पु•ना International School

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BIOLOGY -XI

Specimen Copy

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Chapter 1 The Living World

1.Living World: Characteristics

he earth serves as a home for diverse living organisms. The organisms live in various habitats like forests, mountains, deserts, oceans, freshwater bodies, hot springs, polar regions and almost every place of the earth. Living things possess certain characteristics, which makes Some of these important characteristics are shown in the flowchart given below:

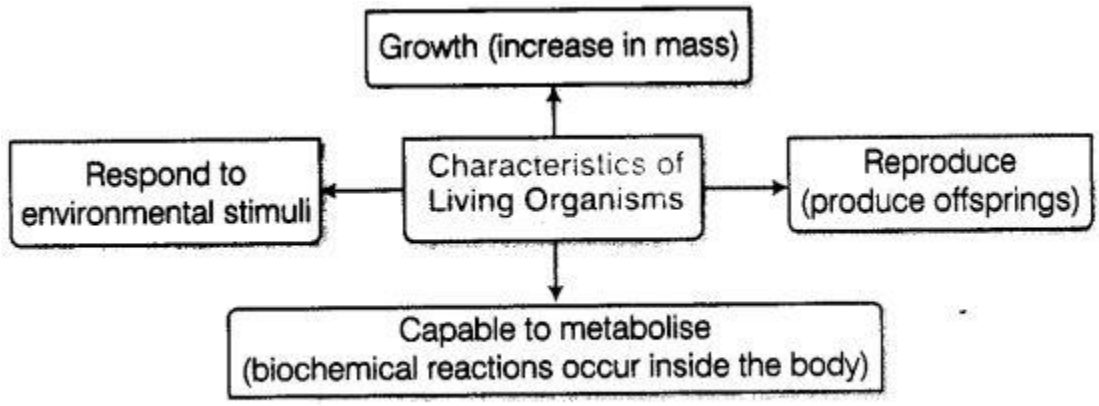

Fig. 1.1 Living organisms (an overview)

Major Characteristics of Living Organisms:
Major characteristics of living organisms are given below
1 Growth
Living things grow by increase in mass and increase in number of individuals/cells. In multi cellular organisms in particular, growth occur by cell division or increase in number of cells. Growth occurs continuously throughout life in plants, whereas, in animals, it occurs up to a certain age only. However, growing in certain body parts like nails, hair and replacement of lost cells, occurs throughout the life.
In unicellular organisms, growth can be observed under the microscope by simply counting the number of cells via in vitro experiment.
Non-living things like mountains, boulders, sand dunes also grow in size, but just by accumulating the material on their external surface. Thus, growth in living things is internal, while in non-living things, it is external. It is to be noted that a dead organism do not grow.

2. Reproduction
Reproduction, a characteristic of living organisms is the process of producing offsprings, possessing features similar to those of parents. In multicellular organisms, the mode of reproduction is generally sexual. Living organisms also reproduce by asexual means.
Some examples are given below
(i) Fungi spread and multiply fast by producing millions of asexual spores. Some fungi, the filamentous algae and the protonema of mosses multiply by fragmentation.
(ii) In yeast and Hydra, budding occurs to produce new organisms. While, in Planaria (flatworm), regeneration of fragmented body parts occur. These parts inturn grow as a new organism.

(iii) Unicellular organisms like bacteria, algae and Amoeba reproduce by increasing the number of cells, i.e., through cell division (growth is synonymous with reproduction).
Some organisms like mules, sterile worker bees, infertile human couples, etc., do not reproduce. Hence, reproduction also cannot be an all-inclusive defining characteristic of living organisms.

3 Metabolism

Metabolism is an another characteristic and defining feature of all living things. The sum total of anabolic or constructive reactions (anabolism) and catabolic or destructive reactions (catabolism) continuously occurring inside the body is called metabolism.
Metabolism —> Anabolism + Catabolism Metabolism occurs in all unicellular and multi cellular organisms. Its two stages include, i.e., anabolism, the process of building up or synthesis of complex substances from simpler ones, e.g., Photo synthesis and catabolism, the process of breakdown of complex substances into simpler substances, e.g., Respiration, releasing waste outside.
Metabolic reactions can also be demonstrated outside the body in cell free systems, which are neither living nor non-living. Thus, these reactions in vitro are surely living reactions not living things. Hence, metabolism can be considered as a defining feature of all living organisms without exception.
The important differences between anabolism and catabolism are

Anabolism	Catabolism
It is the sum total of constructive processes.	It is the sum total of destructive processes.
Complex substances are formed from simpler ones.	Simpler substances are formed from complex ones.
Energy is stored.	Energy is released.
Anabolism is required for growth and maintenance.	Catabolism is required for performance of activities.

Viruses are considered as non-living because they don't need energy for their activities, i.e., metabolic activities are altogether absent in them.

4 Cellular Organisation

The cells are the building blocks of all living things whether plants, animals or humans. The unicellular organisms are made of a single cell, while multi cellular organisms are formed by millions of cells. The cells contain protoplasm (living matter) and cell organelles (inside the cells) which perform several activities at the cellular level and result into various life processes.

5 Consciousness

All living organisms have excellent ability to sense their environment. They respond to various physical, chemical and biological stimuli.
The various external factors to which living organisms respond are light, water, temperature, pollutants, other organisms, etc. Light duration or photo period affects many seasonal breeders, plants as well as animals. All living things respond to chemicals, entering their * bodies.

Humans are superior to all living things as they have an additional ability of self-consciousness. Therefore, consciousness can also said to be a defining property of living organisms.
However, in human beings, it is more difficult to define living state, e.g., Patients lying in coma supported by machines that replace heart and lungs, are brain-dead with no self-consciousness.

6 Body Organisation
The body of living organisms is organised, i.e., several component and sub-components cooperate with each other for the functioning of whole body.

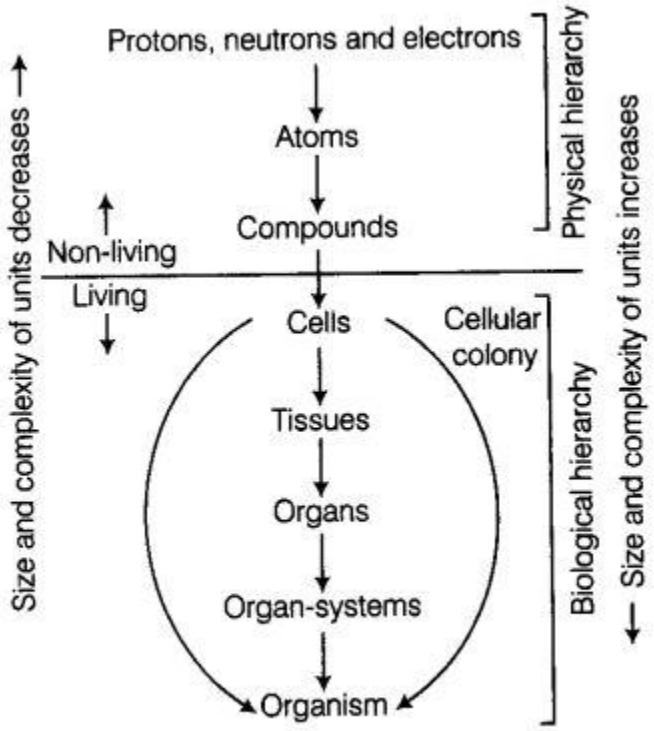

Fig. 1.2 Organisation in living organisms

Physical and Biological Hierarchies
There is a physical (non-living) hierarchy and biological hierarchy in the organisation of living body. In physical hierarchy, various non-living components aggregate to form compounds, which finally enter the living world in the form of cells. These cells organise to form tissues, that form organs and several organs combustive to form organ-systems. Finally, many organ systems organise and form a living organism.
The properties of tissues are not present in the constituent cells but arise as a result of interactions among the constituent cells. For example, bone is a hard tissue, which provides framework to the body. But, the cells present inside it do not have this property. This phenomenon of interactions between various components of the body results in the hierarchy of organisation.
The various life processes are the result of this interaction and coordination. The complexity in organisation enable living organisms as to be self-replicating, evolving, self-regulating and responding to external stimuli. All living organisms along with their ancestors and descendants are linked to one another by sharing of common genetic material in the form of DNA in varying degrees. This DNA is responsible for the expression of specific traits in

organisms. Thus, Biology is the story of life on earth. It is the story of evolution of living organisms on the earth.

Some Other Characteristics of Living Organisms

We have discussed some important and defining characteristics of living things. However, organisms . also have many other features that differentiate them from non-living things, such as, shape & size, life cycle, movement, self-regulation, variations, adaptations, healing & repair, excretion and death.

2.Living World : Diversity and Taxonomy

The earth hosts an immense variety of living organisms. According to a survey, the number of species that are known and described are between 1.7-1.8 million.
This number refers to the biodiversity on the earth. The term Biodiversity or Biological diversity means the number and types of organisms present on the earth, forms of life in the living world. The living world includes all the living organisms, such as microorganisms, plants, animals and humans.
Biodiversity is not limited to the existing life forms. If we explore new areas and even old ones, new organisms are continuously being added. This huge available variety cannot be studied and identified without having a proper system of classification and nomenclature.

Systematics

The word 'Systematics' is derived from the Latin word Systema, which means systematic arrangement of organisms. Linnaeus used Systema Naturae as the title of his book. He. coined the term Systematics in 1751.
Systematics is the branch of science that deals with unique properties of species and groups to recognise, describe, name and arrange the diverse organisms according to an organised plan.
In 1961, Simpson, defined systematics as the study of diversity of organisms and all their comparative and evolutionary relationships based on comparative' anatomy, physiology, biochemistry and ecology. The word 'Systematics' and 'Taxonomy' are often used interchangeably by the biologists. Systematics includes the following:

Identification

It aims at finding the correct name and appropriate position of an organism. The morphological and anatomical characters are examined for proper identification.

Classification

It is almost impossible to study all the living organisms. So, it is necessary to devise some means to make this possible. This can be done by classifying the organisms.
Thus, classification is the process by which organisms are grouped into categories based on some easily observable characters.
Biological classification is the scientific arrangement of organisms in a hierarchy of groups and sub-groups on the basis of similarities and differences in their traits.

Advantages of Classification

(a) It helps to identify an organism easily.
(b) New organisms easily get correct place in their respective groups.
(c) It makes study of fossils easy.
(d) It also helps in building evolutionary pathways.

(e) It becomes easy to know the features of whole group by studying one or two organisms of the group.
Thus, based on these characteristics, all living organisms are classified into different taxa.

Nomenclature
Nomenclature is the system of naming living organism in a way that a particular organism is known by the same name all over the world.
i. Common Names
The common names or vernacular names are the local names given to an organism in a specific language in a particular region. There are different names of a same organism in different regions even with in a country.

Organisms	Common Names
Rose	Gulab (Hindi), Golap (Bangla), Rajapo (Tamil)
Dog	Kukur (Bangla), Kutta (Hindi), Kutto (Gujarati), Svan (Sanskrit), Nay (Tamil)
Cat	Billi (Hindi), Biladi (Gujarati), Marjara (Sanskrit), Poonai (Tamil)
Cotton	Kapas (Hindi), Hatti (Kannada), Kapus (Marathi), Paruthi (Tamil), Karpus (Bengali)
Ginger	Adrakh (Hindi), Shunti (Kanada), Ale (Marathi), Ada (Bengali)

Advantages of Common Names
(a) Common names are easy to pronounce and are short, e.g., Cat or billi.
(b) People are familiar to these names since childhood.
(c) They are based on some features of organisms, e.g., Cowa (crow—Caawn-Caawn sound).
Dis-Advantages of Common Names
(a) All the organisms cannot be named by this method as there are organism of different sizes and shapes.
e.g., Microbes.
(b) An organism may have several names in a given language, e.g., 8 Hindi names of prickly poppy and water lily has 15 English names.
(c) A common names may have different meanings in different countries, e.g., Maize, means wheat and other grains in USA and it is called corn in common wealth countries.
(d) Common names may have little relevance, e.g., Lady's finger (okra), widows tears (Tradescantia-Rhoeo), etc.

(e) Common names may be incorrect, e.g., Jelly fish (a coelenterate), silverfish (an arthropod), starfish (an echinoderm) are not real fishes.
(f) These names are not useful for scientific studies.
ii- Scientific Names
A scientific name is given by biologists. These names represent a particular organism in every part of the world. The system of providing scientific names is called binomial nomenclature.
The scientific names must be
(a) acceptable in every part of the world.

(b) assigned on agreed principles and criteria.

(c **Binomial Nomenclature**

Binomial nomenclature was developed by Carolus Linnaeus in 1751 (Philosphica Botanica). All scientific names for animals under binomial nomenclature were given by Linnaeus in the tenth edition of his book Systerna Naturae (1758). Linnaeus named plants according to binomial nomenclature in his book Species Plantarum (1753). Binomial nomenclature is the system of providing distinct and appropriate names to organisms, each consisting of two words, first generic name {i.e., name of genus) and second specific epithet (i.e., name of species).

For example, Scientific name of mango is written as Mangifera indica. In this name, Mangifera represents the genus and indica is a particular species or specific epithet.) different for each species and not used for other organisms earlier.

Binomial Nomenclature of Some Common Plants and Animals

Common Names	Binomial Nomenclature
Plants	
Pea	*Pisum sativam*
Onion	*Allium cepa*
Mango	*Mangifera indica*
Wheat	*Triticum aestivum*
Banyan	*Ficus benghalensis*
Soyabean	*Glycine max*
Animals	
Frog	*Rana hexadactyla*
Cat	*Felis catus*
Dog	*Canis familiaris*
Housefly	*Musca domestica*
Cobra	*Naja naja*
Common crap (fish)	*Cyprinus carpio*
Humans	*Homo sapiens*
Western honeybee	*Apis mellifera*

Rules of Binomial Nomenclature

Rules of binomial nomenclature were initially framed by Linnaeus in his books, Species Plantarum and Systema Naturae.

The rules were revised again by the following nomenclature codes

(i) International Code for Botanical Nomenclature (ICBN).
(ii) International Code of Zoological Nomenclature (ICZN).
(iii) International Code of Bacteriological Nomenclature (ICBN).
(iv) International Code of Viral Nomenclature (ICVN).
(v) International Code of Nomenclature for Cultivated Plants (ICNCP).

The rules framed by Linnaeus and by these codes are as follows

(i) The names are generally in Latin and written in italics. They are Latinised or derived from Latin irrespective of their origin.
(ii) The first word in a biological name represent the genus while, the second component denotes the specific epithet.
(iii) Both the words in a biological name, when handwritten are separately underlined or printed in italics to indicate their Latin origin.
(iv) The first word denoting the genus starts with capital letter while, the specific epithet starts with a small letter, e.g., Mangifera indica.

(v) Generic and common names may be same, e.g., Gorilla gorilla.
(vi) No names are recognised prior to those used by Linnaeus in 1753 for plants in Species Plantarum and in 1758 for animals in the 10th edition of Systema Naturae.
(vii) The name of categories higher than the rank of genus are not printed in italics. Bold letters can, however be used.
(viii) When a species is transferred or revised, the name of the original worker is retained but in parenthesis, e.g., Syzygium cumini (L) Skeels.

Advantages of Binomial Nomenclature

(i) Binomial names are universally acceptable and recognised.
(ii) They remain same in all languages.
(iii) The names are small and comprehensive.
(iv) There is a mechanism to provide a scientific name to every newly discovered organism.
(v) The names indicate relationship of a species with other species present in the same genus.
(vi) A new organism can be easily provided with a new scientific name.

Taxonomy

It is the science of identification, classification and nomenclature. Based on their special / characteristics, all living organisms can be classified into different taxa. This process of classification is called taxonomy. Carolus Linnaeus is known as father of taxonomy.
The basis of modern taxonomy studies are external and internal structure (comparative morphology), along with the structure of cells (cytology), development process (embryology) and ecological information of organisms (ecology). It provide information according to similarities, dissimilarities and evolutionary relationships of various organisms.

The basic processes for taxonomic studies are

(i) Organisms are described on the basis of morphology and other characteristics.
(ii) The description of characteristics helps in the placement of the organism in various taxa.

(iii) A new taxon can be framed if the organism is different from the existing taxa.
(iv) The correct naming of an organism can be done after placing it in various taxon. A new organism can be given a new name after following the standardized rules.

Comparison between Taxonomy and Systematics

Taxonomy	Systematics
It is related to identification, nomenclature and classification.	It is the science of identification, nomenclature, description and classification.
Taxonomic studies are based on rules and principles of classification.	Systematics is related to unique properties at every level of classification.

Classical Taxonomy (Old Taxonomy)
The concept of classical or old taxonomy exists since, the time of Aristotle and Theophrastus and continued up to Linnaeus. It states that 4 .
(i) Species is the basic unit of taxonomy, that can be described on the basis of one or few preserved specimens.
(ii) Species are fixed and do not change with time.
(iii) A species is delimited based on morphological features.
(iv) Organisms are classified on the basis of some limited features such as root modification, leaf venation, floral structures, number of cotyledons in case of plants.
Due to the limited number of groups, many organisms could not be classified correctly. This finally led to artificial system of classification.

Modern Taxonomy (New Taxonomy)
The concept of modern taxonomy was given by Julian Huxley (1940). It uses evidences from all the areas of biology like morphology, anatomy, biochemistry, cell biology, physiology, genetics, evolution, etc.
The modem taxonomy is based on the following features
(i) The studies are done on a huge number of organisms based on all the variations.
(ii) Study is also focused on sub-species, varieties, races and populations.
(iii) Species are not isolated. They are related by common descent and vary from them due to accumulation of variations.
(iv) Species is considered as dynamic and ever-changing entity.
(v) Biological delimitation includes various branches of systematics, e.g., Cytotaxonomy, experimental taxonomy, numerical taxonomy, chemotaxonomy, etc. This led to the development of phylogenetic system or cladistics of classification.

Taxonomic Categories
Classification is not a single step process. It involves hierarchy of steps in which each step represents a rank or category. Since, the category is a part of overall taxonomic arrangement, it is called the taxonomic category and all categories together constitute the taxonomic hierarchy.

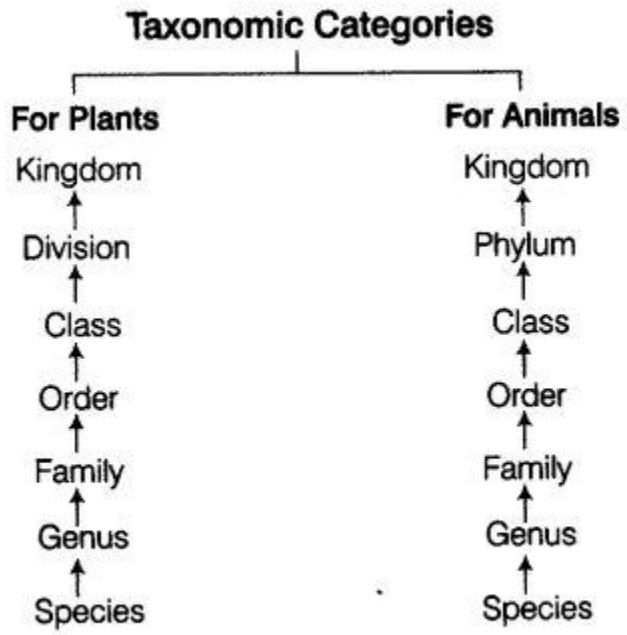

Fig. 1.3 Taxonomic categories showing hierarchial arrangement in ascending order

Taxon

Each category, referred to as a unit of classification, in fact, represents a rank and is commonly termed as taxon (Pi. taxa). The term Taxon was first introduced by ICBN during 1956.

According to Mayr (1964) taxon is a group of any rank that is sufficiently distinct to be worthy of being assigned a definite category. In simple words, taxon refers to a group of similar, genetically related individuals having certain characters distinct from those of other groups.

A taxon that includes a common ancestral species and all the species descended from it is called a clade or a monophyletic taxon.

Taxon	Category
A taxon deals with real biological objects.	A category is an abstract term that simply represents a rank or level in classification.
Taxon may belong to any ranking.	It belongs to one particular ranking.
e.g., The taxon of humans is mammalia.	*e.g.*, The category of humans is class.

Taxonomic Hierarchy

The taxonomic hierarchy is the system of arranging taxonomic categories in a descending order. It was first introduced by Linnaeus (1751) and hence, it is also known as Linnaen hierarchy.

Groups represent category and category further denotes rank. Each rank or taxon represents a unit of classification.

These taxonomic groups/categories are distinct biological entities and not merely morphological aggregates.

Obligate/Common Categories

The taxonomic categories, which are always used in hierarchical classification of organisms are called obligate or common categories.

They are seven in number. In descending order, these are kingdom, phylum or division, class, order, family, genus and species.

All the members of taxonomic categories possess some similar characters, which are different from those of others. The maximum similarity occurs in species, which is also the lowest category in the hierarchy of categories. Similarity of characters decreases with the rise in hierarchy.

i. Species

Taxonomic studies consider a group of individual organisms with fundamental similarities as a species (John Ray)

Species is considered as the lowest or basic taxonomic category, which consists of one or more individuals of a populations that resemble one another more closely than individuals of other species. The members of species interbreed freely and are reproductively isolated from others. For example, Mangifera indica (mango), Solarium tuberosum (potato) and Panthera leo (lion). All the three names indica, tuberosum and leo represent the specific epithets while, the first words Mangifera, Solanum and Panthera are genera and represents another higher level of taxon or category.

Each genus may have one or more than one specific epithets representing different organisms, but having morphological similarities. For example, Panthera has another specific epithet called tigris and Solanum includes species like nigrum and melongena.

Some Organisms with their Taxonomic Categories

Common Name	Scientific Name	Species	Genus	Family	Order	Class	Phylum (Division)	Kingdom
Human	*Homo sapiens*	*sapiens*	*Homo*	Hominidae	Primata	Mammalia	Chordata	Animalia
Dog	*Canis familiaris*	*familiaris*	*Canis*	Canidae	Carnivora	Mammalia	"	"
Housefly	*Musca domestica*	*domestica*	*Musca*	Muscidae	Diptera	Insecta	Arthropoda	"
Mango	*Mangifera indica*	*indica*	*Mangifera*	Anacardiaceae	Sapindales	Dicotyledonae	Angiospermae	Plantae
Tulsi	*Ocimum sanctum*	*sanctum*	*Ocimum*	Lamiaceae	Lamiales	"	"	"
Wheat	*Triticum aestivum*	*aestivum*	*Triticum*	Poaceae	Poales	Monocotyledonae	"	"

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Each genus may have one or more than one specific epithets representing different organisms,

but having morphological similarities. For example, Panthera has another specific epithet called tigris and Solanum includes species like nigrum and melongena.

i.Genus

Genus (John Ray) comprises a group of related species, which has more characters common in comparison to species of other genera. In other words, genera are aggregates of closely related species.

Some Genus and their Species

Genus	Species
Solanum	Potato (*Solanum tuberosum*) and Brinjal (*S. melongena*)
Panthera	Lion (*Panthera leo*), Leopard (*P. pardus*) and Tiger (*P. tigris*)
Felis	Common cat (*Felis catues*), Jungle cat (*F. chaus*) and Golden cat (*F. temminccii*)
Equus	Horse (*Equus ferus cabalus*), Ass (*E. africanus ocinus*) and Zebra (*E. quagga*)

iii. Family

Family (John Ray) is a group of related genera with less number of similarities as compared to genus and species. All the genera of a family have some common or correlated features. They are separable from genera of a related family by important differences in both vegetative and reproductive features.

A plant family ends in a suffix -aeae and sub-family -oideae. While, an animal family has a suffix -idae and sub-family -inae.

iv. Order

An order (Linnaeus) is a group of one or more related families that possess some similar correlated characters, which are lesser in number as compared to a family or genera.

Plants and Animal Orders with their Respective Families

Order Animals and Families

Carnivora Canidae (dog, wolf and fox), Felidae (cat, leopard, tiger and lion), Ursidae (bear) and Hyaenidae (hyaena)

Polemoniales Solanaceae (potato and tomato), Convolvucaceae (sweet potato and morning glory), Polemoniaceae (herbs, shrubs and small trees) and Hydrophyllaceae (water leaf).

Primates Lemuridae (lemurs), Cebidae (new world monkeys), Pongidae (apes) and Hominidae (humans).

Order	Animals and Families
Carnivora	Canidae (dog, wolf and fox), Felidae (cat, leopard, tiger and lion), Ursidae (bear) and Hyaenidae (hyaena)
Polemoniales	Solanaceae (potato and tomato), Convolvucaceae (sweet potato and morning glory), Polemoniaceae (herbs, shrubs and small trees) and Hydrophyllaceae (water leaf).
Primates	Lemuridae (lemurs), Cebidae (new world monkeys), Pongidae (apes) and Hominidae (humans).

v. Class

Class (Linnaeus) is a major category, which includes related orders. For example, order-Primata comprises monkey, gorilla & gibbon and is placed in class—Mammalia along with order—Carnivora that includes animals like tiger, cat and dog.

Class-Mammalia has other orders also.

vi.Phylum or Division

Phylum or Division (Cuvier, Eichler) is a taxonomic category higher than class and lower" in rank to kingdom. The term Phylum is used for animals, while division is commonly employed for plants.

It consists of more than one class having some similar corelated characters.

For example, Phylum— Chordata of animals contain following classes, e.g., Pisces, amphibians, reptiles, aves and mammals.

vii. Kingdom

It is known to be the highest category in taxonomy. This includes all the organisms, which share a set of distinguished characters. For example, all the animals belonging to various phyla are assigned the highest category called kingdom.

For example, Animalia in the classification system of animals. Similarly, all the plants are kept in kingdom—Plantae.

RH Whittaker. (1969) assigned five kingdom classification of organisms.

These are Monera, Protista, Fungi, Plantae and Animalia.

Intermediate Categories

The taxonomic categories from species to kingdom are broad categories or obligate categories. However, taxonomists have also developed sub-categories in this hierarchy to facilitate more sound and scientific placement of various taxa. These sub-categories are sub-species (or varieties), sub-genera, sub-families, sub-orders, sub-classes and sub-phyla.

These sub-categories are referred to as intermediate categories.

Taxonomical Aids

Taxonomical aids are techniques and procedures to store information as well as specimens or identification and classification of organisms.

The taxonomic studies of various plants, animals and other organisms are useful in areas like agriculture, forestry, industry and knowing our bioresources. All these studies need correct

identification and classification of organisms. Identification of organisms requires intensive laboratory and field studies. The collection of actual specimens of plants and animal species, knowing their habitats and other traits are essential and are the prime source of taxonomic studies. All this information is used in classification of an organism and is also stored along with the specimens. Sometimes, specimens are also preserved for future studies.
Some of the taxonomical aids developed by Biologists include Herbarium, Botanical gardens, Museum, Zoological parks, Key, etc.

1 Herbarium

Herbarium (Pi. Herbaria) is a store house of collected plant specimens that are dried, pressed and preserved on sheets. These sheets are arranged further according to a universally accepted system of classification. The institutes and universities maintain their own herbarium by collecting specimens from local and far away places.

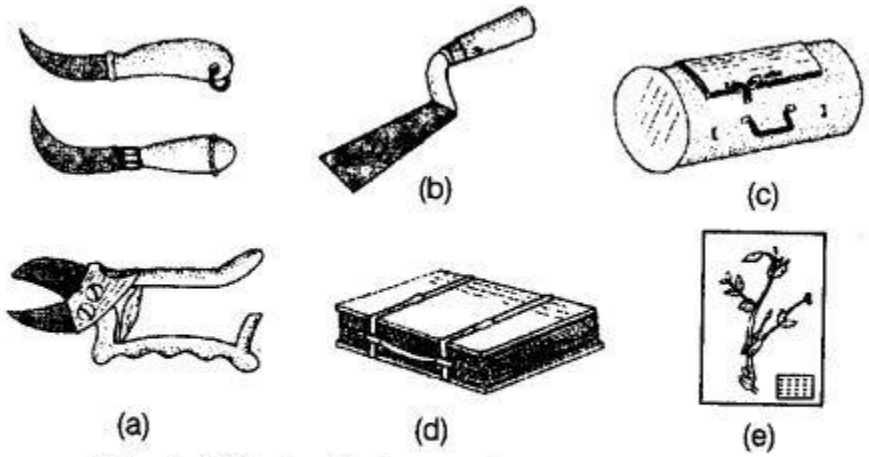


Fig. 1.4 Tools of plant collection (a) Cutters (b) Digger (khurpi) (c) Vasculum (d) Plant press (e) Herbarium sheet

Some Famous Herbaria of the World

Herbarium Name	Place	No. of Herbarium Specimens
Royal Botanical Gardens (largest herbarium)	Kew (London)	6.5 million
Museum of Natural History	Paris	Over 6 million
New York Botanical Garden	New York (USA)	4.0 million
US National Herbarium	Washington (USA)	Over 3 million
British Museum of Natural History	London	3 million
Central National Herbarium	Sibpur Kolkata (India)	2.0 million
Madras Herbarium	Coimbatore (India)	150000
National Botanical Research Institute	Lucknow (India)	80000

ses of Herbaria

The uses of herbaria are listed below

(a) These are used for identification of plants.

(b) Compilation of floras, monographs and manuals are mainly based on the specimens in herbaria.

(c) Herbaria are useful in locating wild varieties and relatives of economically important plants.

(d) They help in knowing the morphological variations found in species.

(e) Herbaria are useful for research in plant taxonomy, morphology, ecological distribution, etc.

2. Botanical Gardens

Botanical gardens are specialised gardens that have collections of living plants for reference. These gardens generally have facilities like library, laboratory, herbarium and museum. The botanical gardens are maintained by government, semi-government and other private organisations. Botanists and gardeners look after plants in botanical gardens.

Some Major Botanical Gardens

Botanical Garden	Place
Royal Botanical Garden	Kew (London)
New York Botanical Garden	New York (USA)
Berlin Botanical Garden and Museum	Berlin (Germany)
Cambridge University Botanical Garden	Cambridge (UK)
Indian Botanical Garden	Howrah, Kolkata (India)
Lloyed Botanical Garden	Darjeeling (India)
National Botanical Garden	Lucknow (India)

Role of Botanical Gardens

A botanical garden has following important roles

(a) Botanical gardens have aesthetic appeal and provide recreation facility to people.

(b) A wide variety of plant species grow there, so they provide ready material for research.

(c) These gardens also play an important role in conservation of endangered plant species and genetic diversity.

(d) There are more than 500 botanical gardens all over the world. These provide free exchange of seeds.

(e) These improve the environment, provide greenery, help in creating pollution free environment and some serves as habitat for animals.

Knowledge Plus

Indian Botanical Garden-Largest Botanical Garden of Asia.

First Botanical Garden-Pisa Botanical Garden, Italy established by Luca Glini (1490-1 **3.**

Museums

Museum is a place for collections of preserved plants and animal specimens for study and reference. The universities and educational institutes maintain their own museums in their botany and zoology departments. Plants, which cannot be kept in herbaria are preserved in museums.

For example, algae, fungi, mosses, ferns, fruits, etc. Specimens are preserves in containers or jars in preservative solutions. Plant and animal specimens may also be preserved as dry specimens. Insects are preserved in insect boxes after collecting killing and pinning. While, the larger animals are stuffed and preserved in skeletal forms.556).

Some Important Museums of other Countries and India

Museums	Place
American Museums of Natural History	New York (USA)
Museum of Natural History	Basel (Switzerland)
Natural History Museum	London
Zoological Museum	Amsterdam (Netherland)
Bird Collection Museum of Natural History	Vienna (Austria)
National Museum of Natural History	Paris
National Museum of Natural History	Delhi (India)
Prince of Wales Museum	Mumbai (India)
Museum of Arthropoda	Pune (India)

4. Zoological Parks

Zoological parks or zoo are the places where wild animals are kept in protected environments under human care and which enable us to learn about their food habits and behaviour. Zoological parks provide natural habitat to the animals.

In India there are about 200 zoological parks. These zoos are managed by the Central Zoo Authority of India. The World Zoo Conservation Strategy (WZCS) refer to all these zoological institutions as zoos.

Role of Zoological Parks

(a) The zoological parks increase understanding of wildlife.

(b) These are the centres for recreation and education.

(c) Zoos are the centres for conservation of threatened and rare animal species.

(d) These provide sites for ex situ breeding of endangered animals. conservation through captive breeding of endangered animals.

Some Famous Zoos of India

Zoos	Place
National Zoological Park	Delhi
Nandankanan Zoo	Odisha
Nehru Zoological Park	Hyderabad
Sanjay Gandhi Jaivik Udyan	Patna
Rajiv Gandhi Zoological Park	Pune
Alipore Zoological Garden	Kolkata
Guwahati Zoo	Asom
Madras Crocodile Bank Trust	Chennai
Mysore Zoo	Karnataka
Allen Forest Zoo	Kanpur

5. Key

Key is also a taxonomical aid used for identification of plants and animals based on the similarities and dissimilarities.

It helps in the identification of plants and animals by selecting and eliminating the characters according to their presence or absence in the organism under study.

The keys generally use two contrasting characters called couplet. This results in acceptance of one present in organism and rejection of the other. Each statement in the key is called a lead.

These taxonomic keys are of two types

Indented Key

The indented key or yolked key provides a sequence of choices between two or more characteristics. By careful selection of characters at each sub-division, the exact name of the organism can be arrived at.

Bracketed Key

The bracketed key also uses contrasting characters like the indented key. But in, these characters are not separated by intervening sub-dividing characters. Each character in this case is given a number in brackets.

Other Means of Recording Descriptions

Apart from the all mentioned means of keeping records of description. Some other means are also present.

These are of following types

Flora

Floras are the important resource that provide information on the taxonomy, nomenclature and descriptive data for the taxa covered.

The floras also include information on the biology, distribution and habitat preferences of the taxa, as well as illustrations, identification keys and other notes. These provide index to the plant species found in a particular area.

Manuals and Catalogues

These are other means of recording descriptions. They also help in correct identification. Manuals are useful in providing information for identification of names of species found in an area.

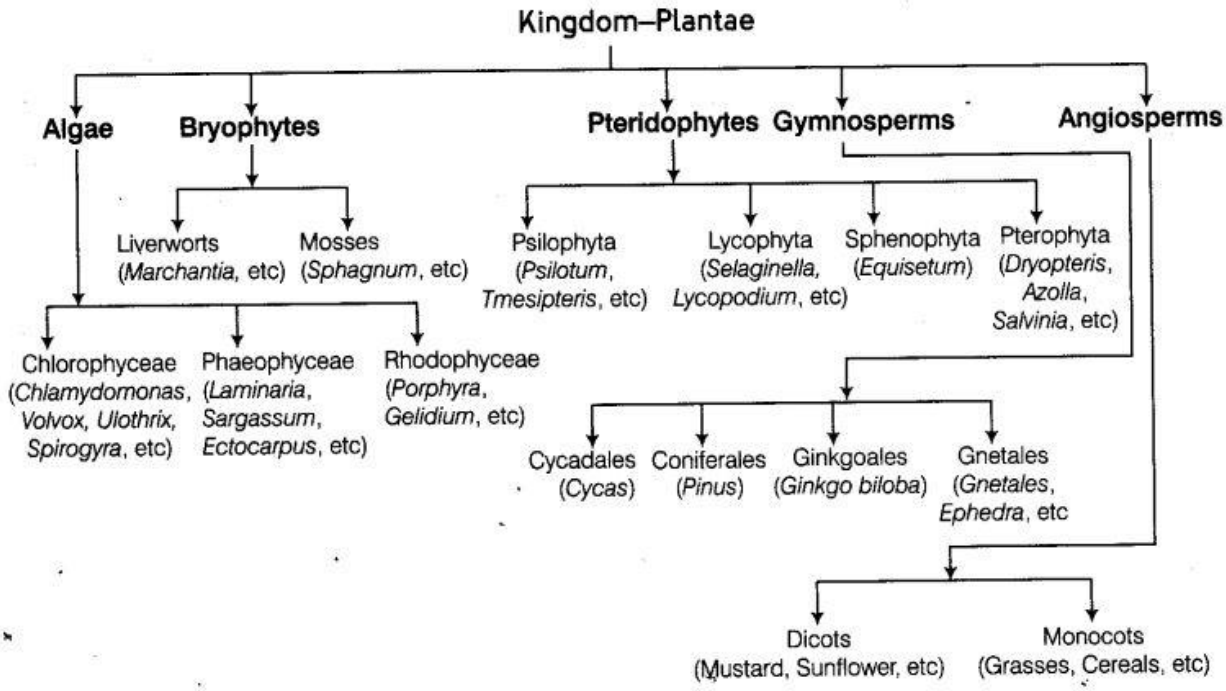
Monograph

A monograph is a comprehensive treatment of a taxon in biological taxonomic studies. These contain information on any one taxon. Monographs revise all known species within a group, add any newly discovered species, collect and organise available information on the ecological associations, geographic distributions and morphological variations within the group.
The first ever monograph of a plant taxon was given in Robert Morison (1672) Plantarum Umbelliferarum Distributio Nova.

L 3 Plant Kingdom

1.Basis of Classification and Algae, Bryophytes & Pteridophytes

Our understanding of the plant kingdom has changed over time. Fungi and members of the Monera and Protista having cell walls have not been separated form Plantae, the earlier classifications kept them in the same kingdom. The kingdom-Plantae has been described under algae, bryophytes, pteridophytes, gymnosperms and angiosperms. The overview of this classification is demonstrated here in the flowchart.



Types of Classification System

These includes artificial system, natural system and phylogenetic system of classification. The various systems used in classification ofiplants are being discussed here

1. Artificial System of Classification

This system is based on comparison of one or a few superficial characteristics, which are helpful in easy identification of organisms. This system remained in use for about two thousand years.

Aristotle is known as father of Zoology.

Carolus Linnaeus is known as father of Taxonomy.

Advantages

Advantages of artificial system as below

(i) Artificial system is easy to remember as only one or few characters are used.

(ii) The traits used are of interest to humans.

Disadvantages

Disadvantages of artificial system are given below

(i) This system use only few superficial characters (i.e., habits, numbers, colours and shapes of leaves, etc) which leads to many orgarfisms grouped together,

(ii) They considered mainly the vegetative characters or the androecium characters as given by linnaeus.

(iii) It does not demonstrate natural and phylogenetic relationships.

(iv) This gave equal weightage to vegetative and reproductive/sexual characters this is not acceptable, as vegetative characters are more easily influenced by the environmental factors.

(v) They sparated the closely related species.

2 Natural System of Classification

It is also known as phenetic system of classification. The natural system of classification is based on natural affinities among the organisms. It considers both external and internal features like structure, anatomy, embryology and phytochemistry.

Advantages

Advantages of natural system are given below

(i) Only related organisms are kept in a group.

(ii) Unrelated organisms are kept in separate groups.

(iii) It shows natural relationships among the organisms.

(iv) It shows possible origin of different taxa.

Disadvantages

Disadvantages of natural system are given below

(i) There is more emphasis given on natural character.

(ii) In this system several related families are separated and unrelated families are put together.

(iii) Evolutionary basis is neglected.

3. Phylogenetic System of Classification

The phylogenetic system of classification indicates the evolutionary as well as genetic relationships among organisms. This system is based on fossil records of biochemical, anatomical, morphological, physiological, embryological and genetical.

The system was initiated by Engler and PrantI (1887-1899) in Die Naturalichen Pflanzefamilien. In phylogenetic system, flowering plants are placed in ascending series related to complexity of floral morphology. The phylogenetic system of classification are mainly the rearrangement of taxonomic characters in addition to the phylogenetic information.

Advantages

Advantages of phylogenetic system are given below

(i) Families and order in this system are of small size.

(ii) This system is in conformation with the modern views of phylogeny.

(iii) They use information from various sources to solve problems of classification. Such informations become more important in the absence of supporting fossil evidences.

Disadvantages

isadvantages of phylogenetic system are given below

(i) This is not helpful in plant identification.

(ii) The classification is outdated as the habit is used as . main basis of classification.

Types of Taxonomies

For the suitability in studies various categorizations has been done in taxonomy.

The important taxonomies are as follows

1. Numerical Taxonomy

It is carried out by quantitative assessment of similarities and differences in order to make objective assessments. It is now easily carried out using computers based on all observable characteristics. Number and codes are assigned to all the characters and the data are then processed. In this way, each character is given equal importance and at the same time hundreds of characters can be considered.

2. Cytotaxonomy

Cytotaxonomy is based on cytological information like chromosome number, structure, behaviour and type of chromosomes. For example,

(i) Chromosome number is constant for a species, e.g., 46 in man, 48 in apes and potato, 20 in maize, 16 in onion and 8 in Drosophila.

ii) Behavior of chromosomes was used by taxonomists during pairing and banding patterns to understand the relationships between species, e.g, Origin of humans from apes, origin of wheat, etc.

3. Chemotaxonomy

It is the system based on the evidences from chemical constituents (enzymes, hormones, proteins, amino acids, etc.), some specific chemicals (usually secondary metabolites) and the chemical nature of proteins have been utilised to establish similarities and relationships. For example, the presence of raphides has been found to be common in 35 families of plants.

Algae

Algae are chlorophyll-bearing, simple, thalloid, autotrophic and largely aquatic (both freshwater and marine) organisms.

The important salient features of algae are given below

Habitat

These are found in both freshwater and marine habitats. Some algal forms are also found in moist habitats like wet rocks and soil, tree trunks, etc. Some of them are also found in close

Thallus Organisation

The plant body (thallus) is without differentiation. The basic form and size of algae is highly variable, and ranges from filamentous {e.g., Ulothrixand Spirogyrd) to colonial {e.g., Volvox). These are attached on the substratum with the help of holdfast.

Structure of Algal Cell

It has an eukaryotic plant cell structure. The cytoplasm contains membrane bound chloroplast, mitochondria, ER, Golgi bodies and other cell organelles. The cell wall contains cellulose. The nucleus contains nuclear membrane.

Food Material

Algae have main food reserve as starch. In brown algae, mannitol and laminarin are the main reserve food material, whereas in red algae floridean starch is the reserve food material.

Reproduction

The algae reproduces vegetatively, asexually and sexually.

i. Vegetative Reproduction

It occurs by fragmentation, tubers, stolons, adventitious branches, etc. Each fragment gets develop into a thallus. association with fungi (lichen) and animals {e.g., on sloth bear).

ii. Asexual Reproduction

It occurs by a number of accessory spores, such as zoospores aplanospores, akinetes, carpospores, etc.

The most common being the zoospores, which are flagellated. The cells which produce spores are called sporangia. The sporangia may be the vegetative cells (e.g. in Chlamydomonas and Ulothrix) or modified vegetative cells (e.g. in Vaucheria).

iii. Sexual Reproduction

It occurs by fusion of two gametes.

On the basis of morphology of reproductive cells, sexual reproduction is of two types

(a) Isogamy In this method, two morphologically similar gametes fuse to form a zygote, e.g., Spirogyra.

(b) Heterogamy In this process, fusion occurs between morphologically as well as physiologically different gametes. It is of two types

Anisogamy It is the fusion of structurally dissimilar gametes, which differ in size and – behaviour. Male gamete is more active and female gamete is less active and bigger in size, e.g., Some species of Chlamydomonas.

* Oogamy In this process, the male gamete is motile, active, small and without reserve food. The female gamete is bigger, passive, non-motile and laden with food, e.g., Volvox, Fucus.

Embryo and Life Cycle

An embryo stage is not present. Life cycle is haplontic, diplontic, diplohaplontic, haplohaplontic, etc. An alternation of generation occurs in diplohaplontic life cycle.

Economic Importance of Algae

(i) Algae are responsible for carrying out about a half of the total carbon dioxide fixation on earth by the process of photosynthesis.

(ii) Some forms of marine brown and red algae produce large amount of hydrocolloids. These are algin (brown algae) and carrageenan (red algae) which have many commercial uses.

(Hi) The algae Gelidium and Gracilaria are used to produce agar, which is used in preparation of ice creams and jellies.

(iv) Some protein rich algae, like Chlorella and Spirullina are used as food supplements by sailors and space travellers.

(v) About 70 species of marine alga are used as food, e.g., Porphyra, Laminaria and Sargassum.

Classification of Algae

Algae are divided into various classes based on pigmentation, stored food and flagellation. The three main classes are

Chlorophyceae, Phaeophyceae and Rhodophyceae.

i.Class-Chlorophyceae (Green Algae)

The members of Chlorophyceae are commonly called green algae.

There are about 7000 species in this class. The reserve food material is starch.

The characteristic features of Chlorophyceae are discussed below

(a) Habitat These are mostly marine forms, only some are freshwater. Chlorella can tolerate moderately warm waters. Snow dweling forms are called cryophytes, e.g., Chlamydomonas

nivalis, Scotiella, etc.
(b) Cell Organisation These are unicellular, colonial, coenocytic and multicellular forms. Cell walls contain cellulose (inner layer) and pectose (outer layer) in most of the green algae. The chloroplasts may be discoid, plate-like, reticulate, cup-shaped, spiral or ribbon shaped.
The chloroplasts contain pigments. Most of the members have one or more storage bodies called pyrenoids located in" the chloroplasts. Pyrenoids contain protein besides starch. Some algae may store food in the form of oil droplets also.

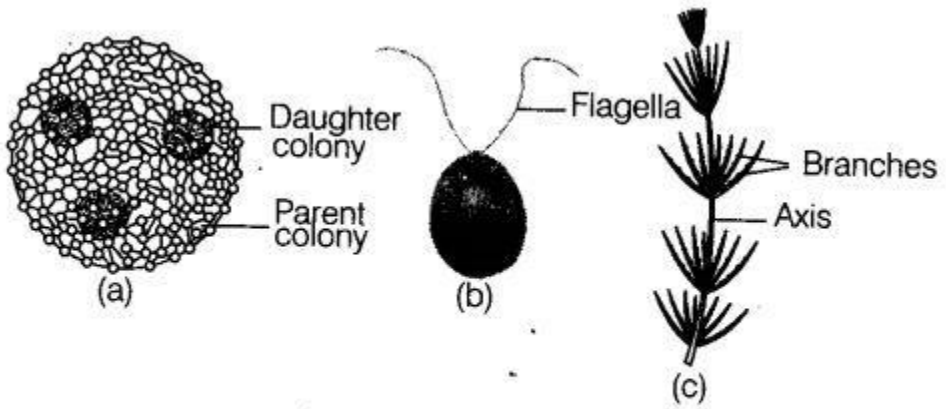


Fig 3.2 Green algae (a) *Volvox* (b) *Chlamydomonas* (c) *Chara*

(c) Thallus Unicellular green algae can- be flagellate, (Chlamydomonas), unicellular, non-flagellate (Chlorella).
Acetabularia (umbrella plant) has unicell upto 10 cm long with distinction of nucleus containing rhizoid, elongated stalk and umbrella like cap.
A colony for fixed number of individual unicells (Volvox) is called coenobium. Coenocytic or siphonaceaus thallus occurs in Caulerpa. Unbranched filamentous thallus in Ulothrix and Spirogyra, Cladophora, heterotrichous in Stigeoclonium and parenchymatous in Ulva.

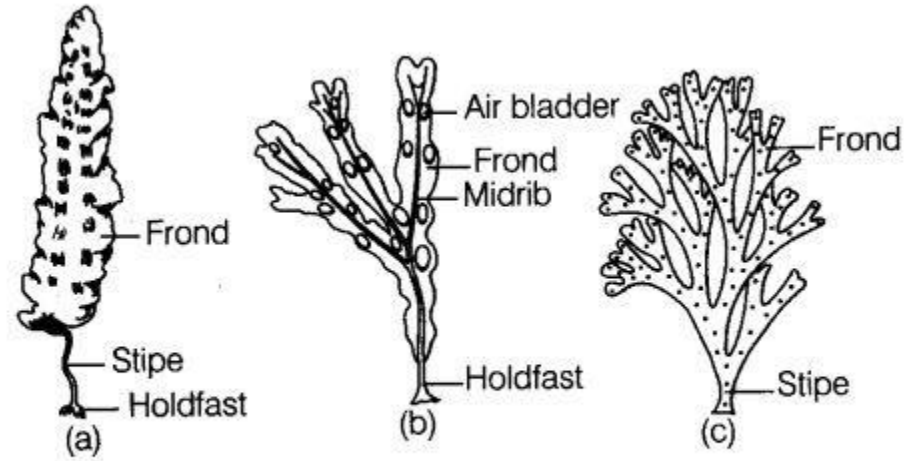


Fig 3.3 Brown algae (a) *Laminaria* (b) *Fucus* (c) *Dictyota*

d) Reproduction The members of Chlorophyceae reproduce vegetatively, asexually and sexually by various methods.
* Vegetative reproduction occurs through cell division (unicellular forms), fragmentation, stolons, tubers, storage cells, etc.
* Asexual reproduction occurs by zoospores, aplanospores, hypnospores, akinetes and daughters colonies.
* Sexual reproduction may be isogamous, anisogamous or oogamous.
(e) Life Cycle It can be haplontic, diplontic and diplohaplontic. In haplontic life cycle, there is a single somatic phase, which is haploid. Diploid stage is represented by a single cell or zygote, e.g., In Spirogyra.

ii. Class-Phaeophyceae (Brovin Algae)
The members of Phaeophyceae are fucoxanthin and phycocolloid rich multicellular eukaryotic algae. Its common members are seaweeds called kelps. This class is comprised of about 2000 species.
(a) Habitat Brown algae are mostly marine. These are found mostly in colder seas or during cold seasons in tropical regions.
(b) Size They range from simple branched, filamentous forms (Ectocarpus) to profusely branched forms as represented by kelps. These represent largest algae. The largest kelps are Macrocystis (40-100m) and Nereocystis (20-30 m).
(c) Cell Organisation All members are multicellular. Cell wall is composed of cellulose, pectose and phycocolloids. The cellulosic wall of vegetative cells is usually covered on the outside by a gelatinous coating of algin.
(d) Thallus It is heterotrichous filament with both prostrate and upright branches (Ectocarpus). The parenchymatous structure is found in higher forms.
The plant body of large forms often differentiated into holdfast (with which it usually attaches to the substratum) a stalk called the stipe and lamina (frond), which is photosynthetic. Conducting tubes or trumpet hyphae are present in larger brown algae or kelps. They help in conduction of food materials.
(e) Photosynthetic Pigments and Colour These include chlorophyll-4, c and carotenoids. They ranges in colour from olivt green to various shades of brown depending upon the amount of the xanthophyll pigment, fucoxanthin present in them.

(f) Food Reserve It remains in the form of complex carbohydrates such as laminarin or mannitol.
(g) Flagellation These contain heterokont flagellation with one smooth (whiplash) and one tinsel flagella.
(h) Reproduction Vegetative reproduction occurs through fragmentation (e.g., Sargassum), adventitious branches and stolons (e.g, Dictyota). Asexual reproduction by biflagellate zoospores, which are pear-shaped having two unequal laterally attached flagella.
Sexual reproduction is performed by isogamy, anisogamy and oogamy. Union of gametes may take place in water or within the oogonium (oogamons species). The gametes are pyriform (pear-shaped) and have two laterally attached flagella.
(i) Life Cycle Isomorphic alternation of generation is found in some brown algae, e.g, Ectocarpus, Dictyota. In many brown algae, the diploid generation or phase is dominant. The haploid phase is either microscopic or represented by gametes only (e.g., Fucus).

Economic Importance of Pheophyceae

* The brown algae that are used as food are Laminaria, Nerocystis, Macrocystis, Alaria, etc.
* Some brown algae like Fucus, Sargassam, Laminaria, Macrocystis are important fodder for catde.
* Brown algae are collected from sea shores and used as manure. They improve mineral content of soils.
* Alginic acid is a phycocolloid obtained from a number of brown algae such as Alaria, Macrocystis, Ascophyllum, Laminaria. It is used as emulsifier, thickener, gelating agent in toothpastes, shaving creams, ice-creams, emulsion paints, shampoo, cosmetics, etc.
* Fucus and Laminaria are rich in iodine.

iii. Ciass-Rhodophyceae (Red Alqae)

The members of Rhodophyceae are commonly called red algae because of the predominance of the red pigment,i.e., r-phycoerythrin in their body.

(a) Habitat Most of the red algae are marine with greater concentrations found in the warmer areas. They are found in both well lighted regions close to the surface of water and also at great depths in oceans where relatively little light penetrates.

(b) Thallus The red thalli of most of the algae are multicellular. Some of them have complex body organisation like Asterocystis is pseudofilamentous, Porphyridium is unicellular, Porphyra has parenchymatous sheets, Cbondrus is ribbon like, Gelidium is a multicellular sea weed.

(c) Cell Wall The cell wall contains cellulose, pectic compounds and certain mucopolysaccharides called phycocolloids, such as agar, carrageenin, etc. In many algae, cell wall contains pits.

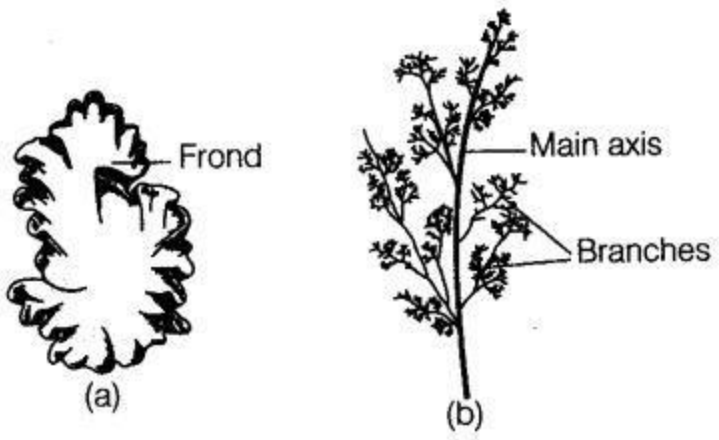


Fig 3.4 Red algae (a) *Porphyra* (b) *Polysiphonia*

d) Photosynthetic Pigments These include chloro¬phyll-4, carotenes, xanthophylls and phycobilins. Phycobilins are water soluble and are of two types, i.e., red-coloured phycoerythrin and blue-coloured phycocyanin.

(e) Reserve Food It is floridean starch similar in constitution to glycogen and amylopectin. if) Reproduction Vegetative reproduction occurs by fragmentation, regeneration of hold fast and gemmae. Asexual reproduction occurs by non-motile spores (carpospores, monospores, tetraspores and neutral spores).

Sexual reproduction occurs by non-motile gametes and is oogamous type. The male sex organs is called spermatogonium or antheridium. The male produced is non-flagellated, called as spermatium. The female sex organ is called carpogonium. After fertilisation, a new structure called carposporophyte is produced. It remains attached to the parent alga.
(g) Life Cycle Life cycle has two or more phases such as haplohaplontic, haplohaplohaplontic, diplodiplohaplontic, etc.

Economic Importance of Red Algae

* The red algae like Porphyra, Chondrus, Rhodymenia, Centerella and Bostrychia are used as food in various parts of the world.
* Agar yielding algae are called aerophytes, such as Gelidium, Gracilaria, Ceramium, Gelidiella, etc.
* Alga like Rhodymenia are used as fodder for cattle.
* Carrageenin a phycocolloid obtained from red algae like Chondrus and Gigartina is used in preparations of emulsions for ice cream, chocolates, sauces, toothpastes, cosmetics, etc. It is also used in clearing liqueurs and finishing leather, etc.
* Funori an adhesive phycocolloid is obtained from red alga Gloiopeltis. It is used in sizing textiles, paper and as glue.
* Some algae like Corallina, Polysiphonia have medicinal properties.

Bryophytes

Bryophytes include the various mosses and liverworts. These are non-vascular embryophytes, characterised by the presence of. an independent gametophyte and parasitic sporophyte.

Habitat

Bryophytes commonly grow in -moist, shaded areas in hills. These are also called amphibians of the plant kingdom because, these can live in soil but are * dependent on water for sexual reproduction.

Rhizoids

hese are attached to the substratum by unicellular or multicellular rhizoids.

Sex Organs

The main plant body produces gametes, hence it is called gametophyte. The sex organs in bryophytes are multicellular, the male sex organs in bryophytes is called antheridium (which produces biflagellate antherozoids) and the flask-shaped female sex organ is called archegonium (produces a single egg).

Reproduction

It is of sexual type reproduction. The antherozoids are released into water where they come in contact with archegonium.

Fertilisation

It occurs inside the archegonium. The egg secretes a chemical which attracts spermatozoids. Sperms require a thin film of water for swimming and reaching the dehisced archegonium. One sperm fuses with an egg and produces a diploid zygote. Zygotes do not undergo reduction division immediately instead, they produce a multicellular body called sporophyte.
Dependent Sporopbvrc The sporophyte is not free-living but attached to the photosynthetic gametophyte deriving nourishment from it. Some cells of the sporophyte undergo reduction division (meiosis) to produce haploid spores (which germinate to produce gametophyte).

The sporophyte of bryophytes is called sporogonium because it is mainly dependent and meant for producing spores.

Life Cycle

Bryophytes have heteromorphic or heterologous alternation of generation. The gametophyte may be produced directly or first from a juvenile stage called protonema.

Economic Importance

Bryophytes in general are of little economic importance. But, several species have some uses.

(i) Some mosses provide food for herbaceous mammals, birds and other animals.

(ii) Species of Sphagnum (a moss), provides peat that
have long been used as fuel. It has the capacity to hold water as packing material for transshipment of living material.

(iii) Mosses along with lichens are the first organisms to colonise rocks. Hence, these help in biological succession. They decompose rocks making the substrate suitable for the growth of higher plants.

(iv) Mosses from dense mats on the soil, they reduce the impact of falling rain and prevent soil erosion.

(v) Marchantia has medicinal properties to cure lungs and liver infections. It also has antitumour properties.

Bryophytes do not attain great heights. They may range of 0.4 to 70 cm and have thalloid body.

The reasons may be following

(i) Root is absent.

(ii) Vascular tissues are not present.

(iii) Cuticle is not present on the plant body.

(iv) Absence of mechanical tissue.

(v) Male gametes need to swim upto the interior of dehisced archegonia.

Types of Bryophytes

The bryophytes are generally classified into two main groups

i. Liverworts

Liverworts (Hepaticopsida) usually grow in moist, shady places such as banks of streams, marshy ground, damp soil, bark of trees and deep in the woods.

(a) Thallus The plant body of a liverwort is thalloid, e.g, Marchantia,. The thallus is dorsoventral and closely appressed to the substrate. The leafy members have tiny leaf like appendages in two rows on the stem like structure.

(b) Rhizoids These are unicellular. These may be of two types in some liverworts, i.e. smooth walled and tuberculate.

(c) Reproduction It may occur both by asexual and sexual means.

• Asexual Reproduction It occurs by fragmentation of thalli or by the formation of specialised structures called gemmae (sing, gemma). Gemmae are green, multicellular, asexual buds which develop in small receptacles called gemma cups located on the thalli. The gemmae become detached from the parent body and germinate, forming new individuals.

• Sexual Reproduction During this male and female sex organs are produced either on the same or on different thalli. The sporophyte is differentiated into a foot, seta and capsule. After meiosis, spores are produced within the capsule.

• These spores germinate to form free-living gametophytes, e.g., Riccia, Marchantia, Pellia, Porella, etc.

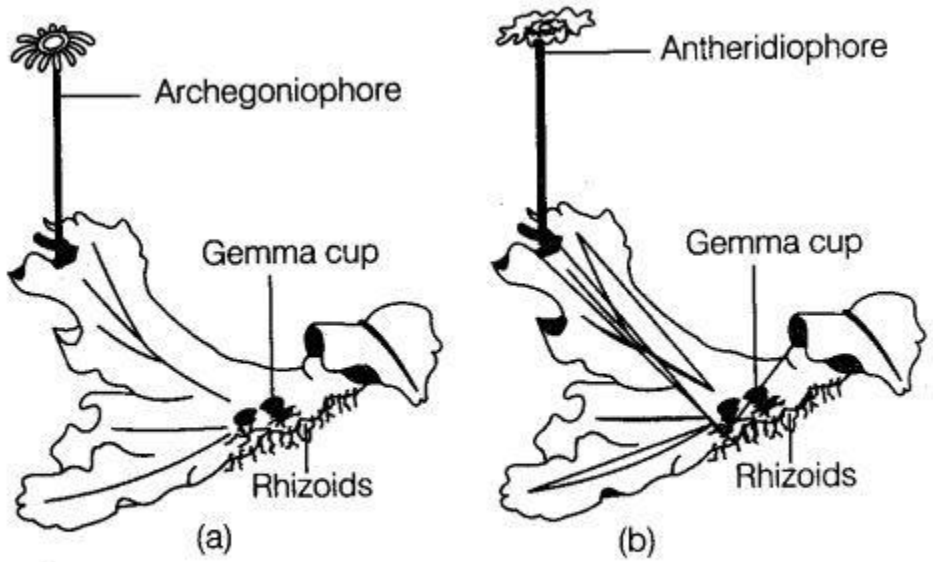


Fig 3.5 A liverwort (*Marchantia*) (a) Female thallus (b) Male thallus

i. Mosses

Mosses (Bryopsida) grow in dense mats over moist shady places, especially during rains. Some mosses grow in desert bogs and streams.

(a) Plant Body The predominant stage of the life cycle of a moss is the gametophyte which consists of two stages the first stage is the protonema stage which develops directly from a spore. It is a creeping, green, branched and frequently filamentous stage; the second stage is the leafy stage which develops from the secondary protonema as a lateral bud. They consist of upright, slender axes bearing spirally arranged leaves. This stage bears sex cells.

(b) Rhizoids These are long, multicellular branched structures with oblique septa. They take part in fixation and absorption of water. However, surface conduction through capillarity is an important mechanism of water supply to aerial parts.

(c) Reproduction This can occur both by vegetative and sexual means.

* Vegetative Reproduction It occurs by fragmentation and by budding in the secondary protonema from exposed rhizoids and other parts (like gemmae, buds and tubers).

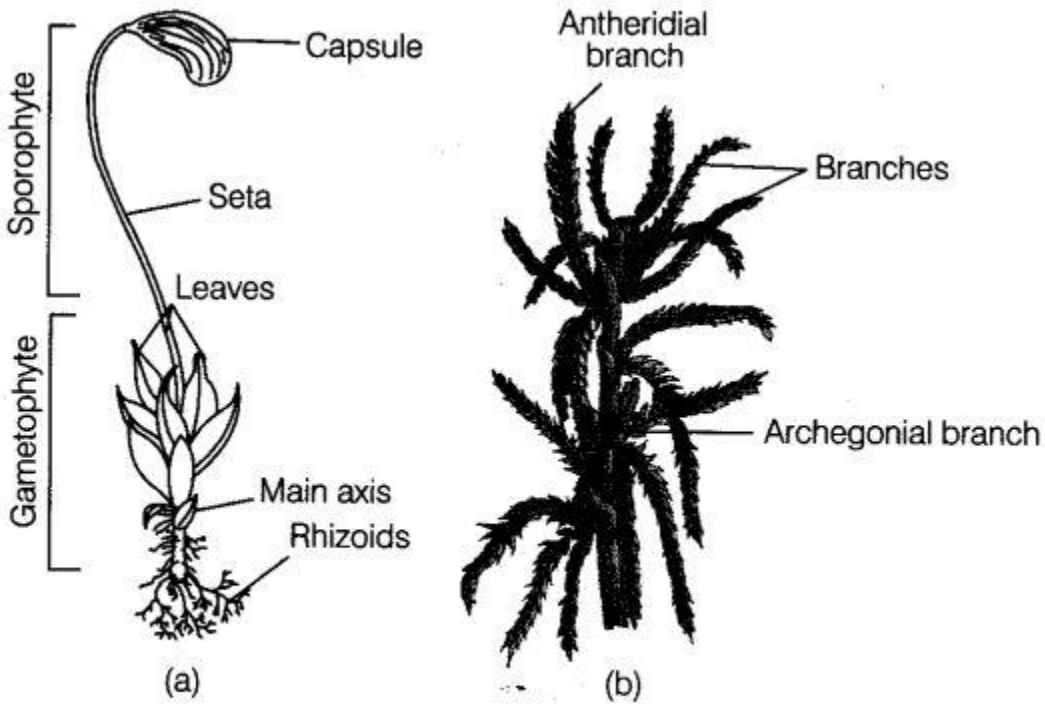


Fig 3.6 Mosses (a) *Funaria*, gametophyte and sporophyte (b) *Sphagnum* gametophyte

Sexual Reproduction Sex organs, antheridia and archegonia are produced at the apex of the leafy surface. Male organs appear cup-shaped, while female organs are bud-like. After fertilisation, the zygote develops into a sporophyte, consisting of foot, seta and capsule (containing spores).

(d) Sporophyte The sporophyte in mosses is more elaborate than that in liverworts. Spores are formed after meiosis. The mosses have an elaborate mechanism of spore dispersal, e.g., Funaria, Polytrichum and Sphagnum.

Differences between Liverworts and Mosses

Liverworts	Mosses
They are dorsiventral.	They have radial symmetry.
Plants are thalloid or foliose.	Mosses are foliose.
Midribs is not present in leaves.	Leaves have unbranched midrib.
Rhizoids are unicellular and unbranched.	Rhizoids are multicellular and branched.
Plants bear scales.	Scales are absent in plants.
A conducting strand is absent.	A conducting strand is commonly present.
Sporophyte is differentiated in foot, seta and capsule.	It is not differentiated in foot, seta and capsule.
Capsule often possesses elaters.	Elaters are absent.
Dehiscence occurs through elaters.	Peristome perform these functions.
A protonema stage is absent. .	A juvenile protonema stage is present.

Pteridophytes

Pteridophytes are primitive seedless vascular plants also called cryptogams. These have conspicuous sporophytic plant body, inconspicuous independent gametophytes with antheridia and partially embedded archegonia having 4-rowed necks.

The term Pteridophyte was coined by Haeckel (1866). There are about 13000 species of pteridophytes have been reported. They were perhaps the first land plants evolved during ordovician (450-500 million years ago) period.

The characteristic features of pteridophytes are as follow

Habitat

The pteridophytes are found in cool, damp shady places though some may flourish well in sandy-soil conditions.

Some members like Azolla, Salvinia, Marsilea species.

Plant Body

The size varies from a fraction of centimeter (e.g, Azolla) to 20 m in tree ferns (e.g, Angiopteris). The main plant body is a sporophyte which is differentiated into true root, stem and leaves. These organs possess well differentiated vascular tissues. The leaves are small (microphyllus) as in Selaginella or large (macrophylls) as in ferns.

Vascular Tissues

These are xylem and phloem present throughout the body. Xylem consists of tracheids and phloem is made up of sieve cells and albuminous cells.

Sporophylls

The sporophytes bear sporangia that are subtended by leaf like appendages called sporophylls. In some cases sporophylls may form distinct compact structure called strobili or cones (Selaginella and Equisetuni). The sporangia produce spores by meiosis in spore mother cells.

Spores

The spores germinate to give rise to inconspicuous, small but multicellular free-living, mostly photosynthetic thalloid gametophytes called prothallus. In majority of the pteridophytes, all the spores are of similar kinds; such plants are called homosporous. Genera like Selaginella and Salvinia which produce two kinds of spores, macro (large) and micro (small) spores; such plants are called heterosporous.

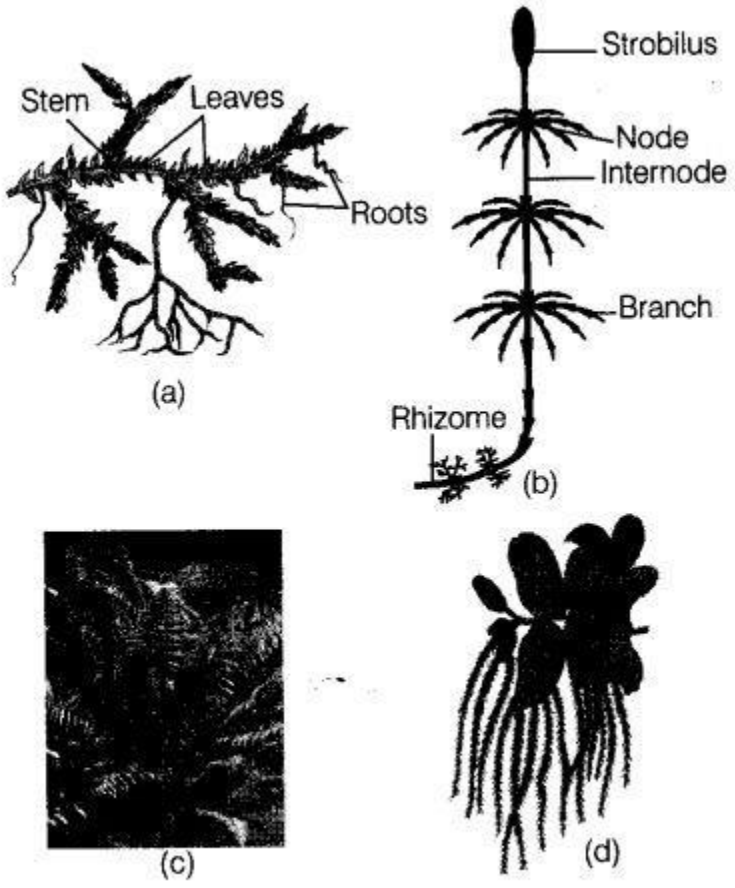


Fig 3.7 (a) *Selaginella* (b) *Equisetum* (c) Fern (d) *Salvinia*

Gametophyte

The thalloid gametophyte or prothallus require cool, damp, shady places to grow. The megaspores and microspores germinate and give rise to female and male gametophytes

respectively. The female gametophytes in these plants is retained on the parent sporophytes for viable periods. In most ferns, prothallus is green and autotrophic. In heterosporous ferns, the female gametophyte depends on food stored by the megaspore.

Sex Organs

The gametophytes bear male sex organs called antheridia and female sex organs called archegonia. Antheridium is sessile and surrounded by a single layered jacket. Archegonium is flask-shaped. It is partially embedded.

Fertilisation

Water is required for transfer of antherozoids. The male gametes released from the antheridia and reach to the mouth of archegonium. Fusion of male gamete with the egg present in the archegonium result in the formation of zygote. Zygote therefore, produces a multicellular, well differentiated sporophyte, which is the dominant phase of the pteridophytes.

Embryo

Fertilisation produces a zygote that undergoes division to produce embryo. The development of the zygote into young embryo takes place within the female gametophyte.

* This event is a precursor of the seed habit and considered as an important step in evolution, e.g., Dryopteris, Selaginella, Adiantum, Equisetum and Salvinia.

Economic Importance of Pteridophytes

(i) Pteridophytes are a good source of food for animals. For example, sporocarps of Marsilea is edible. Angiopteris and Alsophila have starchy pith eaten by natives of Australia.

(ii) Ferns protect soil from erosion by providing a good cover on the hill slopes and other fragile places.

(iii) Equisetum stems have rough surfaces. They are used in scrubbing and polishing.

(iv) Azolla a water fern has a symbiotic association with nitrogen fixing cyanobacterium Anabaena azollae. It is cultured in paddy fields to harbour nitrogen fixing bacterium. Thus, act as a biofertiliser.

(v) Rhizomes and petioles of Dryopteris are used to produce anthelmintic drug. Roots of Adiantum can cure throat infections. Lycopodium is used in treatment of rheumatism and disorders of lungs and kidneys.

(vi) Ferns are also grown as ornamental plants for their graceful plant body.

Classification of Pteridophytes

The pteridophytes are further classified into four classes

(i) Psilopsida (Psilotum)

(ii) Lycopsida (Selaginella and Lycopodium)

(iii) Sphenopsida (Equisetum)

(iv) Pteropsida (Dryopteris, Pteris and Adiantum)

Differences between Bryophytes and Pteridophytes

Bryophytes	Pteridophytes
The main plant body is gametophyte.	It is sporophyte.
These are non-vascular plants.	These are vascular plants.
Sporophyte is parasitic over gametophyte.	Sporophyte is independent of gametophyte.
Plant body can be thallus or foliose.	It is differentiated into stem, leaves and roots.
True stems and leaves are not present.	It has true stems and leaves.
Roots are absent, rhizoids are present.	Roots are present.
Sex organs are stalked.	Sex organs are sessile.
The wall of archegonial neck is 5-6 rowed.	The wall of archegonial neck is 4-rowed.

2 Gymnosperms, Angiosperms and Plant Life Cycles

Gymnosperms

The gymnosperms (Gymnos = naked; sperma = seeds) are plants in which the ovules are not enclosed by any ovary wall and remain exposed, both before and after fertilisation. These are small groups of seed plants which are represented by only 900 living species. Unlike bryophytes and pteridophytes, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophytes.

Habitat

These plants are mostly found in colder parts of northern hemisphere, where they form extensive forests. A number of gymnosperms are now, known as ornamentals, e.g., Ginkgo, Thuja, Araucaria, etc.

Morphology

Gymnosperms include, medium-sized trees or tall trees and shrubs. The giant red wood tree Sequoia is one of the forest tree upto 100 m. Species of Gnetum are woody climbers. The smallest gymnosperm is Zamia pygmaea which reaches a height of 25 cm. Many of the gymnosperms live for more than 4000 years, e.g, Pine (Pinus), redwood {Sequoia).

External Features

The plant body is sporophyte and differentiated into root, stem and leaves.

Plant Body

Tap roots are present for proper anchorage to heavy plant. Roots in some genera have fungal association in the form of mycorrhiza {Pinus), while in some others {Cycas) small specialised roots called coralloid roots are associated with N2-fixing cyanobacteria such as Anabaena, Nostoc, etc.

The stems are branched {Pinus, Cedrus) or unbranched {Cycas). The leaves may be simple or compound.

Archegonia

The megaspore mother cell thus, undergo meiotic division forming four megaspores. Out of which one is enclosed within the megasporangium (nucellus) and develops into a multicellular female gametophyte, bearing two or more archegonia of female sex organs.

The multicellular female gametophyte is also retained within megasporangium.

Fertilisation

Air current required for transport of male gametes. The male gametes are carried to the archegonia, i.e., gamete in the ovule by means o'f a tube called pollen tube and discharge their contents near the mouth of the archegonia. This is called siphonogamy.

Seeds

Following fertilisation, zygote develops into an embryo and the ovules into seeds. The seeds contain food laden tissue called endosperm. It lies naked or exposed. Endosperm provides nourishment for growth of seedling at the time of seed germination.

Examples Cycas, Pinus, Ginkgo, Ephedra, Gnetum, Vaucheria, Cedrus, Abies, etc.

Differences between Microsporophyll and Megasporophyll

Microsporophyll	Megasporophyll
It bears microsporangia.	It bears megasporangia.
It contains numerous microspores.	It usually contains one megaspore.
Microspores are released.	Megaspore are retains inside the megasporangium.

Differences between Male Gametophyte of Pteridophyte and Gymnosperms

Male Gametophyte of Pteridophyte Male Gametophyte of Gymnosperms

A distinct male gametophyte may not be present. A distinct male gametophyte is present.

It contains an antheridium. Antheridium is not present.

Male gametes are flagellate. Male gametes can be flagellate or non-flagellate.

Male gametes reach female gametes by swimming in water. Male gamete reach the female gamete through a pollen tube.

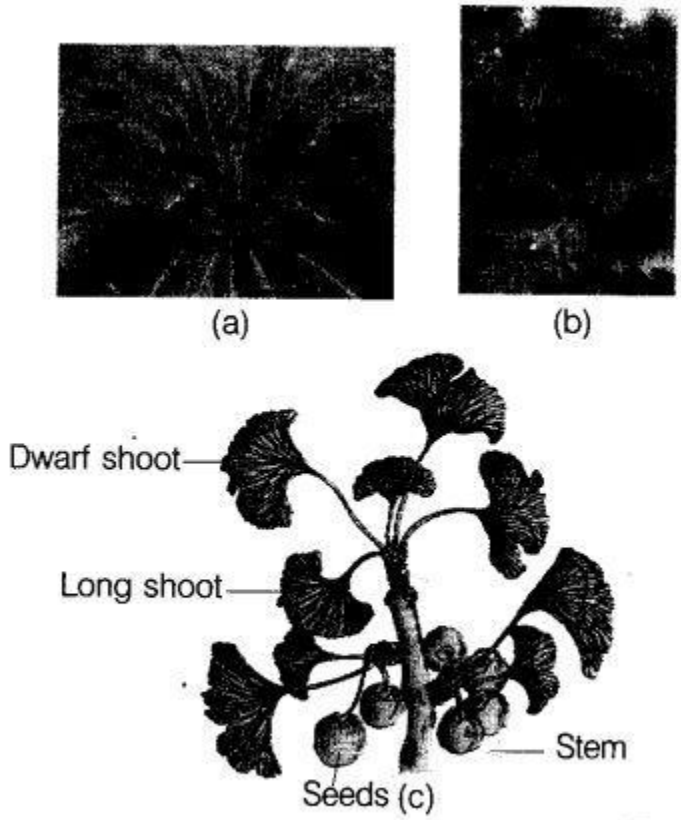


Fig. 3.8 Gymnosperms : (a) *Cycas* (b) *Pinus* (c) *Ginkgo*

Economic Importance of Gymnosperms

(i) Seeds of Pinus gerardiana (chilgoza) are used a food after roasting. Some other edible gymnosperms plant part are endosperm of Ginkgo, seed kernel of some Cycas and Gnetum, sago grains from stems of Cycas, etc.

(ii) Gymnosperms provide softwood for construction, plywood and paper industry.

(iii) Branches of gymnosperm trees are used as fuel food.

Saw dust of conifers is used in making plastics and linoleum.

Resin is a semifluid secreted by special tubes of a number of conifers. It helps in sealing female cones after pollination, scale leaves around leaf bases and apical buds. Resin is distilled to obtain turpentine and resin. Turpentine is used for . thinning paints, varnishes, etc., and resin is used

for sealing joints, wheel green, preparation of writing paper, oil clothes, etc.

(iv) Ephedrine an antibiotic is obtained from Ephedra. It is used for curing respiratory problems and asthma. Taxol is an anticancer drug obtained from Taxus.

Angiosperms

Angiosperms are seed bearing plants or flowering plants. Unlike gymnosperms where the ovules are naked, in angiosperms the sporophyll are organised into flowers and the seeds are produced inside fruits. There are about 250000 species of angiosperms in the nature. They evolved about 130-160 million years ago.

Habitat

Angiosperm are found in wide range of habitats, from the land to up to 6000 m in Himalayas or Antarctica and Tundra, dry hot deserts, cold deserts, tropics, fresh water up to 60°C, underground, over other plants as parasites, saprophyte, etc. Zostera is a marine angiosperm.

Plant Body

These plant are sporophytic, in the form of herbs, shrubs, trees, climber creepers, etc. The smallest angiosperm is water plant Wolffia and tallest is Eucalyptus regnans (100 mand above). Primary root develops from radicle. It forms tap root system. In many angiosperms roots develop from places other than radicle, these are adventitious roots. Stem develops from plumule.

Leaves

These are simple or compound. The leaves bear axillary buds which can grow into stem branches.

Vascular Tissues

Angiosperms have vessels in xylem. Phloem contains sieve tubes and companion cells in regard to gymnosperms which do not have companion cells.

Flowers

Flowers are the reproductive structures formed by the union of one or both types of sporophylls (microsporophylls or stamens and megasporophylls or carpels).

Microsporophylls or Male Sex Organs

Stamens are considered as the male sex organs of a flower. Each stamen has two main parts, i.e., a slender filament with an anther (at the tip). An anther contains four microsporangia where microspore mother cells become differentiated to form four microspores, each developing into a pollen grain.

Megasporophylls or Female Sex Organs

Carpel or pistil is called the female sex organ of the flower. Each carpel has three parts {i.e., an ovary, style and stigma). A megaspore mother cell is differentiated in the nucellus and undergoes meiosis, ultimately one functional megaspore gets enlarged and forms the female gametophyte known as embryo-sac.

Each cell of an embryo sac is haploid:

Embryo Sac

Each embryosac contains a three celled eg® apparatus consisting I of one egg cell and two synergids, three antipodal cells (at the i opposite end) and two polar nuclei (in the central cell). The polar : nuclei eventually fuses and forms diploid secondary nucleus.

Pollination

Pollen grains after dispersal from the anthers are carried by various ways such as wind, water or by various other agencies to the stigma of the pistil.

Fertilisation and Development of a Seed

Each pollen grain germinates on the stigma forming a pollen tube that carries two male gametes to the embryo sac, growing through the tissues of stigma and style.

One of the male gametes fuses with the egg cell to form a zygote (syngamy).

The other male gamete fuses with the diploid secondary nucleus to produce the triploid Primary Endosperm Nucleus (PEN). Because of the involvement of above mentioned two events, it is known as double fertilisation. After fertilisation, synergids and antipodal cells degenerate.

The zygote develops into embryo and the primary endosperm nucleus develops into an endosperm.

The ovule gradually transforms into a seed and the ovary becomes the fruit. A fruit is actually a ripened ovary. They not only protect the seed but also help in their dispersal.

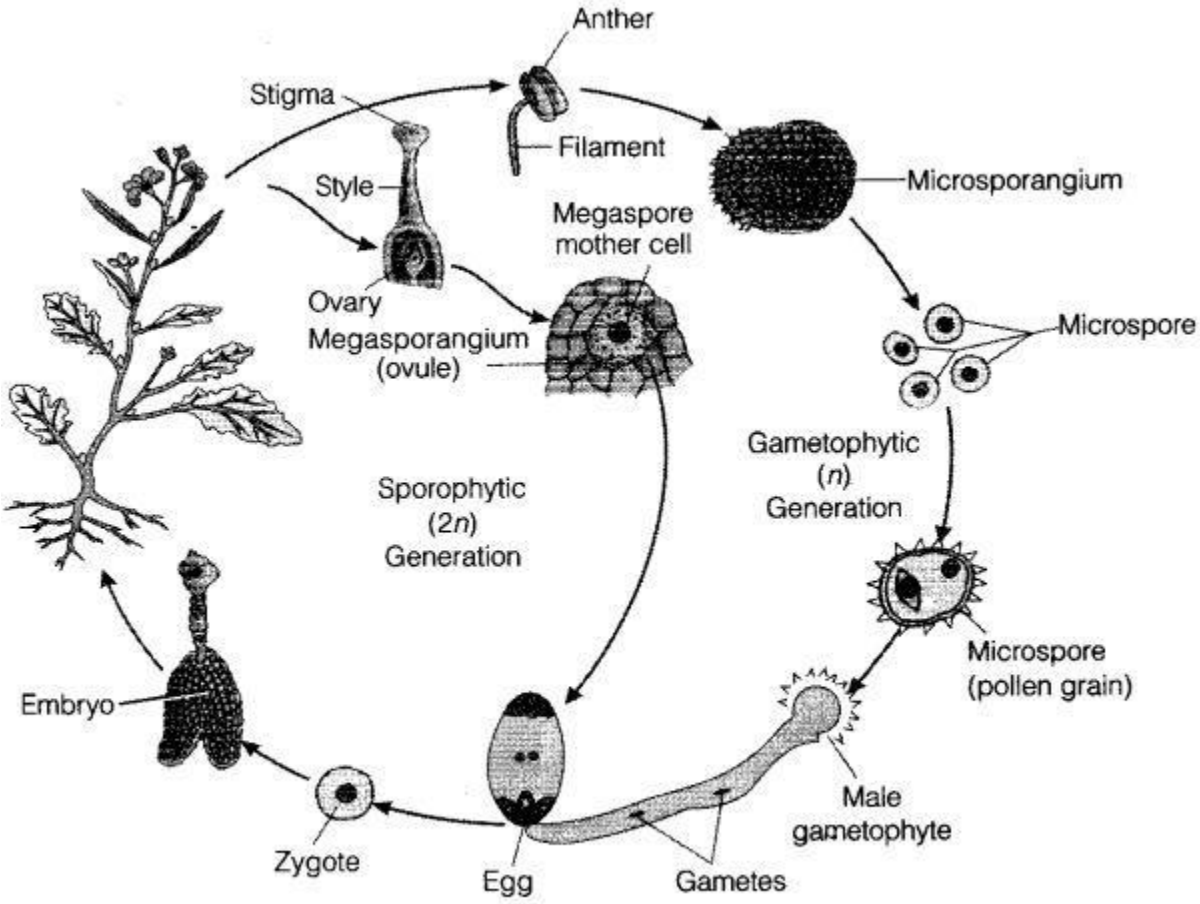


Fig. 3.9 Life cycle of an angiosperm

Differences between Gymnosperm and Angiosperm

Gymnosperms	Angiosperms
Vessels or trachea is absent in xylem.	Trachea is present in xylem.
Phloem contains sieve cells.	Phloem tissue contains sieve tube and companion cells.
Sporophyll are aggregated to form cones.	Sporophyll are aggregated to produce flowers.
Sepals and petals absent.	Sepals and petals present.
Cones are generally unisexual.	Flowers are generally bisexual.
Microsporophyll are broad and leaf like.	Microsporophyll have a stalk and terminal anthers.
Megasporophylls are woody and there is no rolling of megasporophylls.	The magasporophyll are softer and rolled into ovary, style and stigma.
Ovules are exposed.	Ovules are enclosed in ovary.
Archegonia is present	Archegonia absent.
Pollen enters micropyle directly.	Pollen germinates on stigma, pollen tube passes through style to enter ovary.
Single fertilisation.	Double fertilisation
Endosperm is haploid and formed before fertilisation.	Endosperm is triploid and formed after fertilisation.
Seeds exposed because there in no ovary, so no fruit formation.	Seed are enclosed in a fruit which forms after fertilisation.

Classification of Angiosperms

George Bentham and Joseph Dalton Hooker presented the system of classification of angiosperm* published in Genera Plantarum (1862-1883) which appeared in three volumes. This system of classification is used by most of the well known Herbaria of the world. The details of this system are not described here. Conveniently, on the basis of the number of cotyledons angiosperm are classified in two broad groups i.e., Monocotyledonae and Dicotyledonae.

Differences between Monocots and Dicots

Monocots	Dicots
They contain one cotyledon.	They contain two cotyledons.
Leaves have parallel venation.	Leaves have reticulate venation.
Fibrous root system is present.	Tap root system is present.
Stomata are dumb-bell shaped.	Stomata are kidney- shaped.
Vascular bundles are scattered.	Vascular bundles are arranged in rings.
Cambium is absent.	Cambium is present.
Stems do not have concentric arrangement of tissue. A ground tissue is present.	Stems have concentric arrangement of tissue epidermis cortex, endodermis, pericycle, pith, etc.
Secondary growth is absent with some exception in stems.	These show secondary growth in stem.
Root has pith in its centre.	Root is generally devoid of pith.
Secondary growth is absent in roots with some exception.	Secondary growth occurs in roots.

Economic Importance of Angiosperms

(i) The angiosperms are major source of food, fibers, spices and beverages.
(ii) They also provide valuable timber and medicines.
(iii) These also add beauty to our environment as well.

Alteration of Generation

Life cycle of an organism is a sequence of events that occur from birth to death of an organism. In plants, both haploid and diploid cells can divide by mitosis.

This feature leads to the formation of different plant bodies haploid and diploid. The haploid plant body produces gametes by mitosis. This plant body represents a gametophyte.

After fertilization, zygote also divides by mitosis to produce a diploid saprophytic plant body. Haploid spores are produced by this plant body by meiosis. These in turn, divide by mitosis to form a haploid plant body once again.

Thus, during the life cycle of any sexually reproducing plant, there is an alternation of generation between gamete producing haploid gametophyte and spore producing diploid saprophyte.

Plant Life Cycles

Plant Life Cycles

Different plant groups and individual have different features in their life cycle

Haplontic

The dominant photosynthetic phase is a gametophyte produced by haploid spores. The gametophyte produces gametes by mitosis.

The gametes fuse and produce a diploid zygote, that represents sporophytic generation. There

are no free living sporophytes. Meiosis in the zygote results in formation of haploid spores. This kind of life cycle is called haplontic.
Many algae such as Volvox, Spirogyra and Chlamydomonas represent this pattern of life cycle.

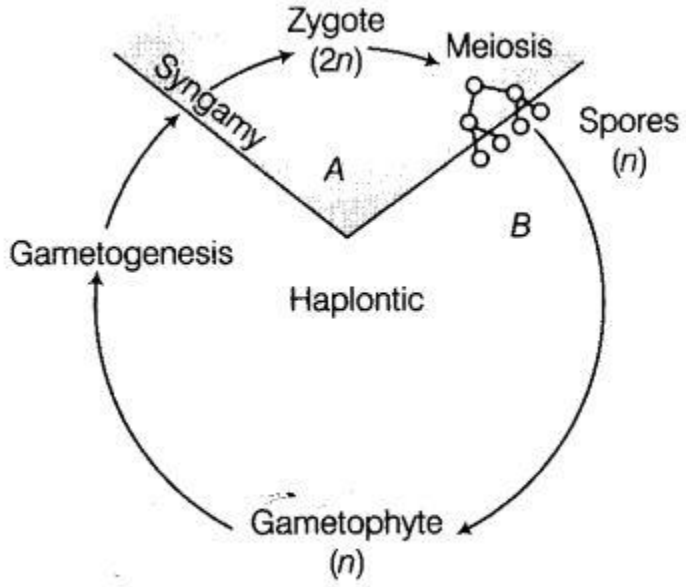


Fig. 3.10 Life cycle pattern : Haplontic

iplontic

In this type, the diploid sporophyte is the dominant. The multicellular diploid phase is called sporophyte. The gametophytic phase is represented by the single to few celled haploid gametophyte.
This kind of life cycle is termed as diplontic. All seed bearing plants, gymnosperms and angiosperms follow this pattern of life cycle. Fucus, an alga is diplontic.

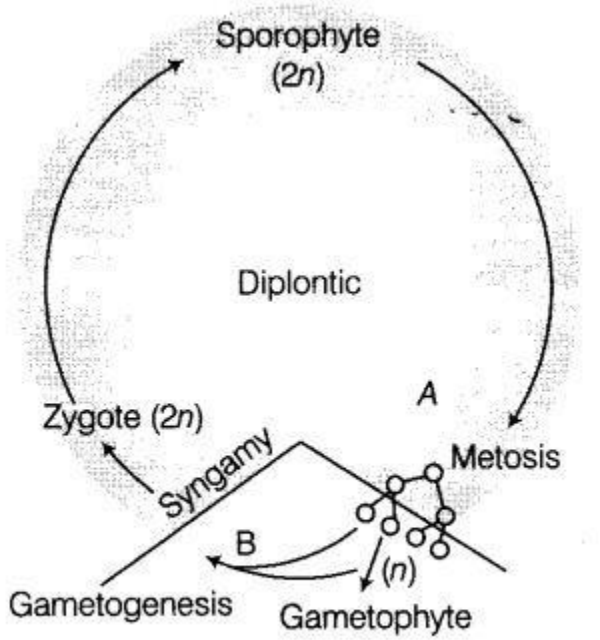


Fig. 3.11 Life cycle pattern: Diplontic

Haplodiplontic

In this type, there are two distinct multicellular phases, diploid sporophyte and haploid gametophyte are present. Both phases are multicellular. However, they dilfer in their dominant phases.

(i) A dominant, independent, photosynthetic, thalloid or erect phase is represented by a haploid gametophyte. It alternates with the short lived multicellular sporophyte totally, partially or dependent on the gametophyte for its anchorage and nutrition. All bryophytes represent this pattern.

(ii) The diploid saprophyte is represented by a dominant independent photosynthetic vascular plant body. It alternates with multicellular saprophytic/autotrophic,
independent but short lived haploid gametophyte. This pattern is called haplodiplontic life cycle. All pteridophytes demonstrate this pattern. However, most algal genera are haplontic, some of them such as Ectocarpus, Polysiphonia and kelps are haplodiplontic.

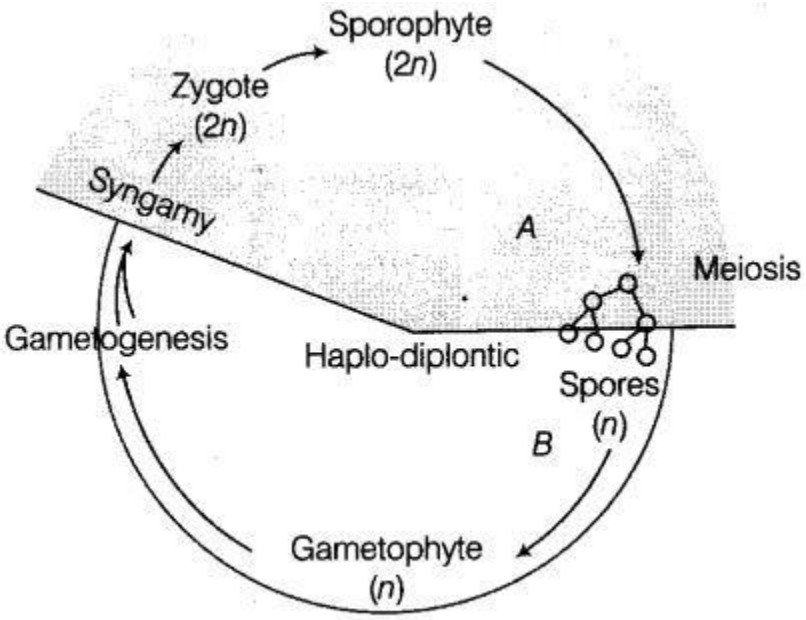


Fig. 3.12 Life cycle pattern: Haplodiplontic

L 5 Morphology of Flowering Plant

The angiosperms or flowering plants show a large diversity in external structure called as morphology (Gk. Morphe—form; logos—study). However, they all are characterised by the presence of roots, stems, leaves, flowers and fruits.

1. Flowering Plants

The plant body consists of a main axis, which may be branched or unbranched bearing lateral appendages.
The main axis is divided into two parts
(i) Root system The underground root system develops from the radicle embryo and helps in fixation of the plant as well as absorption of water and minerals.

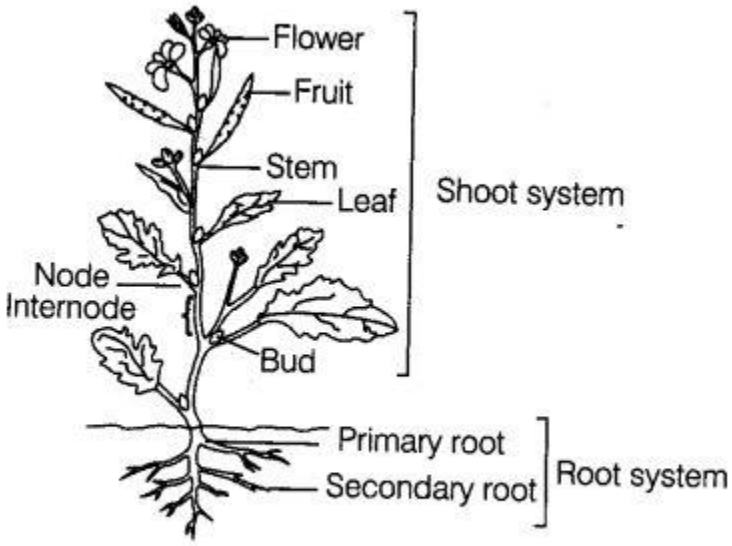


Fig. 5.1 Parts of a flowering plants

(ii) Shoot system The aerial shoot system develops from the plumule embryo.
It contains root, stem, leaves as vegetative parts and flowers, fruits and seeds as reproductive parts. The Vegetative parts are involved in various vegetative functions like structural organisation, fixation, absorption, nourishment, growth and maintenance of various components and ” reproducting parts are for sexual reproduction and germination of new plants.

The Root

In plants, root is the non-green (due to absence of chlorophyll), cylindrical and descending part that normally grows downwards into the soil. It does not bear leaves, buds and not distinguished into nodes and inter nodes.

i. Root Cap (Calyptra)

The root is covered at the apex by a thimble or cap-like structure called the root cap. It protects

the root meristem from friction of the soil particles and also protect tender apex which allow the passage of root through cells, e.g., Lemna, Eichhornia.

ii. Growing Point (Meristematic) Zone

It is a small (about 1 mm in length) thin-walled region having dense protoplasm. It lies partly within and partly beyond the root cap. Its cell divide regularly and repeatedly for elongation. It is responsible for the growth of the root.

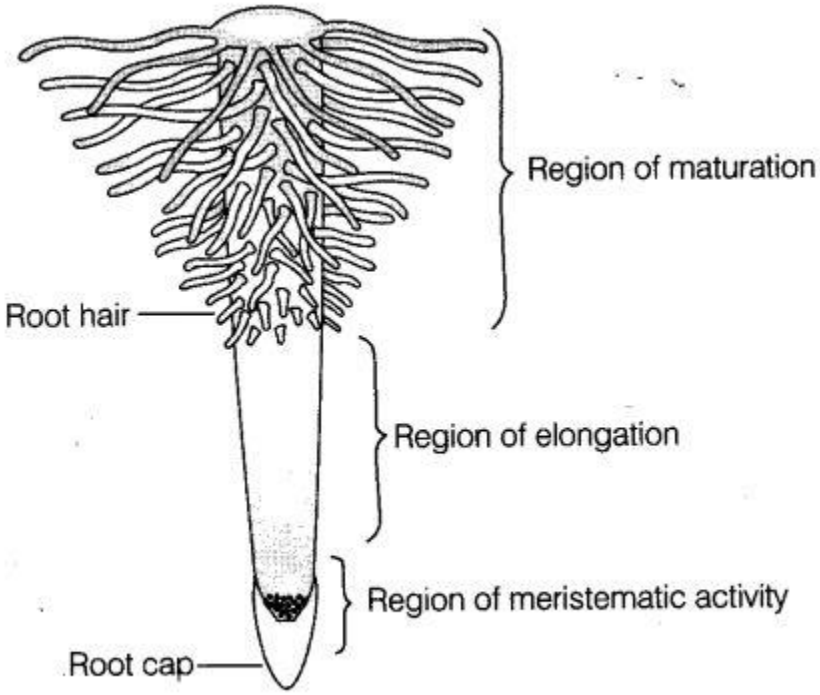


Fig. 5.2 The region of the root tip

iii. Zone of Elongation

It is situated behind the meristematic region (growing point). The cells elongate speedily and increases the length of the root. The cells of this region can absorb water and minerals from the soil.

iv. Root Hair Zone

It is the region where primary tissues differentiate into the root. The vascular tissues like xylem and phloem are formed.

Root hair zone is the most important part of the root for absorption of water (most of the water) from the soil. The root hairs increase the exposed surface of the root for absorption.

v. Zone of Maturation

This zone contains mature cells. It forms the permanent zone of the root and also gives out lateral roots from the interior part of this region, e.g., In dicots and gymnosperms.

- Roots of parasitic plants lack root caps.
- In aquatic plants, root hairs are usually absent.

Types of Root System

The root system can be of two types on the basis of place of origin

i. Tap Root System

The tap root develops from the radicle of embryo of a seed. In most of the plants, primary root persists and becomes stronger to form tap root. The first root forms by the elongation of radicle and is called primary root. It continuously grows and produces lateral roots called secondary roots.

The further branches of the secondary roots are called tertiary roots and so on. These types of roots are present in dicots, e.g., Pea, gram, groundnut, etc.

ii. Adventitious Root System

The roots developing from any part of the plant other than the radicle are known as adventitious roots (L.adventitious .extraordinary). These are usually found in monocots.

The adventitious roots can be further classified as following on the basis of nature of development

(a) Fibrous Roots The primary root soon gets replaced by a cluster of slender, thread-like roots originating from the base of the stem, e.g, Triticum vulgare (wheat), Oryza sativa (rice), Allium sepa (onion).

(b) Foliar Roots These roots develop from the leaf, i.e., from the petiole of the leaf, e.g., Pogostemon, rubber plant.

(c)True Adventitious Roots These roots develop from the nodes and internodes of the stem, e.g., Prop roots of banyan (Ficus), climbing roots of money plant (Pothos), roots from the stem when partially immersed in water (Coleus), roots from nodes (Oxalis repens) etc.

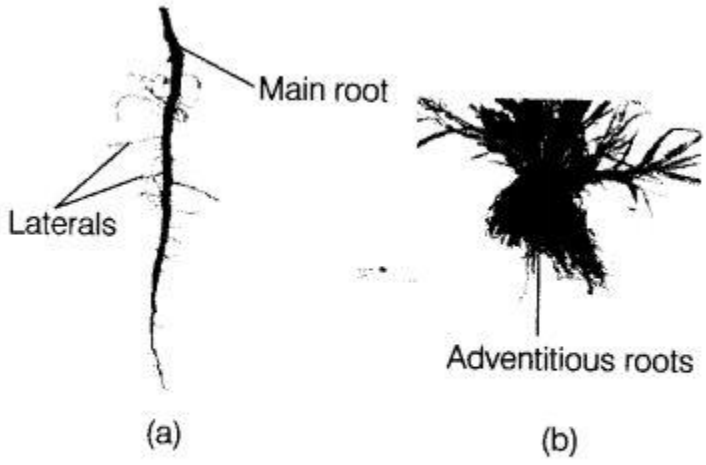


Fig. 5.3 Different types of root system
(a) Tap (b) Adventitious

Modification of Roots

The modifications are the changes in shape, form or structure in an organ to carryout special function other than or in addition to the normal functions. Modification of roots are found in both

tap roots ancf adventitious roots.

Modification of Tap Roots

The tap roots are modified for the function like storage, nitrogen-fixation and respiration.

(a) Conical Roots These are fleshy tap roots that resemble a cone (broad at the base and gradually tapering towards the apex), e.g., carrot (Daucus carotd).

(b) Fusiform Roots The primary root is spindle-shaped. It is swollen in the middle and gradually tapers at both the ends, e.g., Radish (Raphanus sativus).

(c) Napiform Roots The primary root is almost spherical (pitcher-shaped) at the base and tapers abruptly at the lower end, e.g., – beetroot (Beta vulgaris),-turnip (Brassica rapa), etc.

(d) Tuberous Roots The primary root becomes thick and fleshy but do not attain any definite shape (irregularly-shaped), e.g., 4 O'clock plant (Mirabilis jalapd), Echinocystis lobata.

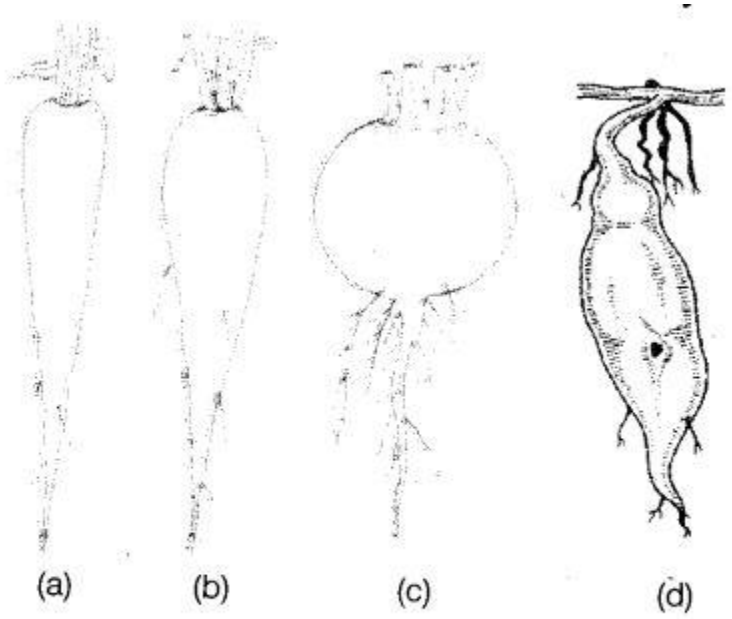


Fig. 5.4 Modification of tap roots for storage
(a) Conical root (carrot) (b) Fusiform root (radish)
(c) Napiform root (turnip) (d) Tuberous root (4 O'clock plant)

(e) Nodulated Tap Roots In this the secondary, tertiary and sometimes primary roots bear many small irregular swellings called root nodules which contain countless, minute nitrogen fixing bacteria of the genus Rhizobium, e.g., groundnut (Arachis bypogea), clover (Medicago falcata), pea (Pisum sativum), etc.

(f) Pneumatophores These are special roots that develop in mangrove plants (grow in marshy areas). The pneumatophores or aerophores or respiratory roots grow vertically upward and are negatively geotropic.

They have minute breathing pores called pneumatophores or lenticels present on the tips of vertical roots that help in getting oxygen for respiration.

Modification of Adventitious Roots

The adventitious roots are modified to perform several additional functions like food storage, mechanical support and other vital functions.
(a) Fasiculated Roots These arises in clusters from the base of the stem, e.g., Dahlia, Asparagus.
(b) Nodulous Roots These roots have swellings occur only near the tips, e.g., Arrow root (Maranta), amia haldi (Curcuma amadd).
(c) Tuberous Roots (Single Root Tubers) These are swollen without any definite shape, e.g., Ipomoea batatas (sweet potato).

d) Prop (Pillar) Roots The prop roots grow as the horizontal branches of the stem and grow vertically downward.
They become thick pillar-like and provide mechanical support to the giant trees, e.g., Banyan tree (Ficus benghalensis).

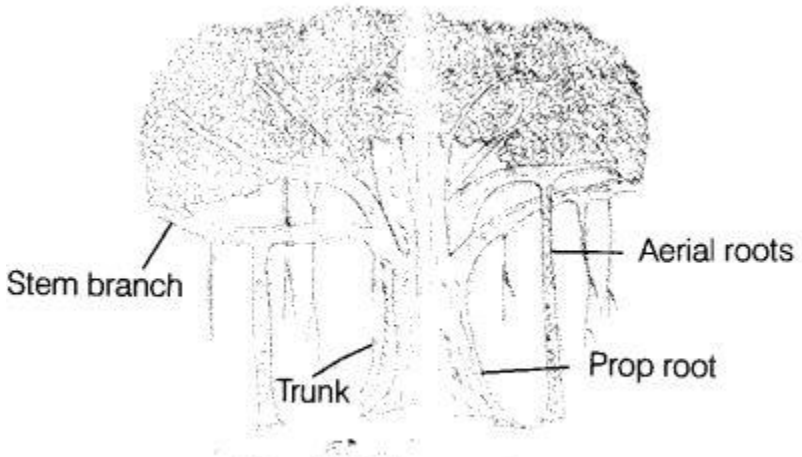


Fig. 5.5 Banyan tree

e) Stilt Roots These are small thick supporting roots growing obliquely from the basal nodes of the main stem. These provide mechanical support, e.g., Saccharum officinarum (sugarcane), Zea mays (maize).
(f) Climbing (Clinging) Roots These roots are found in climbers. They may arise from the nodes, e.g., Ivy, Pothos (money plant).

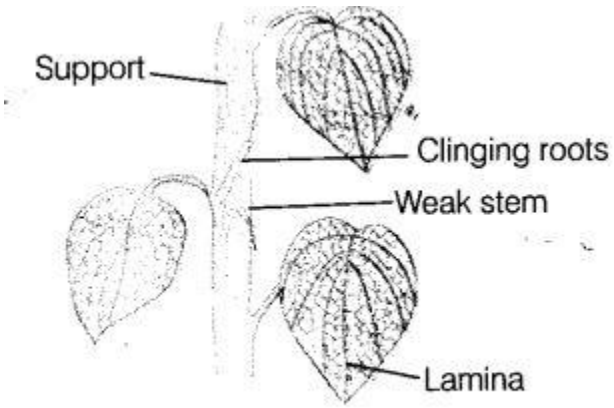


Fig. 5.6 Betel (*Piper betel*)

g) Assimilatory (Photosynthetic) Roots These roots have chlorophyll and can synthesise food, e.g., Aerial or hanging roots of some orchids.
(h) Parasitic (Sucking) Roots These roots occur in parasitic plant for absorbing nourishment from their host. These roots function as haustoria, e.g., Cuscuta (dodder).

unctions of Roots

The major functions of roots are as follows
(i) Fixation Root provides fixation to the plants with soil.
(ii) Absorption Roots absorb water and minerals from the soil and provide it to all parts of the body.
Storage Roots of many plants store food for the use of other plant parts and for animals.
(iv) Aeration Plants growing in waterlogged soil or marshy areas have special roots, i.e., pneumatophores for respiration.
(v) Conduction Roots transport water and minerals in upward direction for the uses of stems and leaves.

The Stem

The stem is the ascending part of the axis bearing branches, leaves, flowers and fruits. It develops from the plumule of the embryo of a germinating seed.
It shows distinction into nodes and internodes; where node is the region from where leaves are born and internodes are the region between two nodes. Its apex bears a terminal bud for growth in length.
A bud can be defined as a condensed embryonic shoot that has a growing point surrounded by closely packed immature leaves. When bud grows, the internodes become longer and the leaves spread out, resulting in the formation of a young shoot.

Note:

* The largest bud is cabbage.
* Bamboo is considered to be tallest herb, tallest shrub or arborescent grass. Bamboos are called culms, after the jointed nature of their stems.

Forms of Stem

Stem may be aerial, subaerial or underground. In most of the plants, stems grow above the soil. These are aerial stems. The aerial stems of some plants trail or creep on the ground. They are

called subaerial stems. In some plants, the stem grow in the soil and are called underground stems.

i. Aerial Stems

The aerial stems have two forms, i.e., reduced stem and erect stem.

(a) Reduced Stems It is reduced to a small disc. The * nodes and internodes are not distinguished, e.g., carrot, radish, turnip, etc. In some aquatic plants, the reduced discoid stem is green and flattened to float on the surface of water. It does not bear leaves, e.g., Lemna, Wolffia, Spirodela. In underground structures also a reduced, non-green stem is found, e.g., Garlic, onion and lily.

(b) Erect Stems These stems are strong enough to remain erect or upright without any external support.

i. Subaerial Stem

In subaerial stems, some part lives underground, whereas, the remaining part of the stem is aerial.

The subaerial stem are also divided into two forms

(a) Upright Weak Stems These stems are weak which climb up a support to expose their foliage and reproductive organs.

These are of two types twiners and climbers

* Twiners These are long, slender and very sensitive and coil around an upright support on coming in contact, e.g, Dolichos lab lab (bean), Clitoria (butterfly pea), Cuscuta.
* Climbers These have weak and flexible stem which climb up a support with the help of certain clasping or clinging structures, e.g., Bougainvillea.

(b) Prostate Weak Stems These weak stems take support of the ground for spreading as growth occurs.

They are of following four types

* Trailers (creepers) They trail along the surface and do not climb up.
* Runners These are subaerial weak stems that grow horizontally along the soil surface, e.g., Cynadon (lawn grass), Centella (brahmi booti), Oxalis, etc.
* Stolons These subaerial weak stems are horizontal or branched runners with long internodes which can pass over small obstacless. Stolons, also propagate vegetatively like runners, e.g, Fragaria verica (strawberry), Jasminum (jasmine), Mentha piperita (peppermint).

Offsets These weak stems are one internode long, stout, slender and runs horizontally and terminates in a bud at a short distance that develops into adventitious roots, e.g., Pistia (water lettuce), Eichhomia (water hyacinth), etc.

iv. Underground Stems

The stem of some plants lie below the soil surface. They are non-green, store food as means of perennation and vegetative propagation.

They are of following types

(a) Rhizome It is a prostrate thick stem growing horizontally beneath the soil surface. It has distinct nodes and internodes. The. nodes bear small scale leaves with buds in their axils, e.g., Zingiber (ginger officinale), Curcuma domestica (turmeric).

(b) Suckers These are non-green slender stem that grows horizontally in the soil and ultimately comes out to form a new aerial shoot. Each sucker contains one or more nodes with scale leaves and axillary buds, e.g., Mentha (podina), Chrysanthemum (guldaudi).

(c) Corm It is a swollen condensed form of rhizome which grows in the vertical direction in the soil. It stores a large amount of food, e.g., Amorphophallus, Colocasia (taro).

(d) Tuber It is a swollen end of underground stem branches. Each tuber has many notches on the surface called eyes or buds, which grow into new plants, e.g, Solanum tuberosum (potato).
(e) Bulb It is a highly reduced disc like stem. It bears a large number of fibrous adventitious roots at its base. Leaf bases form bulblets. The bulblets grow into new plants, e.g., Allium cepa (onion), Allium sativum (garlic).

Branching Pattern of Stem

The stems may be branched or unbranched.
Branching in stems may be dichotomous and lateral.
(i) The dichotomous branching occurs by the division of the apical growing point or bud into two equal parts in a forked manner. It occurs in lower plants-cryptogams (non-flowering plants), higher plants~Hyphaene (palm), Canscora, screw pine, etc.
(ii) The lateral branching occurs from the axillary buds of the nodes, e.g., Pinus, grapevine, etc.

Functions of Stem

Stems perform various primary and secondary functions.

Primary Functions

(a) It bears leaves, fruits, flowers and seeds in position.
(b) It conducts water and minerals to roots, leaves, flowers, fruits, etc.
(c) It holds flower in suitable position, so that pollination and fertilistaion takes place.

Secondary Functions

(a) Many stems store food as reserve food materials.
(b) Some stems also help in photosynthesis and vegetative propagation.
(c) The underground stems help in perennation.
(d) Stem branches provide support to its various parts.

Modification of Stem

The various forms of aerial stem modification are following

i. Stem Tendrils

These are thin, long and sensitive structures which can coil around a support.
Tendrils can be of following types on the basis of their origin (d) Axillary Arise from axiallary buds, e.g., Passiflora (passion flower).
(b) Extra axillary Develop near the axillary bud, e.g., Lujfa, Cucurbita (pumpkin), etc.
(c) Apical bud These are modified to form tendrils, e.g., Vitis vinifera.
(d) Floral bud These are modified to form tendrils, e.g., Antigonon.

Stem Thorns

The stem thorns are stiff, woody, sharp and pointed. They develop from axillary bud. They protect the plants from browsing animals, e.g., Citrus, Duranta, Bougainvillea, Pomegranate, etc.

Prickles

These are modified stems and act as climbing organs. They protect the plants from grazing animals and also help in climbing in some cases, e.g., Argemone maxicana (prickly poppy), Rosa indica (rose), Bombax (sembal), etc.

Phylloclade

These are green, flattened structures bearing several nodes and internodes. The true leaves

are reduced to spines or scales. They show unlimited growth. Some phylloclades also store food and water. The phylloclades are examples of some xerophytic plants, e.g., Opuntia (nagaphani), Casuarina, Euphorbia.

Cladodes (Cladophylls) .

They are green photosynthetic stems generally one inter node long. These develop by the modification of only stem branches of limited growth and are green (photosynthetic). The true leaves of the plant are reduced to scales or spines, e.g., Ruscus, Asparagus.

ii. Bulbils

These are modified vegetative or floral buds arising in the axil of scale or foliage leaves. The bulbil helps in vegetative propagation, e.g., Lilium, Agave, Dioscorea (wild yam), Oxalis, etc.

The Leaf

The leaf is a lateral, generally Battened structure borne on the stem. It develops at the node and bears a bud in its axil. The axillary bud later develops into a branch. Leaves originate from shoot apical meristems and are arranged in an acropetal order. They are the most important vegetative organs for photosynthesis.

Parts of a Leaf

The leaves also consist of two lateral outgrowths called stipules at their bases.

A typical leaf has three main parts.

i.Leaf Base (Hypopodium)

The leaf is attached to the stem by the leaf base. Monocots, the leaf base is said to be sheathing as it expands and partially and wholly surrounds the stem. In dicots, the leaf base bears two lateral outgrowths called stipules.

In some leguminous plants, the leaf base may become swollen which is called the pulvinus. Leaves with stipules are called stipulate and those without them are termed as exstipulate.

ii. Petiole (Mesopodium)

It is the stalk of a leaf. Petiole help hold the leaf blade towards light. Petiole raises the lamina high to the level of stem so as to provide maximum required exposure to light and air.

iii. Lamina (Epipodium)

The lamina or leaf blade is the green, expanded part of the leaf with veins and veinlets. It has a prominent median vein called the midrib. It produces thinner lateral veins which in turn branch to form veinlets.

The lamina is the seat of photosynthesis, gaseous exchange, transpiration and other metabolic activities. The shape, margin, apex, surface and extent of invision of lamina varies in different leaves.

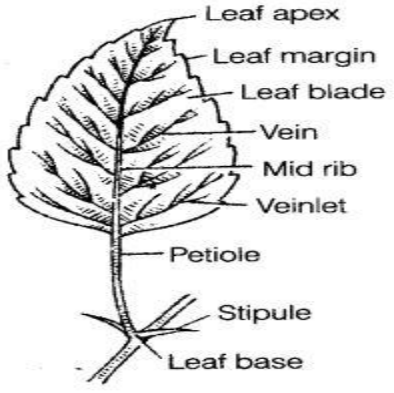


Fig. 5.7 Various parts of a leaf

Venation

The arrangement of veins and veinlets in the lamina of leaf is called venation. The midrib, veins and veinlets are contain vascular tissues, i.e., The xylem and phloem for conduction water, mineral salts and food.

Leaves have mainly two types of venation

i. Reticulate Venation

When the veinlets form a network, the venation is called reticulate. It is found in dicot leaves. However, some monocot leaves like Smilax, Dioscorea and Alocasia also show reticulate venation.

ii. Parallel Venation

When the veins run parallel to each other within a lamina, the venation is termed as parallel, e.g. Calophyllum, Zingiber officinale, etc.

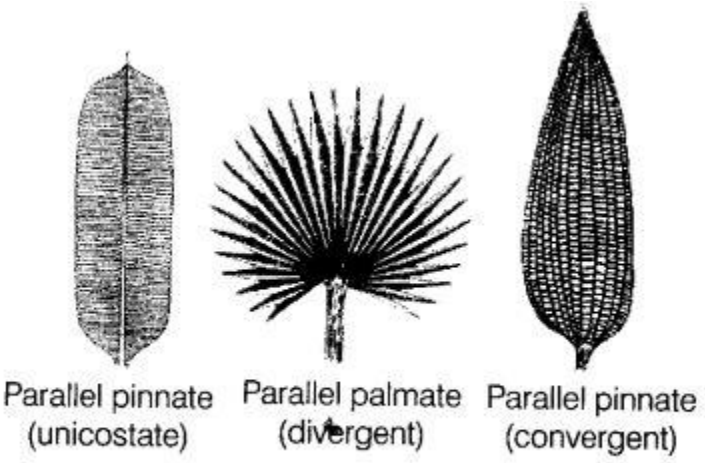


Fig. 5.8 Types of parallel venation

Types of Leaves

Leaves can be of following types

i. Simple Leaves

A leaf having a single or undivided lamina is called simple leaf. The lamina of a simple leaf may be incised but the incisions do not touch the midrib.

The lamina can have various types of incisions which may reach upto half (fid), more than half (partite) or near the base or midrib (sect).

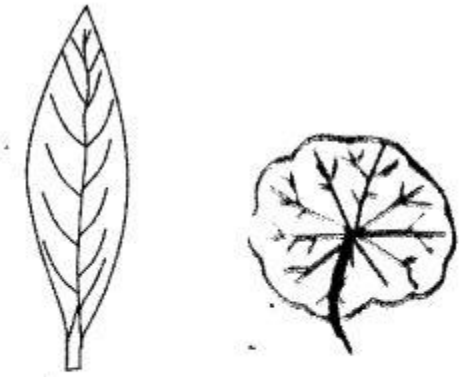


Fig. 5.9 Types of simple leaves
(a) Entire pinnate leaf of mango
(b) Entire partite leaf of garden nasturtium

Compound Leaves

A leaf is called compound when the incision of the leaf blade goes down to the midrib (rachis) or to the petiole so that the leaf is broken up into a number of segments called leaflets.

A bud is present in the axil of petiole in both simple and compound leaves but not in the axil of leaflets of the compound leaf.

A compound leaf can be of following two types

(a) Pinnately Compound Leaves In these leaves, the incision of lamina is directed towards the midrib, which is known as rachis. Leaflets are arranged on both side on the rachis, e.g., Neem, rose, etc.

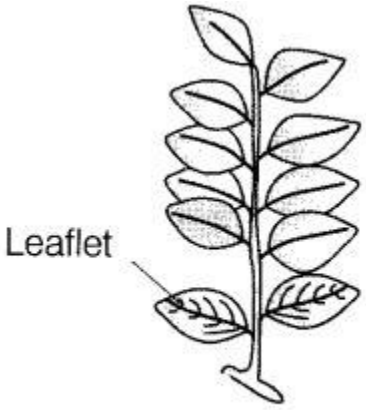


Fig. 5.10 Pinnately compound leaf

b) Palmate Compound Leaves The leaflets are attached at a common point, i.e., at the tip of petiole as in silk cotton.

Fig. 5.11 Trifoliate

Phyllotaxy

The pattern of arrangement of leaves on the stem or branch is called phyllotaxy. It helps to avoid overcrowding and provide every leaf with optimum sunshine.

Phyllotaxy is usually of three types

i. Alternate (Spiral) Phyllotaxy

A single leaf arises at each node in alternate manner, e.g, China rose, mustard and sunflower plants.

ii. Opposite Phyllotaxy

A pair of leaves axises at each node and opposite to each other, e.g., Calotropis and Psidium guajava (guava plants).

Whorled (Verticillate) Phyllotaxy

If more than two leaves arise at a node and form a whorl, it is called whorled. The leaves of one whorl generally alternate with those of the adjacent whorls in order to provide maximum exposure, e.g., Nerium (kaner), Alstonia.

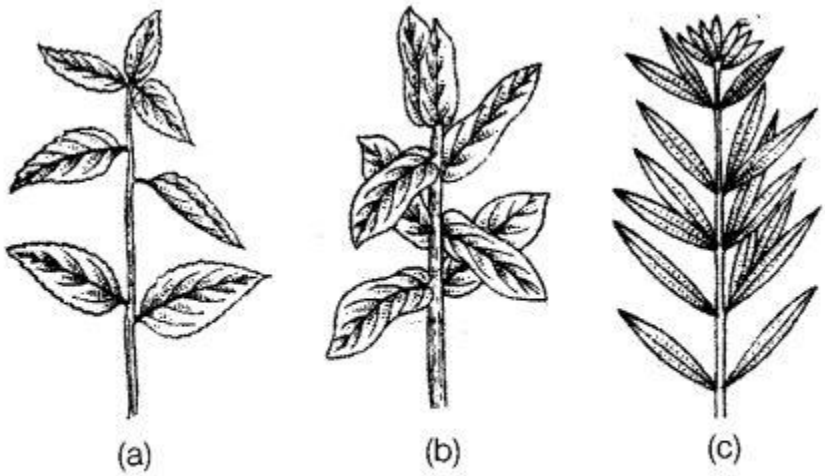


Fig. 5.12 Types of Phyllotaxy (a) Alternate (b) Opposite (c) Whorled

Modification of Leaves

Leaves of plants are modified to perform different additional functions in addition to their main function, i.e., photosynthesis.

i. Leaf Tendrils

These are thread-like sensitive structures, which can coil around a support to help the plant in climbing, e.g, Wild pea (Lathyrus aphaca), Pisum sativum (sweet pea) and Gloriosa superba (glory lily). ”

ii. Phyllode

It is a green, short lived and flattened petiole or rachis of a leaf, which performs the function of photosynthesis, e.g, Australian Acacia. Phyilodes develop usually vertically and possess fewer stomata hence, reduce transpiration.

iii. Bladder

The segments of the leaf modify into bladder-like structures, which trap small insects present in the water. e.g., Bladderwort (Utricularia).

iv. Pitcher

It is a petiole modified into a tendril to hold the pitcher upright. The leaf base is expanded to carry out photosynthesis. The leaf apex is modified into a lid, e.g, Nepenthes, Dischidia and Sarracenia.

v. Leaf Spines

The entire leaf or a part of a leaf may be modified into a pointed structure called a spine, as in Opuntia.

vi. Scale Leaves

These are thin, membranous leaves found at the nodal region. Each scale leaf contains an axillary bud in its axil, e.g, Zingiber officinale (ginger).

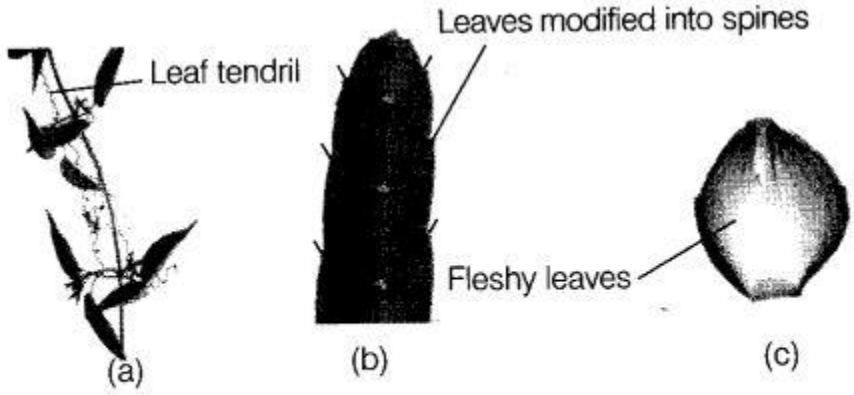


Fig. 5.13 Modification of leaf for (a) Support : tendril (b) Protection : spines (c) Storage : fleshy leaves

Functions of Leaves

The leaves have many primary and secondary functions.

Primary Functions

(a) The most important function of leaves is photosynthesis with the help of sunlight and carbon dioxide.

(b) Leaves contain stomata through, which gaseous exchange occurs,

(c) Leaves are the site of transpiration.
(d) They protect axillary and terminal bud from mechanical injury and desiccation.

Secondary Functions

(a) Leaves store food as in the leaf base, e.g., Onion.
(b) Leaves change into phyilodes to protect against transpiration.
(c) Storage of water in the cells of some succulent plants, e.g., Aloe.
(d) In Salvinia, one leaf of each node is changed into roots that act as balancer for floating.
(e) In some leaves like of Euphorbia, the young leaves are brightly coloured to attract insects for pollination.

The Inflorescence

The arrangement and distribution of flowers over a plant is called inflorescence.

The inflorescence can be of following three types

1. Racemose Inflorescence

In racemose type of inflorescence, the main axis continues to grow and the flowers are borne laterally in an acropetal succession (the older flowers are found towards the base and younger ones at the apex) or centripetal (older towards periphery and younger towards centre).

Fig. 5.14 Racemose inflorescence

2. Cymose Inflorescence

In cymose inflorescence, the tip of the main axis terminates in a flower and further growth continues by one or more lateral branches, which also behave like the main axis.
The arrangement of flowers in either basipetal (younger flowers occupy basal position, while older flowers towards the apex) or centrifugal (older towards center and younger towards periphery).

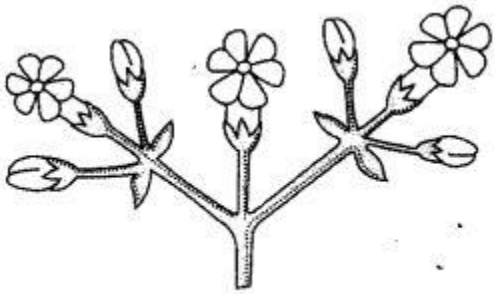


Fig. 5.15 Cymose inflorescence

3. Special Inflorescence

It mainly involves highly modified and densely crowded inflorescences.

The special type of inflorescence can be divided into following types

i. Cyathium

It is highly reduced and is a cup-shaped involucre of five bracts having nectariferous glands. A single large female flower is present in the centre of the cup and scorpioid male flowers surrounded this female flower. Every male flower is represented by a single stalked stamen borne in the axil of a scaly bract, e.g, Euphorbia.

ii. Verticillaster

These are two clusters each having 3-9 flowers that develop on a node in the axils of opposite leaves, e.g., Ocimum sanctum (basil).

iii. Hypanthodium

In this type, the main axis is condensed into a cup or flask-shaped, fleshy receptacle. It bears three kinds of flowers, i.e., male flowers (towards the pore), female flowers (towards the base) and neutral flowers occurs in between male and female flowers, e.g., Peepal (Ficus relegiosa) and banyan (Ficus benghalensis).

The Flower

The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. Morphologically, it is considered as a shoot bearing nodes and modified floral leaves. A flowers is called modified shoot because the position of the buds of both flower and shoot which is same and can be in terminal or axillary in position.

Structure of Flower

A flower arises in the axil of a leaf like structure called bract. Flowers with bracts are called bracteate and those without bracts are called ebracteate.

The terminal part of the axis of the flower is the receptacle or thalamus. The receptacle contains sepals, petals, stamens and carpels. If the leaves are present on the pedical, they are called bracteoles.

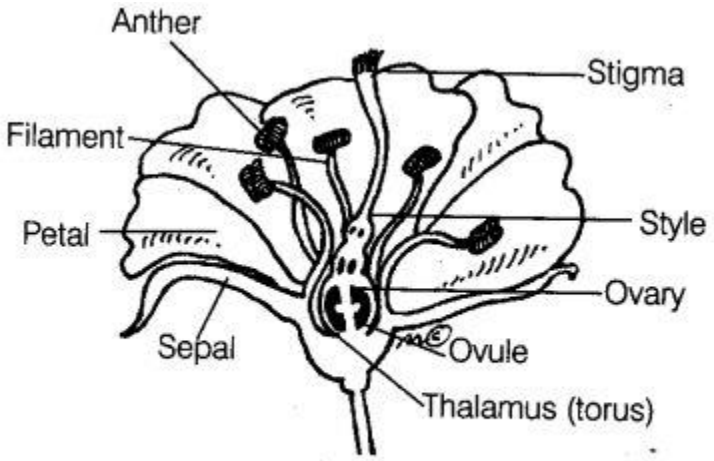


Fig. 5.16 Structure of a typical flower

Parts of a Flower

A typical flower consists of four distinct parts the calyx, the corolla, the androecium and the gynoecium. The calyx and corolla are accessory parts and the androecium and gynoecium are essential parts.

These essential parts consist of two kinds of (male) sporophylls, the microsporophyll (male) and the megasporophyll (female).

A flower can be unisexual or bisexual. It is borne on short or long axis. The axis contains two regions the pedicel and the thalamus or receptacle.

The pedicel may be short, long or even absent. The thalamus is the swollen end of the axis on which the floral whorls are arranged.

Different parts of flower are given below

i. Calyx

It is the outermost whorl of a flower. It is made up of units like sepals. The sepals are generally green, leaf like and protect the flower in the bud stage, i.e., when floral in bud condition. They have veins and stomata like ordinary leaves but are thicker in nature. The sepals may be gamosepalous (sepals united), e.g., Caesalpinia or polysepalous (sepals free), e.g., Crotalaria. The sepals also prevent transpiration from inner parts of the flower. Coloured sepals attract insects for pollination.

ii. Corolla

i. Corolla

It is composed of petals. Petals are usually brightly coloured to attract insects for pollination. Like calyx, corolla may also be gamopetalons (petals united) or polypetalous (petals free). The shape and colour of corolla may vary greatly in shape. Corolla may be tubular, bell-shaped, funnel-shaped.

Aestivation

The mode of arrangement of sepals or petals in floral bud with respect to the other members of the same whorl is known as aestivation. The aestivation pattern is important in classification of – plants.

It is of following types

(a) Valvate Petals come to each other but do not overlap, e.g., mustard (Brassica).
(b) Twisted Regular overlapping of petals occurs in which margin of one petal overlap with the next one petal, e.g., China rose (Hibiscus rosa sinensis).
(c) Imbricate There are five petals, arranged in such a way that one petal is completely external and another petal is completely internal, while three petals are partially external and partially internal, e.g., Cassia, Cullistemon,Caesalpinia.
(d) Vexillary When the largest petal overlaps the two lateral petals which in turn overlap the two smallest anterior petals (keel), the aestivation is called as vexillary or papilionaceous.

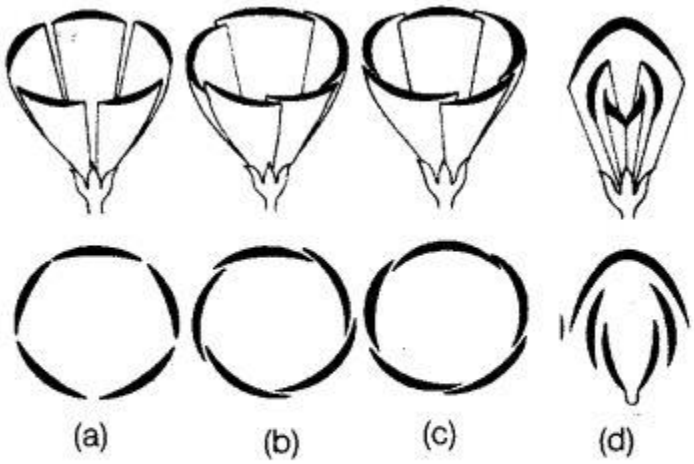


Fig. 5.17 Different types of aestivation of calyx and corolla (a) Valvate (b) Twisted (c) Imbricate (d) Vexillary

iii.Androecium

It is the third whorl of flower composed of stamens or microsporangium. Each stamen, which represents the male reprodutive organ consists of a stalk or a filament and an anther. Each anther is usually bilobed which are attached at the back by a sterile band called connective and each lobe has two chambers, the pollen sacs. The pollen grains are produced in pollen sacs. A sterile stamen is called staminode. Stamens can be of different types depending on their union with other members such as petals or among themselves.
(a) When stamens are attached to the petals, they are epipetalous, e.g., Brinjal.
(b) When stamens are attached to the perianth, the condition is called epiphyllous, e.g., Lily.
(c) The stamens in a flower may either remain free, i.e., polyandrous or may be united in varying degrees.
(d) The stamens may be united into one bunch or one bundle, i.e., monoadelphous as in China rose. It may be two bundles, i.e., diadelphous as in pea or into more than two bundles, i.e., polyadelphous as in citrus.
(e) There may be variation in the length of filament as in Salvia and mustard.

iv. Gynoecium

Gynoecium is the female reproductive part of the flower and is made up of one or more carpels or megasporangium. Megaspores are produced within the megasporangium.'A carpel consists

of three parts, i.e., stigma, style and ovary.
The stigma is usually at the tip of style and is the receptive surface for pollen grains.
Ovary is the enlarged basal part on which lies the elongated tube, the style.
The style connects the ovary to the stigma. Each ovary bears one or more ovules attached to a flattened, cushion like placenta.
Depending on the number of carpel present may be free or united, gynoecium can be of following types
(a) Apocarpous When more than one carpel is present, they may be free are called apocarpous, e.g., Lotus and rose.
(b) Syncarpous When carpels are fused together, the gynoecium is called syncarpous, e.g., Brinjal and Hibiscus.
The cavity enclosed by the ovary wall is called locule. The number of locules in the ovary correspond to the number of carpels in the gynoecium, i.e., unilocular (only one locule, e.g., Pea), bilocular (two locules, e.g., Tomato), trilocular (three locules, e.g., Ricinus), multilocular (many locules, e.g., Orange and lemon).
The arrangement of ovules within the ovary is known as placentation. The placenta is a tissue, which develops along the inner wall of the ovary. The ovule or ovules remain attached to the placenta.

The placentation can be of different types
(a) Marginal The placenta forms a ridge along the ventral suture of the ovary and the ovules are borne on this ridge forming two rows is called marginal placentation, e.g., Pea.
(b) Axile When the placenta is axial and the ovules are attached to it in a multilocular ovary, the placentation is called axile, e.g., China rose, tomato and lemon.
(c) Parietal When the ovules develop on the inner wall of the ovary or on peripheral part, it is called parietal placentation. Ovary is one chambered but it becomes two-chambered due to formation of the false septum, e.g., Mustard and Argemone.
(d) Free central When the ovules are borne on central axis and septa are absent, the placentation is called free central, e.g., Dianthus and primrose.
(e) Basal In this type, the placenta develops at the base of ovary and a single ovule is attached to it as in sunflower, marigold. The placenta develops directly on the thalamus.

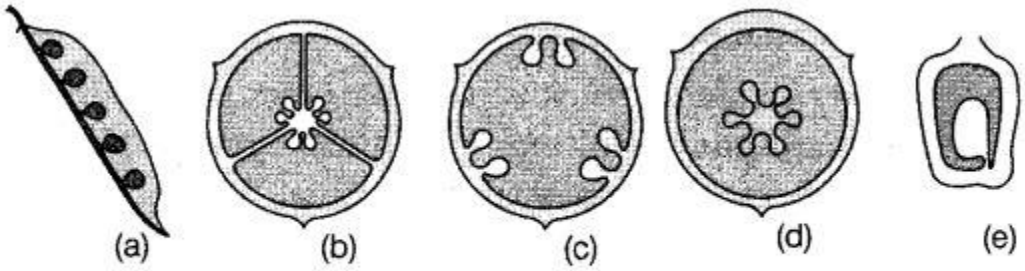


Fig. 5.18 Types of placentation (a) Marginal (b) Axile (c) Parietal (d) Free central (e) Basal

Insertion of Floral Parts (Forms of Thalamus)

The positions of different whorls of flowers are different. This is due to the position of ovary.

These positions may be of three types

i. Hypogynous Flower

The thalamus is conical, dome-shaped or flat. The ovary is present at the top of thalamus. The stamem, petals and sepals are separate and successively inserted below the ovary. Ovary is superior, whereas rest of the structures are inferior, e.g., Brassica, Hibiscus, Petunia.

ii. Perigynous Flower

The margin of thalamus grows upwards forming a cup like structure called calyx tube. The calyx tube encloses ovary, but remains free from it and the sepals, petals and stamens are present in it. The ovary is half inferior, e.g., rose, plum, peach, etc.

iii. Epigynous Flower

The thalamus grows upwards to completely develop the ovary and also fused inseparably with the latter. The other floral parts are borne at the top of the fused thalamus and ovary. The ovary is called inferior, e.g., Helianthus (sunflower), Cucurbita (pumpkin), Pyrus (apple).

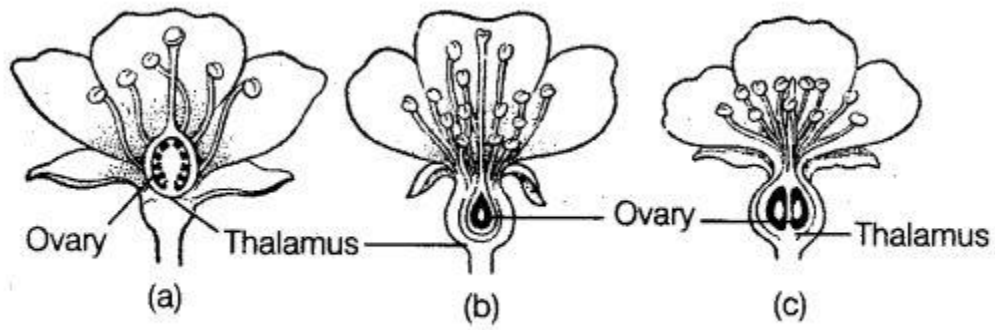


Fig. 5.19 Arrangement of floral leaves on thalamus

Number of Floral Parts

When the floral appendages are in the multiple of 3, 4 or 5, the flower is considered as trimerous, tetramerous or pentamerous respectively.

Dicotyledonous flowers are usually di, tetra or pentamerous, while, monocotyledonous flowers are trimerous.

Symmetry of A Flower

The symmetry of a flower depends upon the shape, size and arrangement of floral parts, e.g., Calyx, corolla, androecium and gynoecium. Flowers can be actomorphic and zygomorphic on the basis of symmetry.

Actinomorphic

In this type, a flower can be divided into exactly equal halves by any vertical section passing through the centre of a flower, e.g., Mustard, datura.

Zygomorphic

In this type, flower can be divided into two identical halves through only one particular vertical plane, e.g., Ocimum, Cassia.

The Fruit

The characteristic feature of flowering plants is fruit. Fruit is a mature or ripened ovary, developed after fertilisation.

During fertilisation, the important changes taking place in the ovary are

(ii) The ovules present in it develops into seeds.

(ii) The wall of the ovary thickens and ripens into pericarp (fruit wall).

Note:

* Fruits developed from the fertilised ovary is called true fruits. A true fruit has two parts pericarp and the seeds.

* Fruits developed from any part of the flower along with ovary is called false fruits. The thalamus grows along with the ovary to form a false fruit i.e. in Pyrus malus (apple).

* The fruit of mango and coconut are also known as drupe, as it develop from monocarpellary superior ovaries and have only one seed.

The ovary after these changes is known as the fruit. If a fruit is formed without fertilisation, it is called parthenocarpic fruit, e.g., Banana, grapes, pineapple, etc. The parthenocarpic fruits do not have seeds.

The fruit consists of wall or pericarp and seeds. The pericarp may be dry or fleshy. When pericarp is thick and fleshy, it is differentiated into outer epicarp, the middle mesocarp and the inner endocarp.

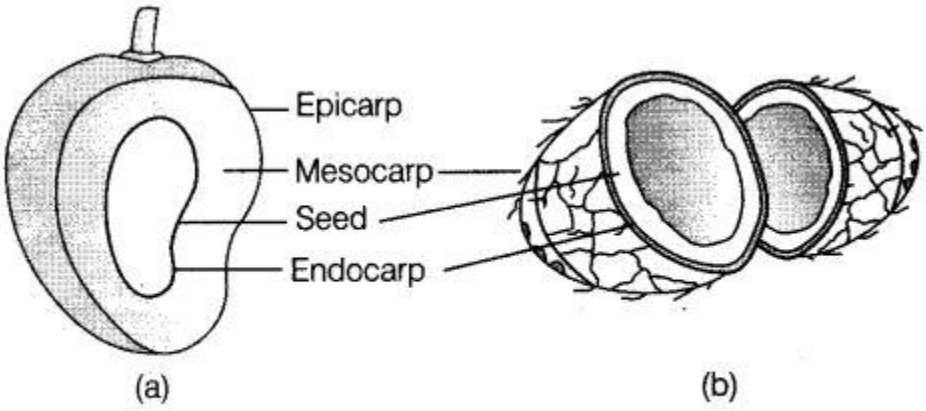


Fig. 5.20 Parts of a fruit (a) Mango (b) Coconut

Types of Fruits

Fruits can be broadly classified into following three types

i. Simple Fruits

A simple fruit develops from the single simple or compound ovary of a flower. These can be dry fruits (pericarp dry) or succulent fruits (pericarp fleshy).

ii. Aggregate (Etaerio) Fruits

An aggregate fruit is a group of fruitlets which develops from a flower having polycarpellary apocarpous (free) gynoecium. The aggregate fruit is also called etaerio.

iii. Multiple (Composite) Fruits

A composite (multiple) fruit develops from an entire inflorescence. The multiple fruit is composed of a number of closely associated fruits (which may or may not get fused) along with

its peduncle. Hence, these fruits are pseudocarps and are also called inflorescence fruits.
Pomology is the branch of horticulture that deals with the study of fruits and their cultivation.
Edible Parts of Some Common Fruits

Simple Fruits	Scientific Name	Type	Edible Parts
Wheat	*Triticum aestivum*	Caryopsis	Endosperm and embryo
Maize	*Zea mays*	Caryopsis	Endosperm and embryo
Rice	*Oryza sativa*	Caryopsis	Endosperm and embryo
Tomato	*Lycopersicum esculentum*	Berry	Pericarp and placenta
Litchi	*Litchi (Nephalium) chinensis*	Nut	Fleshy aril
Banana	*Musa paradisiaca*	Berry	Mesocarp and endocarp
Brinjal	*Solanum melongena*	Berry	Pericarp and placenta
Coconut	*Cocos nucifera*	Drupe	Endosperm, testa, cotyledon and embryo
Almond	*Prunus amygdalus*	Drupe	Seeds
Cucumber	*Cucumis melo*	Pepo	Mesocarp and endocarp
Aggregate Fruits			
Strawberry	*Fragaria vesco*	Etaerio of achenes	Fleshy thalamus and seeds
Lotus	*Nelumbo nucifera*	Etaerio of achenes	Fleshy thalamus and seeds
Multiple Fruits			
Jack fruit	*Artocarpus heterophyllus*	Sorosis	Fleshy axis, bracts, perianth and seeds
Fig	*Ficus carica*	Syconus	Peduncle and seeds
Mulberry	*Morus alba*	Sorosis	Fleshy axis and succulent perianth

Importance of Fruits

(i) Fruits are a source of vitamins, organic acids, minerals, pectin and sugars and some of them are used as vegetables, e.g., Okra (lady's finger), tomato, pumpkin, cucumber, gourd, etc.
(ii) Cereals are one seeded dry fruits, form the stable food of humans.
(iii) Fruits are important foods for fruit eating birds (frugivorous) and some animals.
(iv) Some fruits are also used as medicines, e.g., Emblica officinalis (amla), Datum stramonium (datura), Papaver somniferum (poppy), etc.
(v) They protect immature seeds against climatic conditions till their maturity.

(vi) The unripe fruits are bitter due to the presence of tannins, bitter alkaloids, astringents, sour acids, etc. This way they keep the animals away from eating them.

The Seed

Seed is a ripened ovule which contains an embryo or tiny plant with sufficient reserve food for the development of embyo.

The ovules after fertilisation develops into seeds. A seed is made up of seed coats and an embryo. The embryo is made up of a radicle, an embryonal axis and one (wheat and maize) or two cotyledons (gram and pea).

Types of Seeds

Seeds can be classified into two different types based on the number of cotyledons and presence or absence of endosperms, i.e., dicotyledonous and monocotyledonous seed.

i.Dicotyledonous Seed

Gram seed is a dicot seed formed in a small pod or legume. The outermost covering is the seed coat. An endosperm is absent.

Seed can be studied under two heads, i.e., external structure and internal structure.

It is light or dark brown in colour. Its surface may be smooth or wrinkled. A small oval scar present at the side called hilum. It is the point where the stalk or funicle of the seed is attached to it. A narrow ridge called raphae runs from hilum to chalaza inside the furrow. A small pore called micropyle present between the hilum and pointed end.

The outermost covering of the seed is seed coat. The outer hard and leathery layer of the coat is called testa and the inner thin and membranous layer is the tegmen. In some seeds, the tegmen and testa are fused.

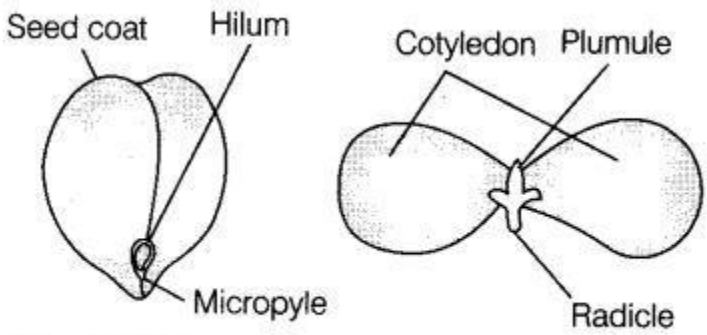


Fig. 5.21 Structure of dicotyledonons seed

The seed coat encloses the embryo, which is differentiated into a radicle, a plumule and cotyledons. The radicle develops into root and plumule into shoot. Cotyledons may be one or two to serve as reserve food.

Hypocotyl is a part present between the point of attachment of cotyledon and radicle. Epicotyle is present between point of attachment of cotyledons and plumule.

In some seeds, such as castor seeds, the endosperm is formed as a result of double fertilisation, which is a food storing tissue. In plants like bean, gram and pea, the endosperm is not present in mature seeds (i.e., non-endospermous seeds).

ii- Monocotyledonous Seed

The monocotyledonous seeds are endospermic but some as in orchids are non-endospermic. In the cereals, such as maize, the seed coat is membranous and generally fused with the fruit wall.
Structure of Monocotyledonous Seed
The endosperm is bulky and stores food. The outer covering of endosperm separates the embryo by a proteinous layer called aleurone layer. The embryo is small and situated in a groove at one end of the endosperm. It consists of one large shield-shaped cotyledon known as scutellum and a short axis with a plumule and a radicle. The plumule and radicle are enclosed in sheaths which are called coleoptile and coleorhiza respectively.

Coleoptile has a terminal pore for the emergence of first leaf during germination. The sheath is capable of growth. It helps the future shoot in passing through the soil during germination, e.g., Maize grain is whitish, yellow, violet or red in colour. It has smooth or shiny surface.
Its grain is covered with a single, thin hard covering. It is formed by the fusion of seed coat or testa and the fruit wall gr pericarp.

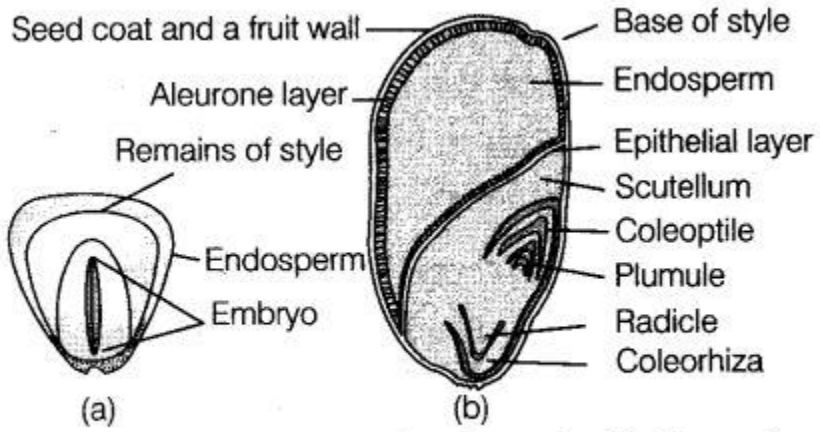


Fig. 5.22 Structure of maize grain (a) External structure

Semi-Technical Description of a Typical Flowering Plant
The description of a flowering plant should be brief, sequential and in scientific language. This is required to designate a plant in its appropriate taxonomic position.
The Plant can be Described Briefly in the following Way

Habit	Herb, shrub, trees, climber, creeper, etc.
Habitat	Mesophyte, xerophyte or hydrophyte, etc.
Vegetative Character	
Roots	Tap or adventitious root system.
Stem	Herbaceous or woody, smooth, hairy, spiny, prickly, cylindrical, angular or flattened, etc.
Leaves	Deciduous or persistent, phyllotaxy may be alternate, opposite or whorled, petiolate or sessile, reticulate or parallel, blade may be simple or compound.
Floral Characters	
Inflorescence	Cymose or racemose and their subtypes.
Flower Parts	Sessile or pedicellate, bracteate or ebracteate, unisexual or bisexual, zygomorphic or actinomorphic, hypogynous, perigynous or epigynous, complete or incomplete, isomerous or heteromerous, etc.
Calyx	Polysepalous or gamosepalous, deciduous or persistent.
Corolla	Polypetalous (free) or gamopetalous (united), aestivation and special appendages.
Androecium	Polyandrous or united. If united, adelphous, syngenesious or synandrous.
Gynoecium	Free or united carpels, ovary superior or inferior, etc.
Fruits	Simple, aggregate or multiple, true or false fruits.
Seeds	Monocot or dicot, endospermic or non-endospermic, etc.

Floral Formula

The symbolic representation of floral characters of a flower is called floral formula. For example, the floral formula ofBrassica (mustard) represented as given by

$$\text{Ebr} \oplus \male\female \text{K}_{2+2}\text{C}_{4}\ \text{A}_{2+4}\ \text{G}_{(2)}$$

Description of this formula is Ebracteate, actinomorphic, bisexual, bimerous, calyx-4, polysepalous, in two whorls of two each corolla-4, polypetalous, cruciform, androecium-6, polyandrous, tetradynamous in two whorls, one with two, gynoecium—bicarpellary syncarpous,

superior.

Symbols used in Floral Formula

Br – Bracteate	G – Gynoecium and carpels
Brl – Bracteolate	$\overline{G}$ – Inferior ovary
	$\underline{G}$ – Superior ovary
⊕ – Actinomorphic	Ebr – Ebracteate
⚥ – Hermaphrodite or bisexual	Ebrl – Ebractealate
♀ – Female or pistillate	% – Zygomorphic
♂ – Male or staminate	
Epi – Epicalyx	
C – Corolla and petals	N – Nectar
K – Calyx sepals	
P – Perianth and tepals	
A – Androecium and stamens	Std – Staminodes

Symbols for Number of Floral Parts

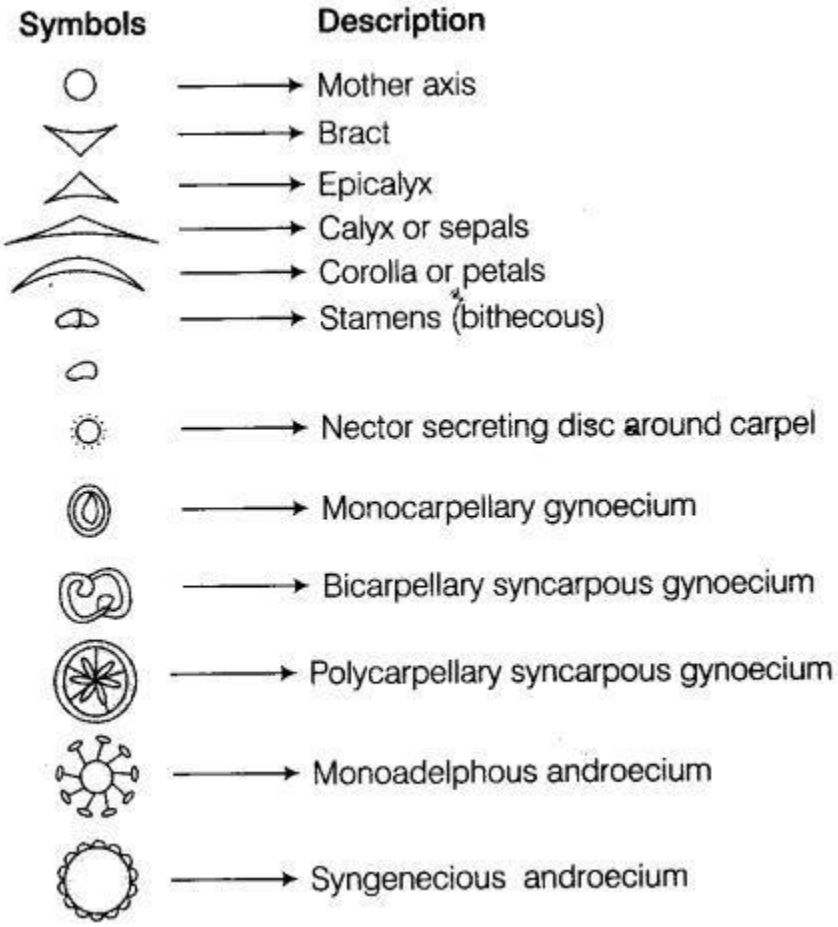
The number of floral parts are written at right foot of the symbol. If they are fused they are bracketed.

Some examples are given below

Sepals 6 free	K_6
Sepals 6 fused	$K_{(6)}$
Petals 5 free	C_5
Petals 5 fused	$C_{(5)}$
Stamens 10 free	A_{10}
Stamens 10 in two whorls of 5 each	A_{5+5}
Stamens indefinite	A_∞
Stamens 10, diadelphous (9 fused and 1 free)	$A_{(9)+1}$
Carpels two free	G_2
Bicarpellary syncarpous	$G_{(2)}$
Epipetalous	$\widehat{CA}$

Floral Diagram

A floral diagram provides information about the number of parts of a flower, their arrangement and the relation, they have with one another.



In the floral diagram, the position of the mother axis with respect to the flower is represented by a dot on the top of the floral diagram.. Calyx, corolla, androecium and gynoecium are drawn in successive whorls, calyx being the outermost and the gynoecium in the centre.

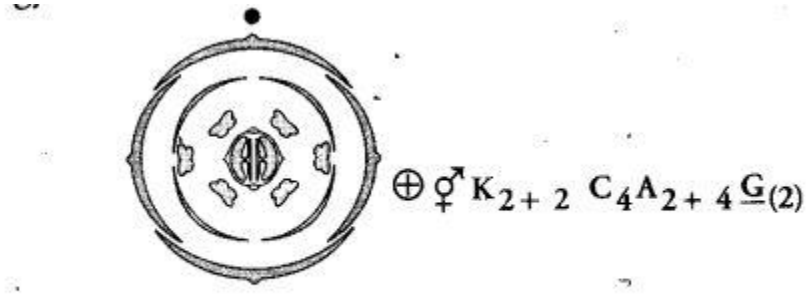


Fig. 5.23 Floral diagram with floral formula

Description of Some important Families

I. Family-Fabaceae

This family was earlier called Papilionoideae, a sub-family of family—Leguminosae. It is distributed all over the world.

1. system position

Division	–	Embryophyta
Sub-division	–	Angiospermae
Class	–	Dicotyledonae
Sub-class	–	Polypetalae
Series	–	Calyciflorae
Order	–	Rosales
Family	–	Fabaceae

2. Distribution The family includes 600 genera and 13000 species. It is distributed all over the world except the Arctic regions.

3. Habit The plants are mosdy herbs, however shrubs, trees and climbers are also common.

4 Vegetative Characters

(i) Root Tap root with lateral branches. The lateral branches mostly contain bacterial nodules (with Rhizobium bacteria which fix atmospheric nitrogen).

(ii) Stem Herbaceous or woody, branched, erect or climbing.

(iii) Leaf Alternate, pinnately compound or simple, leaf base, pulvinate, stipulate, venation-reticulate.

5. Floral Characters

(i) Inflorescence Simple raceme, axillary cyme or solitary.

(ii) Flower Bracteate, pedicellate, subsessile, bisexual, mostly, irregular, zygomorphic, sometimes regular, pentamerous, hypogynous or slightly perigynous.

(a) Calyx Sepals 5, gamosepalous, imbricate aestivation.

(b) Corolla Petal 5, polypetalous, papilionac¬eous, consisting of a posterior standard, two later wings, two anterior ones forming a well (enclosing stamens and pistil), vexillary aestivation.

(c) Androecium Stamens 10, usually diadelphous [(9) +1] or monadelphous, sometimes free, polyandrous, another dithecous, basifixed (attached by its base).

(d) Gynoecium Monocarpallary, ovary superior, unilocular with marginal placentation, style bent, stigma simple and hairy.

(e) Fruit Legume (pod).

(f) Seed One to many non-endospermic.

(iii) Floral Formula

$$\mathrm{Br}\,\%\,\male\,\female\,K_{(5)}\;C_{1+2+(2)}\;A_{(9)+1}\underline{G}_{1}$$

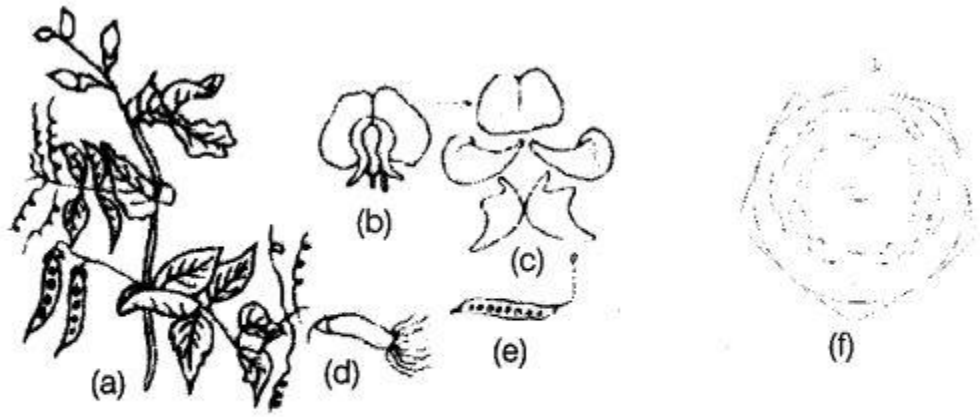


Fig. 5.24 *Pisum sativum* (pea) plant (a) Flowering twig (b) Flower (c) Petals (d) Reproductive parts (e) LS of carpel (f) Floral diagram

Economic Importance with Examples

Plants belonging to this family hqs their importance in the following fields

(i) Pulses and Vegetables The family is an important source of pulses and vegetables. The ^pulses are rich in proteins like gram (chana), pea (matar), field bean (bankla), cluster bean (gwar), lima bean (lobia), lentil (masoor), bean (sem), soya(soyabean), etc.

(ii) Oil Edible oils are obtained from the seeds of Arachis hypogaea (groundnut) and Glycine max (soyabean). Vegetable ghee is prepared by using the oils after hydrogenation.

(iii) Timber Dalbergia sissoo (Indian redwood),Dalbergia latifolia (Indian rose wood), are important timber yielding trees of the family.

(iv) Dye Indigofera tinctoria (indigo), Butea monosperma (flame of the forest) is used to produced red dye used as an astringent.

(v) Fodder Plants like Trifolium alexandrium (barseem), Medicago sativa, Cyamopsis tetragonoloba, etc., yield fodder for the cattle.

(vi) Fibres Crotalaria juncea (sunhemp) is used to produce fibres.

(vii) Ornamentals Some common ornamental plants are Lathyrus odoratus (sweet pea), Clitoria (butterfly pea), Lupinus, etc., are common ornamental plants.

(viii) Jewellar s Weights The seeds of Abrus precatorius (ratti) are used weight by jewellars.

(ix) Medicinal Plants The flowers of Trifolium pratense are used in whooping cough. The gum of Butea monosperma (dhak) is useful for treating dysentery and diarrhoea. There are several other examples in this family that are used as medicines.

iI. Family-Solanaceae

It is a large family, commonly called as the ‘potato family, it is widely distributed in tropics, sub-tropics and even temperate zones.

1. Systematic Position

Division	–	Spermatophyta
Sub-division	–	Angiospermae
Class	–	Monocotyledonae
Order	–	Liliflorae
Series	–	Coronarieae
Family	–	Liliaceae

2. Distribution
The family is represented by 90 genera and 2800 species distributed in both tropical and temperate regions.
3. Habit
Annual or perennial herbs, shrubs or rarely soft wooded trees.
4. Vegetative Characters
(i) Root Usually tap roots.
(ii) Stem Herbaceous or woody, hair or prickles often present, sometimes underground tubers (Solanum tuberosum).

iii) Leaf In vegetative parts alternate and floral regions opposite, exstipulate, simple, rarely pinnately compound as in potato and tomato.
5. Floral Characters
(i) Inflorescence Solitary, axillary or cymose as in Solarium.
(ii) Flower Bisexual, actinomorphic, ebracteate, pedicellate, pentamerous and hypogynous.
(a) Calyx Sepals 5, united, valvate aestivation, usually persistent as in brinjal, tomato, chilly, etc.
(b) Corolla Petals 5, united, valvate aestivation, rotate or tubular, rarely funnel-shaped.
(c) Androecium Stamens 5, epipetalous, alternating with, petals, inserted in corolla tube, filaments usually of unequal length, anthers bithecous.
(d) Gynoecium Bicarpellary, syncarpous, ovary superior, bilocular, placenta swollen with many ovules.
(e) Fruits Berry or capsule.
(f) Seeds Endospermic, embryo straight.

(iii) $\oplus$ $K_{(5)}$ $\overbrace{C_{(5)}\ A_{(5)}}$ $\underline{G}(2)$

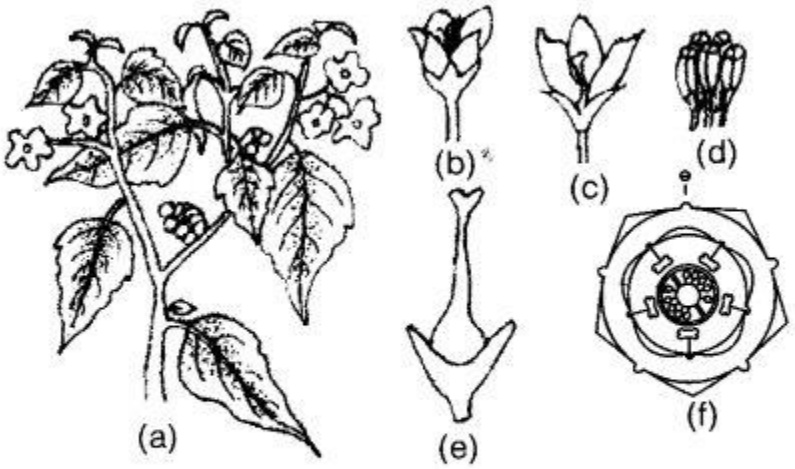


Fig. 5.25 *Solanum nigrum* (makoi) plant
(a) Flowering twig (b) Flower
(c) LS of flower (d) stamens (e) carpel
(f) Floral diagram

Economic: Importance with Examples

Plants belonging to the family-Solanaceae has their importance in the following fields

(i) Food The family-Solanaceae includes a number of vegetables and spice yielding plants. For example., Solanum tuberosum (potato), Solanum melongena (brinjal), Lycopersicon esculentum (tomato), Physalis peruviana (ground cherry), Capscicum annuum (chillies), etc.

(ii) Tobacco Nicotiana tabacum and N. rustica . contain toxic alkaloid nicotine. It is used for chewing, smoking and snuff.

(iii) Medicines Atropa bellodona is used to obtain Bellodona and atropine. Bellodona is used for relieving pain and treating cough. Atropine is used for dilating eye pupil. Datura stramonium is used in asthma. Other medicinal plants are Solanum xanthocarpum, Withania somnifera, Hyoscymus niger, etc.

Ornamentals The common ornamental plants are Cestrum nocturnum (Rat-ki-Rani), Petunia hybrida, Physalis peruviana (cape gooseberry), etc.

II. Family—Liliaceae

1. Systematic Position

Division	–	Spermatophyta
Sub-division	–	Angiospermae
Class	–	Monocotyledonae
Order	–	Liliflorae
Series	–	Coronarieae
Family	–	Liliaceae

2. Distribution

The family—Liliaceae (lily family) includes about 250 genera and 3700 species showing world wide distribution. About 200 species are available in India.

3. Habit

Usually perennial herbs, perenating by underground rhizomes, corms or bulbs, rarely shrubs or climbers (e.g., Smilax, Gloriosa, etc).

4. Vegetative Characters

(i) Root Generally adventitious, fibrous or fleshy (e.g., Asparagus).

(ii) Stem Herbaceous or woody. In some species underground bulbs or rhizomes.

(iii) Leaves Mostly basal, alternate, linear, exstipulate with parallel venation.

5. Floral Characters

(i) Inflorescence Mostly racemose, sometimes cymose, rarely solitary.

(ii) Flower Bracteate, pedicellate, actinomorphic, incomplete, bisexual, trimerous and hypogynous.

(a) Perianth Tepal six (3 + 3), often united into tube, valvate aestivation.

(b)polyandrous, opposite to tepals, sometimes epiphyllous.

(c) Gynoecium Tricarpellary, syncarpous, trilocular with many ovules, axile placentation, rarely unilocular with parietal placentation, ovary superior, style simple with three lobed stigma.

(d) Fruit A loculated capsule, rarely a berry.

(e) Seed Endospermic, embryo curved or straight.

f) Floral Formula by

(iii) Floral Formula $Br \oplus \male \overset{\frown}{P_{(3+3)}} A_{(3+3)} \underline{G}_{(3)}$

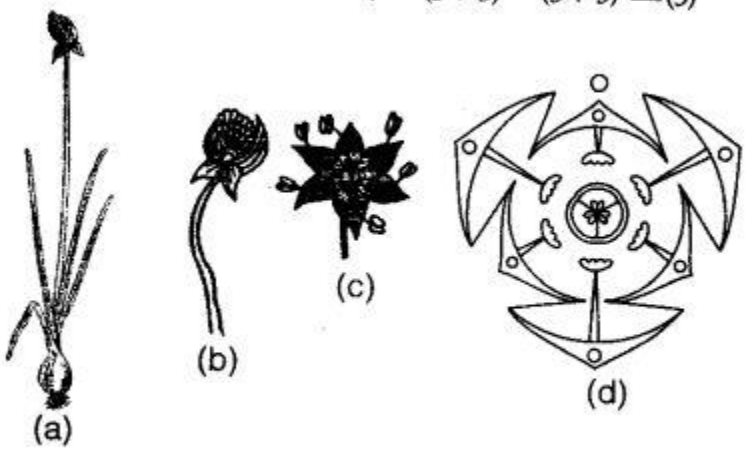


Fig. 5.26 *Allium cepa* (onion) plant (a) plant (b) Inflorescence (c) Flower (d) Floral diagram

Economic Importance with Examples

Plants belonging to this family has their importance in the following fields

(i) Food Allium cepa (onion), Allium sativum (garlic) young shoots and fleshy roots of Asparagus (shatavar) are used as vegetables.

(ii) Medicines Aloe leaves are used to cure piles, liver problems. Roots of Smilax are used as blood purifier. Raw onion is useful in constipation, diarrhoea and cholera. Dried corms of Colchicum autumnale (meadow saffron) are used against rheumatism and gout.

(iii) Ornamentals The common ornamentals are Ruscus, Yucca, Aloe, Asparagus, Gloriosa, Smilax, tulips, lilies, etc.
(iv) Fibres The fibre yielding plants of IHy family are Yucca filamentosa, Sansevieria roxburghiana, etc.

L 7 Structural Organisation in Animals

Topic 1: Animal Tissues

Tissue

All cells are well organised and coordinated to work in a group. A group of similar cells along with intercellular substances perform a specific function, such an organisation is called tissue. The term 'Tissue' was introduced by Bichat and he is known as the father of animal histology.

A tissue can also be defined as a group of one or more types of cells having a same origin and specialised for specific functions along with the intercellular materials.

The intercellular materials or fluid forms the environment of the cell. The cell receives almost all the materials it require from the intercellular fluid and transfer its waste materials again in this fluid.

Note:

* The microscopic study of the tissues and organs in relation to their function is called Histology.

* The term Histology was coined by Mayer, in 1819. The tissues arise from the undifferentiated cells of the primary germ layers (ectoderm, mesoderm and endoderm) in an embryo.Types of Animal Tissues

* The structure of the cells vary according to their function.

This variation in cells leads to the formation of following four types oftissues on the basis of their location andfunction

(i) Epithelial (ii) Connective

(iii) Muscular (iv) Neural

I.Epithelial Tissue

Epithelial tissue or epithelium (Epi – upon; thele – nipple) covers both external and internal surfaces of the animal body.

The epithelial tissue has a free surface, which faces either a body fluid or the outside environment and thus, provides a covering or a lining for some part of the body.

Characteristics

The characteristic features of epithelial tissue are as follows

(i) The cells are compactly arranged.

(ii) Intercellular spaces are narrow, 20-30 nm wide.

(iii) Adjacent cells are held together by intercellular junctions.

(iv) The epithelial tissue lies on a thin, non-cellular basement membrane.

(v) Blood vessels are not present in the epithelial tissue.

(vi) Materials are exchanged by diffusion between epithelial cells and the blood vessels of the connective tissues across the basement membrane.

(vii) Nerve endings may penetrate the epithelial tissues.

Junctions Between Epithelial Cells

The common intercellular junctions may include tight junctions, gap junctions, desmosomes, intercellular bridges and interdigitations.

Tight Junctions

The plasma membrane in the apical region of the adjacent epithelial cells become tightly packed together. These junctions check the flow of materials between the cells

and are called occluding junctions.

Adhering Junctions

Facilitate the cementing process so as to keep the * neighbouring cells together. They include desmosomes and hemidesmosomes.

Desmosomes

These are thick and strong junctions. They serve, anchoring functions.

Gap Junctions

They are fine hydrophilic channels between adjacent cells formed with the help of protein cylinders called connexin. They help in chemical exchange between adjacent cells and hence are called communicating junctions.

Types of Epithelial Tissues

The epithelial tissues are broadly classified into two groups, i.e., simple and compound.

Simple Epithelia

Simple epithelium is made up of a single layer of compactly arranged cells which rest over a non-cellular basement membrane. It occurs over moist surfaces where a little wear and tear occurs by friction. The simple epithelium is generally related with absorption, secretion, diffusion and movement of materials.

It is further sub-divided into following types

i. Simple Squamous Epithelium

The squamous (squama-scale) is formed of a single layer of closely fitted, flattened, polygonal cells, which forms bulges on the cell surface. ,

The given cells are held together by various types of junctions, mainly tight junctions. The cells of squamous epithelium appear as tiles over a floor. They are also known as pavement epithelium.

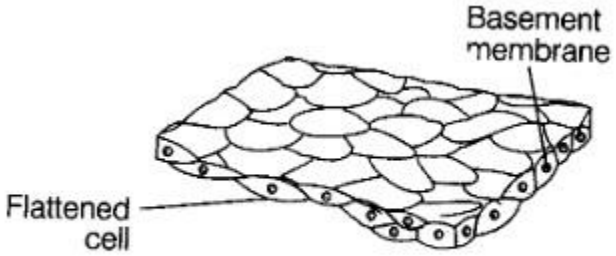


Fig. 7.1 Simple squamous epithelium

The squamous epithelium occurs in the alveoli of the lungs, Bowman's capsule, Henle's loop of uriniferous tubules, pericardial cavity, abdominal cavity, lining of various components of blood vascular system.

Functions Simple squamous epithelium performs the function of protection, excretion, gas exchange and secretion of coelomic fluid.

ii. Simple Cuboidal Epithelium

It is composed of a single layer of cube-like cells. The epithelium overlies on the basement membrane. Nucleus is rounded and placed centrally. The free surfaces of the cells may be smooth or bear microvilli. The microvilli increases the surface area of free ends of cells by many times.

The simple cuboidal epithelium is commonly found in the ducts of glands, tubular parts of nephrons in kidneys, ovaries seminiferous tubules of testes, etc.

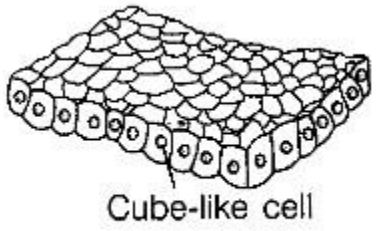


Fig. 7.2 Simple cuboidal epithelium

Functions The main function of this epithelium is protection, secretion, absorption, excretion and gamete formation.

iii. Simple Columnar Epithelium

It is composed of a single layer of tall and slender cells. A single oval or elongated nucleus is situated near the base of the cell. Some of its cells produce mucus, called goblet cells.

The simple columnar epithelium occurs in the lining of stomach, small and large intestine, digestive glands of stomach, intestine and pancreas, gall bladder, etc.

The brush border columnar epithelium occurs in the gall bladder. The mucus secreting goblet cells are found in the lining layer of stomach, intestine, respiratory tract, etc.

Functions The simple columnar epithelium helps in secretion, absorption and protection to the components of most glandular epithelia.

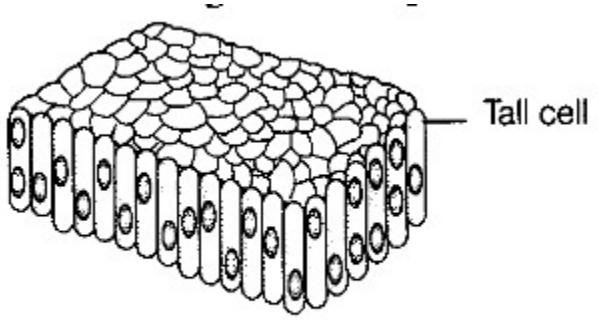


Fig. 7.3 Simple Columnar epithelium

v. Simple Ciliated Epithelium

If the columnar or cuboidal cells bear cilia on their free surface they are called ciliated epithelium. They move particles or mucus in a specific direction over the epithelium. The epithelium lies over a basement membrane. The number of cilia varies in different cellular forms.

In sensory cells of internal ear, a cilium accompanies number of stereocilia.

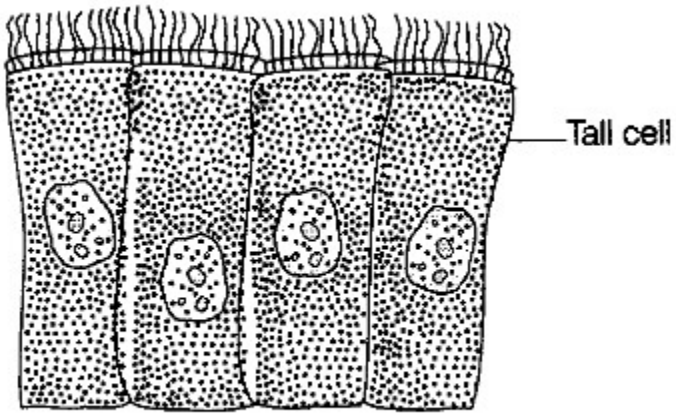


Fig.7.4 Simple columnar cells bearing cilia epithelium

This epithelium is of two types, i.e., ciliated columnar and ciliated cuboidal.
(a) Simple Ciliated Columnar Epithelium It possess columnar cells that possess cilia over their free surface. It occurs in respiratory tract, fallopian tubes, parts of uterus and cervix, the different tubules of testes, etc.
(b) Simple Ciliated Cuboidal Epithelium It has cuboidal or cubical cells that bear cilia on their free surface. It occurs in many parts of ependyma of nervous system and parts of uriniferous tubules.
Functions The epithelium maintains a flow of mucus, liquid or suspended particles constantly in one direction. In the oviducts, cilia helps in the movement of egg towards the uterus. In respiratory tract, cilia helps to push the mucus towards the pharynx. In nephrons of kidney, cilia keep the urine moving.
In nervous system, cilia of the ventricles of the brain and central canal of the spinal cord helps in the circulation of cerebrospinal fluid.

Pseudostratified Epithelium

The epithelium is one-cell thick, but appears 2-layered because all the cells do not reach the free surface. The cells are attached to the basement membrance, hence they are called pseudostratified. The mucus secreting goblet cells also occur in this epithelium.

This epithelium is of two types

(a) Pseudostratified Columnar Epithelium It has columnar cells without cilia. It lines the large ducts of certain glands, like parotid salivary glands and the urethra of human male.
(b) Pseudostratified Ciliated Columnar Epithelium It has columnar cells. The tall cells bear cilia at the free surfaces and the short cells are without cilia. The epithelium lines the trachea and large bronchi. The movements of its cilia push the mucus laden with dust particles and bacteria towards the larynx.Functions The pseudostratified epithelium helps in protection, movement of secretions from glands, urine and semen in urethra and mucus loaded with dust particles and bacteria in trachea.

Compound Epithelia

The compound epithelium is made up of more than one layer of cells. They cover the surfaces where constant replacement of cells is required due to rapid wear and tear by friction.

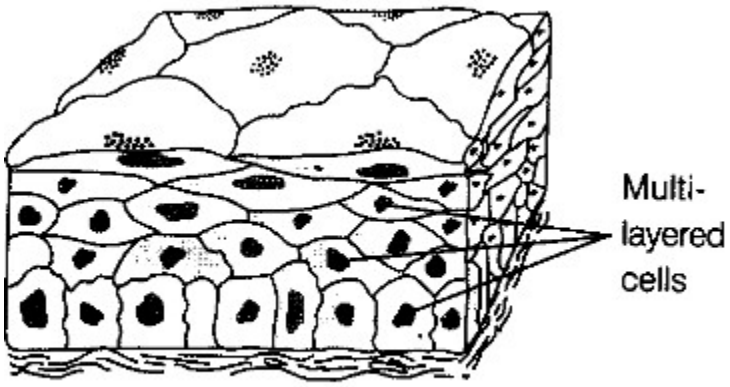


Fig.7.5 Compound epithelium

The compound epithelia are of two types, i.e., stratified and transitional.

(a)Stratified Compound Epithelia

The stratified epithelia consist of many layer of cells. On the basis of the shape of the cells present in the superficial layers, the stratified epithelia are of four types (a) Stratified Squamous Epithelium The cells in the basal (deepest) layer are columnar or cuboidal with oval nuclei. It is called germinative layer. The cells in this region divide by mitosis to form new cells.

The stratified squamous epithelium is further sub-divided as two main types, i.e., keratinised and non-keratinised.

* Keratinised Stratified Squamous Epithelium The cells of the outer few layers replace their cytoplasm with a hard waterproof protein called keratin or horn. This is called keratinisation or cornification. These layers of flat, dead cells are called stratum corneum or homy layer.

The heavy deposits of keratin in the dead superficial cells makes the epithelium impervious to water and highly resistant to mechanical abrasions. This epithelium forms the epidermis of the skin in land vertebrates.

* Non-keratinised Stratified Squamous Epithelium This epithelium does not have keratin and is unable to check water loss. It provides moderate protection against abrasion. It lines the buccal cavity, pharynx, oesophagus,

canal, lower part of urethra, vocal cord, vagina, cervix (lower part of uterus), conjuctiva, cornea of eye and inner surface of eyelids.

b) Stratified Cuboidal Epithelium It has outer layer of cuboidal cells and basal layer of columnar cells. It forms the epidermis of fishes and many urodeles (tailed amphibians like salamanders). It also lines the sweat gland ducts and larger salivary and pancreatic ducts.

(c) Stratified Columnar Ciliated Epithelium Its outer layer consists of ciliated columnar cells and basal layer of columnar cells. It lines the larynx and upper part of the soft palate.

(d) Stratified Columnar Epithelium It consists of columnar cells in both superficial and basal layers. It covers the epiglottis and lines mammary gland ducts and parts of urethra.

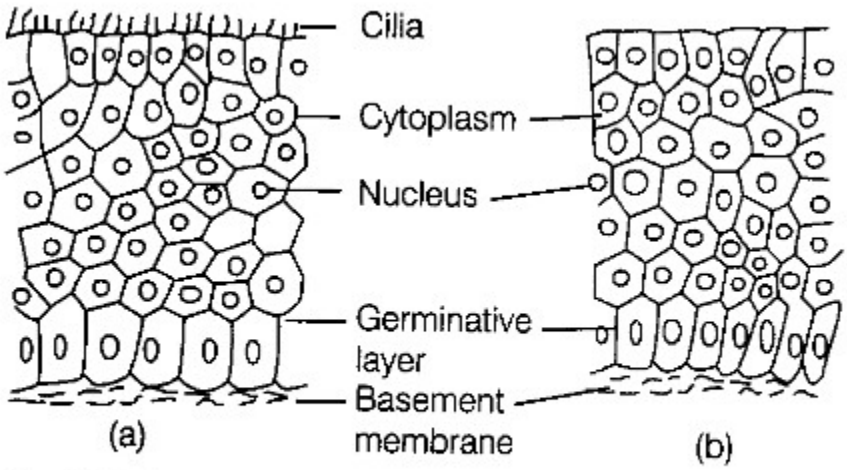


Fig.7.6 (a) Stratified ciliated columnar epithelium
(b) Stratified columnar epithelium

ii- Transitional Compound Epithelium

The epithelium consists of more than one layer of cells, but is much thinner and more stretchable than the stratified epithelium. It contains cuboidal cells at the base, two or three layers of large polygonal or pear-shaped cells in the middle and a superficial layer of large, broad, rectangular or oval cells.

The transitional epithelium lines the inner surface of urinary bladder, ureter and renal pelvis. They have thick membrane with thin regions that fold when the bladder contracts.

3. Glandular Epithelium

Some of the columnar or cuboidal cells get specialised for secretion and forms the glandular epithelium.

It is of two types

Unicellular Glandular Epithelium

It consists of isolated glandular epithelial cells called intraepithelial cells, e.g., Goblet cells of the alimentary canal are one such cell.u. Multicellular Glandular Epithelium

It consists of cluster of epithelial cells called extra epithelial cells. These cells unite to make up one gland, e.g., Salivary gland.

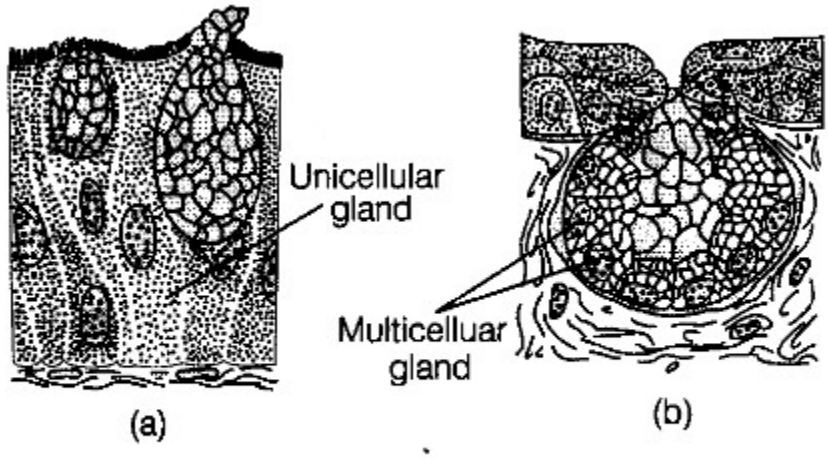


Fig 7.7 Glandular epithelium (a) Unicellular (b) Multicellular

Gland

A cell, tissue or organ, which secretes some substance is called a gland. The secretions of glands may be protein (pancreas), lipids (adrenals), mixture of carbohydrates and proteins (salivary gland) or mixture of all the three materials (mammary glands).

The glands can be classified in different types based on site of secretion, mode ofsecretiori and involvement of single or many cells.

Based on Site of Secretion

The glands can be exocrine, endocrine or heterocrine based on the site where the secretion is released.

(a) Exocrine Glands These glands have ducts to pour their secretions to their site of action. They often secrete enzymes and its examples include salivary glands, intestinal glands, gastric glands, lacrimal or tear glands.

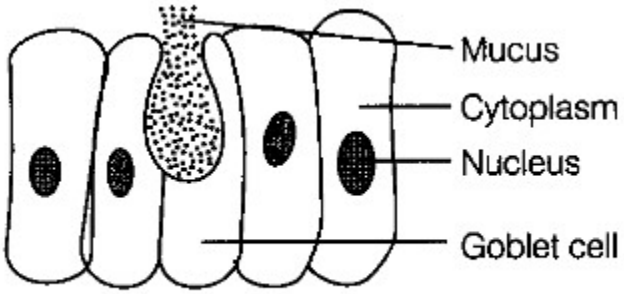


Fig. 7.8 Unicellular glands

(b) Endocrine Glands These glands do not have ducts and pour their secretions directly into the blood or lymph. These glands are also called ductless glands and their secretions are known as hormones. Some examples of endocrine glands are pituitary, thyroid, parathyroid, adrenal, etc.

(c) Heterocrine Glands/Myxocrine Glands These glands are partly exocrine and partly, endocrine in function, e.g., Pancreas,
kidneys, stomach, gonads, intestine, placenta, etc.

Based on Number of Cells

According to the number of cells forming the glands, they are unicellular and multicellular.

(a) Unicellular Glands The mucus secreting goblet cells of the alimentary canal are called unicellular glands.

(b) Multicellular Glands These are composed of many cells and are formed by sinking of the gland into the underlying connective tissue. The multicellular glands may be simple or compound glands

* Simple Glands These may be simple tubular glands, e.g., Crypts of Lieberkuhn, simple coiled tubular glands (sweat glands) and simple alveolar glands having flask-shaped secretory units (mucus secreting glands in the skin of frog.)

* Compound Glands These have branch system of ducts. These may be compound tubular glands {e.g., Gastric glands of stomach, Brunner's glands of intestine), compound alveolar glands {e.g., Some sebaceous glands and salivary glands) and compound tubuloalveolar glands having both tubular and alveolar secretory units {e.g., Pancreas, functional mammary glands).

Functions of Epithelial Tissue

The main functions of epithelial tissue are listed below

(i) The epithelial tissue protects the underlying tissues from mechanical injury, entry of germs, harmful chemicals and drying up.

(ii) It checks the absorption of harmful or unnecessary materials.

(iii) The epithelium of uriniferous tubules is specialised for urine excretion.

(iv) The sensory epithelia of sense organs help to receive various stimuli from the atmosphere and convey them to the brain.

v) The epithelium of alveoli of the lungs brings about the exchange of gases between the blood and air.

(vi) The pigmented epithelium of the retina darkens the cavity of eyeball.

(vii) Epithelium also forms glands that secrete secretions such as mucus, gastric juice and intestinal juice.

(viii) The germinal epithelium of the ovaries and seminiferous tubules of the testes produce ova and sperms, respectively.(ix) Epithelium produces exoskeletal structures like scales, feathers, hair, nails, claws, horns and hoofs.

(x) Ciliated epithelia (e.g., of respiratory and genital tracts) serves to conduct the mucus and other fluids in the ducts they line.

Note:

* The term 'Epithelium' was coined by Ruysch.

* Transitional epithelium

ii. Connective Tissue

The connective tissues are most abundant and widely distributed in the body of complex animals. They are named as connective tissues because of their special function of linking and supporting other tissues/organs of the body.

Generally, connective tissue is made up of three components

1. Matrix

It is a clear and viscous substance. Its consistency may vary from liquid (e.g., blood) to semi-solid (e.g., cartilage) and solid (e.g, bone) form.

2. Cells Embedded in the Matrix

These are responsible for secreting the matrix and other substances.
The cells of connective tissue are of different types
(i) Fibroblasts produce fibres and matrix.
(ii) Adipose cells store fat.
(iii) Plasma cells synthesize antibodies. These are also called 'cart wheel cells' because thin chromatin in their nucleus forms four or five clumps giving the nucleus a resemblance of a cart wheel.
(iv) Mast cells produce histamine, heparin and serotonin. These are related to basophils of the blood.
(a) Histamine dilates the walls of blood vessels in inflammatory and allergic reactions.
(b) Heparin checks clotting of blood inside the blood vessels.
(c) Serotonin acts as a vasoconstrictor to check bleeding and to increase the blood pressure.
(v) Mesenchyme cells produce various types of connective tissue cells.
(vi) Macrophages ingest cell debris, bacteria and foreign matter.
(vii) Chromatophores (pigment cells) are found in the dermis of the skin which impart colour to the animals.
(viii) Reticular cells form reticular tissue and are phagocytic in nature.

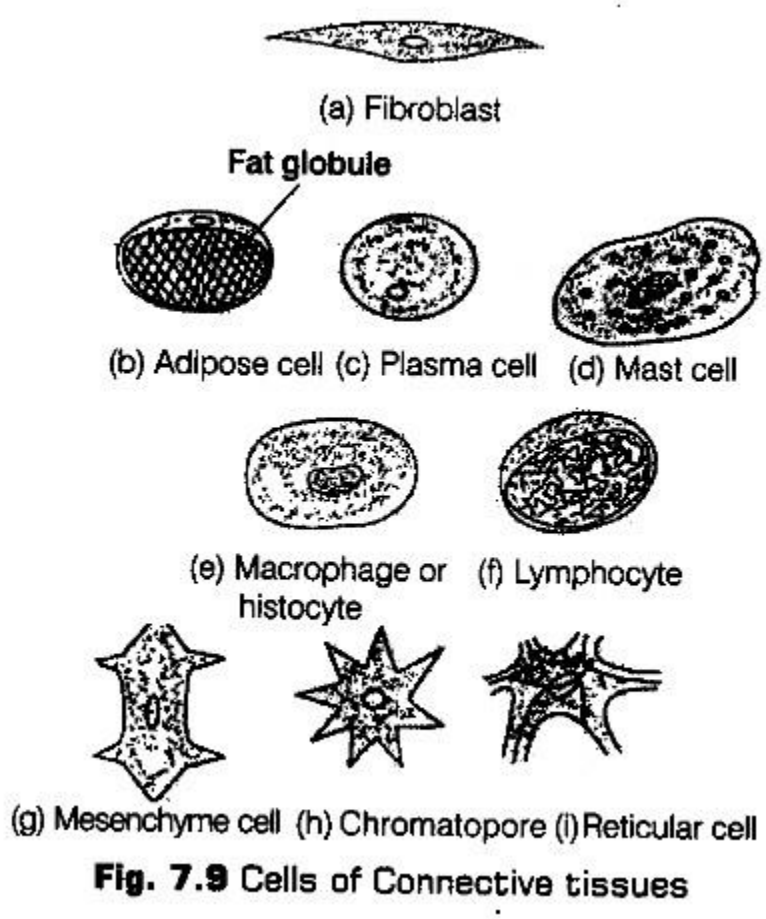


Fig. 7.9 Cells of Connective tissues

3. Fibres

These are non-living products of the cells.

These are of three types

(i) Collagen or Collagenous fibres (white fibres) are made up of collagen protein. When boiled in the water, collagen changes into gelatin.

(ii) Elastic fibres (yellow fibres) are formed of a protein called elastin. These fibres are branched and elastic.

(iii) Reticular fibres are delicate, branched and inelastic. They are made up of reticulin protein. They always form a network.

Types of Connective Tissues

The connective tissues are mainly of following three types

1. Loose Connective Tissue

Loose connective tissue has cells and fibres loosely arranged in a semi-fluid ground substance. These tissues are of two types, i. e., areolar tissues and adipose tissue.

Areolar Tissue

It is found under the epithelial tissue of the skin, visceral organs like stomach, trachea and the walls of the blood vessels, etc. Its matrix is made up of glycoproteins. It contains two types of fibres, i.e., the white collagen fibres made up of collagen and the yellow elastic fibres made up of elastin.

The different cells of areolar tissue are fibrocytes, macrophages and mast cells.

Functions The tensile strength of collagen fibres and the elasticity of the yellow fibres protect the various organs from mechanical injuries.

This tissue also provides rapid diffusion of the materials and migration of wandering cells towards the areas of infection and repair.

Adipose Tissue

It is a modified type of areolar tissue. Its matrix contains large number of adipose cells along with fibrocytes and macrophages. White and yellow fibres are present in the matrix. The cells of this tissue are specialised to store fats.

The excess of nutrients which are not used immediately are converted into fats and are stored in this tissue. The adipose tissues are found in the subcutaneous region, around the heart, kidneys, eyeballs, etc.

e.g., It is also found in the blubber of whales and elephants, hump of camel, fat bodies of frog and yellow bone marrow.

Functions The adipose tissue is mainly a food reserve or fat depot for storage. It forms a shock-absorbing cushion around the eyeballs and kidneys. The tissue also helps in the production of blood corpuscles.

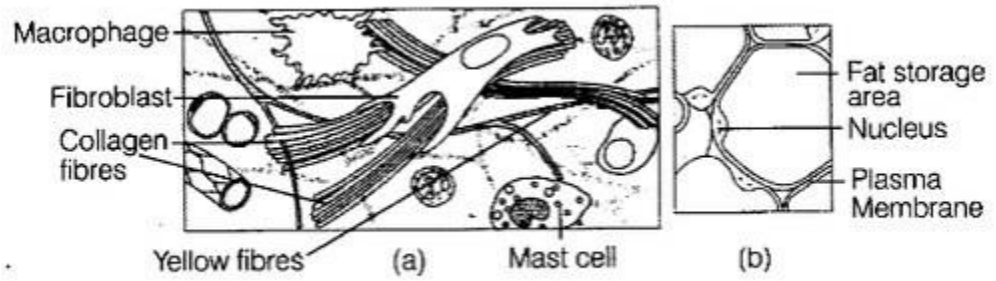


Fig. 7.10 Loose connective tissue (a) Areolar (b) Adipose tissue

2. Dense Connective Tissue

Fibres and fibroblasts are found compactly packed in the dense connective tissues. This tissue is of two types i.e., dense regular and dense irregular connective tissue.

i. Dense Regular Connective Tissue

In this tissue, the collagen fibres are present in rows between many parallel bundles of fibres.

It is further of two types

It mainly consists of white fibres arranged in bundles. The fibroblasts are present in rows between the bundles.

It is of two types

*** Tendons** The white fibrous connective tissue forms the cords called tendons. These join the skeletal muscles with the bones.

*** Sheets** The white fibrous connective tissue also forms flat plates or sheets. It occurs in the dermis of the skin, periosteum of the bone,

perichondrium of Fi8-7'11 Dense re9ular cartilage, pericardium of heart etc .The white fibrous connective tissue has great strength however its flexibility is limited.

It mainly consists of yellow elastic fibres. The fibres are thicker. The fibroblasts and a few white fibres are found in between the yellow fibres.

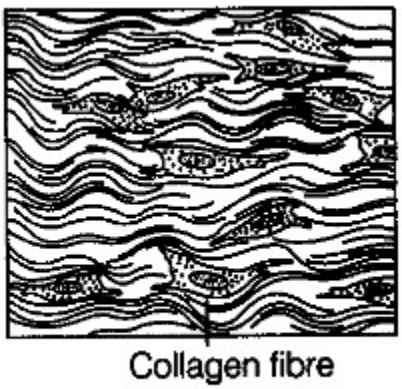


Fig.7.11 Dense regular

It is also of two types

*** Ligaments** The yellow elastic connective tissue forms the cords called ligaments. These join

bones to bones.

*** Sheets** The yellow fibrous sheets formed by this tissue occur in the walls of blood vessels, lungs and bronchioles, true vocal cords, cartilage of larynx, trachea etc.

The yellow elastic connective tissue has considerable strength and remarkable elasticity. Thus, it allows the stretching of various organs.Dense Irregular Connective Tissue

It has fibroblasts and many fibres (mostly collagen) that are oriented in different pattern. This tissue is present in the skin. Collagen fibre

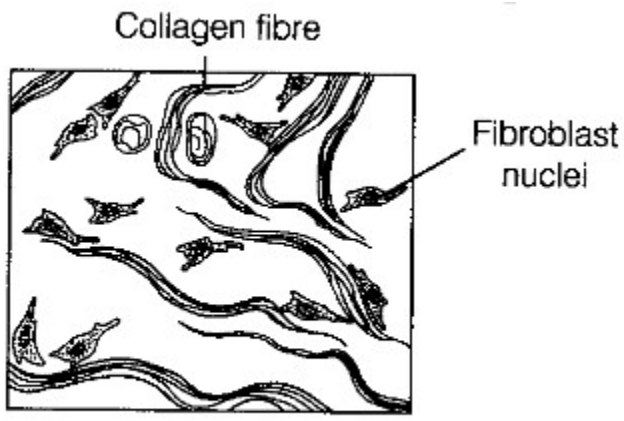


Fig.7.12 Dense irregular

3 Specialised Connective Tissues

The specialised connective tissues are of following types

Skeletal Tissues

These tissues form the endoskeleton of the vertebrates. They form a rigid framework which supports the body, protects the vital organs and helps in locomotion.

The two types of skeletal tissues, i.e., cartilage and bone.

a.Cartilage

It is a tough, semitransparent, elastic and flexible tissue. The cartilage cells lie in groups of 2-3 in fluid filled spaces called lacunae. The cartilage is bounded externally by a stiff sheath called perichondrium containing white fibrous, tissue.

The cartilages are of three types, i.e., hyaline, fibrous and calcified.

* Hyaline Cartilage It has a clear, translucent, bluish green matrix. It is flexible and forms articular surfaces at the joints of long bones, where it is called articular cartilage.

* Fibrous Cartilage It has well-developed fibres in the matrix. It is of two types i.e., white fibrous cartilage and yellow elastic cartilage.

It is a hard and rigid connective tissue. These are non-pliable ground substance rich in calcium salts and collagen fibres providing strength to the bone. The cells of bone are found in a calcified matrix made up of ossein. The bone cells known as osteocytes lodged in the spaces called lacunae..

They also interact with skeletal muscles attached to them to bring about movements.

The bone consists of four parts, i.e.,

* Periosteum It is a thick and tough sheath that forms an envelope around the bone. It is composed of collagen fibrous tissue. The periosteum contains blood vessels. It also contains bone-forming cells, the osteoblasts, which produce new bone material.

* Matrix It is composed of a protein called ossein. The Haversian canals, a characteristic feature of mammalian bones are present in the matrix. Each Haversian canal contains an artery, a vein, a lymph vessel, a nerve and some bone cells.

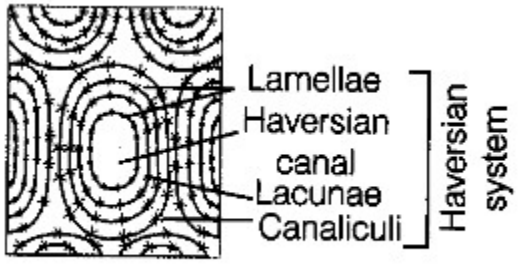


Fig.7.14 Bone

Endosteum It is present outer to the bone marrow cavity. It comprises white fibrous tissue and the bone forming cells called osteoblast. The latter produces new bone material.

• Bone Marrow It is the vascular, soft pulpy connective tissue found in the bone marrow cavity of long bones like humerous, femur, etc.

Bone marrow is of two types

• Yellow marrow (rich in fat cells called adipocytes.) and

• Red marrow (Blood cells are formed in this marrow.)

In foetus, red marrow occurs in all bones. After birth, it restricts to limited places.

Calcified Cartilage When matrix of cartilage contains granules of calcium carbonate, the cartilage is called calcified cartilage.The bones can be spongy or compact on the basis of density and texture.

(a) Spongy (cancellate) Bone It contains a network of thin and irregularly longitudinal and transverse bony bars called trabeculae covered by the endosteum. It is found at the ends of long bones (epiphyses).

(b) Compact (Dense) Bone It is hard and compact and found in the shaft of long bones. It contains yellow bone marrow and has Haversian systems.

In a decalcified bone, the inorganic part of the matrix is removed. For deealcifieation, the bone is kept in dilute hydrochloric acid for long hours. This is to study living structures of the bone as it dissolves all the inorganic salts leaving behind only the organic matter.

Vascular Tissues

These are motile connective tissues consisting of fluid matrix and free cells. The matrix is without fibres. The vascular tissue helps in the transport of materials from one place to another.

Blood

It is a mobile, watery fluid with a slightly salty taste. It is composed of plasma (a fluid matrix) and the cells called blood corpuscles. It is bright red in colour when oxygenated and purple when deoxygenated. The volume of blood in an adult is about 5L.

It circulates within the blood vessels in higher animals. It is slightly alkaline (pH 7.4) in nature.

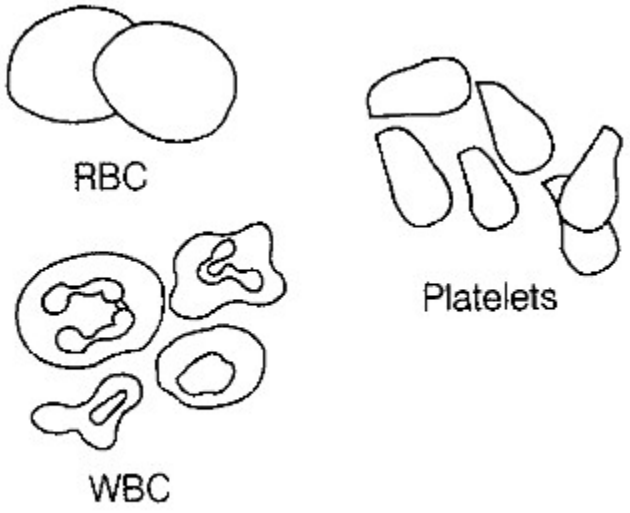


Fig 7.15 Specialised Connective tissue Blood

Plasma is a yellowish, straw-coloured liquid which is composed mainly of water (92%). About 55% of the total blood volume is plasma. The solid materials in plasma include plasma proteins, nutrients (glucose, amino acids, fatty acids and vitamins), hormones, antibodies, enzymes, lactic acid, cholesterol, dissolved gases (oxygen, carbon dioxide), mineral salts and waste products (urea; uric acid and creatinine). Functions It helps in transport of substances, provide body immunity, prevent the blood loses, retain fluid in blood, maintain blood pH and conduct heat to skin for dissipation.

Blood Cells

The blood cells or blood corpuscles forms about 45% of the blood volume. These cells are formed in the bone marrow of the long bones and the lymph nodes. The process of blood cells formation is called haemopoiesis and the tissues where these are formed are called haemopoietic tissues.

The blood cells are of following types

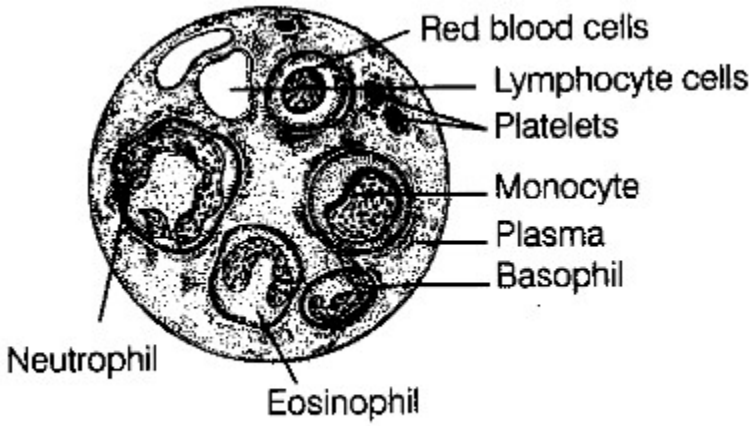


Fig.7.16 Blood Cell

Erythrocytes or Red Blood Corpuscles (RBCs) are the most abundant elements in blood. These carry red-coloured oxygen carrying pigment called haemoglobin. They are 7-8 |Xm in diameter.
* The human RBCs are smaller than the white blood corpuscles. In mammals, they are non-nucleated, biconcave and circular. The formation of erythrocytes is called erythropoiesis.
* Leucocytes or "White Blood Cells (WBCs) lack haemoglobin and are colourless. They are nucleated with rounded or irregular shape. They can change their shape and are capable of amoeboid movement.
* Thrombocytes (Blood Platelets) These are small, colourless, plate like discs having size of about 2-3 pm. Their number ranges between 0.15-0.4 million/mm3 of blood. Their normal life span is about a week. No nucleus is visible in these cells.
The blood performs following functions in the animal body.
* Blood transports oxygen from the respiratory organs to the tissues and carbon dioxide from the tissues to the respiratory organs.
* It transports nutrients to all parts of the body.
* Blood maintains the constant body temperature by distributing the heat throughout the body.
* Lymphocytes and eosinophils produce antitoxins to neutrilise the toxins, released by the microbes.
* Blood helps to maintain water balance to a constant level by bringing about constant exchange of water between circulating blood and tissue fluid.
* It helps to regulate the pH of the body fluids as it contains buffer materials such as proteins and mineral salts.
* Blood helps in healing of injuries by maintaining necessary supplies for the repair of damaged tissues.
It is a mobile connective tissue comprising lymph plasma (fluid) and lymph corpuscles (cells). It is pale yellow in colour and its composition is similar to plasma without the plasma proteins. It is present in the vessels called lymph vessels.

Lymph is formed of liquid components and formed elements or cells. It contains about 94% water and 6% of organic and inorganic substances. The organic part includes protein, fat droplets, carbohydrates, nitrogenous wastes and hormones.

Lymph performs the following functions in animal body

(i) It plays an important role in the defence of the body especially against invading organisms.
(ii) The digested products of fat digestion enter the lymph vessels present in the villus of the small intestine.
(iii) Lymph helps to maintain the blood volume by returning the interstitial fluid back to the blood during circulation.
(iv) The lymph nodes produce lymphocytes.
(v) It keeps the tissue cells moist.

4. Reticular Connective Tissues

Tissues consist of star-shaped reticular cells whose protoplasmic processes joins to form a cellular network. The reticular fibres are present on the reticular cells (composed of a protein called reticulin.)
The reticular connective tissue is present in the liver, spleen, lymph nodes, thymus, tonsils, bone marrow and lamina propria of the gut wall.
Function This tissue provides strength and support as it forms the supporting framework of

many organs. It also helps to bind together the cells of smooth muscles. The reticular cells are phagocytic – and forms the defense mechanism of the body.

5. Pigmented Connective Tissue

The cells of pigmented connective tissue are irregular and are called pigment cells (chromatophores or melanophores). These cells contain yellowish brown, black or blue melanin pigment granules. Melanin is produced by other cells called melanocytes.

This tissue is present in the choroid, ciliary body and iris of the eye and dermis of the human skin.

Functions It gives colour to the structures.

6. Mucoid Connective Tissue

This tissue occurs as a foetal or embryonic connective tissue as it is present in the umbilical cord.

The mucoid tissue contains a jelly like substance called Whartson's jelly and some delicate collagen fibres and primitive type of fibroblasts. It occurs as embryonic connective tissue in the foetus and vitreous humour of the eye.

Functions of Connective Tissue

The connective tissue performs fallowing main junctions

(i) The connective tissue mainly joins one tissue to another in the organs.

(ii) The adipose tissue stores fat.

(iii) The cartilage and bones form a supporting framework for the body.

(iv) Blood and lymph carry materials from one part to another in the body.

(v) The cells of connective tissues like macrophages, monocytes, neutrophils ingest bacteria, cell debris and foreign materials.

Thus, they protect and clean the body.

(vi) The adipose tissue acts as shock absorber around some organs, such as eye balls and kidneys. It also acts as packing material in various organs.

(vii) Bone marrow is the source of blood corpuscles.

(viii) The collagen fibres help in the repair of injured tissues.

Note:

* In old age, the bone marrow of the cranial bones undergo degeneration and is called gelatinous marrow.

* Bone marrow is a special kind of myeloid (myelogenous) tissue.

* Prothrombin and fibrinogen are the largest blood proteins and albumins.are the smallest one.

i. Muscular Tissue

The striated muscle fibres are multinucleated or syncytial in nature. The cytoplasm (sarcoplasm) of each fibre has a large number of myofibrils (actin and myosin myofibrils) which are tightly packed.

Each myofibril shows dark and light bands of stripes alternating with each other. Hence, they are called as striped muscle fibres.

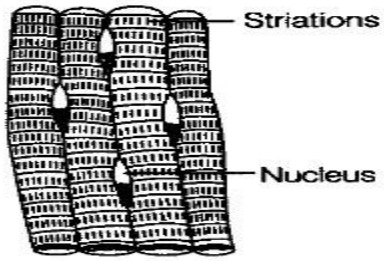


Fig. 7.17 Skeletal (striated) muscle tissue

ii. Non-Striated (Smooth) Muscle

The non-striated muscles are found in the posterior part of oesophagus, stomach, intestine, lungs, urinogenital tract, urinary bladder, blood vessels, iris, ciliary body of eye, dermis of skin, etc.

The non-striated muscle consists of long, narrow, spindle-shaped fibres that are generally shorter than the striated muscle fibres. Their size may range from 20 |Xm (Small blood vessels) -500 (1m in pregnant uterus). Each non-striated muscle fibre contains a single oval nucleus in its thick middle part. In the cytoplasm, the myofibrils are arranged longitudinally. They are composed of myosin. There is no sarcolemma, however, the fibre is enclosed by the plasma membrane.

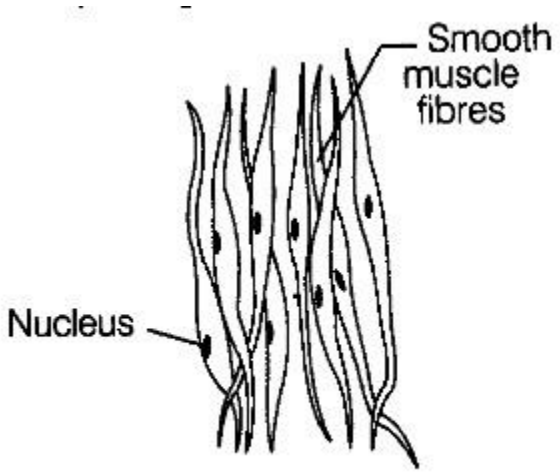


Fig. 7.18 Smooth muscle tissue

The smooth muscles help in the peristalsis which occurs in the tubular viscera. The autonomic nervous system controls these muscles. Hence, they are not under the control of animal's will.

iii. Cardiac Muscles

The cardiac muscles are contractile tissues present only in the heart and in the wall of large veins which enter the heart. The cardiac muscle fibres show the characters of both unstriped and striped muscle fibres.

The myofibrils have transverse faint dark and light bands which alternate with each other.

The cardiac muscle fibres have some specialfeatures

(i) These muscle fibres are supplied with both central and autonomic nervous system and are not under the will of the animal.

(ii) These fibres never get fatigue.

(iii) Blood capillaries penetrate the cardiac muscle fibres, hence they have very rich blood supply.
(iv) These fibres have the property of contraction, even when they are isolated from the body temporarily.

functions of Muscular Tissues

The muscle tissues perform following important junctions
(i) These are involved in the movement of body parts and locomotion of the organism.
(ii) Muscles are responsible for heart beat, production of sound and peristalsis in tubular viscera.
(iii) The muscles support the bones and other structures.
(iv) Muscles are essential during parturition.
The neural tissue is ectodermal in origin. It is specialised to receive stimuli and conducts impulses for controlling and coordinating body functions. It exerts the greatest control over the body's responsiveness to changing conditions. The neural tissue consists of nerve cells and packing cells. The packing cells are called Schwann cells in the peripheral nervous system and neuroglia cells in the central nervous system.

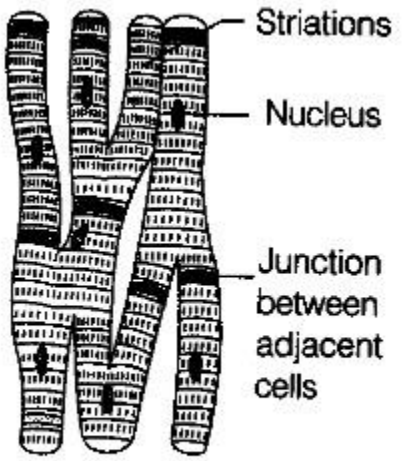


Fig. 7.19 Cardiac muscle tissue

The muscle tissue consists of elongated and contractile cells called muscle cells or myocytes. Due to their elongated nature, the muscle cells are also called muscle fibres. It develops from mesoderm. The muscle cells are surrounded by connective tissue. Each muscle cell is covered by a membranous sheath called sarcolemma.
It consists of plasma membrane and basement membrane. The cytoplasm of a myocyte is called sarcoplasm. The endoplasmic reticulum is called sarcoplasmic reticulum and the mitochondria are called sarcosomes.
The myoglobin keeps the reserve oxygen for immediate supply during muscle activity.
It also provides light pinkish colour to the muscles. The muscle cells may be uninucleate or multinucleate. The contractile structures of muscle cells are called myofibrils. The myofibrils are made of myofilaments. The myofilaments are of two types, i.e., thicker myosin and thinner actin. The contraction of muscles occurs due to sliding of actin filaments passing over the myosin filaments.

Types of Muscles

The muscles can be grouped into three types based on their structure, location andJunction.

(i) Striated or striped or skeletal or voluntary muscles.

(ii) Non-striated or unstriped or visceral or smooth or involuntary muscles. .

(iii) Cardiac muscles.

(iv) Striated Muscles

The striated or skeletal muscles form about 40% of total body weight. These muscles are attached and bring about the movement of the various bones of the skeleton, so are called skeletal muscles. The striated muscles give shape to the body and also release heat during contraction. These muscles have huge supply of nerves and blood vessels. Each striated muscle is a long, narrow, cylindrical, unbranched cell.

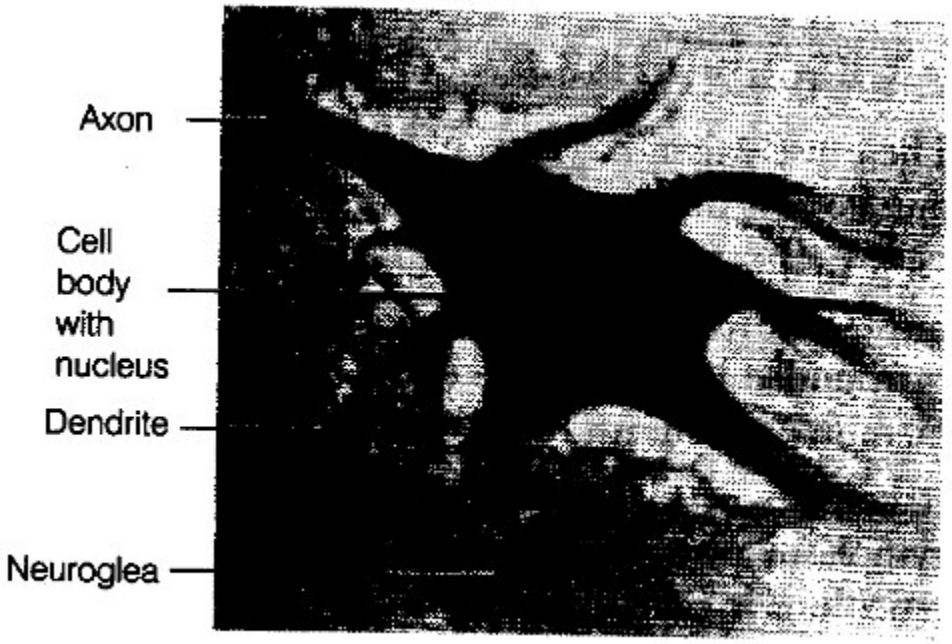


Fig. 7.20 Neural tissue (Neuron with neuroglia)

Nucleus

It is a long and cylindrical structure which has a definite sarcolemma. The fibres are uninucleate and the nuclei lie near the centre.

Neurons

Neurons are the functional unit of neural system. These are excitable cells. A neuron consists of a cell body (cyton) or soma and fine protoplasmic processes called neurites arising from the cell body.

i. Cyton

It contains neuroplasm (cytoplasm), a spherical nucleus, endoplasmic reticulum, mitochondria, Golgi bodies, ribosomes, lysosomes, fat globules, Nissl's granules etc. The Nissl's granules are probably involved in the synthesis of proteins.

Neurites

The processes arising from the neurons are called neurites. These are dendrites and an axon. Axon is single, but dendrites may vary from one to several. The dendrites are usually shorter and tapering processes. The axon is usually a long process of uniform thickness.

Nerve Fibres

The nerve fibres are elongated and slender processes of the neurons, which are formed by ensheathing of axons. A space of 15-20 nm occurs between axolemma and the covering sheath. It is called periaxonal space.

Depending upon the covering sheath, nerve fibres are of two types

(a) Myelinated Nerve Fibre

An axon covered by myelin sheath is called myelinated or medullated nerve fibre. The myelin contains lipids, proteins and water. The medullary sheath serves as an insulating layer, preventing loss of energy of the nerve impulse during its passage along the fibre./; Non-Myelinated Nerve Fibres

A non-medullated or non-myelinated fibre consists of an axis cylinder enclosed by neurilemma and connective tissue. It lacks medullary sheath and appears grey in the fresh state.

On the basis of function also, the nerve fibres are of two types (a) Afferent (Sensory) Nerve Fibres The afferent nerve fibres carry the nerve impulses from the sense organs to the central nervous system (brain and spinal cord).

(b) Efferent (Motor) Nerve Fibres

They carry nerve impulses from the central nervous system to the effector organs (muscles and glands).

Nerves

A nerve is a complex bundle of nerve fibres enclosed together by a common sheath of connective tissue along with the blood vessels. Each nerve fibre is covered by a thin sheath of connective tissue called endoneurium.

A number of nerve fibres, each covered by its own endoneurium are joined together to form a bundle called fasiculus or fascicle.

According to the nature of fibres, nerves can be of following three types

(i) Sensory (Afferent) nerves These nerves bring sensory impulses or excitation from different parts of the body and sense organs.

(ii) Motor (Efferent) nerves These nerves carry message from central nervous system to parts of the body and effector organs to perform their function.

(iii) Mixed nerves The nerves contain both sensory and motor fibres.

Neuroglia

The neuroglia or glia cells are supporting cells which form a packing around the neurons in the brain, spinal cord and ganglia. These cells have different shapes and many processes. The neuroglia cells have various roles like myelin formation, transport of materials to neurons, maintenance of ionic balance and phagocytosis.

Neurosecretory Cells

These are specialised neurons or neuron-like cells, which secrete biologically active substances that are effective in other structures, often at a different site. The neurosecretory cells occur in hypothalamus. They produce hormones called neurohormones.

Functions of Neural Tissue

Neural tissue perform the following functions

(i) The neural tissue coordinates and controls the functioning of different parts of the body.

(ii) The sensation of smell, vision, taste, hearing, pain, pleasure, etc., are performed through the nervous tissue.

(iii) The neural tissue helps in meditating conscious activities.
(iv) The information about the changes in various internal structures is provided by nerves.
(v) It makes us aware about the environment around us.
(vi) The nervous tissue brings about an appropriate response to each and every stimulus.
(vii) The tissue is also a seat of experiences, memories, etc.

Topic 2. Morphology and Anatomy of Animals

In this topic we will discuss morphology and anatomy of three organisms—Earthworm, Cockroach and Frog representing invertebrates and vertebrates at different evolutionary levels to show their organisation and functioning. Morphology refers to study of from or externally visible features. The word anatomy is conventionally used for the study of morphology of internal organs in the animals.

Earthworm

Earthworm is a reddish-brown terrestrial invertebrate that inhabits the upper layer of the moist soil. During day time, they live in the burrows made by boring and swallowing the soil.

In the gardens, they can be find out by their faecal deposits called as worm castings. The two common Indian species of earthworms are Pheretima and Lumbricus.

Systematic Position

Kingdom	Animalia
Phylum	Annelida (metameric segmentation)
Sub-class	Clitellata (presence of clitellum and fewer setae, absence of head and parapodia).
Order	Haplotaxida (terrestrial and no asexual reproduction)
Family	Megascolecidae (male pores are behind the clitellum).
Genus	*Pheretima* (setae occur in a complete ring on almost all segments of the body, clitellum extends over 14-16 segments).
Species	*posthuma* (genital papillae are on the 17th and 19th segments, male genital pores on 18 th segment).

Earthworms inhabit almost all areas over the world, except the Arctic and Antarctic regions. There are about 500 species of Pheretima of which 13 species occur in India.

Habitat and Habit

Earthworm lives in moist soil rich in humus they are nocturnal animals (i.e., they come out at night for feeding and to mate and sleep during the day time).

Locomotion

The earthworm moves by crawling (creeping) in which its body remains on the ground. It moves by muscular contraction and relaxation of the body which is aided by chitinous setae or chaetae. It moves about 15 cm/min.

Food

The earthworm eats decaying organic matter found in the soil. It is omnivorous. The food is digested in the gut and undigested food along with the soil is passed out through the anus as small pills called worm castings.

Breeding

Earthworm is a hermaphrodite (i.e., bisexual or monoecious). It breeds in the rainy season. It is protandrous (i.e., male sex organs mature earlier than the female). Thus, self fertilisation is not possible, only cross fertilisation occurs in them.

The copulation occurs when two earthworms closely attach to each other by their ventral surfaces in a way that the head region of one is opposite to the tail region of the other. Then, the two worms separate after the exchange of spermatozoa.

Several eggs and spermatozoa are packed in an egg case, the ootheca (cocoon), which is deposited just beneath the surface of ground. About four baby earthworms develops in one cocoon.

Regeneration

The earthworm has great power of regeneration. If it is cut into two parts, its anterior half develops into tail, but in the posterior half, the head can be formed only if 4-6 anterior segments are removed.

Defence

Earthworm can defend itself only by ejecting the foul smelling coelomic fluid through the dorsal pores.

Morphology

Size, Shape and Colour

It has a long, cylindrical body. The anterior end is pointed, but there is no distinct head. The posterior end is rounded. The size of an adult worm is about 150 mm long and 3-5 mm wide. The dorsal surface is a bit darker than the ventral surface and bears a dark median line.

Perostomium

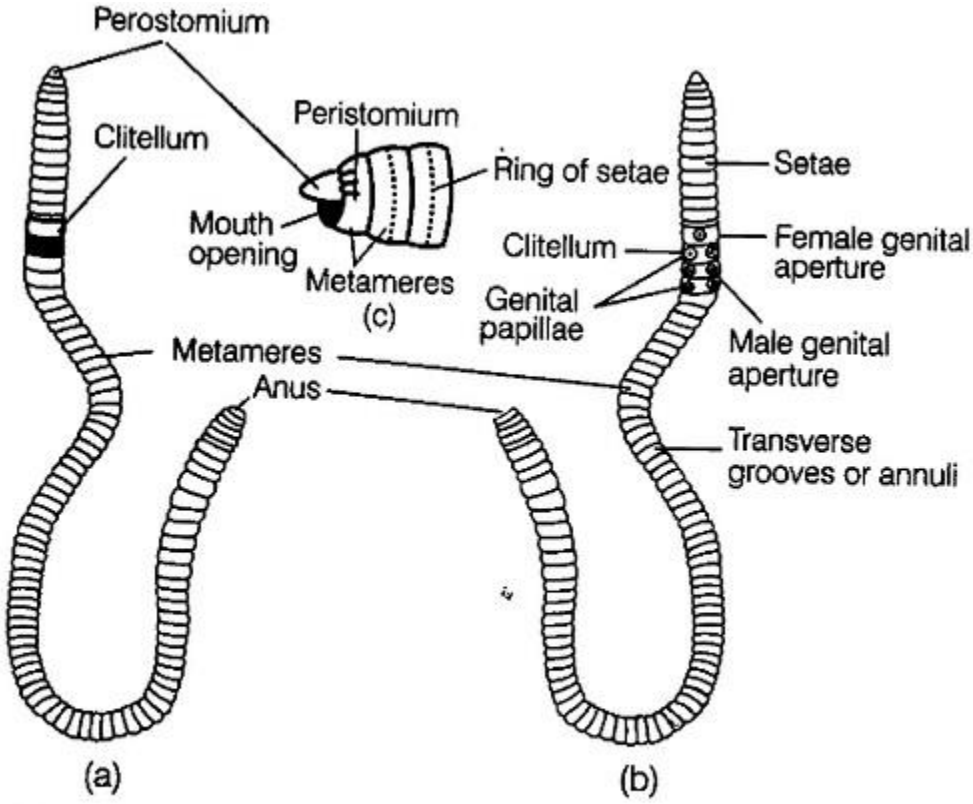


Fig. 7.21 Body of earthworm (a) Dorsal view (b) Ventral view (c) Lateral view showing mouth opening

Segmentation

The body of earthworm is divided into more than hundred short segments, which are similar (metameres, about 100-120 in number). The segments are also divided internally by the septa. This is called true segmentation or metamerism.

The first segment is called peristomium. The mouth is present in this segment. A fleshy lobe called prostomium covers the mouth. The segmentation in the first few segments is visible externally without corresponding internal septa.

The clitellum is a prominent circular muscular band present in the 14th, 15th and 16th segments. It divides the body into pre-clitellar, clitellar and post-clitellar regions.

The female genital pore is a single aperture present mid-ventrally in the 14th segment.

The male genital pores are a pair of openings found on the ventral surface of the 18th segment. Two pairs of genital papillae are present in 17th and 19th segments which helps the animal in copulation.

In the grooves of 5th-9th segments, four pairs of spermathecal pores are present ventro-laterally. These are connected to the sperm storing organ called spermathecae.

On the dorsal side minute pores are found called dorsal pores through which the coelomic fluid exudes out of the body. This fluid keeps the body surface moist.

There are numerous pores called nephridiopores present on the ventral surface of the body. These are the opening of the excretory organs called nephridia that expel out the nitrogenous waste from the body.

The last segment is called the anal segment and it bears the anus.

Anatomy

Body Wall

The body wall of earthworm has four layers, i.e., cuticle, epidermis, musculature and coelomic epithelium or parietal peritoneum.

a. It is a thin, transparent, non-cellular surface layer. The cuticle is secreted by the epidermis and is perforated by numerous minute pores.

b. It is the next layer after cuticle, made up of a single layer of columnar epithelium which contain secretory gland cells, i.e., basal cells, sensor or receptor cells, setigerous cells (seta forming cells), etc.c.

c.It is composed of an outer thin layer of circular muscle fibres and an inner thick layer of longitudinal muscle fibres. Contraction of circular muscles makes the body long and thin whereas, the contraction of longitudinal muscle fibres makes the body thick and short.

d. It is a thin, membrane like coelomic epithelium consisting of flattened squamous cells.It protects the internal organs and prevents excessive evaporation. The receptor cells play a vital sensory function. Setae and muscles help in locomotion. The excretory matter is passed out through the nephridiopores present in the body wall.

Digestive System

A complete alimentary canal is present in the body cavity of earthworm beginning with the mouth in the first segment and ends with the anal opening situated in the last segment. The earthworm swallows the soil and the organic content of the soil is digested.

The various regions of earthworm's alimentary canal are following

(i) Buccal cavity l-3rd segments.

(ii) Pharynx 4th segment.

(iii) Oesophagus (food pipe) 5-7th segments.

(iv) Gizzard 8-9th segments. It helps in grinding the food.

(v) Stomach 10-14th segments. The stomach wall, contains calciferous glands to neutralise the humic acid in the soil.

(vi) Intestine 15th to the last segment where it opens out by anus.

(vii) Typhlosole Between 25-95th segments, there is a prominent infolding on the dorsal wall called the typhlosole. This enhances the area of absorption of the intestine of the digested food.

Respiration

The skin serves as the organ of respiration. It is thin, transparent and richly supplied with blood vessels. Respiration through the skin is called cutaneous respiration. Haemoglobin is found dissolved in the blood plasma.

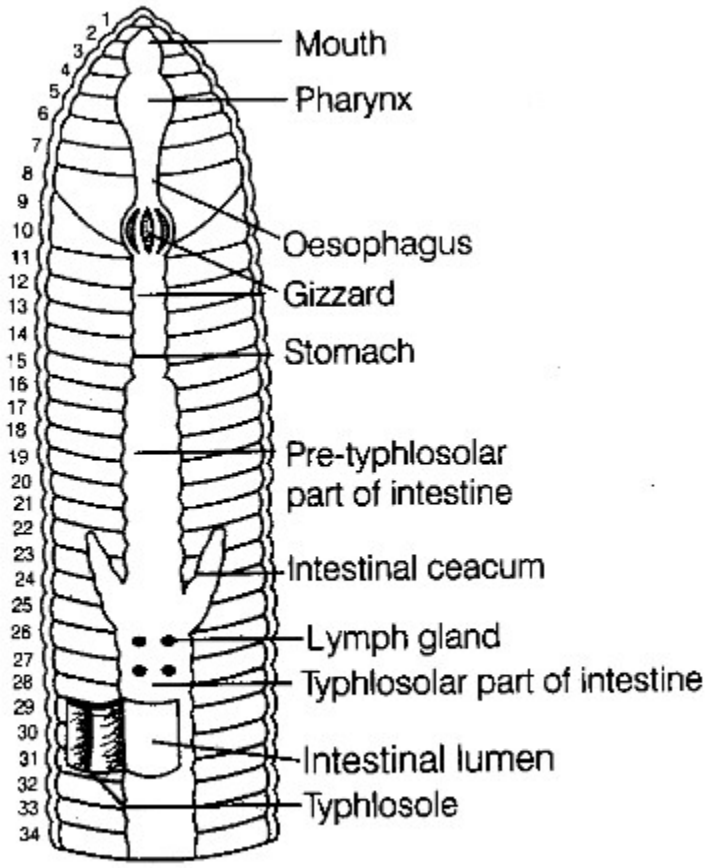


Fig. 7.22 Alimentary canal of an earthworm

Circulatory System

Pheretima exhibits closed type of blood vascular system, consisting of blood vessels, capillaries and heart. Due to closed circulatory system, blood is confined to the heart and blood vessels.

There are three main median longitudinal blood vessels namely a dorsal vessel (above the alimentary canal), ventral vessel (below the alimentary canal) and a sub-neural vessel (lying on the ventral side below the nerve cord). In the blood vessel, the blood flows from the posterior to the anterior end. In the ventral and subneural vessel, the flow of blood is from anterior to the posterior end.

There are four pairs of hearts, a pair of each lying in 7th, 9th, 12th and 13th segments. All the hearts have muscles and pulsatile walls to pump the blood into the ventral vessel by rhythmical contractions. The backward flow of the blood is prevented by the valves present in the heart.

(viii) Anus The undigested food is sent out through it.

Excretory System

The excretory organs occur as segmentally arranged coiled tubules called nephridia (sing, nephridium). They are offollowing three types.

These are present on both the sides of inter segmental septa of segment 15 to the last

that opens into intestine. They discharge the waste matter into the gut via septal excretory ducts and supraintestinal ducts

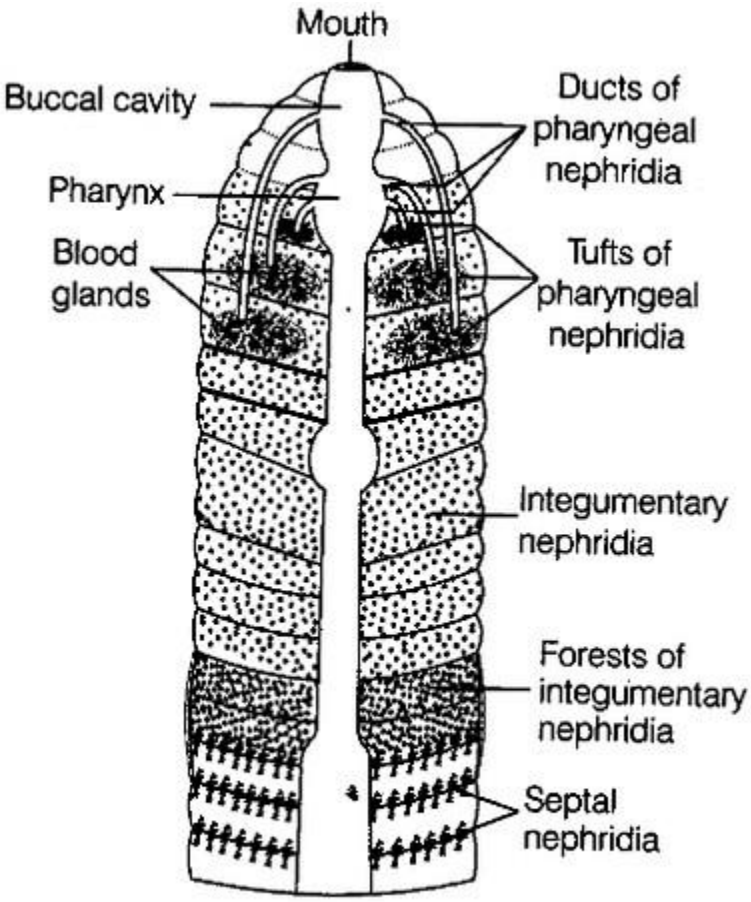


Fig. 7.24 Nephridial system in earthworm

ervous System

Nervous system is basically represented by the ganglia which are arranged segment-wise on the ventral paired nerve cord.

The nerve cord in the anterior region (3rd and 4th segments) bifurcates laterally, encircling the pharynx and joins the cerebral ganglia dorsally to form a nerve ring. The cerebral ganglia along with other nerves in the ring integrate sensory input as well as command muscular responses of the body.

Reproductive System

Earthworm is a hermaphrodite (bisexual), i.e., testes and ovaries are present in the same individual. ‘

Mule Reproductive System

It possess two pairs of testes present in the 10th and 11th segments. The ducts of testes (vas deferentia) run upto the 18th segment, where they join the prostate duct. Accessory glands are present, on the ventral side of the 17th and 19 th segments.

They open out by the fine ducts of genital papillae situated on the under surface of the segments 17th and 19th. Four pairs of sac-like structures called spermathecae are found one in each of the 6th to 9th segments. They receive and store spermatozoa during copulation.

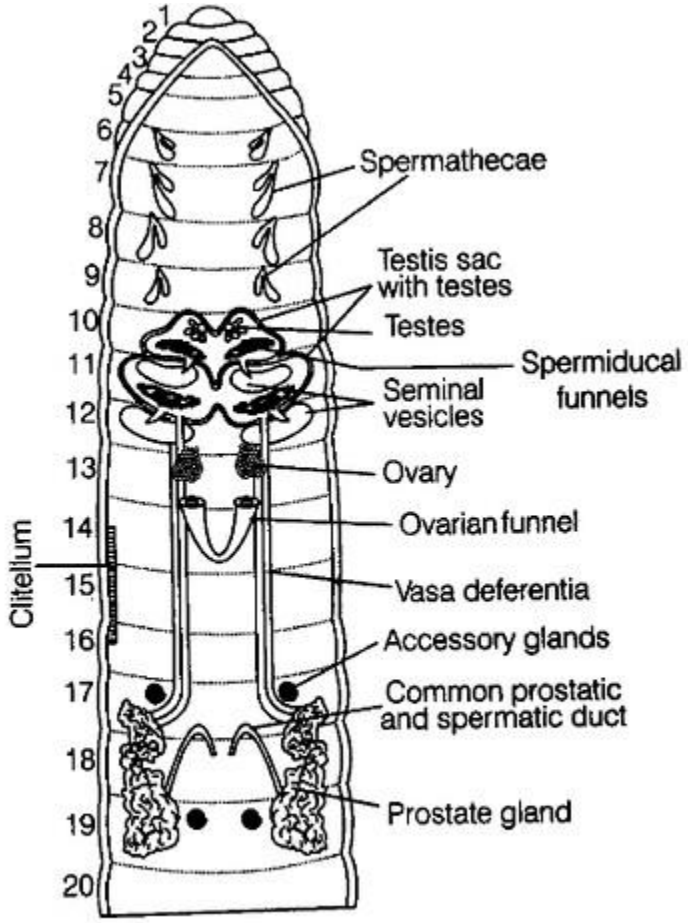


Fig. 7.25 Reproductive system of an earthworm

Femaie Reproductive System

One pair of ovaries is attached to the intersegmental septum between the 12th and 13th segments. Ovarian funnels are present beneath the ovaries which continue into oviduct. These ducts join together and open on the ventral side as a single female genital pore on the 14th segments.

Breeding and Fertilisation [An earthworm becomes sexually mature when it develops the clitellum. A mutual exchange of sperm occurs between the two worms during mating. Mature sperm, egg cells and nutritive fluid are deposited in the cocoons produced by the gland cells of the clitellum. Fertilisation and development occurs within the cocoons, which are deposited in the soil. The eggs are fertilised by the sperms within the cocoons, which then slips off the worm

and is deposited in or on the soil.
The cocoons hold the worm's embryo. After about three weeks, each cocoon produces two to twenty baby worms. Earthworms development is direct, i.e., there is ' no larval stage and all earthworms lay eggs.

Economic Importance of Earthworms

Merits

Earthworms are useful in several ways for humans
(i) Earthworms make the soil porous by digging burrows in the soil. Hence, they are called friends of the fanners.
(ii) The nitrogenous wastes and other waste products of the earthworms form food for plants. This process of increasing fertility of soil by earthworms is called vermicomposting.
(iii) Earthworms are used as fish bait for catching fishes.
(iv) Some tribals in India use earthworms as medicine to cure jaundice, piles, diarrhoea, bladder stones, gout, etc.
(v) In some countries like China, Japan, Australia and Myanmar, earthworms are used as food.
(vi) The worms reduces both acidity and alkalinity of the soil and create optimum conditions for the plant growth.
(vii) Earthworms are eaten by frogs, birds, which are useful to man in some ways. Thus, they are an important part of food chain.
(viii) These are used in scientific studies and dissected in zoological laboratories for academic studies.

Demerits

Earthworms may also be harmful in many ways
(i) Earthworms may damage young and tender plants by eating them.
(ii) During rainy season, they make burrows and cause soil erosion.
(iii) They spoil the play grounds by digging burrows in them.
(iv) Some earthworms are intermediate hosts for some parasites such as tapeworm of chicken and lung nematode of pigs.
(v) The burrows of earthworms in the banks of irrigation channels sometimes cause leakage of the water.

Cockroaches are one of the common insects found in our house. They are brown or black bodied animals, although, bright yellow, red and green coloured cockroaches have also been reported in the tropical regions. In India, two species of cockroaches are found, i. e., Periplaneta americana and Blatta orientalis.

Locomotion

Cockroaches are cursorial insects, i.e., run very fast. They show double mode of locomotion- running and flying. The cockroach run on the tarsi of their legs. At a time, three legs are kept on the ground and the other three are carried forward. By repeating this step, the animal moves forward.

Cockroach flies by beating the hindlimbs with the help of special muscles. They are beaten up and down alternately.

Breeding

Cockroaches are unisexual. They show sexual dimorphism, i.e., male and female sexes can be seen externally. They are oviparous. The young cockroaches called nymphs resemble the adults in many features. The nymph undergo moulting or ecdysis in which the casting of older skin takes place. The nymph gradually become adults under the parental care.
The cockroaches are tropical and sub-tropical insects, but they have reached all parts of the world with trading ships. They are good enough to adapt to new habitats.

Habitat

Cockroaches inhabit the warm, dark and damp places. They are commonly found in underground drains, kitchens, restaurants, godowns, store houses, railway wagons, ships, etc., where food and moisture is available.

Habits

Cockroaches show some peculiar habits. They are nocturnal, i.e., come out of their hiding places at night to feed. These are omnivorous and eat all types of animals and vegetable v foods.

Morphology

The body of cockroaches is dorsoventrally flattened, elongated and bilaterally symmetrical. The adult cockroach is about 34-53 mm long with wings that extends beyond the tip of the abdomen in males.
The entire body of cockroach is covered by a hard chidnous exoskeleton (brown in colour) made of tough plates called sclerites. These are formed of chidn, a polysaccharide of acetoglucosamine molecule. ,

The exoskeleton protects the body and provides space for the attachment of muscles. The adjacent sclerites are joined together by thin, soft, flexible arthroidal membranes.
Head Antenna

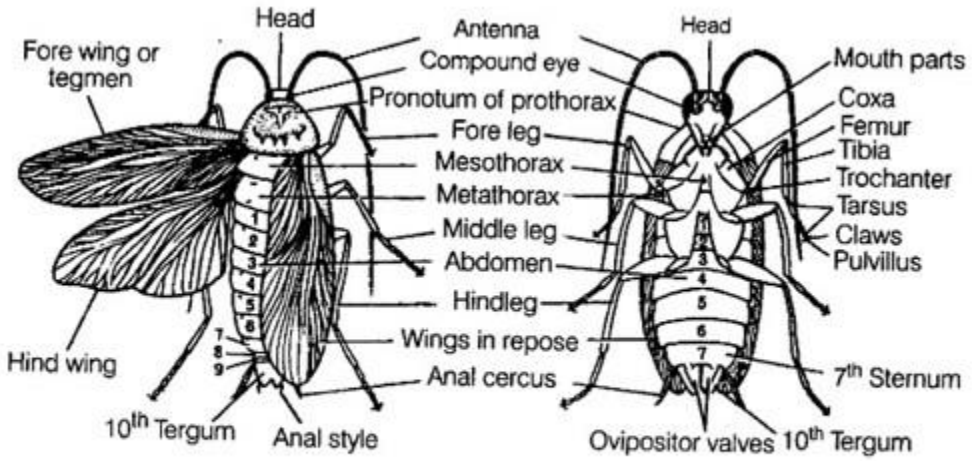


Fig. 7.26 Cockroah (a) Male cockroach (dorsal view) left wings raised
(b) Female cockroach (venteral view)

The body of cockroach is segmented and divisible into three parts, i.e., head, thorax and abdomen.

Head

The head of cockroach is triangular in shape and lies anteriorly at right angles to the longitudinal

body axis. It is formed by the fusion of six embryonic segments. It is flattened anteroposteriorly and movably articulates with the thorax by a short neck. It is covered by sclereites and bear sense organs, mouth parts and mouth. The sclerites of head are fused to form a compact head capsule called vertex.

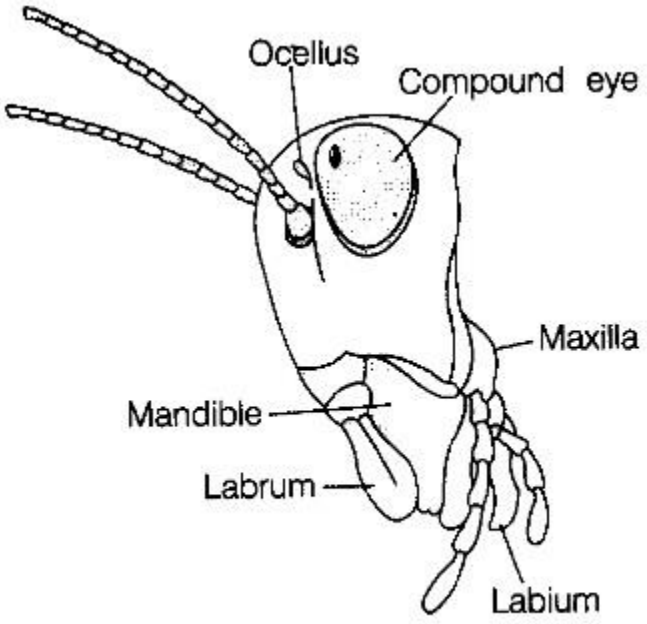


Fig. 7.27 Part of head region of Cockroach

Sense Organs

The sense organs in cockroach includes compound eyes, antenna and fenestrae or ocellar spots.

(i) Compound eyes are a pair of large, black, kidneyshaped organs situated dorsoventrally on the head, one on either side. Their surface is marked by a large number of hexagonal areas called facets. The eyes are the organs of sight.

(ii) Antenna are a pair of long, slender, jointed, tapering j filaments that articulates in the antennal sockets situated on the frons, close to the compound eyes. The antenna are organs of touch and smell. They can be moved in all directions to receive the stimuli. Antenna is made up of many segments called podomeres.

(iii) Fenestrae are a pair of small, whitish spots, each lying just above the inner to the antennal socket of its side, They are sensitive to light.

Mouth

It is a narrow opening that lies at the base of the pre-oral cavity. It is bounded by the mouth parts and leads into the pharynx. The mouth parts of cockroach are of biting and chewing type. They also help in swallowing. The mouth parts are attached to the head capsule.

The mouth parts include the following structures

(a) Labrum is also called upper lip that helps in holding food particles during feeding.

(b) Mandibles lie on the sides of the mouth just behind the labrum. The two mandibles work against each other in a horizontal plane to crush and cut the food into pieces.

(c) First maxillae are a pair of maxillae that lie beneath the mandibles, one on either side of the head.

(d) Second maxillae or labium is also called lower lip. It is a single structure, but it is formed by the fusion of a pair of second maxillae. It lies behind the mouth and forms a type of lower lip.

Neck

It is a slender, flexible (can move in all direction) tube articulating the head with the thorax. It is supported by a few ring-like sclerites.

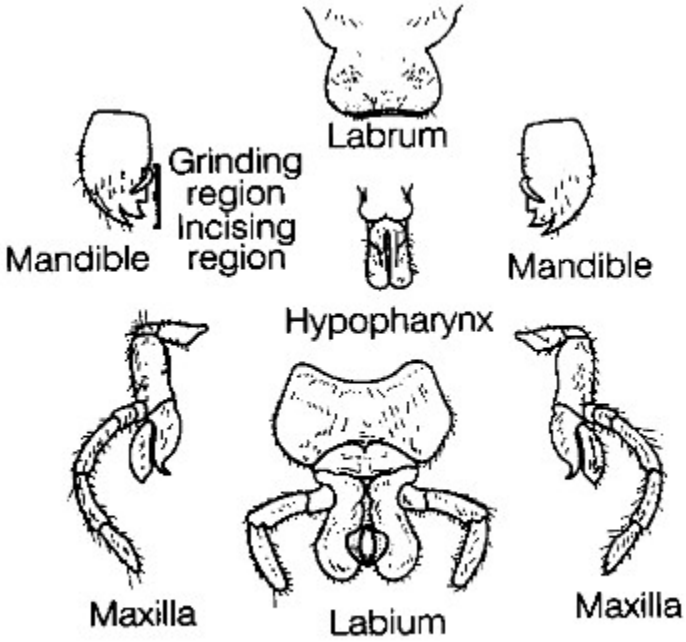


Fig. 7.28 Parts of Mouth of Cockroach

Thorax

The thorax forms the middle part of the body. It consists of three segments, the anterior prothorax, the middle mesothorax and the last metathorax. Each thoracic segment bears a pair of waiting legs. The thorax also contains spiracles for gas exchange.

Each thoracic segment is enclosed by four chitinous skeletal sclerites, a dorsal tergum, a ventral sternum and two lateral pleura. The tergum of the prothorax is called the protergum or pronotum.

The tergum of the mesothorax is called mesotergum or mesonotum. The tergum of metathorax is termed the metatergum or metanotum. The sterna of all the thoracic segments are largely covered by the legs.

The thorax contains three pairs of kgs and two pairs ofwings

(a) Legs are jointed and a pair is present in each thoracic segment which are three in number. Based on the segment that bears them, legs are prothoracic, mesothoracic and metathoracic or simply prolegs, mesolegs and metalegs. They articulate with their respective segment between the sternum and the pleura.

(b) Wings These are paired structures, one on the mesothorax (forewings) and another on the metathorax (hindwings). The wings are movable folds of the integument that grow out from the region between the tergum and the pleura near the anterior end of the segment.

Forewings called tegmina are opaque dark and leathery, used to cover the hindwings when they

are at rest. While hindwing are transparent membranous and are used in flight.
They bear two thin sheets of cuticle with a framework of branching tubes, the veins or nervures.

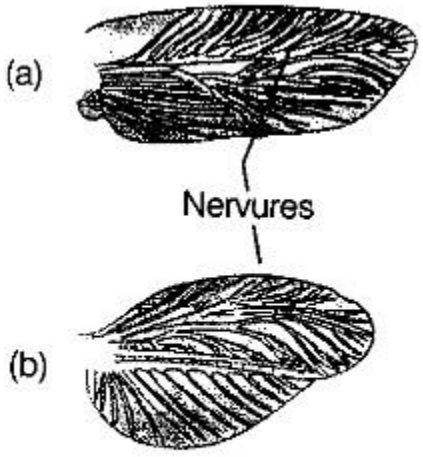


Fig. 7.29 Wings of cockroach
(a) Mesothoracic (b) Metathoracic wing

Abdomen

It is the posterior most and the largest part of the body. It is composed of ten segments in adults and eleven in the embryo. It is dorso-ventrally flattened, broader at the anterior end and narrow posteriorly.
Each abdominal segment bears sclerites. Certain segments have spiracles and stink glands. The terminal segments carry appendages and some apertures.
An abdominal sclerite is enclosed by four sclerites, a dorsal tergum, one ventral sternum and two lateral pleura.
There are ten terga. The 7th tergum covers the 8 th tergum in male and 8th and 9th terga in the female cockroach. The 10th tergum is large and notched in the middle. It projects backwards beyond the body. The abdomen bears 9th sterna, while the 10th one is absent. In male, all the nine sterna are visible and in female, only the first seven can be seen.
The abdomen in both male and female cockroaches comprises of 10th segments. In females, the 7th sternum is boat-shaped and together with 8th and 9th sterna forms a genital pouch.
In males, genital pouch lies at the hind end of the abdomen. It contains dorsal anus, ventral male genital pore and gonapophyses. The abdomen of female cockroach is broader than the male cockroach.
Male bears a pair of short thread like anal styles which are absent in females.
Abdominal Appendages

The abdomen bears small appendages at its hind end only. These appendages are a pair of anal cerci, (joined filamentous structures found in both sexes) a pair of anal styles and gonapophysis or external genitalia.

Apertures

The abdomen bears following three apertures
(a) Anus lies beneath the 10 th tergum between the two chitinous plates. These are called podical plates or paraprocts. They represent the remains of the eleventh segment.
(b) Genital aperture of the male cockroach lies just below the anus on one of the gonapophyses and that of female lies on the eighth sternum in the broad pouch.
(c) Abdominal spiracles are the eight pair structures. They are smaller than the thoracic spiracles.
(d) Stink glands A pair of stink gland is present between the 5th and 6th abdominal terga. These glands produce a secretion that gives a characteristic stinky smell.

Anatomy

The anatomical structure of different parts of cockroach body is described below

Body Wall

The body wall contains cuticle, epidermis and basement membrane. The cuticle is impermeable to water because of its thick, non-cellular surface layer. The epidermis consists of a single layer of columnar cells, enclosing some gland cells.Body Cavity

Cockroaches are coelomate. But, true coelom occurs only in embryonic stage. In adults, it is found in small cavities only around the gonads. The body cavity is filled with haemolymph and is called haemocoel.

Endoskeleton

Certain processes of exoskeleton extend into the body and forms endoskeletal elements. These provide attachment to the muscles and hence called apodemes.
Abdomen of cockroach does not have endoskeletal elements.

Digestive System

The alimentary canal of cockroach is 6-7 cm in length.
It is divisible into following three parts
a. It is the anterior part of the alimentary canal. It is surrounded by the mouth parts. Food is crushed initially by mandibles and mixed with saliva and passed to the short tubular pharynx. The pharynx inturn bends to join a narrow tubular passage called oesophagus, whichs passes through the neck and opens into a sac like structure called crop (a large pear shaped sac that stores the food).
From crop, the food enters a conical and muscular part called gizzard or proventriculus having, outer layer of thick circular muscles.
The gizzard has six large chitinous teeth. (Formed by inner culide layer) and fine bristles in ks grooves.

Therefore, it is efficient in grinding of food particles and straining apparatus.
Gizzard marks the end of foregut. The whole foregut is lined by cuticle protecting the alimentary canal from rough food particles. Its posterior end projects in the form of a narrow tube into the midgut, called stomodael valve.
b. It is a short, narrow tube of uniform diameter, lined by endodermal glandular epithelium. A ring of 6-8 blind tubules called gastric or hepatic caeca present at the junction of foregut and midgut secrete digestive juices. The midgut is the major organ of digestion and absorption of digested food.
The posterior part of the midgut has a sphinter that keeps it closed.
c. It is broader than the midgut and is divisible into ileum, colon and rectum. Ileum is short and

narrow bearing short spines. A ring of about 100-150 fine yellow coloured thread like filaments. Malpighian tubules is joined to the beginning of the ileum. Colon is a wide coiled tube which do not contain spines while, rectum is the last part of the hindgut.
The papillae present in the rectum absorb water and salts from the undigested food. The rectum thus, opens outside by anus (which lies below the 10th tergum.)

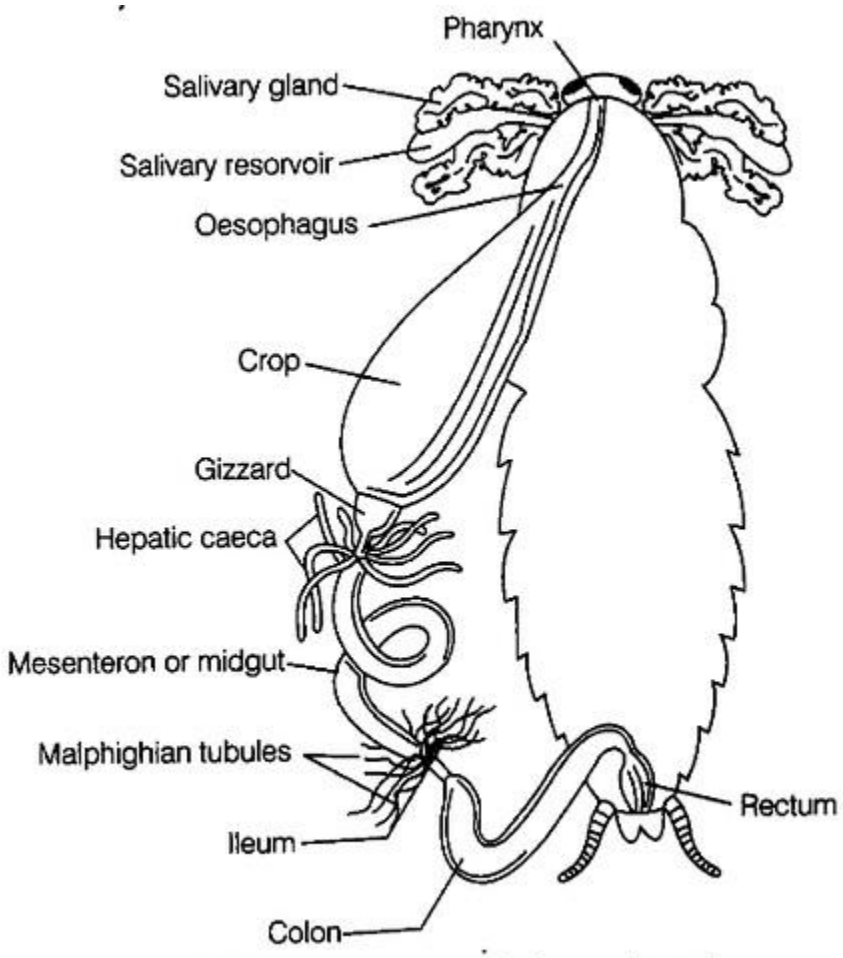


Fig. 7.30 Alimentary canal of a cockroach

espiratory System
The respiratory system is comprised of a network of blind, glistering white air tubes called tracheae. The tracheae are connected to outside by 10 pairs of lateral apertures called spiracles. Two pairs of spiracles occur in thorax and eighth pairs are present in the abdomen. During rest, some of the spiracles are open so, that the oxygen can diffuse continuously reaching the body fluid present in the terminal region of the tracheoles. Exchange of gases occurs between the living cells and the body fluid. Expansion of abdomen draws fresh air into the tracheal system through stigmata and its contraction expels foul air.

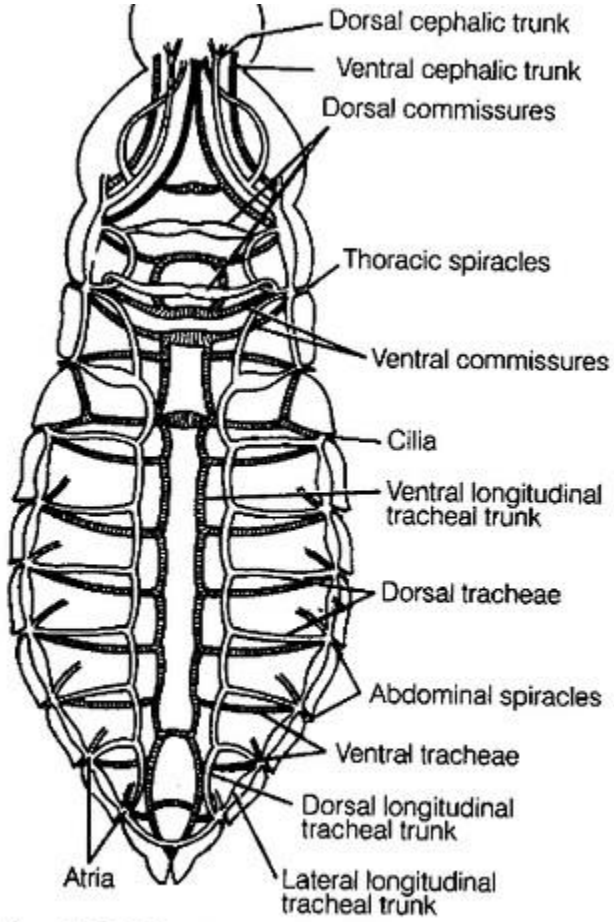


Fig. 7.31 Tracheal system of a cockroach (in ventral view)

Circulatory System

The circulatory system of cockroach is of open type. The blood vessels are poorly developed and blood flows freely in the body cavity which is called haemocoel. Visceral organs located in the haemocoel are bathed in blood (haemolymph).

It contains colourless plasma and corpuscles called haemocytes.

Each heart chamber opens into next chamber through a ventricular valve. Each chamber has a pair of incurrent pores called ostia (which possess valvular mechanism to pass the blood only from haemocoel to the heart chambers).

The heart chambers contract one after the other rapidly. This pushes the blood into the anterior aorta as well as a few lateral or excurrent arteries. From aorta, blood passes into head sinuses and then into perivisceral and perineural sinuses.

Excretory System

Cockroach is urecotelic, i.e., main excretory product of it is, uric acid. The. main excretory organs of cockroach are Malpighian tubules.

The tubules are lined by cuboidal, brush bordered, glandular cells that extract the nitrogenous waste matter from the haemolymph and discharge it into the ileum as uric acid.

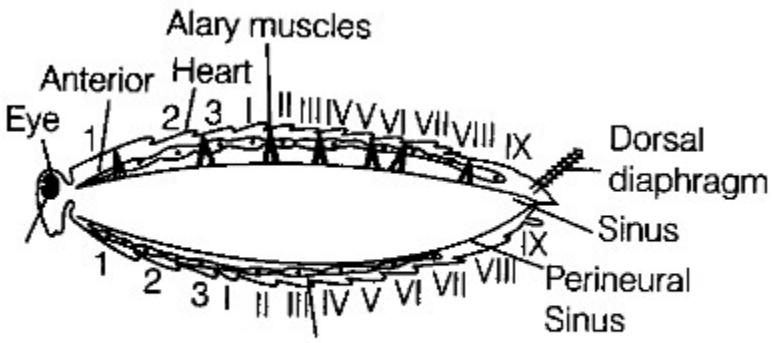


Fig. 7.32 Circulatory system of a cockroach

In rectum, the epithelial lining picks up most of the salts from urine and transport it into the haemolymph. Urine becomes nearly solidified and eliminates along with faces.
In addition to this, the fat body, nephrocytes and urecose glands also helps in excretion.

Nervous System

The nervous system of cockroach consists of a series of fused, segmentally arranged ganglia joined by paired longitudinal connectives.
Three ganglia lie in the thorax and six in the abdomen. The nervous system of cockroach is spread throughout the body. The head holds a bit of a nervous system while, the rest is situated along the ventral part of the body.
In the head region, the brain is represented by supra-oesophageal ganglion, which supplies nerves to antenna and compound eyes. Nerves arise from all the ganglia in the head, thorax and abdomen and innervate various parts in their respective regions.

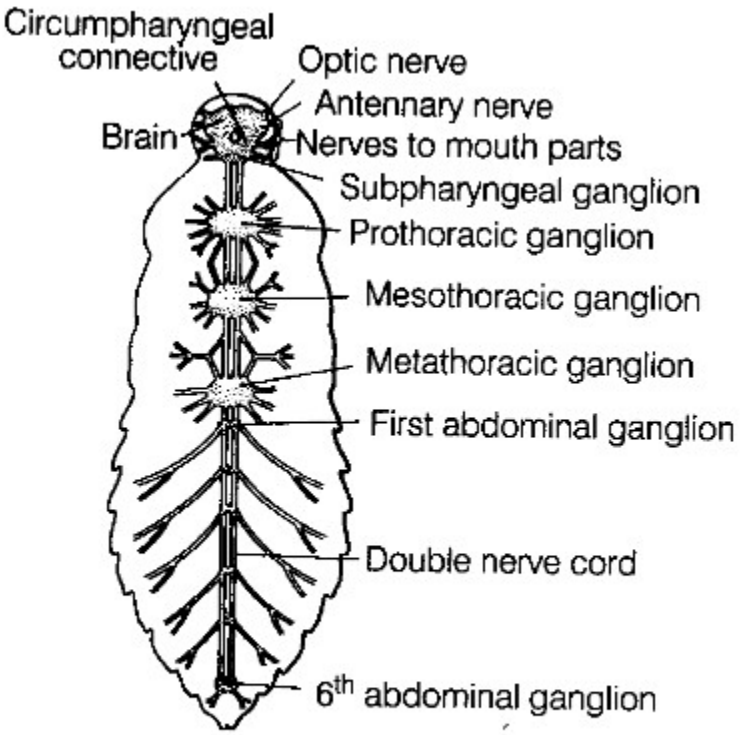


Fig. 7.33 Central and peripheral nervous system of a cockroach

he sense organs in cockroach, are antenna, eyes, maxillary palps, labial palps, anal cerci, etc. The compound eyes are situated at the dorsal surface of the head. Each eye consists of about 2000 hexagonal facets or ommatidia (each capable of forming an image in it).

Reproductive System

Cockroaches are dioecious animals, i.e., both the sexes have well developed reproductive organs.

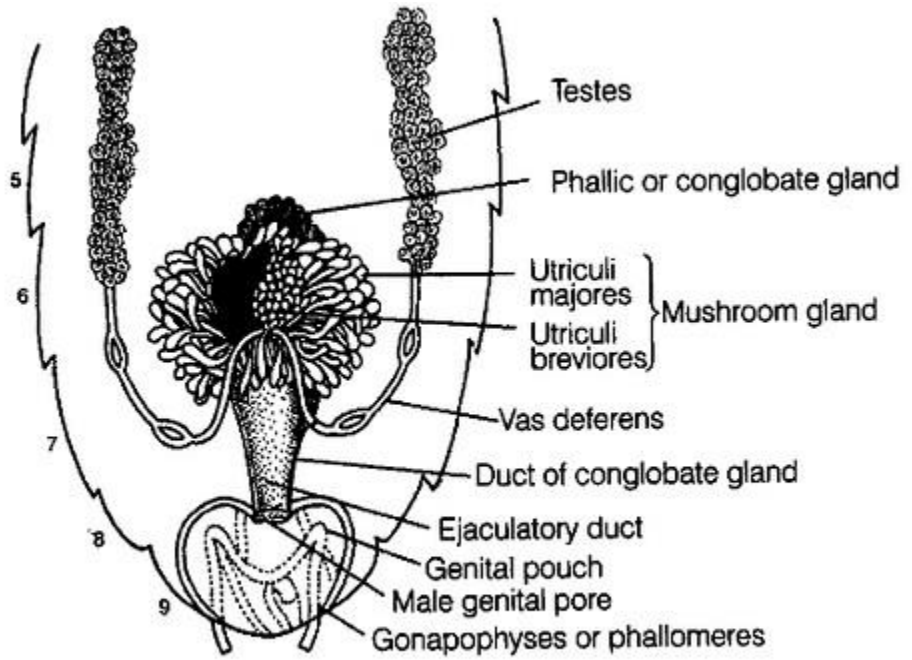


Fig. 7.34 Male reproductive organs of Cockroach (in dorsal view)

It consists of a pair of testes lying one on each lateral side in the 4th-6th abdominal segments. From each testis arises a thin vas deferens which opens into ejaculatory duct through seminal vesicle.

The ejaculatory duct opens into male genopore situated ventral to the anus. A characteristic mushroom shaped gland is present in the 6th-7th abdominal segments which functions as an accessory reproductive gland.

The external genitalia are represented by male gonapophysis or phallomere (chitinous asymmetrical structures surrounding the male gonopore). The sperms are surrounded in the seminal vesicles and are glued together in the form of bundles called spermatophores, which are discharged during copulation.

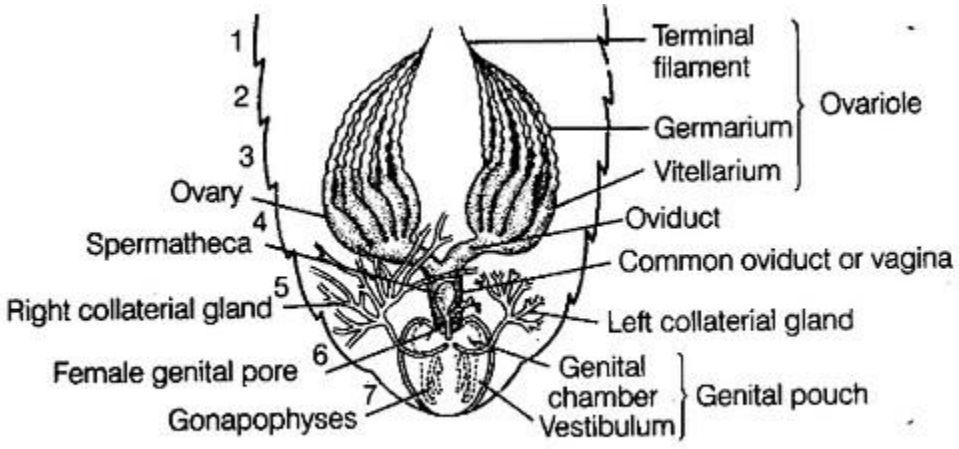


Fig. 7.35 Female reproductive organs of Cockroach (in dorsal view)

The male and female cockroaches come together by their posterior ends. The spermatophores are transferred to the genital chamber of the female. The sperms are liberated from the spermatophores and reaches the left spermatheca slowly.
The eggs come from both the ovaries alternately into the common oviduct and passes through the female genital pore into the genital chamber where they are fertilised by the sperms coming from the left spermatheca.
The secretion of collateral glands form the egg case of the ootheca (ploothecae). The fertilised eggs are encased in oothecae. Ootheca is a dark reddish to blackish-brown capsule, about 3/8″ (8 mm) long.
The oothecae are dropped to a suitable surface, usually in a crack or crevice of relatively high humidity near a food source. On an average, females produce 9-10 oothecae, each containing 14-16 eggs.

Economic Importance of Cockroaches
Many species of cockroaches are wild and are of no economic importance. A few species thrive in and around human habitat. They damage and destroy household objects such as eatables, clothes, shoes, etc. They also carry harmful germs of diseases like diarrhoea, cholera, typhoid, tuberculosis, etc.
The contaminate food items with their smelly excreta. The animals like frogs, toads, lizards, birds and snakes, etc., eat cockroaches. Thus, they form the part of food chain. They are used in laboratories as experimental animals.
Distribution
Frogs are widespread in tropical and temperate regions. There are about 2600 species of frogs all over – the world. In India, four species of frogs are mainly found. ”
These are as follows
(i) Rana tigrina Most widely distributed found all over the world except in countries like Australia, New Zealand and Southern South America and largest species of India.
(ii) Rana cyanophlyctis Found in Rajasthan, UP and MP.
(iii) Rana malabaricus Common in Maharashtra.
(iv) Rana temporaria Common British frog.

Habitat and Habit
Rana tigrina is the most common frog found in India. It is also called bull frog because, of its large and loud call. It is found in or near freshwater, marshes, ditches, ponds and shallow water bodies. It has various reasons to lead amphibious (Amphi — two; bios — life) life, such as
(i) It can respire both through skin and lungs.
(ii) Frog breeds in water and spends its early life in water.
(iii) It is unable to drink water and absorbs it through the skin. Hence, it lives near the water.
(iv) It gets its food, from live insects, worms and spiders mosdy near the water.
The important habits of frog are described below
Feeding
Frog feeds on insects, worms and spiders, etc. It is. carnivorous. The prey is captured with the help of tongue.
ii. Locomotion
The frog usually shows three types of locomotion such as

(a) Swimming The body of frog is boat-shaped. During swimming, the hindlimbs are alternately folded and strengthened quickly. The backward stroke of hindlimbs pushes the body forward and thus, the animal swims.
(b) Leaping The frog moves on land by leaping. In leaping, the hindlimbs are folded and strengthened alternately. When the hindlimbs are extended, the frog's body is pushed forward and upward in the air.
(c) Walking During walking, each limb is lifted, swing forward and placed on-the ground again.

ii. Breeding

Frogs breed in rainy season. The male frog produce a high pitched croaking sound to attract the female. The male frog lacks copulatory organs. The sexual embrace in which the eggs and sperms are discharged in water is called amplexus or false copulation.
It is a characteristic of amphibians. The shedding of oocytes (eggs) by the female at the end of amplexus is called oviposition. The shedded oocytes and sperms remain embedded in a jelly like sac called as spawn. Fertilisation in frogs is exterrtal. The fertilised eggs develop into fish like tailed larvae, the tadpoles, which respire through gills. It feeds on plant matter (herbivore) and gradually develops into adult frog.

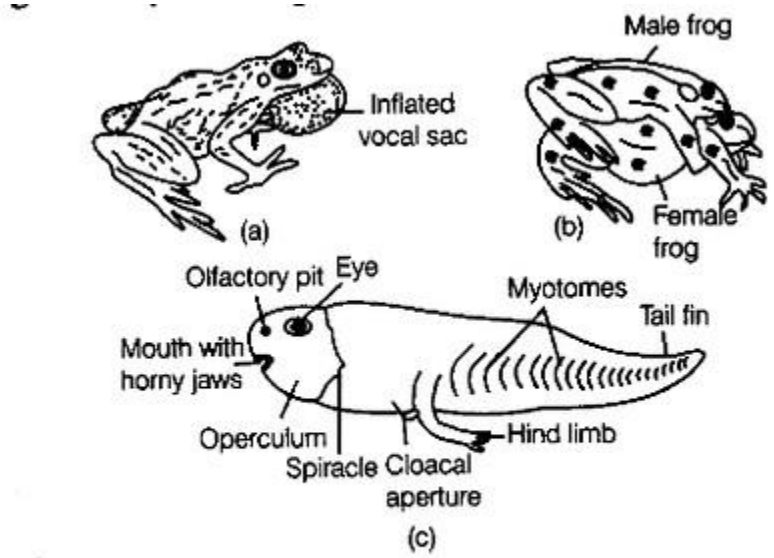


Fig. 7.36 (a) An inflated vocal sac of frog during breeding season (b) Frogs in amplexus (c) Tadpole of frog

v. Hibernation and Aestivation

Frog is a cold-blooded (poikilothermic) animal. Its body temperature fluctuates according to its surrounding temperature. To avoid the adverse conditions of environment, frog burrows inside the soil and lies in a " state of rest or sleep during summers and winters.
The resting condition in winter is called hibernation or winter sleep and the condition of rest in summer is called aestivation or summer sleep.

v. Defences

Frogs escape from their enemies by several ways. If chased, they leap away to safe places or

jump into water. They can also darken or lighten their green shade to blend with the background and thus prevent easy detection (camouflage). This protective colouration is called mimicry.

Morphology

The frog has an ovoid, streamlined and slighdy flattened body. It is about 10-15 cm long and shows bilateral symmetry, i.e., its right and left halves are mirror images of each other.

The skin of frog is naked, smooth, moist and slippery. A thin film of mucus is secreted by the cutaneous glands present in the skin. The body of frog is divisible into head and trunk. It is to be noted that neck and tail in frogs seem to be absent.

The head is triangular in shape with a blunt snout. It bears mouth, external nares, eyes, browspots and ear drums on the upper side and throat on the lower side.

The mouth extends along the entire border of the head. It is bounded by upper and lower jaws. (The lower jaw is toothless in frogs). The mouth gets open only during feeding.

At the top of anterior end, the head bears two small apertures called external nares. Air enters and leaves the body through the nares.

Eye

A little behind the nostrils, two large eyes are present, > situated along the sides. The eyes are spherical and protruded laterally.

Each eye has a thick upper and a thin lower eyelid. The upper part of the lower eyelid is modified into a transparent fold called nictitating membrane. This membrane protects the eye and is pulled over the eyeball when the frog is in water or under the mud and frog can see through it.

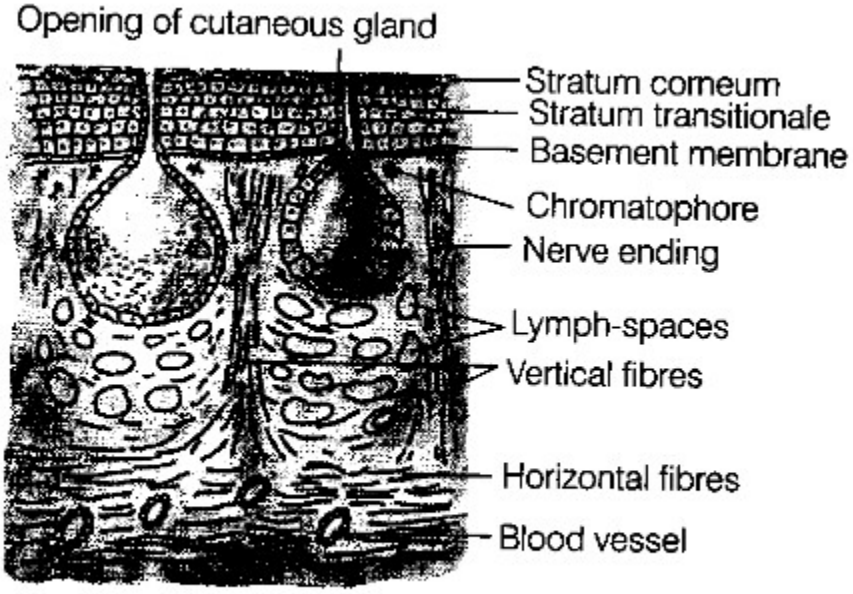


Fig. 7.37 VS of skin of frog

Coelom

The body cavity is a true coelom and large having two pans, a very small pericardial cavity around the heart which contains pericardial fluid and a very large pleuroperitoneal cavity around the other viscera that have coelomic fluid except the kidneys.

Both the fluids are watery, colourless and secreted by peritoneum.

Digestive System

The alimentary canal of frog is short because frogs are carnivores and hence, the length of intestine is reduced. It contains, mouth, buccopharyngeal cavity, oesophagus, stomach, small intestine, rectum and cloaca.

(a) Mouth It is present as a wide opening which opens into bucco-pharyngeal cavity. In frog teeth are not used for chewing but they prevent the escape of live food.

Mouth opens into the buccal cavity that leads to oesophagus through pharynx.

(b) Oesophagus It is a narrow, short tube, which continues in large and distended stomach.

(c) Stomach It helps in converting the food into chyme and secretes gastric juice containing HC1 and proteolytic enzymes.

(d) Intestine It is a coiled structure continued with the stomach. The intestinal wall has several finger-like folds called villi and microvilli, projecting into its lumen to enhance the surface area of absorption for digested food. The first part of small intestine lying parallel to stomach is called duodenum. The duodenum is followed by ileum. Small intestine continues into a wider rectum which opens into a cloaca.

A litde behind and below the eye on each side of head, a circular patch of tightly stretched, dark skin is present. This is called tympanic membrane or tympanum or eardrum. It receives sound waves.

The floor of the head is occupied by a soft throat. In a male frog, there is a pair of bluish-wrinkled patches of skin called vocal sacs. They help in intensifying the croaking sounds.

Trunk

The trunk contains an anterior portion called thorax and a posterior larger portion called abdomen. A pair of forelimb and hindlimb is attached to the trunk. Each forelimb has an upper arm, a forearm and a hand. The hand has a wrist, a palm and four digits.

Each hindlimb consists of an upper thigh, a middle shank and a lower foot. The foot has an ankle, a sole and five digits. The digits are joined together by a fold of skin called web.

At the end of the trunk, between the hind legs, there is a circular aperture called cloacal aperture through which faeces, urine and gametes passes out.

Anatomy

The body cavity of frogs accomodate different organ systems such as digestive, circulatory, respiratory, nervous, excretory and reproductive systems with well-developed structures and functions.

Skin

The skin of frog consists of an outer epidermis and inner dermis. Epidermis is the outermost, non-vascular layer made up of stratified epithelium. The innermost layer of epidermis consists of Malpighian layer or stratum germinativum.

Dermis layer contains mucous glands and poison glands. The poison glands secrete poisonous fluid which protects the frogs from their enemies.

(e) Pulmonary respiration occurs by the lungs and is less frequent than the cutaneous and

buccopharyngeal respiration. It occurs when more oxygen is required.The urinary bladder opens into cloacal chamber through ureter. The cloaca opens externally by a cloacal aperture. This aperture serves both as an anus and as urinogenital pore.

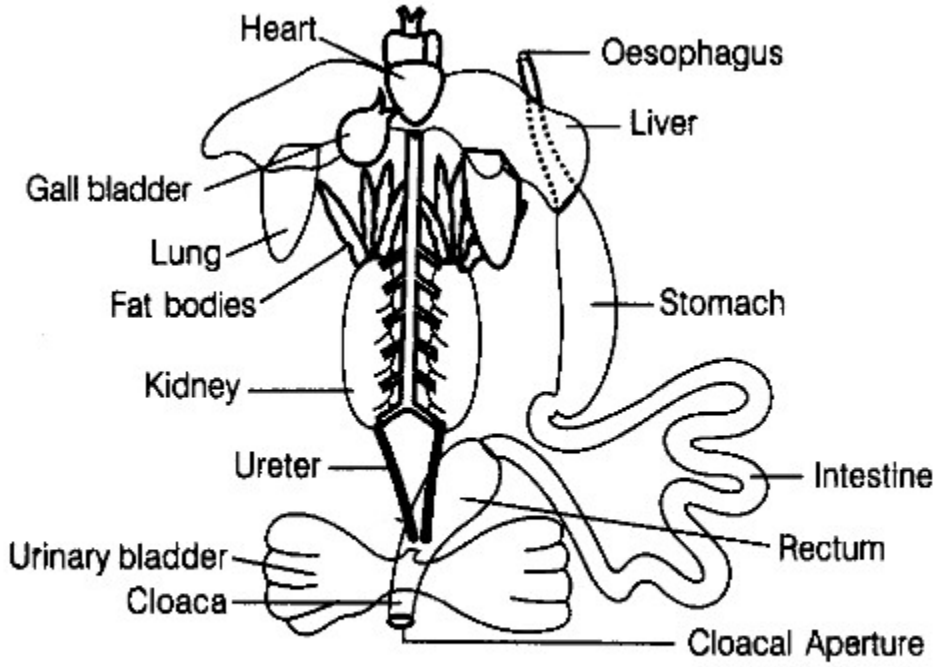


Fig. 7.38 Diagrammatic representation of internal organs of frog showing complete digestive system

The lungs are a pair of elongated, pink coloured sac-like structures present in the upper part of the trunk region (thorax). Air enters through the nostrils into the buccal cavity and then to lungs. The exchange of gases occurs by diffusion in all the three modes of respiration.

Circulatory System

The circulatory system of frog is well developed and is of closed type. It also has a lymphatic system. The blood vascular system includes the heart, blood and blood vessels. The lymphatic system consists of lymph, lymph channels and lymph nodes.

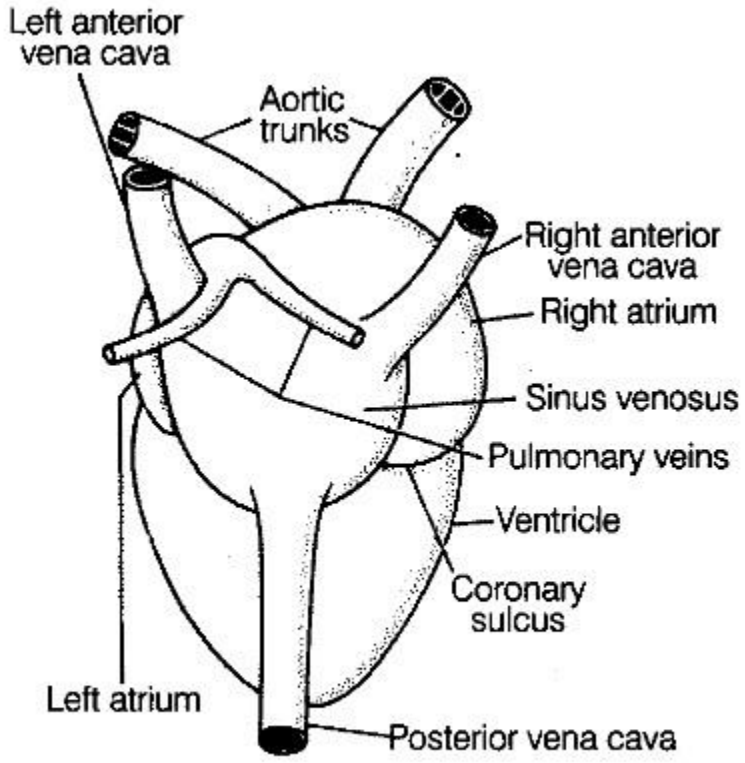


Fig. 7.39 Frog's heart (dorsal view)

The digestive glands include gastric glands, intestinal glands, liver and pancreas. The gastric glands secrete gastric juice and the intestinal glands secrete intestinal juice, which contains a number of digestive enzymes.

The liver produces bile which is temporarily stored in the gall bladder before being released info duodenum. Pancreas is an irregular, elongated gland that produces pancreatic juice containing several digestive enzymes.

Digestion of Food

The digestion of food takes place by the action of HCI and gastric juices secreted from the walls of stomach. The partially digested food called chyme is passed from stomach to the first part of the intestine, the duodenum.

The duodenum receives bile from gall bladder and pancreatic juice from the pancreas through a common bile duct. Bile emulsifies fat and pancreatic juices digest carbohydrates and proteins. Final digestion occurs in the intestine. Digested food is absorbed by the numerous finger-like folds in the inner wall of intestine called villi and microvilli. The undigested solid waste moves into rectum and passes out through cloaca.

espiratory System

Frogs respire by three modes of respiration

(a) Cutaneous respiration occurs through moist skin of the frog. Frogs respires only by the skin when under water or deep under the mltd.

(b) Buccopharyngeal respiration occurs when the animal is on land or partially immersed in water. It occurs by

* thin, vascular, moist lining of buccopharyngeal cavity.

It is a muscular structure situated in the upper part of body cavity. It has three chambers, i.e., two atria (sing, atrium) and one ventricle. The heart is covered by a membrane called pericardium.

There are two accessory chambers in the frog's heart, a tubular truncus arteriosus placed on the ventral side of the right auricle and a triangular sinus venosus present on the dorsal side of the heart.

Left anterior

Sinus venosus receives blood through the major veins called vena cava and opens into right auricle.

The left auricle receives oxygenated blood from the lungs by a common pulmonary vein. The auricles send their blood into ventricle where the blood gets mixed up. The ventricle opens into a sac-like conus arteriosus on the ventral side of the heart.

Nervous System

The system for control and coordination is highly evolved in the frog. It includes both nervous system and endocrine system. The nervous system of frogs consists of a central nervous system, a peripheral nervous system and an autonomic nervous system.

It includes brain and spinal cord. The brain is enclosed in a bony structure called cranium or brain box and the spinal cord lies inside the vertebral column. The brain is classified as forebrain, midbrain and hindbrain.

The forebrain consists of olfactory lobes, paired cerebral hemispheres and unpaired diencephalon.

The midbrain comprises paired optic lobes and the hindbrain comprises cerebellum and medulla oblongata. The medulla oblongata thus, passes out through the foramen magnum and continues into spinal cord present in the vertebral column.

It contain nerves arising from the central nervous system and extending into the organs of the body. Ten pairs of cranial nerves arises from the brain and nine pairs of spinal nerves supply the trunk and limb regions.

It consists of sympathetic nervous system of two ganglionic chains and parasympathetic nervous system of isolated ganglia in the viscera. The autonomic nervous system controls the functions of organs that are not under the voluntary control.

Sense Organs

The frogs have different types of sense organs such j as organs of touch (sensory papillae), taste (taste buds), smell (nasal epithelium), vision (eyes) and hearing (tympanum with internal ears), Out of these, eyes and ears are well organised structures and the rest are cellular aggregations around the nerve endings. Eyes in a frog are a pair of spherical structures situated in the orbit present in the skull. These are simple eyes.

External ear is absent in frogs and only tympanum can be seen externally. The ear is an organ of hearing as well as balancing (equilibrium).

Special venous connection between liver and intestine as well as the kidney and lower parts of the body are present in frogs. The former is called hepatic portal system and the latter is called renal portal system.

The blood vessels found in frogs are arteries, arterioles, veins, venules and blood capillaries. Arteries carry blood from the heart to different body parts. Veins bring blood from different body

parts to the heart. Arteries further divide to form arterioles. The arterioles branch out to form capillaries, which further unite to form venules. The venules thus, join to form veins (which have valves to prevent backflow of the blood).
The blood is composed of plasma and blood cells. The blood cells are RBCs (Red Blood Cells) or erythrocytes, WBCs (White Blood Cells) or leucocytes and platelets. RBCs are nucleated and contain red coloured pigment namely haemoglobin.

The lymphatic system comprises of lymph vessels, lymphatic channels and lymph. Lymph is a mobile connective tissue filtered out from the blood through capillaries. It contains plasma and white corpuscles and lacks red blood cells,
Lymph in the body always flows in following direction Lymph capillaries —> Lymph sinus —> Lymph hearts —> Veins

Excretory System

The elimination of nitrogenous wastes is carried out by a well-developed excretory system.
The excretory system consists of a pair of kidneys, ureters, cloaca and urinary bladder. The kidneys are compact, dark red and bean like structure, situated little posterior in the body cavity on both sides of vertebral column.
Each kidney is composed of several structural and functional units called uriniferous tubules or nephrons. Each nephron is the structural and functional unit of kidney. The Bowman's capsule leads into a coiled, urinary tubule. The urinary tubule opens into transverse collecting tubules, which ultimately communicate with the ureter or urinogenital duct.

In females, the ureters and oviduct open separately into the cloaca. The thin-walled urinary bladder is present ventral to the rectum which also opens in the cloaca.
" The frog excretes urea and thus is a ureotelic animal. The excretory wastes are carried by blood into the kidney where these are separated and excreted.

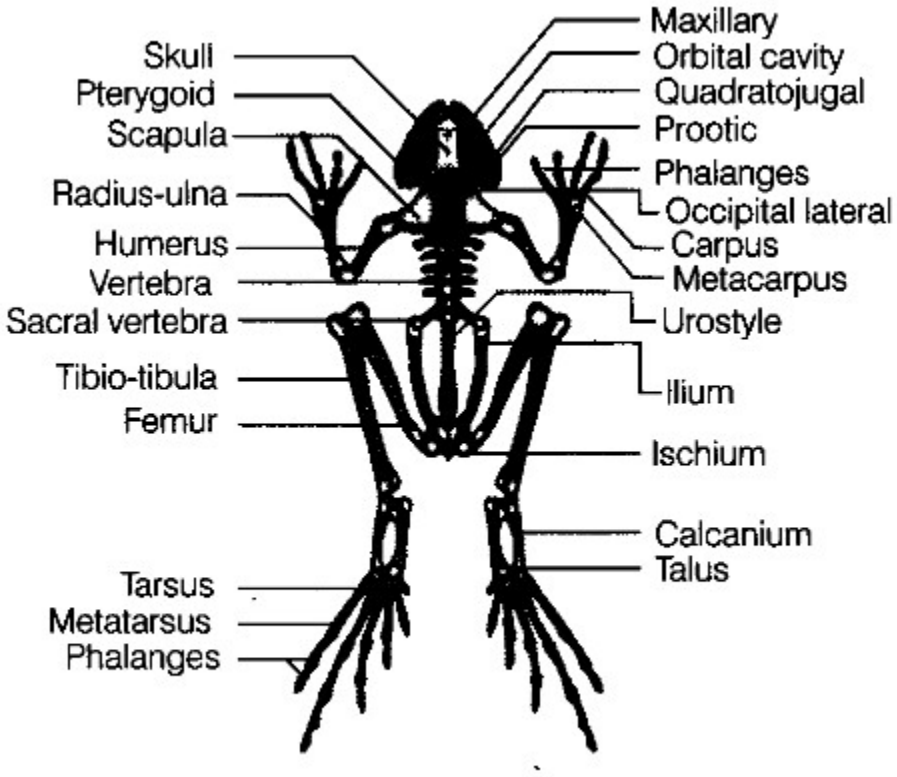


Fig. 7.40 Skeleton of frog

Endocrine System

The chemical coordination of various organs of the body is carried out by hormones, which are secreted by the endocrine glands. The prominent endocrine glands found in the frog are pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals and gonads.

Skeletal System

In frog exoskeleton is absent. The endoskeleton has two parts

(i) Axial skeleton that includes skull located in the head and vertebral column situated in the trunk. Appendicular skeleton includes limb bones in the arms and legs and girdles (pectoral and pelvic) that connects the limb bones with vertebral column. The skull consists of cranium, sense capsules and jaws. Vertebral column consists of 9 ring like vertebrae and a long urostyle. Each forelimb contains many bones namely, a humerus in the upper arm, a radioulna in the forearm, carpals in the wrist, metacarpals in the palm and phalanges in the fingers.

Each hindlimb consists of many bones namely, a femur in the thigh, a tibiofibula in the shank, tarsals in the ankle, metatarsals in the instep and phalanges in the toes.

Frogs have well organised male and female reproductive system. It shows sexual dimorphism.

Maxillary Orbital cavity Quadratojugal Prootic Phalanges Occipital lateral Carpus Metacarpus Urostyle

Hiium

Ischium

Calcanium

Talus

It includes a pair of yellowish, ovoid testes which are found adhered to the upper part of the

kidneys by a double fold of peritoneum called mesorchium.
From testes, 10-12 vas efferentia arises. They enter the kidneys on their side and open into Bidder's canal. The urinogenital duct comes out of the kidneys and opens into the cloaca. The cloaca is a small, median chamber that is used to pass faecal matter, urine and sperm to the exterior.

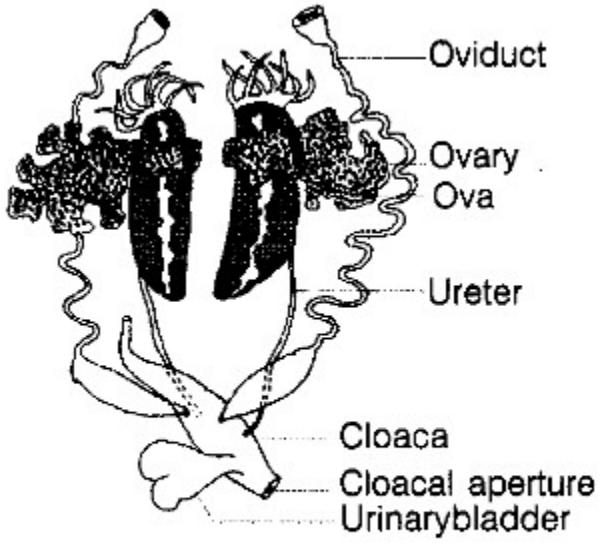


Fig. 7.41 Male reproductive system

t consists of a pair of ovaries situated near the kidneys and there is no functional connection with kidneys. A pair of long oviducts from ovaries opens into the cloaca. Ovaries release about 2500-3000 eggs at a time.
The eggs are released in water, so, the fertilisation is external. Development is indirect. A fish-like tailed larva called tadpole is formed. The tadpole undergoes metamorphosis to form an adult in about three months.

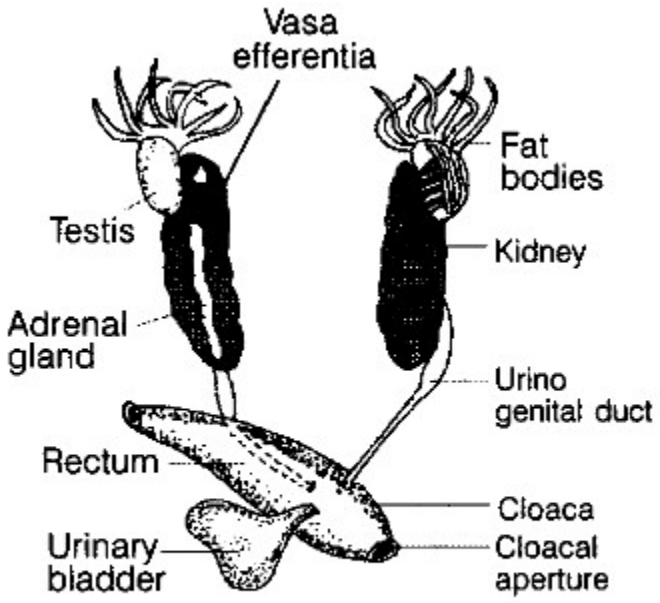


Fig. 7.42 Female reproductive system

Frog is a useful animal for humans in following ways

(i) It feeds on insects which destroy crops and frogs eat up mosquitoes, which are the carriers of various diseases.

(ii) The muscles of legs of frogs are used as food in some parts of India and many other countries.

(iii) Baby frogs are used as fish baits, (any substance which is used to attract or catch fish).

(iv) Frogs are used for researches in medical science and pharmacology.

(v) They help to maintain ecological balance by forming an important part of food chain.