs. According to the function the cells, arrangements are different. As for example, the skin and most of the organs are covered by an epithelial membrane for protection whereas some of the epithelial surfaces are absorptive or secretary also.

In an epithelial tissue, the cells are arranged very close to each other with very little extracellular material or matrix which is a product of these epithelial cells. Their cells rest on

a non-cellular basement membrane. The lining of the skin, alimentary canal, blood vessels, digestive glands, respiratory organs etc. are covered by epithelial tissue. Based on the structure and function, epithelial tissues are divided into two main groups: covering epithelia and glandular epithelia.

The different types of epithelial tissue are as follows :



(A) Simple Epithelium : The cells in a simple epithelium are arranged in a single layer. The intercellular matrix does not occur. Various kinds of simple epithelia can be described on the basis of the form of the cells.

(i) Squamous epithelium : The cells of this kind of epithelium are extremely thin and flat. All the cells are arranged edge to edge and form delicate lining or covering. They are joined by cement material. In surface view, this tissue seems to be composed of flat tiles like that of a pavement. It is because of this appearance it is often known as the pavement epithelium. Cells are thin, flat and polygonal and with prominent round or oval nucleus in the centre. Its main function is protection of the underlying tissue. The outermost layer of skin of frog is made up of squamous epithelium. It forms the inner lining of lung alveoli, lining of blood vessels, Bowman's Capsules of the kidney, peritoneum of body cavity, etc.

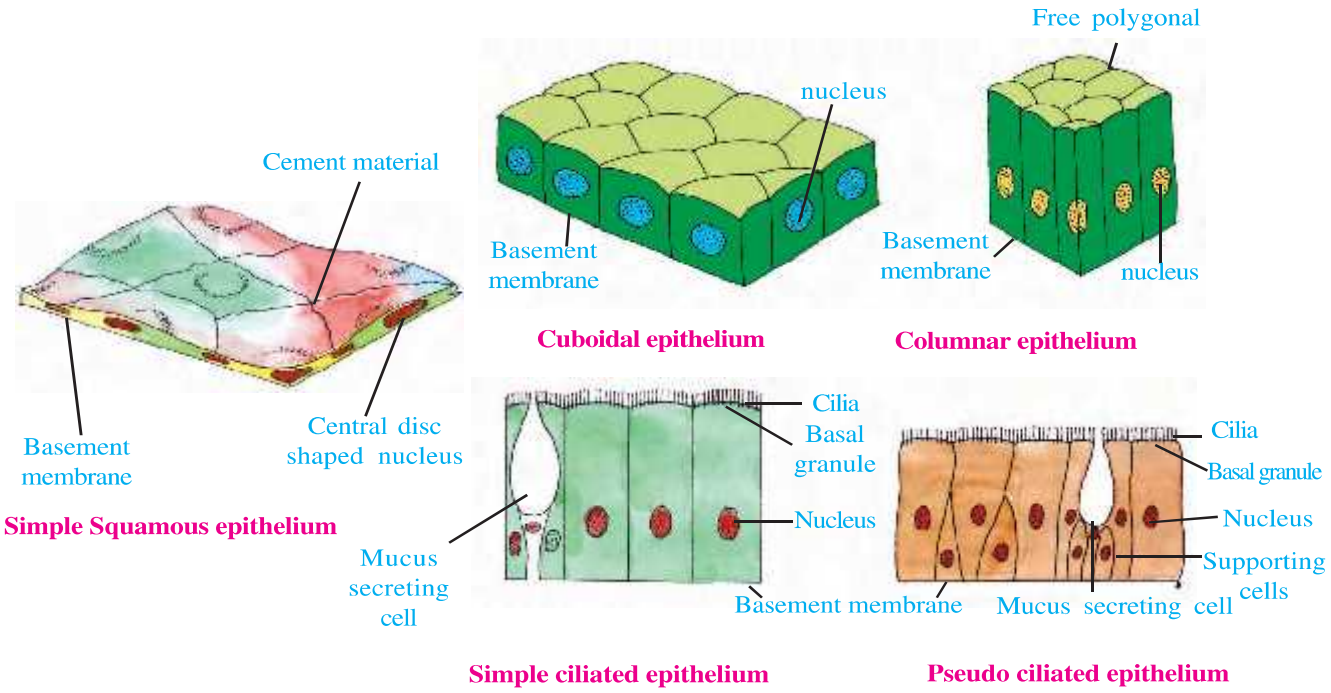
(ii) Cuboidal epithelium : The cuboidal cells are square in vertical sections; they are polygonal in horizontal section. In addition to protection, these cells participate in secretion (gastric juice, hormones, etc), excretion and absorption. The cells of absorptive surfaces often bear microvilli on their free ends. e.g. proximal tubules of kidneys, salivary glands, pancreatic ducts, thyroid gland and ovary.

(iii) Columnar epithelium : Cells of this type of epithelium are elongated and are placed side by side like tall pillars. Their inner ends are generally narrow but free ends are broad having polygonal surface. The function of columnar epithelium is secretion or absorption. The simple columnar epithelium forms the lining layer of the mucous membrane of the stomach, intestine, gall bladder and of the urinogenital organs and their ducts.

(iv) Ciliated epithelium : This is merely a modification of the columnar epithelium. Cells bear thin protoplasmic processes on their free surfaces called cilia (as per diagram). Hence an epithelium is known as ciliated epithelium. Cilia are furnished with extremely delicate vibrating hair-like protoplasmic processes. The function of the cilia is to move

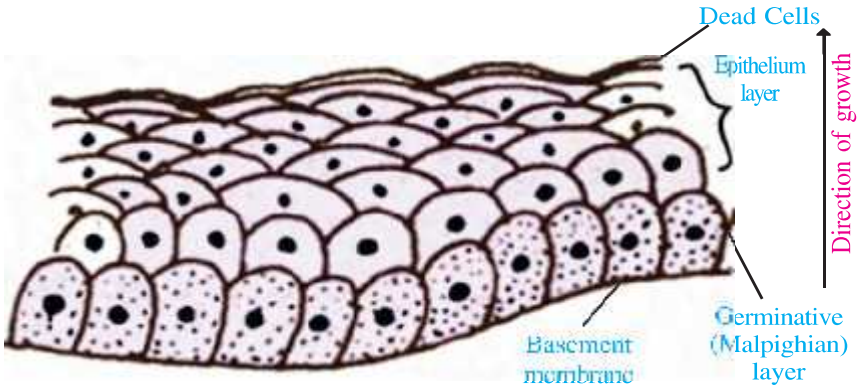
particles, free cells and mucus in a specific direction. They are present in auditory tube, uriniferous tubule, respiratory tract, etc.

(v) Pseudo-stratified epithelium : It is the simple columnar epithelium in which the regular arrangement of the cells is distorted. The cells of this type of epithelium are also twisted with respect to each other giving a false appearance. Cells are arranged in single layer, but appear multi-layered. This type of epithelium is present in the inner linings of trachea, large bronchi and helps to remove mucus.



(B) Compound epithelium : There are only two kinds of compound epithelia which are made of several layers of cells. These are (i) stratified and (ii) transitional. The stratified epithelium appears where there is much wear and tear, such as in the epidermis of skin, the lining of the mouth cavity, the tongue, oesophagus and vagina of mammals. It provides a durable covering to these organs. The cells forming the different layers of this epithelium are not all of the same kind. Due to erosion the cells towards the surface becomes flat and are removed, whereas the lower cells by division go on adding new cells towards upper surface. It consists of more than one layer of cells and gives a stratified appearance. The lower layer of cells arranged on the basement membrane is called germinative layer or malpighian layer. The main function of this type of epithelium is protection to underlying tissues. In stratified cuboidal epithelium, the superficial cells are cuboidal in shape. Such tissue is present in the inner surface of larger salivary gland and pancreatic ducts. Further stratified squamous epithelia are of two types: (i) stratified squamous non-keratinised and (ii) stratified squamous keratinised. When the surface cells contain insoluble protein (keratin), the tissue is called keratinised epithelium.

Another special type of compound epithelium is the transitional epithelium. The transitional type occurs within the passages of the excretory organs.



Stratified epithelium

(2) Connective tissue : The connective tissue is the group of cells and matrix containing of intercellular substance secreted by cells themselves. Cells are quite widely spaced. The connective tissue named so, because its chief function is to connect together the other tissues of the body.

The functions of the tissue are :

(i) to connect up structures,

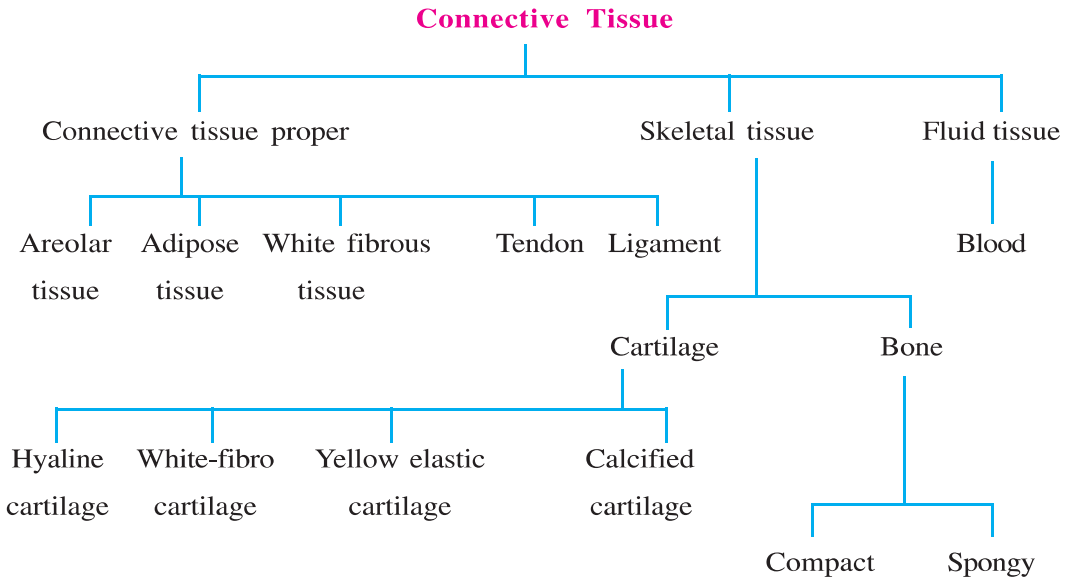
(ii) to form packing around organs,

(iii) to replace tissues which have been destroyed by injury,

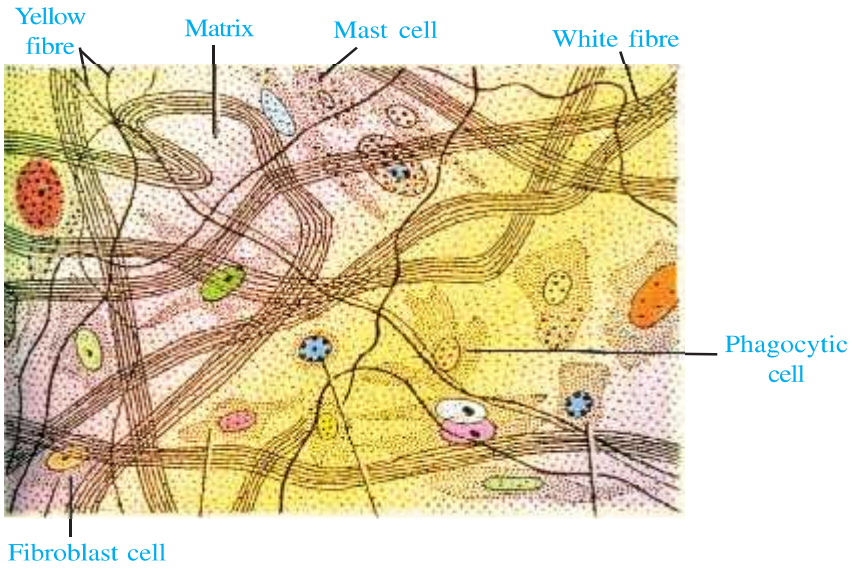
(iv) to combat foreign toxins and

(v) to form a supporting framework (Skeleton in function).

Connective tissues fall into the following three main groups :



(A) Connective tissue proper : The term connective tissue obviously denotes a tissue which connects parts of the body together. It includes five types: (i) areolar (ii) adipose (iii) white fibrous (iv) tendon and (v) ligament.

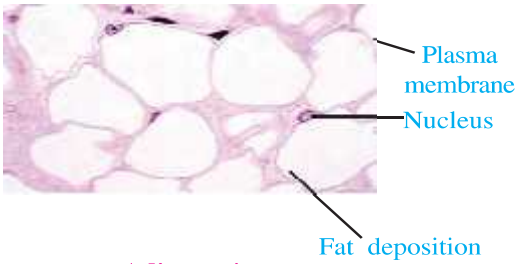


Areolar tissue

Areolar tissue

This is the simplest and the most widely distributed connective tissue. It is also called loose connective tissue. It is made up of fibres and cells. There are two types of fibres: White fibres are wavy, unbranched and are arranged in bundles. Yellow fibres are few in number, more slender than the white fibres and are not arranged in bundles. They are single fibres branched and joined with one another to form a delicate network. The white fibres are formed of a substance called protein collagen. The yellow fibres are made of elastin.

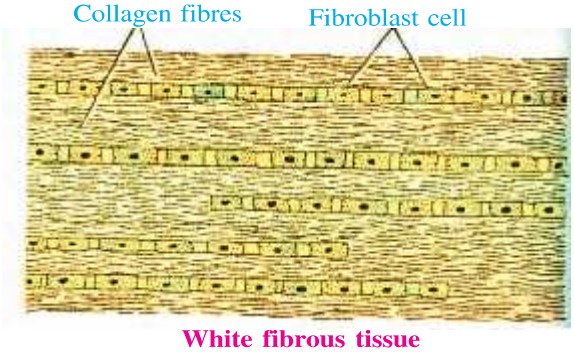
Mainly types of cells found in ground substance are fibroblast, macrophages (histocytes) and mast cells. Of these fibroblasts are the main cells of the tissue. They synthesize two kinds of proteins – collagen and elastin. The other chief type of cell is phagocytic cell or histocyte. It is able to move and ingest foreign particles, and is thus called macrophage. Thus these cells help in the defense of the body. The mast cells are also irregular in shape and large in size. They contain three active substances: heparin, histamine and serotonin.



Adipose tissue

Adipose tissue

The adipose tissue differs little from areolar tissue except that it contains a much higher percentage of fat cells (adipocytes); which constitute the principal components of this tissue. Besides adipocytes, it contains fibroblasts, macrophages, collagen fibre and elastic fibres. The adipose tissue occurs in abundance in the subcutaneous tissue; here it helps to conserve the body heat. Mainly tissues present beneath the skin, around kidneys and in mesenteries and bone marrow.



White fibrous tissue

White fibrous tissue

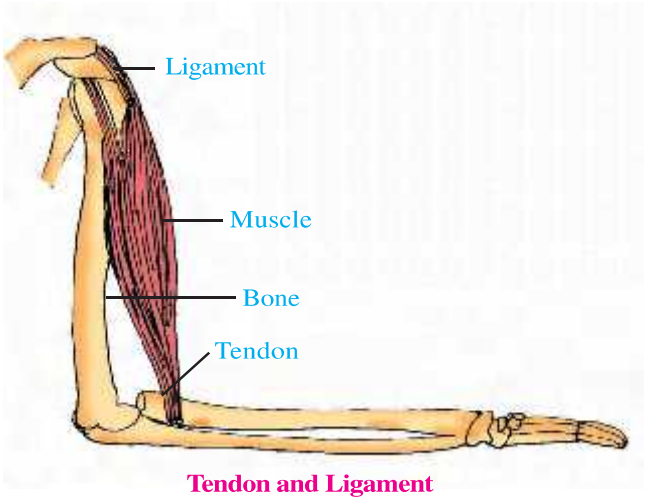
It occurs in tendons, which are elastic cords and connect muscles to the connective tissue sheath which surrounds the bone. White fibres are arranged compactly and parallel in bundles. This kind of tissue is found in places where great strength with limited flexibility is desirable. This kind of tissue is mainly present in the periosteum of the bones and perichondrium of cartilage. They are also seen at the joint between cranium bones and make them immovable.

Tendon :

It is strong fibrous connective tissue. It is composed of bundles of collagen fibres (matrix). A few flat and elongated fibroblast cells lay between the fibre bundles.

Ligament :

The ligament connects the joints and holds them in position. It is a dense fibrous connective tissue. It contains matrix as ground substance. Matrix has yellow elastin fibres. They are branched fibres. Fibroblast lie scattered between the fibres.



Tendon and Ligament

(B) Skeletal tissue : The tissue includes cartilage and bones which form the endoskeleton of the vertebrate body. These two tissues mainly provide material for the attachment of the muscles.

Cartilage :

The cartilage is a specialised connective tissue. It differs from the soft generalised connective tissue for its matrix which is solidified. The cartilage is quite distinct in its structure, physical properties, vascularisation and the pattern of growth and regeneration.

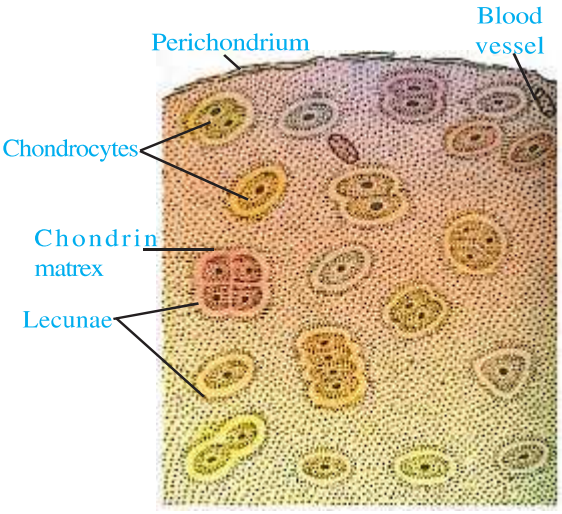
The cartilages are classified into the following four types.

(i) Hyaline cartilage

(ii) White fibro cartilage

(iii) Yellow elastic fibro cartilage

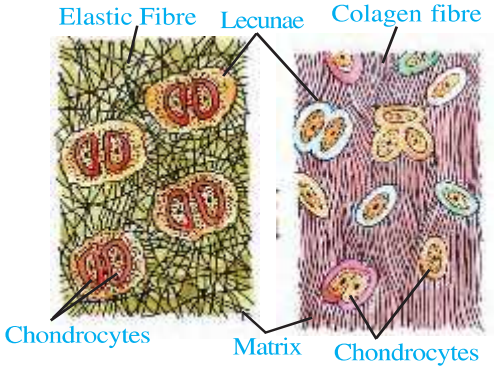
(iv) Calcified cartilage (cellular cartilage)



Hyaline Cartilage

Hyaline cartilage

The word hyaline is derived from the Greek work "hylos" which means "glass", and the hyaline cartilage was so named because in the gross, it appears as a clear bluish coloured glassy surface. Its matrix is clear, homogeneous translucent and laking fibres. It is present in larynx, trachea, sternum, hyoid and ribs etc. The cartilage cells are chondroblasts, which secrete chondrin lie in groups of two, four or eight in fulfilled space called lacunae. It is always covered by a tough fibrous membrane; the perichondrium. It contains blood vessels from which nutritive substances diffuse through the cartilage.



White fibro cartilage **Yellow elastic cartilage**

White fibro-cartilage

White fibro-cartilage

It consists of dense white fibrous tissue arranged in bundles (bundles of collagen fibres) with cartilage cells between the bundles. The cartilage cells are usually ovoid in shape and are surrounded by matrix. It is typically found in the intervertebral discs, which binds the vertebrae in mammals.

Yellow elastic cartilage

Yellow elastic cartilage

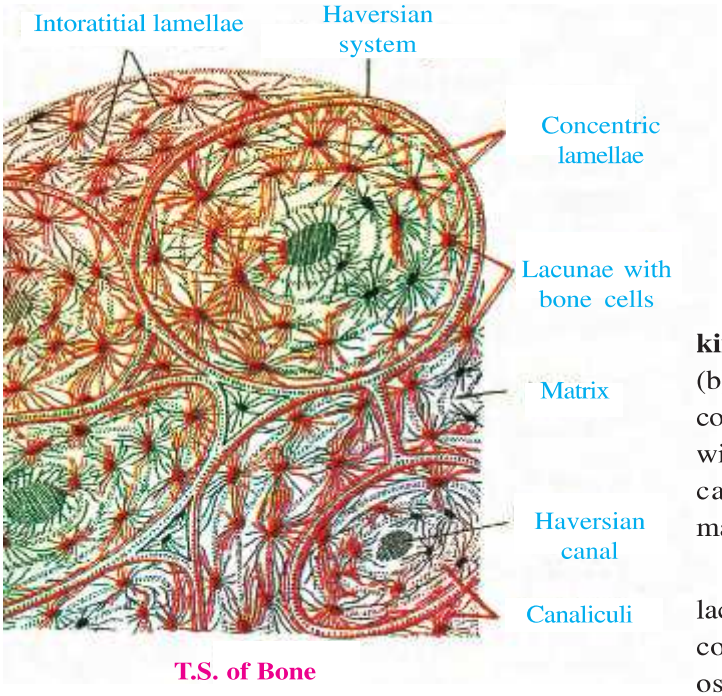
This is similar to fibrous cartilage except for yellow elastic fibres. It has elastin. This type of cartilage is found in the pinna, tips of nose, epiglottis and in certain other regions.

Calcified Cartilage

It differs from the hyaline type in having its matrix impregnated with lime salts. It is seen in a normal stage in the development of cartilage during early embryonic life but it is also found in a permanent tissue in the external ears of many mammals. It occurs in the pubis of frogs, in supra scapula and at the head of humerus and femur.

Bone

The bone is a specialized connective tissue. Some of the features of this tissue are as follows :



T.S. of Bone

- It is highly vascular
- It is mineralized
- It is constantly changing
- It is hard and rigid
- It is resilient
- It has a regenerating capacity
- It has a canalicular system

The mature bone is composed of two kinds of tissues : (a) the compact bone and (b) spongy. The ground substance or the matrix, composed of protein called ossein is impregnated with various inorganic salts of lime, namely, calcium phosphate, calcium carbonate, magnesium phosphate and calcium fluorides.

In adult bone flat irregular spaces called lacuna occurs in the solid matrix. Each lacuna contains a flat bone cell or osteocyte. An osteocyte has an irregular shape and long cytoplasmic process. These processes extended into minute canals radiating from each lacuna. The lacunae are in communication with one another by fine canalicules.

In a long dried bone of frog, large number of lamellae are present in a ground substance. In the center there is a narrow cavity of the bone. It contains a tissue known as the bone marrow which is yellow in colour. It is composed of adipose tissue, blood

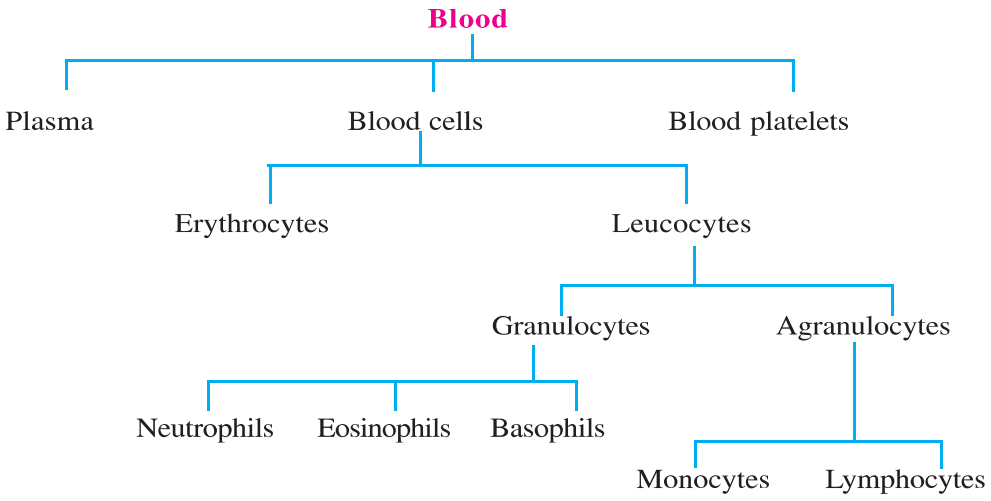
vessels, etc. The bone increases in thickness by the addition of successive layers to the outside as well as to the innerside.

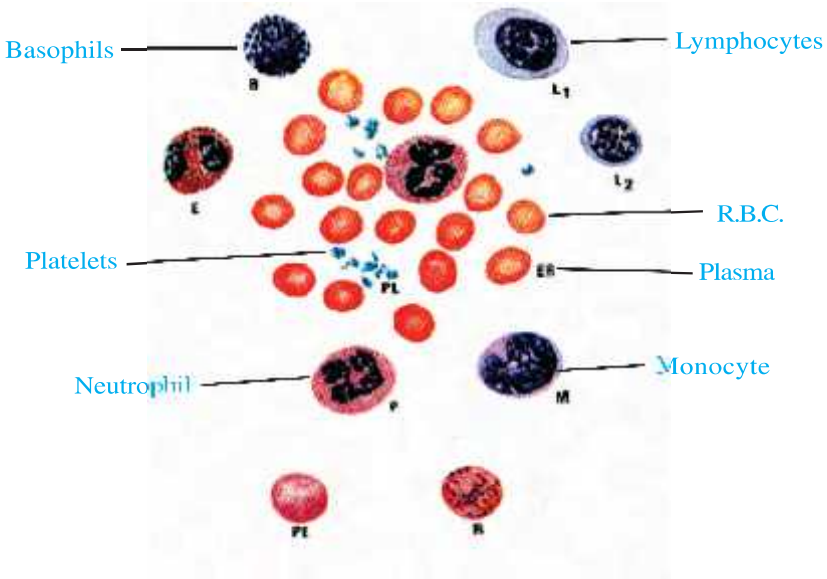
In mammalian bones many column like structures are seen called Haversian system. In each Haversian system, several concentric layers (lamellae) of bony matrix encircle a longitudinal central canal (Haversian canal). This canal carries blood vessels and nerves.

Spongy bones are found in vertebrae, ribs, skull, etc. It contains red bone marrow, which is the seat for formation of erythrocytes and granulocytes.

(C) Fluid tissue : Blood : The blood is an opaque turbid fluid. It is a fluid connective tissue. Its fluid is the intercellular substance or matrix. The fluid part of the blood is known as plasma. The blood cells are of two types: Red and white. The fragments of cytoplasm that are present in the blood are called platelets. Its cells are quite distinct from other connective tissue cells, both in structure and function. Blood differs from other connective tissues in that the secretion of the matrix is not entirely by blood cells and moreover, the new blood cells are not formed by the division of the pre-existing corpuscles.

The composition of blood is shown in the chart below :

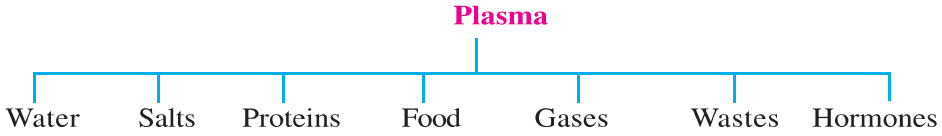




Blood connective tissue

Plasma

This is the fluid matrix or intercellular substance of blood. It is almost colourless having faint yellow tinge. It contains essentially seven classes of substances:



It is also rich in sodium and chloride ions. It also contains potassium, calcium, magnesium, phosphate, bicarbonate and many other ions. It contains many crystalloids and colloids. The colloids of plasma include plasma proteins (including prothrombin and immunoglobulins). It contains usually 80 % water. In addition to these there are metabolic waste products such as urea, uric acid, ammonia, carbon dioxide and water. Various hormones are also present in it. The plasma also contains protective substances such as antitoxins, agglutinins, lysine, etc. and blood proteins like fibrinogen, prothrombin, albumins and globulins.

In adult humans normal blood sugar level after 2 hrs of meal is 90-120 mg per 100 ml of blood. Cholesterol in humans normally ranges from 140 to 260 mg per 100 ml of serum. Except required components for blood clotting of plasma is known as serum.

Erythrocytes

They are also called Red Blood Corpuscles (RBCs). Under normal condition the blood of adult male contains 4,100,000 to 6,000,000 erythrocytes per cubic millilitre, while that of adult female contains 3,900,000 to 5,500,000 per cubic millilitre.

The normal human erythrocyte is a biconcave disc. The red colour of erythrocytes is due to the presence of haemoglobin, a red coloured pigment which is a conjugated protein made up of globin and Fe^{+2} (ferrous) containg haeme. It has high affinity for oxygen. The shape and size of RBC's vary in different animals. The cells are nucleated in all vertebrates, except mammals. Erythrocytes participate in transporting carbon dioxide from tissue to lungs. Erythrocytes have an average life span of about 120 days.

Leucocytes

Leucocytes are also known as White Blood Corpuscles (WBCs). They are small nucleated semi transparent cells devoid of haemoglobin. The leucocytes are capable of changing their shape and moving independently through the intercellular spaces among the tissues. The numbers of WBCs in adult humans are $7.5 \pm 3.5 \times 10^3$ per cubic millimeter of blood. The number of these cells depends upon the condition of the body. During infection of the body they generally increase in number. They are known as phagocytes because they feed on the bacteria and broken down tissue cells by engulfing particles. WBCs are of two types, granulocytes (with granules in cytoplasm) and agranulocytes (without granules). On the basis of staining characteristics of cytoplasm granules and shape of nucleus, granulocytes are of three types.

(1) Neutrophils : The neutrophil whose granules stain weakly with both the acidic and basic stain. Neutrophils have many lobed nucleus.

(2) Eosinophils (Acidophil) : Their granules which stain by acidic dyes such as eosin. Eosinophils are large in size and with bilobed nucleus.

(3) Basophils : The basophil the granules of which stain by basic dyes such as methylene blue. Basophils has 'S' shaped nucleus.

The agranular leucocytes are classified into two groups : **(1) Monocytes (2) Lymphocytes. Monocytes** are the largest leucocytes and its nucleus is kidney shaped. **Lymphocytes** have large and rounded nucleus.

Blood Platelets

Platelets are relatively small non-nucleated oval disc. They are also known as thrombocytes because they secrate thromboplastin. They are especially concerned with the clotting of blood. They are made in the bone marrow.

General Functions

The general functions of blood are summarised here under.

(1) Transport of oxygen
(2) Transport and Removal of carbon dioxide
(3) Transport of food materials
(4) Transport of waste matter
(5) Clotting of blood
(6) Transport of hormones, antitoxins, etc.
(7) To neutralise the toxins
(8) Equalization of body temperature
(9) Disposal of cell wreckage

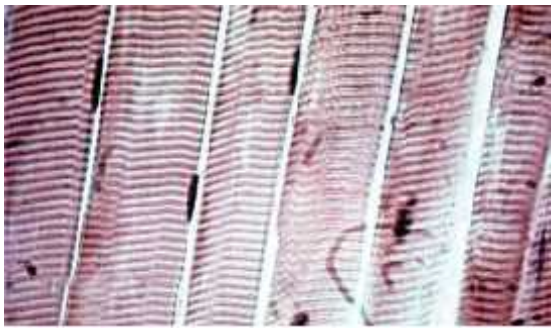
Muscular tissue : It consists of cellular elements in the form of fibres of varying lengths. It has almost no intercellular substances. All muscular tissues have great contractility. There are three types of muscular tissue.

Muscular Tissue

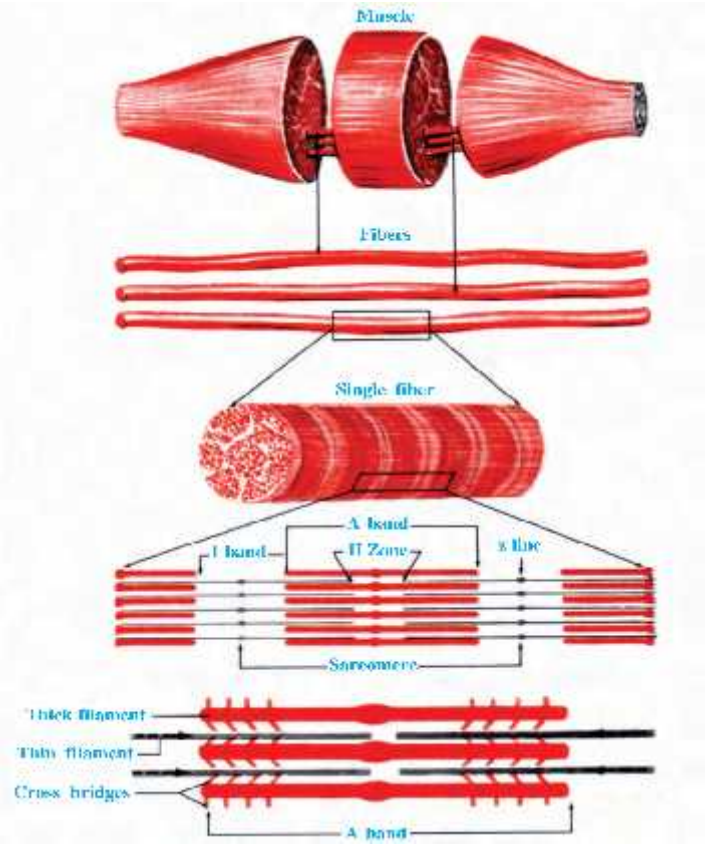
Skeletal muscle	Unstriated	Cardiac muscle
or	or	
Striated	Smooth	
or	or	
Striped	Plain	
or	or	
Voluntary	Involuntary muscle	

Skeletal Muscle

The muscle fibers are the units of skeletal muscle. Each muscle fibre is a single thin and elongated cell provided with many nuclei. The muscle fibres are arranged in bundles (fasciculi). In higher animals, these are found associated with the skeleton through tendon. They are attached to bones by tendons.



Skeletal Muscle

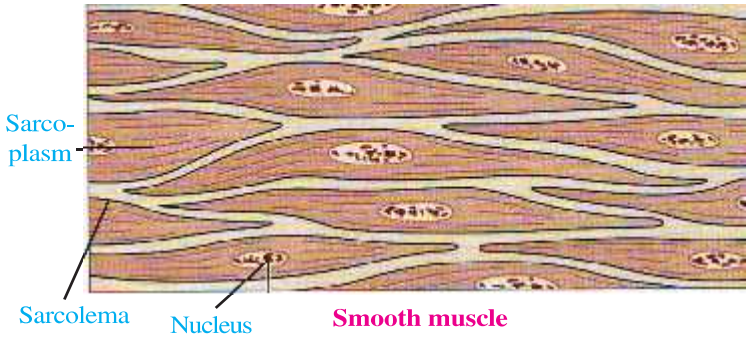


Ultrastructure of striated muscle

Muscle fibers can be contracted as desired. Therefore, they are also called voluntary muscles. Because of their appearance they are called striated or striped muscle.

The cytoplasm (sarcoplasm) of each fibre contains large number of myofibrils. Each fibre has an extensive sheath, the sarcolemma. The muscle fibres show cross or transverse striations of alternating light and dark brands. The darker bands are called 'A' bands; the lighter bands are called 'I' bands. The dark bands or 'A' discs are separated from one another by light bands or J-discs, each of which is itself crossed by Krause's membrane or Z-disc. Each portion between two successive Z-disc is termed as sarcomere. There are two types of filaments: thick filaments and thin filaments. Thick filaments occupy the 'A' band, the central portion of the sarcomere. Thick and thin filaments overlap for some distance within the 'A' band. The thin filaments run between and parallel to the thick filaments and have one end attached to the 'Z' line. Thin filaments being absent in the middle of 'A' band, this part appears light or less dark and is known as 'H'band (Hensen's zone). The thick filaments are made up of the protein myosin. Thin filament is composed of the proteins actin, tropomyosin and troponin.

Smooth Muscle :



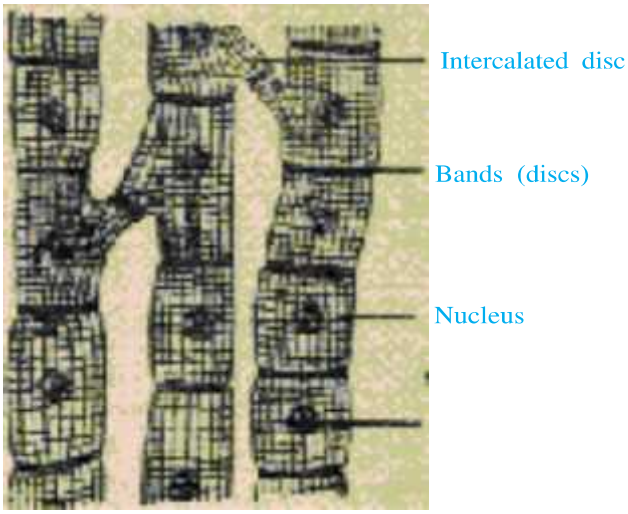
Smooth muscle

The smooth, plain, non-striated, unstriped or involuntary muscle differs considerably from the skeletal and cardiac muscles, both in its structure and physiological properties. The smooth muscle is made up of mononucleate spindle shaped cell. It has granular sarcoplasm around its nucleus. The rest of the cytoplasm has large number of extremely fine myofibrils. They have the property of contraction. These muscles always receive their nerve supply from the autonomous nervous system. These muscles are present in alimentary canal, iris, etc.

Cardiac Muscle

With the light microscope, the heart muscle appears as network of branching and anastomosing cylinders. The spaces between the cardiac muscle cells are occupied by the

endomysium. The endomysium contains fibroblasts, collagen and reticular fibres. Each cell of cardiac muscle shows striation with 'A', 'I', 'Z' and 'H' bands. At the ends of the cardiac muscle cells, there are prominent cross striations called intercalated discs. These discs are thicker than 'Z' discs. It differs from skeletal muscles due to reticulated pattern of fibres. These muscles are capable of contracting rhythmically and are immune to fatigue. There is rich blood supply.



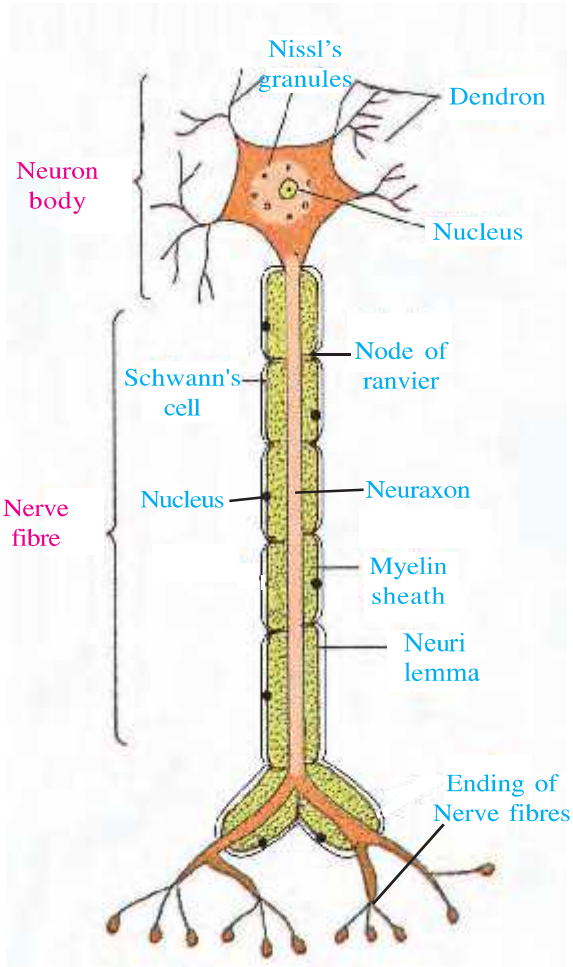
Cardiac muscle

Nervous tissue : Nervous tissue is composed of two types of cells (a) neurons and (b) neuroglia. The neurons form the most important elements of the nervous system. Neurons have long processes which transmit nerve impulses. The glial cells have short processes and they support and protect neurons.

Neuron cells are specialised for reception, integration, transformation and onward transmission of information. Typically each neuron consists of a cell body and branching fibres. Amongst the fibres one of the processes called the axon is long and conducts nerve impulses away from the cell body (efferent) and it ends in a number of small branches on muscle fibres, gland cells or other neurons. The remaining processes conduct nerve impulses towards the cell body (afferent) and are called dendrites or dendrons.

The number of processes arising from a cell body is variable and forms the basis of the morphological classification into three types: unipolar, bipolar and multipolar. In the unipolar neuron the cell body has a single process giving rise to both dendrite and axonal branches. In bipolar neuron, there is a process at each end of the cell body. Out of which one is afferent and opposite to it is efferent. In multipolar neurons, there are more than two processes.

The cytoplasm of the cyton contains a large and spherical nucleus. There are large numbers of dark particles called Nissl's granules in a cytoplasm.



Neuron (Nerve Cell)

The nerve fibres may be surrounded by two concentric sheaths. The inner is known as medullary or myelin sheath. It is surrounded by a transparent cellular outer sheath, the neurilemma. The neurilemma sheath is made up of single layer of flat expanded Schwann's cells. Each myelinated nerve fibre shows constrictions at regular intervals called nodes of Ranvier. The nerve endings of axon are not in direct physical contact with nerve endings of dendrites of another neuron. This physical gap is called synapse. Nerve impulses pass between neurons through the synapse with the help of a hormone Acetylecholine called Neurotransmitters.

Summary

Tissue is the group of cells having similar structure and function. Animals contain four basic types of tissues which are: epithelial tissue, connective tissue, muscular tissue and nervous tissue. Based on structure and function, epithelial tissues are divided into two main groups: covering epithelium and glandular epithelium. Covering epithelia are different types such as squamous, cuboidal, columnar, ciliated, pseudo-stratified, stratified and transitional. They perform different functions: protection, absorption and secretion.

The connective tissues are the group of elements or matrix of intercellular substance secreted by cells themselves. They fall into three main groups: connective tissue proper, skeletal and fluid tissue (blood). Connective tissues proper are of five types : areolar, adipose, white fibrous, tendon and ligament. Skeletal tissue includes cartilage and bones which form the endoskeleton of the vertebrate body. The cartilages are classified into the following four types: hyaline, white fibrous, yellow elastic fibro cartilage and calcified cartilage (cellular cartilage).

Blood is a fluid connective tissue. It is an opaque turbid fluid which is a intercellular substance or matrix (plasma). It is composed of plasma, blood cells and blood platelets. Blood cells are erythrocytes and leucocytes. There are five types of leucocytes: neutrophils, eosinophils, basophils, monocytes and lymphocytes.

Muscular tissue consists of cellular elements in the form of fibres of varying lengths. They have great contractibility. There are three types of muscular tissue: skeletal muscle, unstraited or plain muscle and cardiac muscle.

The nervous tissue is composed of two types of cells (a) neurons and (b) neuroglia. The neurons form the most important elements of the nervous system. They transmit nerve impulses. Neuron cells are specialized for reception, integration, transformation and onward transmission of information. Neuron has two or more processes extending from it. One of the processes carries impulses away from the cell body and is called the axon. Other processes carry nerve impulses towards the cell body and are called dendrites. There is a physical gap between the nerve endings of axon and dendrites called synapse.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Specialized tissue which performs the functions of protection, absorption and secretion.

(A) Neuron ◯ (B) Striped muscle ◯

(C) Blood ◯ (D) Epithelial tissue ◯

(2) Bowman's capsule has which type of epithelium ?

(A) Cuboidal epithelium ◯ (B) Squamous epithelium ◯

(C) Columnar epithelium ◯ (D) Pseudo-stratified epithelium ◯

(3) Which cell secrets heparin and histamine ?

(A) Mast Cell ◯ (B) Neuron ◯

(C) Monocytes ◯ (D) Squamous epithelium cell ◯

(4) The cartilage typically found in the vertebrae in mammals ?

(A) Calcified ◯ (B) Yellow elastic ◯

(C) White fibro ◯ (D) Hyaline ◯

(5) In which tissue Haversian system is present ?

(A) Connective tissue ◯ (B) Blood ◯

(C) Cartilage ◯ (D) Bone ◯

(6) How many erythrocytes are present in adult man ?

(A) 3900000 to 5500000 ◯ (B) $7.5 \pm 3.5 \times 10^3$ ◯

(C) 4100000 to 6000000 ◯ (D) $3.5 \pm 7.5 \times 10^3$ ◯

(7) By which protein the thick filament of striped muscle is made up of ?

(A) Actin ◯ (B) Myosin ◯

(C) Actin and Myosin ◯ (D) Tropo myosin ◯

(8) The distance between two 'Z' disc is termed as .....

(A) Synapse ◯ (B) Sarcolemma ◯

(C) Sqrocomere ◯ (D) Sarcoplasam ◯

(9) The spaces between the cardiac muscles are occupied by

(A) Endomysium ◯ (B) Sarcolemma ◯

(C) Granular sarcoplasam ◯ (D) Sarcoplasam ◯

(10) In which tissue medullary sheath is present ?

(A) Epithelial ◯ (B) connective ◯

(C) Muscle ◯ (D) Nervous ◯

2. What is tissue ? Give a general chart of different tissues with their sub types.

3. Give functions of different tissues.

4. Distinguish between :

(a) Simple and compound epithelial tissue

(b) Cartilage and bone

(c) Erythrocytes and leucocytes

(d) Striated muscle and unstriated muscle

5. Match the terms in Column A with those in Column B.

A		B	
(1)	Axon	(1)	Cardiac muscle
(2)	Z-disc	(2)	Bilobed nucleus
(3)	Eosinophils	(3)	Thromboplastin
(4)	Endomysium	(4)	Kidney shaped nucleus
(5)	Pseudo stratified epithelium	(5)	Striped muscle
(6)	Transitional epithelium	(6)	Compound epithelium
(7)	Blood platelets	(7)	Nervous tissue
(8)	Monocytes	(8)	Simple columnar epithelium

6. Name the tissue which performs the following functions :

(a) Absorption and secretion

(b) Helps to remove mucus

(c) Ingest foreign particles

(d) To conserve body heat

(e) Transportation of O_2 and CO_2

(f) Blood clotting

(g) Transmit nerve impulses.

7. What are the cellular components of blood ?

8. Describe the ultrastructure of striped muscles fibre.

9. Describe different types of simple epithelial tissue.

10. Write short note on :

(1) Leucocytes

(2) Columnar epithelium

(3) Adipose tissue

(4) Cardiac muscle

(5) Neurons

11. Draw a sketch diagram and label only :

(1) Different types of leucocytes

(2) Neuron with myelinated axon

(3) Areolar connective tissue

(4) Different types of simple epithelial tissue

5

Animal Morphology and Anatomy - I

(Earthworm and Cockroach)

In earlier chapter we have understood organization of body, and in which cells form tissue, tissues form organ, and organs form an organ systems. e.g. digestive system, respiratory system, circulatory system, excretory system, reproductive system and nervous system. These systems coordinate with each other to perform various complex physiological functions, which keep body in living state. Thus many cells unite to form multicellular body. In our body organ like heart consists of four different kinds of tissues, such as epithelial tissue, connective tissue, muscular tissue and nervous tissue. As required for adaptation the organs and organ systems evolved more complex organizations. Thus study of various systems in two or three animals can be made to understand evolutionary stages. With this aim the curriculum on earthworm, cockroach and frog has been included in present chapter. The morphology and internal organization in the body and various systems and physiological processes run by them, can be studied. We will understand systems with diagram when required. Let's start with the earthworm.

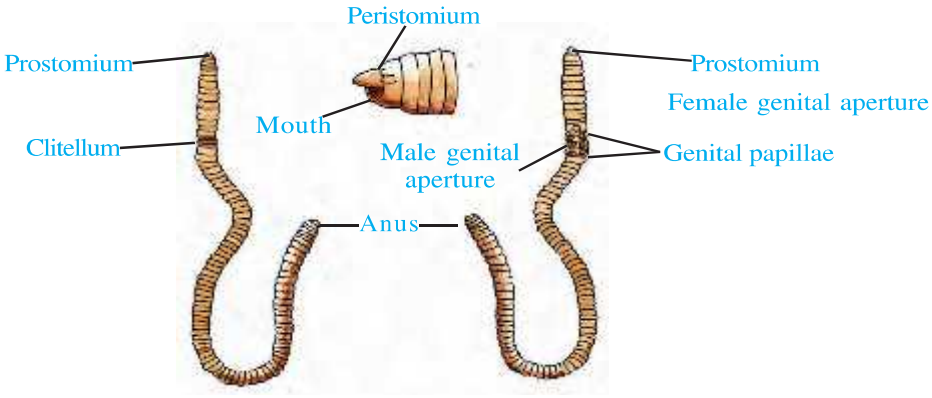
Earthworm

Earthworm is a typical coelomate animal of annelida phylum. In our country, *Pheritima posthuma* is found commonly. Earthworm is a reddish brown terrestrial invertebrate that inhabits on the upper layer of the moist soil. During day time it lives in burrow and eat the soil. Whatever the soil it consumes with food is excreted as worm castings and with the help of these castings earthworms can be traced.

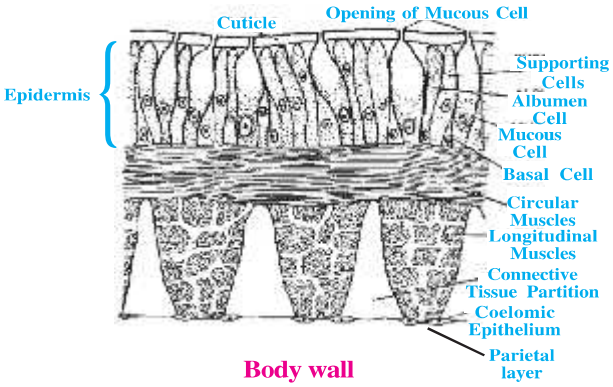
Morphology

Earthworm is cylindrical, a little bit long and thin. It's body is divided into small segments which are approximately 100 to 120 in number. The dorsal surface of the body is marked by a dark median mid dorsal line along the longitudinal axis of the body. The ventral surface is distinguished by the presence of genital pores. Anterior end consists of the mouth and the prostomium, a lobe which serves a wedge to force open cracks in the soil into which the

earthworm may crawl slowly further. The prostomium is a sensitive organ. The first segment is called the peristomium in which mouth is found. In a mature earthworm, 14 to 16 segments are covered by a dark band of glandular tissue called clitellum. Thus the body is divided into three prominent areas preclitellar, clitellar and postclitellar segments. Four pairs of spermathecal apertures are found on the ventro-lateral sides between segments 5/6, 6/7, 7/8, 8/9 in the intersegmental grooves. A single female genital pore is present in the mid-ventral line of the 14th segment. A pair of male genital pores is present on the ventro-lateral sides of the 18th segment. Number of minute pores called nephridiopores, get opened on the surface of the body which are found in all the segments except the first, last and clitellum. In the midst of each segment a circle of setae is found. These setaes are made of chitin and help in locomotion.



Earthworm – dorsal view Earthworm – ventral view



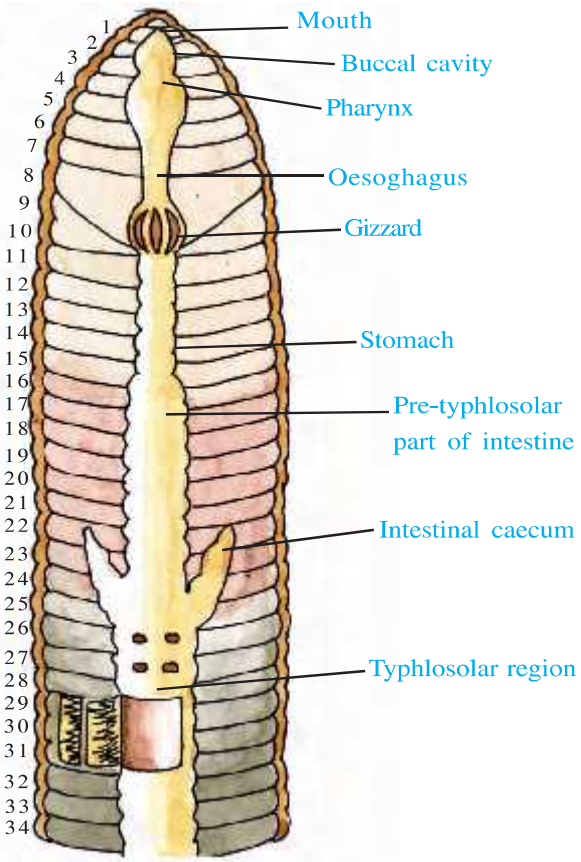
Body wall

The body wall of the earthworm consists of cuticle, epidermis, circular muscles, longitudinal muscles and parietal layer. Cuticle is a thin layer secreted from epidermis. The epidermis is made up of a single layer of columnar supporting cells and oblong gland cells which secrete albumin and mucus. Sensitive cells are found in groups. They bear cilia which takes inspiration from external stimulation.

Digestive System

The alimentary canal is a straight tube and runs between first to last segment of the body. A terminal mouth opens into the buccal cavity which spreads to 1 - 3 segments. Because of the contraction of muscles joining body wall, buccal cavity protrudes out of the body and accepts the food. The pharynx, muscular tube found after buccal cavity is extended upto fourth segment. A small narrow tube like oesophagus is extended from 5 to 7 segments which opens into muscular gizzard of the 8th segment. The wall of this gizzard is thick and there are thick layers of circular muscles. The internal surface of it made up of columnar cells covered with cuticle. Due to the contraction of circular muscles gizzard grinds the soil particles and decaying leaves like a grinder. The stomach is extended from 9th to 14th segment. Calciferous glands, found in stomach, neutralize the humic acid present in humus. Intestine starts from the 15th segment

and continues till the last segment. A pair of short and conical intestinal caecum projects from the intestine on the 26th segment, which secrets enzyme of carbohydrate digestion. In the intestine between 26 to 95 segment is the presence of internal median fold of dorsal wall called typhlosole. Due to this fold there is an increase in the area of absorbtion. Last 23 - 25 segments are without typhlosole and hence it is called post typhlosole. The alimentary canal opens to the exterior by a small rounded aperture - anus. The ingested organic rich soil passes through alimentary canal and digestive enzymes breakdown complex food into smaller absorbable units.

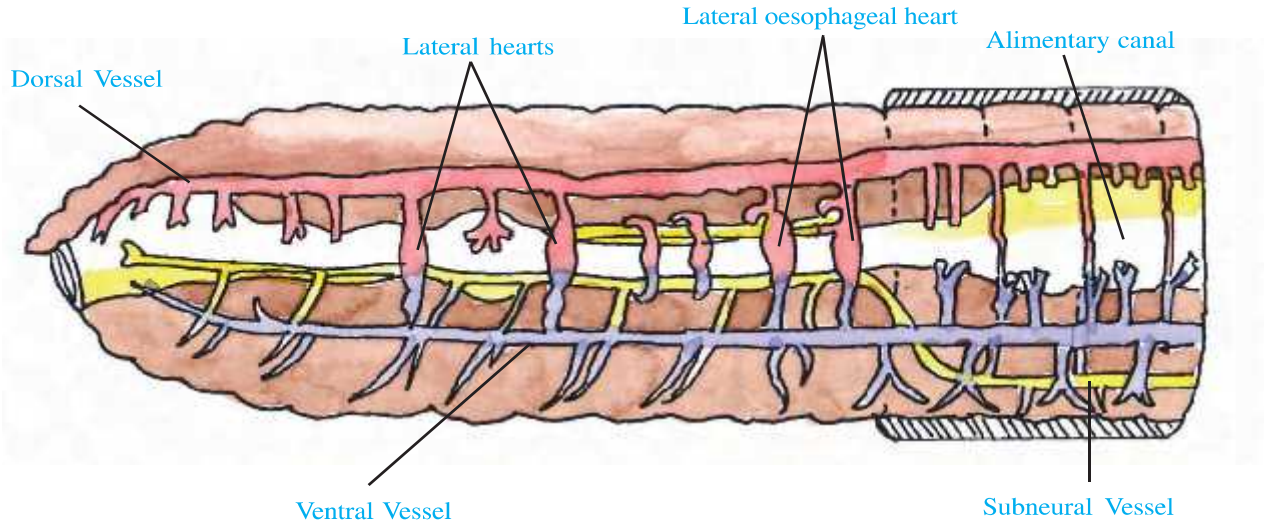


Digestive system of Earthworm

Circulatory System

In earthworm closed type of circulatory system is found. In circulatory system blood vessels, capillaries and heart are included. Due to closed circulatory system, blood is confined to the heart and blood vessels. Due to contraction, blood circulates into one direction and smaller blood vessels supply blood to the gut, nerve cord and the body wall. Blood glands are present on the 4th, 5th and 6th segments. Its function is to produce blood cells and haemoglobin which is dissolved in blood plasma. Blood cells are of phagocytic type.

In earthworms there is absence of specialized breathing device. Respiratory exchange occurs through moist body surface and oxygen gets mixed into blood stream.



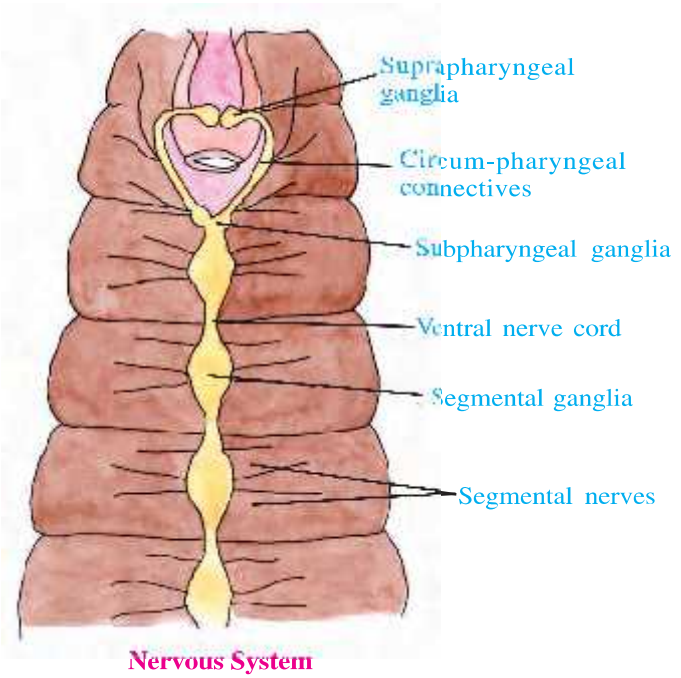
Circulatory System of Earthworm

Excretion

In excretory organs segmentally arranged coiled tubules called nephridia are found in every segment. They are of three types, septal nephridia from 15th segment to the last segment, found on both the sides of intersegmental septa which open into intestine. Integumentary nephridia attached to the lining of the body wall from segment 3 to all. All these nephridia open into external surface of the body through minute pores. Pharyngeal nephridia, present as three paired tufts in the 4th, 5th, and 6th segments. These nephridia discharge their waste into alimentary canal. These all three types of nephridia are basically similar in structure. These nephridia regulate the volume and composition of the body fluids. With the help of nephrostome they absorb the excretory waste from coelome and discharge the wastes through a pore to the surface in the body wall and into the digestive tube.

Nervous System

Nervous system is ganglionated. Nerve ganglia are formed by gathering the nerve cells of any segment. One pair of nerve ganglia is found at the ventral surface of each segment after the fifth segment, which is known as ventral nerve cord. One pair of ganglia is found at the posterior part of ventral side of third segment which is called subpharyngeal ganglion. At the dorsal side of pharynx in the third segment one pair of Suprapharynegeal ganglion is found. These ganglions are connected with sub-pharyngeal ganglion by circumpharyngeal connective. These pairs of connective and sub pharyngeal ganglion connected with Suprapharyngeal ganglion and formed nerve ring. Suprapharyngeal ganglion and other nerves of rings compiles the information and reacts immediately by making the body muscles to implement it. In earthworm specific sensory organs like eyes are not present. Only sensory cells of the body wall perform as a sensory receptor organs. These cells are inspired by the intensity of light, vibrations of the land etc. Some of the sensory cells are inspired by chemical instigators.

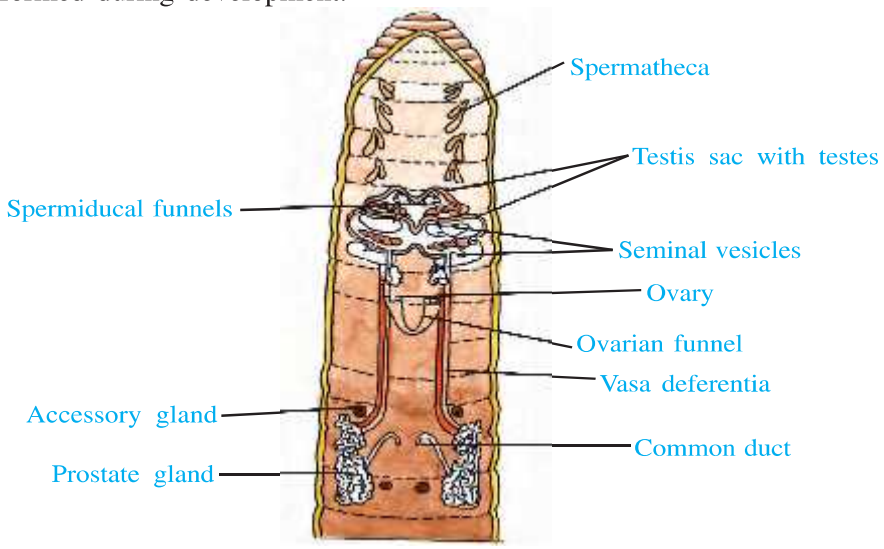


Nervous System

Reproductive System

Earthworm is hermaphrodite (bisexual) i.e. testes and ovary both are present in same animal. Two pairs of testes are found in the 10th and 11th segments. Their vasa deferentia run up to the 18th segment where they join the prostate duct. Two pairs of accessory glands are present, one pair each in the 17th and 19th segment. Common prostate and spermatic duct opens to the exterior by a pair of male genital pores on the ventro-lateral side of the 18th segment. One pair of spermathecae is located in segment 6, 7, 8 and 9 each. One pair of ovaries is attached at the inter-segmental septum of 12/13. Ovaries are small and their front part form oviducal funnels. Ovarian funnels are present beneath the ovaries which continue into oviduct, join together and open on the ventral side as a single median female genital pore on the 14th segment. During mating two earthworms come together and get

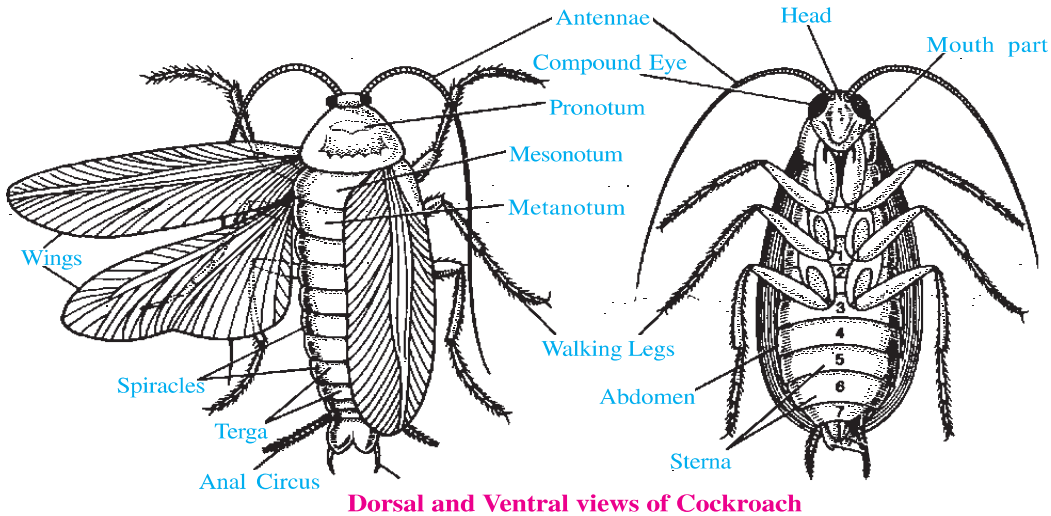
arranged into juxtaposing directions. Thus the mouth region of one faces the anus of the other. Male genital opening of one comes in contact with opening of the spermathecae of another earthworm. In this situation released sperm cells enter into the spermathecae of companion animal. Thus animals get separated after exchanging the sperms. After short time the secretion of clitellum gland forms white cocoon. In this cocoon eggs are released. Due to the contraction of body wall the cocoon slips towards the anterior end. When cocoon slipping towards the anterior end and passes through spermathecal region. Then the sperm stored in spermatheca enter into cocoon. This cocoon contains the egg cells of same animal and sperm cells of another animal with nutritive fluid. Both the ends of the cocoon are sealed when it comes out of the body. In this cocoon eggs are fertilized and resulted into zygote. After three weeks in cocoon, baby earthworms are coming out. The development of earthworm is direct. There is no larva formed during development.



Reproductive System

Earthworms are known as friends of farmers because they make burrows in the soil and thus they provide life giving gas for respiration to the developing plant roots. To increase fertility of soil earthworms are breeded which is called vermicomposting. In addition to this, earthworms as bait are used in fishing.

Cockroach :



Dorsal and Ventral views of Cockroach

Cockroach is included in class Insecta of phylum Arthropada. Generally cockroach is brown or black bodied insect, however in tropical regions, they have been reported to be bright yellow, red and green coloured. It is nocturnal and omnivores that live generally in warm and humid places all over the world. Cockroaches are quite common in kitchens, bathrooms, gutters and hotel kitchens.

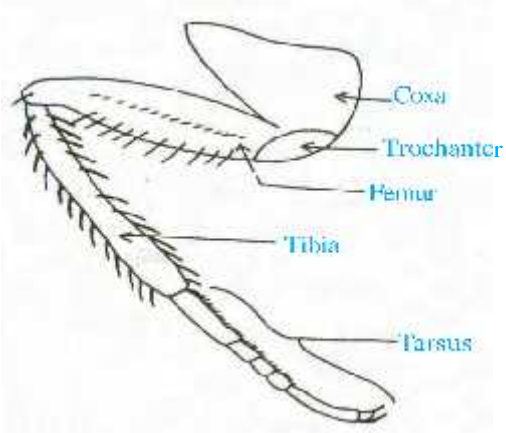
Morphology

The common species of cockroach is *Periplaneta americana*. They are about 25 to 45 mm long and 8 to 12 mm broad. The size of male is slightly bigger. The entire body is protected by a hard chitinous exoskeleton. The body is externally segmented. There is no internal segmentation. In each segment exoskeleton has hardened to thin and flexible articular membrane. The body of the cockroach is divisible into three distinct regions : (1) Head (2) Throax (3) Abdomen

(1) Head : Head is triangular in shape and lies anteriorly at right angle to the longitudinal body axis. It is formed by the fusion of six segments. It is attached to thorax through a flexible neck. So that it can move easily in all the directions. A pair of sessile, kidney shaped compound eyes occur on head. At the anterior end of head, mouth is located. Sensitive mouth parts are associated with mouth. They are concerned with collection of food and its chewing. The mouthparts consist of a pair of mandibles, a pair of first maxillae, labium and labrum. In the cavity surrounded by mouth parts occurs a muscular, folded structure called hypopharaynx. Salivary glands open at its basal region.

(2) Thorax : Thorax consists of three parts : (1) Prothorax (2) Mesothorax (3) Metathorax

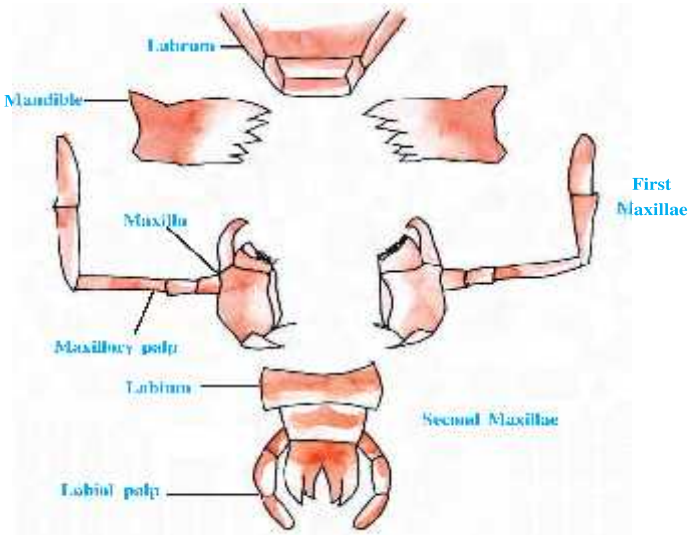
One pair of walking legs arise from ventral side of each segment. Each walking leg is made up of five segments. The first segment is called coxa, the second is trochanter, the third is femur, the fourth is tebia and fifth segment is tarsus. The first pair of wings develops from the dorsal side of mesothorax. These wings are horny and protective. The second pair of wings develops from the dorsal side of metathorax. It is bilobed and transparent. This pair is used for flying.



Walking leg

(3) Abdomen : Abdomen is made up of ten segments in both male and female. Each segment has a dorsal tergum, a ventral sternum and lateral pleurae. The terga of eight and ninth segments are covered under the tergum of seventh segment. The tenth tergum possesses a median groove. Anus occurs under it. A pair of anal cerci is associated with the tenth tergum. Anal cerci are photoreceptor structures. In male cockroach, a pair of anal styles

develop from ninth sternum. In female cockroach, the eighth and ninth sterna jointly form a genital pouch. The male genital opening occurs in mid-ventral region of ninth segment. The female genital opening opens in the eighth segment.



Mouth parts of Cockroach

Anatomy : (Internal Structure)

Body Wall :

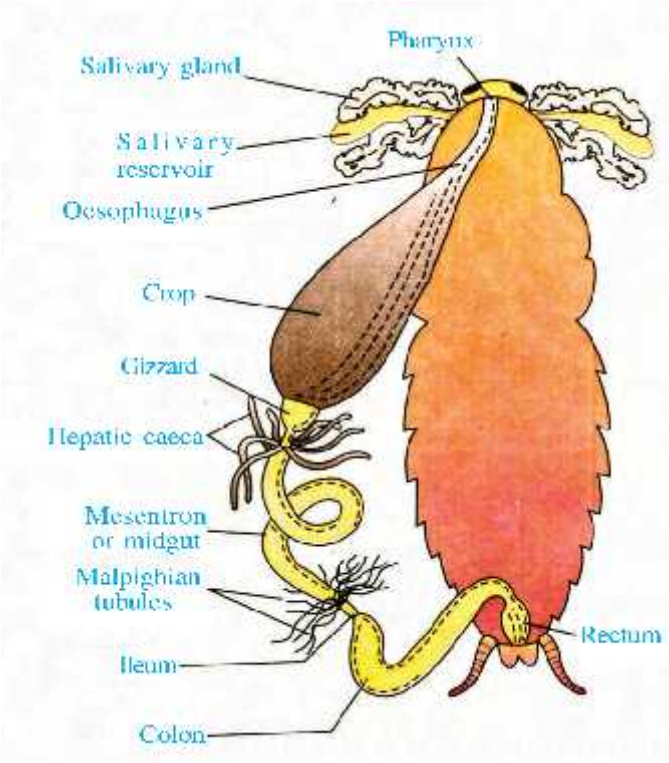
The body wall of cockroach is made up of three main layers. The outermost layer is of cuticle. It forms exoskeleton. The layer under it is epidermis. It is formed of a single layer of columnar epithelial cells. On the innermost side, a basement membrane occurs.

Alimentary Canal :

The alimentary canal of cockroach is complete.

Mouth is located at the anterior end of head. Mouthparts adapted for gathering and cutting food are arranged surrounding the mouth.

The tubular region following the mouth is called - pharynx. Then onwards, the alimentary canal is divided into three regions named foregut, midgut and hindgut. The cavities of foregut and hindgut are lined with cuticle. On the lateral side of the alimentary canal, a pair of salivary glands are found. Each salivary gland consists of two secreting lobes and two reservoirs.

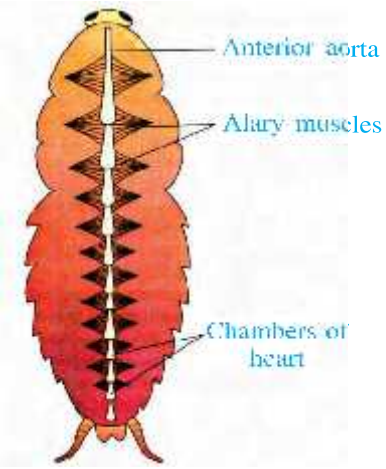


Digestive system of Cockroach

Oesophagus is narrow, tubular structure which follows the pharynx. It enlarges at its posterior end into a 'crop'. Crop opens into a muscular 'gizzard'. Six chitinous teeth occur inside the gizzard. At the posterior end of gizzard, a sieve-like structure made up of chitinous teeth is located. The region of alimentary canal upto gizzard constitutes the foregut. Gizzard opens into the midgut. Eight blind hepatic caeca occur in the midgut. Midgut opens into the hindgut.

At the junction of midgut and hindgut about 150 yellowish, thread like malpighian tubules open. They are excretory units. The proximal region of hindgut is called ileum. It is slightly narrow. The following region is some what coiled. The middle region is called colon. The bag-like posterior end region of hindgut is called rectum. It is folded inside. Rectum opens to the outside through anus. Anal opening is located under the tergum of 10th abdominal segment.

Cockroach is omnivorus animal. Cockroach searches food with help of antennae. In salivary gland saliva is prepared by secretory lobes. Mucus present in saliva makes food wet. The enzyme amylase affect the starch of food and digestion begins. Now food enters into crop and digestion proceeds further. Now food enters into gizzard where it cuts down into small pieces with the help of hard chitinous teeth, and the food enters the midgut. Columnar cells of midgut hepatic caeca secrete enzymes. Various proteolytic enzymes convert protein unit into amino acids. Through lipase fatty acid and glycerol are produced from lipid. Amylase produces the sugar from starch.



Blood Circulatory system of Cockroach

Blood vascular system

Blood vascular system of cockroach is an open type. It means during circulation blood enters into the body cavity instead of blood vessels. Thus body cavity acts as a haemocoel and organs of the body and tissues are directly connected with the blood. The haemolymph is mostly composed of plasma and uncertain shaped cells. The heart is made up of thirteen units. Three units occur in thoracic region and ten occur in the abdominal region. Anterior end of the heart is slightly narrow and posterior end is broad. Two valved openings occur between two nearby units. They are called ostia. The cells of haemolymph are of two types. Proleucocytes of smaller size and phagocytes of larger size. Blood from sinuses enters heart through ostia and is pumped anteriorly to sinuses again.

Respiratory system

Branched tubes known as trachea are main components of respiratory system. The branches of tracheal tubes are spread throughout the body. Terminal branches of tracheal tubes are called tracheoles which carry oxygen to entire body. The trachea have direct contact with the air in atmosphere through pores known as spiracles. Ten pairs of spiracles occur. Two pairs of spiracles occur in thoracic region and eight pairs of spiracles occur in the abdominal region. The walls of spiracles are framed from chitinous bristles. Chitinous bristles work as filter and prevents water and other waste substances entering into the respiratory system. Oxygen gets entered into the tracheas through spircales and from there it comes in contact of tissue fluid and gets dissolved in it. The tissues of body use this dissolved oxygen to get energy to work. The carbon dioxide produced consequently gets dissolved in tissue fluid generally which comes out through exhaling.

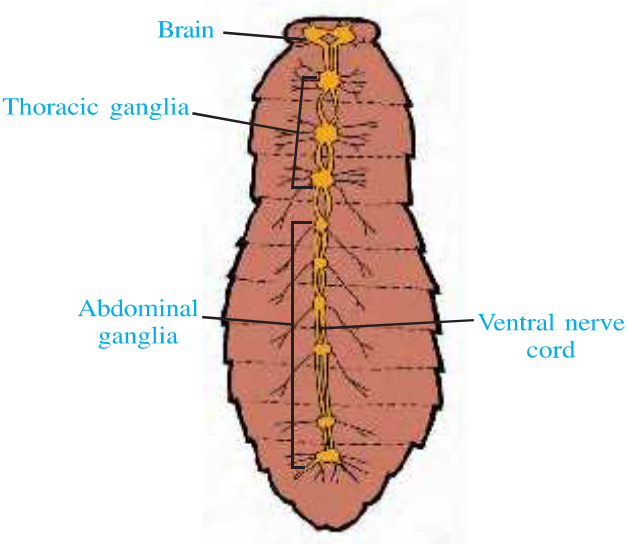
Excretory organs and process of excretion

At the junction of midgut and hindgut about 150 yellowish long, thin and hollow malpighian tubules open. They are main exceretory units. These blind tubules always float in the haemolymph. Each tubule is lined by glandular and ciliated cells. They absorb nitrogenous waste products and convert them into uric acid which is excreted out through the hindgut. Therefore, cockroach

is a uricotelic animal. Excretory substances enter into the hindgut having large amount of water. This water is absorbeded by the wall of hindgut.

Nervous System

Nervous system is made up of paired ganglia, nervecords and nerves. Supraoesophageal formed by the fusion of three ganglia, which is known as brain, are located on oesophagus. They are connected with subeosophageal gangilia through circum-oesophageal commisures. Thus a nerve ring is formed. Suboeosephageal ganglion innervate the mouth parts. Three ganglia occur in the thorax region and the six ganglia occur in abdominal region. Each ganglion is made up of fusion of two ganglia. Thus, nervous system of cockroach is spread throughout the body.

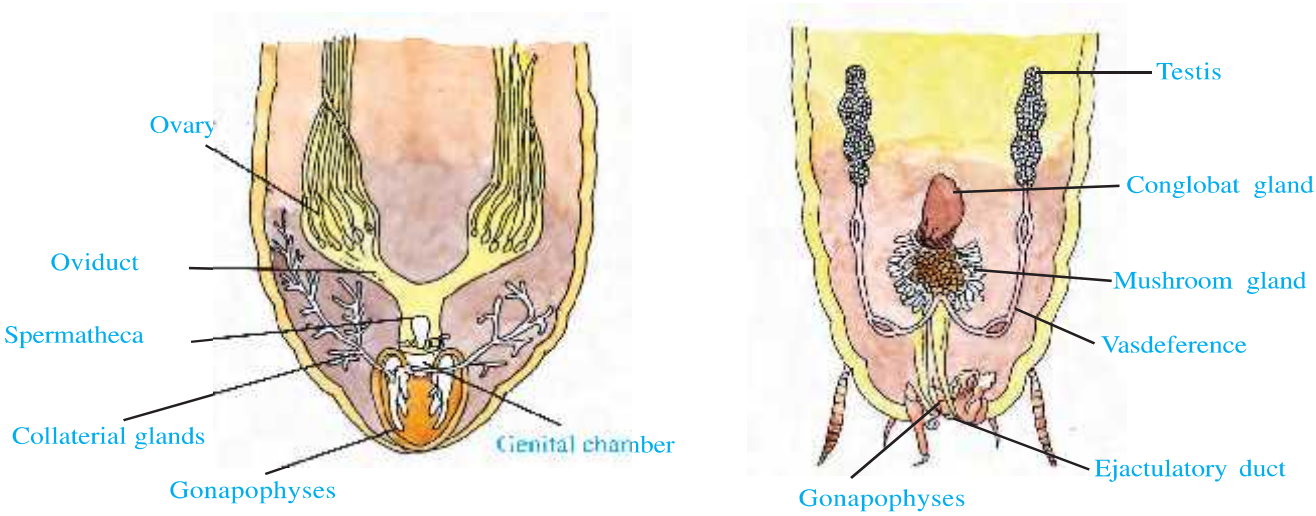


Nervous system of Cockroach

Amongst sense organs in cockroach, antennae, eyes, maxillary palps, tarsus of walking legs and anal cercus are included. The compound eyes are situated at the dorsal surface of the head. Each eye consists of about 2000 hexagonal ommatidium. With the help of several ommatidium a cockroach can receive several images of an object. This kind of vision is known as mosaic vision.

Reproductive system

Cockroaches are unisexual animals and both sexes have well developed reproductive organs. **Male reproductive system** consists of a pair of testis lying one on each lateral side in the 4 to 6 abdominal segments. From each testis arises a thin vas deferens, which opens into ejaculatory duct through seminal vesicle. The ejaculatory duct opens into male gonopore situated ventral to anus. A mushroom shaped gland occurs in segments 6 and 7. It is an accessory reproductive gland. At the end of the abdomen, chitinous gonapophysis are located which form external reproductive organs. The sperm are stored in the seminal vesicles and are glued together in the form of bundles called spermatophores which are discharged during copulation. In the **female reproductive system**, two ovaries lying laterally in the 2 to 6 abdominal segments. Each ovary is formed of a group of eight ovarian tubules or ovarioles, containing a chain of developing ova. Oviducts of each ovary unite into a single median oviduct known as vagina which opens into the genital chamber. A pair of spermatheca is present in the 6th segment. During copulation ovum come in the genital chamber, where they fertile by sperms. A dark brown coloured ootheca is formed by the group of fertilized eggs. Each ootheca has 14 to 16 eggs. Cockroach is developed through nymphal stage (or young insect). The nymphs look very much like adults. The nymph grows by moulting about 6 to 7 times to reach the adult form.



Male and Female reproductive systems of Cockroach

Summary

Earthworm and Cockroach show characterstic features in segmentation, symmetry and body organization. Earthworm is a burrowing and terrestrial animal while cockroach found in kitchens, hotel and laterines, where plenty of food is available. Earthworm exhibits true segmentation, while cockroach's body is segmented and divided into head, thorax and abdomen, segments of the body bares jointed appendages. The alimentary canal is complete in both the animals. The blood circulatory system is closed type in earthworm while in cockroach it is of open type. Earthworm is devoid of special respiratory organs, the exchange of gases take place through body wall. The respiratory system of cockroach consists of trachea which open outside through the spiracles. The excretory organs are nephredia in earthworm while in cockroach its consists of malpighian tubules. Nervous system is well developed in both earthworm and cockroach. Earthworm is a hermaphrodite animal while cockroach is dioecious. i.e. sex are separate. The earthworm exhibits cross fertilization and development takes place in cocoon, secreted by glands of clitellum. Development is direct, there is no larval forms. In cockroach fertilization is internal. Female cockroach produces ootheca, bearing the developing embryos. The young ones, called nymphs.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) The body of an earthworm is divided into how many segments ?

(A) 100 - 120 ◯ (B) 50 - 70 ◯

(C) 150 - 200 ◯ (D) 1000 - 2000 ◯

(2) Which cells are found in the epidermis of earthworm ?

(A) Gland cells and sensory cells ◯

(B) Supporting cells and gland cells ◯

(C) Supporting cells, gland cells, sensory cells and basal cells ◯

(D) Only sensory cells ◯

(3) Cockroach belongs to which class of Phylum Arthropoda ?

(A) Crustacean ◯ (B) Arachnida ◯

(C) Insecta ◯ (D) Myriapoda ◯

(4) Body of cockroach is divided into :

(A) Two parts ◯ (B) Four parts ◯

(C) Three parts ◯ (D) Five parts ◯

(5) In which segments does the clitellum found in *Pheretina posthuma* ?

(A) 12th, 13th and 14th ◯ (B) 13th, 14th and 15th ◯

(C) 14th, 15th and 16th ◯ (D) 15th, 16th and 17th ◯

(6) In earthworm one pair of male gential apertures is found in ventro lateral side of which segments ?

(A) 19 ◯ (B) 17 ◯

(C) 18 ◯ (D) 15 ◯

(7) The abdomen of cockroach is made up of :

(A) 10 segments ◯ (B) 8 segments ◯

(C) 9 segments ◯ (D) 7 segments ◯

(8) How many chitinous teeth are present in the cavity of gizzard ?

(A) 5 ◯ (B) 6

(C) 3 ◯ (D) 4 ◯

(9) In which segments typhlosole region is found ?

(A) 26 to 95 segments ◯ (B) Last 25 segments ◯

(C) 15 to last 15 segments ◯ (D) First 25 segments ◯

(10) In earthworm which segments possess blood gland ?

(A) 4th, 5th and 6th segments ◯

(B) 7th, 8th and 9th segments ◯

(C) 1st, 2nd and 3rd segments ◯

(D) 9th, 10th and 11th segments ◯

(11) Heart of cockroach is made up of :

(A) 12 units ◯ (B) 10 units ◯

(C) 11 units ◯ (D) 13 units ◯

(12) How many spiracles are present in cockroach ?

(A) 10 pairs ◯ (B) 8 pairs ◯

(C) 9 pairs ◯ (D) 6 pairs ◯

(13) How many types of nephridia are found in earthworm ?

(A) Three types ◯ (B) Two types ◯

(C) One type ◯ (D) Four types ◯

(14) In which segments, the testis lie in earthworm ?

(A) 10th and 11th segments ◯ (B) 12th and 13th segments ◯

(C) 13th and 14th segments ◯ (D) 15th and 16th segments ◯

2. Describe the following :

(1) Internal structure of body wall of earthworm

(2) Head of cockroach with mouth parts

(3) "Alimentary canal of earthworm" – Explain with diagram.

(4) Walking legs of cockroach

(5) External features of earthworm

(6) "Digestive system of cockroach" – Explain with diagram.

(7) Different types of nephridia of earthworm

(8) Respiratory system of cockroach.

(9) "Nervous system of earthworm" – Explain with diagram.

(10) Excretion and excretory process in cockroach

(11) Male reproductive organs of earthworm

(12) Female reproductive organs, process of copulation and cocoon formation

(13) Male reproductive system of cockroach

(14) Female reproductive system of cockroach, process of copulation and cocoon formation.

6

Animal Morphology and Anatomy - II
(Frog)

Frog is a member of class Amphibia. The class amphibia includes all those animals which live in fresh water as well as on land habitat. They are the first tetrapods which evolve from fish-like ancestors. They are characterized by their outstanding features and thus stand in between the fishes and reptiles. The systematic position of frog is as under:

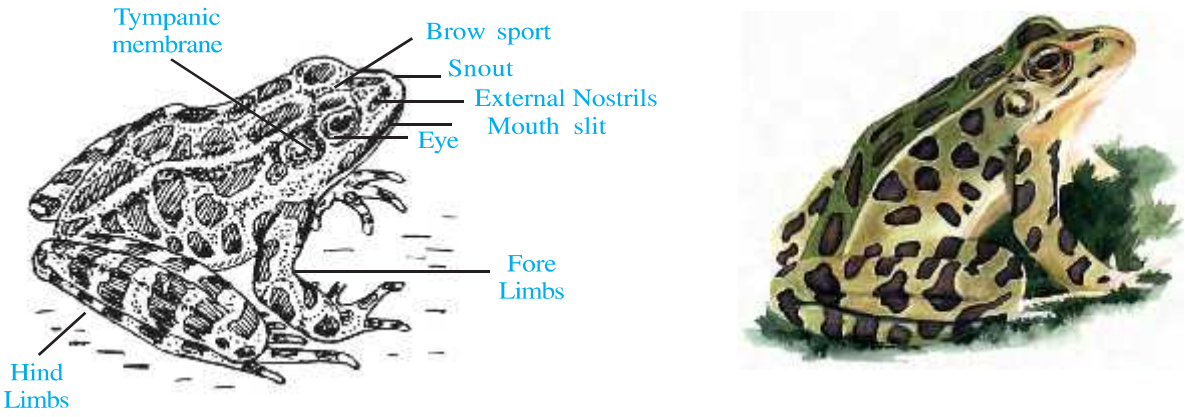
Systematic position

Phylum	:	Chordata
Subphylum	:	Vertebrata
Division	:	Gnathostomata
Class	:	Amphibia
Order	:	Anura
Genus	:	*Rana*
Species	:	*tigrina*
Binomial nomenclature	:	*Rana tigrina L.*

The common Indian bull frog *(Rana tigrina L.)* generally lives in or near the water. The dormant life during winter and summer known as hibernation and aestivation respectively. It is carnivorous which feeds on small animals. There are many natural enemies of frog such as snakes, some birds, man etc. Frog has capacity to change the skin colour according to the environment and this helps frog to escape from enemies.

External Morphology

The size of the frog varies in the same species depending upon the age of the individual. Frog has streamlined body which helps them to swim in water.

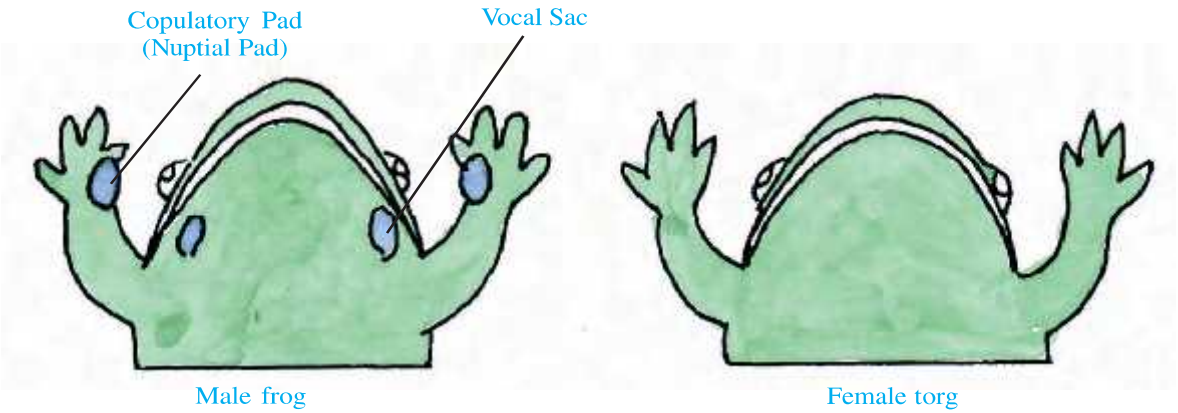


External morphology of Frog

The colour of the body at the dorsal side is green with black spots but ventrally it is lighter. The body is divided into two parts, head and trunk. The true neck and tail are absent. The anterior most part of the head is snout with two nostrils and laterally proputed eyes. On the mid dorsal line, in between two eyes there is browsport. Mid ear is represented by tympanic membrane. On the ventral side wide mouth is seen. The trunk bears two pairs of limbs; fore limbs are shorter with four digits while hind limbs are larger with five toes. Toes of hind limbs are connected by webs, which helps the animal in swimming.

Rana tigrina exhibits external sexual dimorphism, the phenomenon where two sexes (male and female) are morphologically different. During breeding season frog exhibits following characters.

Male	Female
• Two vocal sacs are present	• Vocal sacs are absent
• Nuptial pad present in the index finger	• Nuptial pad is absent
• The skin shows dark yellow colour during breeding season.	• Skin colour is not changed.
• The abdominal region narrow and flat.	• The abdominal region is broad and buldged.

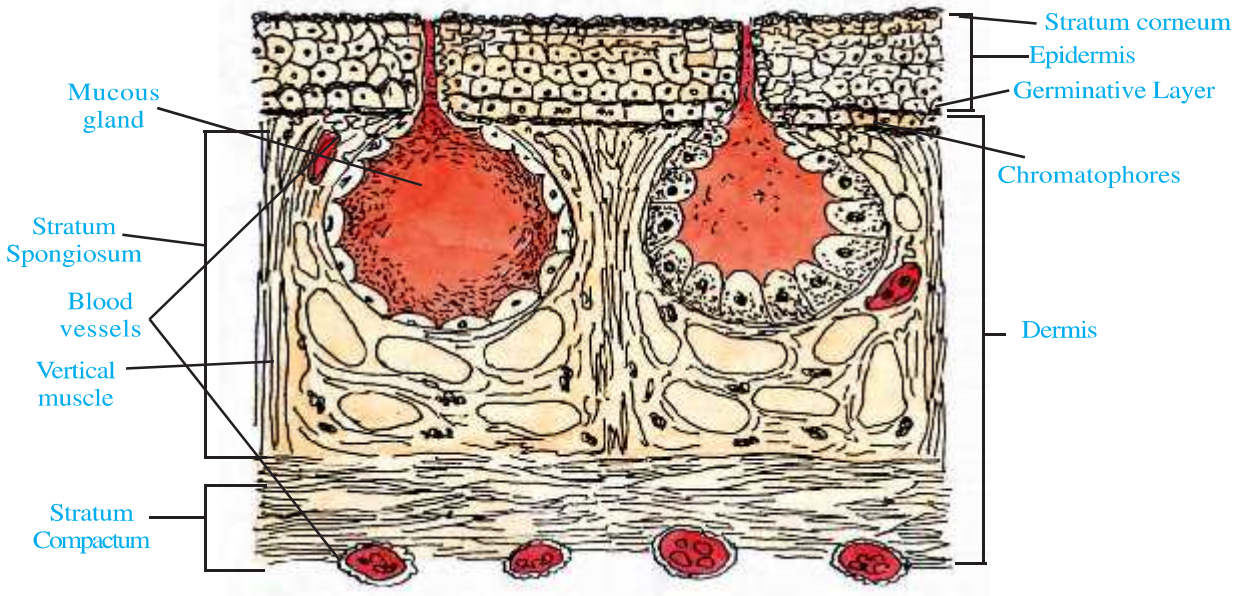


Sexual Dimorphism in Frog

Skin

The skin of frog is moist, smooth, slimy and without any exoskeleton. It consists of two layers, namely an outer epidermis and an inner dermis. The epidermis formed of several layers of epidermal cells. It is further divided into two layers, outer stratum corneum and inner stratum germinativum. Stratum cornium formed of a single layer of cells. This layer is dead and shed periodically. Stratum germinativum is formed of columnar cells. New cells are formed from this layer.

Dermis is the inner layer of skin. It is differentiated into two layers, outer stratum spongiosum and inner stratum compactum. The stratum spongiosum consists of loose network of connective tissue, blood vessels and mucous glands. Superficial part of this layer contains chromatophores. The stratum compactum is made by dense connective tissue, smooth muscle fibers, nerves and blood vessels.



Vertical section of the skin of Frog

Functions of the skin

(1) It gives definite shape and texture to the body.

(2) It protects the body against foreign bodies and fungi.

(3) It acts as a chief respiratory organ.

(4) It acts as an important sensory organ.

(5) The frog never drinks water but absorbs water through skin.

Anatomical Structure

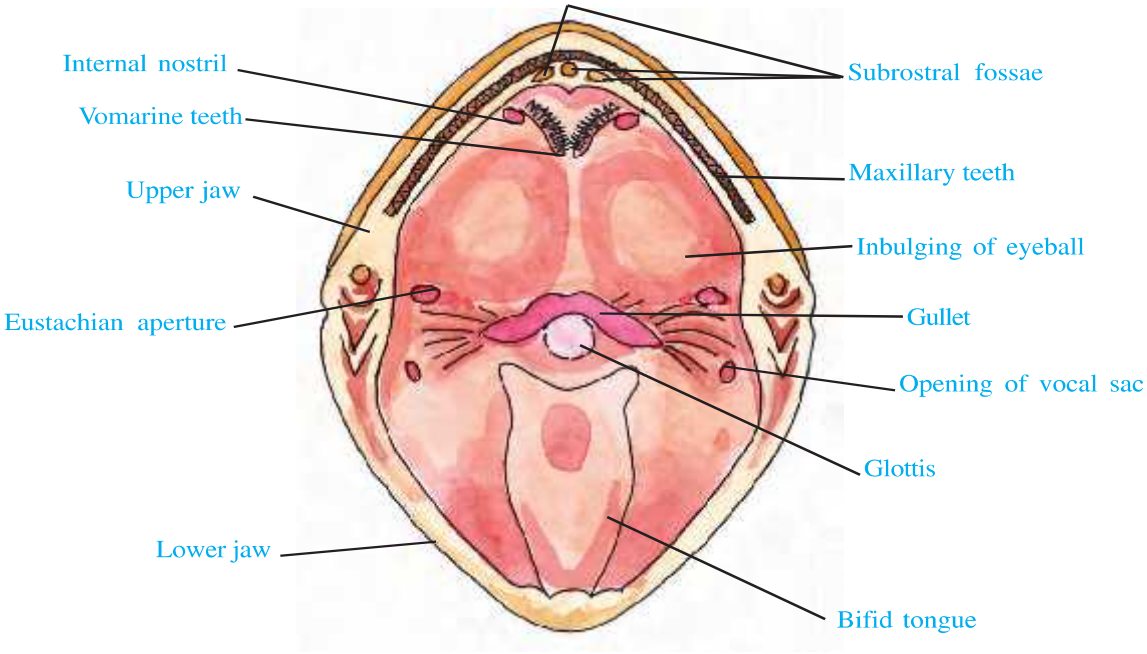
Frog has clear body cavity and different types of organ systems such as digestive system, skeleton system, circulatory system, respiratory system, urinogenital system and nervous system are seen in it.

Digestive System

The digestive system of frog mainly includes the alimentary canal and digestive glands. Alimentary canal starts from the mouth and ends at cloaca. The alimentary canal includes buccal cavity, pharynx, oesophagus, stomach, intestine, rectum and cloaca.

Alimentary Canal

Mouth is wide opening located at the anterior end of the head. It is bounded by the upper and lower jaws. A single row of teeth is present in the upper jaw. Mouth leads into a wide and broad cavity called buccal cavity which lies in between two jaws. The buccal cavity contains, maxillary teeth, vomerine teeth, internal nostrils, inbulging of eye-ball, eustachian apertures, opening of vocal sacs (only in male) and bifid tongue. The internal nostrils are a pair of openings located near the vomerine teeth. They serve in respiration. Behind the vomerine teeth there are two inbulging areas on the roof of the buccal cavity known as eye-balls. A pair of eustachian apertures lies on the roof of the buccal cavity, almost at the angles of the jaws. The eustachian apertures connects the pharynx with the middle ear and help in keeping the air pressure equal on both the sides of tympanic membrane. The two vocal sacs are present only in male frog and they open into buccal cavity, near the lateral surface of lower jaws. The bifid tongue is soft, slimy and fleshy. It is attached by its anterior end and is free at the posterior end. The free end of the tongue is bifid.

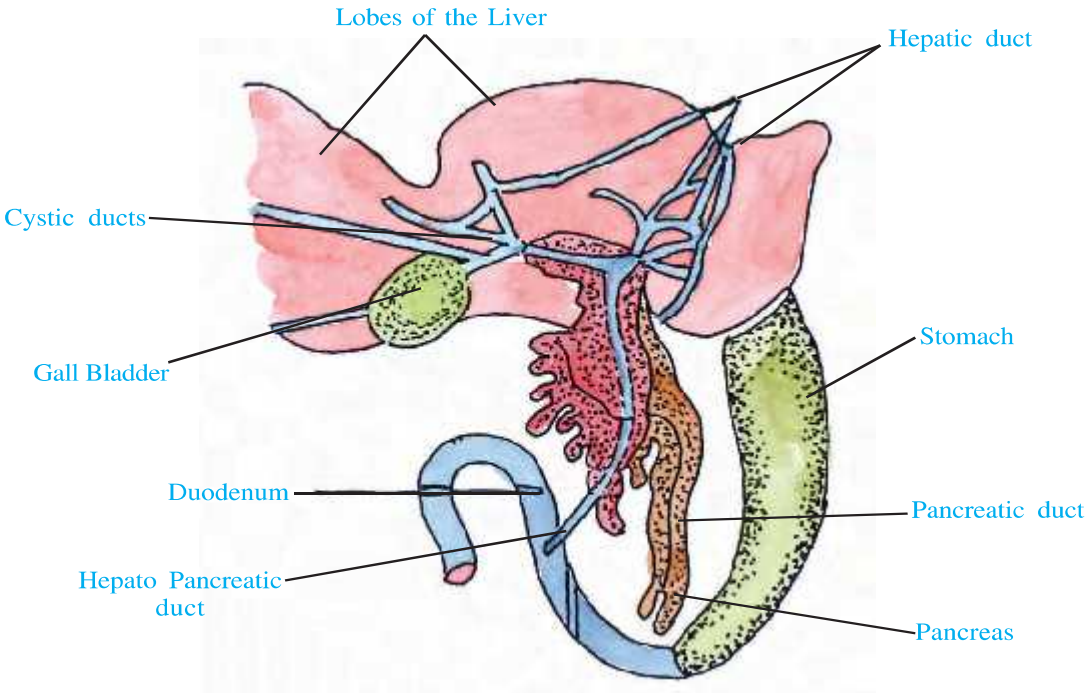


Open Bucco - Pharyngeal Cavity of Male Frog

The posterior end of the buccal cavity is the pharynx due to absence of neck. There is no demarcation between the buccal cavity and the pharynx. Hence, both the structures sometimes are collectively known as a bucco-pharyngeal cavity.

The oesophagus is a short, wide, muscular and highly distensible tube leading in to the stomach. The stomach lies on the left side in the body cavity. It is a large, broad and slightly curved chamber. It is formed of two regions, large broder anterior part is called cardiac stomach and posterior narrow part is called pyloric stomach. Its mucous epithelium contains multicellular gastric glands secreting the pepsinogen enzyme, diluted hydrochloric acid and mucus. Posterior end of pyloric stomach contains pyloric sphincter valve. The stomach is an organ for temporary food storage churning and partly digestion of proteins. The pyloric stomach leads to the small intestine.

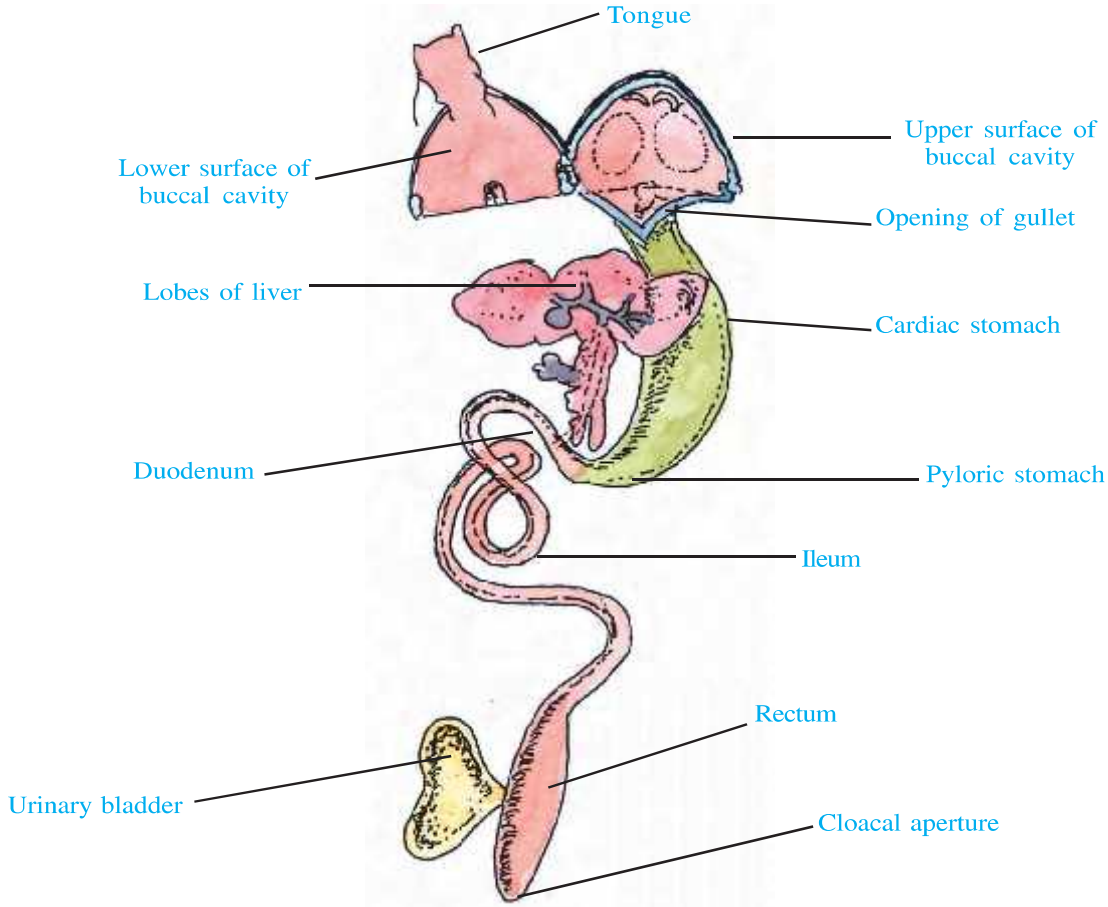
The small intestine is divided into anterior duodenum and a posterior ileum. Duodenum runs ahead parallel to stomach forming a U-shaped structure. It receives the hepatopancreatic duct from liver and pancreas which brings bile and pancreatic juice. The coiled ileum is the longest part of alimentary canal. Digestion and absorption of digested food occur in the small intestine.



Connectivity of Liver and Pancreas

The ileum leads to the large intestine. Anterior is a short, wide tube, running straight and opens into the cloaca. Its function is the re-absorption of water and the preparation and storage of faeces.

Cloaca is the small terminal sac like part. The term cloaca is used to denote the end part of the large intestine which opens into the rectum and the urinogenital apertures. Cloaca opens outside by the vent or cloacal aperture located at the posterior end of body.



Digestive tract of Frog

Digestive glands

The organ in which food does not enter but its secretion helps in physiological process of digestion are called digestive gland which includes Liver and Pancreas.

Liver

Liver is the largest gland found in the frog. It is a dark brown coloured gland located close to the heart and lungs. Liver is divided into two lobes and the left is again sub divided so it appears trilobed. A gall bladder lies between the right and left (lateral) lobes. The liver secretes greenish liquid called bile which contains bile salts and bile pigments like bilirubin and biliverdin is stored in gall bladder. The bile is transported to gall bladder by small hepatic ducts. Cystic ducts from gall bladder and hepatic ducts from liver combine to form a common bile duct. The bile duct passes through the pancreas and receives numerous pancreatic ducts. Now the bile duct is called heptopancreatic duct. It opens into the duodenum. Bile has no digestive enzymes, it only emulsifies fat so that liver is not truly a digestive gland.

Pancreas

It is the exocrine and endocrine pale yellow colored gland. It is situated at the junction between the stomach and duodenum. The pancreas produces pancreatic juice which contains

various enzymes which helps in digestion of proteins, carbohydrates and fats. In between the Pancreatic lobule groups of cells are found which are known as **islets of Langerhans.** These cells endocrine in nature which secretes hormones like **insulin and glucagon** directly into blood vessels. Insulin and glucagon maintain level of glucose in blood.

Digestion in Frog

Frog is a carnivorus animal. Generally it feeds on insects, worms, crustaceans, molluscs etc. The prey is captured by rapid action of its prehensile tongue. If prey is large, it is gripped with jaws, and prevented from escape. The prey is swallowed. The mucus helps in swallowing. The digestion of captured prey takes place in the stomach, duodenum and intestine. The physiology of digestion in different organs, enzymatic action and role of hormone in it are summarized in following table :

Table 1

Physiology of Digestion

Organs involving in digestion	Enzymes, Hormones and other substances	Function
Buccal cavity	No digestion	Prevent the escape of the prey
Tongue		Captured prey and put it into buccal cavity
Gullet		Helps in swallowing prey due to its slimy surface
Oesophagus	Mucus secretion from mucus secreting gland	-Prey undergoes physical changes due to constant peristaltic movement of wall -Prey easily passes toward stomach through it
Stomach	Secretion of Gastric juice from gastric gland (1) Gastrin (H)	-Stimulate gastric gland.
	(2) Diluted HCl (0.4%)	-Kills microbes from food -Provides acidic medium to activate enzyme Pepsinogen
	(3) Inactive Pepsinogen (E)	-Inactive Pepsinogen + HCl $\longrightarrow$ Active Pepsin -Protein + Pepsin $\longrightarrow$ Peptones or Proteoses
	(4) Mucus	- Lubricates the wall
	The liquefied semi digested acidic food is now called **Chyme.**	

Liver (Digestive gland)	Secretion of bile juice Contains Bile Salts.	-Greenish alkaline fluid which neutralized the acidity of chyme -Emulsifies fats -Activates pancreatic Lipase
Pancreas (Digestive gland)	Secretion of pancreatic juice (1) Inactive Trypsinogen (E) Inactive Chymotripsinogen (E) Procarboxypeptidase (E) (2) Enterokinase (co-enzyme)	Alkaline juice Inactived Trypsinogen + Enterokinase ⟶ Active Trypsin; which activates other inactive enzyme.
	(3) Trypsin (E)	Peptons or proteoses + Trypsin ⟶ Peptides and Amino acids
	(4) Amylase (E)	Polysacharide + Amylase ⟶ Maltose
	(5) Lipase (E)	Emulsified Fats + Lipase ⟶ Fatty acid + Glycerol
Duodenum	(1) Enterogastrone (H)	Reaches stomach and stop production of gastric juice
	(2) Cholecystokinin (H)	Contracts Gall bladder and releases bile juice into duodenum
	(3) Secretin (H) (4) Pancreozymin (H)	Combine effect is to stimulates pancreas to secrete pancreatic juice into duodenum
	(5) Enterocrinin (H) (6) Deokinin (H)	Stimulates Intestine to secrete Intestinal juice
Intestine	Secretion of Intestinal juice (1) Erepsin or Peptidases (E)	 Peptides + Erepsin ⟶ Amino acids
	(2) Maltase (E)	Maltose + Maltase ⟶ Glucose + Glucose
	(3) Sucrase or Invertase (E)	Sucrose + Sucrase or Invertase Glucose + Fructose
	(4) Lipase (E)	Lipid + Lipase ⟶ Fatty acids + Glycerol

* **Note :** Here E = Enzymen and H = Hormone

Absorption

Absorption is a process in which the digested food is taken into blood. Mainly this process takes place into duodenum and ileum. The walls of these organs are folded with villi which increase the absorptive surface. Water, mineral, salts and other nutrients in solution are directly absorbed through the epithelial lining and then they pass into blood capillaries.

Adsorption of digested food and egestion

As the food passes downwards in the alimentary canal the water and the digested products are absorbed whereas the indigested food, debries epithelial cells, leucocytes, bile pigments and large number of bacteria form faeces are removed time to time through cloacal opening.

Respiratory System

Respiration is a process in which living organisms obtain oxygen for oxidation and CO_2 is removed regularly from the body. Organs involved in respiration are known as respiratory organs. Frog as an amphibian animal exhibits three types of respiration i.e. (i) Cutaneous respiration or respiration through skin, (ii) Bucco-pharyngeal respiration and (iii) Pulmonary respiration or respiration through lungs. Generally frog respires through skin, but when the need of oxygen is greater it respires through bucco-pharyngeal cavity and lungs.

(1) Cutaneous respiration

This type of respiration takes place through the skin, so it is known as cutaneous respiration. The skin of frog is suitable for respiration due to following characters:

- Skin remains moist due to mucus, secreted by the mucous glands.
- Skin is permeable for gases.
- Skin is very thin.
- Skin has rich blood supply through blood capillaries.

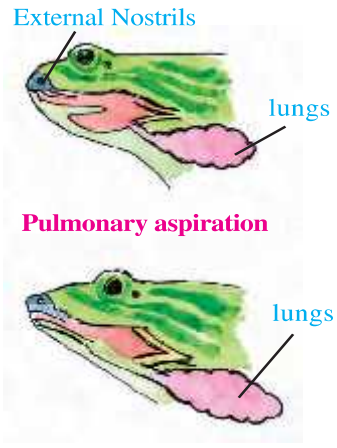
Due to above characters, the oxygen from water or air diffuses into blood and carbon dioxide diffuses from the blood into surrounding medium of water or air through the skin. This type of respiration takes place in both media, water as well as on land. So when frog lives in any habitat, either water or land, it respires through skin.

(2) Bucco-pharyngeal respiration

Respiration takes place through the buccal cavity and the pharynx then it is called bucco-pharyngeal respiration. It is a terrestrial respiration. Both the organs are lined with thin mucus, permeable to gases and rich with blood vessels. Lowering and raising of the floor of the buccal cavity bring the bucco-pharyngeal respiration, during the course of which the air is constantly sucked into the buccal cavity and is drawn out through the external and internal nares. When the floor of the buccal cavity is lowered, the air enters the buccal cavity through the nostrils or the nares. During this respiration gullet remains closed.

(3) Pulmonary respiration

Respiration takes place through lungs in terrestrial habitat is called pulmonary respiration. The system consists of respiratory tracts and lungs. There are two respiratory tracts, each respiratory tract starts from an external nostril. It opens into the bucco-pharyngeal cavity. Bucco-pharyngeal cavity leads into a sac called laryngotracheal chamber through glottis. This laryngotracheal chamber opens into lungs.



Pulmonary aspiration

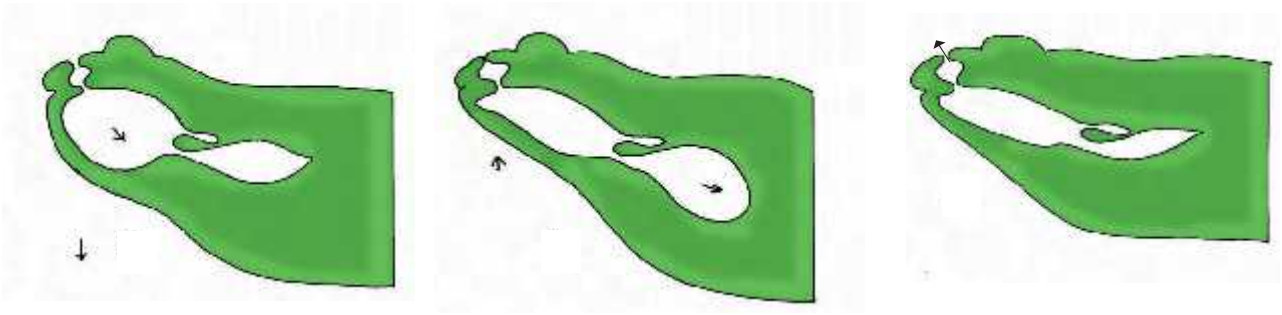
Pulmonary expiration

The entire process of pulmonary respiration is completed in three steps : (1) Aspiration, (2) Inspiration and (3) Expiration.

(1) Aspiration : The entry of the gases into the bucco-pharyngeal cavity is called aspiration.

(2) Inspiration : The gases pass through the bucco-pharyngeal cavity to lungs is called inspiration, during this process diffusion of oxygen occurred.

(3) Expiration : The passage of impure air from the lungs to the outside of the body is called expiration.



Aspiration Inspiration Expiration

Pulmonary respiration in frog

Circulatory System

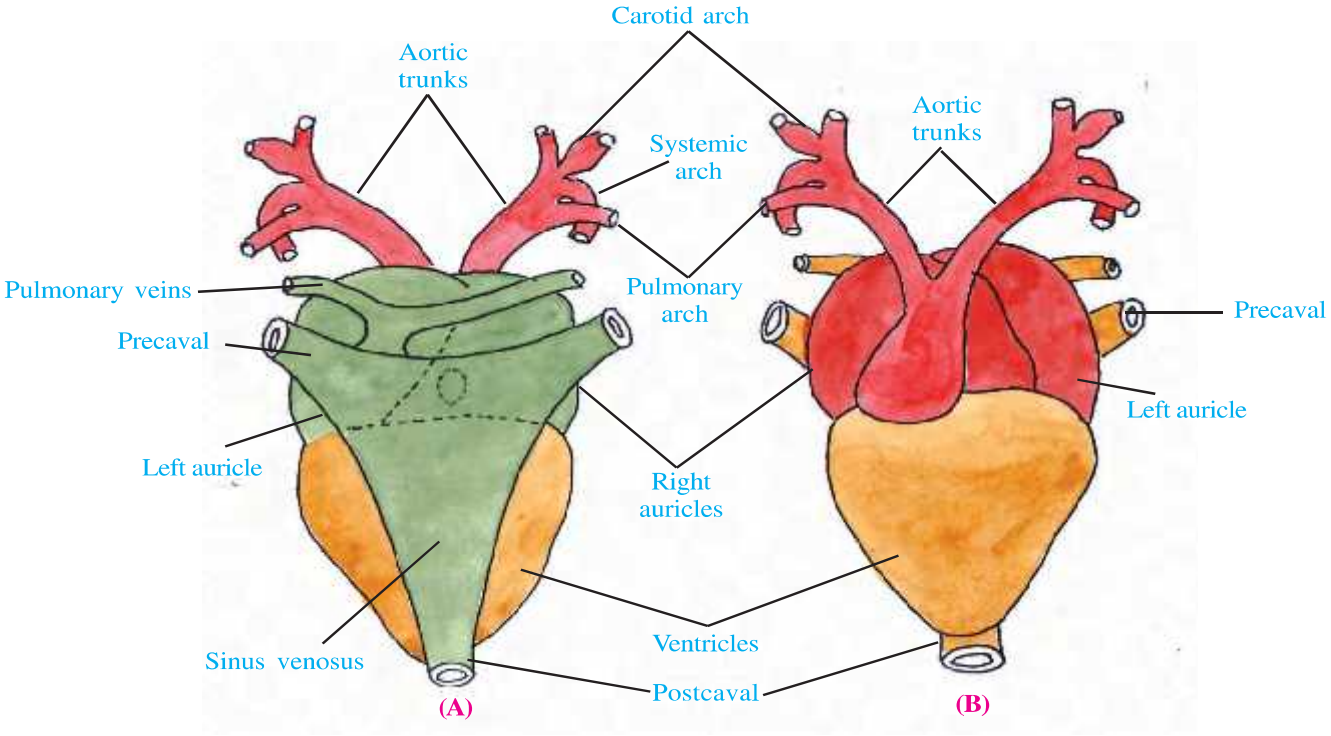
Frog as a vertebrate animal has closed type of circulatory system. This system has four main components i.e. blood, heart, arteries and veins.

Blood is a red coloured liquid connective tissue. It is composed of blood cells (corpuscles) and blood plasma. Blood corpuscles are of three types (1) Red Blood Corpuscles (RBCs) - nucleated and contain hemoglobin, (2) White Blood Corpuscles (WBCs) - colourless and nucleated and (3) Platelets - nucleated. The blood plasma is a liquid in nature and consists of mainly water and salts (see blood as a tissue in Chapter 4).

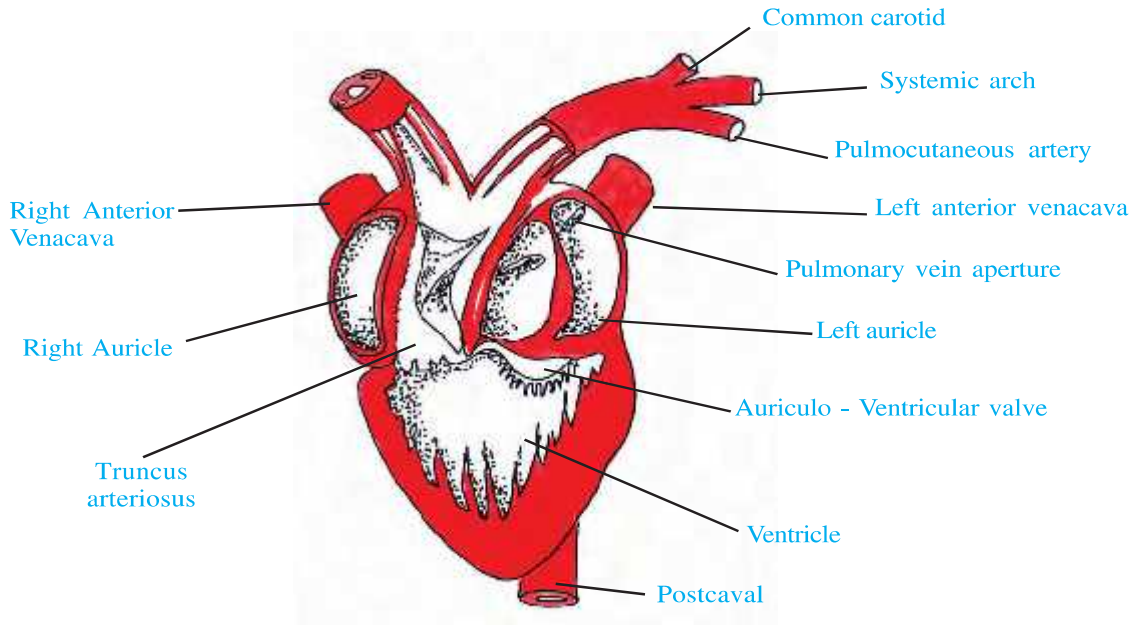
The heart is protected inside a double walled bag called pericardium. In between these walls pericardium fluid is present. The heart is located in the anterior region of coelom. It is muscular, conical and three chambered (two auricles and one ventricle) pulsative organ. On the dorsal side of heart sinus venosus is located, which collects deoxygenated blood from various parts of the body and empty up into right auricle through sinu-auricular aperture.

The left auricle receives oxygenated blood from lungs through a common pulmonary vein. The blood from both auricles enter the ventricle through a single opening called auriculo-

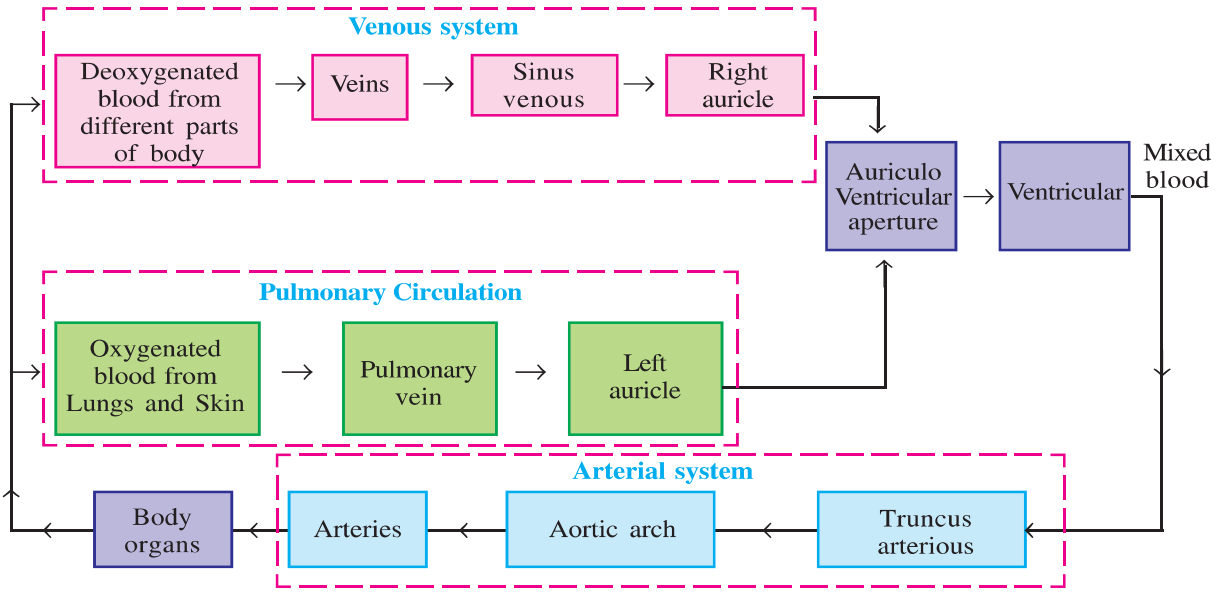
ventricular aperture. Thus, oxygenated blood from left auricle and deoxygenated blood from right auricle is mixed in ventricle. As a result in frog, mixed blood is circulated through arterial system. The ventricle contracts and forces the blood into truncus arterious from where it enters into arterial system.



Structure of Heart : (A) Dorsal view (B) Ventral views

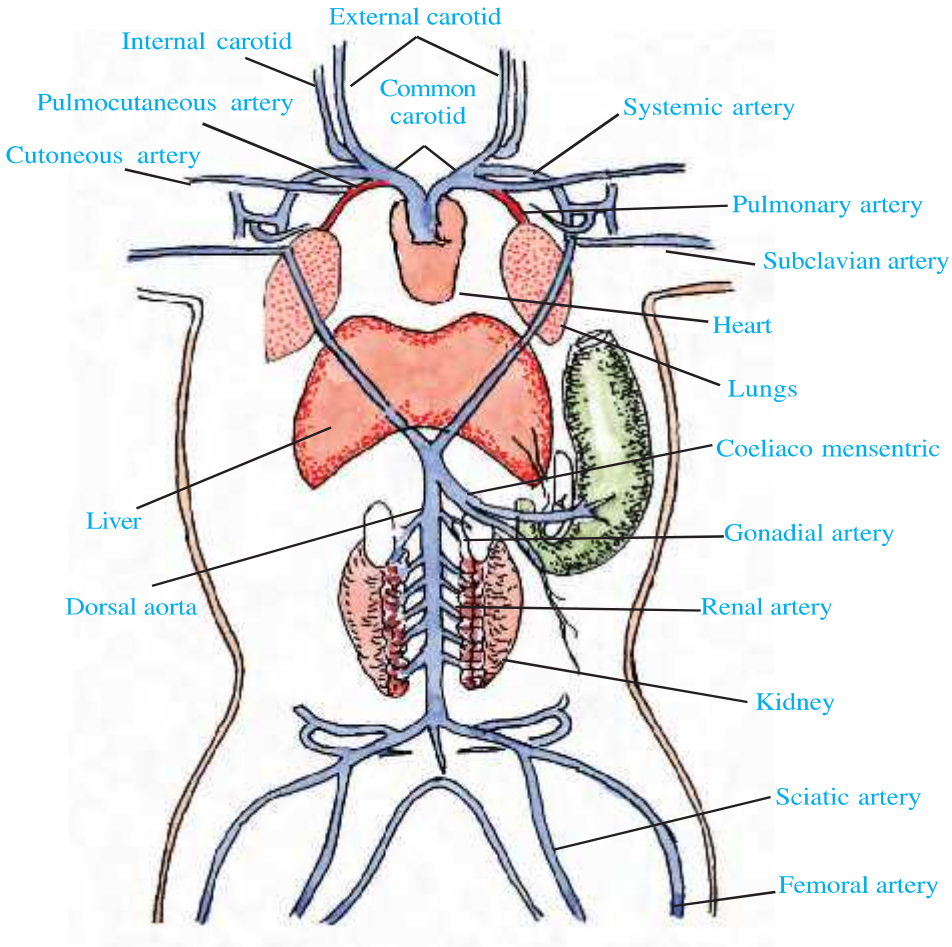


Verticle section of the Heart of Frog



Flow of blood in the frog

The arterial system, supplies blood from heart to different parts of the body. The system starts from truncus arteriosus and supplies mixed blood through aortic arteries.



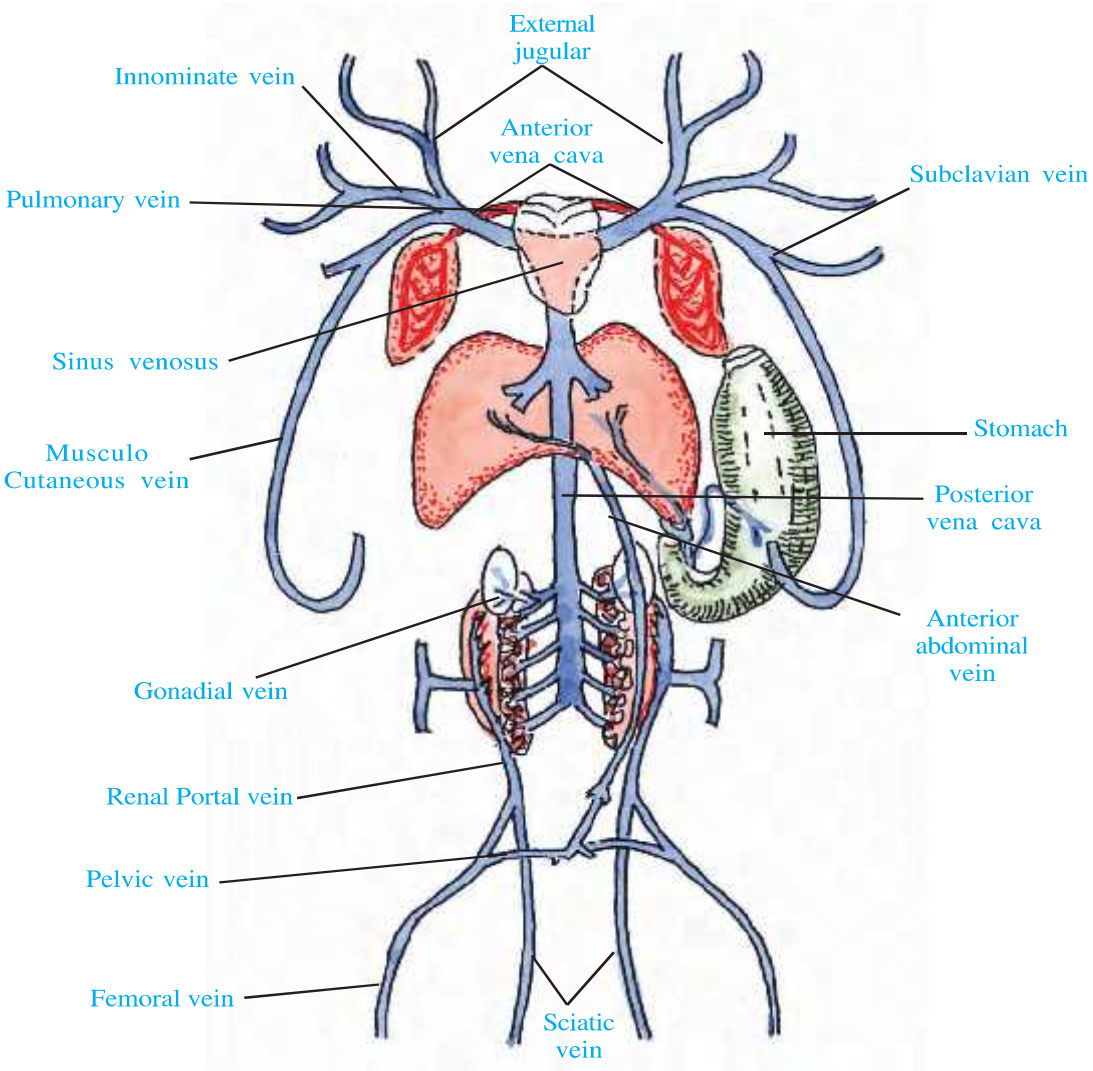
Arterial system of Frog

(1) carotid arch : external carotid and internal carotid arteries supply blood to head region. **(2) Systemic arch :** Unites to form a dorsal aorta. It supplies blood to posterior region through various arteries such as Coeliaco-mesenteric artery (supply blood to alimentary canal), gonadial artery (supply blood to gonads), renal artery (supply blood to kidneys) and iliac artery (supply blood to hind limbs). **(3) Pulmocutaneous artery :** Supplies blood to lung and skin.

The venous system brings blood from different parts of the body to heart. Collected impure blood from all the parts of the body is empty up into sinus venosus through three cavals (two pre-cavals and one post

caval). Each pre-caval receives blood from both sides through external jugular, innominate and sub-clavian veins. These veins drain impure blood from different organs like tongue, lower jaw, head, brain, fore limb etc. while cutaneous vein and the branches of sub-clavian veins exceptionally carries oxygenated blood. Renal veins emerging from two kidneys open into posterior vana cava which passes through right lobe of liver and opens in to sinus venosus, which bring blood from kidneys, gonads and liver through different veins.

Generally arteries and veins divided to form capillaries. Vertebrate animal like frog exhibits a special type of vein arrangement called Portal system. Veins gerenrally collect deoxygenated blood from various organs but some veins before entering into the heart enter into some organs (liver & kidney) and divide into many capillaries such veins are known as portal veins they form portal system. Frog has two types of portal systems **(1) Renal portal system :** In this system blood vessels carries blood from the hind limbs to the kidneys and **(2) Hepatic portal system :** It collects blood from the digestive tract and supplies blood to the liver.



The venous system of Frog

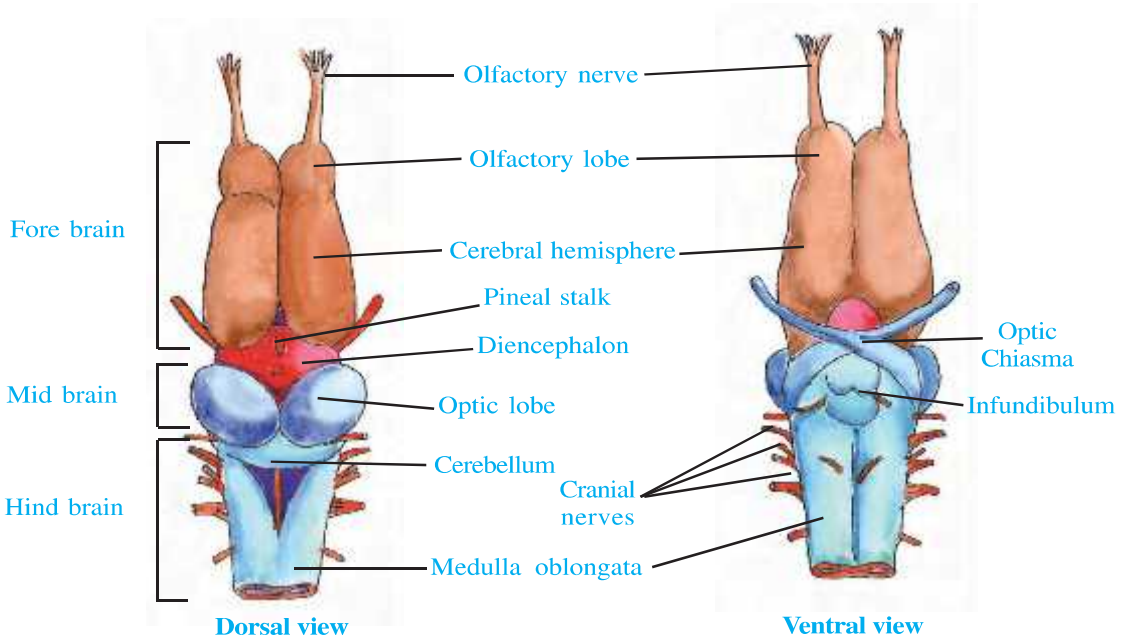
Nervous system

In frog the nervous system is located on the dorsal side of the body as found in all vertebrates. It is divided into two sections. (1) Voluntary nervous system and (2) Involuntary nervous system.

The regulation of voluntary nervous system is under the willingness of animals. Voluntary nervous system divides into central and peripheral nervous system. Central nervous system consists of brain and a spinal cord. Brain is situated in the head and protected within the cranium. Which divided into three regions : fore brain, mid brain and hind brain. Fore brain includes a pair of olfactory lobes, a pair of cerebral hemispheres and diencephalons. On the ventral side of diencephalons one hollow, bilobed and pouch like part is located, which is known as infundibulum. Pituitary gland is attached to the broad posterior end of it. It is master endocrine gland controlling various physiological activities, animal growth and development. The mid brain includes of two large oval and obliquely arranged optic lobes. While hind brain is composed of cerebellum and medulla oblongata. The medulla oblongata continues as the spinal cord in the vertebral column. Spinal cord forms the voluntary central nervous system in the trunk region and terminates in the hollow cavity of urostyle of a vetebral column as a filum terminale.

The peripheral nervous system is formed by cranial nerves and spinal nerves arising from brain and spinal cord respectively. In frog 10 pairs of cranial nerves from brain and 9 pairs of spinal nerves from spinal cord arise.

Involuntary or autonomous nervous system is associated with the controlling of involuntary activity of animal. It has two sections: sympathetic nervous system and parasympathetic nervous system. They perform complementary functions to each other. For example, the sympathetic nervous system accelerates the heart beat while parasympathetic nervous system deaccelerates the heart beat.

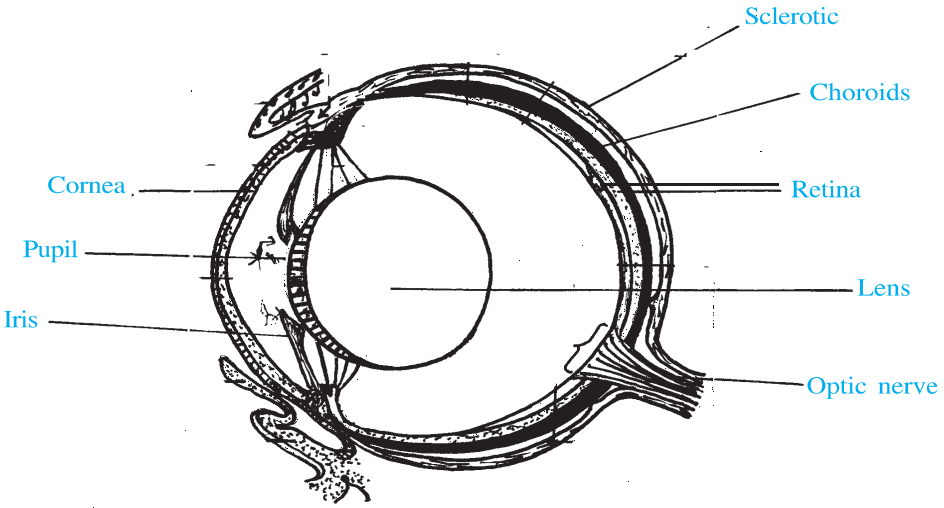


Brain of Frog

Five kinds of sense organs are found in frog: touch sensory, taste sensory, smell sensory, sight sensory and sound sensory. Of these, eye and ears are well organized structures. Other kinds of sense organs are constituted by specialized groups of cells, connected at near nerve endings. Tactile structures occur in skin. The tongue possesses taste receptors. In the lining of olfactory chambers, smell sensory structures are located.

Two eyes are located in the orbits. The wall of the eyeball is made up of three layers. The outer layer is sclerotic, the middle layer is choroids and the inner layer is retina. Towards the outerside a transparent cornea occurs in the eyeball. On its inner side, the choroids coat forms an iris. In the centre of iris, an aperture known as pupil occurs. Behind iris, the lens is arranged.

The ear consists of an inner ear and a middle ear. External ear is absent. The internal ear is also called membraneous labyrinth. It is located in a fluid-filled auditory capsule. Middle ear is an air-filled chamber which possesses the tympanic membrane at its outer end.



Ventral Section of Frog's eye

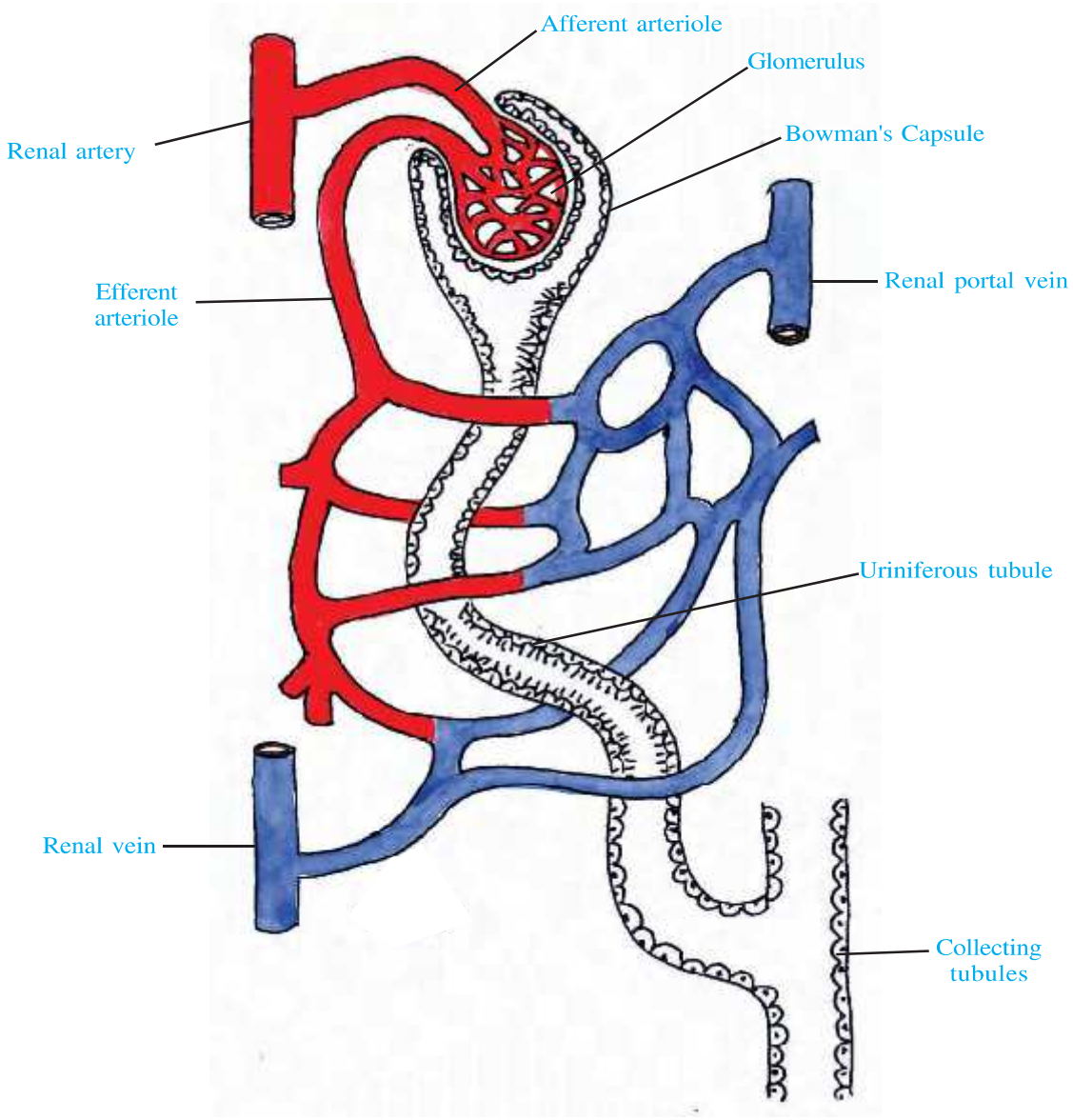
Over and above the nervous system, we also find an endocrine regulatory system made of endocrine glands. Which includes pituitary glands located in brain, thyroid gland in throat region, adrenal gland sunk in kidneys and gonads (testis and ovary). Islets of Langerhans of Pancreas also secretes hormones. Hormones are chemical regulators.

Urinogenital system

The urinogenital system comprises the excretory and the reproductive organs. The excretory system is closely associated with the genital system in male but they are separated in female. So here, we discuss this system separately.

In frog, a pair of kidneys act as main excretory organs. They are arranged on lateral sides of vertebral column in posterior part of the body. Kidneys are flat, oblong and brown in colour. A large number of uriniferous tubules occur in each kidney as units of excretion called Nephrons. Each uriniferous tubule possesses a double walled bowl like structure at its anterior end called Bowman's Capsule. Glomerulus is located within the Bowman's

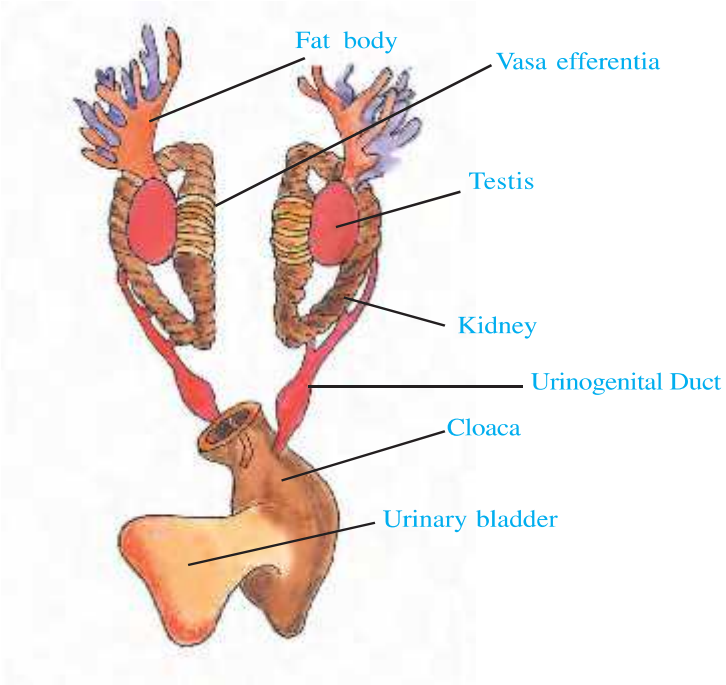
capsule which jointly called malpighian body. The process of urine formation begins here. The liquid urine formed in kidneys, is transported through ureters. Ureters come out from posterior lateral ends of kidneys. They transport urine towards cloaca. A bilobed, thin walled urinary bladder is associated with cloaca. Urinary bladder stores urine. When it is filled up, it contracts and discards urine through the cloacal aperture. The main excretory substance in urine is urea. In male frog, transport of sperms also occurs through the ureters, hence, the ureters are called urinogenital ducts.



Excretory unit of Frog

Reproductive System

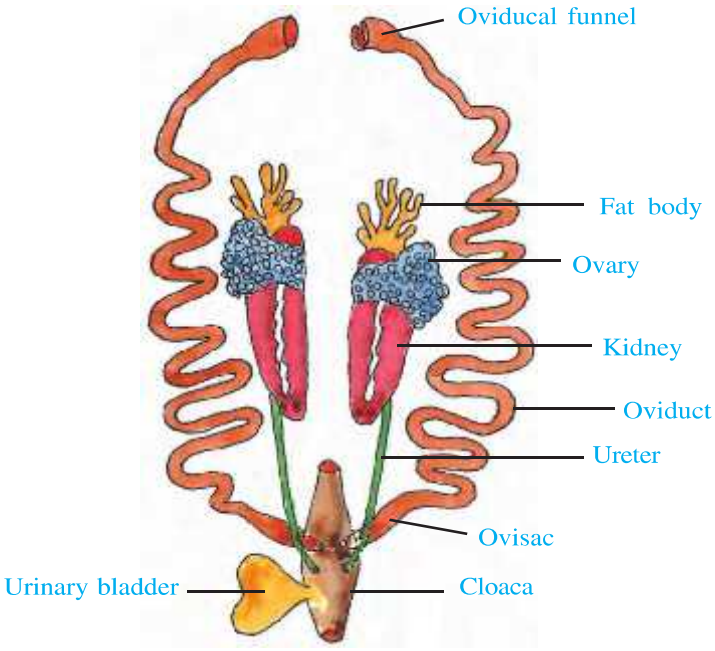
Frog is a unisexual animal. The male reproductive organs includes a pair of testes, vasa efferentia, Bidder's canal and urinogenital ducts. Each testis is located at the antero-lateral part of the kidney. It is oval-shaped, small and yellowish in colour. It remains connected to the kidney by mesorchium. The sperms produce in testes are transported to Vasa efferentia, Bidder's canal and finally, it is transported by urinogenital ducts to cloaca.



Male urinogenital system

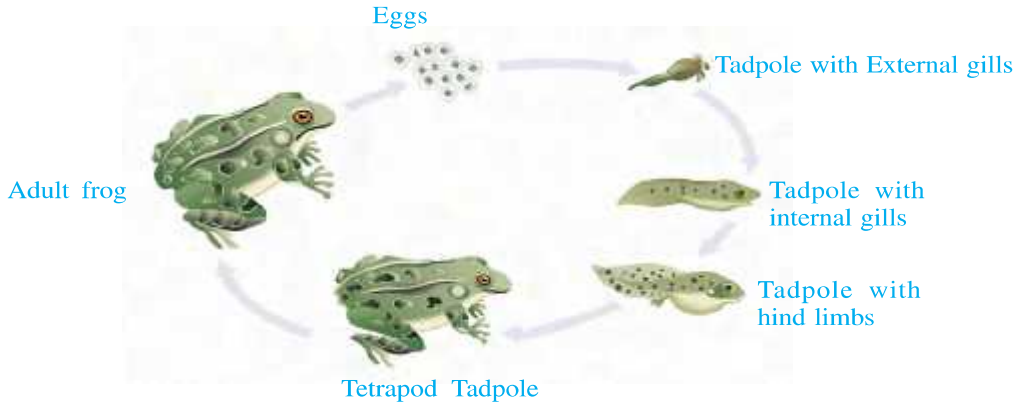
The reproductive organs of female frog includes a pair of ovaries, a pair oviducts and ovisac. Ovaries enlarge during the breeding season and produce ova. Each ovary is located at antero-lateral region of kidney. It is attached through mesovarium. Each oviduct begins as an oviducal funnel. It is a highly coiled structure which terminates into an ovisac and opens into the cloaca. The female frog releases large number of ovums in water.

The fat bodies situated at anterior end of kidney also act as accessory reproductive organs which supply energy during formation of gonadial cells.



Female urinogenital system

The breeding season of frog is monsoon, when it exhibits external and cross-fertilization. The medium of fertilization is water. Embryonic development is incomplete, external and metamorphosis type. So, instead of baby frog, the larval form of tadpole comes out from the egg. The tadpole passes through different forms like tadpole with external gills, internal gills, hind limbs, tetrapod tadpole etc. and it gets converted into baby frog.



Metamorphosis in Frog

Summary

Frog is a member of class Amphibia. The class amphibia includes all those animals which live partly in fresh water as well as on land habitat. *Rana tigrina,* the common **Indian bull frog** generally lives in or near the water. Frog has capacity to change the skin colour according to the environment and this helps frog to escape from enemies.

The body is divided into two parts, head and trunk. The head bears anterior snout, two large eyes, brow spot, tympanum and two nostrils. The trunk bears two pairs of limbs : fore limbs and hind limbs. Rana tigrina exhibits sexual dimorphism. The skin of frog is moist, slimy and without any exoskeleton. It acts as a chief respiratory organ. Frog has clear body cavity, in which, different types of organ systems accommodate, such as digestive system, circulatory system, respiratory system, urinogenital system and nervous system. The digestive system of frog mainly includes the alimentary canal and digestive glands. Alimentary canal starts from mouth and ends in cloaca. In between, it consists of the buccal cavity, pharynx, oesophagus, stomach and intestine. Other than the gastric gland (stomach) and intestinal gland (small intestine) two glands namely liver and pancreas are also associated with the alimentary canal. Frog is a carnivorus animal. The mucus helps in swallowing. The digestion of captured prey takes place in stomach, duodenum and intestine. Absorption is a process in which the digested food is taken into blood. Mainly this process takes place into duodenum and ileum. Faeces are removed time to time through the cloacal opening.

Respiration is a process in which living organisms obtain oxygen for oxidation and during this process CO_2 is removed regularly from the body. Frog as an amphibian animal exhibits three types of respiration, i.e. (i) cutaneous respiration or respiration through skin, (ii) bucco-pharyngeal respiration and (iii) pulmonary respiration or respiration through lungs.

Frog as a vertebrate animal has closed type of circulatory system. This system has four main components, i.e. blood, heart, arteries and veins. Blood is a red coloured liquid connective tissue. It is composed by blood cells (corpuscles) and blood plasma. Heart is muscular, conical and three chambered (two auricles and one ventricle) pulsative organ.

The arterial system, supplies blood from heart to different parts of body. The arterial system starts from truncus arteriosus and supplies mixed blood to various arteries.
The venous system brings blood from different parts of body to heart. Collected impure blood from all the parts of the body brings into sinus venosus. Vein collects deoxygenated blood from various organs and supply it in definite organs instate of heart is called portal vein. Frog has two types of portal systems : (i) Renal portal system and (ii) Hepatic portal system.

As in all vertebrates, in frog also the nervous system is located on the dorsal side of the body. It is divided into two sections : (i) Voluntary nervous system and (ii) Involuntary nervous system. Voluntary nervous system has two divisions: central nervous system and peripheral nervous system. Central nervous system consists of brain and a spinal cord. The peripheral nervous system is formed by cranial nerves and spinal nerves arising from brain and spinal cord respectively. Involuntary or autonomous nervous system is associated with the controlling of involuntary organs of the animal body. Five kinds of sense organs are found in frog : touch sensory, taste sensory, smell sensory, sight sensory and sound sensory.

The urinogenital system comprises the excretory and the reproductive organs. In frog, a pair of kidneys act as main excretory organs.

Frog is a unisexual animal. The male reproductive organs occur as a pair of testes, vasaefferentia Bidder's canal and urinogenital ducts. And the reproductive organs of female frog are a pair of ovaries, one pair oviducts and ovisac. In frog, cross-fertilization occurs, it is external. The medium of fertilization is water.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Give scientific name of Indian Bull Frog ?

(A) *Rana silvetica* ◯ (B) *Rana tigrina* ◯

(C) *Rana asqulenta* ◯ (D) *Rana cylophyletis* ◯

(2) Which of the following enzymes digests carbohydrate ?

(A) Amylase ◯ (B) Lipase ◯

(C) Trypsin ◯ (D) Pepsin ◯

(3) Bidder's canal is formed to transport .....

(A) Sperms ◯ (B) Ova ◯

(C) Urine ◯ (D) Sperms and Urine ◯

(4) Sinus venous opens in which part of heart ?

(A) Right auricle ◯ (B) Left auricle ◯

(C) Ventricle ◯ (D) Auricle and Ventricle ◯

(5) How many pairs of cranial nerves are found in frog?

(A) 09 pairs ◯ (B) 10 pairs ◯

(C) 12 pairs ◯ (D) 11 pairs ◯

(6) In which part of alimentary canal of frog complete digestion of protein takes place ?

(A) Rectum ◯ (B) Stomach ◯

(C) Duodenum ◯ (D) Large Intestine ◯

(7) Which type of fertilization is seen in frog ?

(A) Self and internal fertilization ◯

(B) Cross and external fertilization ◯

(C) Self and external fertilization ◯

(D) Cross and internal fertilization ◯

(8) Which organ of frog collects faeces, urine and gametes ?

(A) Rectum ◯ (B) Urino-genital duct ◯

(C) Urinary bladder ◯ (D) Cloaca ◯

(9) Which part of alimentary canal produces chyme ?

(A) Stomach ◯ (B) Duodenum ◯

(C) Rectum ◯ (D) Large intestine ◯

2. Answer in short :

(1) Write phylum, subphylum and division of frog.

(2) Write a scientific name of frog

(3) What is Aestivation ?

(4) Which jaw has maxillary teeth in buccal cavity of frog.

(5) Name two parts of stomach of frog ?

(6) Write location of brow spot.

(7) In which part of body glottis opens ?

(8) In which part of stomach pyloric valve is located ?

(9) What is secreted by liver ?

(10) Hepato-pancreatic duct is a formed by the combination of which ducts ?

(11) Write location of Islets of Langerhans.

(12) Which hormone converts blood glucose into glycogen ?

(13) Name the enzymes which digesting protein ?

(14) Write functions of Cholecystokinin.

(15) Which are the three steps of pulmonary respiration ?

(16) What is portal vein ?

(17) Write location of pituitary gland.

(18) How many pairs of cranial nerves are present in frog ?

(19) Write a function of Cloaca.

(20) What is chemical conduction ?

(21) Write location of Infundibulum.

3. Answer in brief :

(1) Classify frog from phylum to species.

(2) What is sexual dimorphism ? Give comparison of sexual dimorphism of frog.

(3) Give brief information of habitat and food of frog.

(4) Write functions of skin.

(5) Give only chart of blood circulation in heart of frog.

(6) Write differences : Urinogenital system of male frog and Urinogenital system of female frog.

4. Write a short note :

(1) Internal structure of skin

(2) Buccal cavity of frog

(3) Alimentary canal of frog

(4) Digestive gland of frog

(5) Digestion of protein

(6) Inspiration and expiration

(7) Portal system

(8) Autonomous nervous system

(9) Urinary tract of frog

5. Answer the question as per instruction :

(1) Write external features of frog in detail.

(2) What is digestion ? Explain digestion process in the stomach of frog.

(3) Explain digestion in duodenum.

(4) Explain Cutaneous and Bucco-pharyngeal respiration in frog.

(5) Explain pulmonary respiration in frog.

(6) Describe with figure : Heart of frog.

(7) Explain : Venous system of frog.

(8) Explain in short : Sense organs of frog.

6. Draw only labelled diagram :

(1) L.S. of frog skin

(2) Alimentary canal of frog

(3) Open buccal cavity of frog

(4) L.S. of frog heart

(5) Venous system of frog

(6) Dorsal and ventral views of frog brain

(7) Urinogenital system of male frog

(8) Urinogenital system of female frog

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