ZOOLOGY AND BOTANY PRACTICAL

SC–126

Self Learning Material

Directorate of Distance Education

SWAMI VIVEKANAND SUBHARTI UNIVERSITY
MEERUT–250 005
UTTAR PRADESH

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Study Material Assessment Committee, as per the SVSU ordinance No. VI (2)

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Published by : Pragati Prakashan, 240 W.K. Road, Meerut
Tel. : 2643636, 2640642, 6544643, E-mail : pragatiprakashan@gmail.com

Typeset by : Pragati Laser Type Setters (Pvt.) Ltd., Meerut Printed at : Arihant Electric Press, Meerut

EDITION : 2016

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SYLLABUS

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BOTANY

Laboratory Requirements : Introduction, Compound Microscope, Some Staining Procedures, Preparation of Permanent Slide, Microtomy, Preparation of Solutions, Reagents and Stains

Gymnosperms : What are Gymnosperms, Disinguishing Features, Indian Genera, Classification, Characters and identification of selected Gymnospermous Taxa

Taxonomical Terminology : Root, Stem, Leaf, Venation, Stuple, Flower, Bract, Calyx, Corolla, Androccium, Gynoecium, Placentation, Fruit.

General Texonomical Aspects : Major Taxonomic Categories, Systems ofClassification of Angiosperms, Features Used to Describe an Angiospermic Plant, Flowchart of the Classification Proposed by Armen Takhtajan, Herbaria and Botanical Gardens, Some National and International Herbaria, Botanic Gardens

Families of Dicotyledons : Ranunculaceae, Caryophyllaceae, Rutaceae, Fabaceae : Papilionaceae, Caesalpinioideae or Caesalpiniaceae, Mimosoideae or Mimosaceae, Rosaceae, Aplaceae or Umbelliferae, Rubiaeae, Aslepiadaceae, Apocynaceae, Solanaceae, Acanthaceae, Lamiaceae or Labiatae, Amaranthaceae, Euphorbiaceae

Family of Monocotyledons : Gramineae or Proaceae, Triticum aestivum, Some Staining Procedures

Body Plan of a Dicotyledonous Plant

Shoot Apex and Root Apex : Shoot Apex, Root Apex

Anatomy (General Aspects) : Plant Tissues, Difference Between Monocots and Dicots, Some Anatomical Differences, How to Identify anatomical Material ?

Anatomy of Monocot and Dicot Stems, Roots & Leaves : Normal Monocot Stems, Monocot Stem with Secondary Thickenings, Dicotyledonous Stem, Dicotyledonous Stem with secondary growth, Anatomy of Dicotyledonous Root, Anatomy of Monocot Leaf, Anatomy of Dicot Leaf

Anatomy of Phylloclade and Phyllode : Ruscus-Phylloclade, Acacia moniliformis-Phyllode

Diversity in Leaf Shape and Stomata : Leaf Shape Exercise, Stomata, Trichome

Viva-Voce

UNIT 1

ZOOLOGY

STRUCTURE

- Characters and Outline Classification of Urochordata
- Characters and Outline Classification of Pisces
- Characters and Outline Classification of Amphibia
- Study of Museum Specimens of Reptilia
- Study of Museum Specimens of Aves
- Museum Specimens of Mammalia
- Study of Cells and Cell Organelles
- Preparation of Mitotic and Meiotic Slides
- Numerical Exercises in Genetics
  - Summary
  - Student Activity
  - Test Yourself

LEARNING OBJECTIVE

After going through this unit you will learn :

- To perform the experiments and requisites therefor Effectively

1.1. CHARACTERS AND OUTLINE CLASSIFICATION OF UROCHORDATA

1. They are marine solitary or colonial and fixed or free swimming.
2. Body in covered by ***tunic*** or ***"test"*** in adults.

Classification of Subphylum – Urohordata

Class

Ascidiacea

1. Adults do not have ***Notochord*** tail or nerve cord.
2. Test is permanent.

Larvacea

1. Free swimming & ***Neotenic forms.***
2. ***Test temporary & Gill slits one pair.***
3. ***They remain as larva for whole life e.g., oikopleura.***

Thaliacea

1. Free swimming, solitary or colonial.
2. ***Test transparent*** and permanent.
3. Muscles in the form of circular bands.
4. ***Tail & monotochord absent in adults*** & show ***alternation of generation.***

Orders

Ascidiae simplicea

1. Fixed solitary and with ***retrogressive metamorphosis.***
2. Asexual reproduction rare or absent. *e.g., Herdmania; Ascidia & ciona.*

Acicidial Luciae

1. Free swimming & colonial colony made of ***zosids*** enclosed in a common ***transparent test.***
2. Colony is ***phosphorescent*** and test is closed at one end. *e.g., Pyrosoma.*

Ascidiae compositae

1. Fixed & colonial and larva develops in atrial cavity. Test is ***"synascidal".***
2. Reproduction generally by ***Gemmation*** i.e., Botryllus

Heinimyaria	Cyclomyaria
1. Muscle bands incomplete.	1. Muscl bands complete.
2. Body has atrial & branchial apertures at opposite ends & in fusiform.	2. Body is cask shaped & with opposite atrial branchial apertures.
3. ***No tailed larva e.g., salpa.***	3. ***Tailed larva*** & sexual generations ***"polymorphic"*** *e.g., Doliolum.*

3. Notochord absent in adults but found in larvae and is restricted to tail.
4. Dorsal tubular nerve cord is absent in adults but present in larvae.
5. Numerous Gill-slits are present in adults.

1. Herdmania

Classification :

Phylum	–	**Chordata**
Group	–	**Protochordata** (Acrania)
Subphylum	–	**Urochordata** (Tunicata)
Class	–	**Ascidiaceae**
Subclass	–	**Pleurogona**
Order	–	**Stolidobranchia**
Family	–	**Pyuridae**
Genus	–	*Herdimania*
Species	–	*Pallida*

1. It is marine, unsegmented and solitary animal.
2. The body is somewhat square and enclosed in a soft transparent tunic—'the ***test***'.
3. The adults are without tail.
4. The individuals remain attached to substratum through a well marked foot.
5. It's alimentary canal is 'U'-shaped.
6. The mouth and cloaca open into definite chambers : the ***branchial*** and ***atrial sipons.***
7. Pharynx is perforated with stigmata in young and adult both.
8. The ***vascular system*** is of open type.
9. Nerous system is represented by single ganglion in adults.
10. A ***dorsal tubular nerve cord*** is present in embryonic stages.

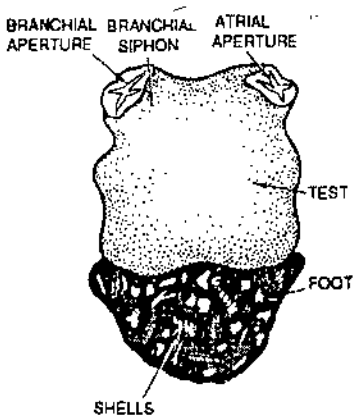


Fig. 1 Herdmania

11. Skull, jaws, oxb- and end-oskeleton are absent.
12. ***Notochord is present only in embryonic stage and is restricted to tail.***
13. The excretion is through unpaired neural gland, situated above the nerve ganglion.

2. Amphioxus

Classification

Phylum	–	**Chordata**
Subphylum	–	**Cephalochordata** (Cephalic-head; chordata-notochord)
Genus	–	*Branchiostoma*
Species	–	*lanceolatum*

1. They are burrowing, marine and fish like. They are commonly called ***lancelet.***

2. Body is laterally compressed having a distinct tail and a caudal fin.

3. A dorsal fin is present all along the back and the ventral fin is present in front of caudal fin. Dorsal ventral and caudal fins are continuous. Two lateral fins of ***metaphleural folds*** are also present.

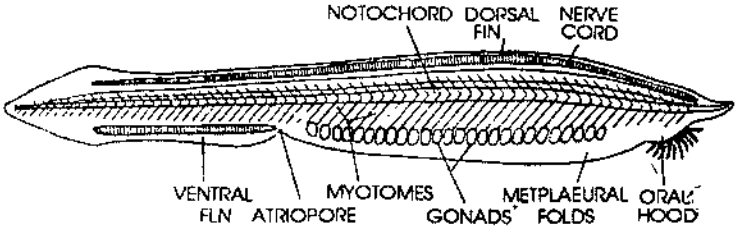


Fig. 2. Amphioxus

4. Body s divisible into trunk and tail. ***head is absent.***

5. Skull, jaws and exoskeleton are absent.

6. ***Mouth*** is surrounded by a ring—***the oral-hood*** made of about ***18-20 oral cirri.***

7. Opening between buccal cavity and pharynx is guarded by a ring – ***the velum*** having ***8 tentacles.*** Pharynx is surrounded by atrium and is perforated by ***oblique gill slits*** (stigmata).

8 Anus asymmetrically placed on right side.

9. ***Dorsal tubular nerve chord and noto-chord are present throughout life. Notochord extends*** into head region also.

10. Sexes are separate but no sexual dimorphism is visible.

1. Petromyzon

Classification :

Phylum	–	**Chordata**
Subphylum	–	**Agnatha**
Class	–	**Cycloatomata**
Order	–	**Petromyzontiformes**
Genus	–	*Petromyzon*
Species	–	*marinus*

1. It is both marine and fresh water and lives as ***ectoparasite on aquatic vertebrates*** and is commonly called ***"lamprey".***

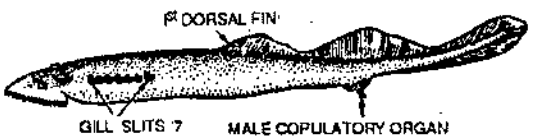


Fig. 3. Petromyzon male.

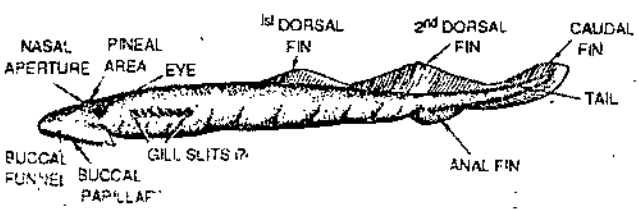


Fig. 4. Petromyzon female.

2. **Elongated eel-like body is divisible into cylindrical head, trunk and laterally compressed tail.**

3. ***Exoskeleton (scales) is absent*** **but skin is covered with thick mucous.**

4. ***Paired fins absent*** but unpaired or median fins are present. Two membranous median ***dorsal fins*** near posterior end and ***a caudal fin*** around tail are present and supported by fin rays.

5. In female ***an anal fin*** is also present behind anus.

6. ***Mouth is funnel like,*** bears adhesive papillae, hooks and radiating rows of horny teeth and is used for sucking. Protrusible tongue is rasping in nature and ***jaws are absent.***

7. Pharynx is perforated with ***7 pairs of round gill slits.***

8. Head bears one pair of eyes laterally.

9. Single nostril is present mid-dorsally on head but internal nares is absent.

10. Cloaca is present on ventral side at the junction of trunk and tail.

2. Myxine

Classification :

Phylum	–	**Chordata**
Subphylum	–	**Agnatha**
Class	–	**Cyclostomata**
Order	–	**Myxiniformes**
Genus	–	*Myxine*
Species	–	*glutinosa*

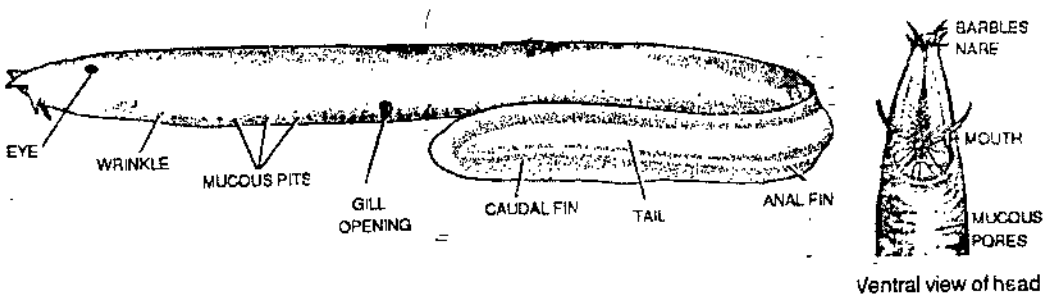


Fig. 5. Myxine

1. It is marine and quasiparasite and is found buried in mud and sand.

2. It is commonly called ***'hag-fish'*** or ***"slime-eel".***

3. Elongated eal like body is differentiated into head, trunk and tail.

4. ***Exoskeleton is absent*** but skin is covered with thick mucous.

5. Double rows of mucous glands are present all along the body.

6. ***Paired fins absent.*** But median fins are present. One caudal fin around the tail and one ventral fin are also present.

7. ***Jaws are absent*** but suctorial terminal mouth is guarded by soft and wrinkled lips and is surrounded by ***8 tentacles.***

8. The single median and terminal ***nasal aperture (nostril)*** lies close to the mouth and communicates with it.

9. ***Eyes are greatly reduced*** and covered with a fold of skin.

10. ***Pharynx is perforated with paired round gill slits which open externally through one pair of common external gill slits.***

11. It is hermaphrodite, ***protandrous*** having ***single ovotestis.***

3. *Scoliodon* and *Chiloscyllium*

Classification :

Phylum	–	**Chordata**
Group	–	**Vertebrate** (Craniata)
Subphylum	–	**Gnathostomata**

Super class	–	**Pisces**
Class	–	**Chondrichthyes**
Subclass	–	**Selachil**
Order	–	**Picurotremata**
Genus	–	*Chilosyllium* and *Scoliodon*
Species	–	*tigrinum*

1. It is commonly called ***"shark"*** and is found is found in Indian ocean coast of Australia, China, Japan and upto Cape of Good Hope.

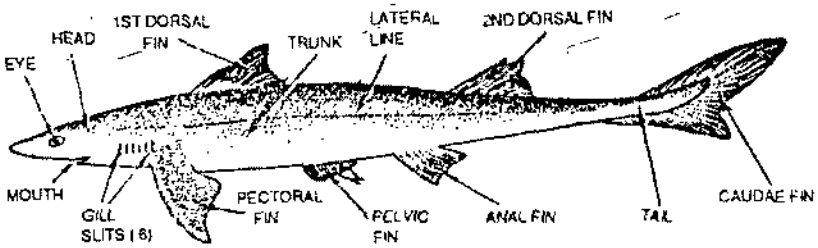


Fig. 6. Chiloscyllium

2. ***Exoskeleton is made of placoid scales.***

3. Body bears median and paired fins (Dorsal fins-2; caudal-1 and anal fin-1). ***The tall is heterocercal but stralght*** (not bent upwards).

4. The first dorsal fin commences opposite or in front of pelvic fins.

5. Jaws are well developed and upper jaw is produced into snout. The mouth is ventral and crescentic.

6. Spiracles one pair and are located behind eyes. The eyes are ***without nictitating membrane.***

7. ***Nasal cavity confluent with buccal cavity*** and ***pharynx is perforated with 5 pairs of gill-slits.***

8. Dorsal tubular nerve cord is modified into brain at its anterior end and notochord is modified into cartillagenous vertebral column in adult.

9. ***Males have paired claspers*** at the base of pelvic fins.

• 1.2. CHARACTERS AND OUTLINE CLASSIFICATION OF PISCES

1. Fish in an aquatic, cold blooded (***Poikilothermic***) vertebrate.

2. Body covered by ***exoskeleton of scales, dermal plates or denticles.***

3. Endoskeleton may be cartilagenous or bony.

4. Respiration by ***paired gills*** which ***open by gill slits.*** The bony fishes have ***operculum*** covering ***Gill slits*** and cartilaginous fishes have ***spiracles.*** They have ***paired and median fins*** for swimming.

6. ***Heart is four chambered and venous.***

7. ***Lateral line*** organs are well developed.

8. Development is indirect.

4. *Wallago*

Classification :

Phylum	–	**Chordata**
Subphylum	–	**Vertebrata** (craniata)
Class	–	**Ostelchthyes** (Teleostomi)
Subclass	–	**Actinopterygi**
Superorder	–	**Teleostel**
Order	–	**Cypriniformes**

Family – **Siluridae**
Genus – *Wallago*
Species – *attu*

Classification of *Series* or Superclass *Pisces*

Classes

Elasmobranchi
1. Endoskeleton cartilagenous.
2. No Gill cover & air bladder.
3. Body covered by ***Placoid scales*** or nacked.
4. Snout, classpers and spiracles are present.

Telostomi
1. Endoskeletion bony.
2. Gills covered by ***operculum.***
3. Air bladder present but spiracles absent.
4. Cloaca & claspers absent.
5. Mouth terminal & snout absent.

Holocephali
1. Endoskeleton of cartilage.
2. Gills are covered in adult.
3. Scales spiracle, cloaca absent in adult.
4. Tail whip like.

Subclass . ***Chimaeral***
1. Notochord persists *e.g.*, ***Chimaera.***

Dipnoi
1. Endoskeleton bony.
2. Gill slit one pair covered by opercycli.
3. Notochord persits.
4. ***Airbladder acts as lung.***
5. Paired fins lobate.

Ceratodiformes
1. Airbladder unpaired e.g., **Neocaratsdus.**

Capidosirenifor
1. Airbladder paired ***e.g., protopeteri lepidosiren.***

Orders Subclass – ***Selachii***

Hypotermata (Batoidea)
1. Body flat & Gill slits on ventral surface.
2. Pectoral fins fused along lateral side & body

Pleurotremata (Squalioidea)
1. Body spindle shaped + gill slits lateral.
2. Pectoral + Pelvic fins free.

Suborder

Torpediniformes
1. Electric organs present *e.g.*, ***Astrape + Toopedo***

Rajiiformer
1. No electron pair *e.g.*, ***aja; Rhinobates Pristis; Myeliobatis Trygon.***

Order : ***Laminiformes***
1. Two dorsal fins
2. Five pairs of Gill slits *e.g.*, ***Scoliodon; Scillium Stegostoma; Sygaena***

Teleostomii

Subclasses

Ainopterygii
1. Paired fins radial + not lobate
2. No internal nerves.
3. Tail is generally ***homocercal***

Crossopterygii
1. Paired fins lobed and covered by scales.
2. Internal nares present.
3. Tail ***proterocercal.*** Order : ***Coelacanthiformes.*** *e.g.*, ***Latimaria & coelacanthus***

(1) *Polperiformes*
1. Scales ***rhombic ganoid.***
2. Dorsal fin with free finlets.
3. Air bladder biloked + pectoral fin has prominent base *e.g.*, ***Polypterus.***

(3) *Acipeuseriformes*
1. Body covered by bony sales.
2. Snout long + prominent
3. Tail Hetericereal *e.g.*, ***Acipenser + Polyodon.***

(2) Lepidosteiformes
1. Scales rhombic, ganoid.
2. ***Caudal fin heterocercal.***
3. ***vertebrae opisthocoelous i.e., Lepidosteus*** (Garpike)

(4) *Amciformes*
1. Snout normal
2. Dorsal fin along back & Caudal fin round & ***bow like.***
3. Scales cycloid *e.g.*, ***Amia.***

(7) *Beloniformes*
1. Head produced into ***beak.***
2. Fins without spines.
3. Pectoral fins large a may help in gliding in air. *e.g.*, ***Belone*** (Xenentodon); ***Exocoetin; Cypselurus; Hemiramphus.***

(5) *Scopeliformes*
1. Dorsal and anal fin without spines.
2. Luminous organ present.
3. Adipose fin present.
4. Mouth target with teeth. *e.g.*, ***Harpodon (Bombay dyck)***

(8) *Syngnathiformes*
1. Snout tube like.
2. Fin rays of Pectoral, dorsal and anal fin unbranched.
3. They show ***Parental care*** + have a ***broad pouch.***

(6) *Anguilliformes*
1. Body long + eel like.
2. Skin almost naked.
3. Fins without spines and dorsal + anal fins continuous *e.g.*, ***Anguilla*** and ***Muraena.***

(9) *Symbranchi formes*
1. Body eel like, almost naked.
2. Air bladder absent.
3. Fins without spines.
4. Gill slit single, ventral & transverse.
5. Medium fins continuous *e.g.*, ***Amphipnous cuchia.***

(11) *Pleuronectiformes*
1. Body flat & ***both eyes on dorsal side.***
2. Median fins confluent & without spines.
3. Air bladder absent *e.g.*, ***Pleuronectes & Synaptura***

(10) *Periciformes*
1. Fins without spins & Dorsal fins two.
2. Air bladder closed.
3. Weberian apparatus absent *e.g.*, ***Pterois; Anabas Trichurus; Nandus*** & ***Trichogaster.***

(12) *Echeiniiformes*
1. ***First dorsal fin modified into sucker.***
2. Air bladder absent.
3. Spines absent from second dorsal and anal fins *e.g.*, ***Echeneis*** & ***Remore.***

(15) *Ophiocephalifomes*
1. Snake like snout.
2. Air bladder long & physocleistous.
3. Accessory respiratory organ membranous sacs in head.
4. Fins iwithout spines *e.g.*, ***Channa or ophiocephalus.***

(13) *Tetradontiformes*
1. Body baloon like.
2. Scales modified into spines.
3. Gill slits, generally one pair *e.g.*, ***Diodon; Tetradon & astracion.***

(16) *Mestacembeliiforms*
1. Body eel shaped long.
2. Median fins confluent & have free sprines.
3. Upper jaw produced into snout.
4. Air bladder closed *e.g.*, ***Medacembelus.***

(14) *Lophiformes*
1. Air bladder absent.
2. First ray of first dorsal fin on the head as bait & is called ***cllicium.*** *e.g.*, ***Lophius & Antennarius.***

(17) *Clupeiformes*
1. Scales small.
2. Caudal fin homocercal.
3. Webberian apparatus absent.
4. Fins without spines *e.g.*, ***Hilsa; Salmon Notopterus.***

(18) *Cypriniformes*
1. Well developed Webberian apparatus and air bladder opening in a limentary canal.
2. They have ***barbles.***

Sub-order (division)

Ciprini
1. Body covered with large scales. *e.g.*, ***labeo, catla, Barbus, arihina cyprinus.***

Siluri
1. Body without scales. *e.g.*, ***Wallego; Mystus*** (Macrones); ***Arius; Clarias & Heteropheustes***

1. It is a fresh watr predatory fish, distributed throughout India and is commonly called ***cat-fish, lachi, Mullee or boalli".***

2. The colour is greyish brown above and white below with purplish head.

3: Head is with large mouth, small trunk and long tail which tapers behind.

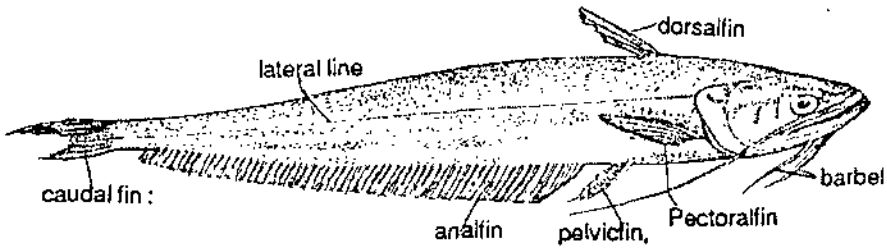


Fig. 7. Wallago.

4. ***Mouth extends behind the orbits*** and has villiform teeth in jaws.
5. Head bears ***2 maxillary and 2 mandibular barbels.***
6. The eyes are prominent.
7. ***Skin is scaleless.***
8. ***Dorsal*** and ***Pectoral fins*** are small. ***Pectoral spine*** is stout and serralted.
9. ***Anal fin is long but not confluent with caudal fin.***
10. Gill membranes free. ***Weberian ossicles are present.***

5. *Labeo*

Classification :

Phylum	–	**Chordata**
Subphylum	–	**Vertebrata**
Class	–	**Osteichthyes** (Teleostomi)
Subclass	–	**Actinopterygill**
Superorder	–	**Teleostel**
Order	–	**Cypriniformes**
Family	–	**Cyprinidae**
Genus	–	*Labeo*
Species	–	*rohita*

1. It is commonly found in fresh water ponds, rivers, lakes and estuaries. It is commonly called ***"Rohu*** or ***Indian carp".***

2. It is herbivorous and bottom feeder.

3. Body is fusiform and the colour is blusish or brownish above and silvery white below.

4. ***Exoskeleton is of large cycloid scales.***

5. Head is produced into a short and blunt snout covered with tubercles.

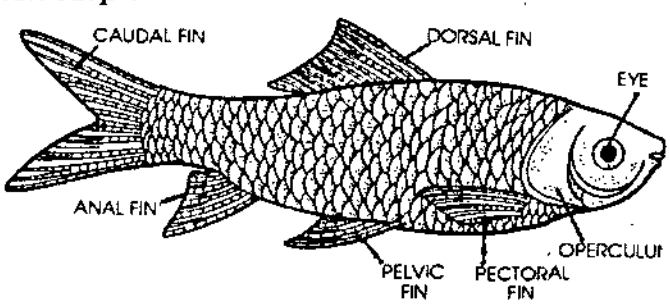


Fig. 8. Labeo

6. ***Mouth is sub-terminal and bounded by thick and fleshy lips.***
7. A pair of small ***maxillary barbells*** arise from the upper lip.
8. Median and paired fins have bony fin rays.
9. Four pairs of gills are covered by operculum.
10. ***Dorsal fin is large and single.***
11. ***Pectoral, pelvic*** and ***anal*** fins are present.
12. ***Homocercal tail is*** surrounded by a ***deeply notched caudal fin.***
13. Prominent lateral line runs along the sides of the body.
14. it is oviparous and breeds only in running water *i.e.*, rivers and bund type of tanks.

15. Fertilization is external and takes place in running water.

1.3. CHARACTERISTICS AND OUTLINE CLASSIFICATION OF AMPHIBIA

1. They live on land as well as in water.

2. They are cold blooded ***(poikilothermic)*** animals and show ***hibernation*** (winter sleep).

3. Their skin is smooth and without exoskeleton.

4. They have ***two pairs by limbs*** and their endoskeleton is bony.

5. They have ***three chambered heart*** and respiration, in these, takes place by ***lungs*** (pulmonary). ***skin*** (cutaneous) and buccal cavity (Buccopharyngeal).

6. They have ***movable eyelids, nucleated RBC*** and ***two occipital condylles in skull.***

7. They do not have lateral line organs and copulatory organs.

8. Eggs have yolk and are laid in water and develop into free swimming larva resembling adult fish.

Classification of Amphibia

Orders

Anura (Saliéntia)
1. Tail. Gills are absent in adult.
2. Two pairs of unequal gills.
3. Respiration mainly by lungs

Stagocephalia

Suborder : **Apoda**
1. Limbless worm like burrowing amphibians.
2. Very small scales are present burried in skin.
3. Tail is almost absent. *e.g.,* ***Uraeotyphlus & Ichthyphis.***

Urodela (caudata)
1. A well developed tail is present.
2. Skin naked and slimy.
3. Gills may or may not be present in adults.
4. Teeth in both jaws.
5. Limbs are of equal size.
6. Larvae mostly resemble adults.

Suborders

Procoela
1. Vertebrae **procellous.**
2. Lower jaw without teeth *e.g., Bufo & Hyla.*

Diplasiocoela
1. First seven vertebrae procoelous, 8th amphi-coelous & 9th biconvex.
2. Ribos absent. *e.g., Rana & Rhaeophorus*

Opisthocoela
1. All vertebrae opisthocoelous.
2. Ribs free. *e.g., Pipa, Algtes.*

Suborders

Ambystomoidea
1. *Neoteny* is very common.
2. Fertilization internal.
3. Eyelids present *e.g., Ambistoma* and *Axolloe larva.*

Proteida
1. 3 pairs of ***external gills*** are present in adults.
2. Eyelids absent.
3. Limbs weak and permanent larval characters present throughout life. *e.g., Noeturus + Proteus.*

Salamandroidea
1. Viviparous forms.
2. Fertilization internal.
3. Eyelids may or may not be present.
4. Gills may be present in adults. *e.g., Salmandra and Amphiuma.*

Meantes
1. Body thin and eel like.
2. Hind limbs absent.
3. Eyelids absent.
4. 3 pairs of external gills are present. *e.g., Svien.*

1. *Bufo*

Classification

Phylum	–	**Chordata**
Class	–	**Amphibia**
Order	–	**Salientia *(Anura)***

Suborder	–	**Procoela**
Genus	–	*Bufo*
Species	–	*melansotrictus*

1. It is terrestrial and nocturnal, *i.e.*, remains hidden during day and becomes active during night. It is commonly called ***"Indian toad"***.

2. Body is divisible into head and trunk.

3. ***Hind legs are much longer than the fore legs and have five and four digits respectively. The web is poorly developed in hind legs.***

4. ***Skin on the dorsal surface is rough and bears warty outgrowths and poison glands.***

5. Eyelids are well formed and nictitating membrane is also present in eyes.

6. Large, poison secreting ***parotid*** glands are present behind each tympanum.

7. ***External ear is absent but middle ear is represented by columella oris*** which is connected with tympanum.

8. Both jaws are edentulous.

9. Skull has two occipital condyles.

10. All vertebrae are ***procoelus*** including VII and IX. Urostyle has two condyles.

11. Heart is three chambered and kidney is mesonephric.

12. ***Males have a subgular vocal sac.***

13. Breeding takes place in water. Fertilization external.

6. *Axoloti Larva*

Classification

Phylum	–	**Chordata**
Group	–	**Vertebrates**
Class	–	**Amphibia**
Order	–	**Caudata** (urodela)
Suborder	–	**Ambystomoides**
Genus	–	*Axiolloti larva of Ambystoma*

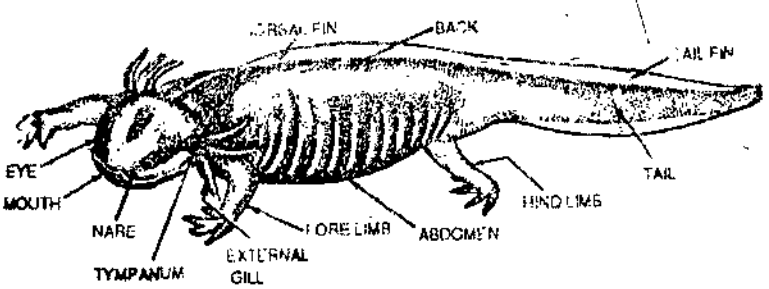


Fig. 9. Axololl larva.

1. It is the ***Axoloti larva of Ambystoma*** and is found ***in lakes of Mexico.***

2. It is perennial and its body is divisible into head, trunk and laterally compressed tail surrounded by tail fin.

3. Three external gills and 4 gill-clefts are present on either side behind the head.

4. Both pairs of limbs have 4 digits in each.

5. Eyes are with movable eyelids.

6. ***Jaws are toothed*** and are well developed.

7. ***Vertebrate amphicoelus.***

8. ***In Iodine deficient water the larva does not metamorphose into adult. Instead it becomes sexually mature i.e., develops gonad but remains morphologically immature. These sexually mature larvae mate and produce fertile eggs. This phenomenon is known as Neteny.***

• 1.4. MUSEUM SPECIMENS OF REPTILIA

1. These are ***cold blooded (poikiothermic),*** terrestrial pentadactyle ttrapod vertebrate animals.

2. ***Their skin is dry, rough non-glandular and covered by scales or spines or dermal sculls.***

3. ***In their skull there is one occipital condyle*** and their ***teeth are pleurodont and homodont.***

4. ***Heart is three chambered or four chambered*** and ***kidney metanephric.***

5. They are mostly oriparous, their eggs are mostly yolky, fertilization internal and development direct.

Classification

Subclasses

Anapsida
1. No temporal opening in skull.
2. Body enclosed in a bony box made of ***carapace*** above and ***plastron*** below.
3. Jaws without teeth but have horny surface & nasal opening single *e.g., Turteles, Tortoises, terrapins.*

Parapsida (Extinct)

Synapsida (Extinct)

Diapsida
1. Skull has ***two openings separated*** by ***squamoid*** and ***post orbital.***

Super order

Archosauria
1. Teeth ***thecodont*** and ***rhomodont.***
2. ***Vertebral amphicoelous.***
3. Upper opening closed in skull in adults.

Order ***Crocodilia***
1. Skin covered by bony plates.
2. Tail laterally compressed and powerful.
3. They are ***viviparous.***
4. ***Heart in four chambered*** *e.g., Crocudilus, Alligator and Garialin.*

Lepidosouri
1. Skull has 2 temporal openings.
2. Teeth plaurodont

Rhynchocephalia
1. ***Functional pineal eye is present.***
2. ***Vertebrae amphicoelous.*** *e.g., Spherodon*

Squamata
1. ***Vertebral Procoeloid.***
2. Cloacalapt operature transverse.
3. Nasal openings two

Lacertilia
1. Limbs 2 pairs pentadactyle.
2. Tympanum present.
3. Quadrate movable *e.g., Lizards.*

Ophidia
1. Lims absent.
2. Both temporal openings fused.
3. Tympanum absent. *e.g., Snakes.*

SNAKES

Key to distinguish the **poisonous** and **non-poisonous snakes :**

Snakes

A — Tail side-ways (Laterally) compressed marine Snakes(Poisonous)

B — Tail cylindrical Land Snakes

I — Small scales on belly. Non-poisonous

II — Belly scales not broad enough to extend right across its, width, Non-poisonous

III — Broad belly plates covering entire

I — Small scales on head, Poisonous *e.g.*, Viper.

II — Small scales are on the head and a lateral pit, between the eye and nostrial, *e.g.*, pit viper. Poisonous

III — Shield on head

a — 3rd supra-labilal touchess eye and nostril. Poisonous.

b — Ventrals enlarged bands may bear the black 4th infra orbital which is largest, Poisonous *e.g.* Kraits (Bungarus)

c — None of these features. Non-poisonous

(i) — With a hood *e.g.*, cobra Poisonous

(ii) — Without hood, coral spots on body *e.g.*, coral snakes. Poisonous

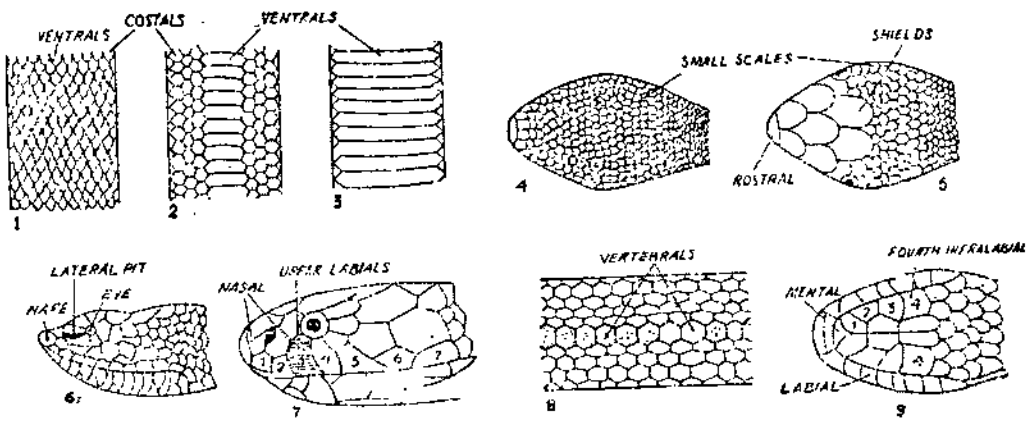


Fig. 10. Showing difference between poisonous and non-poisonous snakes.

7. *Naja (Cobra)*

Classification

Phylum	–	**Chordata**
Class	–	**Reptillia**
Subclass	–	**Diapsida**
Order	–	**Squamata**
Suborder	–	**Ophidia**
Genus	–	*Naja*
Species	–	*naja*

1. It is a diurnall and deadly poisonous snake commonly known as ***Cobra*** or ***"Naag"***.

2. It's bllackishbrown body is long cylindrical and ***without limbs*** and ***girdles.***

3. Tail is narrow and cylindrical and head is small.

4. ***Body is covered with small scales on dorsal side and broad transverse and plate-like scales on belly.***

5. ***Head is covered with shields. Of these third supra labial shield touches the eye and nasal shied.***

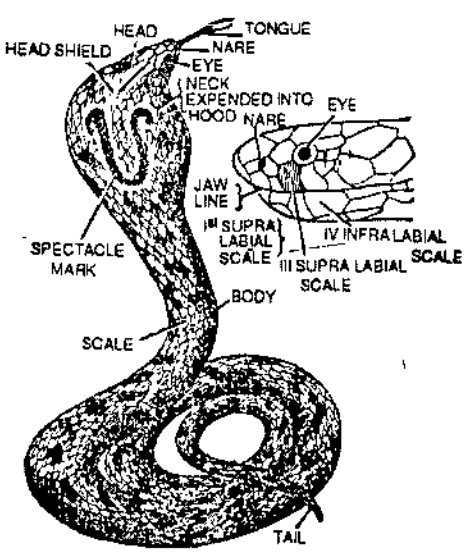


Fig. 11. Naja

6. ***The fourth infra labal shield is the largest. The subcaudal shields (scales under the tail) are in two rows and are divided.***

7. Eyes have immovable eyelids and pupil is round. Tympanum is absent.

8. ***Bifid tongue is protrusible.***

9. ***The maxilla has two anterior, grooved and permanently erect Proteroglyphous fangs.***

10. ***The neck is expandable into hood and bears a spectacle mark (v) above. It is a defensive organ.***

11. ***It's poison is neurotoxic.***

12. ***It's poison is neurotoxic.***

13. It's food is small birds, rats, frogs and lizards etc.

8. *Vipera (viper)*

Classification

Phylum	–	**Chordata**
Class	–	**Reptillia**
Subclass	–	**Diapsida**
Order	–	**Squamata**
Suborder	–	**Ophidia**
Genus	–	*Vipera*
Species	–	*russelli*

1. It is nocturnal, terrestrial and the ***largest pitless viper snake*** found in Europe, Asia, Sri Lanka, Burma and India. It is commonly called ***"Chained viper" 'Daboia'*** or ***"Suskarna".***

2. Body is covered with small scales. Of these the ventral scales are broad, transverse and plate-like and cover the whole belly.

3. ***The head is somewhat triangulalr and flat and is covered with uniform small scales as are present on dorsal surface of the body. A yellow '^' mark is pesent on the head.***

4. ***Tail small and subcaudal shields are in two rows.***

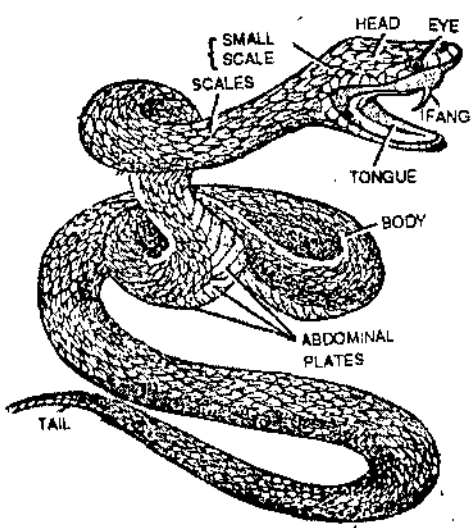


Fig. 12. Vipera

5. ***Three rows of large black rings, which appear like a chain, are present on the upper surface of body.***

6. Large ***fangs are solenoglyphous*** (tubular) and remain folded when not in use.

7. Nostrils are large, and oblique.

8. Eyes have movable eyelids and pupil is vertical. Tympanum is absent.

9. Tongue is bifid and protrusible.

10. ***It is a deadly poisonous snake, its venom is haemolytic and produces severe pain and bleeding.***

8. *Natrix (Water snake)*

Classification

Phylum	–	**Chordata**
Class	–	**Repitilla**
Subclass	–	**Diapsida**
Order	–	**Squamata**
Genus	–	*Natrix*

Species – *piscicator*

1. It is a diurnal and ***non-poisonous snake found in fresh water or in grass*** along water and is an inhabitant of USA, Mexico, India and North Africa. It is commonly called ***"water snake"***.

2. long and, cylindrical body is covered with black spots arranged like squares of the chess-board.

3. Body is covered with scales of which ventral scales are broad, tansverse and plate-like. ***On either side of transverse belly scales, small scales are present.***

4. Head is covered with large scales-***the shields.***

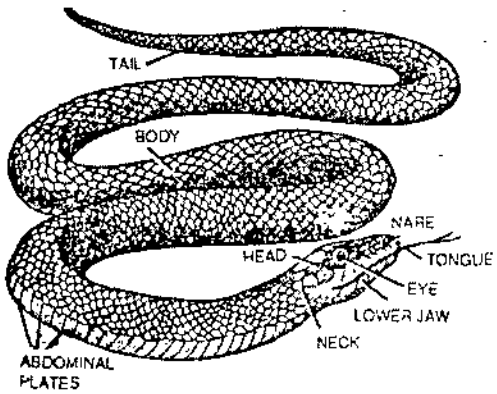


Fig. 13. Natrix

5. ***Fangs are absent*** but pleurodont teeth are present.

6. Tongue is bifid and protrusibe, eyes with immovable eyelids and tympanum absent. It is a viviparous snake.

9. *Zamaenis* (flat snake)

Classification

Phylum	–	**Chordata**
Class	–	**Reptilla**
Subclass	–	**Diapsida**
Order	–	**Squamata**
Suborder	–	**Ophidia**
Genus	–	*Zamaenis or Ptyas*
Species	–	*mucosus*

1. It is a non-poisonous, terrestrial and most common Indian ***'Rat snake'*** and is commonly called ***'Dhaman'*** or ***"Rope snake"***.

2. Body is olive green with circular black rings above and whitish below.

3. Scales on dorsal surface are small and hexagonal. Belly is covered with broad plate-like scales along with small scales on either side and subcaudals are divided.

4. Head distinct from the neck and is covered with regular shields.

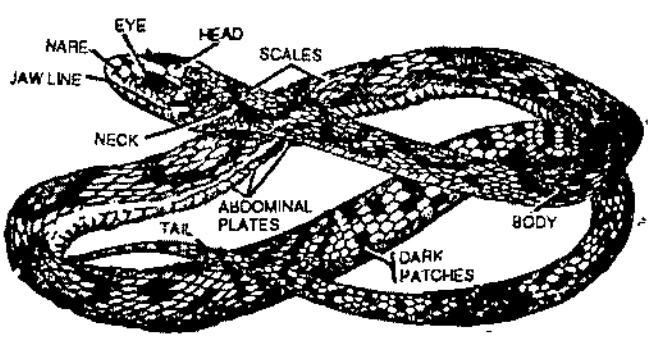


Fig. 14. Zamaenis

5. Cylindrical long tail forms more than 1/3 part of the body.

6. Large eyes with immovable eyelids and round pupil.

7. ***The median dorsal part is raised into a distinct ridge.***

8. Tongue is bifid and protrusible.

9. The maxilla bears pleurodont teeth.

10. Tympanum is absent.

11. It feeds on rats, frogs and lizards etc.

12. ***It's fat is used externally for treatment of leprosy.***

• 1.5. STUDY OF MUSEUM SPECIMENS OF AVES

1. Body of these animals is covered by ***exoskeleton of feathers***, scales.

2. They are tetradactyle but the ***forelimbs are modified into wings*** for flying and have ***3 clawed digits.*** Their ***hind limbs are modified for perching, walking, running, swimming and clining*** etc.

3. The ***Jaws are modified into beak*** and are ***without teeth.***

4. Neck is distinct and movable.

5. They have only **preen** *or* **oil gland at the base of tail** otherwise the skin is without glands.

6. They are ***homeothermic.***

7. ***Bones*** are ***pneumatic and filled with air.***

8. Body boat shaped and sternum keeled.

9. ***Skull monocondylic*** and ***vertebrae heterocoelous.*** Tail has ***pyrgostyle.***

10. ***Clavicles and interclavicls fused into a V. shaped turcula.***

11. Sacral and luniber vertebrae fused into ***synsacrum.***

12. ***Heart four chambered and only right aortic arch is present*** in adult.

13. ***Lungs have extensions as air sacs.***

14. Alimentary canal has ***crop and Gizzard but no stomach.***

15. They have a ***syrinx*** or ***voice box.***

Classification of Aves

Subclass

Neornithes
1. Jaws without teeth.
2. Tail is reduced and with pygoslijle.
3. Vertebrae heterocoelous.
4. Sternum has keel.

Archiornithes
1. Fossil birds of Jurrassic Era.
2. Teeth in jaws.
3. Tail long with 13 vertebrous and tail feathers in two raws.
4. Vergebral amphicoelous.
5. Pygostyla absent & sternum without keel. *e.g., Archaeopteryx* **and** *Archaeornis.*

Orders

Palaeognathae
Fossil birds.

Odontognathae (Ratitas)
1. Flightless birds, Teeth absent in jaws.
2. Sternum without keel and Pygostyle & syrinx are absent.
3. Hind limbs well developed for running.
4. Skull besmognathous. *e.g., astrich, Rhea, Emu, Kiwi, Moa, Tinamus* and *Elephant bird* etc.

Neognathae
1. Flying birds with well develops wings.
2. Pygostyle present and sternum has keel.
3. Skull neognahus

Orders

(3) *Spheniscifomes*
(i) Flightless birds + their fore wing is adapted for swimming.
(ii) Very small feathers.
(iii) Below skin is present thick layer of fat *e.g., Penguin.*

(2) *Pelicamiformes*
(i) Aquatic + fond of diving and fishing.
(ii) Gular pouch in throat.
(iii) Foot webbed *e.g., Pelrians.*

(1) *Gassiiformes*
(i) Legs & neck long.
(ii) They can run, swim & dive, *e.g., cranes & Sarus.*

(4) *Ciconiformes*
(i) Legs & neck long and toes without web.
(ii) Beak abruptly decurved in middle. Eat fishes. *e.g., Flamingoes & Great blue nerons.*

(5) *Anseriformes*
(i) Aquatic have webbed feet.
(ii) Beak flat & tones fleshy. *e.g., Duck, Suran, Geese.*

(6) *Falconiformes*
(i) Stout curved beak.
(ii) Feet with strong claws. *e.g., Vullure, Kites, Hawks, Faleons* and *Cheel.*

(9) *Chadriformes*
(i) Wings strong, hind limbs long & toes webbed ot base.
(ii) Eggs heavily spotted. *e.g., Wood pecker.*

(8) *Strijiformes*
(i) Head large & round.
(ii) Binoculor vision.
(iii) Beak curved, feet strongly, clawed.
(iv) Nocturnal *e.g., Owls.*

(7) *Galliformes*
(i) Beaks small & feet adafoted for running. *e.g., Gullus, Teetar, Peacock* and *Phaesons.*

(10) *Columbiformes*
(i) Beak short with thick skin at base called *cerea.*
(ii) Crop produces pigeon's milk. *e.g., Pigeon, Herial.*

(11) *Cuculiformes*
(i) Beak short, yellowish.
(ii) Tail long, feet are adapted for walking with two toes in front and two behind *e.g., Koel + Coccoo*

(12) *Psettaciforones*
(i) Upper jaw movably articulated with skull.
(ii) Beak small & hooked at tip.
(iii) hind limbs not adapted for grasping *e.g., Parrots.*

(15) *Pisciformes*
(i) Beak long & stout.
(ii) Tongue protrusible.
(iii) Toes 2 in front & 2 behind *e.g., Hornbill.*

(14) *Coraciiformes*
(i) Beak strong stout long. *e.g., Kingfisher & Blue gay* (Neelkanth)

(13) *Apodiformes*
(i) Small birds with pointed wings.
(ii) Tongue long and tubular.
(iii) Beak & hind limbs small & weak. *e.g., Swift & Humming bird*

(16) *Passeriformes*
(i) Beak sharp and adapted for cutting.
(ii) 3 toes in front one behind for perching. *e.g., House sparrow, Bulbul, house crow, Baya, Maina, indian Robin & Shams.*

(17) *Caprimulgiformes*
(i) Very wide mouth.
(ii) Beak small & delicate.
(iii) Feet small & weak. *e.g., Cprimurlgus.*

(18) *Colliformes*
(i) Small birds of Africa.
(ii) Tail very long.
(iii) First & fourth toes reversible. *e.g., Mouse bird.*

(22) *Procelluriformes*
(i) Tubular nortrils.
(ii) Wings long & narrow.
(iii) Beak horny. *e.g., Puffinus; Diomedia.*

(21) *Podiciptiformes*
(i) Fresh water bird.
(ii) Wings long & narrow.
(iii) Feet lobed. *e.g., Podiceps.*

(20) *Diatrymiformes*
(i) Large flightless extinct bird *e.g., Diatryena.*

(19) *Trogoniformes*
(i) Beak short and stout.
(ii) Feet small & weak. *e.g., Trogon*

16. ***Gallbladder and urinary bladder are absent*** in flying bird.

17. ***They are oviparous. Eggs are polylecithal and they also show parental care and make nests. They have single ovary on left size.***

• 1.6. MUSEUM SPECIMENS OF MAMMALS

1. They are ***warm blooded (homeotheimio)*** animals.

2. ***Skin is covered by hair*** (except catracea) and ***has sweat and sebaceous glands.***

3. ***Females have mammary glands.***

4. ***External ear or pinna*** is well developed.

5. ***Teeth heterodont, thecodont and diphyodont.***

6. ***Two occipital condyles in skull*** and ***lower jaw is made of single bone-mandible (dentary).*** The ***centrum of vertebrae acoelous or flat.***

7. Limbs generally pentadactyle.

8. A muscular diaphragm is present between thoracic and abdominal cavities, Heart four chambered RBC without nucleus.

9. ***Viviparous*** (except monotremes) and penis well developed.

Classification of Mammals

Subclasses

Theria

1. Pinna well developed.
2. Teeth are both in young + adult.
3. Cloaca absent. Anus present.
4. Testes extra abdominal and ***corpus callosum present*** in brain.
5. Viviparous.

Prototheria

1. No external ear or pinna.
2. Teeth only in young.
3. Cloaca present.
4. Testes abdominal and ***no corpus collosum*** in brain.
5. Oviparous. *e.g., Echidna* and *Ornithorhyrchus.*

Metatheria

1. ***Marsupium*** or broad pouch in female.
2. Placenta usually absent.
3. Corpus callosum feebly developed *e.g., Opposum, Bandicoot, Kangaroo* and *Dasyurus* (Tiger cat)

Sutheria

1. Marsupium absent.
2. Placenta well developed.
3. Corpus callosum developed.

10. *Ornithorhinchus (Duck-billed Platypus)*

Classification

Phylum	–	**Chordata**
Class	–	**Mammalia**
Subclass	–	**Prototheria**
Order	–	**Monotremata**
Genus	–	*Ornithorhynchus*

1. It is an aquatic, burrowing, nocturnal and carnivorous mammal ***found in the rivers of Australia and Tasmania*** and is commonly called ***"Duck-billed platypus".***

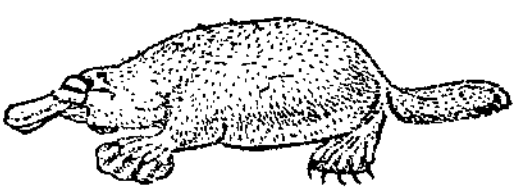


Fig. 15. Duck-billed Platypus.

2. Body is covered with soft, brown, waterproof ***fur*** with ***interspersed spines.***

3. Upper jaw forms a flattened, dorsally convex. sensitive and edentulous ***bill*** lined with ***horny plates*** and covered with ***hairless rubber-like skin.***

4. Two pairs of limbs. Each limb has 5 clawed and webbed digits. ***Web extends beyond the claws.***

5. Eyes small and rudimentary and have nictitating memberane.

6. Sexual dimorphism is distinct. In males a sharp. stout, movabte and hollow tarsal ***spur is present on the heel*** and is ***connected with the poison gland located in the thigh.***

7. ***Mammary glands without teats.***

8. It is oviparous. Female usually lays 2 eggs at a time in a nest of grass curled around them for incubation.

11. Macropus (Kangaroo)

Systematic Position :

Phylum	–	**Chordata**
Group	–	**Vertebrata (Craniata)**
Class	–	**Mammalia**
Subclass	–	**Metatheria**
Order	–	**Marsupialla**
Genus	–	*Macropus* (Kangaroo)

1. Macropus feeds on many types of plants and is good grazer of browser (herbivorous).

2. The head is small, body large with hairs all over the body.

3. Larger, hairy and non-prechensile tail which is thick at its base.

4. The external ears are distinct and large.

5. Its hind legs are longer than the fore legs and the animal moves by leaps.

6. Female with ***marsuplum*** surrounding nipples on the abdomen. The young ones are born premature and are well nursed in this pouch. The baby seeks shelter in the pouch of the mother till it is fairly grown up.

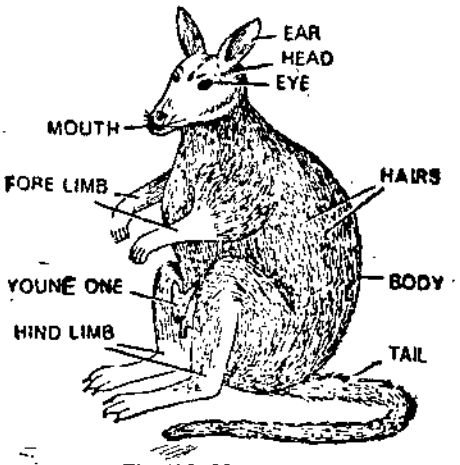


Fig. 16. Macropus

7. Dental formula is I(3/1) C(1-/o), pm (2/2), M(4/4)×2 = 32 or 34 teeth in total.

8. Its meat is eaten by the natives of Australia, Tasmania, New Guninea etc.

9. ***Distribution :*** It is distributed all over Australia, Tasmania, New Guninea and is also found in New Zealand.

98. *Rattus (Rat)*

Classification

Phylum	–	**Chordata**
Class	–	**Mammalia**
Subclass	–	**Eutheria**
Order	–	**Rodentia**
Genus	–	*Ratius*

1. It is a burrowing, gregarious and noclturnal animal found throughout the world and is commonly called **"Rat".**

2. Body is covered with brown fur and is divisible into head, neck, trunk and a long, cylindrical tail covered with scales.

3. Head is produced into moustachoid pointed snout.

4. Head bears well developed eyes and external ears.

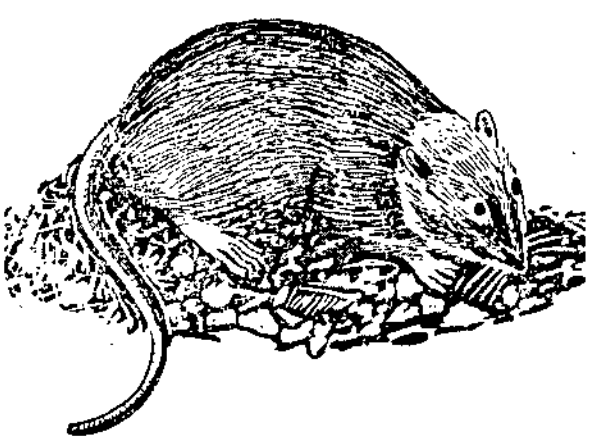


Fig. 17. Rat

5. ***Jaws bear heterodont and thecodont teeth. The canines being absent to form diastemma. Dental formula is 1022/1022.***

6. ***Incisors have yellow enamel on their inner surface and white enamel on their outer surface.***

7. Two pairs of limbs with 5 clawed digits in each.

8. Sexual dimorphism present. It is viviparous.

9. They are herbivorous and are responsible for destruction of plants and food grains.

10. ***It is a carrier of plague and typhus virus.***

• 1.7. STUDY OF CELLS AND CELL ORGANELLES

Under this exercise students are normally supposed to observe the different types of cells and various cell organelles under electron microscope themself. But, since the

facility is not available for the University departments, they are being provided here the actual electron microphotographs of cell and each organelle of the cell along with its line drawing so that they may be abreast with the details of these organelles as they appear under electron microscope. They should draw the line diagram sketch and also write the comments from their theory knowledge or as given below :

1. *Electron Microphotograph of Procaryotic Mycoplasma Cell*

It is the electron microphotograph of a ***prokaryotic cellof Mycoplasma*** and it has the following characters :

1. Procaryotic cells are the smallest and simplest living cells in the living world which are found in soil and sewage.

2. The cell is bound by ***plasma membrane*** outside which there is present a cell wall.

3. It has free ***circular and loop-like double helical DNA*** which acts as a ***"nucleoid"*** and represents the nucleus.

4. The cytoplasm is filled with round prominent ***Ribosomes*** and tiny protein and lipid bodies.

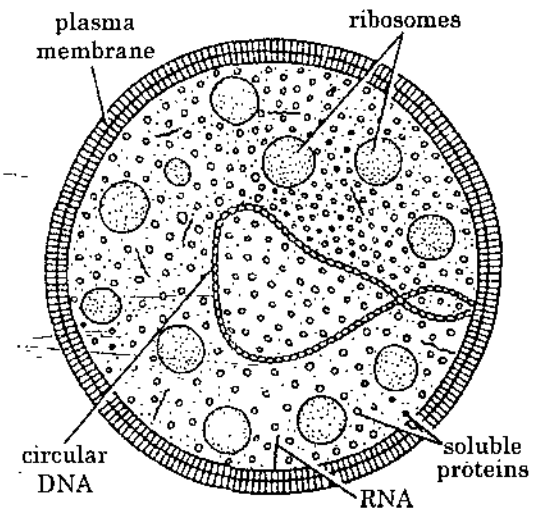


Fig. 18. Microphotograph of procaryotic mycoplasma cell.

2. Electron Microphotograph of Procaryotic Blue-Green Algal Cell

It is the electron microphotograph of a ***prokaryotic blue-green algal cell*** belonging to Cynophyceae and is also known ***cynobacterium.*** It has the following characteristics.

1. The cell is round and is enclosed in ***plasma membrane*** outside which lies a ***cell wall*** and outside the cell wall lies a thick ***gelatinous sheath*** made of carbohydrates.

2. In the cytoplasm are present hollow tubular ***photosynthetic lamellae*** along whose surface are present ***cyanosomes*** or ***phycobilisomes*** filled with ***phycocyanin***

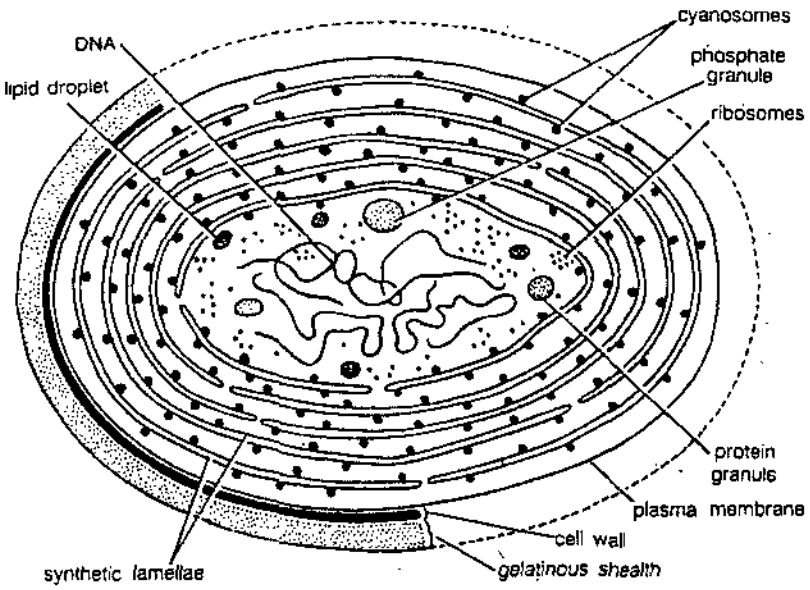


Fig. 19. Electron microphotograph of a procaryotic blue-green Algal Cell.

and ***phycoerythrin*** pigments. The photosynthetic lamellae are filled with ***bacterial chlorophyll*** and ***carotenoids.***

3. In the centre lies a ***circular*** and ***double helical DNA*** and numerous round and prominent ***Ribosomes.***

4. Besides these there are present starch and protein granules.

3. Electron Microphotograph of a Bacterium (E. Coli)

It is the electron microphotograph of the most extensively studied ***bacterial prokaryotic cell,*** the ***E. coli.*** It is found in the intestine of man as a harmless symbiotic bacterial entity. It shows the following features :

1. It belongs to the category of ***bacilli*** and is rodshaped and rectangular in outline.

2. It is bound by a ***plasma membrane*** outside which lies a thick ***bacterial cell wall*** made of protein and carbohydrates.

3. The cytoplasm is full of round prominent ***Ribosomes*** and ***Polyribosomes*** and ***RNA.***

4. The ***DNA is circular, double helical*** and freely existing and forms ***"nucleoid".***

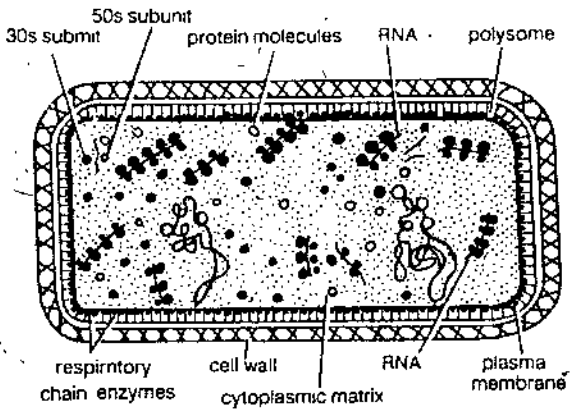


Fig. 20. microphotograph of a bacterium (*E. coli*)

4. Electron Microphotograph of a Plant Cell

It is the ***microphotograph of a eucaryotic plant cell*** which is irregular or generally hexagonal or pentagonal in shape. It exhibits the following characters :

1. The cell is enclosed in ***plasma membrane*** outside which there is eucaryotic cell wall of carbohydrates ***(Cellulose).***

2. The cytoplasm is characterized by large ***vacuoles;*** a large ***Nucleus*** always from the centre: ***Chloroplasts, Mitochondria, Endoplasmic reticulum, Golgi bodies*** or ***dictyosomes*** and ***80s eucaryotic Ribosomes.***

3. The ***Centriole*** is ***generally absent.***

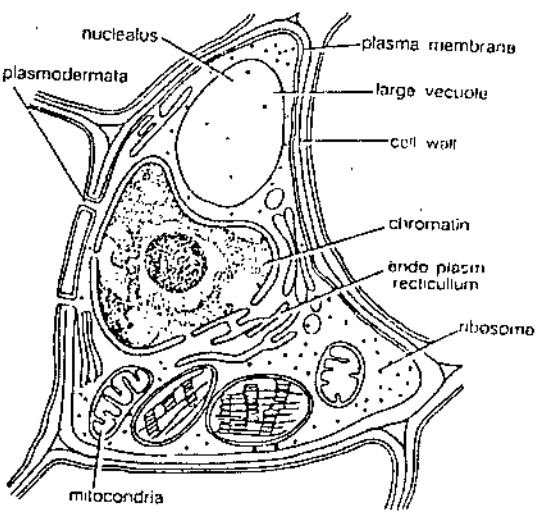


Fig. 21. Electron microphotograph of plant cell.

5. Electron Microphotograph of an Animal Cell

It is a microphotograph of a ***Eucaryotic animal cell*** which is generally round in shape. It exhibits the following characters :

1. The cell is enclosed in a ***plasma membrane*** outside which there is ***no cell wall.***

2. The ***Chloroplasts and vacuoles are absent*** but ***Centriole is present.***

3. In the cytoplasm are present Mitochondria. Golgi body, Endoplasmic reticulum and 80^s ribosomes.

4. In the centre is present a Nucleus enclosed in nuclear membrane having a nucleolus and chromosomes.

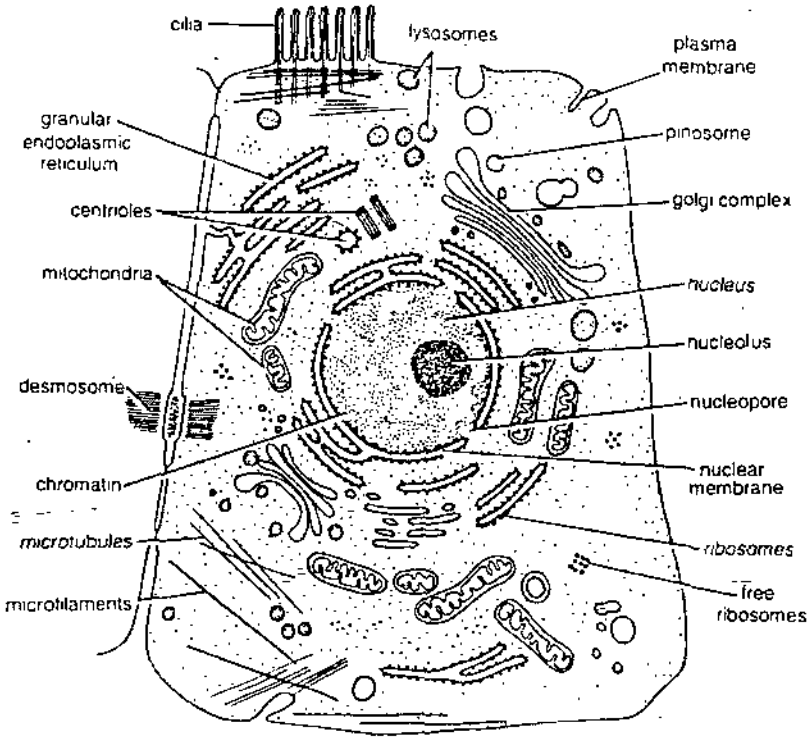


Fig. 22. Electron microphotograph of an Animal cell.

8. *The electron micrograph of Mitochondria*

It is an electron micrograph of cell's largest and most important organelle – ***the mitochondria*** and is characterized by the following features.

1. ***The name mitochondria was given by Benda (1898)*** and their main function was brought to light by ***Kingsbury (1912).***

2. Each ***mitochondria*** in section appears as sausage or cup or bowl shaped structure lined by *double membranes.* Theoretically, the membrane is similar in structure and chemical composition to plasma membrane.

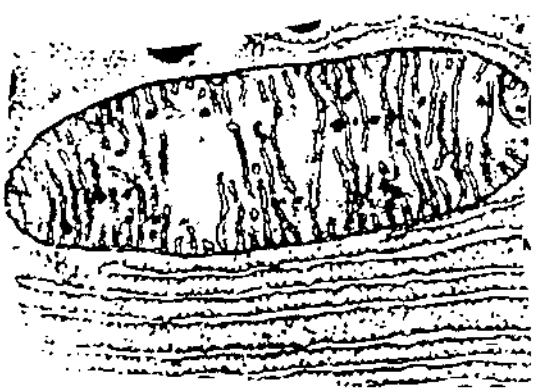


Fig. 23. (a) The electron microphotograph of a mitochondrion.

3. Two membranes are seperated by a 6–8 mm wide fluid filled space called ***perimitochondrial space.***

4. The ***inner membrane*** is projected into the central cavity as finger like outgrowths – ***the cristae.***

5. Numerous small, rounded and stalked particles – ***The oxysomes*** or ***F1*** or ***ATP*** are attached to the inner surface of inner membrane.

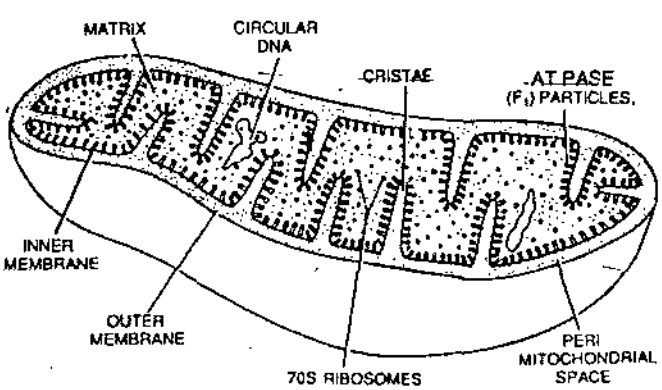


Fig. 23. (b) hypothetical detailed line structure of the aforedrawn electron microphotograph of mitochondrion.

6. The central cavity is filled with ***matrix*** which theoretically possesses ***circular DNA ribosomes*** and respiratory enzymes.

7. ***The main function of mitochondria is to synthesize chemical energy-ATP from glucose as substrate.***

8. From one molecule of glucose 38 ATP molecules (40%) are synthesized and the rest of the energy (60%) goes as heat.

• 1.8. THE ELECTRON MICROGRAPH OF GOGI COMPLEX

It is the electron micrograph of ***golgi complex*** along with its line drawing and is characterized by the following features (Fig. 24 & 25).

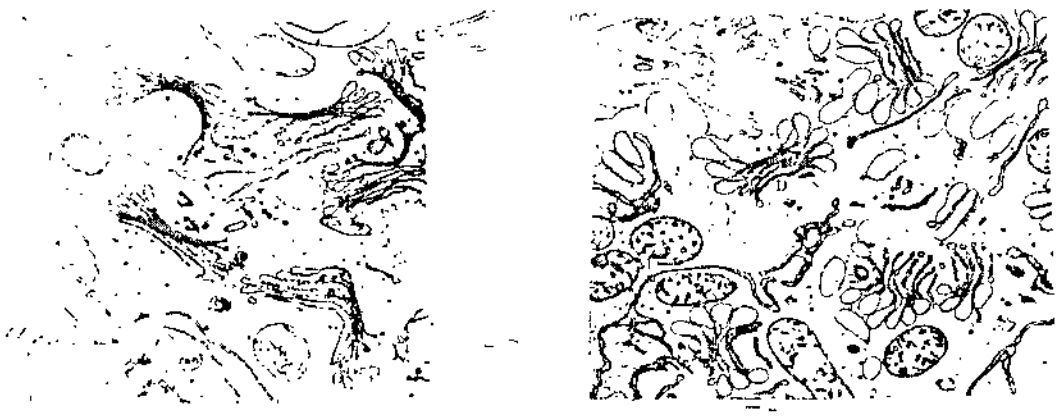


Fig. 24. Electron micrographs of Golgi Body.

1. It was discovered by ***Camillio Golgi*** (1898) and was named after his name.

2. The Golgi complex, as is visible in electron microphotograph, is a stack (bundle) of hollow tubules, which, in actual form, are ***hollow flattened sacks*** arranged above each other. On either side certain large ***globular vesicles*** and ***smaller vacoules*** are also visible.

3. Each ***tubule*** or ***lamella*** is lined by membrane, which is theoretically similar to plasma membrane in structure and chemical composition.

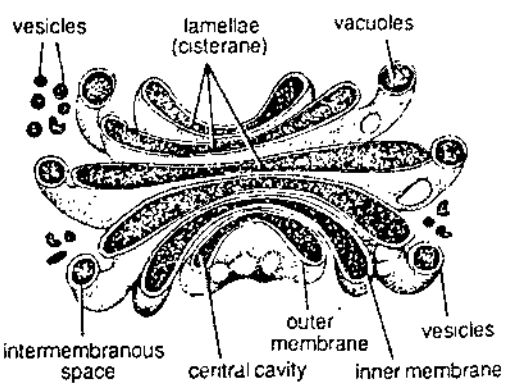


Fig. 25. Golgi body three dimentional and diagramatic model.

4. The ***golgi complex is more prominent and well developed in secretory cells*** and absent in RBC of mammals and prokaryotic cells.

5. Its main function is to ***glycolise the proteins*** which are synthesized by ribosomes *i.e.*, it converts these inert proteins into glycoproteins to act as ***hormones, enzymes and coenzymes.***

6. It also helps in the ***formation of lysosomes and acrosome of sperms.***

The electron micrograph of Endoplasmic reticulum

It is an electron micrograph of ***endoplasmic reticulum*** and is characterized by following features (Fig. 26 and 27) :

1. ***It was discovered and named by Porter (1948).***

2. It is made up of large number of interconnected and branched ***tubules,*** long, flattened and sac-like ***cisternae*** and hollow approximately rounded ***vesicles*** present all over in the cytoplasm forming a continuous system.

3. Each ***tubule, cisternae*** or ***vesicle*** is made up of membrane, which is theoretically similar to ***plasma membrane*** in structure and chemical composition.

Fig. 26. Electromicrograph of rough endoplasmic reticulum.

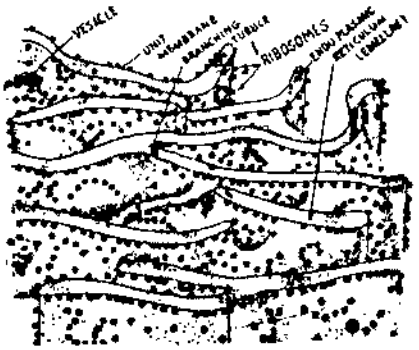


Fig 27. Diagrammatic representation of endoplasmic reticulum in three dimensionalview.

4. Some cisternae and tubules bear small, dark, rounded and granular structures, ***ribosomes,*** *along their surface. This endoplasmia reticulum is called* ***rough*** *or* ***ganullar E.R.*** The endoplasmic reticulum ***without ribosomes*** is called ***smooth*** or ***agranular ER.***

5. ***The main function of rough endoplasmic reticulum is protein synthesis.***

6. The main functions of smooth endoplasmic reticulum are (a) ***detoxification*** (b), ***synthesis of lipids & cholesterol*** (c) ***to mobilize*** Ca^{+++} and Ma^{++} ***ions*** and (d) ***Glycogenolysis.***

7. ***It is absent in R.B.C. of mammals and prokaryotic cells.***

8. Both types of reticulum provide ***mechanical support, transport*** within the cell, ***conduction of nerve*** and ***electric impulses*** and ***formation of nuclear membrane at the time of cell division.***

Electronmicrograph of Lysosomes

This is the electron micrograph of ***Lysosome,*** and is characterized by the following features. These are also called ***Suicide bags*** or ***Death bags of the cell*** (Fig. 28 & 29).

Fig. 28. Electron microphotograph of Lysosomes.

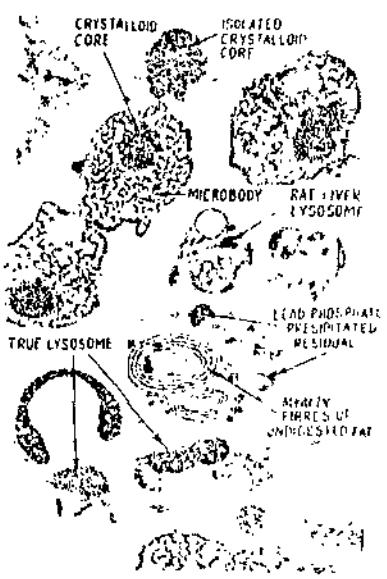


Fig. 29. Diagrammatic representation of Lysomes.

1. ***These were discovered by de Duve (1954).***

2. They are spherical or irregular membrane bound ***vesicles*** filled with ***digestive enzymes.***

3. The ***Lysosomes*** in a cell occur in three forms viz., ***primary lysosome, secondary lysosome*** and ***residual body.***

4. The ***primary lysosomes*** are nascent lysosomes which are in a dormant stage; the ***secondary lysosomes*** are those which have fused with phagocytic vesicles and have released their enzyme contents into the vesicle. ***This is also called phagosome.*** The *residual body* is one which has completed its digestive function and is ready to be thrown out of the cell.

5. ***They develop from Golgi complex.***

6. Besides ***digestion,*** their other function is ***autophagic digestion*** during extreme starvation or extreme toxicosis. They also promote (a) ***aging*** (b) ***cancerous growth,*** (c) ***metamorphosis,*** (d) ***defence against disease, bacteria and viruses and*** (e) ***ostogenesis.***

7. ***These are absent in mammalian RBC, Procaryotic cells and most plant cells.***

Electronmicrograph of Plastids

This is an electronmicrograph of ***plastid*** or ***chloroplast,*** which is an integral component of all green plant leaves and is characterized by the following features (Fig. 30 & 31) :

Fig. 30. Electron micrograph of Plastid.

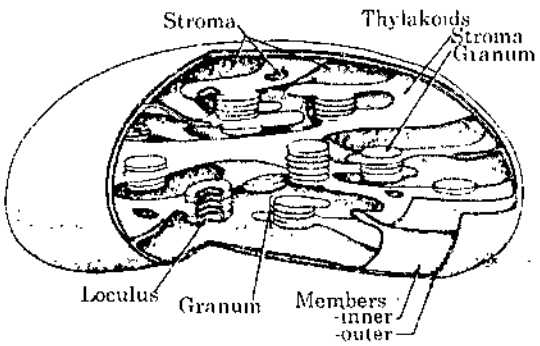


Fig. 31. Diagram showing Plastid.

1. They may be spheroidal. ovoid. stellate or ocollar shaped and differ in size and number in different cells.

2. Each ***chloroplast*** is a sac-like structure. which is made up of double membranes separated from one another by ***periplastidial space.***

3. Two types of double membranous lamellae are embedded in the ***stroma*** or ***matrix*** filled cavity.

(a) Smaller flattened disc-shaped lamellae – ***The thylakoids,*** placed one above the other in a stack – ***The grana.***

(b) Large tubular lamellae between grana called ***lamellae*** or ***frets*** which connect adjascent granna.

4. ***The inner surface between the two membranes of a thylakoid bear countless granular chlorophyll particles the Quantasomes.***

5. The ***plastids*** also have their own ***circular DNA 55^S-Ribosomes and RNA.***

6. The main function of chloroplast or plastid is to ***synthesize carbohydrate molecules from $CO_2 + H_2O$ using light energy.***

Electron micrograph of Nucleus

This is an electron micrograph of ***nucleus.*** (Fig. 32 & 33).

1. ***Nucleus*** was discovered by ***Brown*** (1931).

2. It is a characteristic entity of almost all eukaryotic cells ***except mammalian RBCs.***

3. The ***nucleus*** is generally one but may also be ***two, four*** or ***many.***

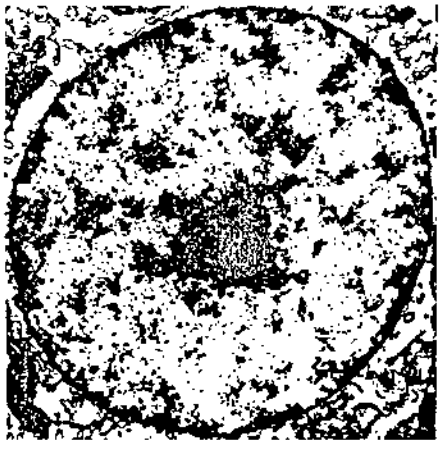


Fig. 32. Electron microphotograph Nucleus.

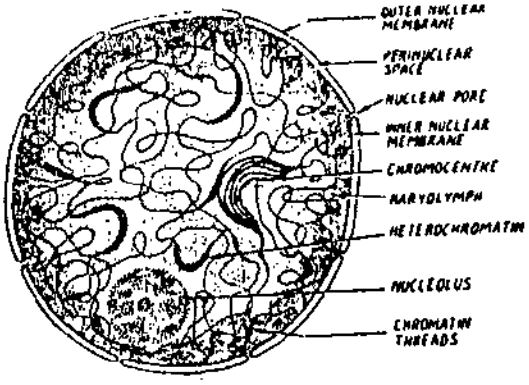


Fig. 33. Gross structure of nucleus and nucleoplasm

4. Each ***nucleus*** is surrounded by double ***nuclear membrane*** perforated by numerous ***nuclear pores.*** Each nuclear membrane is just like unit membrane. Inside, there is present a large darkly stained ***nucleolus*** and a network of ***chromatin threads.***

5. The ***nucleolus*** is responsible for all the ***ribosomal RNA synthesis*** and ***Chromatin*** (DNA) is responsible for ***controlling all the metabolic activities of cell a swell as for all hereditary activities.***

6. The ***chromatin threads*** are made up of *double helical* ***DNA*** molecule which are the carriers of heredity units – the ***genes.***

• 1.9. PREPARATION OF MITOTIC AND MEIOTIC SLIDES

Mitotic Cell Division

The **mitotic** cell division or mitosis occurs in somatic cells of all animals and plants. From the mitotic division one parent cell produces two identical daughter cells with same number of chromosomes as in the parent cell. The mitotic division may conveniently be studied in *onion root tips* in the laboratory.

Experiment–1

To prepare a slide of *root tip of onion* by *squash method* and to identify, study and draw the various mitotic stages.

Material required : Onion root tips fixed in ***Carnoy fluid*** (6 parts absolute alc. + 3 parts glacial acetic acid + 1 part Chloroform); ***Aceto carmine stain;*** slides; coverslip; blotting paper; spirit lamp; watch glass; 1-N HCl, 45% Acetic acid and filter paper.

Procedure : Take large sized mature onions about a week before the experiment. Cut all the dried roots from the stem at the base of the bulb. Now place these onions on the mouth of couplin jars filled with water in such a way that the stem portion remains dipped continuously in water. In about a week's time new roots would develop and would start growing downward in the water. *Take the onions and cut the milkey white portion of root tips viz., upto 5 mm length.* Cut each piece into smaller pieces and fix them in ***Carnoy fixative*** for half an hour. Transfer the material to 90% alcohol and then to 70% alcohol keeping the material for 10 minutes in each. Now preserve the material in 70% alcohol. At the time of proceeding for experiment in the laboratory take a few pieces from 70% alcohol in a watch glass in few drops of 1 – N HCl and leave for 5 minutes. By this procedure the material would become soft. Now drain off the HCl and wash the pieces with a little distilled water at least twice or thrice. Now put the root tips on a clear slide on right hand side and pour a few drops of 2% ***Acetocarmine.*** Warm the slide gently on spirit lamp for a few minutes at least 3-4 times *but never let it boil.* Cool and leave for 10 minutes in the stain. Now drain the excess of stain with the help of filter paper and put a few drops of 45% ***acetic acid.*** Place a cover slip over the material and put above the coverslip a piece of blotting paper or filter paper folded two to three

times. Press the coverslip gently with your thumb to break the cell membranes. The blotting paper or filter paper would save the coverslip from breaking and would also absorb the excess stain which will ooze out from the coverslip. Take care that your thumb does not move side-ways while pressing. Seal the coverslip with nail polish if you want to keep the slide for some time.

Fix the slide under low power of microscope and focus. Now change to high power and observe the various stages which would appear as shown in the attached photographs. Draw the various stages and write down comments on each of them.

Different stages of Mitotic cell division

1. The interphase stage

The slide shows ***interphase*** stage which is characterised by the following features (Fig. 34).

1. The **nucleus** is conspicuous and large and ***nuclear membrane*** is also intact and ***nucleolus*** is quite large.

2. The chromosomes are thread-like and appear as a network.

3. In this stage active protein synthesis and nucleic acid duplication takes place.

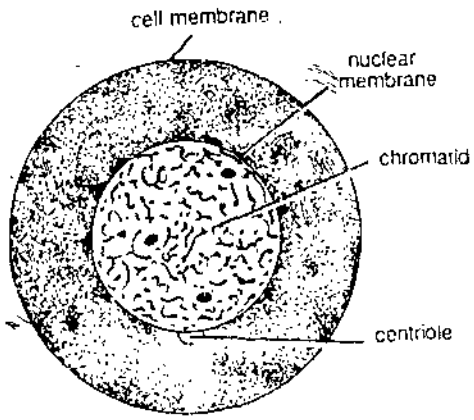


Fig. 34. Early interphase

2. The Early Prophase stage

The slide shows early **prophase stage** which is characterized by the following features (Fig. 35).

1. The ***nucleus*** is intact, large and prominent ***nuclear membrane*** is also intact. The ***nucleolus*** is large and conspicuous.

2. The ***chromosomes*** appear as long thread-like structures.

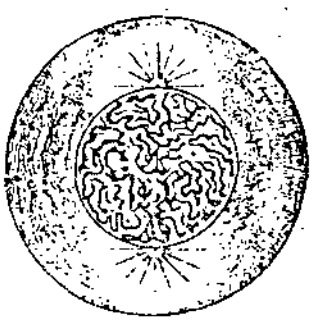


Fig. 35. Early prophae.

3. The Late Prophase stage

It is the slide of *late prophase* of mitosis and it is characterised by the following features (Fig. 36).

1. The ***nuclear membrane*** or envelop has been broken down and ***nucleolus*** has disappeared

2. The ***chromosomes*** are now visible as thick rods and each has divided into two chromatids.

3. ***Spindle fibres*** are also visible.

4. Both ***centrioles*** have reached the opposite poles.

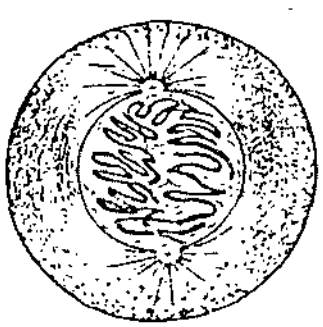


Fig. 36. Late prophase

4. The Metaphase stage

The slide shows **metaphase stage** of mitosis which is characterized by the following features (Fig. 37 & 38) :

1. ***Spindle fibres*** are faintly visible.

2. ***Chromosomes*** are arranged in a row on the equator of the spindle.

3. The ***nuclear membrane*** and ***nucleolus*** are absent.

4. ***Each chromosome*** has spit longitudinally into two identical chromatids attached at centomere only.

5. Theoretically the ***centromeres of chromatids*** are attached to spindle fibres and the arms of the chromatids are directed towards opposite poles.

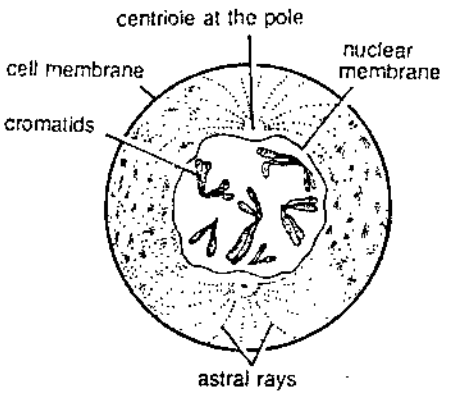


Fig. 37. Early Metaphase.

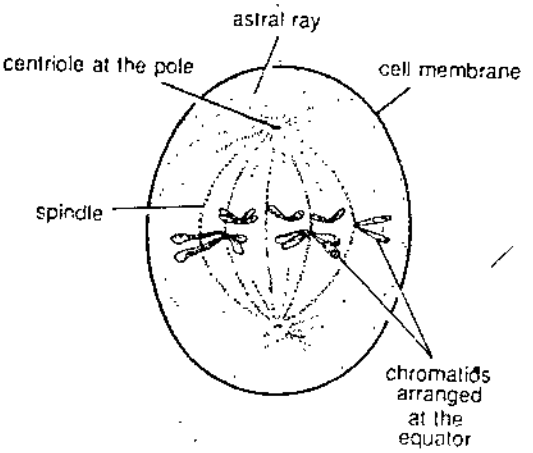


Fig. 38. Late Metaphase.

5. The Anaphase stage

The slide shows ***anaphase stage*** of mitosis which is characterized by the following features (Fig. 39 & 40).

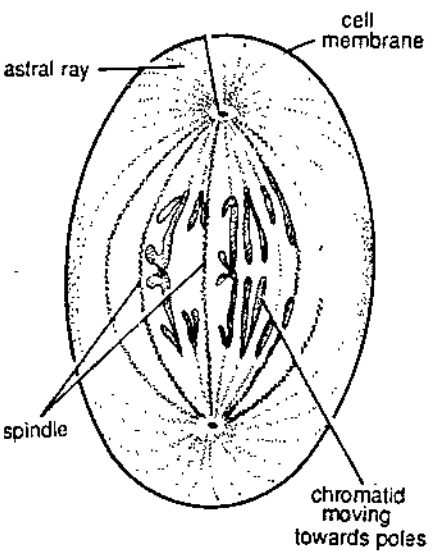


Fig. 39. Early Anaphase.

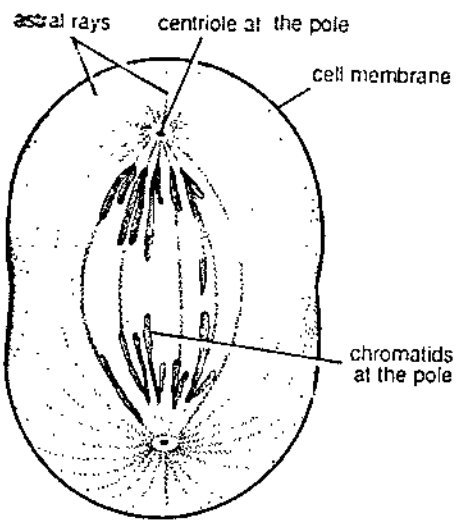


Fig. 40. Latey Anaphase.

1. The ***centromeres*** of two chromatids are now separate and are connected to independent spindle fibres of respective side but the chromatid's arms have reversed their direction and are now facing towards equator.

2. The ***chromatids*** appear as ***V.L.*** or ***J*** shaped.

3. The ***spindle fibres*** have started contracting and thus the ***chromatids*** have also started separating from each other and moving towards respective poles.

4. The ***nuclear membrane*** and ***nucleolus*** have not yet appeared.

6. The Telophase stage

The slide shows ***Telophase stage*** which is characterized by the following features (Fig. 41).

1. The ***chromotids*** have reached the poles and have started showing uncoiling.

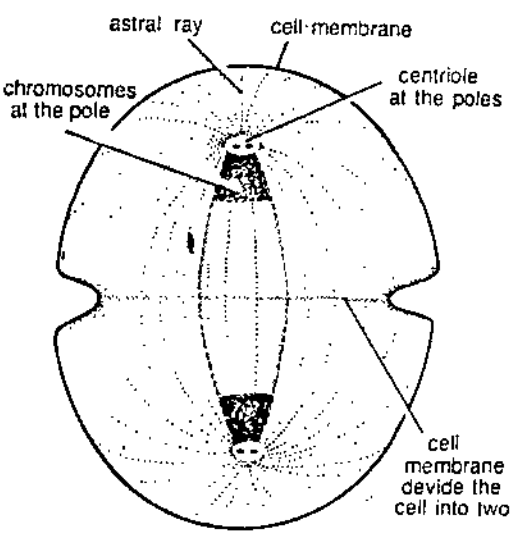


Fig. 41. Telophase.

2. The ***chromatids*** at this stage appear slightly elongated and thread like.

3. The ***nuclear membrane*** has reappeared and so also the ***nucleolus.*** As such two daughter nuclei are visible.

• 1.10. REDUCTIN DIVISION OR MEIOSIS

The ***meiosis*** or meiotic cell division is commonly called ***reduction division*** and it occurs in *germinal cells* or *reproductive cells* of animals and plants *i.e., in testis and ovary of animals* and *anthers* and *ovary of plants*. Meiosis results in the formation of 4 daughter cells from one parent cell with ***chromosome number reduced to half in daughter cells.*** It is responsible to produce **gametes** *i.e., sperms* and *ova in animals* and *pollen grains* and *ovule* in plants. In *meiosis* the *first division is reduction division* and is much different from mitotic division. *In this division the number of chromosomes is reduced to half* (2N becomes "N" in two daughter cells). This division is responsible for the maintenance and continuity of the chromosome number and genetic specificity of a species.

The second division is ordinary mitotic division

For the study of meiosis the testes of *Grass hopper, Drosophila, Cockroach,* Gryllus. *Chironomous larva* and even ***rat*** etc. among animals and unripe anthers from the buds of ***Tradescantia*** and ***Flax*** and ***Spikes of Baira*** are the most suitable materials.

Experiment–2

To prepare a slide of meiotic stages through squash method, from testis of Chironomus larva of grass hopper, buds of Tradescantia or spikes of Bajra.

Material : Buds of *Tradescantia* or *Flax* or immature spikelets of *Bajra* or Testes of *Grasshopper* or *Chironomous larva* of *rat;* ***carnoy fluid; Acetocarmine;*** needles; slide; watch glass; 45% Acetic acid; coverslip; filter paper or blotting paper; spirit lamp; normal saline; 1% sodium citrate; and 2.2% Trisodium citrate.

Procedure – 1 (for grass hopper testis) :

Dissect out testes of grassopper and keep in a watch glass in saline. Transfer them into another watch glass containing 1.0 ml of fresh *sodium citrate solution* so that their nuclei may swell up and chromatids may spread over larger area. Transfer the testes into ***carnoy fluid*** for 20 minutes to 1 hr. Dehydrate the testes through 90% and 70% alcohol for 10 minutes each. Now from *70% alcohol* transfer the testes to *2%* ***acetocarmine*** solution for 20 minutes. Drain off the excess stain and pour ***45% acetic acid*** and leave the testes in it for 10 minutes. Now, place one testicular follicle on a clean slide in **45% acetic acid** and put a cover slip over it. Put a piece of filter paper or blotting paper over the coverslip and put your thumb on the coverslip and gently press the coverslip. The excess fluid shall be blotted off by filter paper. Now seal the coverslip with nail polish and observe under microscope.

Procedure – 2 *(For rat testis) :*

1. Kill or anesthetise the rat and dissect out its testis. Place it in a 2" patri dish containing ***isotonic 2.2% trisodium citrate*** solution.

2. Pierce tunica and expose tubules and shake or spin them in isotonic solution to wash away fat.

3. Transfer these tubules to another dish ***containing 3 ml of fresh*** isotonic solution and tease tubules with forceps or needles. Transfer contents of dish gently to a ***4 ml centrifuge tube*** with the help of a pipette. Allow to stand for 10 minutes.

4. Spin for 5 second and centrifuge to sediment larger tubule segments. Transfer supernatant to a clean 4 ml centrifuge tube and discard sediment.

5. Spin for 5 min at 500 rev/min. Discard supernatant and resuspend *pellet* in minimum volume of residual supernatant.

6. Slowly add 3 ml of hypotonic (*1% Trisodium nitrate*) solution to the tube. Meanwhile flicking it with forefinger, divide the fluid (solution) between two narrow conical tipped tubes of 2 ml capacity.

7. Spin for 5 min at 500 rev/min. Pour off supernatant. Let tubes stand for 1 min and then remove, with a fine pipette, the residual fluid that drains down the walls. Make up fixative (4.5 ml *abs. Alc.* + 1.5 ml *acetic acid* _ 0.1 ml *chloroform*) while the material is in the centrifuge.

8. Flick the tube repeatedly so as to disperse *pellet* as a dense suspension. Allow two drops of fixative to fall directly on to cells and then flick tube vigorously. Add more fixative until the centrifuge tube is about 3/4 full. Meanwhile continue to flick the tube. Spin for 3 min. at 500 rev/min. Change fixative then spin again and change fixative twice more.

9. The final suspension of cells in fixative should be diluted. Lt it stand for 1-3 hrs before making preparation.

10. Take cell suspension into a fine pipette and put 3 drops at even space on a clean slide. Allow the fluid to spread and then blow it gently to dry. Repeat till there are sufficient cells on the slide.

11. As soon as dry it may be stained with ***Lactic-acetic orcein*** (2 gm *Orcein* in 50 ml *acetic acid* and 50 ml *lactic acid*. Filter, leave over night and filter again. Dilute with 50% distilled water.

Procedure – 3 *(For plant material)*

Take young buds of *Tradescantia* or *Flax* or immature male spikeletes of *Bajara* (Millet) and fix them in freshly prepared ***Carnoy's fluid*** for 10 hrs. After rehydrating in 90% and 70% alcohol store the material in 70% alcohol.

1. Take a bud of *Tradescantia* or few smaller anthers from the male spikelet of Bajra in 70% alcohol in a watch glass.

2. Dissect out the bud or dissect each anther taken from the spikelet with needles and keep them in 45% *acetic acid*.

3. Put a few anthers on the slide and few drops of ***Acetocarmine*** solution over them.

4. Warm the slide gently a few times, but never let it boil.

5. Drain off excess stain and put a few drops of *45% acetic acid*.

6. Now put coverslip over the material and cover it with filter paper or blotting paper folded 2 to 3 times.

7. Press the coverslip with your thumb so as to rupture the anthers.

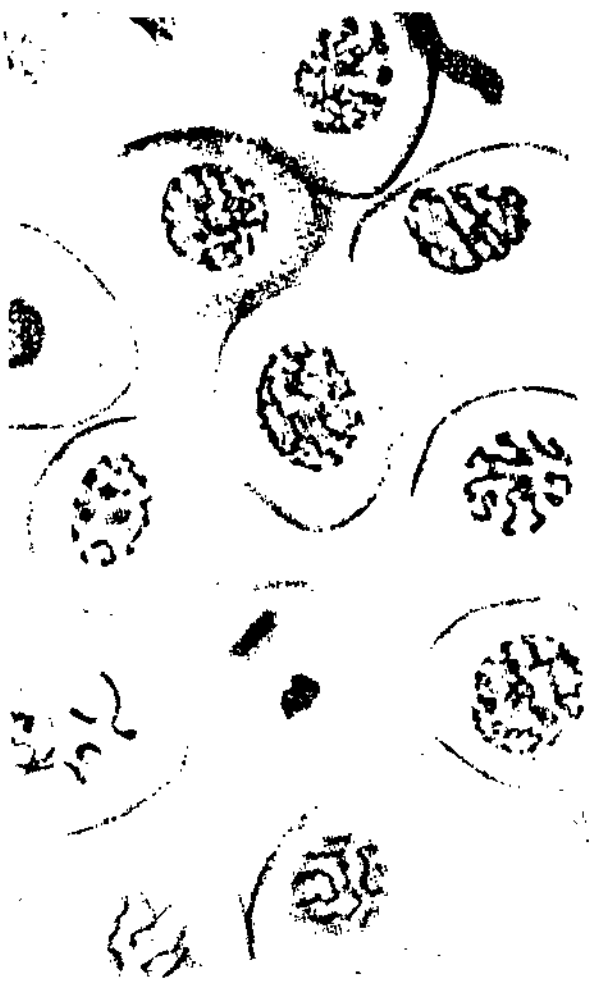


Fig. 42. Showing photomicrographs of different stages of meiosis

8. Observe under the microscope first in low power and then in high power. Draw the various stages and write down the comments (Fig. 42) : The slide prepared by you might show the following stages :

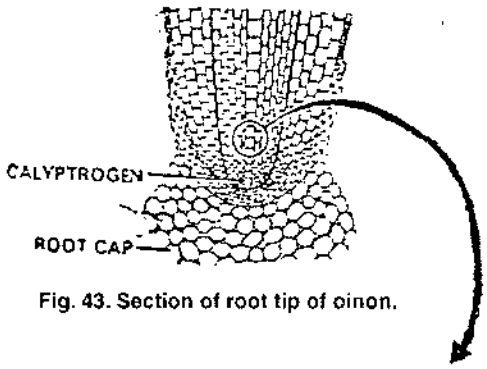


Fig. 43. Section of root tip of oinon.

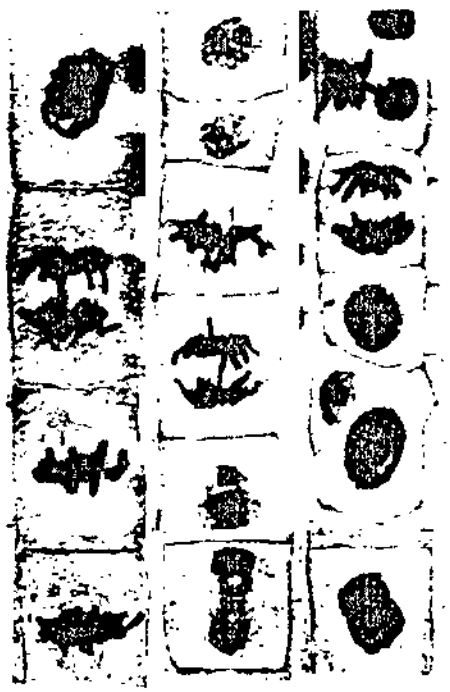


Fig. 44. Photomicrograph of a portion of onion root tip.

• 1.11. THE FIRST MEIOTIC DIVISION OF HETEROTYPIC DIVISION

1. First Prophase stage

This stage is divided into following stages :

(a) Leptotene sub stage : This slide shows the first or ***leptotene sub-stage*** belonging to first prophase of first meiotic division and is characterized by following features (Fig. 45) :

1. The *nuclear membrane* is distinct and so also the *nucleolus.*

2. The *chromosomes* are visible as thread like structures with a some what beaded appearance due to presence of ***chromomeres.***

3. The *centriole* has divided into two but is still on the same pole

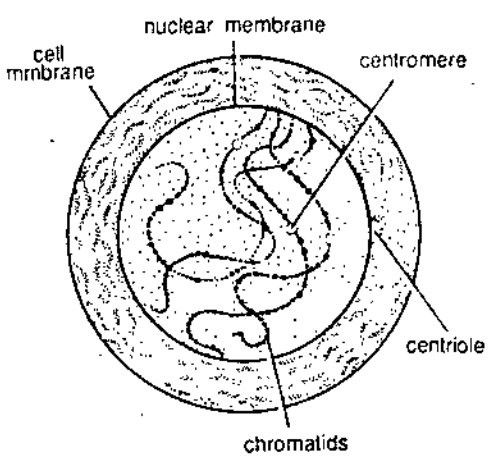


Fig. 45. Leptotene.

(b) Zygotene sub stage : The slide shows ***zygotene sub stage*** belonging to the prophase of first meiotic division and is characterized by following features (Fig. 46).

1. The *nuclear membrane* and *nucleolus* are still present and are quite prominent.

2. The *chromosomes* have started condensing and thickening. The homologous chromosomes have started pairing known as *synapsis.*

3. The pairing begins at a few points only.

4. The paired chromosomes are called ***bivalents*** or ***diads.***

(c) Pachytene sub-stage : The slide shows ***pachytene sub stage*** of first prophase of first meiotic division (Fig. 47).

1. The *nuclear membrane* and *nucleolus* are still intact and visible.

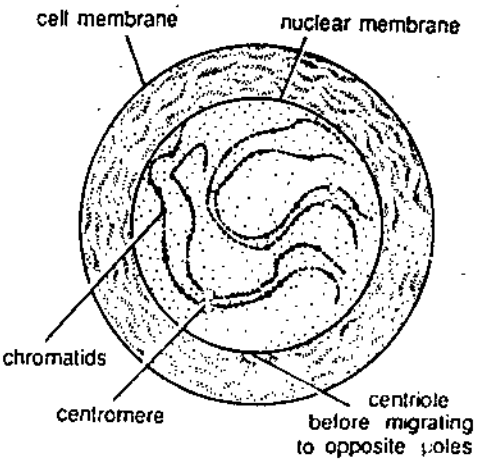


Fig. 46. Zygotene

2. The *synaptic bivalent chromosomes* have started showing coiling or twisting around each other. The points of contact are called ***chiazmata.***

3. Further, each chromatid of a bivalent homologue starts splitting lengthwise into two Chromatids resulting thereby into a tetravalent or *tetrad.* ***There is no splitting at the centromere.***

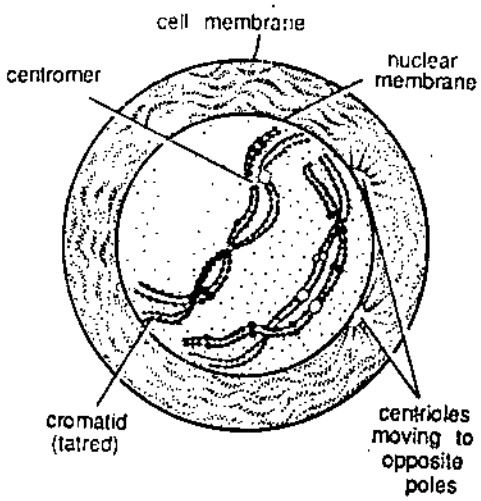


Fig. 47. Pachytene

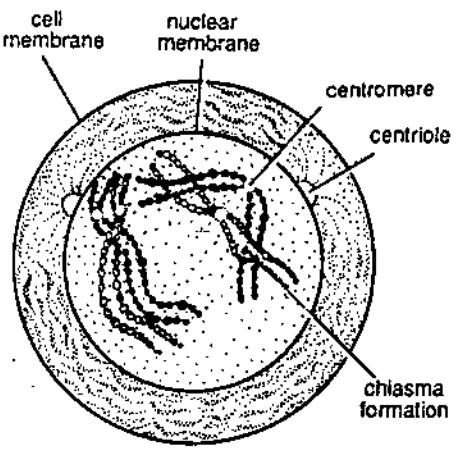


Fig. 48. Diplotene

(d) The Diplotene sub-stage : The slide shows the fourth or *diplotene stage* of first prophase of first meiotic diision and is characterized by the following characters (Fig. 48) :

1. The *nuclear membrane* and *nucleolus* have started distintigrating.

2. The *chromatids* from the *tetrad* have started separating at a number of points, but at certain points they appear to cross each other. These points of crossing over are known as *chismata* and this phenomenon is known as ***crossing over.***

3. The chromatids have started sliding in opposite directions and thus the *chiasmata* have started moving towards the tip of the cromatids.

(e) The Diakinesis sub-stage : The slide shows *diakinesis stage* of Ist prophase of Ist

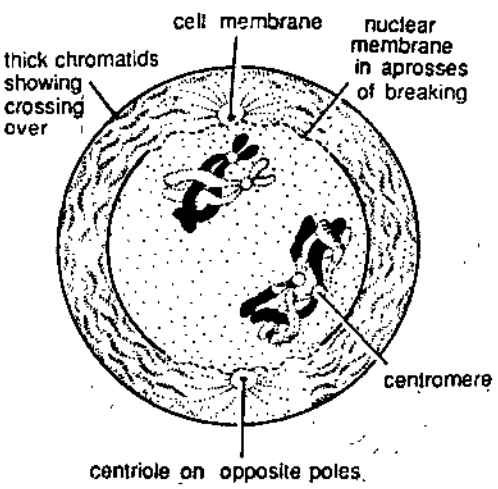


Fig. 49. Diakinesis

meiotic division and is characterized by the following features (Fig. 49) :

1. The chiasmata have terminated and chromosomes are at this stage very thick and dark divalents.

2. It is difficult to differentiate between the two chromatids of a bivalent chromosome due to condensation of ***chromomeres.***

3, The ***nucleus*** and ***nuclear membrane*** have disappeared.

2. The metaphase stage of Ist meiotic division

The slide shows *meaphase stage* belonging to first meiotic division and is characterized by the following features (Fig. 50).

1. It is different from mitotic metaphase.

2. The *nucleolus* and *nuclear membrane* are absent and spindle is formed.

3. The homologous chromosomes have started arranging themselves in a line at the *equator* of the spindle.

4. The chromosomes get attached to spindle fibres by their *centromeres.*

5. The *arm of each homologous chromosome* of a tetrad is always directed towards the opposite pole.

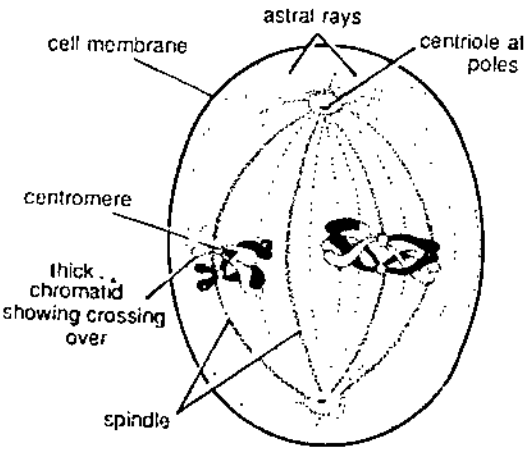


Fig. 50. Metaphase

3. Anaphase stage of Ist Meiotic division

The slide shows *anaphase stage* of first prophase of Ist meiotic division and is characterized by the following features (Fig. 51) :

1. In the beginning of this stage, as soon as spindle fibres start contracting, the chromosomes of a homologous pair reverse their arrangement from that of metaphase stage and now their arms are facing towards equator and their *centromere* towards opposite poles.

2. The most characteristic feature of this division is that each chromosome is having two chromatids, one coming from mother (maternal) and the other from father (paternal).

3. The *spindle fibres* in later stage have contracted and the chromosomes have reached mid way to poles.

4. Hence, the chromatid number has reduced to half.

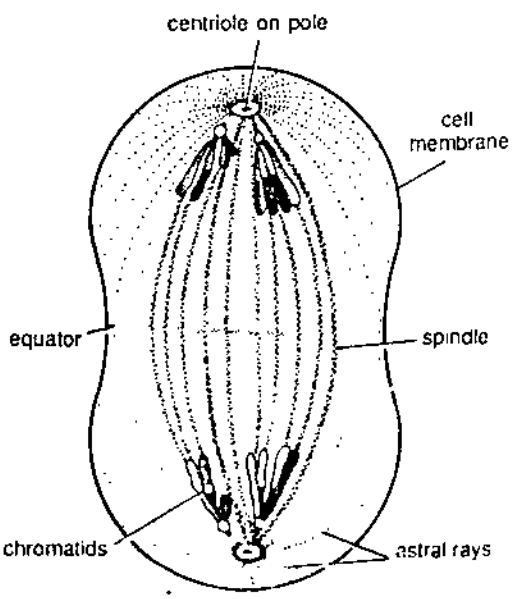


Fig. 51. Anaphase

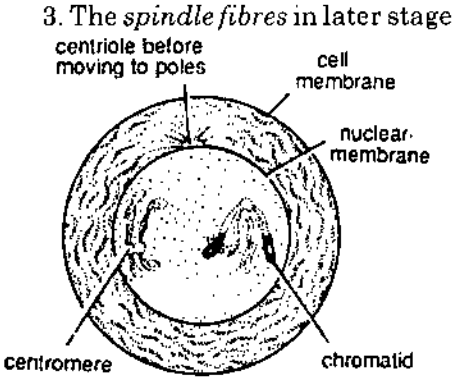


Fig. 52. Telophase

4. Telophase stage of Ist Prophase of Meiotic division

The slide shows telophase stage belonging to first prophase of meiotic division and is characterized by the following features (Fig. 52) :

1. In this stage the separation of homologous chromosomes has completed and they have reached the opposite poles.

2. The nuclear membranes have reappeared around.

3. The chromosomes have started uncoiting.

4. The division of nucleus is followed by cytokinesis *i.e.*, the division of cytoplasm.

• 1.12. THE SECOND MEIOTIC DIVISION OR HOMEOPTYPIC DIVISION

The characteristic features of this division are that the spindle now forms at right angle to the previous spindle formed in heterotypic division (first meiotic division). The details are similar to those described for mitosis. The specific characters are as follows :

1. Prophase II

The slide shows second prophase stage of *meiotic division* (Fig. 53) :

1. The *nuclear membrane* and *nucleolus* once again disappear.

2. The *spindle* starts appearing.

3. The *chromosomes* appear as dyads and are thick and coiled.

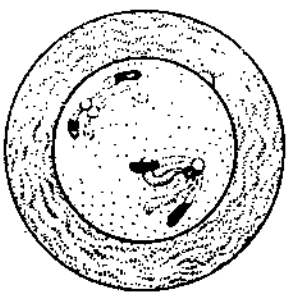


Fig. 53. Prophase

2. Metaphase II

The slide shows *metaphase of second meioic division* and is characterized the following features :

1. The ***dyads*** are arranged on the ***equator of spindle.***

2. The ***spindle*** is formed.

3. The ***arms of two chromatids*** of each ***dyad*** are facing towards opposite pole.

Anaphase II

The slide shows *anaphase II stage of second meiosis* and is characterized by the following features (Fig. 54) :

1. The centromeres of dyad have divided and both have started separating due to contraction of spindle fibres.

2. The *arms* of chromatids of a dyad are facing the equator and their *centromeres* are facing towards poles.

3. The haploid chromatids are still thick, short, stumpy and coiled.

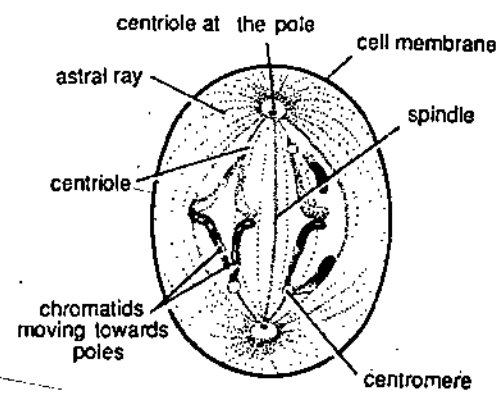


Fig. 54. Anaphase

4. Telophase II

The slide shows *IInd telophase stage of second meiotic division* and is characterized by the following features (Fig. 55) :

1. The *haploid chromatids* have reached the poles.

2. Around them *nuclear membrane* has reappeared.

3. The *chromatids* have started uncoiling and are now appearing as comparatively long and thin thread like structures.

4. This stage is followed by ***cytokinesis*** in which the two nuclei are separated by cell membrane and they become independent ***haploid daughter cells.***

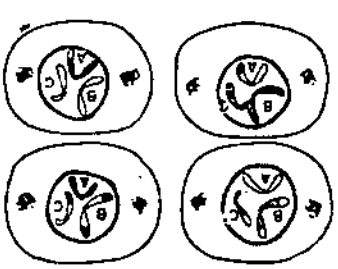


Fig. 55. Telophase

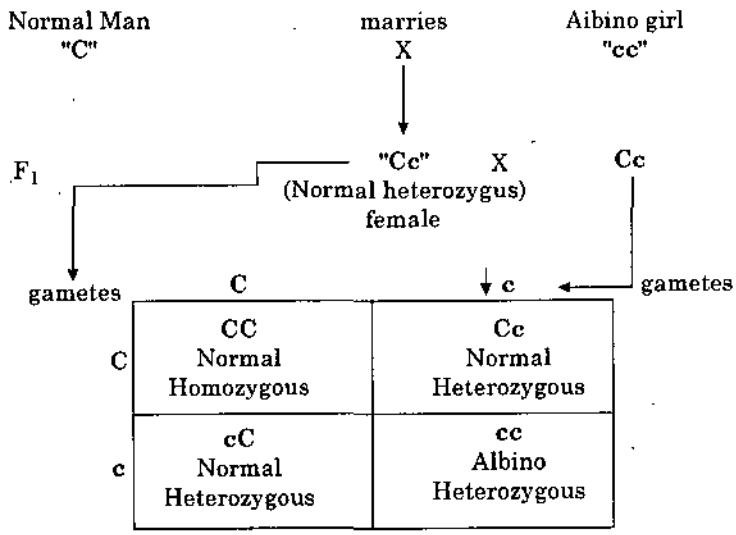
• 1.13. NUMERICAL EXERCISES IN GENETICS

Prob. 1 : ***Albinism is recessive*** *to* ***normal body pigmentation*** *in man. It is an* ***autosomal trait.*** *If a homozygous normal man marries an albino girl, what would be the phenotypic and genotypic ratios in F2 generation from this marriage.*

Solution : Since the two traits (*albinism and normal body colour)* are present in autosomes, they would behave as Mendelian monohybrid cross.

Since ***albinism*** is recessive it might be denoted with ***"cc"*** alleles and ***normal*** body pigmentation by ***"CC"*** genes because both are homozygous.

Now see chart below :



Conclusions :

(a) The marriage would produce, ***phenotypically 3 normal children*** and ***1 albino child.***

(b) The marriage would produce, ***genotypically, 1 normal homozygous : 2 normal heterozygous;*** and ***1 albino homozygous child.***

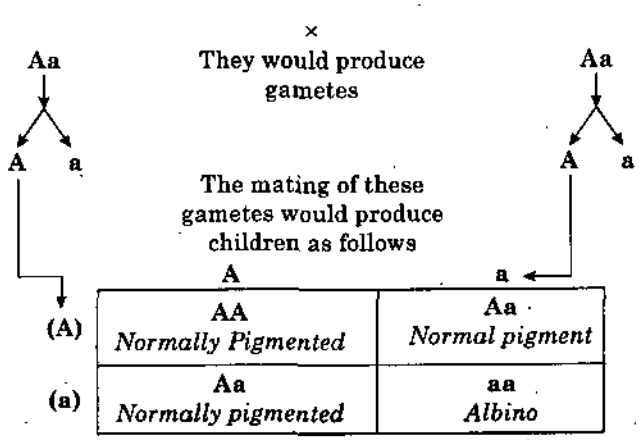
Prob. 2. ***Albinism,*** the total lack of pigment is due to a *recessive gene.* A man and woman plan to marry and wish to know the probability of thir having an *albino child.* What advice would you give to them if.

(a) ***Both are normally pigmented, but each has one albino parent.***

(b) ***The man is an albino.***

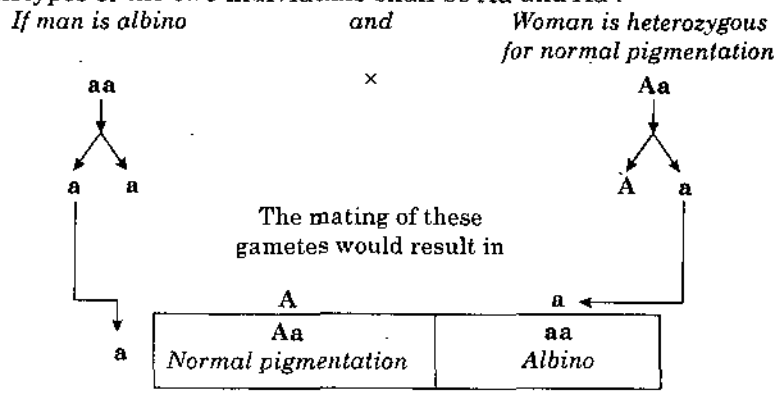
(c) ***The man is an albino and woman's family includes no albino for at least three generations.***

Solution : ***Albinism*** *is due to an autosomal gene and is expressed in homozygous condition. As such, the problem shall be solved on the Mendel's principles of Dominance and Segregation.*



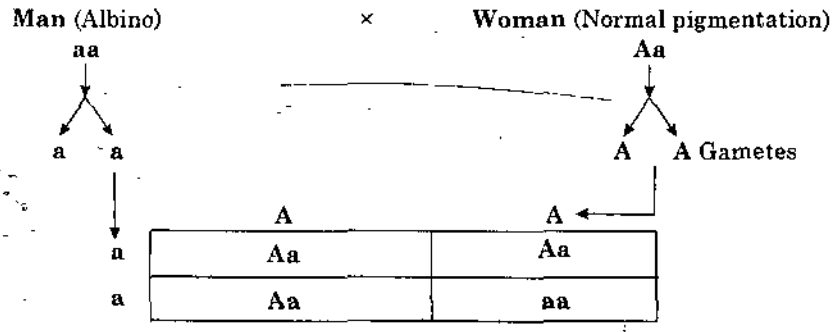
(A) Since both man and woman now have normal pigmentation but one of their parents was ***albino,*** the genotype of the two individuals shall be ***heterozygous "Aa"*** (if we denote albinism with ***"a"*** and normal pigmentation with ***"A"***). ***If they marry the chances of having an albino child are 25%*** as explained above in the chart.

The Genotypes of the two individuals shall be Aa and Aa :



Conclusion : Out of four possible combinations only one would result in producing an ***albino child.*** Hence chances are 25%.

(B) *If man is albino and woman is normally pigmented their genotypes would possibly be* ***"aa"*** (homozygous recessive for albinism) *for man and for the woman either the genotype shall be "AA" or "Aa", because both cases shall produce the phenotype normal pigmented.* ***The two crosses would give under noted results as shown in chart :***



Conclusion : ***The possibility of an albino child would be 50%.*** (ii) If man is albino and women is homozygous for normal pigment the possibility of albino child will be nil as shown in the chart.

(C) *If the man is albino and woman's family includes no albino for three generations the genotypes of man and woman would be homozygous (****"aa"*** *for albino and* ***"AA"*** *for normal pigmentation) and shall produce children having only normal pigmentation as above in (B ii).*

Conclusion : ***All normal pigmented (Heterozygous) children.***

Prob. 3 : In a case of disputed parentage, the mother of an illegitimate child has blood group ***N***, the child has ***MN,*** one suspected father has ***N*** and the other ***MN.*** How would you decide the case ?

Solution : In case of blood groups it is established that blood groups ***M*** and ***N*** are homozygous and are denoted by genotype $M^M M^M$ and $M^N M^N$ respectively. The blood group ***MN*** however, is heterozygous and is denoted by genotype $M^N M^N$. According to these facts we proceed as follows :

(a) Since, the mother of illegitimate child is ***N*** she should have the homozygous genotype ***MN MN*** and would produce gametes of only one type *i.e.,* having ***MN*** genes.

(b) The Child is, since, ***MN,*** he would be having the heterozygous genotype ***MM MN*** and must have received ***MM*** gene from one of the disputed fathers because the other gene ***MN*** must have come from his mother.

(c) Now, we have two persons in question, one of whom is having blood group *N* and the genotype ***MN MN*** because blood group *N* is homozygous. The other person in question is having blood group ***MN*** and the genotype in this case would be ***MM MN*** because blood group ***MN*** is heterozygous.

(d) Keeping the genotypes of the two suspected persons in view if we try to analize the responsibility of passage of ***MN*** gene to the child we would arrive at the conclusion that the person with group ***N*** could not have contributed ***MN*** gene and therefore the only possibility left is the other person with blood group ***MN*** and genotype ***MM MN*** who can contribute an ***MM*** gene.

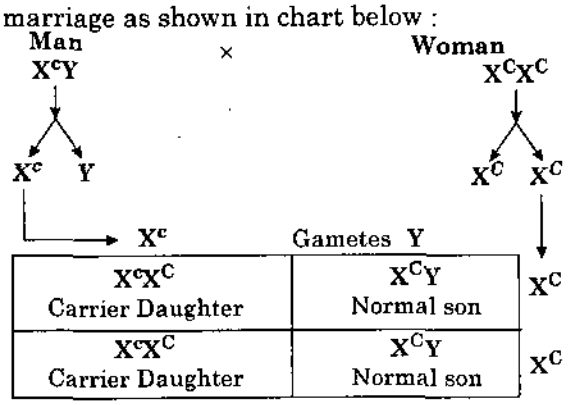
Conclusion : ***The father of the child must be the person with MN blood group.***

SEX-LINKED INHERITANCE EXERCISES

Prob. 4. Of what type will be the children with reference to ***colour blindness***, when a ***man is colourblind*** and his wife is normal ?

Solution : The cause of the colour blindness is the presence of recessive ***(c)*** gene on th X chromosome.

Because man is colourblind ***(X^c Y)*** and his wife is normal ***(X^CX^C)***, the following will be the result of the marriage as shown in chart below :



Following will be the result after fertilization :

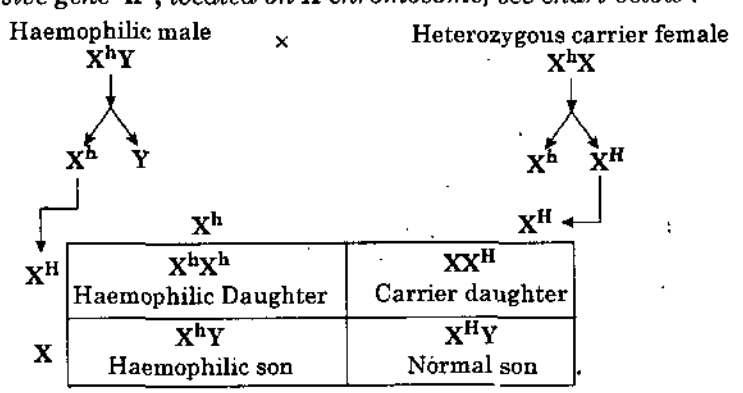
(i) X^C X^c *i.e.*, normal son but carrier daughter.

(ii) X^CY *i.e.*, normal son.

Conclusions : ***No child will be colour blind.***

Prob. 5 : When a **haemophilic** male is married to a heteroygous **carrier** female, what haemophilic proportion will be present in children of each sex.

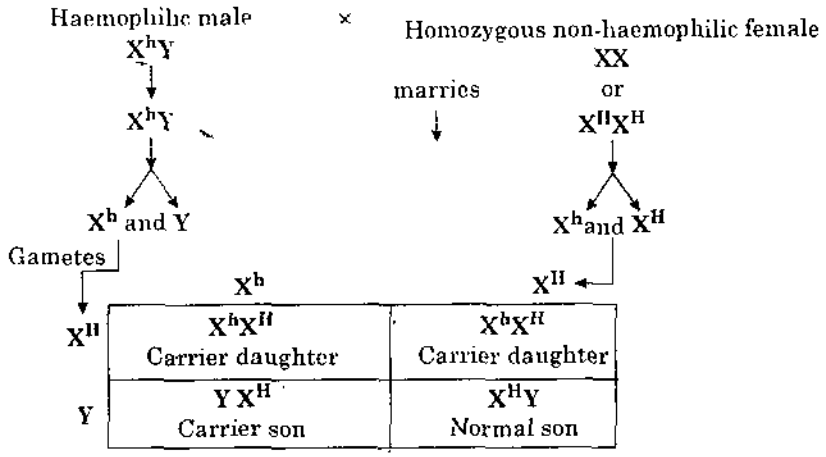
Solution : Since, *Haemophilia is a disease that causes delayed clotting of blood. It is due to a recessive gene* **'h'**, *located on X chromosome, see chart below :*



Conclusions : One haemophilic daughter, One carrier daughter, One haemophilic son, One normal son.

Prob. 6 : When a ***haemophilic male*** is married to a homozygous ***non-haemophilic female*** what will be the result of this marrige ?

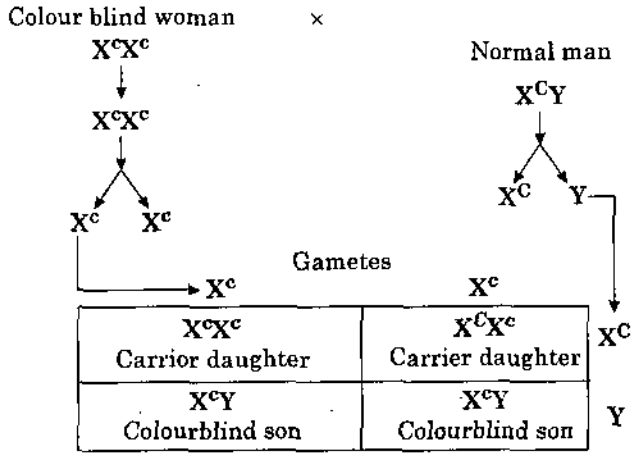
Solution : See chart below :



Conclusion : ***A ratio of 2 carrier daughters and 2 normal sons will be produced.***

Prob. 7 : Of what type will be the children with reference to ***colour blindness,*** when a ***woman*** is colourblind and her husband is normal ?

Solution : See Chart below :



Conclusion : ***In such cases all sons would be colour blind and of the daughters both would be normal but carrier.***

Prob. 8. A ***woman has normal vision*** but her ***father was colourblind.*** She marries a man who is ***colour blind.*** Find out the probability of the ***first child being colour blind*** if it is (a) ***Son*** or (b) ***Daughter.***

Solution : ***Colour blindness*** is a ***recessive sex-linked characer*** and gene is located in X^c ***chromosome.*** As such it expresses in phenotype in males in hemizygous condition but in females it would only express in phenotype when homozygous (present in both X^cX^c chromosomes).

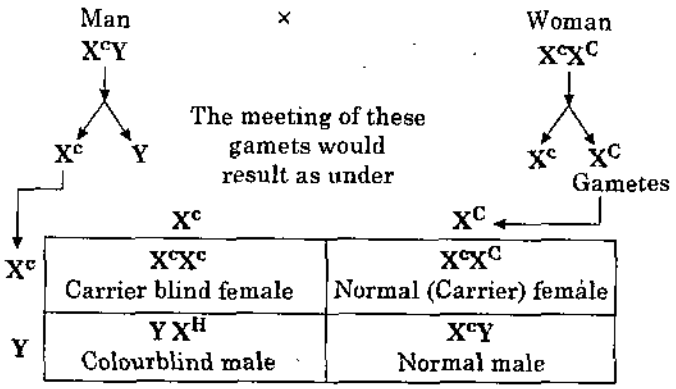
Now : The woman with normal vision and colourblind father meaning thereby that she is a ***carrier*** or ***heterozygous*** with genotype "X^cX^C".

She marries the ***man,*** who is ***colour blind*** and would have the gnenotype "X^cY".

Their marriage would result in as shown in chart below :

Conclusion : ***In this problem there is a slight twist that the probability of first colour blind child if male and if female is asked. The answer should be 25% for male child or female child, but if we do not emphasize on the word if then probability of first child being colour blind would be 50%.***

Prob. 9. A girl of ***normal vision,*** whose ***father was colour blind,*** marries a man of ***normal vision, whose father was also colour blind.*** What type of vision can be expected in their offsprings ?

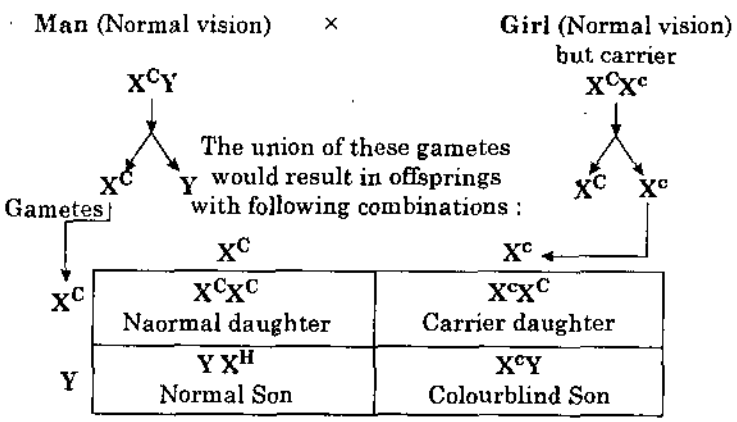


Solution : Knowing fully well that gene for ***colour blindness*** is recessive and is located in X^c chromosome we proceed to solve the problem as follows :

(a) Girl has normal vision but her father was colour blind. It means the father, although hemizygous, would behave as homozygous in case of daughters because the single X^c chromosome with gene for colour blindness would be transferred to the daughters. Since the daughter still has normal vision it means she is a *carrier* and carries no colour blind gene in her other X^c chromosome and therefore her genotype shall be "X^cX^C".

(b) The man also has normal vision and his father was also colour blind. Contrary to the aforesaid explanation in (a) the genotype of man should be "$X^C Y$". This is because he would have received Y chromosome from his colour blind father and, since he has normal vision he should have the X^C chromosome free of the gene for colour blindness.

(c) The marriage of this girl and this man would produce offsprings as shown in chart below :



Conclusion : ***All daughters shall have normal vision, but 50% of the sons would have colour blind vision.***

BOTANY

UNIT

1

LABORATORY TECHNIQUES

STRUCTURE

- Introduction
- Compound Microscope
- Some Staining Procedures
- Preparation of Permanent Slide
- Microtomy
- Preparation of Solutions, Reagents and Stains

• 1.1. INSTRUCTIONS

Observe the following precautions when you are in the laboratory:

1. See that your seat is clean, contains all the apparatuses, chemicals and reagents required for today's practical, and all the chemicals and reagent bottles are well-labelled.

2. **Work**

(a) independently;

(b) strictly according to the instructions of your teacher and;

(c) systematically, *i.e.*, first external morphology, then internal study and then the reproductive structures. (It is generally observed that students, just after getting the material, start the section cutting without going through its external study and then they think of the latter which is now not possible because now they do not have the required material or those stages in the material which are required for external study).

3. Also note strictly that you are required not only to do practical work like section cutting or setting the experiment etc., but equally important work is to:

(a) observe the details of your experiment;

(b) note the observations and final results of the experiment;

(c) see whether all the informations, given to you in the instructions by your teacher, are present in your material or not, and;

(d) draw the diagrams of different stages present in your material with the unaided eye or with the help of a *magnifying lens, dissecting microscope, binocular microscope or compound microscope*, there itself in the laboratory.

4. **Keep**

(a) every thing clean;

(b) your desk and table in order;

(c) your hands clean and dry at the time of mounting the ribbons on the slide in the process of microtomy;

(d) the containers filled with anhydrous solutions tightly corked;

(e) every record and data up-to-date, and;

(f) the bottle of Canada-balsam away from light.

5. You will be provided by your teacher with a daily schedule, and you should check your work for the day against the schedule to make sure that no measurements or preparations have been overlooked.

6. Science students should have a note-book to record what they do day-by-day in the laboratory. Every thing pertaining to the provided problem should be

recorded in the note-book. *It should be kept up-to-date.* One cannot work efficiently in the laboratory periods unless the work of the preceding period is finished.

7. Read carefully the laboratory instructions before you report to the laboratory. A lot of work may be there in the laboratory periods and so you must arrive knowing what you are expected to do.

8. You will have to perform new experiments daily in the laboratory and so a need to learn and use new technical words will arise. From *glossary,* you should see and note the explanations of all these words.

9. You must do your best when you are performing *an experiment with a team.* In scientific investigations, both team work and individual work are very important.

10. *An extremely important part of a team work experiment is the discussion.* Note the following at the time of discussion :

(a) Treat the discussion time as the period of your practical class.

(b) Review the questions asked, procedures followed and results obtained from your investigations.

(c) Discuss clearly and frankly what you do not understand about the experiment you have performed.

(d) Try to suggest your own ideas in which the given experiment could be performed in a better way than the instructions given in the laboratory.

(e) Try to develop the *"etch of curiosity* about the ways and methods for the given experiment.

• 1.2. COMPOUND MICROSCOPE

Parts of Microscope

1. The instrument is so named because it consists of two or more lens systems (Fig. 1).

2. At the top is present the *ocular lens.* It can be turned around or may be removed. At the top of ocular lens is written 5X or 10X, signifying the 5 times or 10 times magnification, respectively.

3. Just below the ocular is a *body tube,* the bottom end of which contains a circular piece called *nose piece.* It contains three lenses called *objective lenses.* Nose piece can be rotated to change the position of objectives.

4. The flat platform present below the objectives is called *stage.*

5. On the arm of the microscope are present two knobs, i.e., *coarse adjustment knob* and *fine adjustment knob.*

6. Out of the three objectives, the shortest is the *low power objective.* It has the largest lens but its magnifying power is least of the objective lenses. On the objective may also be written 10X like ocular lens. It means if a 10X ocular lens is used the magnification is $10 \times 10 = 100$ times.

7. The other objective is high power objective. Its magnification is equal to the number written on it multiplied by the power of ocular, *i.e.,* 5X or 10X (objective x ocular).

8. The third objective is called oil immersion. Generally, it contains a black band around the lower end. Use a drop of oil on the slide at the time of studying with the oil immersion objective. Its magnification can be estimated as ocular x objective.

The use of oil is essential in order to keep the light rays properly aligned with the small objective.

9. Just below the stage is the *condenser.* Its function is to gather light from the mirror and direct it to the objective lens. Condenser may be lowered or raised by a knob present on one side of the microscope beneath the stage.

10. Condenser contains a shutter' called *Iris diaphragm.*

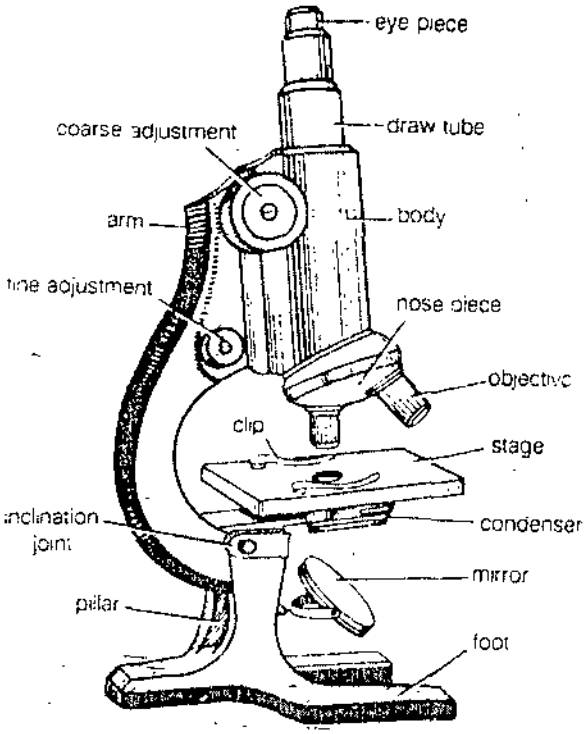


Fig. 1. Compound microscope.

11. Just below the condenser is present a *mirror* having its one surface flat and other surface concave. Use the concave surface in day light. Flat surface of the mirror is used when electric lamp is used.

• 1.3. SOME STAINING PROCEDURES

1. *Safranin-Fast Green Method:* Keep the material to be stained in *safranin* for three to five minutes and then wash it with water. See under the microscope that only thick-walled cells are stained. Excess of stain is destained by acid alcohol. Again wash the material very thoroughly with water so that even the traces of acid are removed. Now stainn the material with a few drops of fast green for a few seconds. Time for keeping material in fast green varies from a few second to one minute for different materials. Wash the material with glycerine and mount in a drop of glycerine.

With this method, all thick-walled cells get red stain and thin-walled cells the green stain. The entire procedure can be summarised as follows :

Select a thin section → Stain with safranin (for 3 to 5 minutes) → Wash with water → Destain with acid alcohol (if need be) → Wash thoroughly with water to remove the traces of acid → Stain with fast green (few seconds to one minute) → Wash with glycerine → Mount in glycerine.

2. ***Safranin-Aniline Blue Method:*** *Follow exactly* the same procedure as mentioned above except that in place of fast-green use aniline blue.

3. ***Haematoxylin-Safranin Method*** : Keep the sections in Delafield haematoxylin for four to five minutes and remove the excess of stain with water. Wash with ammonia and then wash the material very thoroughly with water. Now stain with safranin for few minutes. Wash the sections with glycerine for removing excess of stain and mount in glycerine. The entire procedure can be tabulated as follows:

Select a thin section → Stain with haematoxylin (4-5 minutes) → Wash with water → Wash with ammonia water till stain turns blue → Wash with tap water → Stain with safranin (2-3 minutes) → Wash in glycerine → Mount in glycerine.

• 1.4. PREPARATION OF PERMANENT SLIDE

1. Safranin-Fast Green Combination

Select a thin section → Stain with aqueous safranin (for 3 to 4 minutes) → Wash thoroughly with water (till water remains colourless) → Dehydrate with 15% alcohol → 30% alcohol → 50% alcohol → 70% alcohol → 90% alcohol → Stain with fast green prepared in 90% alcohol → Destain with 90% alcohol → Absolute alcohol → Dealcoholize with 25% xylol → 50% xylol → 70% xylol → 90% xylol → Pure xylol (give two changes) → Mount in Canada Balsam or DPX.

2. Crystal Violet-Erythrosin Combination

In place of safranin use aqueous crystal violet stain and in place of fast green use erythrosin stain. Other details are similar as in safranin-fast green combination mentioned above.

3. Haematoxylin-Safranin Combination : It is also similar to above-mentioned safranin-fastgreen combination except the following differences. Use haematoxylin in place of safranin. Wash with ammonia water and then thoroughly with tap water. Use the safranin stain after 70% alcohol and destain with 70% alcohol and then use 90% and absolute alcohol. Other details are same as in safranin-fast green combination.

• 1.5. PREPARATION OF SOME SOLUTIONS, REAGENTS AND STAINS

Acetocarmin : Add 110 ml distilled water in 90 ml glacial acetic acid. Boil it and immediately add 1 gm carmine dye.

Acid Alcohol : Dissolve 30 ml of 37% hydrochloric acid in 970 ml of 90% ethanol.

Agar-Agar : Boil 1000 ml distilled water and add 30 gm of agar with constant stirring. When the agar dissolves, completely, pour this semisolid matter uniformly into petri dishes. In case it is to be stored for long time, autoclave the containers with agar agar.

Amino acid Solution : Take 1 mg of amino acid (aspartic acid or glycine) and dissolve it in 1 ml of distilled water.

Ammonium Molybdate in HNO_3 : 1 gm ammonium molybdate in 12 ml HNO_3.

Ammonium Molybdate Reagent : (a) Take 25 gm ammonium molybdate and dissolve it in 200 ml of distilled water; (b) Prepare 10% soludion of Na_2SO_4 in 300 ml of distilled water.

Now add solution (a) in solution (b), mix them thoroughly and make 1 litre solution by adding water.

Aniline Diphenyl Reagent : Mix 5 volumes of 1% aniline and 5 volumes of 1% diphenylamine in acetone with 1 volume of phosphoric acid (85%). Heat it for 10 to 15 minutes at 100°C.

Barium Chloride : 20 gm of barium chloride is dissolved in 100 ml water.

Benedicts Reagent : Dissolve 173 gm of sodium citrate and 100 gm of sodium carbonate separately in about 400 ml of hot water.

Filter them into a 1000 ml measuring jar and add water to make the solution upto 850 ml. Dissolve separately 17.3 gm of copper sulphate in about 150 ml of water. Add this solution slowly to the solution of sodium citrate and sodium carbonate prepared earlier. Mix the two solutions by constant stirring.

Biuret Reagent : Prepare 40% NaOH solution and 1% $CuSO_4$ solution. Add a few drops of $CuSO_4$ solution in NaOH solution until deep blue colour is obtained. This method of preparation of Biuret reagent is called Wilker's method.

Carnoy's Fluid 1 : Add glacial acetic acid and absolute ethyl alcohol in a ratio of 1 : 3.

Carnoy's Fluid 2 : Add glacial acetic acid, chloroform and absolute ethyl alcohol in a ratio of 1 : 3 : 6.

Caustic Potash : 1% = 1 gm in 100 ml water

1 N = 56.11 gm in 1000 ml of water

Chlorophyll Extract : Take about 250 gm fresh green leaves of spinach or any other soft green plant in a mortar. Add only a small amount of anhydrous sodium carbonate. Now add some amount of 80% acetone and grind the leaves. Also add some amount of solvent ether. With the help of separating funnel separate the whole mixture and use the solution as chlorophyll extract.

Cobalt Chloride : For 1% = 1 gm of cobalt chloride dissolved in 100 ml of water.

Copper Sulphate : For 1% = 1 gm of $CuSO_4.5H_2O$ per 100 ml of water.

Crystal Violet : Dissolve 1 gm of crystal violet in 100 ml of distilled water.

Crystal Violet (Hucker's Modification) : Dissolve 2 gm crystal violet in 20 ml 90% ethanol in one test tube and 0.8 gm of ammonium oxalate in 80 ml of distilled water in another test tube. Mix the solutions of both the test tubes.

Diphenylamine—H_2SO_4 Reagent : Dissolve 1 gm of diphenylamine in 100 ml of H_2SO_4 (conc.) and store in a dropping bottle.

Enzyme Solution : Dissolve one enzyme tablet in about 50 ml of distilled water.

Eosin : For 1% = Dissolve 1 gm of eosin in 100 ml of water.

Erythrosin : Dissolve 1 gm erythrosin in 100 ml of 90% ethyl alcohol.

F.A.A. : It is also called formalin-aceto-alcohol and is used as a standard preservative. It is prepared by adding :

50% (or 70%) ethyl alcohol	90 ml
Glacial acetic acid	5 ml
Formalin	5 ml

Fast Green : Dissolve 1 gm of fast green stain in 100 ml of 90% alcohol.

Fehling Solution : (a) Dissolve 24.65 gm of $CuSO_4.5H_2O$ in water and make the whole amount upto 500 ml; (b) Take 125 gm of KOH and 173 gm of Rochella salt (Potassium sodium tartarate), dissolve them in water and make the whole amount upto 500 ml.

Immediately before use, mix equal amounts of solutions (a) and (b). This mixture is used as Fehling solution.

Glycerine Jelly : It is prepared by mixing gelatin, glycerine and water in a ratio of 1 : 7 : 6.

Warm the gelatin by adding water and glycerine and then add a little amount of 1% phenol. A few crystals of safranin may be added to make the solution coloured. Cool the solution. On cooling, it settles in the form of jelly. Glycerine jelly is used for mounting purposes for preparations without undergoing the dehydration process.

Glycerine Solution (10%) : Mix 10 ml of glycerine in 90 ml of distilled water and add a few drops of formalin.

Gum Guiacum : For 1% = 1 gm of gum guiacum dissolved in 100 ml of 95% ethyl alcohol.

Hydrogen Peroxide : Dilute 10 ml of 30% hydrogen peroxide (H_2O_2) in 100 ml of water.

Indol Acetic Acid (IAA) : 100 ppm or 10 mg/100 ml : Dissolve 10 mg of IAA in 1 or 2 ml of absolute ethyl alcohol, add approximately 90 ml of water, heat it slowly to evaporate alcohol and dilute with water to make 100 ml.

Iodine Solution : Dissolve 6 gm potassium iodide (KI) and 2 gm iodine (I_2) in 100 ml of water.

Iodine Solution in KI (1%) : *Iodine = 1 gm, KI = 2 gm. Water = 300 ml.*

KOH (0.5 N alcoholic) : This is prepared in 95% ethanol exactly by titration.

Lactophenol : It is prepared by dissolving 100 gm of phenol in 100 ml each of lactic acid, glycerine and water.

Lactophenol Cotton Blue : Warm pure crystals of 20 gm phenol in 20 ml distilled water and thenadd 20 ml of lactic acid and 40 ml of glycerol. At the end add 0.05 gm cotton blue.

Methylene Blue (aqueous 5%) : Dissolve 0.3 gm of methylene blue in 30 ml of 95% ethanol and then add 100 ml of distilled

Methyl Orange : Dissolve 0.33 gm of methyl orange in 1000 ml of water

Methyl Red : Dissolve 0.5 gm of methyl red in 300 ml of 95% ethyl alcohol. Make the entire volume to 500 ml with distilled water , and mix the solution well.

Million's Reagent 'a' : Dissolve 1 gm of mercury in 9 ml of HNO3 (conc.) of specific gravity 1.52. Dilute the solution with equal

Million's Reagent 'b' : Add 10% mercuric sulphate to 10% sulphuric acid.

Ninhydrin : Dissolve 0.1 gm ninhydrin in 100 ml water saturated by n-butanol.

Osmic Acid : For 1% = 1 gm osmic acid dissolved in 100 ml of water.

Paper Chromatography Solvent :

(a) For Sugar Separation : Isopropanol and water in a ratio of 4 : 1; or n-butanol, acetic acid and water in ratio of 4 : 1 : 5.

(b) For Anthocyanin Separation : Butanol, acetic acid and water in a ratio of 3 : 1 : 1.

For Separation of Chlorophyll Pigments : Petroleum ether and acetone in a ratio of 100 : 12 or benzene **and** acetone in a ratio of 8.5 : 1.5.

Phenol (80%): Melt the phenol at 60°C in an oven. Take 80 ml of melted phenol and mix it in 20 ml of distilled water

Phenolphthale in Solution (1%) : Dissolve 1 gm of phenolphthalein in 50 ml of 25% ethyl alcohol and then add 50 ml of water

Phloroglucinol : Dissolve 1 gm of phenolphthalein in 50 ml of 95% ethyl alcohol and then add 50 ml of water.

Potassium Chromate : 5 gm of K_2CrO_4 per 100 ml of water.

Potassium Hydroxide : Mix 30 gm of potassium hydroxide in 100 ml of methyl alcohol.

Potassium Iodide (7.5%) : Take 7.5 gm of potassium iodide and dissolve in 100 ml of water.

Potassium Permanganate : Dissolve 1 gm potassium permanganate in 100 ml water

Protein Solution : Take Besan (gram flour) or egg albumin (white part of egg), dissolve it well in distilled water and use as protein solution.

Pyrimidine Sulphate Dibromide Reagent : This is prepared in three parts :

(a) (Take 5.4 ml of H_2SO_4 (conc.) and mix in 20 ml of glacial acetic acid.

(b) (Take 8.1 ml of pyridine and mix in 20 ml of glacial acetic acid.

(c) (Take 2.5 ml of bromine and mix in 20 ml of glacial acetic acid.

Now mix the solution (b) with (a) and add the resultant mixture in (c). With the help of glacial acetic acid dilute this mixture of all the three solutions till the entire amount becomes 1 litre. This reagent is used as Pyridine sulphate dibromide reagent.

Saframn : Dissolve 1/gm safranin in 100 ml water or 50% (or 70%) ethyl alcohol.

Silica Gel Slury : It may be prepared in 0.02 M sodium acetate. It is spread evenly, approximately 250 μ thick on a thin glass sheet. The glass sheet with silica gel slurry is kept for about 30 minutes in an oven at 150°C before use.

Silver Nitrate : For 10% = 10 gm of $AgNO_3$ dissolved in 100 ml of water.

Sodium Carbonate : 124.2 gm of $Na_2CO_3.H_2O$ is dissolved in 1000 ml of distilled water for preparing 1 M solution.

Sodium Chloride : 58.45 gm of sodium chloride is dissolved in 100 ml of water for preparing 1 M solution. For 5 M solution 292.25 gm of the salt is dissolved in 1000 ml of water. For making 10% solution dissolve 10 gm of NaCl in 90 of water.

Sodium Hydroxide : For 20% = 20 gm of sodium hydroxide dissolved in 100 ml of water.

Sodium Hypochloride : For 1% = 1 gm of sodium hypochloride dissolved in 100 ml of water.

Solvent for Amino acids : n-butanol (300 ml), glacial acetic acid (100 ml) and water (100 ml), *i.e.*, in a ratio of 3 : 1 : 1.

Starch Solution (1%) : Dissolve 1 gm starch in about 10 ml of distilled water, boil it and add more distilled water till the solution becomes 100 ml.

Starch Suspension (0.5%) : Dissolve 0.5 gm of starch by boiling it in 100 ml of distilled water.

Sucrose : 1% solution is prepared by dissolving 1 gm sucrose in 100 ml of distilled water. 1 M solution is prepared by dissolving 342.30 gm sucrose in 1000 ml of distilled water.

Sudan III : Dissolve 100 mg of Sudan III in 50 ml of 95% ethyl alcohol. Now add 50 ml of glycerol.

Sudan IV : Dissolve 100 mg of Sudan IV in 100 ml of 70% ethyl alcohol. Warm to dissolve.

Tetrazolium Chloride : Dissolve 0.1 gm of 2, 3, 5-triphenyl tetrazolium chloride in 100 ml of water and keep in a bottle.

Tetrazolium Reagent : It is 2, 3, 5-triphenyl-tetrazolium bromide.

Thin Layer Chromatography (TLC) Plate : Prepare a homogenous slurry of 4 gm silica gel and 10 gm cellulose in 80 ml of distilled water and spread it uniformly over the slide. Use 1 ml of this slurry for an area of 19 sq cm.

Thin Layer Chromatography (TLC) Solvent : Butanol, acetic acid and water in a ratio of 5 : 1 : 4 are mixed to prepare the solvent for TLC.

Universal Indicator : It is a mixture of many indicators having different critical pH (from 3 to 11). BDH Universal Indicator is generally used.

UNIT

2

GYMNOSPERMS

STRUCTURE

- What are Gymnosperms ?
- Disinguishing Features
- Indian Genera
- Classification
- Characters and identification of selected Gymnospermous Taxa

• 2.1. WHAT ARE GYMNOSPERMS ?

*"**Phanerogams** without an ovary"* have been referred as *Gymnosperms (Gymnos,* naked; *sperma,* seed) or *naked-seeded plants* by Goebel. This sub-division of *Phanerogams* **(flowering plants)**, *i.e.*, Gymnosperms, is represented by over 60 genera and 700 species, of which about 16 genera and 53 species have been reported from India.

• 2.2. DISTINGUISHING FEATURES

1. Plants are perennials with tree like habit and show xerophytic characters.
2. Plant body is differentiated into roots, stem and leaves.
3. Leaves are of two types–foliage leaves and scaly leaves.
4. In male cones, many microsporophylls are arranged on the central axis, each having many microsporangia containing microspores or pollen grains.
5. The ovules are covered by a single integument and are orthotropous. The integument consists of an outer fleshy, a middle stony and inner fleshy layer. It surrounds the nucellus.
6. Each ovule opens with the help of a mouth opening or micropyle.
7. Formation of embryo is meroblastic, i.e., develops from a small part of zygote.
8. *Polyembryony* is-present in many members, *e.g.*, *Pinus*.
9. True fruits are lacking.
10. Plants show alternation of generations.
11. Members of most of the orders (Cycadales, Coniferales and Ginkgoales) are living while those of the other orders like Cordaitales and Cycadeoideales are represented by fossil genera.

• 2.3. CHARACTERS AND IDENTIFICATION OF SELECTED GYMNOSPERMOUS TAXA

Division GYMNOSPERMS

1. Sporophytic plant body differentiated into roots, stem and leaves;
2. Ovules naked;
3. Phloem usually lacks companion cells;
4. Seeds attached to scale.

Class *Cycadopsida*

1. Leaves large, frond-like;
2. Wood manoxylic;

3. Vessels absent;
4. Plants dioecious with motile male gametes;
5. Seeds show radial symmetry.

Order *Lyginopteridales*

1. Large, frond-like pinnately compound leaves;
2. Leaf traces large;
3. Sporangia arranged in synangia.

Family *Lyginopteridaceae*

1. Monostelic stem;
2. Single vascular strand present in petiole; e.g., *Lyginopteris.*

Order *Bennettitales*

1. Persistent leaf bases cover the massive trunk;
2. Tip of frond-like leaves bear microsporophylls;
3. Megasporophylls form cones.

Family *Cycadeoideaceae*

1. Columnar massive trunk covered by leaf bases;
2. Flowers remain sunk in the apical part of the trunk; *e.g., Cycadeoidea.*

Order *Cycadales*

1. Plants are not large trees;
2. Stem woody and generally urbranched;
3. Palm-like in habit;
4. Mucilage canals present in cortex and pith;
5. Dipolyxylic leaf traces;
6. Ovule orthotropous and unitegmic.

Family *Cycadaceae*

1. Young leaves circinately coiled;
2. Coralloid roots present;
3. Leaf-like megasporophylls, *e.g., Cycas.*

Class *Coniferopsida*

1. Leaves needle-shaped or fan-shaped and not very large;
2. Pycnoxylic wood;
3. Seeds show bilateral symmetry;
4. Male cones in clusters.

Order *Coniferales*

1. Scaly and foliage leaves present;
2. Foliage leaves needle-shaped;
3. Resin canals present;
4. Pollen grains winged.

Family *Pinaceae*

1. Female cone woody and bears bract scales and ovuliferous scales;
2. Plants monoecious;
3. Seeds winged;
4. Polyembryony present; *e.g., Pinus.*

Order *Taxales*

1. Leaves simple, solitary and flat; 2 Plants mostly dioecious;
3. Single terminal ovule represents female strobilus;
4. Aril present.

Family *Taxaceae*

Characters same as of Order Taxales, e.g., *Taxus*.

Class *Gnetopsida*

1. Vessels present in wood;
2. Resin canals and mucilage canals absent;
3. Flowers present in compound strobili compa rable with the inflorescence of angiosperms;
4. Several envelopes surround the ovule.

Order Gnetales

1. Plants shrubs, lianas or trees:
2. Simple leaves arranged in opposite or whorled manner;
3. Male flowers contain perianth.

Family *Ephedraceae*

1. Usually branched shrubs with jointed stems;
2. Leaves minute and scale-like;
3. Strobili cone-like;
4. Archegonia present; *e.g., Ephedra*.

Family *Gnetaceae*

1. Usually woody lianas;
2. Leaves large, reticulate venation;
3. Strobili not cone-like;
4. Archegonia absent; e.g., *Gnetum*.

1. Cycas

Some Indian Species : *Cycas revoluta, C. circinalis, C. rumphii, C pectinata, C. siamensis, C. beddomei, etc.*

Systematic Position

Division	: Gymnosperms
Class	: Cycadopsida
Order	: Cycadales
Family	: Cycadaceae
Genus	: *Cycas*

• 2.4. ANATOMY OF DIFFERENT PARTS

Cut thin transverse sections of different parts (young normal root, old normal root, coralloid root, young stem, old stem, rachis and leaflets of Cycas revoluta and C. circinalis), stain them separately in safranin-fast green combination, mount in glycerine and observe the anatomical details.

T.S. Normal Root (*Young*)

1. Outermost layer of the root is called epiblema. From some cells arise the root hair (Fig. 1).
2. Inner to the epiblema is the parenchymatous cortex.
3. Inner to the cortex is a single-layered endodermis.

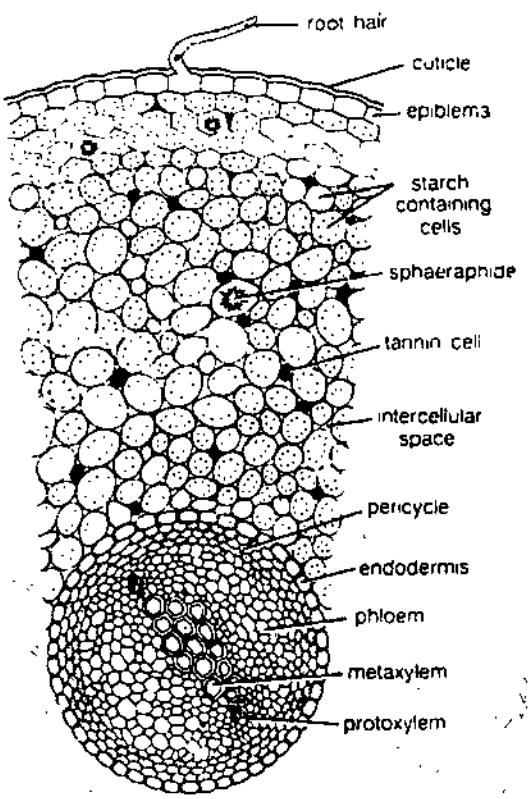


Fig. 1. Cycas revoluta. T.S. root

4. Vascular bundles are radial, i.e., xyiem and phloem are present on different radii. Xyiem is exarch.

6. The exarch protoxylem contains spiral thickenings, while the metaxylem has sca

T.S. Stem *(Young)*

1. It is wavy or irregular in outline due to persistent leaf bases and woody scales.
2. Outermost layer is the epidermis (Fig. 2).

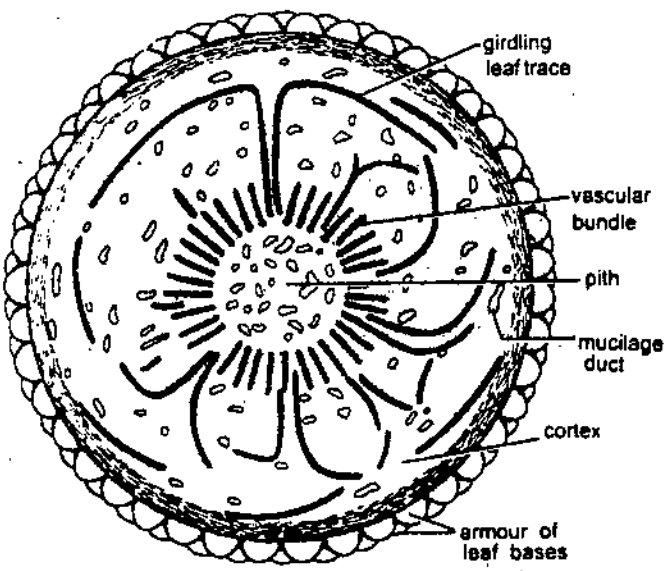


Fig. 2. Cycas. T.S. stem (young).

3. Cortex is very large, parenchymatous and contains many girdle traces and mucilaginous ducts.

4. Endodermis and pericycle are not very clear.

5. Vascular bundles are arranged in a ring. Each vascular bundle is conjoint, collateral, open and endarch.

6. Xylem consists of tracheids and xylem parenchyma. There are no vessels.

7. Phloem which consists of sieve tubes and phloem parenchyma. Companion cells are absent.

8. Pith is present with many mucilage ducts..

T.S. Rachis

1. It is rhomboidal, biconvex or roughly cylindrical in outline, if the section passes through the base, middle or apex of the rachis, respectively.

2. Two arms are present on rachis, one on each side. These are the bases of the leaflets, which arise from the rachis.

3: The outermost layer consists of thick-walled epidermis which is heavily cuticularized.

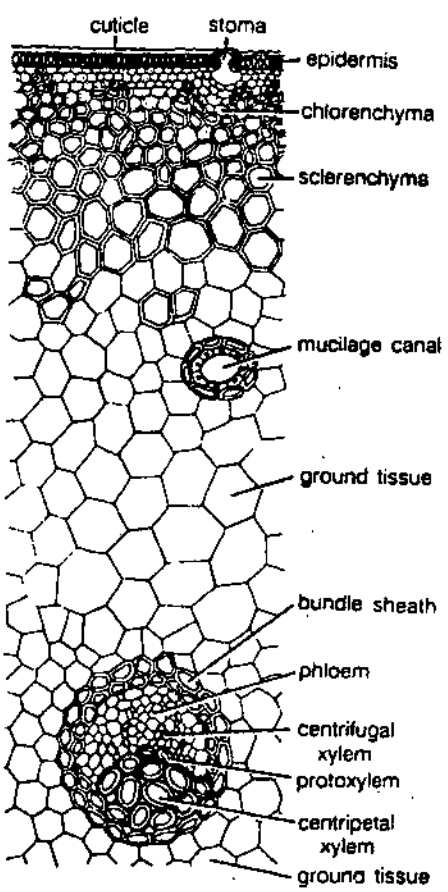


Fig. 3. Cycas revoluta. A part of T.S. rachis.

4. The continuity of epidermis is broken by many sunken stomata present on upper as well as lower side of rachis.

5. Below the epidermis is present chlorophyll-con taining cells of chlorenchyma followed by thick-walled sclerenchymatous region (Fig. 3).

6. Sclerenchyma is four to six-layered.

7. Below the sclerenchyma is present a large region of ground tissue consisting of thin-walled parenchymatous cells. In this region are present many mucilaginous canals and vascular bundles.

8. Each mucilaginous canal is a double-layered structure consisting of an inner layer of epithelial cells surrounded by an outer layer.

9. *Vascular bundles* are arranged in omega (Ω)-shaped manner.

10. Each vascular bundle is conjoint, collateral and open, and remains surrounded by a bundle sheath.

11. In vascular bundles, the xylem is present towards inner side consisting of tracheids and xylem paren chyma with no vessels. It is separated from the phloem by the cambium. The xylem is *diploxylic, i.e.,* consisting of centripetal and centrifugal xylem (Fig. 3).

12. Phloem is present on outer side and consists of sieve tubes and phloem parenchyma with no companion cells.

The vascular bundles show different structures at different levels of rachis starting from the base to the apex with regard to their diploxylic nature as under:

(a) *Vascular Bundles at the Base of Rachis*

1. Only the centrifugal xylem is well-developed.
2. Its protoxylem faces towards the centre showing endarch condition.
3. Centripetal xylem is not developed.

(b) *Vascular Bundles in the Middle of Rachis*

1. Centripetal xylem as well as centrifugal xylem are present showing diploxylic condition.
2. Centripetal xylem is present just opposite to the protoxylem of the centrifugal xylem.

(c) *Vascular Bundles at the Apex of Rachis*

1. Centripetal xylem is well-developed, triangular and exarch.
2. Centrifugal xylem is much reduced and present in the form of two patches lying one on each side of the protoxylem elements of centripetal xylem.
3. At the extreme tip, the centrifugal xylem is totally absent.

T.S. Leaflet of Cycas revoluta

1. The wings are curved downward or revoluted at the margins (Fig. 4).
2. Outermost layer consists of thick-walled epidermis surrounded by a layer of cuticle.

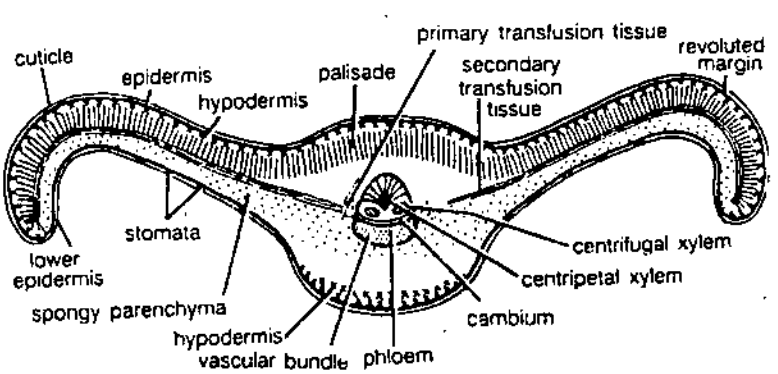


Fig. 4. Cycas revoluta. T.S. leaflet (diagrammatic).

3. Below the upper epidermis is present the sclerenchymatous hypodermis which is more cells thick in the midrib region.

4. Hypodermis is absent below the lower epidermis, except in the midrib region.

5. Mesophyll is differentiated into *palisade* and *spongy parenchyma* (Fig. 5).

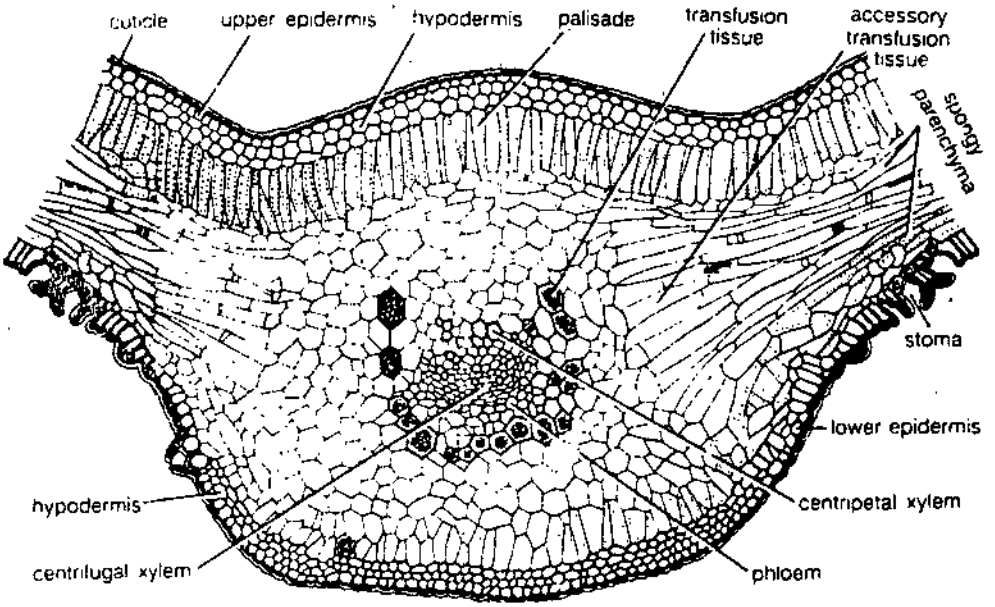


Fig. 5. Cycas revoluta. T.S. leaflet (a part cellular).

5. Few layers of transversely elongated cells are present in both the wings. This is *secondary transfusion tissue.*

6. A single vascular bundle is present in the midrib portion of the leaflet.

7. *The vascular bundle* is conjoint, collateral and open.

REPRODUCTIVE STRUCTURES

1. Plants are strictly dioecious.

2. Male structures are in the form of a compact conical body called *male strobilus or male cone.*

3. Female structures are not present in the form of compact cones but they are loosely arranged and are called megasporophylls.

T.S. Microsporophyll

Cut transverse section of microsporophyll, stain in safranin-fast green combination, mount in glycerine and study:

1. Many microsporangia (Fig. 6) are present on abaxial side.

2. Each shortly-stalked sporangium is surrounded by many layers with the innermost layer of tapetum. Many pollen grains are present in each sporangium.

3. Many vascular bundles are present in the microsporophyll.

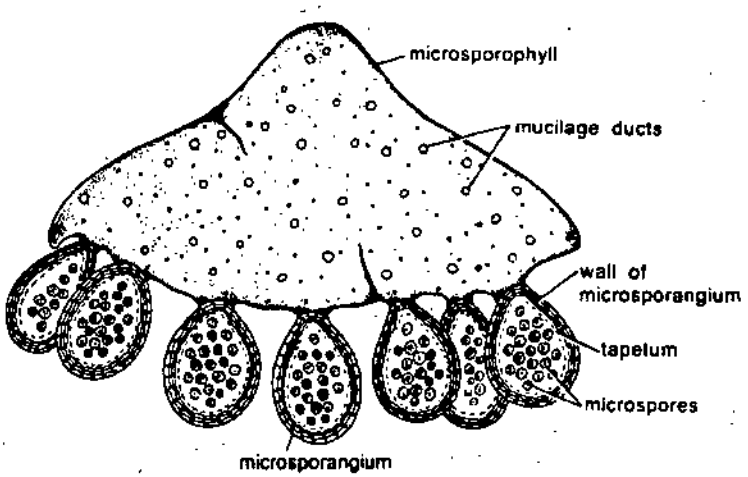


Fig. 6. T.S. microspropophyll.

Female Reproductive Organs

There is no true female cone or strobilus. Female reproductive organs are present in the form of *megasporophylls.*

L.S. Mature Ovule

1. The single integument covers the ovule from all the sides except at micropyle.

2. Single integument consists of the following three layers (Fig. 7):

(a) (*Outer*, fleshy layer called *sarcotesta;*

(b) (*Middle*, stony layer called *sclerotesta* and;

(c) (*Inner*, fleshy layer.

3. In the nucellar beak is present a hollow small cavity or chamber called *pollen chamber.*

4. In the centre of the ovule is present a female gametophyte.

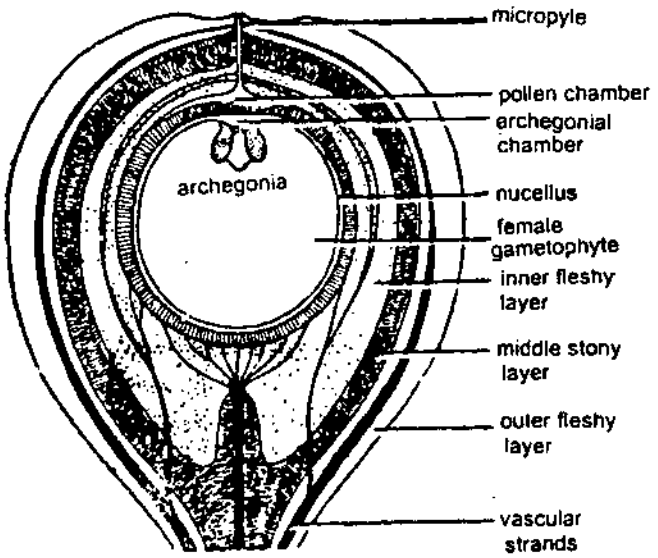


Fig. 7. Cycas. LS. ovule showing two archegonia and female gametophyte.

5. Two *archegonia* are present in the female gametophyte near the archegonial chamber.

6. Ovule gets vascular supply by the vascular strand in the outer and inner fleshy layers.

2. Pinus

Common Name: "Pine"

Common Indian Species : *Pinus gerardiana, P. roxburghii, P. wallichiana and P. insularis.*

Systematic Position

Division	:	Gymnosperms
Class	:	Coniferopsida
Order	:	Coniferales
Family	:	Pinaceae
Genus	:	*Pinus*

Occurrence Pinus occurs in India in Kashmir, Kinnaur district of Himachal Pradesh, hilly regions of U.P., Punjab, Assam, Meghalaya, etc.

• 2.6. ANATOMY OF DIFFERENT PARTS

Cut thin sections of different parts of the plant (Young root, old root, young long shoot, old long shoot, T.L.S. wood, R.L.S. wood, young dwarf shoot, old dwarf shoot and needle), stain them separately in a safranin-fast green combination, mount in glycerine and study. Also compare your preparations with the permanent slides shown to you in the laboratory.

T.S. Root

1. Outermost layer of the circular roots is thick-walled epiblema with many root hair.

2. Epiblema is followed by many layers of parenchymatous cortex.

3. Inner to the cortex is present a layer of endodermis and many layers of pericycle.

4. Vascular bundles are radially arranged and diarch to tetrarch with exarch protoxylem.

5. Protoxylem is bifurcated (Y-shaped) towards the periphery, and in between each bifurcation is present a resin cannal.

6. Phloem is present alternate to the protoxylem.

7. Pith is poorly-developed or absent.

T.S. Old Root Showing Secondary Growth

1. Below the phloem patches develops cambium, which cuts secondary phloem towards outer side and secondary xylem towards inner side.

T.S. Shoot

1. The number of the resin canals present in the cortex is generally six.

2. The number of the vascular bundles is also generally six.

3. Pith is smaller.

4. Structure of the vascular bundles is conjoint, collateral, open and endarch.

T.S. Needle (Foliage Leaf)

1. It is circular in outline in *Pinus monophylla*, semi-circular in *P. sylvestris* and triangular (Fig. 10) in *P. longifolia, P. roxburghii, etc.*

2. Outermost layer is epidermis.

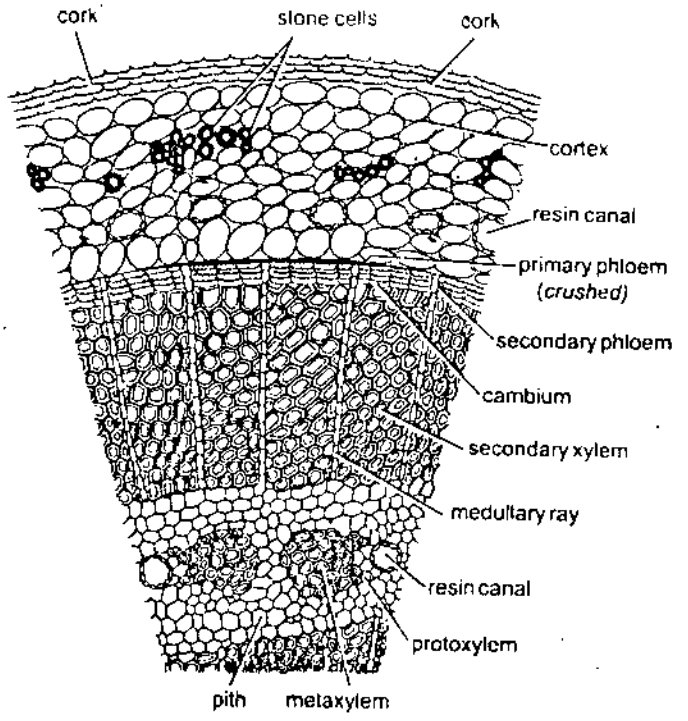


Fig. 8. Pinus T.S. old root.

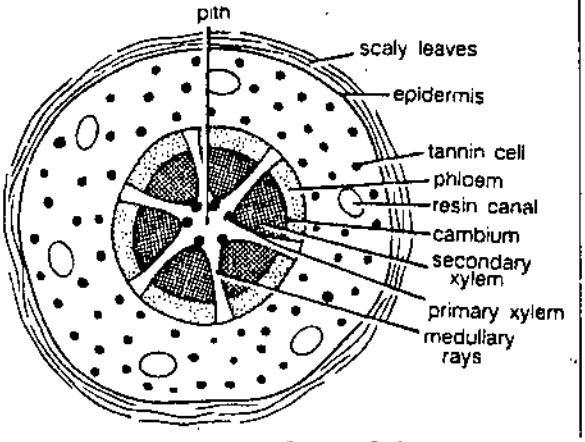


Fig. 9. Pinus. T.S. dwarf shoot.

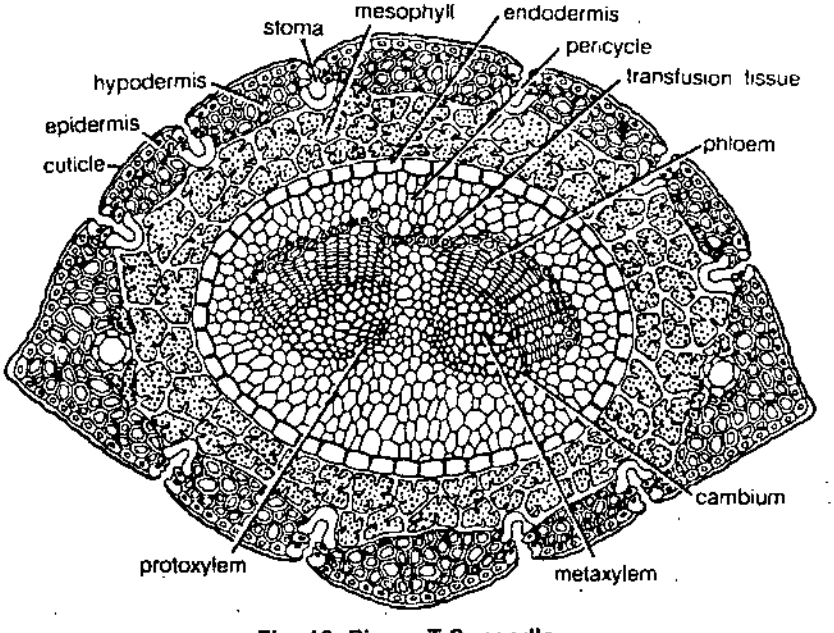


Fig. 10. Pinus. T.S. needle.

3. Many sunken stomata are present on the epidermis (Fig. 10).

4. Below the epidermis are present thick-walled sclerenchymatous hypodermis.

5. In between the hypodermis and endodermis is present the mesophyll tissue.

6. A few resin canals are present in the mesophyll.

7. Endodermis is single-layered.

8. Two conjoint and collateral vascular bundles are present in the centre.

9. Xylem lies towards the angular side and the phloem towards the convex side of the needle.

• 2.7. REPRODUCTIVE STRUCTURES

1. Plant body is sporophytic.
2. *Pinus* is monoecious.

Male Cone

Separate a male cone from the cluster, cut its longitudinal section.

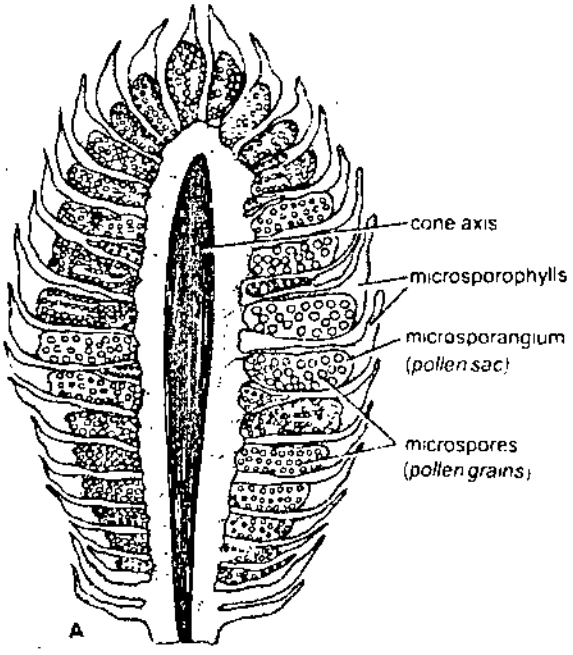
1. *Each male cone* is ovoid in shape and ranges from 1.5 to 2.5 cm. in length.

2. A male cone consists of a large number of *microsporophylls* arranged spirally on the cone axis.

3. A microsporophyll is consists of a stalk with a terminal leafy expansion. the tip of which is projected upwards which is called apophysis.

4. Two pouch-like microsporangia are present on the abaxial or undersurface of each microsporophyll. In each microsporangium are present many microspores (= *pollen grains).*

5. A few microsporophylls of lower side of cone are sterile.



L.S. Male Cone

Fig. 11. *Pinus*. L.S. male cone.

Female cone

Observe the longitudinal section of a young female cone.

L.S. Female Cone

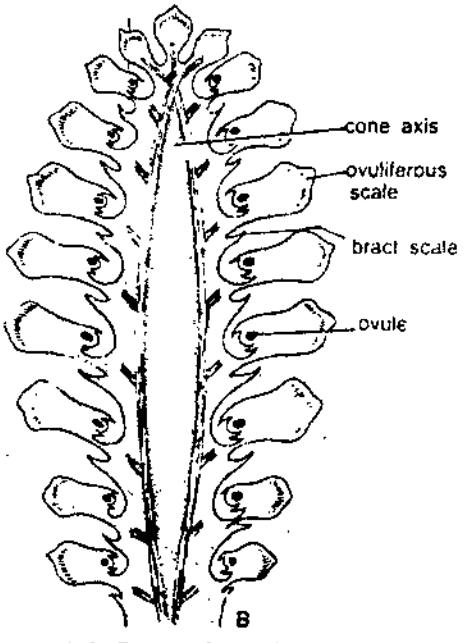
1. In the centre is present a cone axis (Fig. 12).

2. Many megasporophylls are arranged spirally on the cone axis.

3. A few megasporophylls, present at the base and at the apex of strobilus, are sterile.

4. Each megasporophyll consists of two types of scales, known as *bract scales* and *ovuliferous, scales.*

5. At the base of upper surface of each ovuliferous scale are present two sessile and naked ovules.



L.S. Female Cone (*Mature*)

Fig. 12. Pinus. L.S. female cone.

6. Micropyle of each ovule faces towards the cone axis.

7. *Each ovule* is surrounded by a single integument, consisting of an outer fleshy, a middle stony and an inner fleshy layer. It opens with a mouth opening called micropyle.

8. Just opposite the micropyle is present a pollen chamber.

9. In the endosperm or female gametophyte are present 2 to 5 archegonia.

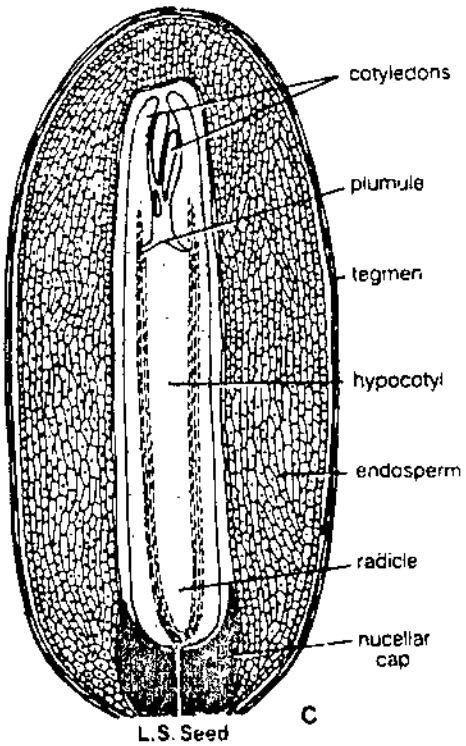


Fig. 13. *Pinus*. L.S. seed.

Anatomy of seed

1. It is enveloped by a seed coat developed from the middle stony layer of the ovule.

2. Well-developed endosperm is present.

3. In the centre is present the embryo consisting of a hypocotyle, radicle, plumule and 2 to 14 or more cotyledons.

3. Ephedra

Species Reported From India; *Ephedra pechyclada, E. intermedia, E. saxatilis, E. nebrodensis, E. regeliana and E. joliata.*

Systematic Position

Division	:	Gymnosperms
Class	:	Gnetopsida
Order	:	Gnetales
Family	:	Ephedraceae
Genus	:	*Ephedra*

Occurrence : Most of the species occur as xerophytic shrubs in both eastern and western hemispheres. In India, *Ephedra* occurs in north-west Himalayan region, Punjab and Rajasthan. *Ephedrafoliata* is a climber while *E. triandra* attains a tree-like habit.

ANATOMY OF DIFFERENT PARTS

Cut thin transverse sections of internodes of young and old stems, stain them in safranin-fast green combination, mount in glycerine and study.

Stem: T.S. Stem

1. The outline shows many ridges and grooves (Figs. 14, 15).

2. Outermost layer in epidermis. Continuity of the epidermis is broken by many stomata present in the grooves.

3. Below the ridges are present the patches of sclerenchyma.

4. Cortex is separated into palisade and spongy parenchyma.

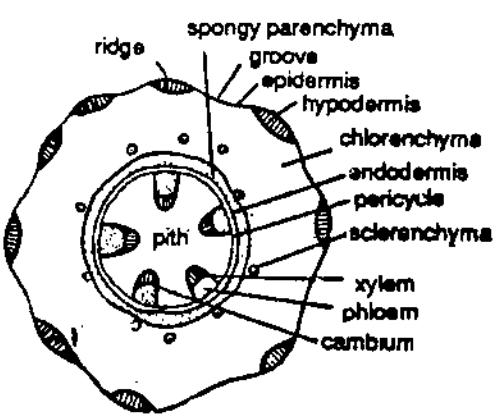


Fig. 14. *Ephedra*. T.S. young stem (diagrammatic).

5. Vascular bundles are arranged in a ring.

6. Stele is bounded by a layer of endodermis and unilayered pericycle.

7. Each vascular bundle is conjoint, collateral, open and endarch (Fig. 15).

8. In each vascular bundle phloem is present on the outer side and xylem on the inner side and both are separated by cambium.

9. Cambium cuts secondary phloem towards outer side and secondary xylem towards inner side.

10. Parenchymatous pith is present at the centre of the stem.

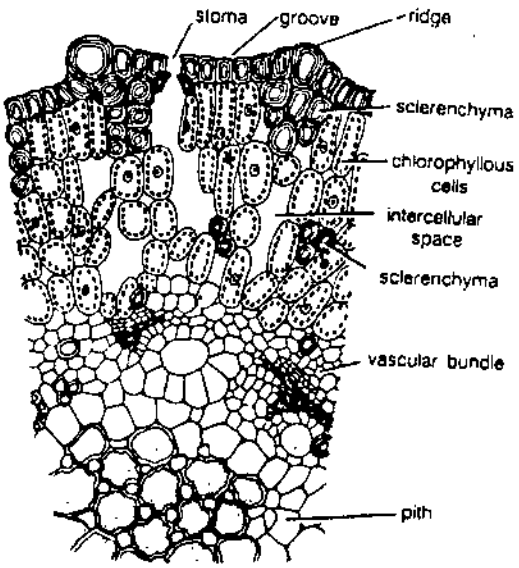


Fig. 15. *Ephedra trifurca*. T.S. Young Stem.

Stem: T.S. Old Internode

1. Primary medullary rays connect primary phloem and primary xylem while the secondary medullary rays connect secondary phloem and secondary xylem. Medullary rays are uniseriate in young stem while in the old stem these are multiseriate.

2. Resin canals are absent.

3. Parenchymatous pith is present in the centre.

REPRODUCTIVE PARTS

Ephedra is heterosporous, i.e., two types of spores (microspores and megaspores) are present.

Male Strobilus

2. Each strobilus is round or ovoid in shape.

4. On the strobilus axis are arranged 2 to 12 pairs of bracts in opposite decussate manner (Figs. 16).

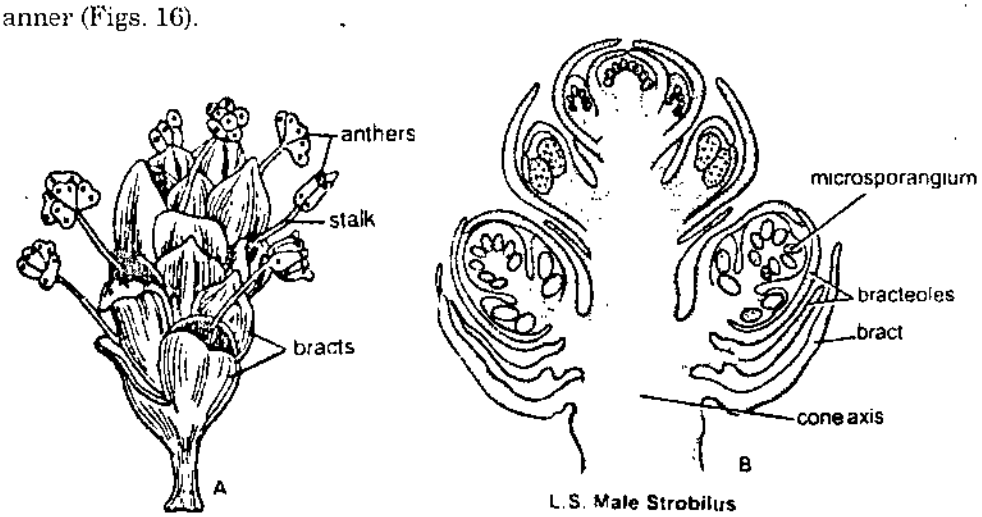


Fig. 16. *Ephedra*. Upper, A compound male strobilus; Lower, LS. male strobilus.

5. All the bracts are fertile except a few on the lower side.

7. Each male flower consists of two bracteoles and a stamen (Fig. 16).

8. Each stamen is a stalked structure with 2 to 4 anthers or microsporangia at the top.

9. Each anther or microsporangium is bilocular or trilocular, and each locule is surrounded by a double-layered anti wall an innermost layer of tapetum (Fig. 16).

10. Many pollen grains or microspores are present in each locule.

Female Strobilus

1. Similar to the male strobilus, the female strobilus also develops in the axil of the leaf on the node.
2. It is sessile and smaller than male strobilus.
3. Two to four pairs of bracts are arranged in opposite decussate manner on the strobilus axis (Figs. 17, 18).
4. Except the uppermost pair of bracts, all are sterile.
5. Two ovules are present.

Ovule

1. It is covered by a cup-shaped outer integument and an inner integument.
2. Outer integument perianth is attached at the basal part of the ovule (Fig. 18).
3. Inner integument protrudes out of the bracts.
4. A long micropyle is formed by inner integument (Fig. 18).

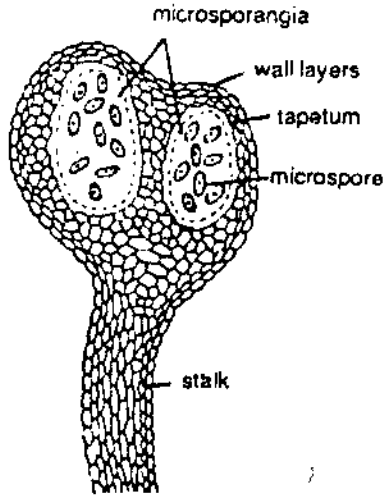


Fig. 17. *Ephedra*. L.S. stamen.

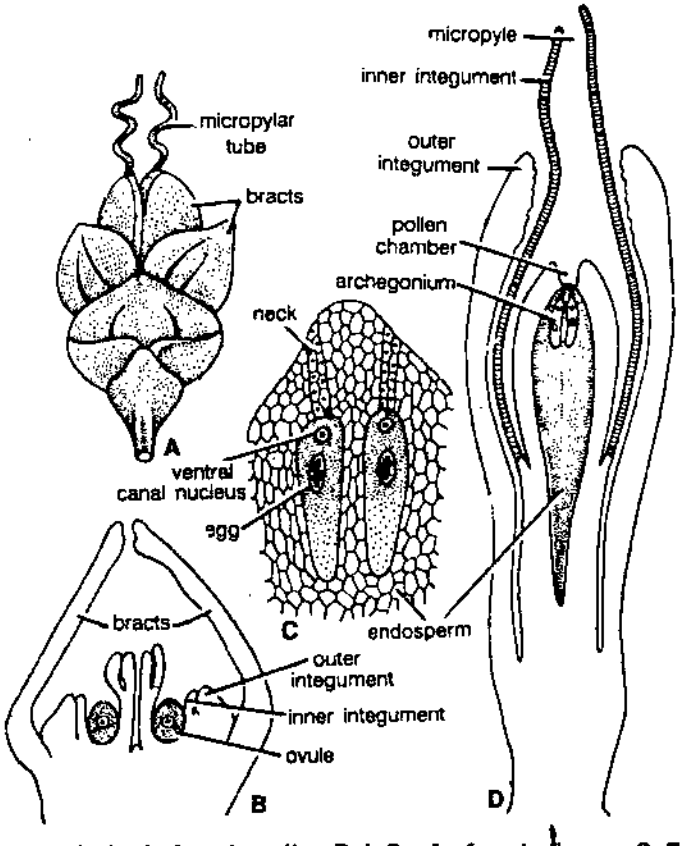


Fig. 18. *Ephedra*. A, A single female spike; B, L.S. of a female flower; C, Endosperm with two archegonia; D, LS. ovule.

5. Near the micropyle develops a small pollen chamber in the nucellus.
6. Female gameto- phyte is present in the centre.
7. Archegonia are present in the female gametophyte near the micropylar end.

UNIT

3

TAXONOMICAL TERMINOLOGY

STRUCTURE

- Root
- Stem
- Leaf
- Venation
- Stuple
- Flower
- Bract
- Calyx
- Corolla
- Androccium
- Gynoecium
- Placentation
- Fruit

• 3.1. ROOT

Generally, root is said to be the part of a plant which remains inside the soil. But there are subaerial as well as aerial roots also. Actually, root is a positively geotropic part of the

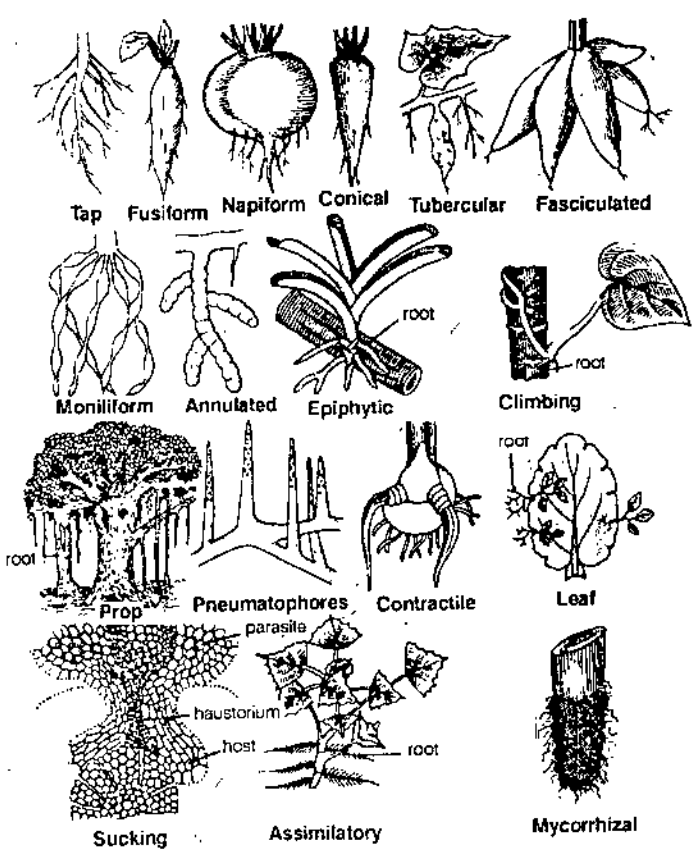


Fig. 1. Kinds of root.

plant having a root cap and many unicellular root hair. Ontogenically the root arises from the radicle.

(i) Tap root: The primary root with its many small lateral branches, which are normally meant to absorb water from the tap root system *e.g.*, Fusion, Napifom, Conical tuberular.

(ii) Adventitious root: A root that grows from any part of the plant like stem, leaves etc. but not from the radicle. is called adventitious root. *e.g.*, Fasciculated, moniliform, annulated, epiphytic, prop climbing, leaf respiratory roots and sucking

• 3.2. STEM

A negatively geotropic structure which develops from the plumule is called stem.

Forms of Stem (Fig. 2)

(A) Creepers

Weak herbaceous plants which cannot support themselves and run along the ground are called creepers *e.g.*, Runner, Stolon, Sucker and Offset.

(B) Trailers

Weak, thin, long shoots lying prostrate on the ground but lacking roots at the nodes are called trailers *e.g.*, *Diffuse Decumbent, Procumbent.*

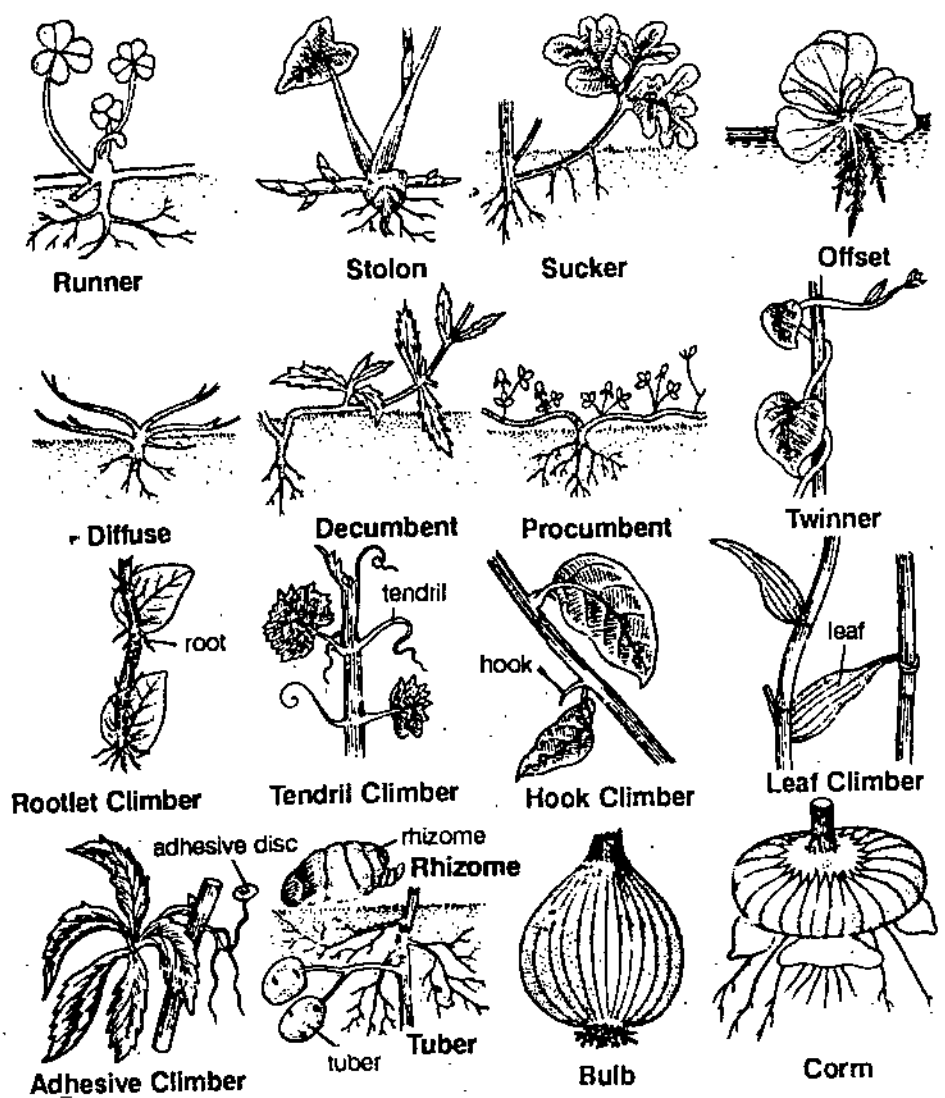


Fig. 2. Kinds of stems and their modifications.

(C) Twinners

Plants ascending by coiling on the support without any special device on the latter, *e.g. Clitoria ternatea.*

(D) Climbers

Weak-stemed plants, ascending on the support by means of some special modifications *e.g.*, Root climber, Tendril climber, Hookclimber, Leafclimber, dhesive disc climber, Lianas.

• 3.3. LEAF

Leaf Types

1. **Seed leaves** : These are the cotyledons present on the seed.
2. **Foliage leaves** : Flat, green, lateral appendages developing on stem or branch.
3. **Scaly leaves** : Scale like, small, stalkless, non-green leaf. It is also called cataphyll.
4. **Bract leaves or Hypsophylls**: These are present at the base of flower or inflorescence.
5. **Prophylls:** These are bracteoles.
6. **Ligule:** These are finger-like small parts present at the upper end of leaf sheath.
7. **Floral leaves** : Calyx, corolla, stamens and carpels.
8. **Sporophylls** : Spore-bearing leaves ot pteridophytes, gymnosperms and angiosperms.

Phyllotaxy

The arrangement of leaves on the stem (Fig. 3) is called phyllotaxy. It is of following three different categories:

1. **Alternate:** When only one leaf develops at each node.
2. **Opposite:** When a pair of leaves are present just opposite to each other at each node.
3. **Whorled** : When more than two leaves are arranged in the form of a whorl at each node.

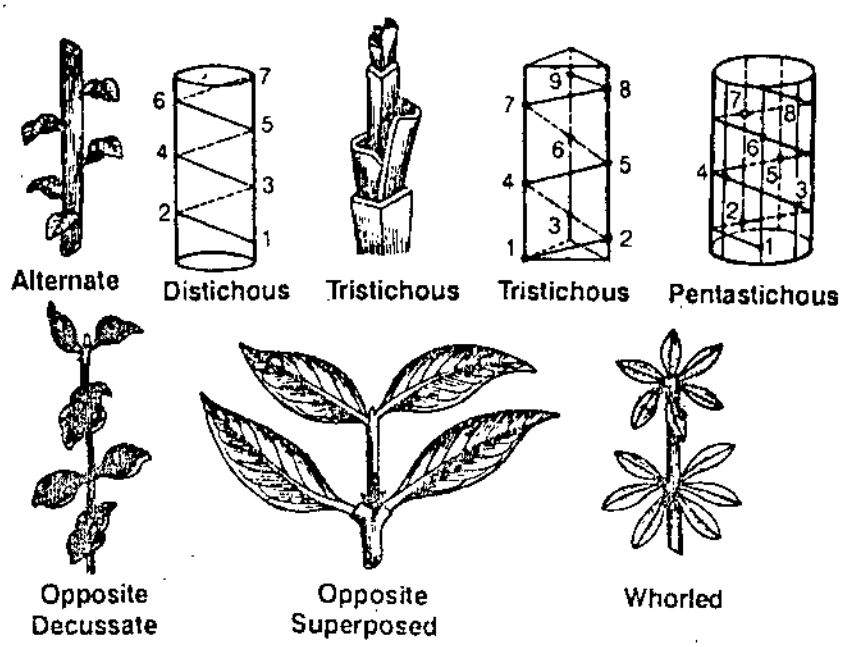


Fig. 3. Phyllotaxy.

Simple Leaf

A leaf consisting of single entire or divided blade, but the divisions of the blade are not so deep as to reach down upto the midrib (Fig. 4).

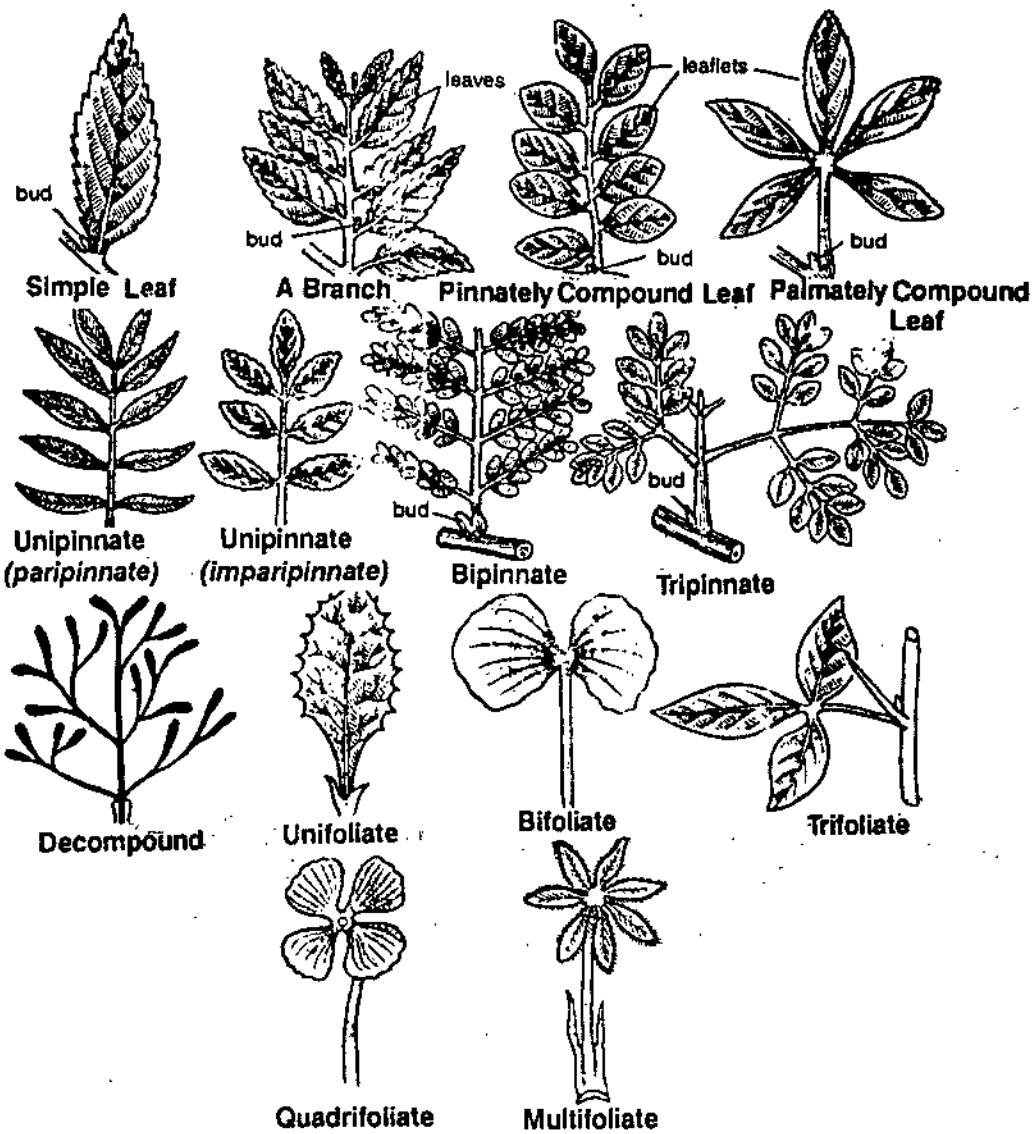


Fig. 4. Kinds of leaves.

Compound Leaf

When the divisions of the leaf blade or lamina are deep so as to reach upto the midrib and the leaf is divisible into many segments or *leaflets*, it is leaf (Fig. 4).

Leaf Shapes (Fig.5)

1. **Acicular** : Long and needle like, *e.g., Onion, Pinus roxburghii.*

2. **Linear:** Long, flat and narrow, *e.g., grasses.*

3. **Lanceolate** : Lance-shaped, broad and tapering either at both ends or generally towards the apex, *e.g., Nerium indicum.*

4. **Subulate:** It is an awlshaped leaf, *e.g., Isoetes.*

5. **Oblanceolate**: Broad in the middle and tapering towards both the ends, *e.g., Gnaphalium.*

6. **Elliptical** : Ellipse-shaped with both the ends rounded, *e.g., Psidium, Carissa,* etc.

7. **Ovate** : Egg shaped, *i.e.* broad at the base and narrowing towards apex, *e.g., Hibiscus rosa-sinensis.*

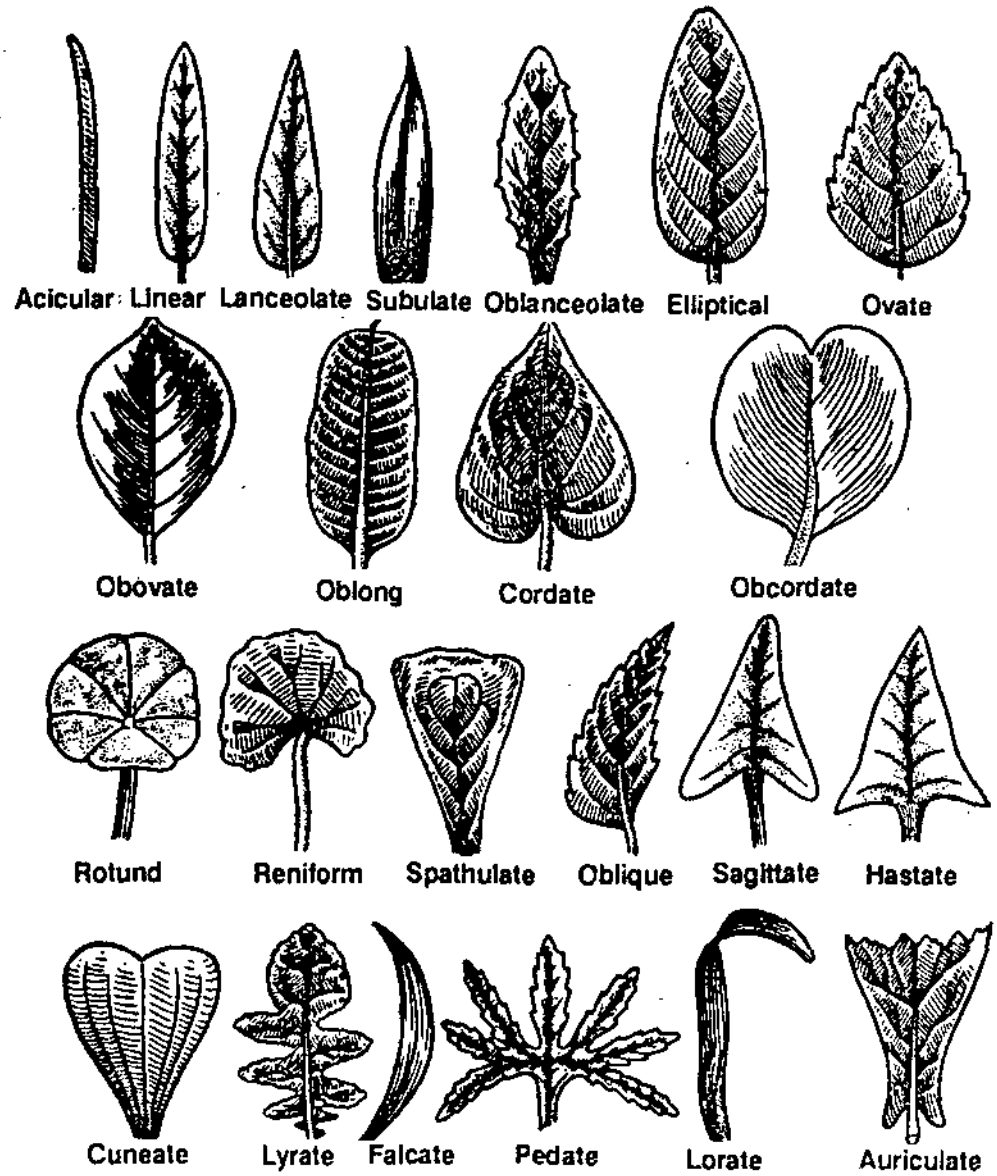


Fig. 5. Leaf shapes.

8. **Obovate** : It is inversely ovate, *i.e.*, upper end broader narrowing towards the base (Fig. 5). *e.g.*, *Artocarpus*.

9. **Oblong** : Long, wide with parallel-running margins. *e.g.*, *Banana*.

10. **Cordate:** Heart-shaped, *e.g.*, *Piper betel*.

11. **Obcordate:** Inversely cordate, *e.g.*, *Oxalis*.

12. **Rotund:** When blade is circular. *e.g.*, *Lotus*.

13. **Reniform** : Kidney-shaped (Fig. 5). *e.g.*, *Centella asiatica*.

14. **Spathulate** : Spathula-shaped, *i.e.*, broad and round at the top and narrowing towards the base, *e.g.*, *Drosera*.

15. **Oblique** : When two halves of the lamina are unequal, *e.g.*, *Azadirachta*, *Melia*, etc.

16. **Sagittate:** When leaf blade is like an arrow (Fig. 5), *e.g.*, *Sagittaria sagittifolia*.

17. **Hastate** : When two basal lobes of a sagittate leaf become pointed and directed outward. *e.g.*, *Ipomoea*.

18. **Cuneate**: Wedge-shaped leaf with lower narrow end, *e.g.*, *Pistia stratiotes*

19. **Lyrate** : When the leaf blade is like a lyre, *i.e.*, contains a big terminal lobe and many smaller lateral lobes. *e.g.*, *Raphanus sativus*.

20. **Falcate:** When the shape is like a sickle (Fig. 5), *e.g., Eucalyptus globulus.*
21. **Pedate:** Like the claw of a bird, e.g., *Vitis pedata.*
22. **Lorate:** When the shape is like a narrow strip of leather, e.g., *Vallisneria.*
23. **Auriculate:** When the leaf blade is ear-shaped, *e.g., Magnolia fraseri* (Fig. 5).

• 3.4. VENATION

Arrangement of veins and veinlets in the lamina is called venation (Fig. 6). It is of two types : reticulate and parallel.

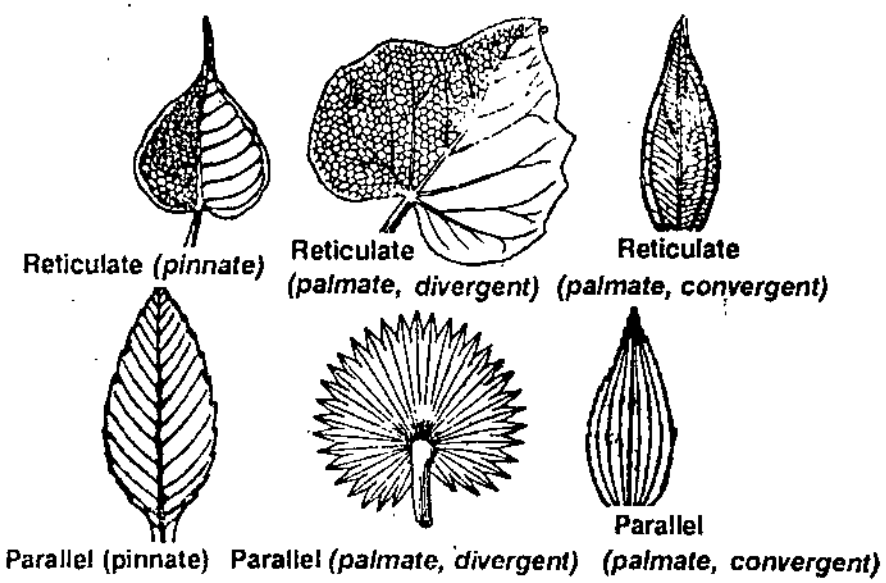


Fig. 6. Leaf venation.

1. *Reticulate venation*

When the veins and veinlets are distributed irregularly in the lamina and form a sort of net. It is of two types (Fig. 6).

2. *Parallel venation*

When the veins run parallel to each other *monocotyledons.* It is of two types (Fig. 6).

• 3.5. STIPULE (FIG. 8)

A small, leaf-like organ, which grows at the base of a petiole. It may be of following types :

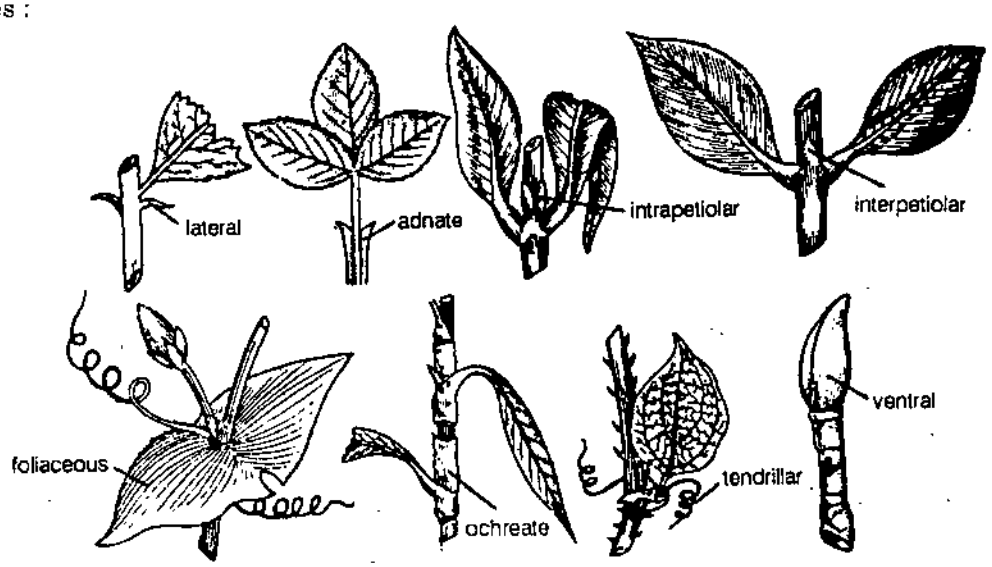


Fig. 7. Kinds of stipules

1. **Lateral**: Present laterally on or at the side of the base of petiole. *e.g., Hibiscus.*

2. **Adnate:** Present as wings due to their fusion with the petiole (Fig. 7), *e.g., Rosa.*

3. **Scaly** : Present as a **dry,** small, membranous structure, *e.g., Spergula.*

4. **Intrapetiolar**: Present in the axil of leaf and their margins fuse above the petiole, *e.g., Gardenia.*

5. **Interpetiolar:** Present in between the petioles of opposite or whorled leaves, *e.g., Mussaenda.*

6. **Foliaceous** : Present in the form of a large leaf, *e.g., Lathyrus aphaca.*

7. **Ochreate**: Present in the form of a tubular sheath round the internode, *e.g., Polygonum.*

8. **Spinous**: Present in the form of hard spines, *e.g., Acacia nilotica.*

9. **Tendrillar**: When the stipules modify in the form of tendrils, *e.g., Smilax.*

10. **Ventral:** Present on the ventral side of petiole, *e.g., Magnolia.*

• 3.6. INFLORESCENCE

Mode of the arrangement of flowers on the plant is called inflorescence.

Types of Inflorescence

An inflorescence may either be of racemose or cymose type.

Racemose or indefinite or indeterminate type of inflorescence

The arrangement in which the youngest flower is present near the apex and older towards the base, *i.e.,* in acropetal succession.

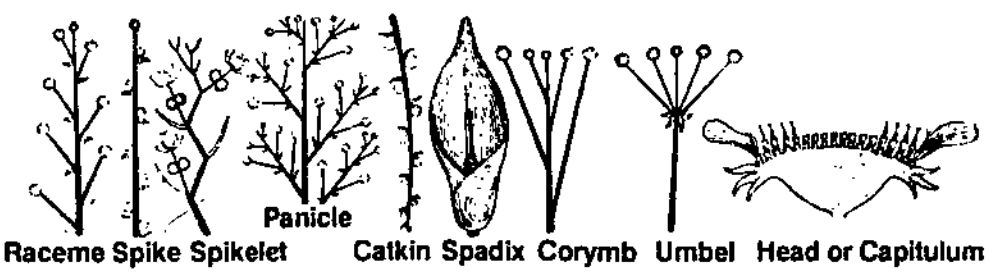


Fig. 8. Types of racemose inflorescence.

1. **Raceme:** When peduncle bears many pedicellate flowers in an acropetal manner, *e.g., Delphinium ajacis, Veronica,* etc.

2. **Spike** : A raceme with sessile flowers, *e.g., Adhatoda vasica, Callistemon,* etc.

3. **Spikelet**: Small spikes arranged in a spike, raceme or panicle manner. Each flower consists of an awned bract, three stamens and an ovary with two feathery stigmas, *e.g., Triticum.*

4. **Panicle**: Branched raceme, *e.g., Delonix regia.*

5. **Catkin** : Pendant spike with unisexual flowers, *e.g., Moris alba, Salix,* etc.

6. **Spadix** : Spike with a fleshy axis, enclosed by one or more large bracts called spathes, *e.g., Musa, Pistia,* etc.

7. **Corymb**: Raceme, in which all the flowers reach the same level due to more elongation of the pedicel of older flowers, *e.g., Iberis amara,*

8. **Umbel**: When pedicellate flowers arise from a common point as in *members of Umbelliferae or Apiaceae.*

9. **Capitulum or Head** : When numerous, small, sessile flowers are aggregated to form a dense inflorescence as in *members of Compositae or Asteraceae.*

Cymose (Fig. 9) or definite or determinate type of inflorescence.

When the apical growth of the floral axis is checked by the formation of a flower, it is called cymose inflorescence. Flowers are arranged in basipetalous manner, *I e.*, the terminal flower is oldest and young flowers are present on lower side. It is of the *following types :*

1. Monochasial or Uniparous Cyme : When peduncle bears a single terminal flower, and a single lateral branch which also bears a single terminal flower *e.g., Juneus*. It is of three types (Fig. 9).

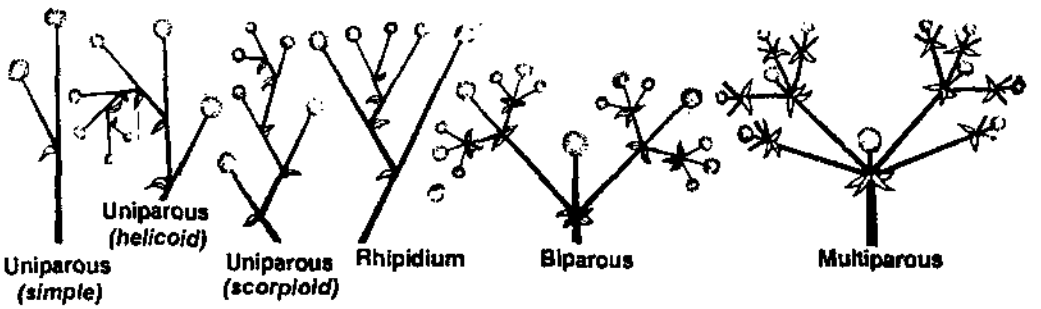


Fig. 9. Types of cymose inflorescence.

2. Dichasial or Biparous Cyme : When peduncle bears a terminal flower and a pair of opposite lateral branches which also bear terminal flowers, *e.g., Stellaria media.*

3. Polychasium or Pleiochasium or Multiparous Cyme: When the peduncle bears a single terminal flower and just below it are present more than two lateral branches bearing terminal flowers, *e.g., Calotropis procera.*

• 3.6. FLOWER

The part of the plant which is capable of producing either male (etamen) or female (stigma) or both the reproductive elements, is called *flower*. It may or may not be surrounded by the accessory whorls, *i.e., calyx* and *corolla*.

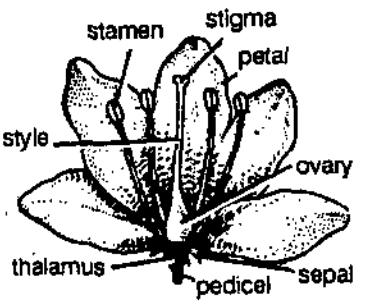


Fig. 10. Parts of a flower.

Some Terms Related to Flower (Fig. 10)

1. Complete: Having all the four flower parts, i.e., *sepal, petal, androecium* and *gynoecium*.

2. Unisexual: Flower with only one sex, i.e., either male or female. Male flowers are called *staminate* and the female flowers as *pistillate*.

3. Bisexual *(hermaphrodite)*: Flowers having both the sex organs.

4. *Dioecious* : When male and female flowers are borne on different plants.

5. Monoecious: When male and female flowers are borne on the same plant.

6. Actinomorphic: Flowers which can be bisected into similar halves along two or more planes. *e.g., Physalis, Datura,* etc.

7. Zygomorphic : Flowers which can be bisected into similar halves only in one plane. *e.g., Leucas, Adhatoda, Pisum sativum* etc.

8. Hypogynous: Flowers, in which floral parts are situated below the ovary and thus the ovary is superior, are called hypogynous, *e.g., Magnolia.*

9. Perigynous : Flowers, in which floral parts are situated around the ovary and thus the ovary is half-inferior, are called perigynous, *e.g., Pisum sativum, Prunus,* etc.

10. Epigynous : Flowers, in which floral parts are situated above the ovary, and *thus the ovary is inferior, are called epigynous, e.g., Helianthus.*

• 3.7. BRACT

A small leaf, with a flower growing from its axil, is called a bract.

1. **Foliaceous** : Large, green and leaf-like, *e.g., Adhatoda vasica.*

2. **Spathe**: Large, boat-shaped bract enclosing the cluster of flowers, *e.g., Musa* (banana).

3. **Petalloid** : Brightly-coloured bracts, *e.g., Bougainvillea, Euphorbia pulcherrima,* etc.

4. **Involucre**: When bracts are arranged spirally in one or more whorls around the cluster of flowers, as in *members of Compositae or Asteraceae.*

5. **Scaly**: When bracts are small and membranous, *e.g., Compositae.*

6. **Epicalyx** : Additional whorl of bracteoles over the calyx, *e.g., Hibiscus.*

7. **Cupule** : Cup-shaped, fused bracteoles as in *Fagus.*

8. **Glumes**: Small, dry bracts of spikelets of Potfceae and *Cyperaceae.*

• 3.8. CALYX

The outer whorl of perianth consisting of sepals is called calyx.

1. **Polysepalous** : When calyx lobes or sepals are free, *e.g., Cassia.*
2. **Gamosepalous**: When calyx lobes or sepals are fused or united, *e.g., Datura.*
3. **Caducous**: When sepals wither or drop off very soon, *e.g., poppy.*
4. **Persistent**: When sepals persist even in the fruit, *e.g., Solatium nigrum.*
5. **Petalloid** : When sepals are coloured, *e.g., Delphinium.*

• 3.9. COROLLA

The inner whorl of the perianth of a flower, composed of petals, is called corolla

1. **Polypetalous** : When petals are free, *e.g., Brassica.*
2. **Gamopetalous**: When petals are fused or united, *e.g., Adhatoda.*
3. **Apetalous**: When petals are absent.

• 3.10. ANDROECIUM

The male part of the flower, consisting of stamens is called androecium.

1. **Monandrous** : Flowers with one stamen, *e.g., Euphorbia.*
2. **Diandrous** : Flowers with two stamens, *e.g., Coronopus.*
3. **Polyandrous**: When stamens are many and free, *e.g., Corchorus.*
4. **Monadelphous**: When all the filaments are fused to form a single tube but their anthers are free, *e.g., Hibiscus* (Fig. 11).

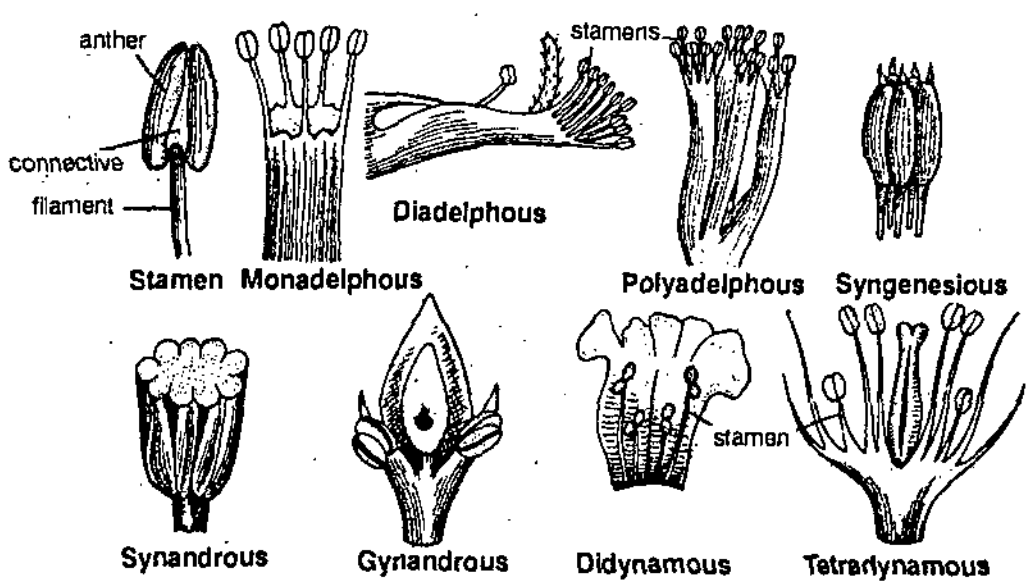


Fig. 11. Types of stamen.

5. Diadelphous: When filaments are united in two groups with their anthers being free, *e.g., Lathyrus* (Fig. 11).

6. Polyadelphous : When filaments are united in many groups with their anthers remaining free. *e.g., Ricinus, Citrus,* etc.

7. Syngenesious : When all anthers are united in one group with their filaments free. *e.g., Asteraceae* (Fig. 11).

8. Synandrous : When all anthers as well as filaments are united and form one group, *e.g.,* members of *Cucurbitaceae.*

• 3.11. GYNOECIUM

The innermost female whorl of the flower occupying the uppermost position on the receptacle and consisting of carpels or megasporophylls is called gynoecium.

1. Parts of a Typical Gynoecium: Terminal pollen-receptive part called *stigma;* median sterile part called *style* and basal, ovule-bearing part called *ovary.*

2. Monocarpellary : Gynoecium consisting of a single carpel, *e.g., Leguminosae.*

3. Apocarpous : When carpels are free, *e.g., Ranunculaceae.*

4. Syncarpous : When carpels are united or fused to form one compound gynoecium, *e.g., Solanaceae.*

5. Pistillode: A sterile carpel which lacks any ovule, as in *Moraceae.*

6. Locule and Loculi: The ovary is hollow from inside and encloses a chamber called locule (Fig. 12), or chambers called *loculi.*

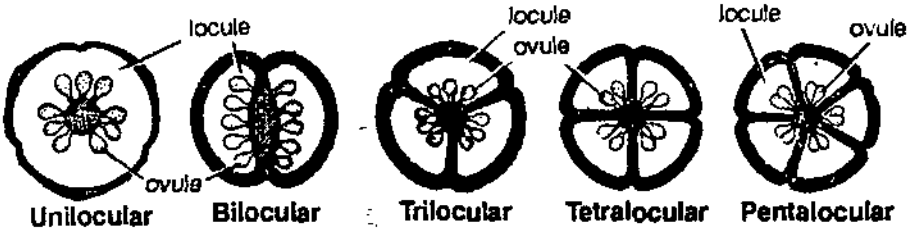


Fig. 12. Chambers of the ovary.

7. Unilocular : One - chambered ovary, *e.g., Stellaria.*

8. Bilocular : Two - chambered ovary, *e.g., Acanthaceae* (Fig. 12).

9. Trilocular : Three - chambered ovary, *e.g., Liliaceae* (Fig. 12).

10. Multilocular : Many - chambered ovary, *e.g., Malvaceae.*

11. Replum: False septum, as in *Cruciferae.*

• 3.13. PLACENTATION

Placenta : A cushion-like structure formed by the tissues of the carpels at the place where infolded margins of the megasporophylls meet is called *placenta.* From the placenta originate the ovules.

Placentation ; *Arrangement of ovules within the ovary is called placentation (Fig. 13).*

• 3.14. FRUIT

A fruit is the product of ripened ovary and adnate regions like thalamus. It contains seeds. Fruits are of following three different types :

1. Simple: The fruit derived from a monocarpellary or a polycarpellary syncarpous gynoecium.

2. Aggregate : Fruit derived from a single flower with more than one free carpels.

3. Multiple: Fruit derived from several flowers or from inflorescence.

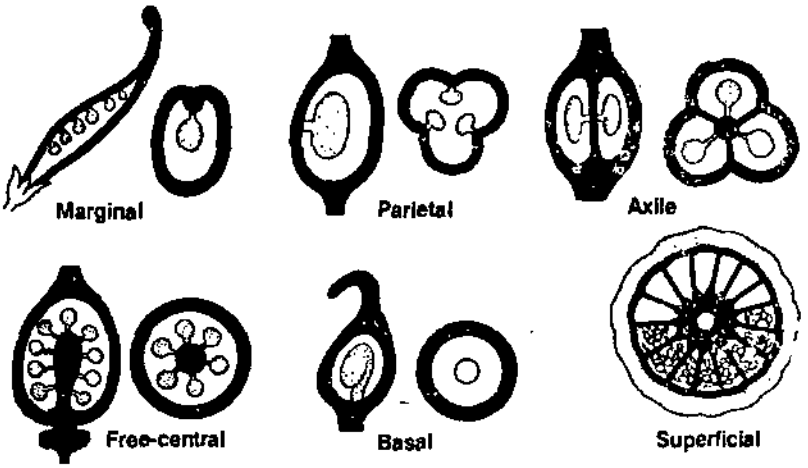


Fig. 13. Types of placentation.

EDIBLE PARTS OF SOME COMMON FRUITS

S.No.	Fruit	Edible parts
1.	Banana	Mesocarp and endocarp
2.	Coconut palm	Endosperm
3.	Date palm	Pericarp
4.	Mango	Mesocarp
5.	Iitchi	Fleshy aril
6.	Grape	Placentae and pericarp
7.	Apple	Thalamus
8.	Guava	Pericarp and thalamus
9.	Cucumber	Mesocarp and endocarp
10.	Orange	Juicy placental hair
11.	Pear	Fleshy thalamus
12.	Pineapple	Receptacle portion, perianth and bracts
13.	Tomato	Placentae and pericarp
14.	Pea	Cotyledons
15.	Wheat	Starchy endosperm
16.	Maize	Starchy endosperm
17.	Rice	Starchy endosperm
18.	Melon	Mesocarp
19.	Cashew nut	Peduncle
20.	Citrus	Endocarp.

UNIT

4

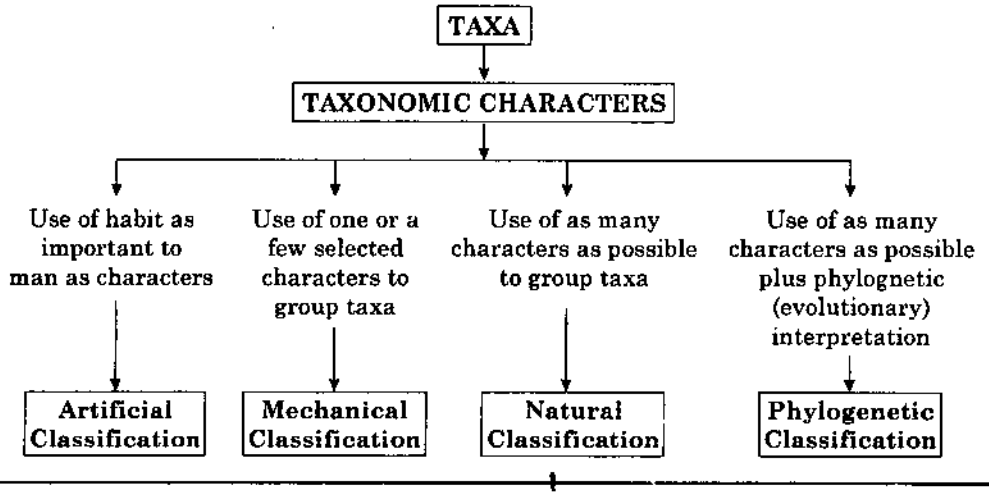
GENERAL TEXONOMICAL ASPECTS

STRUCTURE

- Major Taxonomic Categories
- Systems ofClassification of Angiosperms
- Features Used to Describe an Angiospermic Plant
- Flowchart of the Classification Proposed by Armen Takhtajan
- Herbaria and Botanical Gardens
- Some National and International Herbaria
- Botanic Gardens

• 4.1. MAJOR TAXONOMIC CATEGORIES

Fundamental unit of classification is called as *species*. It is a group of individuals showing very close structural and functional resemblances. The group in which we place various species are named as *genera* (singular, *genus)*. Related genera are, in turn, placed in *families*. Related families comprise *orders* and closely related orders are placed together in *classes*. Similar classes are grouped together in *division/phylum*, and all related divisions/phyla make up a kingdom, *i.e., plant kingdon or animal kingdom*.



• 4.2. SYSTEMS OF CLASSIFICATION OF ANGIOSPERMS

The natural system proposed by *Bentham and Hooker (1862-1883)* is most convenient and most suitable for the practical purposes, *and the same has been followed in the present book.*

Distribution of Taxa in *"Genera Plantarum"* of Bentham and Hooker:

Classes and Sub-classes	Orders (Families)	Genera	Species
Dicotyledons			
Polypetalae	82	2,610	31,874
Gamopetalae	47	2,619	34,556
Monochlamydeae	36	801	11,784
Gymnospermae	3	44	415
Monocotyledos	34	1,495	18,516
TOTAL	202	7,569	97,205

An outline of the classification, proposed by *Bentham and Hooker,* with a few points of each class and important orders, is given in the annexed chart. In a separate chart, an outline of classification by *Armen Takhtajan (1969)* is given.

Floral Formula

Different parts of the flower are represented by different symbols which form a formula called *floral formula.* Various parts are represented as follows :

Bracteate = Br
Ebracteate = Ebr
Bracteolate = Bri
Actinomorphic = ⊕
Zygomorphic = ↀ
Male = ♂
Female = ♀
Hermaphrodite = ⚥
Calyx = K
Corolla = C
Perianth = P
Androecium = A
Gynoecium = G

Number of the floral parts :

= By different numbers as 1, 2, 3, 4, 5 and so on, *e.g.,* K_5 means 5 sepals and polysepalous Cohesion of whorl:

= Enclosing the number in the bracket, *e.g.,* K(5) means 5 sepals are fused or gamosepalous.

Adhesion of the floral parts :

= Line drawn on the top of the two concerned whorls, *e.g.,* C_5 A(α) indicates that many fused stamens are epipetalous.

Superior ovary

= A line below gynoecium as $\underline{G}$.

Inferior ovary

= A line on the top of gynoecium as $\overline{G}$. Different whorls of floral parts

= Different figures separately, *e.g.,* C_{5+5} means 10 petals are arranged in two whorls of 5 each.

Absence of a parts = O.

Indefinite number of a part = α

Floral Diagram

After carefully drawing the other necessary diagrams (like a part of the plant, structure of the flower, L.S. of the flower, a stamen, gynoecium, and T.S. of the ovary) of the given plant, the most essential and most important diagram is the *floral diagram.* It

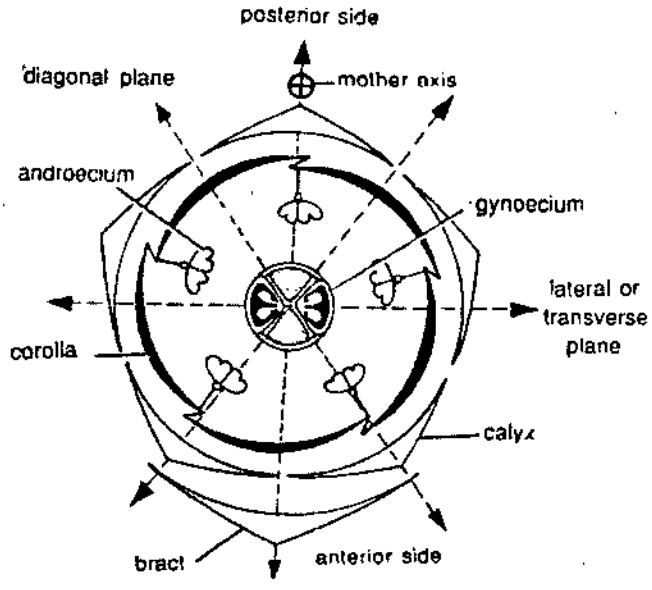


Fig. 1. Floral diagram showing different planes of a flower.

is actually an *ideal ground plan of a flower* which represents all floral parts in a perfect manner. It expresses the number, fusion, symmetry and other similar characteristics of the floral parts in a flower.

Different floral parts in a flower are expressed in a circular manner. In the different concentric circles of a floral diagram the *sepals* are drawn in the outermost circle. The sepals are followed by *petals, stamens* and *carpels* towards inner side, respectively. Gamosepalous or polysepalous condition is made by joining the sepals or making them free. Same is the case with petals.

Position of sepals and petals is drawn in the respective circles corresponding to their actual position in section. A small circle above the floral diagram represents the mother axis. In zygomorphic flower the mother axis is shown as ⦶ while in actinomorphic flower it is drawn as ⊕. The *bract*, if present, is drawn below the floral diagram while the *bracteoles* are shown on the sides.

For drawing the floral diagram note whether a sepal or space between two sepals stands towards mother axis. Start from this particular sepal and mark the position of other sepals. Petals are drawn alternate to sepals. In actinomorphic flowers all sepals and petals are drawn of same size. But in case of zygomorphic flowers unequal sized sepals or petals are drawn. Spur in a sepal or petal is drawn in the form of a loop.

In case of *epipetalous* condition of stamens join the stamens to petals with a line. Stamens are shown by transverse section of anthers. In *obdiplostamenous* condition the stamens of outer whorl are drawn opposite to petals.- Introrse stamens face towards gynoecium while extrorse towards petals. Use a cross *(x)* or asterisk (*) in place of a staminode, if present. The gynoecium is drawn in the form of transverse section of the ovary.

Some National and International Herbaria:

S.N.	*Name of the Herbarium*	*Established in*	Total Number of Specimens	*Remark*
1.	Herbarium of Royal Botanic Gardens, Kew, Richmond, Surrey, *Great Britain.*	1841	About 6,000,000	Plants of all groups
2.	Museum National d' Histoire Naturelle, Laboratorie de Phanerogamie, Paris, *France*	1635	About 5,000,000	Phanerogams and Vascular Cryptogams

3.	Herbarium of Botanical Institute, Academy of Science, Leningrad, *U.S.S.R.*	1714	About 5,000,000	Plants of all groups
4.	British Museum of Natural History, London, Great Britain	1753	About 4,000,000	Plants of all groups
5.	U.S. National Museum (Deptt. of Botany), U.S. Smithsonian Institute. Washington, *U.S.A.*	1868	About 2,700,000	Plants of all groups
6.	Herbarium of Academy of Natural Science, Philadelphia, *U.S.A.*	1812	About 2,000,000	Worldwide Phanerogams
7.	Herbarium of Indian Botanical Garden, Kolkata, *India.*	1787	About 1,000,000	Ferns and some lower cryptogams of India
8.	Herbarium of Forest Research Institute, Dehradun, *India.*	1890	About 3,000,000	Worldwide Phanerogams and ferns
9.	Blatter Herbarium. St. Xaviers College, Fort, Bombay, *India.*	—	About 1,000,000	Phanerogams and Fungi
10.	Herbarium of Commonwealth Mycological Institute, Kew, *Great Britain*	1921	63,347	Fungi
11.	Gordern college Herbarium, Lahore, *Pakistan*	1893	55,000	Ferns and Flowering plants
12.	Herbarium of National Botanical Gardens, Lucknow, *India.*	1948	40,000	Phanerogams and other groups
13.	U.S. National Arboretum Herbarium, Washington. *U.S.A.*	1934	37,000	Vascular plants

• 4.3. HERBARIA AND BOTANICAL GARDENS

Herbaria

A collection of plants which have been dried, preserved on the sheets of thick papers and arranged according to a well-accepted system of classification is known as *herbarium*. A picture of the plant world can be obtained with the help of the specimens kept in an international herbarium. Some of the Indian and international herbaria are listed in the given table.

Some other important herbaria include the Botanical Survey of India Herbarium, Pune (India): Botany Division Herbarium of Indian Agricultural Research Institute, New Delhi (India); Botanical Gardens herbarium, Singapore; and Herbarium, State University of Utrecht, Netherlands.

Botanic Gardens

A botanic garden is a place for growing flowers, vegetables or fruits, and in more strict term it is an educational institution for botanists and other laymen. It should be represented by maximum possible types of ornamental plants, medicinal plants and the plants of economic and other values.

Some of the important national and international botanic gardens are listed below :

(1) Royal Botanic Gardens, Kew (England): It was started by *Sir Henry Capel (1696)* as his private garden but later on in about 1759 Princess of Wales started to develop here a royal botanic garden.

The present area of these gardens is about 300 acres. Various departments of this garden are its Library, Herbarium, Economic Museums, Gardens and the Jodrell Laboratory.

(2) National Botanic Gardens, Lucknow (India): It is situated on the south bank of river Gomti and covers about 75 acres of land. It is bounded on one side by Rana Pratap Marg and on the other side by Ashok Marg.

Many *big lawns, a beautiful lake, aquatic garden, conservatory, Palm House, Fern House, Cactus House, Orchid House* and a *Medical Plot* are some of the other peculiarites of this beautiful, attractive and scientifically arranged garden.

(3) Lloyd Botanic Gardens, Darjeeling **(India)**: This garden is situated at an elevation of about 6,000 feet in the East Himalayas in the district of Darjeeling (West Bengal), and was named after the donor of the space for the garden Mr. William Lloyd.

The garden was established in 1878 and its present area is more than 40 acres. The complete area of the garden is divided into three main sections, *i.e.*, (i) Upper indigenous section, (ii) Lower exotic section, and (iii) Miscellaneous section. A temperate flora of thirteen countries is represented by more than 1500 kinds of plants, arranged in twenty divisions. A small herbarium of about of 20,000 sheets is also attached with the garden.

(4) Royal Botanic Garden, Sibpur, Kolkata (India): It was founded by Lt. Col. Robert Kyd in 1787 at Sibpur, and he also acted as the first Director of this garden. Fern Houses, Orchid Houses and Palm Houses are the specialities of the garden. It is also the headquarter of the Botanical Survey of India.

UNIT

5

FAMILIES OF DICOTYLEDONS

STRUCTURE

- Ranunculaceae
- Caryophyllaceae
- Rutaceae
- Fabaceae : Papilionaceae
- Mimosoideae or Mimosaceae
- Rosaceae
- Aplaceae or Umbelliferae
- Rubiaeae
- Aslepiadaceae
- Apocynaceae
- Solanaceae
- Acanthaceae
- Lamiaceae or Labiatae
- Amaranthaceae
- Euphorbiaceae

• 5.1. RANUNCULACEAE[2-5] (Butter-cup Family or Crowfoot Family)

Aids for Field Identification : Herbs; leaves often palmately compound; stamens α, spirally arranged; pistil unilocular, unicarpellate.

1. *Delphinium ajacis* L. (Larkspur)[2-5]

Habit: Annual, ornamental herb.

Root: Tap root, branched and fibrous.

Stem: Herbaceous, erect, cylindrical, branched, sometimes hairy, solid and green.

Leaf: Cauline and ramal, simple, alternate, exstipulate; much dissected, each lobe is smooth, linear to elliptical with acute apex.

Inflorescence: Axillary raceme.

Flower : Bracteate, bracteolate (2), pedicellate, hermaphrodite, complete, zygomorphic, posteriorly spurred, pentamerous and hypogynous.

Calyx: Sepals five, polysepalous, petalloid, bluish to violet-coloured, posterior odd sepal prolonged to form a long spur, quincuncial aestivation.

1. Takhtajan (1969) spelt it as "Dicotyledones".
2. **Classification according to A.B. Rendle (1925)** : Dicotyledones, Dialypetalae, Ranales. Ranunculaceae.
3. **Classification according to Engler and Prantl (1931) : Class**—Dicotyledoneae, **Order**—Ranales, **Suborder**—Ranunculineae. Family—Ranunculaceae.
4. **Classification according to J. Hutchinson (1959) : Phylum**—Angiospermae, **Sub-phylum**—Dicotyledones. **Division**—Herbaceae, **Order**—Ranales, **Family**—Ranunculaceae.
5. Classification according to A. Takhtajan (1969) : Division—Magnoliophyta, **Class**—Magnoliatae. **Sub-class**—**Ranunculidae. Super-order**—Ranunculanae, **Order**—Ranunculales, **Family**—Ranunculaceae.

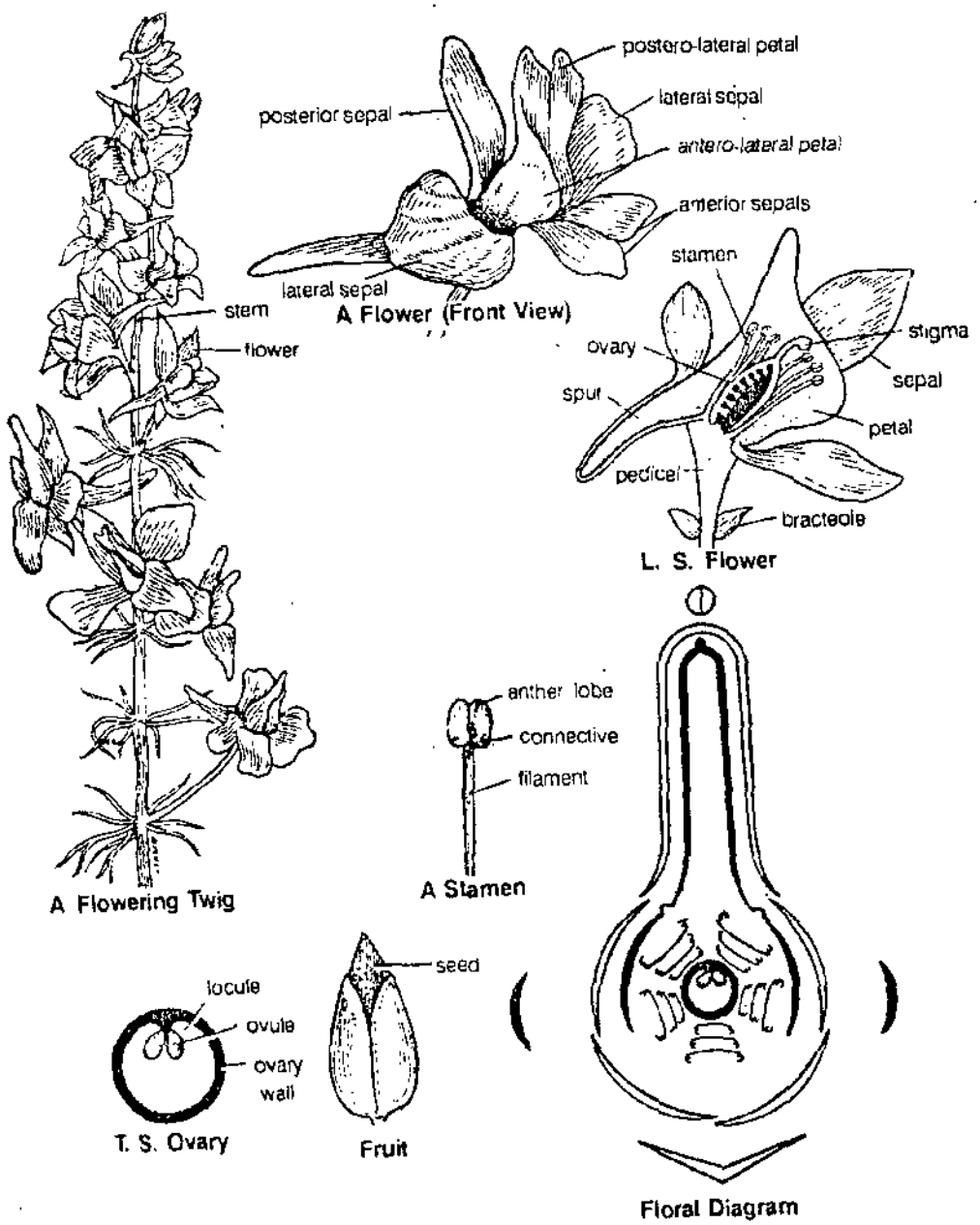


Fig. 1. ***Delphinium ajacis*** **L. (Larkspur)*.**

Corolla : Petals four, gamopetalous, *two posteriolateral petals are fused to form* the spur, present inside the spur formed by the posterior sepal; anterior petal absent. valvate.

Androecium : Stamens 15, polyandrous, arranged spirally around the ovary in 5 groups, each of 3 stamens; each group alternates with petals; filaments are broad at the base and taper gradually; **anther** adnate or basifixed; dithecous and extrorse.

Gynoecium : Monocarpellary, superior, unilocular; many ovules in the locule; marginal placentatioin; style one, short and curved; stigma one, capitate and hairy.

Fruit: A follicle.

Seed: Endospermic with a small embryo.

Floral Formula: Brl, Brl, *|*, ⚥, K_3, C(4), A_{15}, G_1.

• 5.2. CARYOPHYLLACEAE[1-4] (The Pink Family)

Aids for Field Identification: Herbs; leaves opposite; nodes often swollen; inflorescence cymose or flowers solitary; free-central placentation.

Dianthus caryophyllus (The Carnation)

Habit: An annual, ornamental herb.

Root: Well branched, tap root.

Stem: Herbaceous, aerial, erect, branched, cylindrical, solid, glabrous, green.

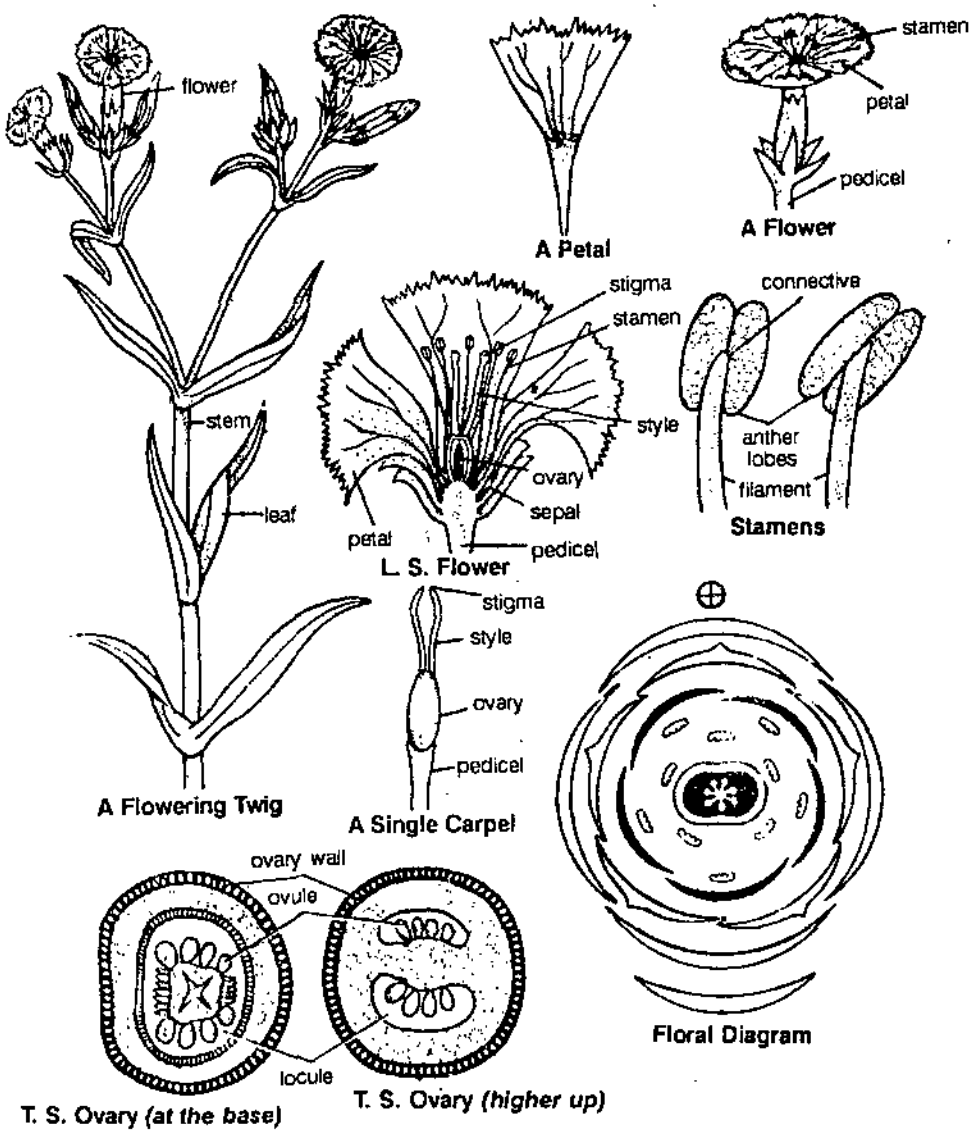


Fig. 2. ***Dianthus caryophyllus*** **L***

* **Economic Importance :** It is a beautiful ornamental plant. The flowers are considered to be cardiotonic, antiseptic and diaphoretic.

1. **Classification according to A.B. Rendle (1925) :** Dicotyledons, Monochlamydeae, Centrospermae. Caryophyllaceae.
2. **Classification according to Engler and Prantl (1931) :** Clr.ss—Dicotyledonae, **Subclass**—Archichlamydeae, **Order** Centrospermae, **Suborder**—Caryophyllineae, **Family**—Caryophyllaceae.
3. **Classification according to J. Hutchinson (1959) :** Phylum—Angiospermae, **Sub-phylum**—Dicotyledones. **Division** Herbaceae, **Order**—Caryophyllales, **Family—Caryophyllaceae.**
4. **Classification according to A. Takhtajan (1969) : Division— Magnoliophyta,** Class—Magnoliaiae, **Sub-class** Caryophyllidae, **Super-order**—Caryophyllanae, **Order**—Caryophyllales, **Family**—Caryophyllaceae.

Leaf: Ramal and cauline, simple, exstipulate opposite decussate; sessile, conate at the base, linear to lanceolate, entire, acute, unicostale reticulate.

Inflorescence : Dichasial cyme, or solitary terminal, or solitary axillary.

Flower : Bracteate (bracts many and present just outside the calyx appearing like epicalyx), pedicellate, complete, hermaphrodite, actinomorphic, pentamerous, hypogynous, cyclic.

Calyx : Sepals, 5, gamosepalous, tubular, valvate or quincuncial, persistent and green.

Corolla : Petals 5, polypetalous, longer than sepals, caryophyllaceous, toothed at apex and differentiating into a claw and a limb, twisted, variously coloured.

Androecium: Stamens 10, polyandrous, arranged in two whorls of 5 each, obdiplostamonous, anthers oblong, filament slender and of equal length, dithecous, dorsifixed and introrse.

Gynoecium : Bicarpellary, syncarpous, superior, unilocular at the base but bilocular apically; many ovules; free-central placentation; styles two, long and entire; stigmas two and simple.

Fruit: A capsule.

Seed: Endospermic, embryo straight.

Floral Formula: Br, ⊕, ⚥, Epik$_{2+2}$, K$_{(5)}$, C$_3$, A$_{5+5}$, G(2).

• 5.3. RUTACEAE[1-4] *(The Orange Family)*

Aids for Field Identification : Shrubs or trees; leaves with aromatic glandular dots; ring-shaped disc below the ovary; polyadelphous stamens; fruit hesperidium.

Citrus aurantifolia Swing *(= C. medica Var. acida)*

Habit : A cultivated tree.

Root: Tap root, branched.

Stem: Woody, erect, branched, solid, cylindrical and green.

Leaf : Ramal and cauline, exstipulate, alternate, petiolate, swollen leaf base, ovate to elliptical, serrate, acute; unicostate reticulate venation; many dot-like glands are present on the leaves.

Inflorescence: Axillary cyme or solitary axillary.

Flower : Ebracteate, pedicellate, complete, hermaphrodite, actinomorphic, pentamerous, hypogynous, cyclic, white coloured and scented.

Calyx : Sepals 5, gamosepalous, valvate, green, cup shaped and dotted with glands, persistent.

Corolla : Petals 5, polypetalous, gland-dotted, imbricate, white.

Androecium : Stamens many, polyadelphous, bases of the filaments are fused; anthers dithecous, dorsifixed or basifixed, introrse.

Gynoecium : Penta- to multicarpellary, syncarpous, superior, multilocular, one or rarely more ovules in each locule; axile placentation; style one and short; stigma capitate and yellow; below the ovary is present a nectariferous disc.

Fruit: Hesperidium.

Seed: Non-endospermic.

1. Classification according to A.B. Rendle (1925) : Dicotyledons, Dialypetalae, Rutales, Rutaceae.
2. Classification according to Engler and Prantl (1931) : Class—Dicotyledoneae, Sub-class—Archichlamydeae, Order—Geraniales, Sub-order—Geranineae, Family—Rutaceae.
3. Classification according to J. Hutchinson (1959) : Phylum—Angiospermae, *Sub-phylum—Dicotyledones*, Division—*Lignosae*, Order—Rutales, Family—Rutaceae.
4. Classification according to A. Takhtajan (1969) : Division—Magnoliophyta, Class—Magnolietae, Sub-class—Rosidae, Super-order—Rutanae, Order—Rutales, Family—Rutaceae.

• 5.6. MIMOSOIDEAE OR MIMOSACEAE[1-2] (The Acacia Family)

Aids for Field Identification: Herbs, trees; leaves bipinnate, stipule spinous; inflorescence cymose head; flowers ⊕; corolla tubular; fruit lomentum.

Acacia nilotica L.Del. (= A. arabica Willd.)[1-2] (Common name = Babool)

Habit: A medium-sized tree.

Root: Tap root, branched.

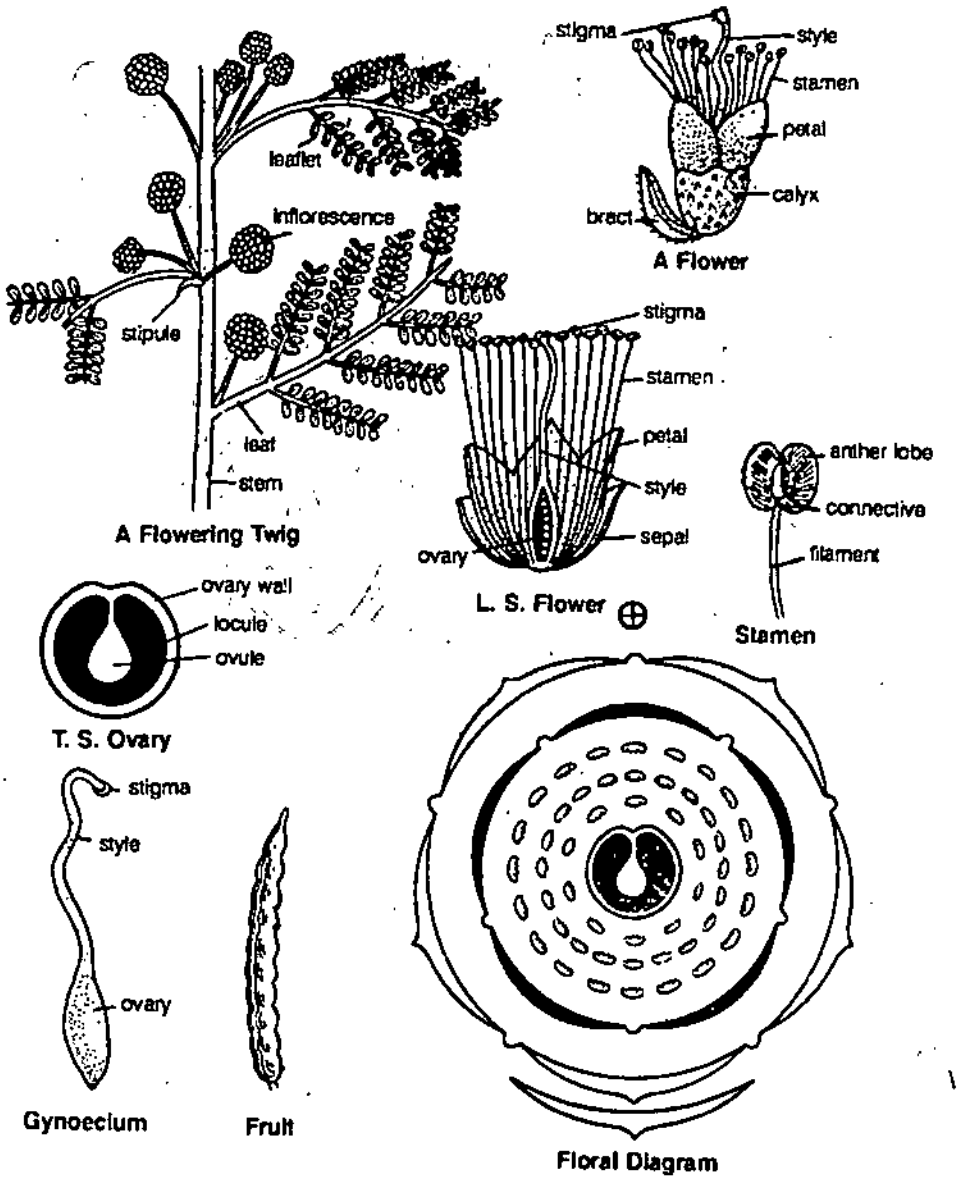


Fig. 5. *Acacia nilotica* L.*

* **Economic Importance :** *Acacia nilotica* (Vern. Babool or Keekar) bark is used as a tan while gum obtained from stem is used in dysentry. Tender leaves are used as blood purifier while young twigs are used as "Datoon" for cleaning teeth.

1. **Classification according to A.B. Rendle (1925) :** Dicotyledons, Dialypetalae, Rosales, Leguminosae, Mimosoideae.
2. **Classification according to Engler and Prantl (1931) : Class**—Dicotyledoneae, **Sub-class**—Archichiamydeae, **Order**— Rosales, **Suborder**—Rosineae, **Family**—Leguminosae.
3. **Classification according to J. Hutchinson (1959) : Phylum**—Angiospermae, **Sub-phylum**—Dicotyledones, **Division**— Lignosae, **Order**—Leguminales, **Family**—Mimosaceae.
4. **Classification according to A. Takhtajan (1969) : Division**—Magnoliophyta, **Class**—Magnoliatae, **Sub-class**—Rosidae, **Superorder**—Rosanae, **Order**—Fabales, **Family**—Mimosaceae.

Stem : Woody but upper portion herbaceous, aerial, erect, branched, solid, bark dark brown; a gum called *gum arabica* is secreted by the bark.

Leaf: Ramal and cauline, alternate; stipulate, stipules modified into 1/2 to 2" long straight thorns: petiolate, compound, bipinnate and paripinnate, pinnae 5-7 pairs.

Pinnules: 10-20 pairs, sessile or subsessile, ovate or oblong, entire, unicostate reticulate.

Inflorescence: *Axillary cymose head.*

Flower: Bracteate, ebracteolate, sessile or subsessile, complete, actinomorphic, hermaphrodite, hypogynous, pentamerous, yellow, very small.

Calyx : Sepals 4 or 5, gamosepalous, campanulate; odd sepal anterior; valvate, minute in size.

Corolla : Petals 4 or 5, gamopetalous, tubular, about double the size of the calyx, valvate, yellow.

Androecium: Stamens many, polyandrous, filaments filiform, longer than corolla, dithecous, basifixed, introrse, yellow.

Gynoecium : Monocarpellary, superior, unilocular; ovules many, marginal placentation; shortly stalked ovary, style long, stigma flat and minute.

Fruit: A lomentum.

Seed: Many, large, non-endospermic.

Floral Formula : Br, ⊕, ⚥, $K_{(4) \text{ or } (5)}, C_{(4) \text{ or } (5)} A_{\alpha}$, Gl

• 5.7. ROSACEAE[1-4] (THE ROSE FAMILY)

Aids for Field Identification : Perennial herbs, shrubs or trees; leaves stipulate; pentamerous; stamens in 5s; ovary semi-inferior; endosperm absent.

Rosa indica L. (Rose, Vern. Gulab)[1-4]

Habit: A branched, prickly, perennial shrub.

Root: Branched, tap root.

Stem : Woody but herbaceous at upper portions, aerial, erect, branched, prickly, solid, green.

Leaf: Ramal and cauline, alternate, petiolate, stipulate, stipules adnate and present in the form of sheath on the leafstalk, compound, imparipinnate.

Leaflets : 3 to 7 or more, opposite, ovate, dentate or serrate, acute; unicostate reticulate; odd leaflet terminal in position.

Inflorescence:Solitary axillary, sometimes in clusters.

Flower : Bracteate, sometimes bracts are absent, pedicellate, complete, hermaphrodite, actinomorphic, perigynous, large, scented, variously coloured, thalamus deep and cup shaped.

Calyx: Sepals 5, gamosepalous, odd sepal posterior, each sepal is lanceolate, denate, hairy; sometimes one or more sepals become leafy, green; calyx tube urn-shaped or tubular, persistent.

Corolla : Petals 5 or in multiples of 5 or indefinite in .riltivated varieties; polypetalous, rosaceous, imbricate; each petal is obovate, large, variously coloured, showy and fragrant.

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1. **Classification according to A.B. Rendle (1925)** : Dicotyledones, Dialypetalae, Rosales, Rosaceae.
2. **Classification according to Engler and Prantl (1931)** : **Class**—Dicotyledoneae, **Subclass**—Archichlamydeae, **Order**—Pvi'iiles, Suborder—Rosineae, **Family**—Rosaceae.
3. **Classification according to J. Hutchinson (1959)** : **Phylum**—Angiospermae, **Sub-phylum**—Dicotyledones, **Division**—Ueaosae, **Order**—Rosales, **Family**—Rosaceae.
4. **Classification according to A. Takhtajan (1969)** : **Division**—**Magnoliophyta**, **Class**—Magnoliatae, **Sub-class**—Rosidae, Superorder—Rosanae, **Order**—Rosales, **Family**—Rosaceae.

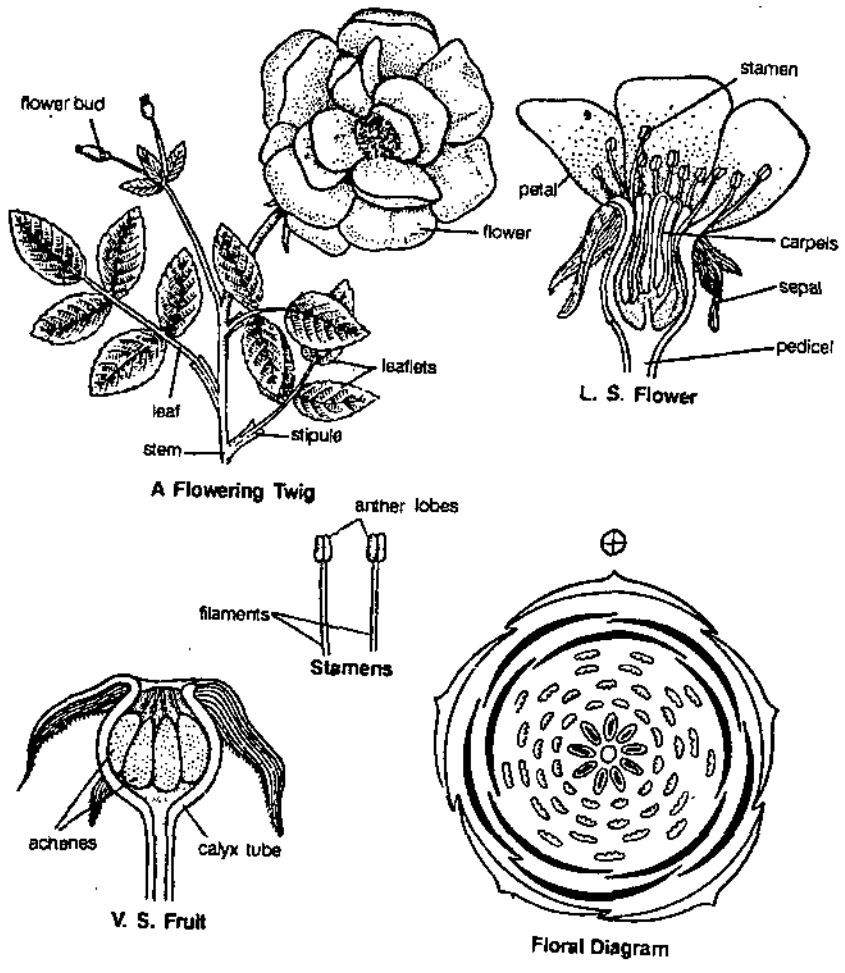

Fig. 6. *Rosa indica* L.*

Androecium: Stamens many, polyandrous, inserted on the edge of the disk, unequal, dithecous, basifixed, introrse.

Gynoecium : Polycarpellary, apocarpous, semi-inferior, ovules one in each carpel; basal placentation; style lateral, hairy, free; stigma terminal.

Fruit: Etaerio of achenes, enclosed by the succulent bright red calyx tube called hip.

Seed: Non-endospermic.

Floral Formula: Br or Ebr, ⊕, ⚥, $K_{(5)}$, C_5, Aα, Gα-

• 5.8. UMBELLIFERAE (APIACEAE OR AMMIACEAE)[1-4] (The Carrot Family)

A ids for Field Identification : Herbs; leaves aromatic; umbellate inflorescence; ovary inferior; stylopodium present; fruit schizocarp.

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* **Economic Importance** : *Rosa indica* (Vern, Gulaab) is well known ornamental plant. Its petals yield gulkand, rose water, as well as an essential oil.

1. **Classification according to A.B. Rendle (1925)** : Dicotyledons, Dialypetalae, Umbelliflorae, Umbelliferae.
2. **Classification according to Engler and Prantl (1931) : Class—Dicotyledoneae, Sub-class**—Archichlamydeae. **Order**— Umbelliflorae, **Family**—Umbelliferae.
3. **Classification according to J. Hutchinson (1959) : Phylum—Angiosperraae, Sub-phylum—Dicotyledones, Division— Herbaceae, Order**—Umbellales. **Family**—Umbelliferae.
4. **Classification according to A.** Takhtajan **(1969) : Division—Magnoliophyta, Class—Magnoliatae. Sub-class—Rosidt*. Saper-order**—Aralianae, **Order**—Cornales (Umbellales), **Family**—Apiaceae (Umbelliferae).

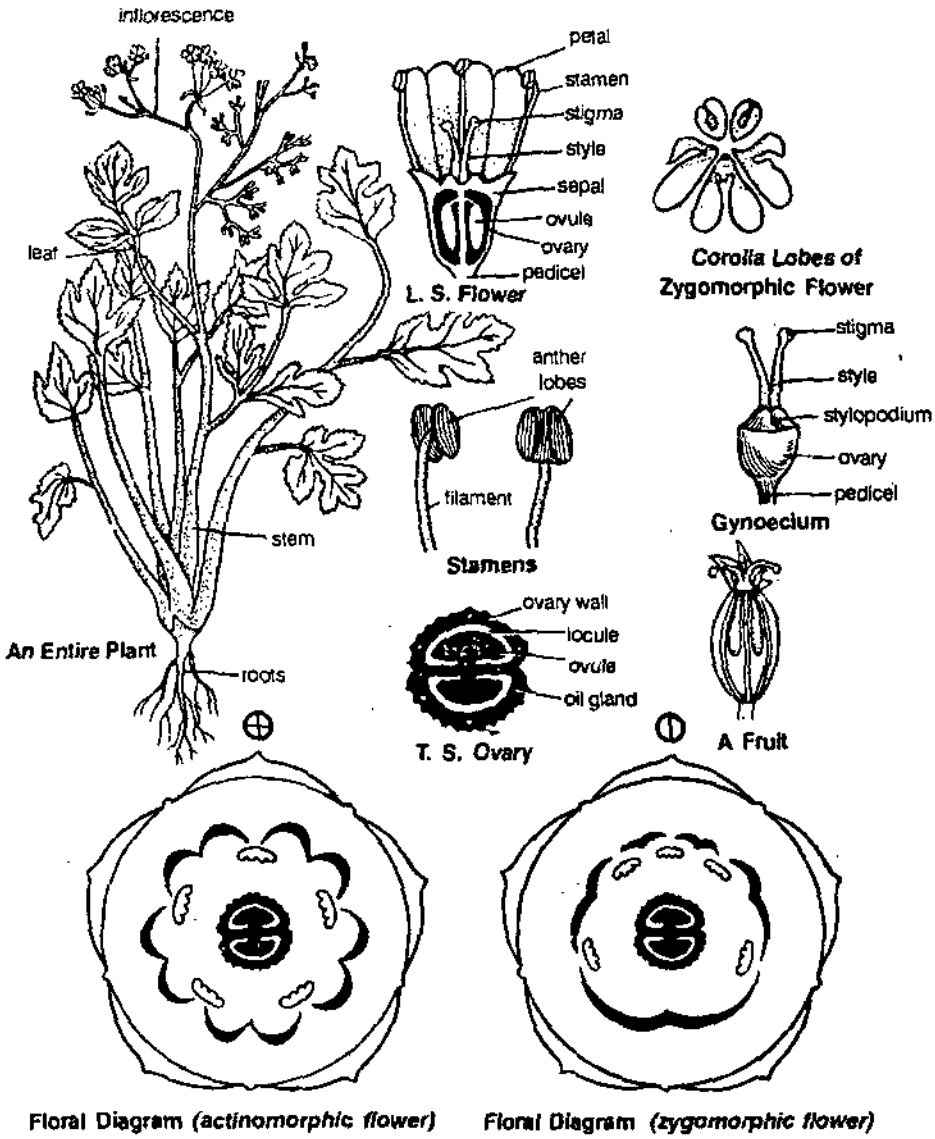

Fig. 7. *Coriandrum sativum**

Coriandrum sativum L. (Cariander, Vern. Dhania)

Habit: An annual, cultivated herb.

Root: Branched, tap root.

Stem : Herbaceous, erect, cylindrical, branched, angular, green, aromatic.

Leaf : Ramal and cauline, alternate, exstipulate, petiolate or sub-sessile; decompound with ovate or lanceolate segments; upper leaves are more finely dissected with linear, small segments; sheathing leaf base; each leaflet is linear, entire, acute, unicostate reticulate; aromatic.

Inflorescence: Compound umbel.

Flower: Ebracteate, pedicellate, complete, hermaphrodite; outer flowers zygomorphic, inner flowers actinomorphic; pentamerous, epigynous, cyclic, white.

Calyx : Sepals 5, gamosepalous, valvate; in outer flowers the anterior sepals are larger, green or slightly petalloid.

Corolla : Petals 5, polypetalous; bilobed, lobes are equal in size in actinomorphic flowers; but in zygomorphic flowers two posteriorly placed petals are equally lobed, two

* **Economic Importance** : *Coriandrum sativum* (Vern. **Dhania**) leaves and fruits are used as condiment, its fruits are also used as carminative, diuretic and stimulant.

lateral ones are unequally lobed and the anterior petal's lobes are large and equal: white or bluish-white.

Androecium : Stamens 5, polyandrous; alternipetalous;, filaments as long as the petals; dithecous, dorsifixed, introrse.

Gynoecium : Bicarpellary, syncarpous, inferior, bilocular; one ovule in each locule, ovule pendulous; axile placentation; styles two, styles arise from a nectar-secreting disc called stylopodium; stigma simple and capitate.

Fruit : An oblong or sub-globose cremocarp, or schizocarp with a carpophore.

Floral Formulae:

(a) Outer Flowers: EBr, ⊕, ⚥, $K_{(5)}$, C_5, A_5, $G\overline{(2)}$.

(b) Inner Flowers: EBr, ⊕, ⚥, $K_{(5)}$, C_3, A_5, $G\overline{(2)}$

• 5.9. RUBIACEAE[1-4] (THE MADDER FAMILY)

Aids for Field Identification : Herbs or shrubs; leaves opposite or whorled, stipulate; carpels 2; ovary inferior.

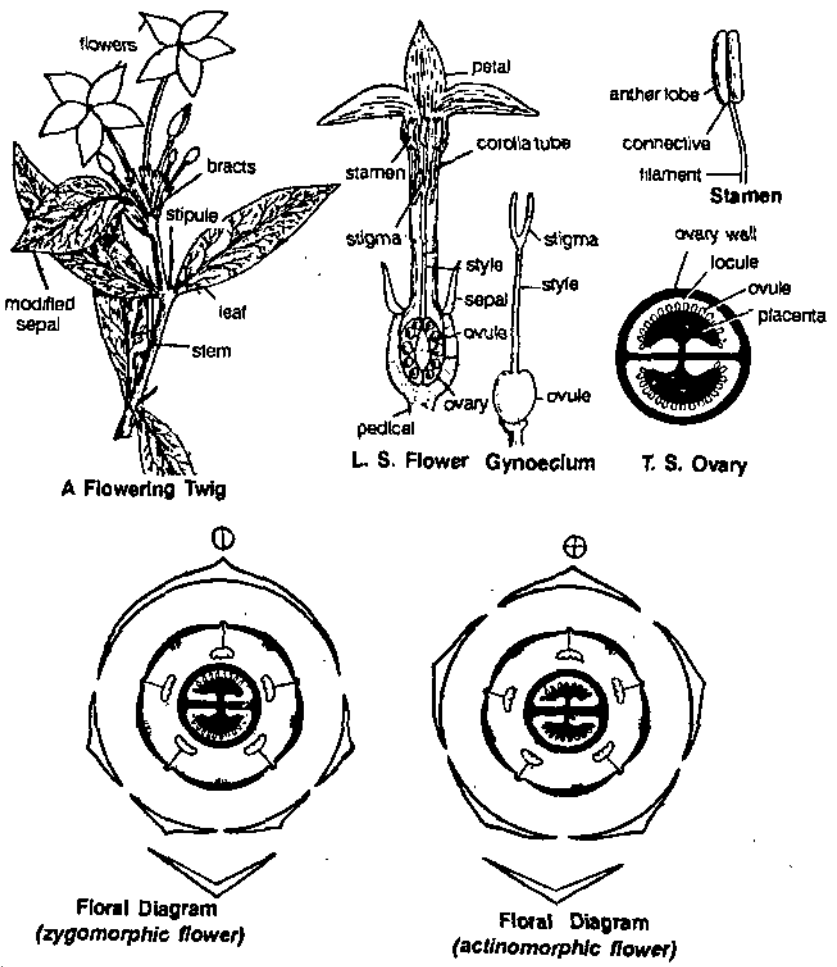

Fig. 8. *Mussaenda luteola**

* **Economic Importance :** Besides being an ornamental plant, the roots of some species of *Mussaenda*, when given with cow's milk are effective in serious diseases such as leprosy, jaundice, *etc.*

1. Classification according to **A.B. Rendle (1925)** : Dicotyledons, Sympetalae. Rubiales, Rubiaceae.
2. **Classification according to Engler and Prantl (1931)** : **Class**—Dicotyledoneae, **Sub-class**—Metachlamydeae (Sympetalae), **Order**—Rubiales, **Family**—Rubiaceae.
3. **Classification according to J. Hutchinson (1959)** : **Phylum**—Angiospermae, **Sub-phylum**—Dicotyledones. **Division—Lignosae, Order**—Rubiales, **Family**— Rubiaceae.
4. **Classification according to A.** Takhtajan **(1969) : Division**—Magnoliophyta, **Class**—Magnoliatate. **Sub-class**—Asteridae. **Superorder**—Lamianae, **Order—Gentianales, Family**—Rubiaceae.

***Mussaenda luteola* Dillle (Vern. Bedina)**

Habit: An ornamental, perennial, evergreen, shrub.

Root: Branched, tap root.

Stem: Herbaceous but woody in the lower portions; erect, cylindrical, branched, differentiating into nodes and internodes; internodes are swollen, hairy and green.

Leaf: Ramal and cauline, simple, opposite decussate; sub-sessile, interpetiolar stipules are present, lanceolate, entire, acute, unicostate reticulate.

Inflorescence: Dichasial cyme.

Flower : Bracteate, pedicellate, complete, hermaphrodite, actinomorphic but mature and older flowers are zygomorphic; pentamerous, epigynous, whitish yellow.

Calyx : Sepals 5, polysepalous or sometimes gamosepalous; 4 sepals are smaller and 5th one is modified into a yellow leafy bract in zygomorphic flowers; all sepals are of same shape, size and colour in actinomorphic flowers; persistent, valvate, green.

Corolla : Petals 5, gamopetalous; corolla tube is elongated and funnel-shaped, valvate or rarely imbricate; yellow; coronary structures are present in the form of silky hair.

Androecium : Stamens 5, alternipetalous, polyandrous, epipetalous, dithecous, basifixed or dorsifixed, introrse.

Gynoecium : Bicarpellary, syncarpous, inferior; bilocular, many ovules, axile placentation; style long with two stigmatic lobes.

Fruit: A berry.

Seed: Many, small, endospermic.

Floral Formulae:

(a) Young Flower : Br, ⊕, ⚥, $K_5, C_{(5)}, A_5, G\overline{(2)}$

(b) Older Flowers: Br, ⊕, ♂, $K_5, C_{(5)}, A_5, G\overline{(2)}$

• 5.10. ASCLEPIADACEAE *(The Milk Weed Familyr)*[1-4]

Aids for Field Identification: Herbs or vines; milky sap present; leaves opposite or whorled; flowers pentamerous; gynoecium bicarpellate; corona, gynostegium and pollinia present; fruit follicle.

***Calotropis procera* (Ait.) R. Br. (= *Asclepias gigantia*) (Common name—Madar or Aak)**

Habit : A shruby weed, covered with soft, white, wooly tomentum and contains milky latex.

Root: Well branched, tap root.

Stem: Herbaceous but lower portion soft and woody; erect, branched, cylindrical, solid, covered with white soft wooly tomentum; contains milky latex.

Leaf: Ramal and cauline, simple, opposite decussate, exstipulate, sessile or subsessile; ovate to oblong, base auriculate; entire, acute, under surface covered with wooly tomentum; contains milky latex, unicostate reticulate.

Inflorescence: Axillary umbellate cyme.

Flower : Bracteate, bracteoles two, pedicellate, complete, hermaphrodite, actinomorphic, pentamerous, hypogynous, large, purplish red to white, smell very strong.

1. *Classification according to* A.B. Rendle (1925) : Dicotyledons, Sympetalae, Superae, Asclepiadaceae.
2. Classification according to Engler and Prantl (1931) : Class—Dicotyledons, Sympetalae, Contortae, Asclepiadaceae.
3. Classification according to J. Hutcninson (1959) : Phylum—Angiospermae, Sub-phylum—Dicotyledones, Division—Lignosae, Order—Apocynales, Family—Asclepiadaceae.
4. Classification according to A. Takbtajan (1969) : Division—Magnoliophyta, Class—Magnoliatae, Sub-class—Asteridae, Super-order—Lamianae, Order—Gentianales, Family—Asclepiadaceae.

Stem : Lower portion woody but upper one is herbaceous, erect, branched, cylindrical, solid, green with milky latex.

Leaf : Ramal and cauline, simple, alternate or sub-opposite, exstipulate, sessile or subsessile, tapering at both the ends, linear to lanceolate, entire, acute, dark green and shining, unicostate reticulate, with milky latex. Inflorescence: Solitary axillary or dichasial cyme.

Flower : Bracteate, bracteolate or ebracteolate, pedicellate, complete, hermaphrodite, actinomorphic, pentamerous, hypogynous, large, yellow, fragrant.

Calyx : Sepals 5, polysepalous, imbricate or quincuncial, green.

Corolla: Petals 5, gamopetalous, twisted or imbricate, long cylindrical tube and campanulate limb, yellow.

Androecium: Stamens 5, polyandrous, epipetalous, alternipetalous, borne at corolla throat, sagitate, basifixed, dithecous, introrse.

Gynoecium : Bicarpellary, syncarpous, superior, bilocular, two ovules in each locule, axile placentation, style filiform and stigma bilobed, a disc is present below ovary.

Fruit: A drupe, more in breadth than length.

Floral Formula : Br, Brl or Ebrl, ⊕, ⚥, K_5, $C_{(5)}$, A_5, $G\underline{(2)}$.

• 5.12. SOLANACEAE[1-4] *(The Potato Family)*

Aids for Field Identification: Herbs or shrubs; flowers 5-merous; ovary 2-locular or falsely 3- to 5-locular; fruit berry or septicidal capsule.

Solanum nigrum L. *(BlackNight-Shade,* Vern. *Makoi))*

Habit: A small, annual herb attaining a height of 1–3 feet.

Root: Branched, tap root.

Stem : Herbaceous but woody below, erect, cylindrical, branched, solid, dark green, slightly ridged.

Leaf: Ramal and cauline, simple, alternate but opposite in floral region, exstipulate, petiolate, ovate to rhomboidal, entire, dentate or sinuate, acute, unicostate reticulate.

Inflorescence: Extra-axillary scorpioid cyme called *rhipidium* (modified scorpioid cyme in which flowers appear to rise in one plane).

Flower : Ebracteate, ebracteolate, pedicellate, complete, hermaphrodite, actinomorphic or may be called slightly zygomorphic due to the oblique position of carpels, pentamerous, hypogynous, white, small.

Calyx : Sepals 5, gamosepalous, valvatepersistent, bell-shaped, green.

Corolla: Petals 5, gamopetalous, valvate, white, rotate

Androecium: Stamens 5, polyandrous, epipetalous, alternipetalous; filaments short but equal in length and hairy at base; anthers long, not fused but slightly united to form a cone-like envelope around the style, dithecous and basifixed; terminal pores are very clear.

Gynoecium : Bicarpellary, syncarpous, superior, bilocular, obliquely placed carpels in relation to mother axis, many ovules in each locule, axile placentation; placentae

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* **Economic Importance** : *Tabernaemontana divaricata* is an ornamental shrub. The pulp around the seeds is used as a Leaf juice and is used in eye diseases.

1. **Classification according to A.B. Rendle (1925)** : Dicotyledons, Sympetalae, Superae, Tubiflorae, Solaninene, Solanaceae.
2. **Classification according to Engler and Prantl (1931)** : Dicotyledonae, Sympetalae, Tubiflorae, Solanaceae.
3. **Classification according to J. Hutchinson (1959) : Phylum—Angiospermae, Sub-phylum—Dicotyledones, Division—Herbaceae, Order—Solanales, Family—Solanaceae.**
4. **Classification according to A. Takhtajan (1969) : Division—Magnoliophyta, Class—Magnoliatae, Sub-class—Asteridae, Superorder—Lamianae, Order—Scrophulariales, Family—Solanaceae.**

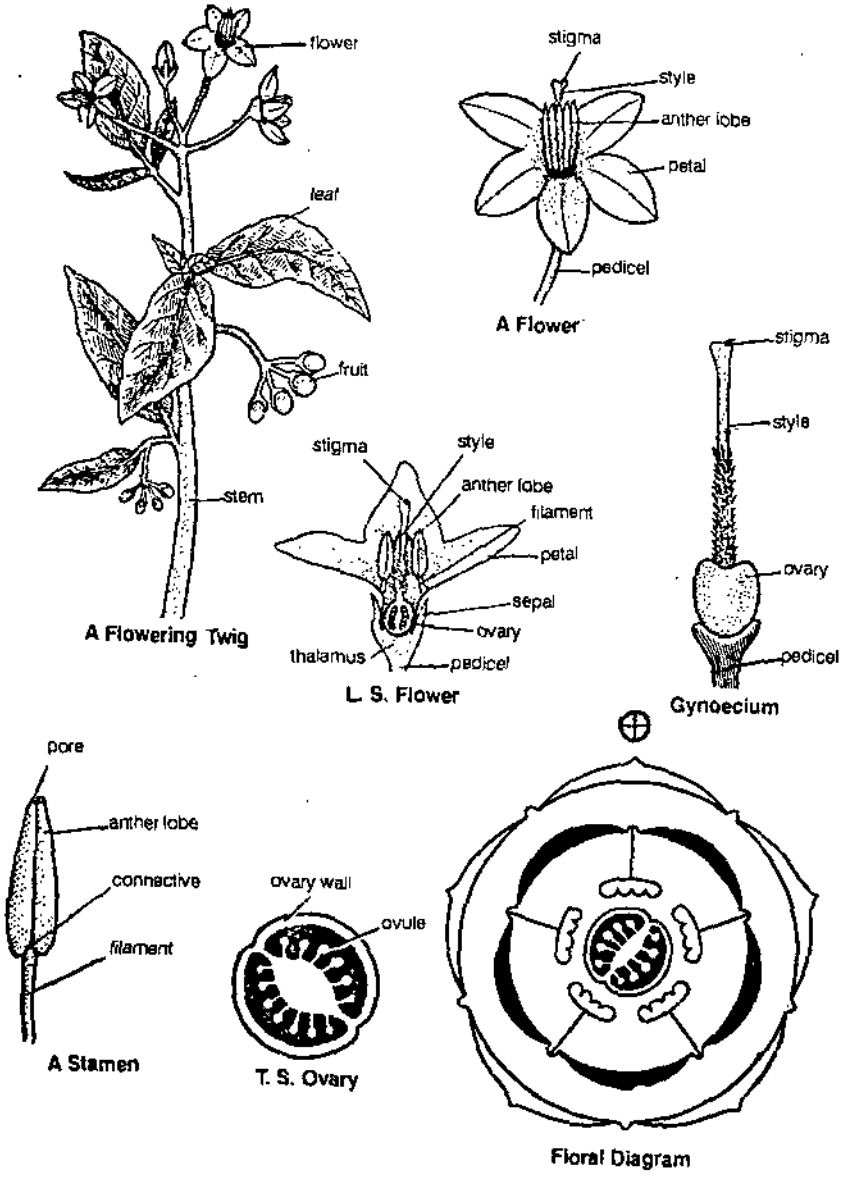

Fig. 22. ***Solanum nigrum*** **L.***

swollen; style long and slightly twisted, hairy at the base, stigma bifid, green and capitate.

Fruit: A berry.

Seed: Many, small, endospermic.

Floral Formula: Ebr. ⊕, ⚥, $K_{(5)}$, $C_{(5)}$, A_5, $G\underline{(2)}$.

• 13. ACANTHACEAE[1-4] *(The Acanthus Family)*

Aids for Field Identification: Herbs or trees; leaves opposite decussate; inflorescence axillary racemose spike, cyme or verticillaster: flowers bilipped; seeds with jaculators; bilabiate personate corolla.

* **Economic Importance :** *Berries of this plant are edible.* Plant juice is useful in liver enlargement.

1. **Classification according to A.B. Rendle (1925) :** Dicotyledons, Sympetalae, Superae, Tubiflorae, Solanineae, Acanthaceae.
2. ***Classification according to Engler and Prantl (1931)*** **: Class**—Dicotyledoneae, Metachlamydeae, Tubiflorae, Acanthacete.
3. **Classification according to J. Hutchinson (1959) : Phylum**—*Angiospermae*, **Sub-phylum**—Dicotyledones, **Division**— Herbaceae, **Order**—Personales, **Family**—Acanthaceae.
4. **Classification according to A.** Takhtajan **(1969) : Division**—Magnoliophyta, **Class**—Magnoltatae, **Sub-class**—*Asteridae*, **Super-order**—Lamianae, **Order**—Scrophulariales, **Family**—Acanthaceae.

***Adhatoda vasica* Nees. (Common Name—Basak or Roosa)**

Habit: Annual herb.

Root: Branched, tap root.

Stem: Herbaceous, erect, branched, cylindrical, solid, swollen nodes, green to pale-green in colour.

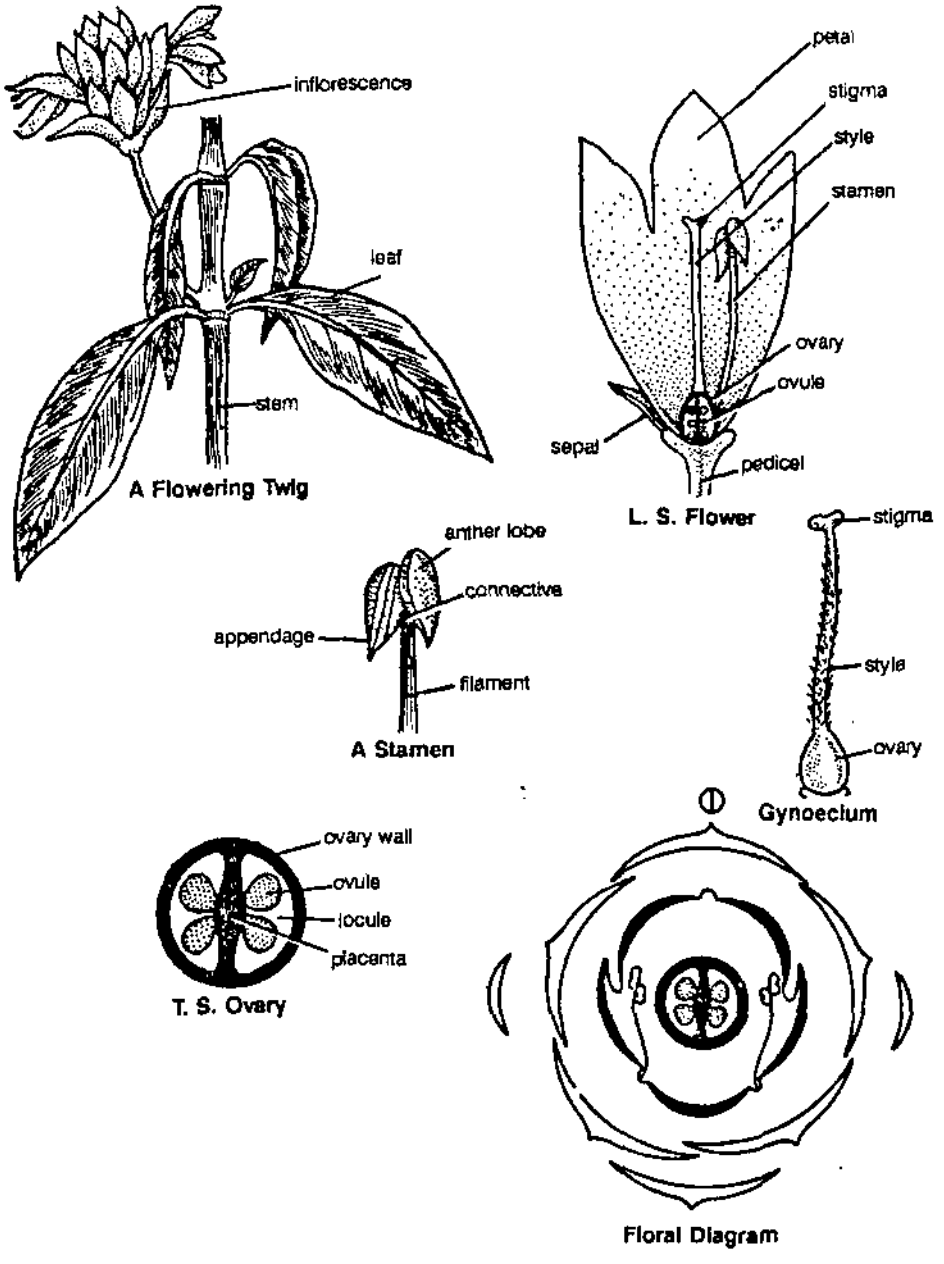

Fig. 12. *Adhatoda vasica.**

Leaf: Ramal and cauline, simple, exstipulate, opposite decussate, petiolate, lanceolate to ovate, entire, acute, unicostate reticulate, pale green.

Inflorescence: Axillary racemose spike.

Flower : Bracteate (leafy bracts), bracteolate (bracteoles leafy and enclose the bud), sub-sessile, complete, hermaphrodite, zygomorphic, pentamerous, hypogynous, large, white.

Calyx: Sepals 5, polysepalous but slightly conate at the base, quincuncial, pale green in colour.

* **Economic Importance :** Leaves and roots of *Adhatoda vasica* are used in cough, asthama, bronchitis and rheumatism.

Corolla: Petals 5, gamopetalous; bilipped, 2/3 bilabiate personate, consisting of a posterior curved lip of two petals and an anterior lip of three petals; anterior-most middle petal of the anterior lip is raised and strongly nerved, white.

Androecium: Stamens 2, polyandrous, epipetalous, laterally placed; external anther lobe is higher than inner; dithecous, basifixed, introrse.

Gynoecium : Bicarpellary, syncarpous, superior, bilocular, carpels medianly placed; one to two ovules in each locule, axile placentation; style simple, long hairy; stigma slightly bifid.

Fruit: Capsule.

Seed : Large, non-endospermic and provided with hooks called *jaculators*.

Floral Formula: Br, Brl, ⊕, ⚥, K_5, $C_{(M)}$, $A_{(2/3)}$, G(2).

• 5.14. LAMIACEAE OR LABIATAE[1-4] *(The Mint Family)*

Aids for Field Identification : Perennial herbs, often form corms, bulbs or rhizome; perianth showy; scented leaves; inflorescence verticillaster.

Ocimum hasilicum Linn. (Common Name—'Bantulsi' or 'Niazbo')

Habit: A cultivated, aromatic, tall herb.

Root: Branched, tap root.

Stem : Herbaceous but woody below, erect, quadrangular, branched, hairy, green, aromatic.

Leaf : Ramal and cauline, exstipulate, petiolate, opposite decussate, simple, ovate, serrate, hairy, unicostate reticulate, aromatic.

Inflorescence: Verticillaster.

Flower: Bracteate, ebracteolate, pedicellate, complete, hermaphrodite, zygomorphic, hypogynous, bilabiate, small, aromatic.

Calyx : Sepals 5; 1/4 bilipped consisting of upper posterior lip of one big lobe and anterior lip of 4 lobes, gamosepalous, valvate, violet green.

Corolla: Petals 5; 4/1, bilabiate, consisting of upper posterior lip of 4 lobes and lower anterior lip of 1 lobe; gamopetalous, valvate, white or pink coloured.

Androecium: Stamens 4, polyandrous, epipetalous, didynamous, the posterior stamen is lacking, anther lobes broad and slightly separated, dithecous, dorsifixed, introrse.

Gynoecium : Bicarpellary, syncarpous, superior, bilocular in very early stages but later on becomes quadrilocular due to the formation of false septum; each locule with one ovule, axile placentation; ovary 4 lobed; style long and gynobasic coming up between the 4 parts of the ovary; stigma bifid. A 4-lobed hypogynous disc is present below the ovary.

Fruit : Schizocarpic (carcerulus), made up of four nutlets.

Seed: Four, non-endospermic.

Floral Formula: Br,Ebrl, ⦶ , ⚥, $K_{(1/4)}$,$C_{(4/1)}$, A_{2+2}, G(2)

1. **Classification according to A.B. Rendle (1925) :** Dicotyledons, Sympetalae, Superae, Tubiflorae, Verbenineae, Labiatae.
2. **Classification according to Engler and Prantl (1931) : Class**—Dicotyledoneae, **Subclass**—Metachlamydae, **Order**—Tubiflorae, **Family**—Labiatae.
3. **Classification according to J. Hutchinson (1959) : Phylum**—Angiospermae, **Sub-phylum**—Dicolyledones, **Division**— Herbaceae, **Order**—Lamiales, **Family**—Labiatae.
4. **Classification according to A. Takhtajan (1969) : Division**—Magnoliophyta, **Class**—Magnoiiatae, **Sub-class**—Asteridae, **Super-order**—Lamianae, **Order**—Lamiales, **Family**—Lamiaceae (Labiatae).

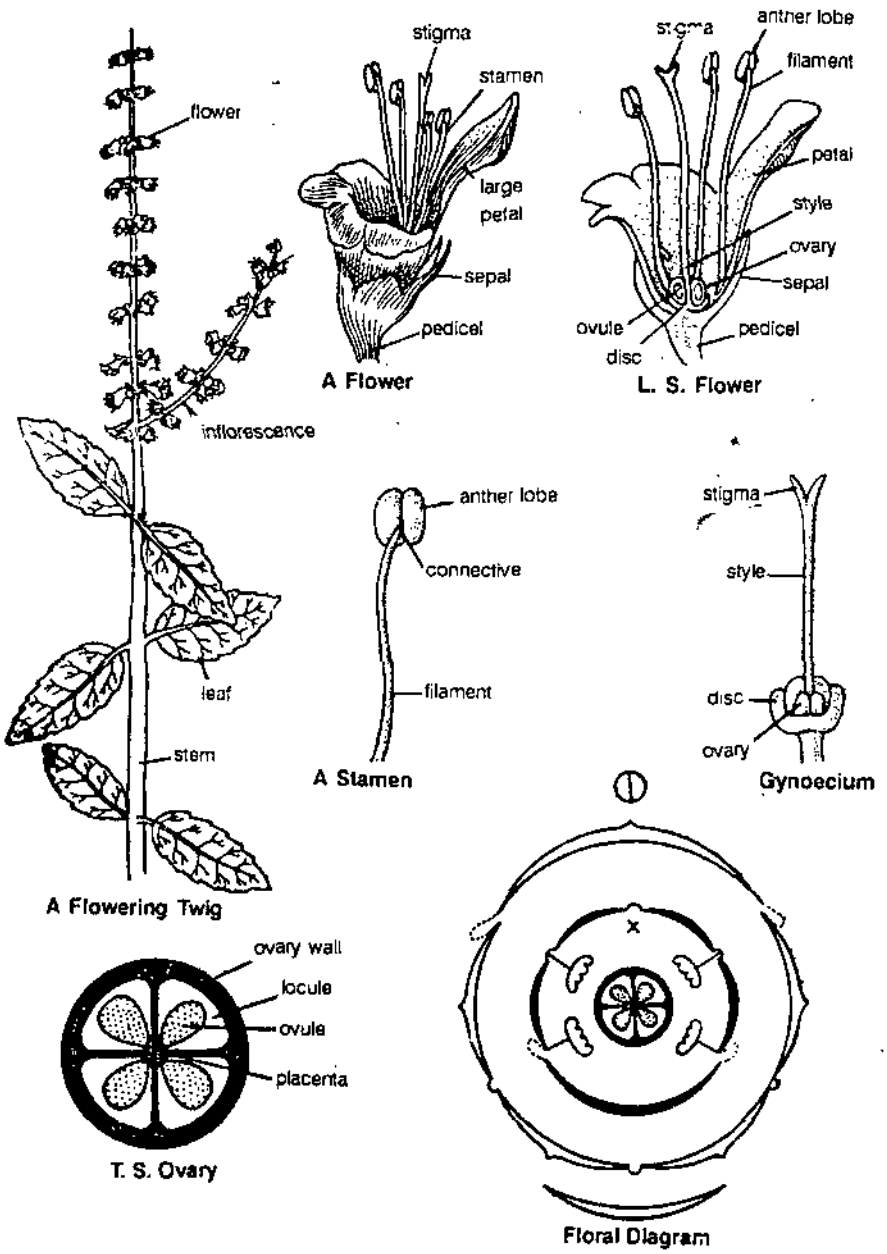

Fig. 13. ***Ocimum basilicum* L.***

• 5.15. AMARANTHACEAE[1-4] *(The Amaranthus Family)*

Aids for Field Identification : Mostly herbs; flowers small with dry scarious bracts; stamens connate at least at the base; fruit a utricle or capsule.

* **Economic Importance :** Its flowers are carminative, diuretic, stimulant, and seeds are used in gonorrhoea, dysentry and diarrhoea.

1. **Classification according to A.B. Rendle (1925) :** Dicotyledons, Monochlamydeae, Centrospermae, Amaranthaceae.
2. **Classification according to Engler and Prantl (1931) : Class**—Dicotyledoneae, **Subclass**—Archichlamydae, **Order**—Centrospermae, **Suborder**—Chenopodiineae, **Family**—Amaranthaceae.
3. **Classification according to J. Hutchinson (1959) : Phylum**—Angiospermae **Sub-phylum**—Dicotyledones, **Division**— Herbaceae, **Order**—Chenopodiales, **Family**—Amaranthaceae.
4. **Classification according to A. Takhtajan (1969) : Division**—Magnoliophyta, **Class**—Magnoliatae, **Subclass**—Caryophyllidae, **Superorder**—Caryophyllanae, **Order**—Caryophyllales.

***Amaranthus viridis* Linn. (Vern. Karund) (= A. *gracilis* Desff.)**

Habit: A wild or sometimes cultivated annual herb.

Root: Branched, *tap root, deep feeder.*

Stem : Herbaceous but lower portion woody, erect, angular, branched, solid, sometimes hairy, green.

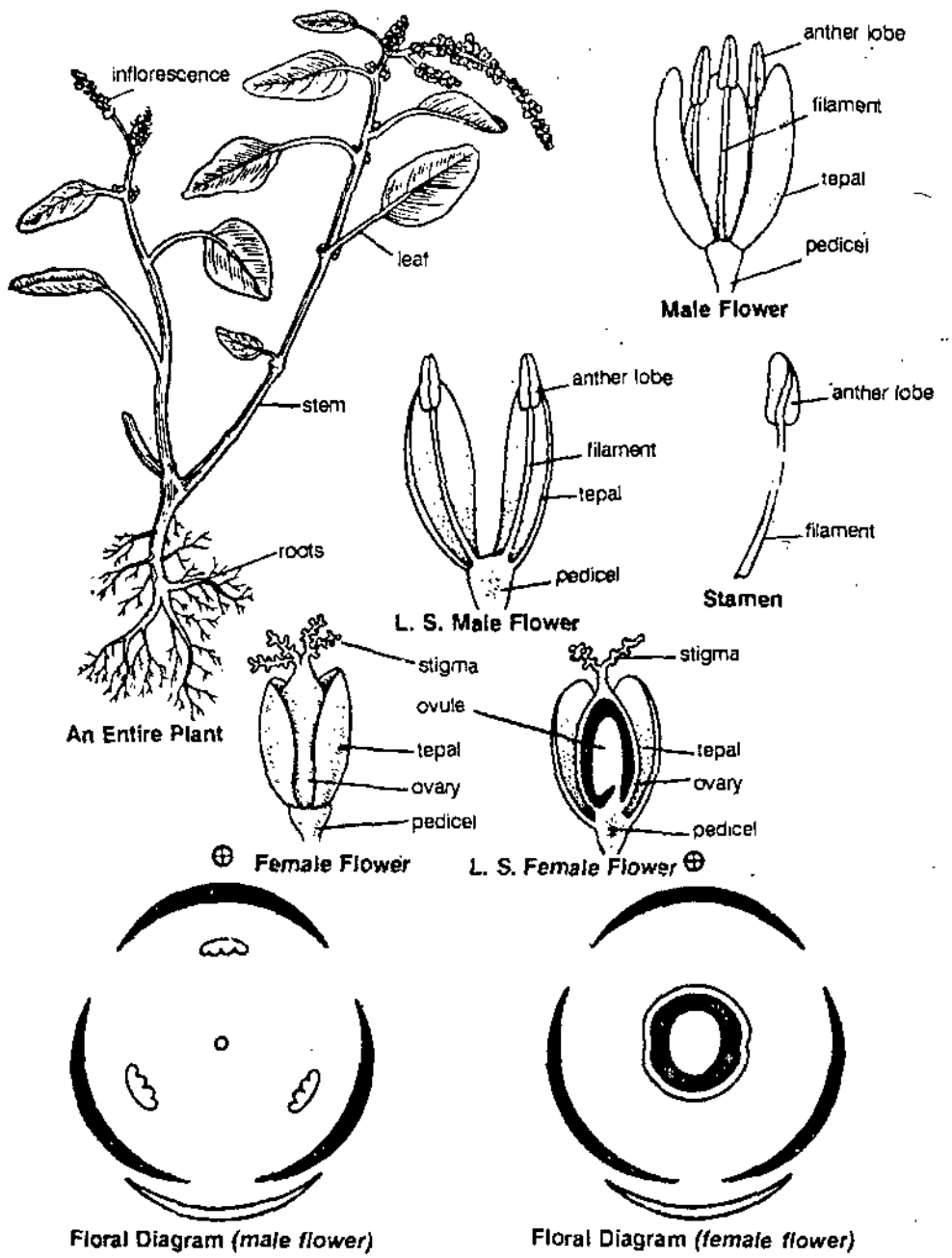

Fig. 14. *Amaranthus viridis**

Leaf: Ramal and cauline, simple, alternate, exstipulate, petiolate, ovate, obtuse or mucronate, hairy; unicostate reticulate.

Inflorescence : Condensed, slender, axillary or terminal spike.

Flower : Bracteate, bracteolate, bracteoles two; sessile, actinomorphic, unisexual; male flowers are staminate while the female flowers are pistillate; hypogynous, very small, green. Sometimes bisexual flowers are also present.

* **Economic Importance** : Leaves and tender twigs are cooked as vegetable

Male or Staminate Flower :

Perianth : Tepals 3, polytepalous, ovate, oblong, quincuncial.

Androecium: Stamens 3, polyandrous, antiphyllous, dithecous, versatile, introrse.

Gynoecium: Absent.

Female or Pistillate Flower:

Perianth: Similar to male flowers.

Androecium: Absent.

Gynoecium : Bicarpellary, syncarpous, superior. unilocular; one ovule in the locule; basal placentation; style hairy and stigma bifid.

Fruit: An indehiscent utricle.

Seed: Endospermic with curved embryo.

Floral Formulae:

Male Flowers: Br, BrI, ⊕, ⚥, P_3, A_3,G0.

Female Flowers: Br, BrI, ⊕, ♀,P_3, A_0,G(2).

• 5.16. EUPHORBIACEAE[1-4] *(The Spurge Family)*

Aids for Field Identification: Herbs (monoecious or dioecious), shrubs or small trees; apetalous; carpels 3; fruit regma or capsule.

39. *Ricinus communis* Linn. ("Castor Oil Plant" or "Arand")

Habit: An annual or perennial, tall shrub.

Root: Branched, tap root.

Stem: Herbaceous but woody below, erect, branched, cylindrical, solid, glabrous, green, latex is present.

Leaf: Cauline and ramal, simple, alternate, stipulate, petiolate, palmately lobed and veined, lobes 7 to 11, serrate, acute or acuminate, multicostate reticulate, latex is present.

Inflorescence: A sub-panicled, terminal raceme with the female flowers at the apex and male flowers borne below.

Flower : Bracteate or sometimes ebracteate, pedicellate, incomplete, actinomorphic, unisexual, male flowers are staminate while female flowers are pistillate, female flowers are hypogynous.

Male Flower :

Perianth : Tepals 5, gamophyllous, rarely polyphyllous and connate at the base, valvate, caducous, ovate, green.

Androecium : Stamens 5, with their profusely branched, tree-like filaments having dithecous, basifixed and introrse anther lobes at their apex.

Gynoecium: Absent.

Female Flower;

Perianth : Tepals generally 3 or 5, gamophyllous, valvate, caducous, green.

Androecium: Absent.

Gynoecium : Tricarpellary, syncarpous, superior, covered with warty prickles, trilocular, one ovule in each locule, axile placentation, styles 3, each bifurcating apically into two feathery stigmas.

1. **Classification according to A.B. Rendle (1925)** : Dicotyledons, Dialypetalae, Tricoccae, Euphorbiaceae.
2. **Classification according to Engler and Prantl (1931) : Class**—Dicotyledoneae, Sub-class—Archichlamydae, **Order**— Geraniales, **Family**—Euphorbiaceae.
3. **Classification according to J. Hutchinson (1959)** : Phylum—Angiospermae, **Sub-phylum**—Dicotyledones, **Division**— Lignosae, **Family**—Euphorbiaceae.
4. **Classification according to A. Takhtajan (1969) : Division**—Magnoliophyta, **Class**—Magnoliatae, **Sub-class**—Dilleniidae, **Super-order**—Malvanae, **Order—Euphorbiales, Family**—Euphorbiaceae.

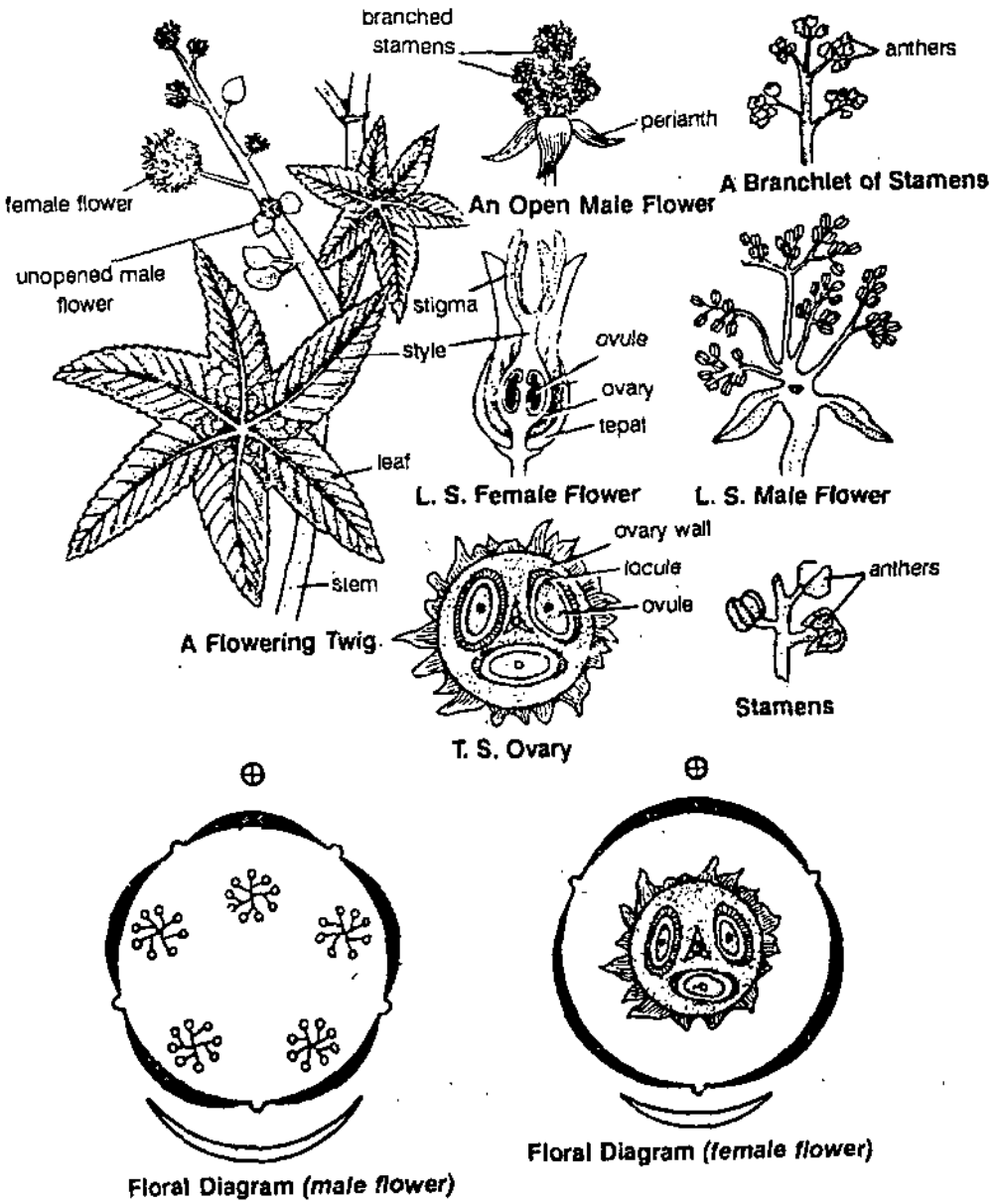

*Fig. 15. Ricinus communis**

Fruit: Regma or schizocarpic capsule.

Seed: Endospermic, oily with a knob-like caruncle.

Floral Formulae:

Male flower: Br, ⊕, ⚥, $P_{(5)}$, A_5, G_0.

Female flower: Br, ⊕, ♀, $P_{(3-5)}$, A_0, C (3).

* **Economic Importance** : Its seeds yield castor oil which is used as lubricant and mild purgative. Leaves are applied to head in headache. Oil is also used in preparing detergent washing powder. Seeds are also toxic.

UNIT

6

FAMILY OF MONOCOTYLEDONS

STRUCTURE

- Gramineae or Proaceae
- Triticum aestivum
- Some Staining Procedures

• 6.1. GRAMINEAE OR POACEAE[1-3] (The Grass Family)

Aids for Field Identification: Herbs: stem (culm) with hollow internodes, terete: leaves mostly flat and 2-ranked, leaf sheath usually open; fruit caryopsis.

1. *Triticum aestivum* L. (Wheat; Vern. Genhu)

Habit: An annual cultivated, cereal crop.

Root: Fibrous, adventitious.

Stem: Herbaceous, erect, cylindrical, unbranched but rarely branched, nodes and internodes are very clear, fistular, rough and green.

Leaf: Radical when young but cauline later on simple, alternate, exstipulate, sessile, differentiating into a long blade and a sheathing leaf base covering the internode; a membranous ligule is present at the junction of blade and leaf base; linear to lanceolate, entire, acuminate; multicostate parallel venation.

Inflorescence: Spike of spikelets. Each spikelet consists of a pair of glumes, many inferior palea or lemma, superior palea, and encloses the lodicules, stamens and gynoecium.

Flower: Bracteate (lemma or inferior palea), bracteolate (superior palea), sessile, complete, hermaphrodite, zygomorphic, hypogynous, small and inconspicuous; lemma is prolonged into a long 'awn'.

Perianth: Reduced into two modified, fleshy, small and white antero-laterally placed structures called lodicules. .

Androecium: Stamens 3, polyandrous, one anterior and two posterolaterally placed, filament long and comes out of the flower, dithecous, versatile, introrse.

Gynoecium: Monocarpellary (but according to some, it is bi- to tri-carpellary, syncarpous, unilocular); superior, unilocular, one ovule in the locule; marginal placentation; style absent; stigmas two, feathery and lateral.

Fruit: Caryopsis.

Seed: Endospermic.

Floral Formula: Br, Brl, 0, ⚥, P_2, A_3; $G\underline{1}$.

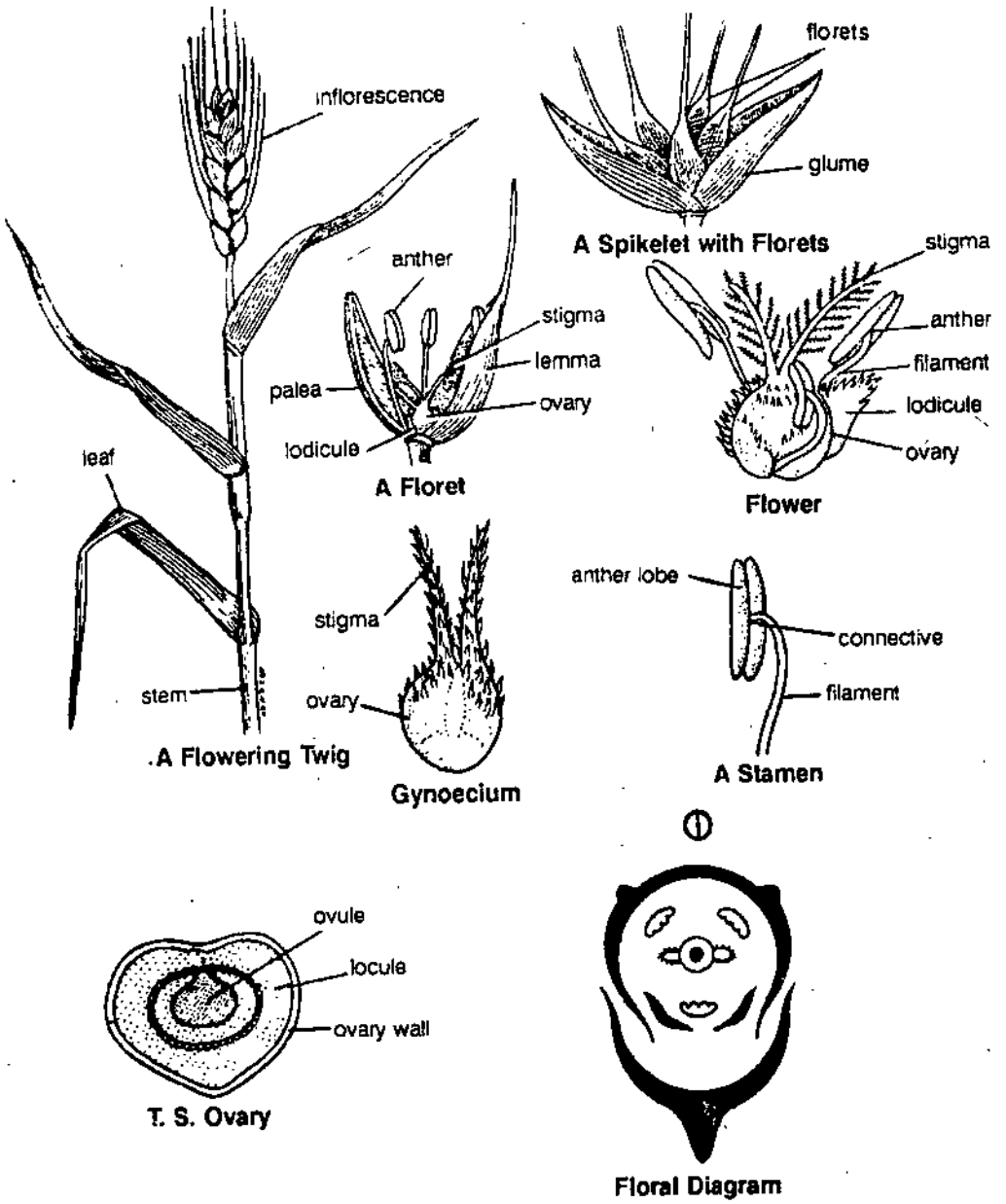

Fig. 1. Triticum Aestivum*

* **Economic Importance** : Cultivated throughout the world for wheat flour and several other wheat products. Straw is used as fodder. Fruits contain severals mineral including Mg, Mn, Fe, Cu and Zn.

UNIT

7

BODY PLAN OF A DICOTYLEDONOUS PLANT

STRUCTURE

- Body Plan of a Dicotyledonous Plant

Exercise 1. *To study the body plan of a dicotyledonous plant.*

Requirements : A complete, small-sized herbaceous plant *(e.g., Brassica campestris* or *Solarium nigrum*, etc.) and a chart showing basic anatomical details of the plant.

Observations and Comments

1. The plant body is divisible into roots, stem, leaves, flowers and fruits (Fig. 1).

2. Roots are well-developed and branched. They are covered with root hair. Their function is to absorb water from the soil.

3. Stem is solid, branched and erect. It is divisible into nodes and internodes.

4. Leaves are simple, broad, petiolate or sessile. Their margin is serrate and their apex is acute.

5. Several flowers bearing seeds are also present.

6. *Anatomically,* root has root hair, epiblema, cortex, endodermis, phloem and xylem (Fig. 2). They are exarch. They have a root cap. Main function of roots is to absorb water.

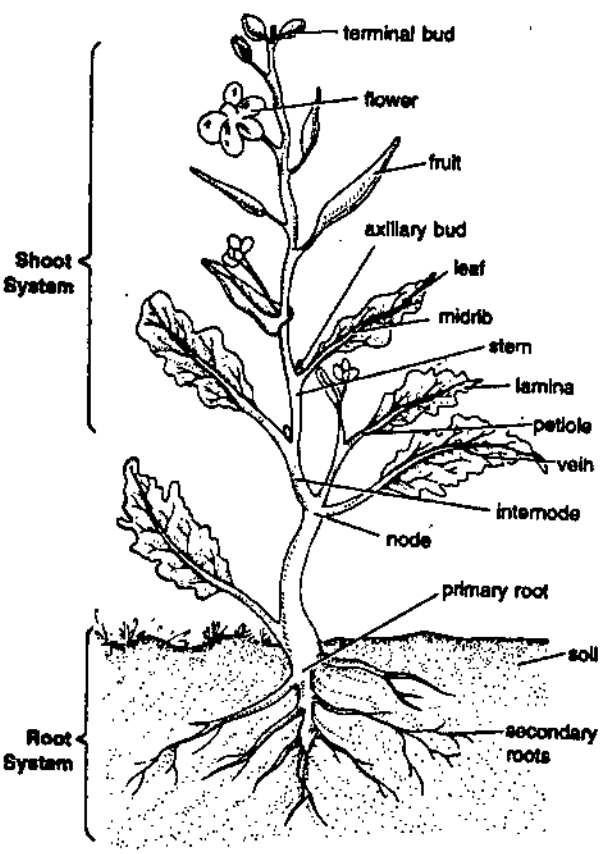

Fig. 1. A complete plant of *Brassica campestris*.

7. Stem or shoot contains pith, xylem. cambium, phloem, cortex and epidermis. Stem shows endarch condition. Upward movement of water and translocation of food takes place through various parts of stem. Stem divides into many branches, on which develop leaves.

8. Leaves are responsible for photosynthesis and transpiration, the two main functions of plant. They have palisade and spongy parenchyma, filled with chloroplast. Stomata are found on the leaf epidermis.

9. Flowers are the reproductive parts of plant. After fertilization, the ovary wall develops into fruit wall while the ovule develops into seed.

UNIT

8

SHOOT APEX AND ROOT APEX

STRUCTURE

- Shoot Apex
- Root Apex

• 8.1. SHOOT APEX

Exercise 1. *To study L.S. shoot tip for studying cytohistological zonation and origin of leaf primordia.*

1. Shoot apex is somewhat convex or slightly elongated with a broad base (Figs. 1).

2. It can be distinguished into four distinct regions, *i.e.*, tunica, corpus, flank meristem and rib-meristem.

3. Tunica may be one-layered or two-layered.

4. In case of two-layered tunica, the outer tunica cells are generally smaller than the cells of inner tunica layer.

5. Corpus is a region of irregularly arranged cells of different shape and size.

6. Cells of the flank meristem are small, narrow and radially elongated.

7. Below the corpus is present the region of ribmeristem.

8. Leaf is generally initiated by periclinal divisions in a few cells of inner tunica.

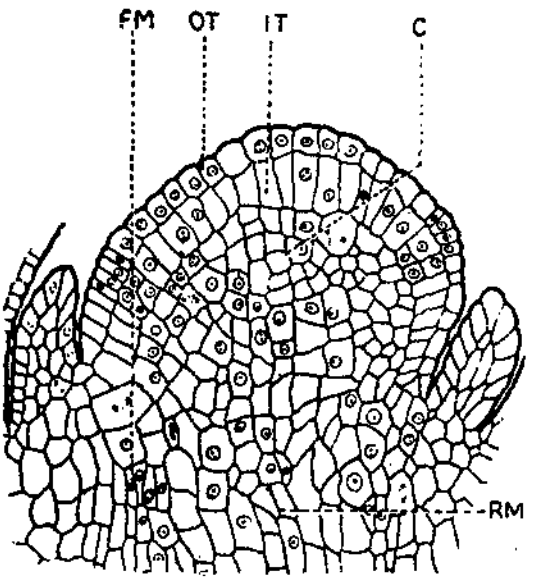

Fig. 1. Median LS. of shoot apex of *Cyperus paniceus* war. roxburghianus. (C = corpus; FM = flank meristem; IT = inner tunica; OT = outer tunica; RM = rib meristem)

9. Leaf primordia in different stages of development are seen in young stages.

• 8.2. ROOT APEX

Exercise 2. *To study LS. root apex.*

1. Three distinct sets of initials are seen in the root apex which are responsible for the formation of **root cap,** dermatogen, **periblem** and central cylinder or stele.

2. Root cap is a well developed region and in some species a columella is also present in this region.

3. Dermatogen, which is responsible for the formation of epidermis, is single-layered.

4. Inner to the dermatogen is present many cells thick region of periblem which is responsible for the development of cortex.

5. Sometimes cortex is divisible into outer cortex and inner cortex.

6. In the centre is present the central cylinder or stele.

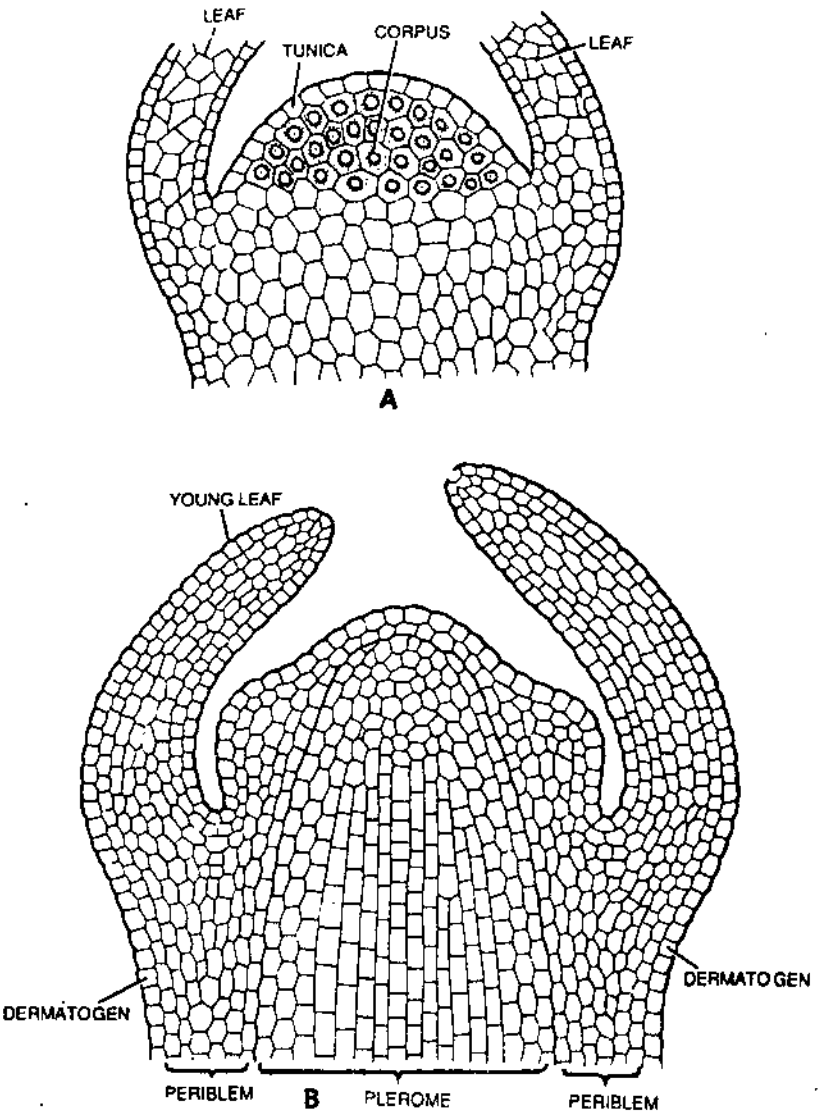

Fig. 2. Stem apex. A, Apex of an angiosperm showing tunica and corpus; B, Median longitudinal section of the stem apex of an angiosperm.

7. In the roots, an inactive zone is present in the tip called **quiescent center** (Fig. 3).

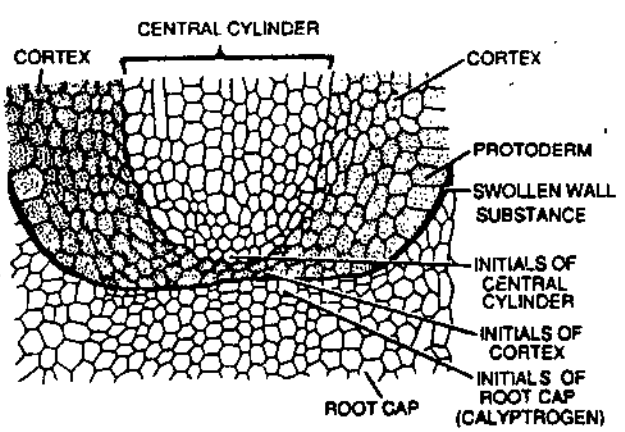

Fig. 3. Root apex of Zea mays in L.S.

UNIT 9

ANATOMY (GENERAL ASPECTS)

STRUCTURE

- Plant Tissues
- Difference Between Monocots and Dicots
- Some Anatomical Differences
- How to Identify anatomical Material ?

Study of gross internal structure of an organ, as observed in a section, is called anatomy *(ana,* as under; *temnein,* to cut). According to Sugdon (1984), *anatomy* is the study of the way in which tissues and organs are arranged in organisms.

Many cells constitute a *tissue.* A group of tissues forms a system called *tissue system.* Many different kinds of tissue systems constitute an *organ* and a group of organs constitute an *organism.*

• 9.1. PLANT TISSUES

A tissue consists of cells of only one or several types, having a common origin and performing an identical function (Fig. 1).

(a) **Meristematic**: These are small, thinwalled cells, devoid of any central vacuole and situated at the growing point of stems and roots. Their chief function is mitosis.

(b) Protective: The cells of these tissues are found on the surface of roots, stems and leaves. Top and bottom surface of these flat cells are parallel and their sides are irregularly arranged.

(c) **Parenchyma**: These are large, thin walled, living cells, each having a nucleus and central vacuole. Intercellular spaces are present in between these cells. Parenchymatous cells, present in the areas not exposed to light, possess leucoplast.

Parenchyma cells, specialized for the process of photosynthesis, are called *chlorenchyma.*

(d) Collenchyma: These cells have thick secondary wall, especially at their corners. Mechanical support is provided for the plants by these cells.

(e) Sclerenchyma : In these cells, very thick secondary walls are present in the form of a thick uniform layer around the entire margin. Generally, after the formation of secondary cell wall, the protoplasts of these cells die.

(f) Xylem : It consists of several types of cells like xylem vessels, xylem tracheids. Vessels are absent in the xylem of Gymnosperms. Vessels have thick secondary cell walls which are not deposited in a uniform layer but usually thickened in the form of spiral bands. Spiral bands are not present in the tracheids. Tracheids are tapered at the ends and are interconnected by means of pits. Xylem develops into wood.

(g) Phloem: Important cells of this mixed tissue are sieve tubes and companion cells. Sieve tubes have perforated end walls. Nucleus is absent in the sieve tubes at maturity but it is present in the companion cells. Chief function of the phloem is the transport of food throughout the plant.

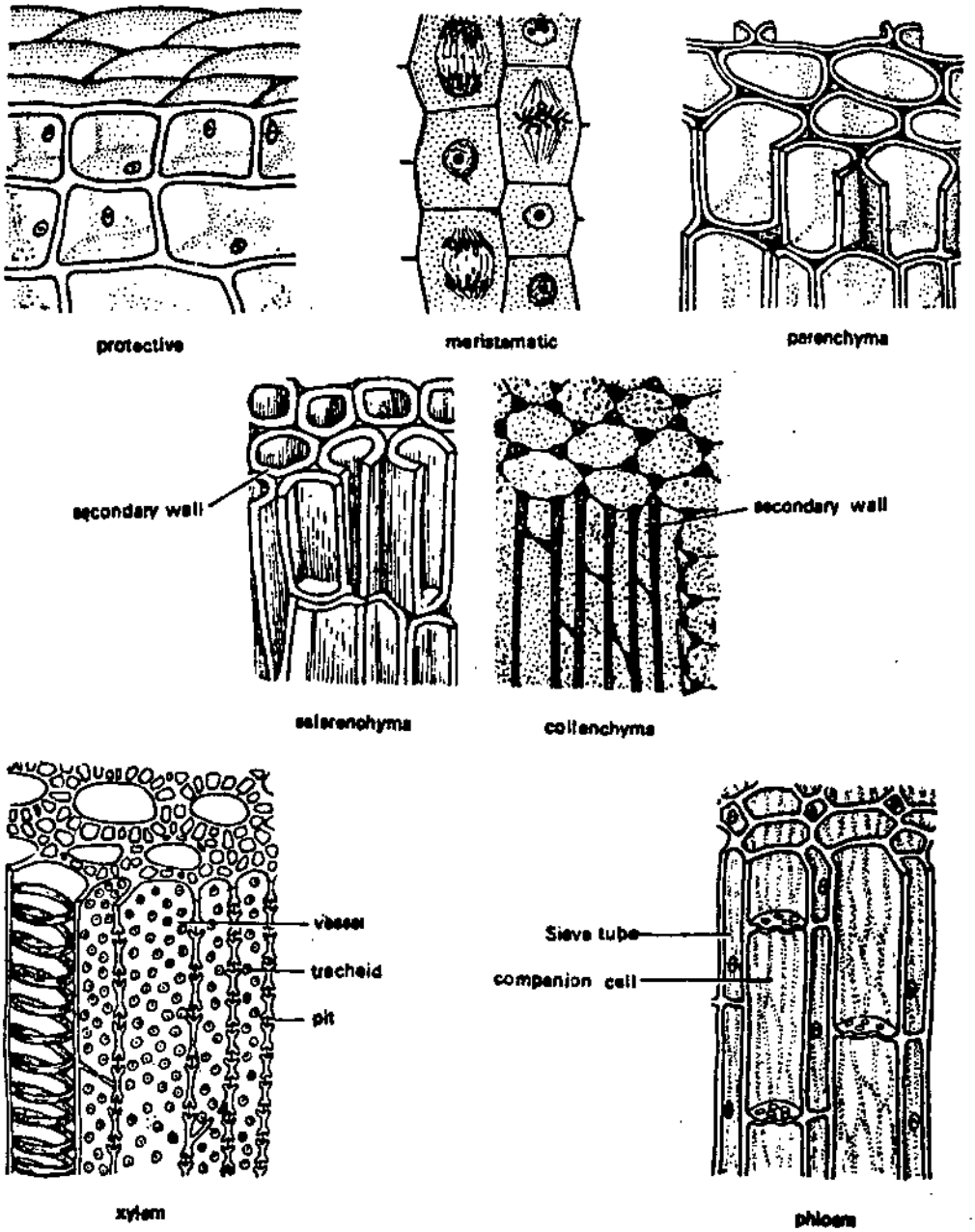

Fig. 1. Plant tissues.

• 9.2. DIFFERENCE BETWEEN MONOCOTS AND DICOTS (FIG. 2)

S.No. Monocots	Dicots
1. Presence of one cotyledon.	Two cotyledons are present.
2. Parallel venation is present in the leaves.	Venation is reticulate.
3. Flowers are di- to tri-merous.	Flowers are generally pentamerous.
4. Many vascular bundles are arranged irregularly.	Vascular bundles are arranged in ring.

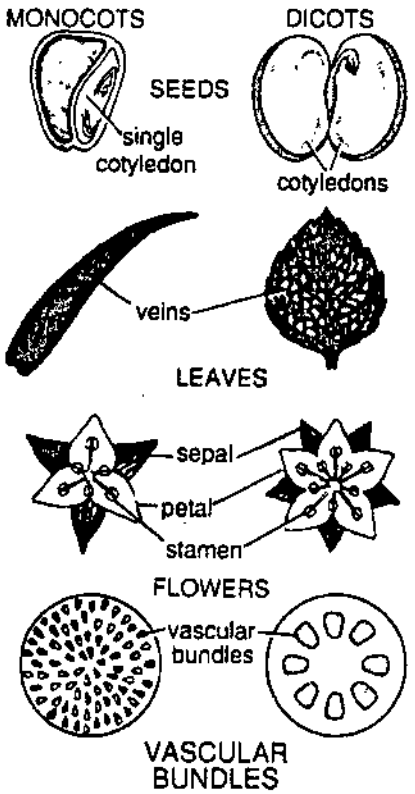

Fig. 2. Difference between monocots and dicots.

• 9.3. SOME ANATOMICAL DIFFERENCES

1. Stem and Root

S. No.	Stem	Root
1.	Endarch protoxylem.	Protoxylem is exarch.
2.	Feebly developed endodermis.	Endodermis well developed.
3.	Vascular bundles are conjoint, *i.e.*, both xylem and phloem lie one above the other.	Vascular bundles are radial, *i.e.*, both xylem and phloem form separate groups and lie on different radii.

2. Dicot Stem and Monocot Stem

S. No.	Dicot Stem	Monocot Stem
1.	Generally hairy.	Usually glabrous.
2.	Hypodermis, if present is generally collenchymatous.	Hypodermis is sclerenchymatous.
3.	Below the hypodermis, the cortex is generally well differentiated.	Cells below the hypodermis are undifferentiated, generally parenchymatous and form ground tissue.
4.	Endodermis is generally absent or poorly developed and pericycle is either parenchymatous or sclerenchymatous.	Pericycle not well-developed.
5.	Vascular bundles are arranged in one or more rings.	Vascular bundles are scattered in the ground tissue.
6.	Vascular bundles are of almost equal size.	Vascular bundles are dissimilar in size. Generally, outer bundles are smaller than inner ones.outer bundles are smaller than inner ones.

7.	Presence of cambium.	Cambium is absent.
8.	Phloem parenchyma is present.	Phloem parenchyma absent.
9.	Pith is well-developed.	Pith is feebly-developed.

3. Dicot Root and Monocot Root

S.No.	Dicot Root	Monocot Root
1.	Diarch to hexarch condition is present, *i.e.*, protoxylem groups are two to six.	Polyarch condition is present, *i.e.*, number of protoxylem groups is more than six.
2.	Cambium is present.	Cambium is absent.
3.	Vessel's cavities of metaxylem are small.	Cavities of vessels are very large.
4.	Pith is feebly-developed.	Pith is well-developed.

4. Dicot Leaf and Monocot Leaf

S.No.	Dicot Leaf	Monocot Leaf
1.	Leaves are dorsiventral.	Leaves are isobilateral.
2.	Stomata are present only on lower side of the leaf.	Stomata are present on both sides of the leaf.
3.	Mesophyll is differentiated into palisade and spongy parenchyma.	Mesophyll is undifferentiated.
4.	Sclerenchyma is absent.	Sclerenchyma is present on both sides of vascular bundle.

5. Dicot Stem and Dicot Root

S.No.	Dicot Stem	Dicot Root
1.	Hair are multicellular.	Hair are unicellular.
2.	Stomata are present.	Stomata are absent.
3.	Hypodermis is sclerenchymatous or collenchymatous.	Hypodermis is normally absent.
4.	Chlorenchyma may also be present in the cortex.	Chlorenchyma is absent in the cortex.
5.	Endodermis is generally absent.	Endodermis is generally present.
6.	Vascular bundles are conjoint, collateral, open and endarch.	Vascular bundles are radial and exarch.
7.	Pith is well-developed.	Pith is ill-developed or absent.

6. Monocot Stem and Monocot Root

S. No.	Monocot Stem	Monocot Root
1.	Epidermal hair are multicellular.	Epidermal hair are unicellular.
2.	Stomata are present.	Stomata are absent.
3.	Hypodermis is sclerenchymatous.	Hypodermis is absent.
4.	Endodermis is absent.	Endodermis is present.
5.	Pericycle is not clearly demarcated.	Pericycle is present.
6.	Vascular bundles are conjoint, collateral, closed, and endarch.	Vascular bundles are radial and exarch.

• 9.4. HOW TO IDENTIFY ANATOMICAL MATERIAL ?

A thin, perfect T.S. of the material

- (i) Vascular bundles conjoint, collateral or bicollateral and endarch.
  (ii) Endodermis ill-developed or absent.
  (STEM)
  - (i) Vascular bundles conjoint, collateral or bicollateral and open.
    (ii) Vascular bundles arranged in ring.
    (iii) Well-developed pith.
    (DICOT)
  - (i) Vascular bundles conjoint, collateral and closed.
    (ii) Vascular bundles scattered in the ground tissue
    (iii) Pith ill-developed.
    (MONOCOT)
- (i) Vascular bundles radial and exarch.
  (ii) Endodermis well-developed.
  (ROOT)
  - (i) Secondary growth is present.
    (ii) Number of protoxylem groups only upto 6.
    (iii) Pith small.
    (DICOT)
  - (i) Secondary growth is absent.
    (ii) Number of protoxylem groups more than 6.
    (iii) Pith large.
    (MONOCOT)

UNIT

10

ANATOMY OF MONOCOT AND DICOT STEMS, ROOTS & LEAVES

STRUCTURE

- Normal Monocot Stems
- Monocot Stem with Secondary Thickenings
- Dicotyledonous Stem
- Dicotyledonous Stem with secondary growth
- Anatomy of Dicotyledonous Root
- Anatomy of Monocot Leaf
- Anatomy of Dicot Leaf

• 10.1. NORMAL MONOCOT STEMS

1. *Zea mays*-Stem

T.S. of the material shows the following tissues from outside within:

It is circular in outline with a well-defined *epidermis, hypodermis, ground tissue* and many *scattered vascular bundles (Fig. 1).*

1. **Epidermis** is the outermost layer of stem.

2. The outer wall of cells is covered by a thick *cuticle.*

3. The continuity of the layer is broken by a few *stomata.*

4. Epidermal hair are absent.

5. **Hypodermis** is two to three cells thick, *sclerenchymatous* and present just below the epidermis.

6. *Cells are polygonal is shape.*

7. **Ground tissue** is not differentiated into cortex, endoderrnis, pericycle and pith.

8. The cells are parenchymatous and extend from below the sclerenchyma up to the centre.

9. The cells are small and compactly arranged below the hypodermis but they are large, round and loosely arranged in the centre.

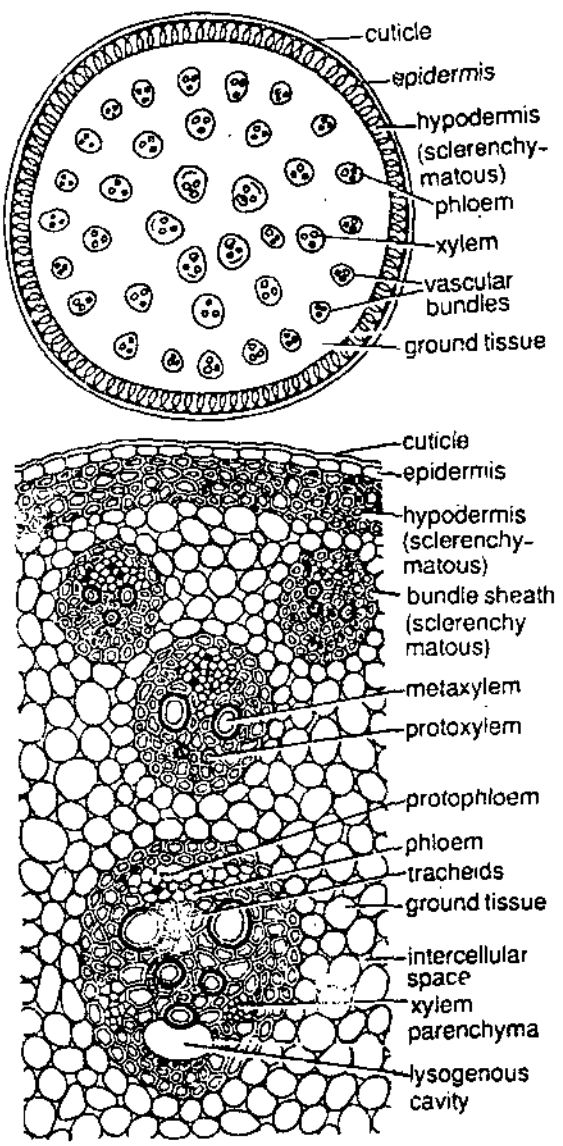

Fig. 1. *Zea mays* : Upper—T.S. stem (diagrammatic); Lower—T.S. stem (a part cellular).

Vascular Bundles :

10. Vascular bundles are many and *scattered* in the ground tissue with no definite arrangement.

11. They are small and more in number towards the periphery than the centre of the section.

12. Each vascular bundle is *conjoint, collateral, closed* and *endarch.*

13. A well-developed *sclerenchymatous sheath* surrounds each vascular bundle which is more prominent at its upper and lower faces.

14. Xylem **and** phloem constitute the vascular bundle.

15. **Xylem** : (i) Consists of *vessels* (protoxylem and metaxylem), *tracheids* and *xylem parenchyma.* (ii) Vessels are in the form of" Y'.

(iii) Metaxylem is present at the divergent ends of 'Y' in the form of two big oval vessels. (iv) Protoxylem is present at the lower arm of 'Y', consisting of two small vessels, (v) Protoxylem is surrounded by tracheids and xylem parenchyma, (vi) Inner protoxylem vessel and parenchyma break down and form a water-containing cavity called lysigenous cavity.

16. **Phloem** : (i) Consists of only *sieve tubes* and *companion cells.*

(ii) Phloem fibres and phloem parenchyma are absent, (iii) The outer parts of the phloem, which are broken and disorganized, are called *protophloem.* (iv) Inner phloem contains sieve tubes and companion cells, and is called *metaphloem.*

Identification

(a) 1. *Presence of vessels in the xylem*..... **Angiosperms**

(b) 1. *Vascular bundles are conjoint, collateral and endarch.* **Stem**

(c) 1. *No differentiation of ground tissue.*

2. *Sclerenchymatous hypodermis.*

3. *Vascular bundles are closed.*

4. *Scattered vascular bundles.*

5. *Absence of secondary growth*..... **Monocot**

Special Points

1. *Scattered vascular bundles.*
2. *'Y'-shaped vessels.*
3. *Presence of protophloem and metaphloem.*

• 10.2. MONOCOT STEM WITH SECONDARY THICKENINGS*

2. *Dracaena**-Stem

T.S. is circular in outline and reveals the following tissues from outside with-in:

Epidermis: 1. Single-layered epidermis, consisting of rectangular cells, is present in the younger stages but at maturity it gets ruptured due to secondary growth and is replaced by *cork.*

2. Some lenticels are also present.

3. **Periderm** in old stems is present and consists of *cork, cork-cambium* and *secondary cortex.* These are also known as *phellem, phellogen* and *phelloderm,* respectively.

4. *Cork cambium* is one-to few cells deep and consists of barrel-shaped, thin-walled cells. It cuts off cork towards outer side and secondary cortex towards inner side.

5. *Cork* consists of rec- tangular and dead cells,

The name of *Dracaena* of family Liliaceae has been suggested to the author by Dr. C.R. Metcalfe, Royal Botanic Gardens. Kew, England, while commenting on the first edition of this book in 1975

6. *Secondary cortex* is either parenchymatous or chlorenchymatous. It is many cells deep.

7. **Vascular System** : *Primary structure* consists of numerous, scattered vascular bundles which are closed and collateral.

8. In the later stages the stem shows *secondary growth.*

9. At the time of secondary growth many-layered *cambium (meristematic tissue)* develops outside the primary bundles in the parenchyma.

10. Cambium or meristematic tissue cuts many *secondary vascular bundles only towards inner side.*

11. A small amount of thin-walled parenchyma is cut off on the outer side by the cambium (meristematic zone).

12. *Primary bundles* are central in position, scattered and large.

13. *Secondary bundles* are peripheral in position, small in size, oval in transection and amphivasal, *i.e.,* phloem is surrounded by xylem.

14. *Phloem* consists of sieve tubes, companion cells and phloem parenchyma.

15. *Xylem* consists of tracheids and xylem parenchyma.

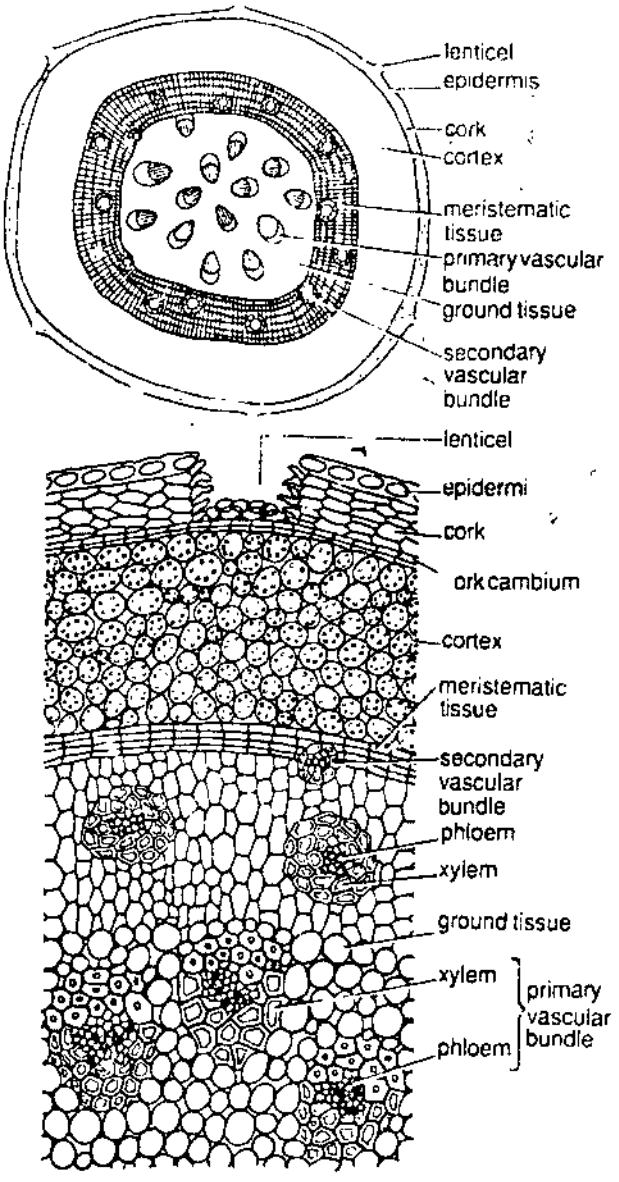

Fig. 2. Dracaena : Upper—T.S. stem (diagrammatic); Lower—T.S. stem (a part cellular).

16. **Ground Tissue** is well-developed, thin-walled and parenchymatous.

Secondary Growth

The meristematic tissue, instead of cutting separate vascular tissues, cuts individual vascular bundles. Primary bundles are large and collateral whereas these secondary bundles are small and amphivasal. This meristematic zone stops functioning after some time. It originates near leaf primordia.

• 10.3. DICOTYLEDONOUS STEMS

3. *Luffa-Stem*

T.S. exhibits the following details:

It is wavy in outline, usually with five ridges and five furrows, and ten vascular bundles remain arranged in two rings of five each.

Epidermis : 1. Single-layered epidermis consists of many barrel- shaped cells covered with *cuticle.*

2. Some of the epidermal cells protrude out as multicellular shoot hair.

3. **Cortex:** It consists of *coltenchymatous hypodermis, chlorenchyma* and an innermost layer of *endodermis.*

4. *Collenchyma* is present just below the epidermis, in the form of six to ten or more layers in the ridges and only a few layers or none in the furrows.

5. *Chlorenchyma* is present in the form of two to three layers in between the collenchyma and endodermis. Its cells are filled with chloroplasts.

6. *Endodermis* is the innermost layer of cortex. It is wavy in outline. The cells are filled with starch grains and lack casparian strips.

7. **Pericycle:** It consists of four to five layers of thick-walled, lignified sclerenchymatous zone present just below the endodermis.

8. **Ground Tissue:** The space between sclerenchyma and the central pith cavity is filled with many thin-walled, parenchymatous cells of ground tissue, in which the vascular bundles remain embedded.

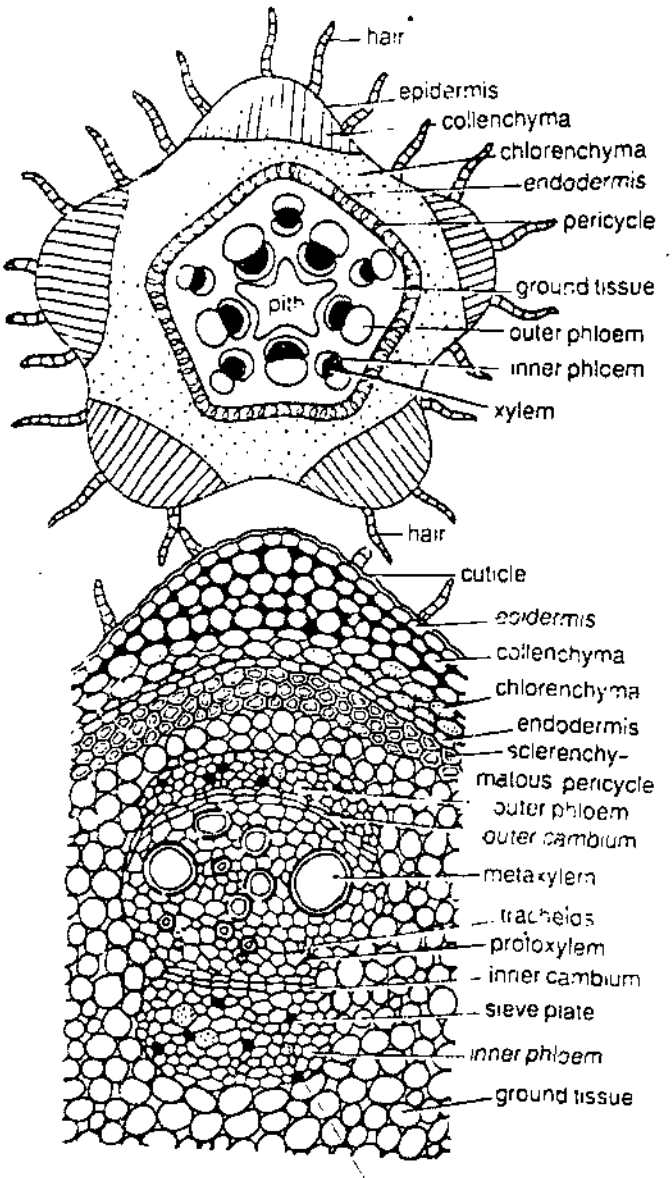

Fig. 3. Upper—T.S. stem (diagrammatic); Lower—T.S. stem (a part cellular).

Vascular Bundles

9. Ten vascular bundles are arranged in two rows of five each.

10. Five vascular bundles of outer ring are present opposite the ridges whereas the remaining five of the inner ring face the furrows.

11. Vascular bundles are *conjoint, bicollateral, open* and *endarch.*

12. *Each vascular bundle* consists of centrally located *xylem,* surrounded on its outer and inner faces by strips of *outer and inner cambia. Outside the outer cambium is* present a patch of *outer phloem,* and inner to the inner cambium is present the *inner phloem,* thus representing the *open* and *bicollateral* condition of vascular bundles.

13. *Xylem* consists of wide vessels present on the outer side representing the *metaxylem* and narrow vessels present towards inner side representing the protoxylem. Xylem also contains certain tracheids, wood fibres and xylem parenchyma.

14. *Cambium* is present in the form of strips on both the sides of the xylem. It consists of thin-walled, rectangular cells arranged in radial rows.

(i) *Outer cambium* is flat and many-layered.

(ii) *Inner combium* is curved and only few-layered.

15. *Phloem* is situated in the form of patches of outer phloem and inner phloem. It consists of *companion cells,* thin-walled cells of *phloem parenchyma,* and well-developed sieve tubes.

16. **Pith:** Thin-walled parenchymatous cells of ground tissue form the pith.

4. *Bignonia*-Stem

T.S. shows many ridges and furrows and reveals the following tissues from outside with-in :

1. **Epidermis** : Single-layered epidermis consists of rectangular cells.

2. A thick *cuticle* is present.

3. A few *multicellular hair* are also arising from some cells.

4. **Cortex:** It is well-differentiated into collenchyma and parenchyma.

5. *Collenchyma* is present below the epidermis in the ridges in young stem but at maturity there develops *sclerenchyma.*

6. *Parenchyma* is present below the sclerenchyma or collenchyma in the ridges and directly below the epidermis in the grooves.

7. *In old stem* cortex consists of cork, cork cambium and cortex.

8. *Endodermis* is un-distinguishable from cortical ceils. The cells lack casparian strips.

9. **Pericycle** : It is in the form of sclerenchymatous patches.

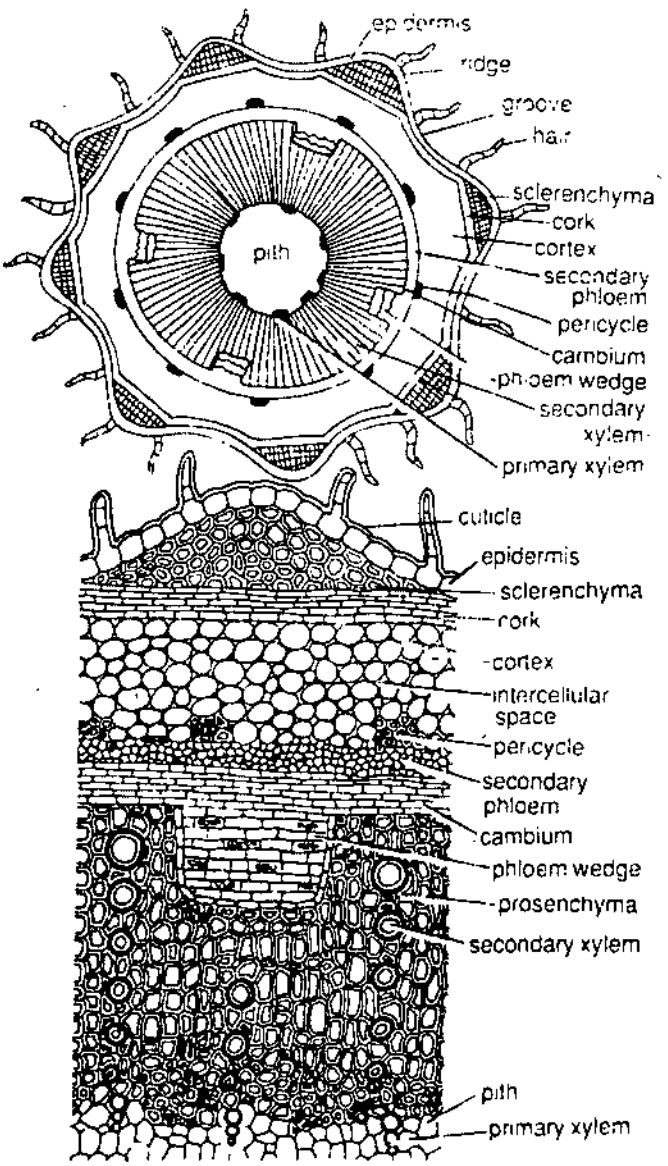

Fig. 4. Bignonia. Upper—T.S. stem (diagrammatic); Lower—T.S. stem (apart cellular).

Vascular system

10. It consists of primary phloem, secondary phloem, cambium, secondary xylem and primary xylem.

11. *Four longitudinal furrows of secondary phloem* are present which are wedged in between the secondary xylem cylinder.

1Z *Vascular bundles* are conjoint, collateral, open and endarch.

13. Primary phloem is crushed and present in small patches.

14. *Secondary phloem* is in the form of a ring which remains intruded into the secondary xylem at four places.

15. Intruded furrows (four) of secondary phloem are arranged in the form of a cross.

16. In *Bignonia un- guiscatae,* bars of sclerenchyma are present in the furrows of secondary phloem.

17. *Cambium* is single-layered, present in between xylem and phloem and remains bent towards inner side along the furrows of secondary phloem.

18. *Secondary xylem* consists of vessels, tracheids, fibres and xylem parenchyma.

19. Due to the intrusion of the phloem at four places. secondary xylem is ridged and furrowed at four places.

20. *Primary xylem* is present close to the pith facing its protoxylem towards the centre. Its location is just opposite to the patches of primary phloem.

Pith: 21. It is thin-walled and parenchymatous.

Secondary Growth

Formation of four furrows of secondary phloem in the secondary xylem is due to the abnormal functioning of cambium which was behaving normally some time earlier. At four or more places cambium produces less amount of secondary xylem towards inner side and large amount of secondary phloem towards outer side. Thus, four wedges of secondary phloem are formed. They intrude into the secondary xylem. and so the xylem cylinder appears ridged and furrowed.

• 10.5. ANATOMY OF DICOTYLEDONOUS ROOTS

5. *Cicer-Root*

It is circular in outline (Fig. 5) and reveals following tissues from outside with-in :

1. **Epiblema** : It is the outermost layer consisting of many thin-walled cells.

2. From some of its cells arise unicellular hair.

3. Cuticle is absent.

4. **Cortex** : It is very large, parenchymatous and well-developed occupying the large part of the section.

5. In this region there are present many intercellular spaces.

6. Cortical cells are filled with starch grains.

7. In older roots, few-layered *exodermis*, consisting of thin-walled compact cells, is present just below the epiblema.

8. *Endodermis* is the ring like innermost layer of cortex made up of barrel-shaped cells.

9. *Casparian strips* are present in the endodermal cells.

10. Some of the endodermal cells, particularly those opposite to the protoxylem. are thin-walled and have been termed *as passage cells*.

11. **Pericycle** : Single-layered, ring-like pericycle is present close to the endodermis on its inner side.

12 It is also a compact layer of thin-walled cells.

13. **Vascular Bundles** : The vascular bundles are 2 to 6 and radial, *i.e.*, xylem and phloem present on different radii alternating with each other.

14. Xylem and phloem patches are equal in number.

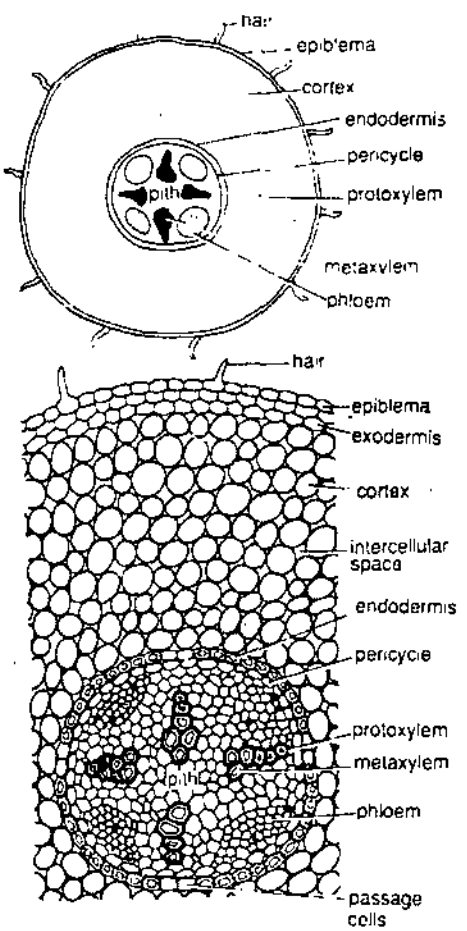

Fig. 5. Cicer. Upper—T.S. root (diagrammatic); Lower—T.S. root (a part cellular)

15. *Xylem* consists of protoxylem and metaxylem.

16. *Protoxylem* is *exarch* and consists of small annular and spiral vessels.

17. *Metaxylem* strands are big, present towards the centre and are made up of large reticulate and pitted vessels.

18. In some cases the metaxylem meets in the centre and thus obliterates the pith.

19. *Phloem* is made up of sieve tubes, companion cells and phloem parenchyma.

20. In mature roots, *cambium* also appears cutting the secondary structures.

21. The parenchymatous cells in between xylem and phloem strands form conjunctive tissue.

22. **Pith**: It is very small, parenchymatous and without any intercellular spaces. It gets reduced after the formation of secondary structures.

• 10.5. ANATOMY OF MONOCOT ROOT

6. *Zea mays*-Root

It is circular in outline and reveals the following tissues (Fig. 6) from outside with-in:

1. **Epiblema**: Single-layered epiblema consists of barrel-shaped or rounded cells.

2. From some cells arise unicellular hair.

3. **Cortex**: It is well-developed, several cells deep and parenchymatous.

4. The cells are thin-walled, rounded in shape and leave many intercellular spaces.

5. Just below the epiblema are present 2 to 6 layers of *collenchyma* in old roots. This represents exodermis.

6. Remaining part of the cortex is parenchymatous.

7. *Endodermis* is the innermost layer of cortex. It consists of many compactly arranged, barrel-shaped cells.

8. *Casparian strips* are present on the radial and transverse walls of the endodermal cells.

9. Thin-walled endodermal cells are known *as passage cells*. They lie opposite to protoxylem.

10. **Pericycle**: Single-layered pericycle consists of thin-walled cells and is present inner to the endodermis.

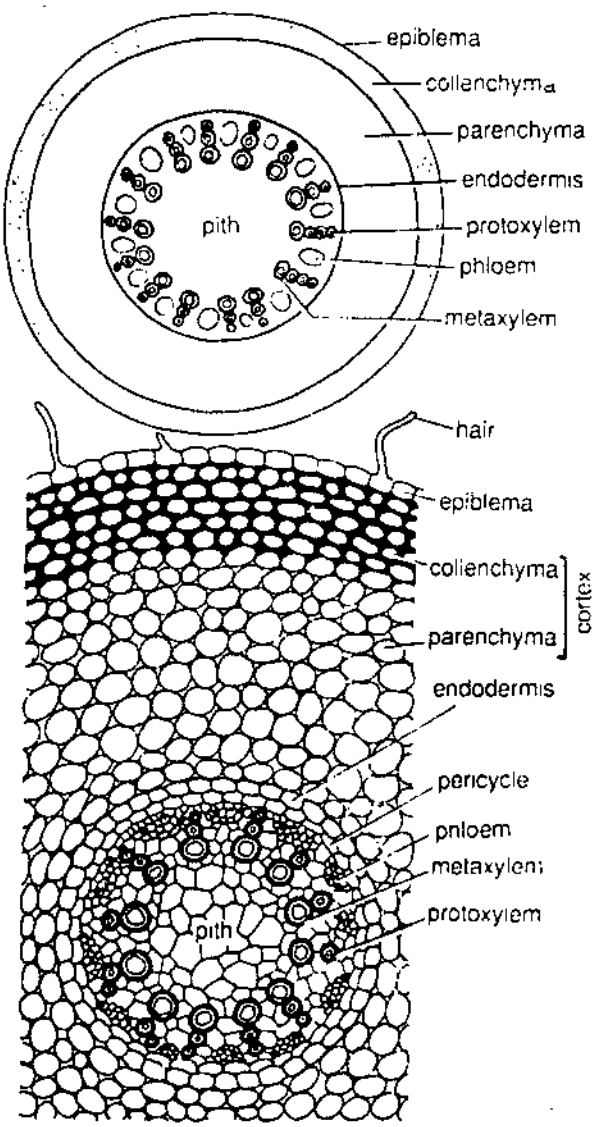

Fig. 6. Zea mays. Upper—T.s. root (diagrammatic); Lower—T.s. root (a part cellular)

Vascular Tissue

11. It is composed of alternating strands of phloem and xylem.

12. Vascular bundles are radial, exarch and polyarch. Cambium is absent.

13. Xylem consists of vessels, tracheids and xylem parenchyma.

14. *Protoxylem* elements are towards the outer side, *i.e.*, exarch, small in diameter and their walls have thickenings.

15. *Metaxylem* vessels face towards the centre and have larger diameter. Innermost metaxylem vessel is very large and spherical or oval.

16. *Phloem* consists of sieve tubes, companion cells and phloem parenchyma. It exhibits exarch condition with its protophloem towards the periphery and metaphloem towards the centre.

17. Thick-walled, sclerenchymatous *conjunctive tissue* is present in between the vascular bundles.

18. **Pith**: It is well-developed and parenchymatous.

19. The cells are round in shape and have many intercellular spaces.

• 10.6. ANATOMY OF MONOCOT LEAF

15. *Triticum*-Leaf

T.S. shows prominent ridges and grooves and reveals the following tissues:

Epidermis : 1. Two epidermal layers are present, one each on upper and lower surfaces.

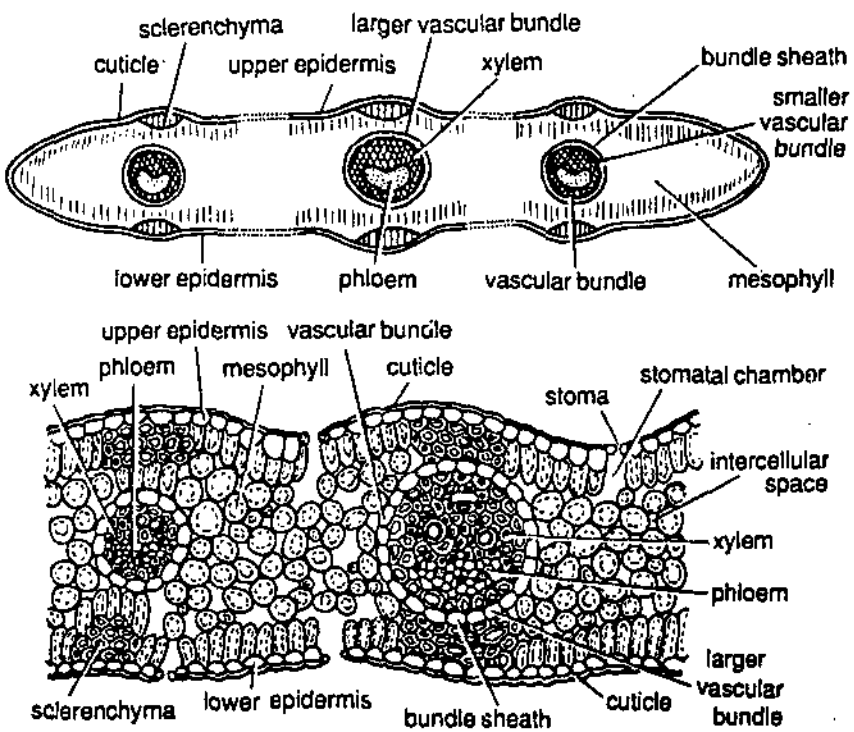

Fig. 7. *Triticum* : Upper, T.S. root (diagrammatic); Lower, T.S. root (a part cellular)

2. Uniseriate upper and lower epidermal layers are composed of more or less oval cells.

3. Few big, motor cells or *bulliform cells* are present in groups here and there in the furrows of upper epidermis.

4. *Stomata*, each consisting of a pore, guard cells and a stomatal chamber, are present on both the epidermal layers.

5. A thick cuticle is present on the outer walls of epidermal cells.

6. Bulliform cells help folding of leaves.

7. **Mesophyll**: It is not clearly differentiated into palisade and spongy parenchyma but the cells just next to the epidermal layers are a bit longer while the cells of the central mesophyll region are oval and irregularly arranged.

8. The cells are filled with many chloroplasts.

9. Many intercellular spaces are also present in this region.

10. Sub-stomatal chambers of the stomata are also situated in this region.

Vascular System

11. Many vascular bundles are present. They are arranged in a parallel series.

12. The central vascular bundle is largest in size.

13. Vascular bundles are *conjoint, collateral* and *closed.*

14. Each vascular bundle remains surrounded by a double-layered *bundle sheath.*

15. Outer layer of bundle sheath consists of thin-walled cells while the inner layer is made up of thick-walled cells.

16. On the upper as well as lower surface of large vascular bundles are present patches of *sclerenchyma* which are closely associated with the epidermal layers. There is no such association between the sclerenchyma and small vascular bundles.

17. *Xylem* occurs towards the upper surface and phloem towards the lower surface.

18. *Xylem* consists of vessels and tracheids. Sometimes small amount of xylem parenchyma is also present.

19. *Phloem* consists of sieve tubes and companion cells.

Xerophytic Characters

(i) Thick cuticle on epidermis.

(ii) Presence of motor cells.

(iii) Sclerenchyma patches are present.

(iv) Stomata in furrows.

• 10.7. ANATOMY OF DICOT LEAF

16. *Mangifera indica*-heaf

Following tissues are visible in the transverse section of the material:

1. **Epidermis**: An epidermal layer is present on the upper as well as lower surface.

2. One-celled thick upper and lower epidermal layers consist of barrel-shaped, compactly arranged cells.

3. A thick cuticle is present on the outer walls of epidermal cells. Comparatively, thick cuticle is present on the upper epidermis.

4. *Stomata* are present only on the lower epidermis.

5. **Mesophyll**: It is clearly differentiated into palisade and spongy parenchyma.

6. *Palisade* tissue lies just inner to the upper epidermis. It is composed of elongated cells arranged in two layers.

7. The cells of palisade region are compactly arranged and filled with chloroplast. At some places the cells are arranged loosely and leave small and big intercellular spaces.

8. Palisade cells are arranged at a plane at right angles to the upper epidermis, and the chloroplasts in them are arranged along their radial walls.

9. *Parenchymatous* cells are present above and below the large vascular bundles. These cells interrupt the palisade layers and are said to be the extensions of the bundle sheath.

10. *Spongy parenchyma* region is present just below the palisade and extends upto the lower epidermis.

11. The cells of spongy parenchyma are loosely arranged, filled with many chloroplasts and leave big intercellular spaces.

Vascular Region

12. Many large and small vascular bundles are present,

13. Vascular bundles are conjoint, collateral and closed.

14. Each vascular bundle is surrounded by a *bundle sheath.*

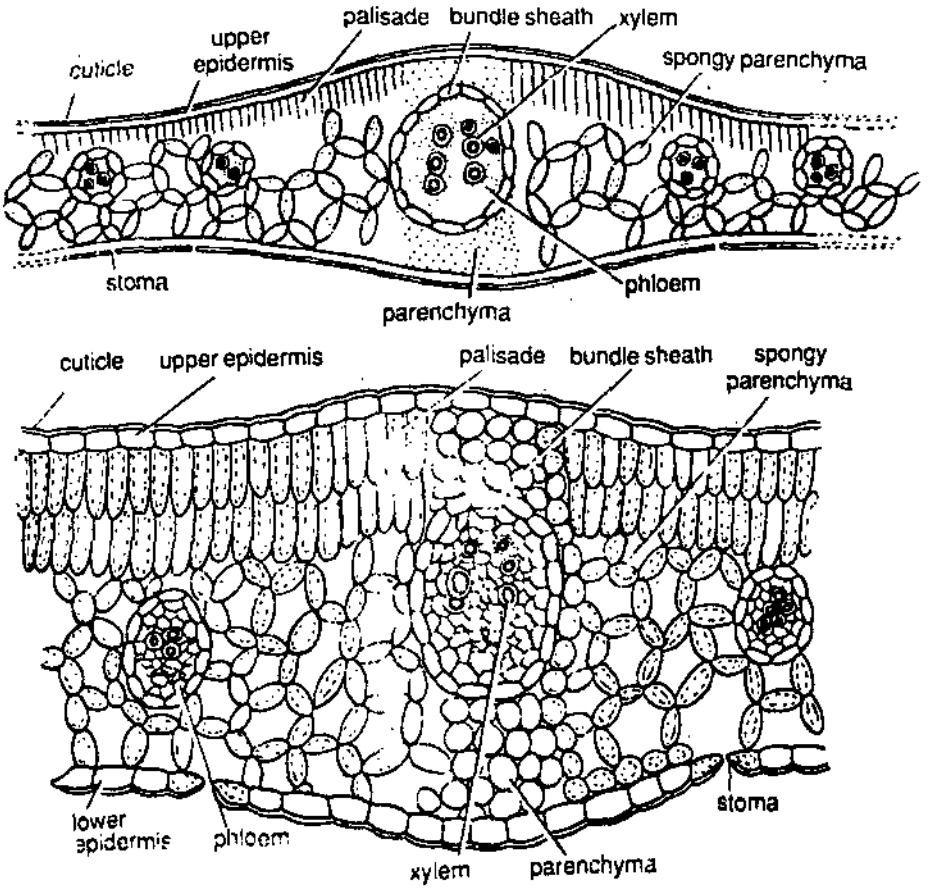

Fig. 8. *Mangifera indica*. Upper, T.S. leaf (diagrammatic); Lower, T.S. leaf (a part cellular)

15. Bundle sheath is parenchymatous and in case of large bundles it extends upto the epidermis with the help of thin-walled parenchymatous cells.

16. The *xylem* is present towards the upper epidermis and consists of vessels and xylem parenchyma. Protoxylem is present towards upper epidermis while the metaxylem is present towards the lower epidermis.

17. *Phloem* is is present and is situated towards the lower epidermis and consists of sieve tubes, companion cells and phloem parenchyma.

UNIT

11

ANATOMY OF PHYLLOCLADE AND PHYLLODE

STRUCTURE

- *Ruscus*-Phylloclade
- *Acacia moniliformis*-Phyllode

• 11.1. *RUSCUS*-PHYLLOCLADE

(Phylloclade is a modified stem which appears and functions like a leaf)

T.S. appears flat, leaf-like and reveals the following tissues:

1. **Epidermis** : A single epidermal layer is present on upper as well as lower surface representing upper epidermis and lower epidermis.

2. A thick *cuticle* is present on the outer wall of the cells of both the epidermal layers.

3. Epidermal cells are radially elongated and their continuity is broken by many stomata present on both surfaces.

4. Stomata consist of guard cells filled with chloroplasts and clear sub-stomatal chamber.

5. Central region of the material is somewhat bulged.

6. **Chlorenchyma** : Immediately below the upper epidermis are present one or two layers of loosely arranged parenchymatous cells filled with chloroplasts.

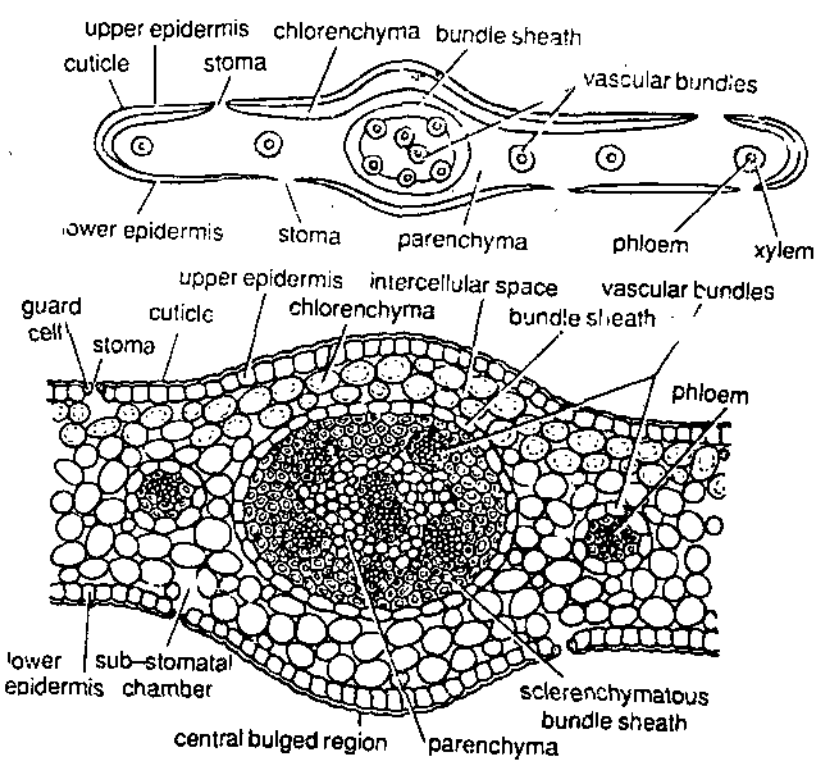

Fig. 1. *Ruscus*. Upper—T.S. phylloclade (diagrammatic); Lower—T.S. pylloclade (a part cellular)

7. The cells are rounded or oval in shape and leave many intercellular spaces.

8. **Parenchyma** : Parenchymatous region is well-deveioped and is present next to the chlorenchyma.

9. The cells are thin-walled, loosely arranged and leave many intercellular spaces.

Vascular System

10. Many vascular bundles are arranged in parallel series.

11. In the central bulged region of the section are aggregated a few amphivasal vascular bundles surrounded by a bundle sheath.

12. A thick, sclerenchymatous *bundle sheath* is present around each vascular bundle.

13. Each vascular bundle is *concentric* and *amphivasal* (phloem in the centre surrounded by the xylem).

14. Well-developed, parenchyma is present in the central region.

Leafy Characters

1. *Dorsiventral symmetry.*
2. *Presence of upper and lower epidermal layers with stomata.*
3. *Central bulged region is comparable with midrib.*
4, *Presence of chlorenchyma below upper epidermis.*

Stem-like Characters

1. *Presence of amphivasal vascular bundles.*
2. *Phloem does not face towards the lower epidermal layer.*
3. *Parenchyma of the central bulged region is comparable with the ground tissue or pith of stem.*
4. *Well-differentiated cortex.*

Xerophytic Characters

1. *Presence of thick cuticle.*
2 *Sclerenchymatous bundle sheath.*

• 11.2. *ACACIA MONILIFORMIS*-PHYLLODE (Common Name: Australian Acacia)

(In phyllode, the lamina of the leaves is reduced, and from the remaining part, i.e., petiole, a flat, leaf-like photosynthetic organ is developed. So it is a modification of petiole.)

T.S. of the meterial is flat, appears leaf-like and reveals the following tissues :

1. **Epidermis**: A single row of epidermal cells is present on upper as well as lower surfaces.

2. Outer wall of the epidermal cells is thickly cuticularized.

3. Epidermis is interrupted by many *sunken stomata,* each with a clear sub-stomatal chamber.

4. Cells of the epidermis are rectangular in shape but two extreme ends of the section possess radially elongated cells.

5. **Palisade** : Just below the epidermis are present a few layers of palisade.

6. Palisade cells are radially elongated and filled with many chloroplasts.

7. Many intercellular spaces are also present in the region.

8. **Parenchyma**: Next to the palisade is the parenchyma region which is well-developed and central in position.

9. The region consists of thin-walled, rounded cells with many intercellular spaces.

Vascular Tissue

10. Vascular bundles are many and are arranged below the palisade.

11. There are two big vascular bundles in the centre facing their xylem to each other. One big vascular bundle is present at each corner. Many smaller vascular bundles are present inner to the palisade.

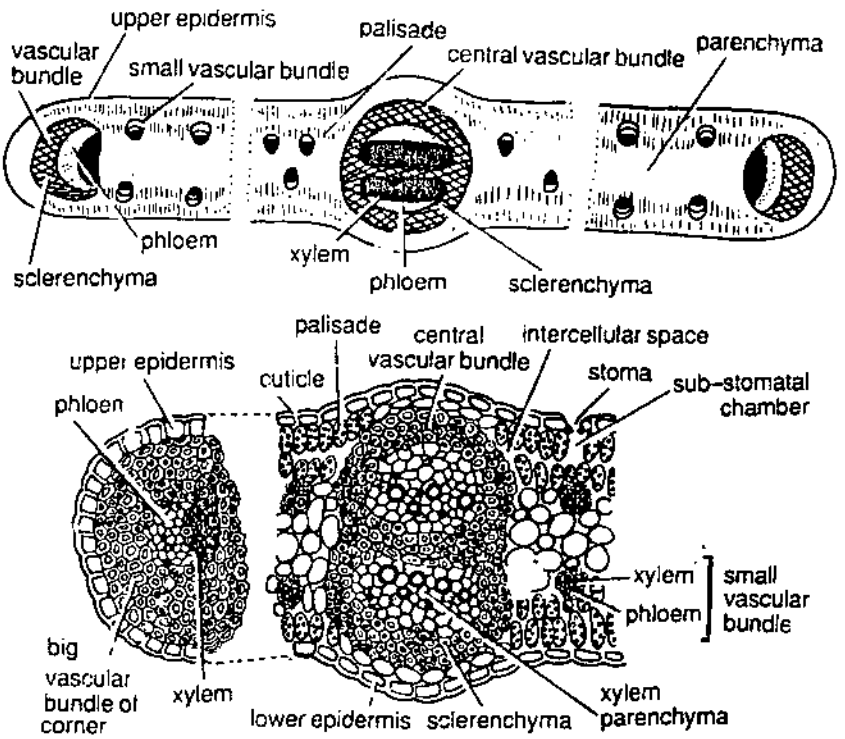

Fig. 2. Acacia moniliformis : Upper—T.S. phyllode (diagrammatic); Lower—T.S. phyllode (a part cellular)

12. Central and corner vascular bundles are bigger in size and remain surrounded by well-developed sclerenchyma.

13. Smaller vascular bundles are surrounded by a layer of thin-walled cells.

14. Vascular bundles are composed of xylem and phloem.

15. *Xylem* in each vascular bundle faces towards the centre and consists of tracheids, vessels and xylem parenchyma.

16. *Phloem* consists of sieve tubes, companion cells and phloem parenchyma. It faces towards the outer side or epidermis.

Xerophytic Characters

(a) Thick cuticle and radially elongated epidermal cells.

(b) Sunken stomata.

(c) Well-developed sderenchyma.

Leafy Characters

(a) Palisade tissue is present. *Petiole Characiers*

(a) Vascular bundles in a ring.

(b) Centra! and corner bundles are large in size.

UNIT

12

DIVERSITY IN LEAF SHAPE AND STOMATA

STRUCTURE

- Leaf Shape Exercise
- Stomata
- Trichome

• 12.1. LEAF SHAPE EXERCISE

Exercise 1. *To study the diversity in leaf shape.* See *"Leaf shapes"* in the chapter of *Taxonomical Terminology* on page 70-71 Fig. 78.

Exercise 2. *To study the surface properties (stomata and trichomes) of leaf.*

• 12.2. STOMATA

Stomata *(sing.-stoma)* are very minute openings found in the epidermal layer of leaves, stem and other aerial parts of the plant. Each stoma remains surrounded by two kidney-shaped or bean-shaped cells called **guard cells.** Chloroplasts are always present in the guard cells. The inner wall of each guard cell is thicker while its outer wall is thinner. The epidermal cells bordering the guard cells are called **subsidiary cells.**

In the absence of light, *i.e.* at night, the stomata remain closed. On the other hand in the presence of light, *i. e.* during daytime the stomata remain open. The closing and opening of stomata is due to the movement of guard cells.

Usually in monocotyledonous leaves, the stomata are arranged in parallel rows whereas in dicotyledonous leaves the stomata remain scattered.

In dicotyledons following four main types (Fig. 1) of stomata are found :

1. Anomocytic or Type-A

(i) No subsidiary cells are present.

(ii) Stoma remains surrounded by several irregularly arranged ordinary epidermal cells.

(iii) This type of stomata are also called *Ranunculaceous type* or *irregular-celled type.*

This type of stomata are found commonly in several dicotyledons, including *Tridax, Citrullus, Ranunculus etc.*

2. Anisocytic or Type-P

(i) Stoma remains surrounded by three subsidiary cells (Fig. 1). (ii) Of the three subsidiary cells, one is distinctly smaller than the other two. (iii) This type of stoma is also called *unequal-celled type* or *cruciferous type.* This type of stomata are seen commonly in *Brassica, Sedum* etc.

3. Paracytic or Type-C

(i) One or more subsidiary cells are present.

(ii) Subsidiary cells flank the stoma parallel with the long axis of the guard cells (Fig. 1).

(iii) This type is also called *parallel-celled type* or *Rubiaceous type.*

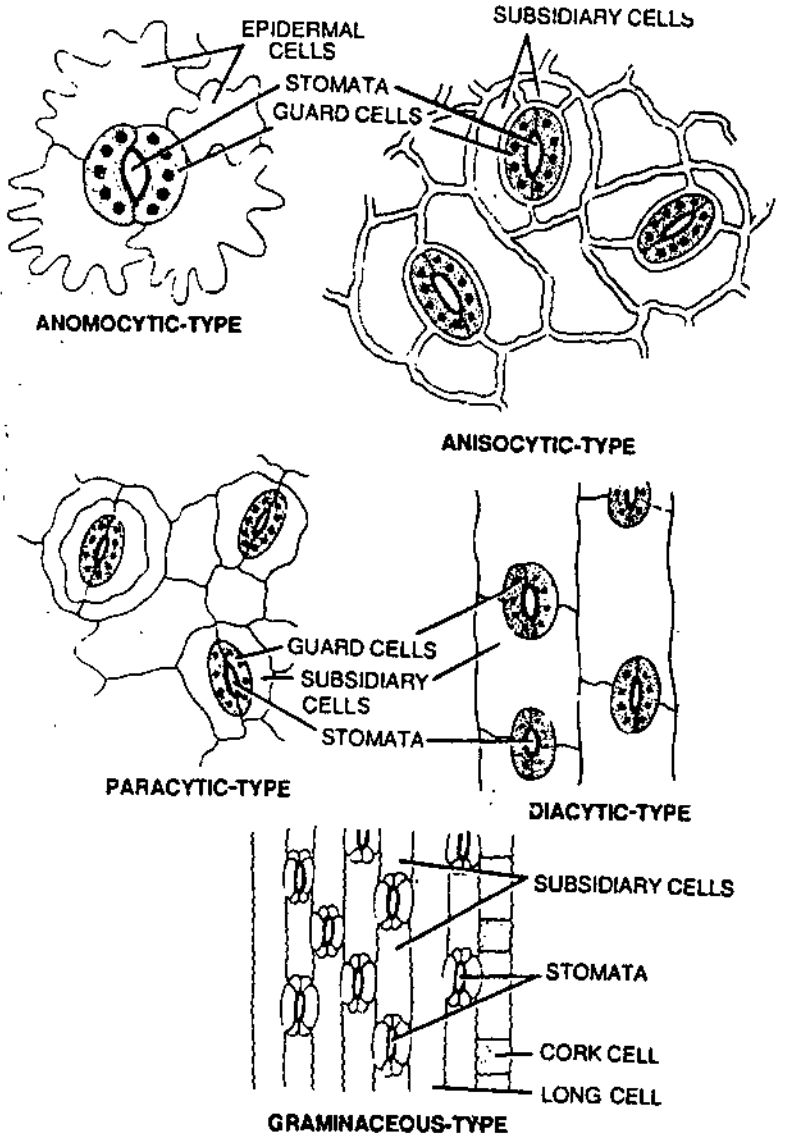

Fig. 1. Stomatal types.

This type is commonly seen in members of Rubiaceae, *Vigna*, etc.

4. Diacytic or Type-D

(i) Stoma remains surrounded by a pair of subsidiary cells (Fig. 1).

(ii) Common walls of subsidiary cells remain at right angles to the long axis of the guard cells,

(iii) This type is also called *cross-celled type* or *caryophyllaceous type.*

This type is commonly seen in *Ocimum,* Caryophyllaceae *(e.g., Dianthus),* etc.

• 12.3. TRICHOMES

Some of the epidermal cells of axis, and other plant parts grow out in the form of *trichomes* or *hair*. They show the following characteristics:

1. These are the elongation or extension of epidermal cells.
2. They are found singly or in groups.
3. Trichomes may be unicellular or multicellular. Morphologically, root hair are typical hair.
4. They are highly variable in shape varying from small protuberances of epidermal cells to very complex, multicellular, branched or stellate structures.

5. Hair may consist of either living or dead cells.
6. Hair with living cells contain very little cytoplasm in their cells.
7. They persist throughout the life of a plant, part of it or may fall very soon.
8. Innumerable types of the hair are known, of which some are uniseriate hair, stinging hair, mucilage hair, etc.
9. Functions of trichomes include :

(i) control of transpiration rate,

(ii) reduction of heating effect of sunlight, and

(iii) protection of body.

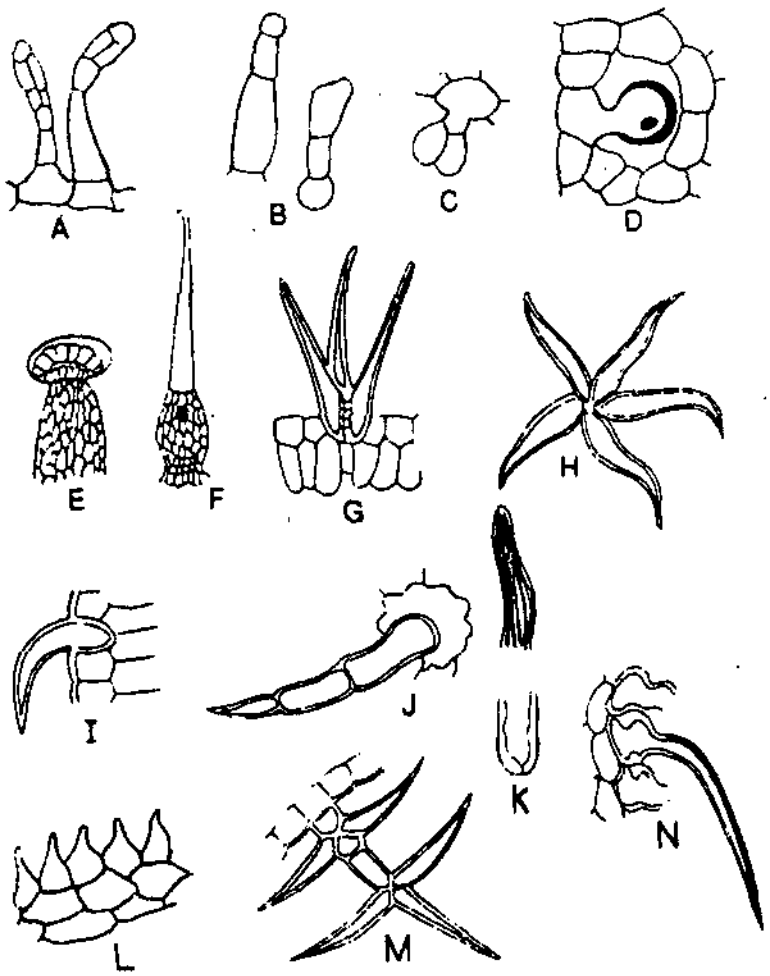

Fig. 2. Trichome types in angiosperms. A, Hyoscyamus; B, Atropa; C, Digitalis; D, Dryopteris; E, Cannabis; F, Urtica dioica; G-H, Hamamelis; I, Cassia; J, Datura; K. Strychnos; L, Arnica; M, Verbascum; N, Strophonthus.

UNIT 16

VIVA-VOCE

STRUCTURE

- Gymnosperms
- Taxonomy
- Embryology
- Anatomy

• 16.1. GYMNOSPERMS

Q.1. *Give a concise definition of Gymnosperms.*

"Phanerogams without an ovary" are called Gymnosperms.

Q. 2. *What is the most characteristic feature of Gymnosperms?*

Gymnosperms are characterized by having the ovules borne unprotected (naked) on the surface of megasporophyll, i.e., ovules are not enclosed inside the ovary.

Q. 3. *Which are the living orders of Gymnosperms?*

Cycadales, Ginkgoales, Coniferales and Gnetales.

Q. 4. *Which order of Gymnosperms was discovered by an Indian botanist?*

The group 'Pentoxyleae' was discovered by the well-known Indian palaeobotanist Professor Birbal Sahni(1948).

Q. 5. *What is polyembryony?*

Formation of more than one embryo per ovule is called polyembryony, *e.g., Pinus.*

Q. 6. *Name some of the Indian species of Cycas.*

Cycas circinalis, C. beddomei, C. rumphii, C. pectinata and C. siamensis.

Q.7. *What constitute the algal zone of Cycas coralloid root?*

In the algal zone of coralloid root of *Cycas* following members have been reported: *Anabaena cycadae, Nostoc punctiforme, Oscillatoria, Azotobacter, Pseudomonas radicicola* and some fungi.

Q.8. *How are the vascular bundles arranged in Cycas rachis?*

Vascular bundles in *Cycas* rachis are arranged in Omega (Ω)-shaped manner.

Q. 9. *Cyas is monoecious or dioecious?*

Cycas is strictly dioecious.

Q. 10. *Name some of the Indian botanists who worked on Gymnosperms.*

R. Khan. R.N. Konar, Madhulata, P. Maheshwari, D.D. Pant, B. Sahni, V. Vasil.

Q. 11. *Name some of the foreign workers on Gymnosperms.*

C.A. Arnold, C.J. Chamberlain, R. Florin, A.S. Foster, E.M. Gifford, K.R. Sporne, D.W. Bierhorst.

Q. 12. *Name some economically important genera of Coniferales. Pinus, Larix, Abies, Picea, Taxus, Cedrus, Libocedrus and Juniperus.*

Q. 13. *Where does Pinus occur in India?*

Species of *Pinus* in India are distributed in Himalayas, NEFA, Kashmir, Assam, Kulu, Manali, Nilgiris & West Bengal.

Q. 14. *What do you mean by a quadrifoliar spur?*

In *Pinus*, a dwarf shoot having four needles is called quadrifoliar spur, *e.g. P. quadrifolia.*

Q. 15. *Give one basic point of difference between pollen grains of Cycas and Pinus.*

'Pollen grains of *Pinus* have two baloon-shaped wings while the wings are absent in pollen grains of *Cycas*'.

Q. 16. *What is Chilgoza?*

Chilgoza is the seed of *Pinus gerardiana.*

Q. 17. *From which plant Canada-Balsam is obtained?*

Canada-Balsam, a common mounting medium for microscopic preparations, is obtained from *Abies balsamea.*

Q. 18. *From which species of Pinus terpentine is obtained?*

Terpentine is obtained from *Pinus insularis. P. roxburghii & P. wallichiana,*

Q. 19. *Name the Indian species of Ephedra.*

Ephedra is represented in India by 6 species. These are *Ephedra foliata, E. gerardiana, E. intermedia, E. nebrodensis, E. regeliana* and *E. saxatilis.*

Q. 20. *Ephedrine is obtained from which species of Ephedra?*

Ephedra gerardiana, E. intermedia and E. nebrodensis.

Q. 21. *In which member of Gymnosperms the polien chamber is situated deepest in nucellus ?*

In *Ephedra.*

Q. 22. *Ephedra seeds are mono- or dicotyledonous ?*

Dicotyledonous.

Q. 23. *Name three Indian botanists who have worked on Ephedra,*

R. Khan (1940,1943), P. Maheshwari (1935) and P.N.Mehra(1938,1947).

• 16.2. TAXONOMY

Q. 1. *What is taxonomy?*

The science of classification of organisms according to their resemblances and differences.

Q. 2. *What is morphology?*

It is the science of form or structure.

Q. 3. *Explain the major difference between a tap root and adventitious root?* A tap root is the main, primary root of a plant which shows apical dominance whereas an adventitious root is a root which grows from a tissue other than the pericycle or endodermis of an older root.

Q. 4. *What do you mean by velamen ?*

Velamen is the tissue of dead cells underneath the epidermis of aerial roots of some plants, *e.g.*, orchids. The velamen has the property of absorbing water.

Q. 5. *What does the word lignin' stand for?*

Lignin is a complex aromatic compound, deposited in the cellulose cell walls of the xylem and sclerenchyma during the process of secondary thickening. Wood is largely made of lignin.

Q. 6. *What is suberin ?*

Suberin is a mixture of substances formed from fatty acids which is found in cork cell walls. It prevents water from passing through the cork.

Q. 7. *Explain the difference between the adaxial and abaxial side of the leaf.*

Adaxial is the top side of the leaf which points towards the stem. On the other hand, abaxial is the underside of the leaf which points or faces away from the stem.

Q. 8. *"Phyllotaxy " stands for what ?*

The arrangement of leaves on a stem is called phyllotaxy. It may be of any of the three types : alternate, opposite and whorled.

Q. 9. *What do you mean by the word "succulent"?*

Succulents are the plants or parts of plants that are thick or fleshy, due to the presence of water-storing tissues, *e.g.*, members of Cactaceae.

Q. 10. *Coriaceous' is the term used for what?*

Leaves, which are thick, stiff and leathery, are called coriaceous.

Q. 11. *What are variegated leaves?*

The leaves with patches of different colours are called variegated.

Q. 12. *What is the meaning of phyllode?*

A flat petiole which has the appearance of a leaf.

Q. 13. *Auricle is the term used for what?*

Auricle is a small outgrowth at the side of the base of the leaf in some grasses.

Q. 14. *What is a tepal?*

A tepal is an organ of a perianth in which there is no difference between calyx and corolla.

Q. 15. *Explain the difference between actinomorphic and zygomorphic flowers?*

Actinomorphic flowers are symmetrical in all directions (radially symmetrical) when seen from above, *i.e.*, their each whorl consists of organs of the same size. Zygomorphic flowers are symmetrical only in one direction (bilaterally symmetrical).

Q. 16. *What is the difference between receptacle and torus?*

Receptacle is top of the stalk of a flower, bearing calyx, corolla, stamens and pistil. Torus is the another name given to the receptacle of a flower.

Q. 17. *What is a staminode?*

A sterile stamen which does not produce pollen is called staminode.

Q. 18. *Explain the meaning of sporopollenin.*

Sporopollenin is the material contained in the exine of the pollen grains of several plants. This material is resistant to decay, and thus provides long life for pollen grains.

Q. 19. *Explain entomophilly?*

Pollination by insects is called entomophilly.

Q. 20. *What do you mean by ornithophilly?*

Pollination by birds is called ornithophilly.

Q. 21. *What is a pollinium?*

Pollinium is a large group of pollen grains which are carried together at the time of pollination, as in Orchidaceae.

Q. 22. *Define a carpel.*

A carpel is the female reproductive unit of a flower, made up of ovary with ovules. Carpels are actually the sporophylls of angiosperms.

Q.23. *What is a pistil?*

Pistil is the female reproductive unit of a flower, made up of the ovary , style and stigma.

Q. 24. *Explain the difference between superior ovary and inferior ovary.*

In *superior ovary,* the ovary remains attached to the receptacle above the stamens, corolla and calyx, whereas in *inferior ovary,* the ovary is beneath the point of attachment of calyx, corolla and stamens of the flower.

Q. 25. *What is a placenta?*

It is the margin of a carpel where the ovules remain attached.

Q. 26. *Explain double-fertilization?*

Fusion of one male nucleus with egg nucleus to form zygote and of the other male nucleus with primary endosperm nucleus to form endosperm nucleus, as in angiosperms, is called double fertilization.

Q. 27. *What do you mean by cauliflory?*

A condition in which the flowers or inflorescences develop on the stem or trunk of the plant is called cauliflory.

Q.28. *What is silicula?*

It is a long dry fruit, developed from a bicarpellary ovary, as in Cruciferae.

Q. 29. *What for Carl Linnaeus is so famous?*

Carl Linnaeus (1707-1778) is famous for the discovery of the modern system of naming animals and plants. This system is called *binomial system of nomenclature.* He described all the plants, known to man at that time and published in his famous book, **Species Plantarum,** published in 1753.

Q. 30. *What do you mean by 'authority'?*

Authority is the name of the author who first gave the name to a species. In reference to species, the authority is given after the binomial.

Q. 31. *Define a herbarium?*

Herbarium is a collection of dried and pressed plant samples, used by taxonomists in the classification of plants.

Q. 32. *Explain the meaning of the* ***word 'taxon'.***

'Taxon' is a word used for any taxonomic group, sharing similar characteristics, *e.g.*, a species or a family.

Q. 33. *How will you define a 'species' and a 'genus'?*

A *species* is usually the smallest unit of classification. It includes the individuals which are alike and can breed with each other. A *genus* is a group of related species.

Q. 34. *What do you mean by monotypic?*

A genus with only one species, or a family with only one genus, is called monotypic.

Q. 35. *Explain the meaning of the word 'endemic'*

The taxa that are found only in one particular area or region are called endemic.

Q. 36. *Define the word 'liana'*

A woody perennial climber is called *liana.* Lianas occur commonly in tropical rain forests.

Q. 37. *Explain the meaning of ecotype.*

Ecotype is a set of individuals in a particular habitat that differ phenotypically from the representatives of the same species in other habitats.

Q. 38. *What is the type of fruit in Lady's finger and which of its parts is edible?*

Lady'sfinger (Bhindi) is a simple dry, dehiscent fruit and its entire fruit is edible.

Q.39. *What is the type of fruit in Litchi and which of its parts is edible?*

Litchi is a simple, dry indehiscent nut and its edible parts is fleshy aril.

Q. 40. *What is the type of fruit in mango and which of its part is edible?*

Mango is a simple fleshy drupe and its edible part is fleshy mesocarp.

Q. 41. *Which part of the coconut (Nariyal) is edible?*

Endosperm and endospermous milk.

Q. 42. *What do you mean by a hypotype?*

Any described specimen of a species is called hypotype

Q. 43. *Explain the meaning of the word holotype ?*

A single specimen upon which a species is based is called a holotype.

Q.44. *Who proposed the most convenient natural system of classification mainly suitable for practical purposes?*

George Bentham and Joseph Hooker.

Q. 45. *Bentham and Hooker described how many families and species of flowering plants?*

They described 202 families and 97205 species of the flowering plants.

Q.46. *Armen Takhtajan, the famous taxonomist. belongs to which country?*

Former U.S.S.R.

Q. 47. *What is the name of the book in which Bentham and Hooker described the classification of flowering plants?*

Genera Plantarum.

Q. 48. *Name any two major characters of Polypetalae.*

Petals are free, and flowers are with calyx and corolla.

Q.49. *What are two major characters of Monochlamydae ?*

Incomplete flowers, and either calyx or corolla or sometimes both are absent.

Q.50. *Name any two phylogenetic systems of classification of plants.*

(1) Engler and Prantl's system, and (2) Hutchinson's system.

• 16.3. EMBRYOLOGY

Q. 1. *What do you understand by embryology?*

A plant or an animal in early stages of development forms a zygote which is called *embryo*, and the study of embryo is called *embryology*.

Q. 2. *Name some well-known plant embryologists.*

G.L. Davis, P. Maheshwari, B. M. Johri, R.N. Kapil, Heslop, Harrison, Schnarf.

Q. 3. *What are the different types of pollen tetrad arrangements?*

Isobilateral tetrad, Decussate tetrad, T-shaped and Linear.

Q. 4. *Name some common types of ovules.*

Orthotropous, Anatropous, Hemitropous, Campylotropous and Circinotropous.

Q. 5. *What are different types of endosperms?*

Nuclear type, Cellular type and Helobial type.

Q. 6. *What is the structure of a Polygonum type of embryo-sac?*

Near the micropylar end is present an egg apparatus consisting of an egg and two synergids. Near the chalazal end are present three antipodals. In the centre are present two polar nuclei which fuse and form a secondary nucleus.

Q. 7. *What type of fruit is present in wheat?*

Caryopsis.

Q.8. *What is the structure of a wheat grain?*

Wheat.grain consists of an outer *husk*, the *aleurone layer* containing protein, the *endosperm* having starch, and the *embryo*.

Q. 9. *What is the coconut milk?*

Coconut milk is the endosperm of the seed.

Q. 10. *What is palynology?*

The science of studying pollen and spores is called *palynology*.

Q. 11. *Name an Indian palynologist.*

Dr. P.K.K.Nair.

• 16.4. ANATOMY

Q.1. *What do you mean by anatomy?*

Anatomy is the study of the way in which tissues and the organs remain arranged in organisms.

Q. 2. *What is a tissue?*

A group of cells of similar shape and same function is called a tissue.

Q. 3. *What is a casparian strip?*

Casparian strip is a band of suberin present around the endodermal cells.

Q. 4. *Explain the meaning of exodermis.*

Exodermis is the layer of cortical cells present on the outer surface of the cortex, below the epidermis. Suberin is present in the cell walls of exodermal cells.

Q. 5. *Define lenticel.*

Lenticel is a part on the outer surface of the stems of some plants. It allows the exchange of gases between the atmosphere and the stem.

Q. 6. *Differentiate between sclereid and stone cell.*

Sclereids are the groups of the cells found in the sclerenchyma of several plants with heavily lignified walls. An isodiametric sclereid is called a stone cell.

Q. 7. *How will you define lignin ?*

Lignin is a complex aromatic compound which remains deposited in the cell walls of sclerenchyma, xylem vessels and tracheids, making them all rigid and strong. It forms about 30% of the wood of the trees.

Q. 8. *What do you know about the heartwood?*

The dense and compact wood, present in the centre of a trunk or branch is called heartwood. It provides support to the tree.

Q. 9. *What is bark?*

Bark is the tissue present outside of woody stems and usually consists of dead cork cells and phloem.

Q.10. *How will you define suberin ?*

Suberin is a complex mixture of substances formed from fatty acids. It is present in the walls of the cork cells rendering them impervious to water.

Q.11. *What is cuticle?*

Cuticle is a superficial, non-cellular layer of cutin present on the surface of leaves and stems of plants.

Q. 12. *What is cutin?*

It is a complex mixture of oxidation and condensation products of fatty acids. Plant cuticle is composed of cutin.

Q. 13. *Explain the term apoplast.*

Apoplasts are the non-living parts of the plant, *i.e.*, intercellular spaces, xylem and cellulose cell walls.

Q. 14. *What do you know about symplast?*

Living parts of the plant, *i.e.*, all the cytoplasm-containing cells, are included under symplast.

Q. 15. *What is latex?*

Latex is a mixture of many substances including proteins, sugars, oils, alkaloids,-mineral salts, etc. Latex coagulates on exposure to the air.

Q. 16. *How will you define a stele?*

Stele is the vascular cylinder of a root or stem.

Q. 17. *Explain the meaning of vascular cylinder.*

Vascular cylinder is a tube of vascular tissues made up of xylem and phloem in stems or roots.

Q. 18. *What is a leaf trace?*

A leaf trace is the vascular tissue which branches off from the stem, at a node, into the leaf.

Q. 19. *What is xylem?*

Xylem is a tissue of the vascular cylinder of a plant, made up of vessels, tracheids, parenchyma and sclerenchyma.

Q.20. *How will you define a tracheid?*

Tracheid is a thin, long, dead cell in the xylem having lignified walls and closed ends.

Q.21. *What is phloem?*

Phloem is a living tissue of vascular system of plants, made up of seive elements and companion cells. It is a conducting tissue. Products of photosynthesis translocate from leaves to other plant parts through phloem.

Q. 22. *What is a sieve tube?*

It is a tissue in the phloem through which translocation of substances takes place. It is made up of sieve elements with sieve plates between them.

Q. 23. *Explain the meaning of vascular cambium.*

Vascular cambium is a meristematic region in the vascular system which produces phloem on the outer side and xylem on the inner side.

Q. 24. *Explain the meaning of morphogenesis.*

The development of shape and structure of organs and tissues is called morphogenesis.

Q. 25. *Define the term ontogeny.*

The developmental process of an individual from zygote to adult is called ontogeny.

Q. 26. *Differentiate between periclinal and anticlinal division.*

Under periclinal the division occurs parallel to the surface of the plant, whereas under anticlinal division the division occurs at right angles to the surface of the plant.

Q. 27. *Define the term plastochrone.*

The time between the formation of one primordium and the next is termed as plastochrone.

Q.28. *What is a bud?*

Bud is an undeveloped shoot enclosed by several protecting scales.

Q.29. *Name three important theories of cellular organization and zonation of meristematic tissues.*

Apical Cell Theory, Histogen Theory, and Tunica-Corpus Theory.

Q. 30. *What do you mean by root-stem transition ?*

Transformation of radial vascular bundles from root to collateral vascular bundles in stem through a zone of transition is called root-stem transition.

Q. 31. *What is meant by periderm ?*

Periderm is the tissue which forms the part of the bark. It consists of phelloderm, phellogen and phellem.

Q. 32. *What come within the limits of periderm ?* Phellem, phellogen and phelloderm.

Q. 33. *What is the other name of heart wood?* Autumn wood.

Q. 34. *Explain the terms 'meristem' and 'rib meristem'.* Meristem is the region of active cell division in plants, whereas in rib meristem columns of cells are formed lengthwise due to anticlinal divisions.

Q. 35. *Define mass meristem.*

Formation of bulk or mass of cells because of cell division in all planes results in 'mass meristem'.

Q. 36. *How will you define procambium?*

The progenitor of cambium, made up of ray initials and fusiform cells represents procambium.

Q. 37. *What is dermatogen?*

The outermost layer of the young growing apex, responsible for the formation of epidermis, is called dermatogen.

Q. 38. *Explain the meaning of raphide.*

Raphides are the needle-like crystals of calcium oxalate occuring in some xerophytes and hydrophytes.

Q. 39. *What is a cystolith?*

This by-product of protoplasm is a crystalloid, sessile or stalked structure of $CaCO_3$ which originates from the cellulose-impregnated epidermis of leaf, *e.g.*, Indian rubber plant.

Q. 40. *Differentiate between tunica and corpus.*

Tunica is represented by the outer layers of cells in the apical meristem whereas corpus is represented by the inner layers of cells in the apical meristems of angiosperms. Tunica cells divide periclinally whereas corpus cells divide only anticlinally.

Q. 41. *How do the vascular bundles remain arranged in monocots and dicots?*

Vascular bundles are irregularly arranged in monocots while in one or more rings in dicots.

Q. 42. *What is the position of protoxylem in roots and stems?*

Protoxylem is endarch in stems while it is exarch in roots.

Q. 43. *Give some points of differentiation between dicot stem and monocot stem.*

In dicot stems, vascular bundles remain arranged in ring, cambium is present, phloem parenchyma is present and pith is well-developed. On the other hand, in monocot stems, the vascular bundles remain scattered in the ground tissue irregularly, cambium is absent, phloem parenchyma is absent, and pith is feebly-developed.

Q.44. *What is the condition of protoxylem in dicot and monocot roots?*

In dicot roots the protoxylem groups are two to six showing diarch to hexarch condition whereas in monocot roots the protoxylem groups are more than six, *i.e.*, polyarch.

Q. 45. *How will you differentiate between the vascular bundle of a stem with that of a root?*

In stem the vascular bundles are conjoint, *i.e.*, both xylem and phloem lie one above the other, whereas in root the vascular bundles are radial, *i.e.*, both xylem and phloem lie on different radii.

Q. 46. *How will you differentiate between a dicot and a monocot leaf?*

Dicot leaves are dorsiventral whereas monocot leaves are isobilateral.

Q. 47. *What is the condition of mesophyll in dicot leaves and monocot leaves?*

Mesophyll remains differentiated into palisade and spongy parenchyma in dicot leaves, whereas in monocot leaves the mesophyll remains undifferentiated.

Q. 48. *How will you differentiate between the hair of a dicot stem and dicot root?* Hair of a dicot stem are multicellular while these of a dicot root are unicellular.

Q. 49. *Differentiate between the vascular bundles of a dicot stem and a dicot root.* Vascular bundles of a dicot stem are conjoint, collateral, open and endarch, while those of a dicot root are radial and exarch,

Q.50. *What is callus?*

Callus is the tissue of a carbohydrate polymer produced on injured plant surfaces.

Q. 51. *What is the difference between cutin and chitin ?* Cutin is the waxy material secreted by the exposed epidermal cells of the plants while chitin is the nitrogen-containing polysaccharide that forms the cell walls of many fungi.

Q. 52. *Define a trichome?*

A trichome is an epidermal appendage of different shape, size and structure.

Q.53. *How will you differentiate between chlorenchyma and collenchyma?* Chlorenchyma are chlorophyll-containing parenchymatous cells while the collenchyma is the supporting plant tissue consisting of living cells whose walls are thickened (Fig. 1) on the corners.

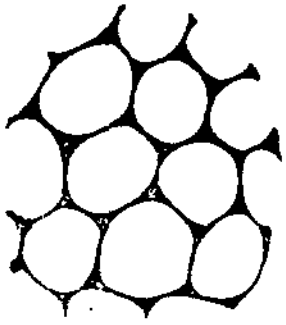

Fig. 1. Collenchyma in T.S.

Q. 54. *What is parenchyma?*

Parenchyma is a plant tissue made up of thin-walled cells (Fig. 2) which are often loosely packed. It's function is either in photosynthesis or in storage of food.

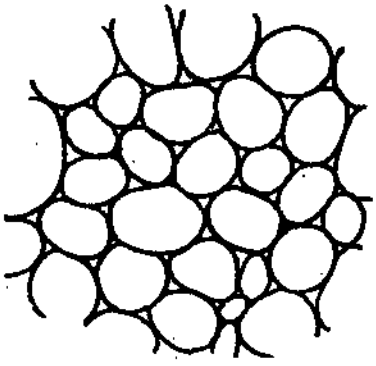

Fig. 2. Parenchyma

Q. 55. *How will you define sclerenchyma?*

Sclerenchyma is the supporting plant tissue consisting of cells whose walls are uniformly thickened and generally lignified e.g., sclereids, fibres etc.

Q. 56. *What is the difference between sclereid and fibre?*

A sclereid is a sclerenchyma cell of variable shape with thick and lignified walls (Fig. 3). They are not elongated. A fibre is a tapering elongated sclerenchyma.

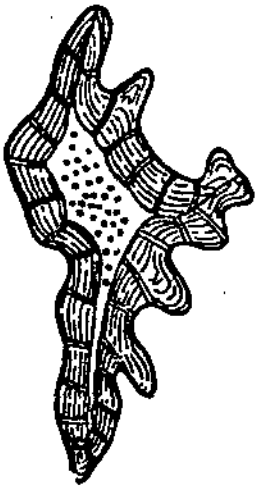

Fig. 3. A sclereid

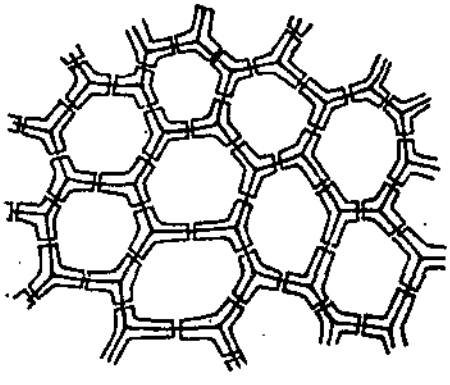

Fig. 4. Fibres in T.S.

Q.57. *What is a companion cell?*

It is a special type of parenchyma cell which remains in association with sieve tube in phloem.

Q. 58. *How will you differentiate between interxylary and intraxylary phloem ?*

Interxylary (included) phloem is the secondary phloem embedded in the secondary xylem while the intraxylary (internal) phloem is the primary phloem situated inner to the primary xylem-

Q. 59. *How will you differentiate between a tracheid and a vessel?*

Vessels are tube-like structures, the common walls of which are perforated while tracheids are the xylem tracheary elements which do not have the perforated cross walls.

Q. 60. *What is the difference between a simple pit and a bordered pit?*

In simple pit the cavity becomes wider while in case of the bordered pit the pit membrane is overarched by the secondary wall which forms the border.

Q. 61. *What are the thickenings of vessles?*

Annular, spiral, scalariform and reticulate.

Q. 62. *How will you differentiate between endarch, exarch and mesarch conditions?*

When the protoxylem elements face towards the centre of the axis it is called endarch *(e.g.,* in stems) but when they face towards the outer side *i. e.* away from the centre, it is called exarch *(e.g.,* in roots). Sometimes the protoxylem elements are present in the centre and this condition is known as mesarch.

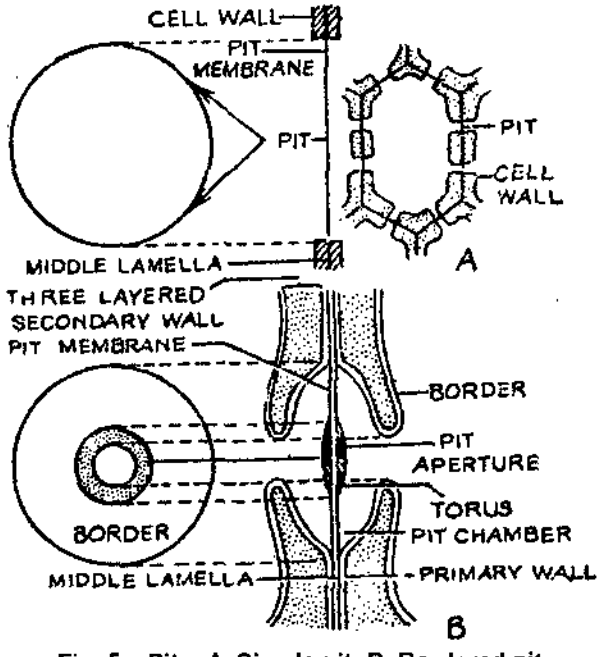

Fig. 5. Pits: A, Simple pit; B, Bordered pit

Q. 63. *How will you differentiate between the conditions diarch, triarch and polyarch?*

In case of root when primary xylem contains two, three or many protoxylem poles the condition is known as diarch, triarch or polyarch, respectively.

Q. 64. *What do you understand by the open and closed vascular bundles?*

Vascular bundles having cambium in between xylem and phloem are called *open,* as in dicotyledons. When cambium is absent the vascular bundles are called closed *e.g.,* monocotyledons.

Q. 65. *What is a radial vascular bundle?*

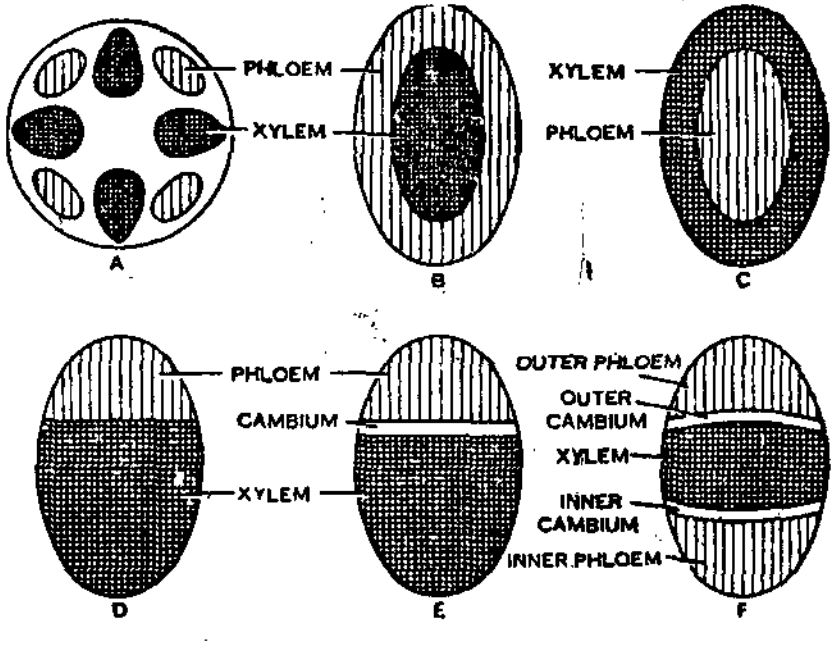

Fig. 6. Types of vascular bundles. A, Radial; B, Concentric-amphicribal; C, Concentric amphivasal; D. Conjoint, collateral and closed; E, Conjoint, collateral and open F, Conjoint, bicollateral and open.

In case of *roots* when xylem and phloem are present in different groups and on different radii alternating with each other, it is called radial vascular bundle (Fig. 6A).

Q. 66. *What do you understand by concentric type of vascular bundles?*
Concentric vascular bundles (Fig. 6) are of two types *i.e. amphicribal* and *amphivasal.* In case of the former the xylem remains surrounded by the phloem (Fig. 6B) but in case of the latter, *i.e.* amphivasal, the phloem remains surrounded by the xylem (Fig. 6C).

Q. 67. *What do you mean by conjoint?*
When xylem and phloem lie one above the other in the vascular bundle, it is called conjoint (Fig. 6D.E).

Q.68. *Differentiate between collateral and bicollateral vascular bundles.*
In a conjoint vascular bundle when phloem is present only on one side it is called collateral (Fig. 6E) but when phloem is situated on both the outer and inner sides it is called bicollateral (Fig. 6F).

Q. 69. *Mention a few differences between monocots end dicots.*
Presence of one cotyledon, parallel venation, di-to tri-merous flowers and many irregularly arranged vascular bundles are the characters of monocots. But in dicots two cotyledons are present, venation is reticulate, flowers are pentamerous and the vascular bundles are arranged in rings.

Q. 70. *What is the basic anatomical difference between stem and root?*
Protoxylem is endarch in stems and exarch in roots.

Q. 71. *Give two differences between a dicot leaf and a monocot leaf.*
Dicot leaf is dorsiventral and its mesophyll is differentiated into palisade and spongy parenchyma while the monocot leaf is isobilateral and its mesophyll is undifferentiated.

Q. 72. *Give an anatomical difference between a dicot root and monocot root.*
Dicot root is diarch to hexarch while monocot root is polyarch.

Q. 73. *What is the characteristic feature of an old Dracaena stem?*
Stem exhibits secondary growth.

Q. 74. *Mention one of the distinguishing points of a Luffa stem.*
Presence of open bicollateral vascular bundles.

Q. 75. *How does the anamolous secondary growth take place in Bougainvillea?*
By the formation of the successive rings of collateral vascular bundles.

Q. 76. *What is the abnormality in Bougainvillea stem ?*
Presence of interxylary phloem and medullary bundles.

Q.77. *Give a characteristic feature of Boerhaavia stem?*
Vascular bundles are arranged in three rings.

Q. 78. *How will you identify a Nyctanthes stem ?*
Four cortical bundles are present in the cortex situated one each in each protruded bulge.

Q. 79. Give a *point of identification of Bignonia stem.*
Presence of four phloem wedges.

Q. 80. *Name a characteristic point of the epidermis of a grass leaf.*
Presence of motor cells or bulliform cells.

Q. 81. *What is a phylloclade?*
A phylloclade is a modified stem which appears and functions like a leaf *e.g. Ruscus.*

Q. 82. *What is a phyllode?*
In phyllode the lamina of the leaf is reduced and from the remaining part, *i.e.* petiole, a flat leaf-like photosynthetic organ develops. So, it is a modification of petiole *e.g. Acacia moniliformis.*