Uttar Pradesh Rajarshi Tandon Open University

Bachelor of Science

UGBY-104

Plant Diversity – II

Gymnosperms and Angiosperms

Course Introduction

The term spermatophyta is derived from two Greek words i.e. Sperma = seed and phyton = plants i.e. including all seed bearing plants. **Gymnosperms** and **Anagisperms** are two subdivisions of division spermatophyta. The term ‘Gymnosperm’ is also coined by two Greek words i.e. Gymnos = naked and sperms i.e. naked seeded plants. These plants are also referred as ‘Phenerogams without overy’. Angiosperms are vascular seed plants in which the ovule is fertilized and develop into a seed in an enclosed hollow overy. The overy develops into fruit. The gymnosperms and anagiosperms both are seed bearing plants with a few similarities. This is due to the fact that gymnosperms were present for at least 200 million years before the angiosperms evolved and they may have shared a common ancestor. The main different between **Angiosperms** and **Gymnosperms** is their diversity. The diversity of **Angiosperm** is greater than the **Gymnosperms.** The higher diversity indicated the **Angiosperms** adapted to wide plethora of terrestrial ecosystem.

This is a 2 credit course divided into following 3 blocks:

Block-I **Gymnosperms** has 3 units in which you will study introduction of Gynmosperms, morphology, anatomy and life cycle of two genus *Cycas* and *Pinus.*

Block-II **Plant Anatomy** has 3 units which contains tissue system, structure of root and stem as well as anomalous secondary growth in some dicot and monocot stem.

Block-III **Plant Taxonomy** has 2 units in which you will study classification of angiosperm, characteristic features of some important families of dicots and monocots.

Block-I

Gymnosperms

The Gymnosperms also known as Acrogymnospermae are a group of seed producing plant that consists of four main phyla. The Coniferophyta, Cycadophyta, Gingkophyta and Gnetophyta. Confiers are the dominant plant of the gymnosperms having needle like leaves and living in areas where the weather is cold and dry. This block is divided into 3 units I, II and III

Unit I – **Introduction of Gymnosperms** tell you about characteristics, classification and economic importance of Gymnosperms.

Unit II – ***Cycas*** give you information about structure and life cycle of *Cycas* plant.

Unit III- ***Pinus*** tell you about structure and life cycle *Pinus* plant.

Objectives:

After studying this block you will be able to:

- Know about information of Gymnosperms.
- Be acquainted about the life cycle of *Cycas* and *Pinus.*

UNIT 1
INTRODUCTION OF GYMNOSPERMS

Structure:

1.1 Introduction

Objectives

1.2 Characteristics

1.3 Classification of Gymnosperms

1.4 Economic Importance of Gymnosperms

1.5 Summary

1.6 Terminal Questions

1.7 Answers

1.1 INTRODUCTION

Gymnosperms and ***Angiosperms*** are two sub-divisions of division Spermatophyta. The term 'Spermatophyta' is derived from two Greek words i.e. Sperma= seed and phyton= plants i.e. including all seed bearing plants. The term 'Gymnosperm' is also coined by two Greek words i.e. Gymnos=naked and sperms i.e. naked seeded plants and it was first used by ***Theophrastus.*** These plants are also referred as '***Phenerogams without ovary***'.

Gymnosperms may be defined as 'Seed bearing plants with naked ovules'. Since ovary is absent so that ovules and seeds remain naked not inside ovary as found in Angiosperms. Therefore pollens are found to germinate on the surface of the ovules. These plants lack vessel in xylem except in Gnetales, and absence of double fertilization also differentiates them from Angiosperms.

According to fossil records Gymnosperms were found originated in Palaeozoic era and flourished as a dominant flora during Jurassic and Cretaceous periods of Mesozoic era of geological time scale on earth, therefore considered as most ancient group of seed plants. The existence of Angiosperms came later and might have been evolved by Gymnosperms.

SAQ.1:

a. The gymnosperms are known as naked seeded plants because ....is absent.

b. Among Gymnosperms vessels are present only in the members of ....

c. Gymnosperms were evolved during ....era and well flourished during ....and........periods of..........era.

Objectives

After studying this unit you will be able to know :

.The Characteristics of gymnosperms.

.Classification of gymnosperms.

.The economic importance of gymnosperms.

1.2 CHARACTERISTICS

As stated earlier that gymnosperms are most primitive seed plants. The characteristic features are as follows:

- Mature plants are **tall, woody** and **perennials** may be trees or shrubs.
- The main plant body is **sporophytic** and differentiated into root, stem and leaves having xerophytic characters.
- **Roots** bear tap root system with **exarch** and **di** or **polyarch** stele.
- **Stem** is usually **branched** except in *Cycas* where it is unbranched.
- **Leaves** are of two types: small microphyllous **scale leaves** and large megaphyllous **foliage leaves**.
- The arrangement of leaves are **acropetal** and **spiral** except in Cupressaceae and Gentales it is cyclic.
- The reproductive organs are usually arranged in cone or strobilus as **male and female cone**. Female cone is absent in *Cycas* where ovules are arranged in megasporophylls.
- **Vascular bundles** in stem are arranged in **ring** and are **conjoint, collateral, open** and **endarch.**
- The **secondary growth** is distinct developing **annual rings** in secondary wood which facilitate in calculating the age of plants.

- **Xylem** is composed of **xylem parenchyma** and **xylem tracheids** with **bordered pits.** Xylem vessels are absent in Gymnosperms except in Gnetales.
- **Phloem** is composed of **sieve tubes** and **phloem parenchyma**. Companion cells are not found.
- **Secondary growth** in stem is of two types: **Manoxylic** (Scanty secondary growth with large pith and cortex) e.g. *Cycas* and **Pycnoxylic** (large secondary growth with scanty pith and cortex) e.g. *Pinus.*
- Plants may be **unisexual** (dioecious e.g. *Cycas*) or **bisexual** (monoecious e.g. *Pinus*). **Cones** are monosporangiate or unisexual mostly sometimes bisporangiate or bisexual.
- Heterospory shows two types of spores: **Microspores** or pollen grains and **Megaspores**.
- **Male Cone** bear microspores (pollen grains) inside microsporangia (pollen sac), which is present in the axis of spirally, arranged microsporophylls. Microsporangia are present on abaxial side (lower side) of microsporophylls which are arranged compactly to form cone.
- Development of sporangium is **Eusporangiate type** i.e. multilayered sporangium wall and tapetum is formed by sporogenous cells.
- The **most ancient seed plants** with rich fossil records. The orders like Cycadofilicales, Cordaitales, Benettitales or Cycadeoidales are exclusively fossils. The orders Cycadales, Coniferales, Ginkgoales have both fossils and living forms. Whereas Gnetales considered as advanced Gymnosperm and showing affinities with Angiosperms.
- The male gametophyte develops one or two prothallial cells.
- Female cone bears number of spirally arranged megasporophylls around the central axis. Female cone is absent in *Cycas* where each megasporophyll bear ovules.
- Ovules are naked and unitegmic generally but sometimes bitegmic e.g. *Ephedra.*
- Archegonia are developed from female gametophyte except in *Gnetum* and *Welwitschia.* Neck canal cells absent in neck of archegonia.
- Direct pollination i.e. pollen grains directly come in contact with the ovule.
- Development of embryo is **meroblastic** type i.e. only lower part of the oospore is involved in development.
- Sometimes **polyembryony** (more than one embryo in an ovule) is reported e.g. *Pinus.*

- After fertilization embryo develops into seed and integument of ovule becomes as seed coat. True fruit is absent due to the absence of ovary.
- The life cycle shows alternation of generation. The sporophytic phase is dominant, long lived and gametophytic phase is short lived and dependent on sporophytic phase.
- The seed represent three phases:
    a. Integument and nucellus – Sporophytic
    b. Endosperm- Gametophytic
    c. Embryo- Sporophytic (post fertilization)

SAQ.2:

a. The xylem vessels are absent in gymnosperms except in the members of.........

b. In ....the ovule is surrounded by two integuments.

c. More than one embryo is found inside the single ovule in...........

1.3 CLASSIFICATION OF GYMNOSPERMS

There are various groups of scientists to classify the Gymnosperms in distinct ways. Earlier Gymnosperms were not ranked separately. There are different types of classification proposed on the basis of various characteristics. Here some important classifications are listed below.

Robert Brown (1827) separated gymnosperms from angiosperms and placed as a distinct group due to the presence of naked ovules.

Bentham and Hooker (1883) placed gymnosperms as a group in between Dicotyledons and Monocotyledons of Angiosperms and divided this group into 3 natural orders: 1. Gnetaceae 2. Coniferae 3. Cycadaceae

Eichler (1883) divided Phenerogamae (seed plants) into Gymnospermae and Angiospermae , followed Bentham and Hooker's classification. Further gymnospermae divided into 4 families: 1. Cycadaceae 2. Cordaitaceae 3. Coniferae 4. Gnetaceae

Coulter and **Chamberlain (1917)** classified gymnosperms into 7 orders: 1. Cycadofilicales 2. Bennettitales 3. Cycadales 4. Cordaitales 5. Coniferales 6. Ginkgoales 7. Gnetales

Seward (1919) divided gymnosperms on the basis of types of wood, into two groups:

1. Manoxylic with orders: i. Cycadales ii. Cycadeoidales iii. Cycadofilicales
2. Pycnoxylic includes orders: i. Cordaitales ii. Ginkgoales iii. Coniferales iv. Gnetales

Prof. Birbal Sahni (1928) an Indian Palaeobotanist, divided gymnosperms into two groups:

1. Phyllosperms (plants bearing seeds on leaf i.e. megasporopylls) with 3 orders: i. Cycadofilicales ii. Bennettitales iii. Cycadales
2. Stachyosperms (plants bearing seeds on stem) includes 4 orders: i. Ginkgoales ii. Cordaitales iii. Coniferales iv. Taxales

He did not consider Gnetales in his classification.

Tippo (1942) divided gymnospermae into 2 subclasses:

1. Cycadophytae includes 3 orders: i. Cycadofilicales ii. Cycadales iii. Bennettitales
2. Coniferophytae having 4 orders: i. Ginkgoales ii. Cordaitales iii. Coniferales iv. Gnetales

Arnold (1948) kept Gymnosperms under subphylum-Pteropsida and divided it into 4 divisions: i. Cycadophyta ii. Ginkgophyta iii. Coniferophyta iv. Chlamydospermophyta

Prof. D.D.Pant (1957) modified Arnold's classification and proposed a new system of classification having 3 divisions, 9 classes and 11 orders as follows:

Division I: *Cycadophyta*

(Unbranched or ill branched stem, manoxylic wood and large pinnately compound leaves)

Class 1. Pteridospermopsida

Order:

i. Lyginopteridales *(e.g. Lyginopteris)*
ii. Medullosales *(e.g.Medullosa)*
iii. Glossopteridales (*e.g. Glossopteris*)
iv. Peltaspermales *(e.g. Lepidopteris)*
v. Corystospermales *(e.g. Pachypteris)*
vi. Caytoniales *(e.g.Caytonia)*

Class 2. Cycadopsida

Order:

vii. Cycadales *(e.g. Cycas)*

Class 3. Pentoxylopsida

Order:

viii. Pentoxylales (e.g.Pentoxylon)

Class 4. Cycadeoideopsida (Bennettitopsida)

Order:

ix. Cycadeoidales (Bennettitopsida) *(e.g. Cycadeoidea)*

Division II: *Chlamydospermophyta*

(Angiosperms like)

Class 1.Gnetopsida

Order:

i. Gnetales *(e.g. Gnetum)*

ii. *Welwitschiales (e.g.Welwitschia)*

Division III: Coniferophyta

(large tree with profusely branched stem, leaves simple, pycnoxylic wood)

Class 1.Coniferopsida

Order:

i. Cordaitales *(e.g. Cordaites)*

ii. *Coniferales (e.g.Pinus)*

iii. *Ginkgoales (e.g.Ginkgo)*

Class 2.Ephedropsida

Order:

iv. *Ephedrales (e.g.Ephedra)*

Class 3.Czekanowskiopsida

Order:

v. *Czekanowskiales (e.g. Czekanowskia)*

Class 4.Taxopsida

Order:

vi. *Taxales (e.g.Taxus)*

This system of classification was much appreciated, popular and widely accepted as compared to the other system of classifications proposed by various scientists. Some salient features of Pant's classification are as follows;

1. There are 3 divisions: Cycadophyta, Chlamydospermophyta and Coniferophyta.
2. The suffix of classes and orders has been according to the International code of Botanical Nomenclature such as –opsida and –ales respectively.
3. The Peltospermales, Caytoniales, Corystospermales and Glossopteridales have been ranked as distinct orders under class Pteridospermosida.
4. The order Ephedrales has been removed from division Chlamydospermophyta and placed as class Ephedropsida of the division Coniferophyta.
5. A new class Czekanowskiopsida with an order Czekanowskiales has been created and genus *Czekanowskia* and its allies have been placed under this.
6. Division Chlamydospermophyta includes order Gnetales and Welwitschiales placed in between Cycadophyta and Coniferophyta due

to the resemblance with Cycadeoideopsida in relation to presence of syndetochelic stomata.

7. The order Pentoxylales included under class Pentoxylopsida placed between classes Cycadeoidopsida and Cycadophyta
8. ***Demerit of classification:*** The imperfectly known fossil Vojnovskyales (having bisexual cones arising from clusters of leaves) has not considered in this classification.

SAQ.3:

a. .... and .... placed gymnosperms as a group in between Dicotyledons and Monocotyledons of Angiosperms

b. Prof. Birbal Sahni (1928) an Indian Palaeobotanist, divided gymnosperms into two groups:............and............

c. The classification of Gymnosperms proposed by..........in .... has widely accepted.

1.4 ECONOMIC IMPORTANCE OF GYMNOSPERMS

The gymnosperms are small group of plants. It represents the most primitive type of seed plants, having great economic value. These plants serve various purposes to the human beings such as ornamentals, food, medicines etc. on one hand as well as production of essential oils, resins, fatty oils, fibres, papers, packaging materials etc. on the other hand. Some of their importance is focussed below:

1. **As Ornamentals:** Gymnosperms are naturally very exquisite. These plants bear beautiful leaves or foliage which have strong and leathery texture as well as they remain green for longer duration after detachment from the plants. Therefore these plants, such as *Cycas, Pinus, Cedrus, Araucaria, Agathis, Juniperus, Thuja, Ephedra* etc. are widely used as ornamentals and grown in parks, gardens, homes, offices and other public places. The leaves of these plants are also used in bouquet, wreath and other ceremonial places. The beautiful leaves of *Ginkgo biloba* (Maiden Hair tree) have ethical values and cultivated in the temples of China and Japan. Usually gymnosperms grow slowly, therefore costs high e.g. *Araucaria*, *Cryptomeria* etc. hence also enhances economy.
2. **As Food:** The fruit of some gymnosperms are nutritious and edible. Various other edible products are also obtained from these plants such as **'Arrowroat'** from *Zamia,* **'Sago'** from *Cycas* i.e. Sago palms. **'Chilgoza'** used as a dry fruit is the seeds of *Pinus geradiana* with high

nutritious values. The young and succulent leaves of *Cycas* are roasted and eaten by men. The cooked fruits of *Cycas rumphii* is eaten by the tribes of Andaman and Nicobar. In Africa several species of Encephalartos is used to prepare **'kaffir'** bread since these plants are rich in starch, commonly referred as **'Bread palms'**. The young leaves and inflorescence of *Gnetum* is used as vegetable and their roasted and cooked seeds are also eaten by some people. The seed kernels are smashed, dried and moulded to prepare biscuits and cakes. The edible oil is also extracted from *Gnetum ula.* The seeds of *Ginkgo biloba* are nutritious and usually eaten by Chinese and Japanese.

3. **Industrial Uses:** Different plant parts of the gymnosperms are also used for other aspects such as to obtain wood, medicines, fibres, oil, resins and in paper industry etc.

   a. **Timber or wood:** Woods of gymnosperms are used for various purposes according to their quality. The pycnoxylic coniferous wood obtained from *Pinus, Abies, Cedrus, Sequoia, Taxus, Podocarpus* etc. have different types of wood. The wood of *Pinus* , *Agathis sp., Cryptomeria japonica* etc. are light wood and generally used in making railway sleepers, packaging materials like boxes, furniture and match sticks, boat , transmission poles etc. the wood of *Juniperus* is used in making pencils, scales, holders etc. the wood of Biota is soft brittle and durable used as telegraph and building boats. The wood of *Podocarpus* and *Pseudotsuga taxifolia* are generally used in making plywood, tanks, arches etc. *Taxus* wood is most durable and used for decorative purposes for poles and in making bows.

   b. **Medicine:** Most of these plants are poisonous and have great medicinal values. Few of them are specified here as follows:

   Taxus buccata – The entire plant is used as fish poison and leaves are used in asthma, bronchitis, cough, epilepsy and for indigestion. The seeds are also used as sedative.

   Thuja- A chief homeopathy drug is extracted from it named as Thuja. It is used in intermittent fever, cough, scurvy and rheumatism. A volatile oil extracted from its leaves often used as vermifuge.

   Juniperous- The oil obtained from it has medicinal importance.

   Gnetum ula- The oil obtained is used as massage oil in rheumatic pains.

Cycas- Fresh leaves of *C. circinalis* juice is beneficial in stomach disorders, blood vomiting and certain skin diseases. Gums obtained from *C. rumphii* plants found effective against malignant tumours. Pollen grains of some species reported as narcotic. Crushed seeds, megasporophyll and barks mixed with coconut oil used as ointment for sores and wounds.

Ephedra- An important drug Ephidrine is obtained from these plants used to cure cough, bronchitis, asthma, pneumonia, diphtheria, mild, heart attacks, nasal and ear disorders, and hay fever etc.. It has tonic, diaphoretic, antipyretic, cardiac and circulatory stimulant properties.

Pinus gerardiana-The oil is found helpful in dressing wounds and ulcers.

c. Oils-The seeds of some species of gymnosperms are used as the good source of fatty and essential oils e.g. *Macrozamia, Gnetum ula, Juniperus, Cephalotaxus drupacea, Pinus cembra etc.* These are used for various purposes such as in cooking, medicine, room spray, perfume or deodorant etc. A well known essential oil 'Hemlock' is extracted from *Tsuga canadensis* used as deodorant. The turpentine oil is hugely used in paint and varnish industry is chiefly isolated from different species of *Pinus* such as P. *roxburghii, P.wallichiana, P.insularis* and *P.merkusii.*

d. **Fibres:** The fibres obtained from some gymnosperms are strong, durable and tensile, used in making ropes, cloth, twines, net etc. such as *Gnetum patifolius, G.gnemon, Cycas revoluta.* The ramantal hairs removed from leaf bases of *Cycas rumphii, Macrozamia* etc. are used for stuffing pillows.

e. **Paper:** Fibres of *Gnetum gnemon* is used in manufacturing paper. *Pinus roxburgii, Abies pindraw, Cryptomeria japonica* etc. are used to obtain the paper pulp by crushing and bleaching of their wood. The good quality paper is made by using wood pulp of *Abies balsemea*, species of *Picea* and *Tusga.*

f. Resins: These are plant exudates chiefly from conifers. Resins are usually composed of esters, acids and essential oils. It is generally used in soap and paper industries, also used as grease and water proofing agents. Resins are obtained by distillation and used for various purposes few of them are listed here. The species of *Pinus* yields many resins oils and turpentine as mentioned earlier used in preparations of varnish, enamel, paint, ointment etc. *P. marittima* is good source of **'Boradeaux terpentine'**. The fossilized resin obtained as **'Amber'** used for ornamental and carving purposed, secreted by extinct species of *Pinus* i.e. *P. succinifera.* 'Manila copal' a varnish resin obtained from *Agathis alba*, used in preparation of varnish, plastics, polishes, linoleum etc. **'Canada balsam'**, a turpentine used as mounting medium in biological laboratories isolated from *Abies balsamea.*

4. **Other uses:**
    - ***a.*** **Domestic uses:** The leaves of *Cycas rumphii* are used in making and making baskets, brooms, thatching huts. Indonesians use stems of the plant in making small houses too.
    - ***b.*** **As fuel:** The woods of *Pinus* sp. are used as fuel since it contains resins. Wood gas, wood tar and wood alcohol are also obtained by the species of *Pinus* .The rhizomes of *Ephedra gerardiana* also used as fuel in Tibet.
    - ***c.*** **As Gum:** Gum is obtained by *Cycas circinalis.*
    - ***d.*** **Ethics:** The plant of *Ginkgo biloba* has ethical and religious value and worshipped in Chiana. The species of *Juniperous* are usually burnt incense in the temples.

SAQ: 4

- ***a.*** Chilgoza used as a dry fruit is the seeds of ....with high nutritious values.
- ***b.*** 'Canada balsam', a mounting medium used in biological laboratories is isolated from ....
- ***c.*** An important drug ....is obtained from *Ephedra.*

1.5 SUMMARY

- Gymnosperms are Spermatophytes or Phenerogams without ovary, a group of naked seeded plants.
- These plants might evolve during Palaeozoic era and flourished well during Jurassic and Cretaceous of Mesozoic era.
- These plants were considered to be most ancient seed plants.
- The main plant body is sporophytic, tall, and woody perennials may be trees or shrubs.
- Roots bear tap root system with exarch and di or polyarch stele.

- Stem is usually branched except in *Cycas* where it is unbranched.
- Leaves are two types: small microphyllous scale leaves and large megaphyllous foliage leaves.
- The reproductive organs are usually arranged in cone or strobilus as male and female cone. Female cone is absent in *Cycas* where ovules are arranged in megasporophylls.
- Vascular bundles in stem are arranged in ring and are conjoint, collateral, open and endarch.
- Secondary growth in stem is two types: Manoxylic and Pycnoxylic
- Vessels are absent in xylem except in the members of Gnetales.
- Phloem is composed of sieve tubes and phloem parenchyma. Companion cells are not found.
- Plants may be unisexual (dioecious e.g. *Cycas*) or bisexual (monoecious e.g. *Pinus*). Cones are monosporangiate or unisexual mostly sometimes bisporangiate or bisexual.
- Male Cone bear microspores (pollen grains) inside microsporangia which is present on abaxial side (lower side) of microsporophylls and arranged compactly to form cone.
- Development of sporangia is Eusporangiate type.
- The male gametophyte develops one or two prothallial cells.
- Ovules are naked and unitegmic generally but sometimes bitegmic.
- Development of embryo is meroblastic type.
- Sometimes polyembryony is reported e.g. *Pinus.*
- After fertilization embryo develops into seed and integument of ovule becomes as seed coat. True fruit is absent due to the absence of ovary.
- The seed represent three phases: Integument and nucellus – Sporophytic, Endosperm- Gametophytic, Embryo- Sporophytic (post fertilization)
- These plants serve various purposes to the human beings and have a great economic value such as ornamentals, food, medicines etc.
- These plants are also used in production of essential oils, resins, fatty oils, fibres, papers, packaging materials etc.

1.6 TERMINAL QUESTIONS

OBJECTIVE TYPE QUESTIONS:

Q.1. Among Gymnosperms xylem vessels are present only in the members of ..

a. Cycadales b. Coniferales

c. Pentoxylales d. Gnetales

Q.2. The Gymnosperms are known as naked seeded plants because they lack..

a. Ovule b. Integument

c. Ovary d. Cell-wall

Q.3. The term 'Gymnosperm' was first used by....

a. Prof. Birbal Sahni b. Prof. D. D. Pant

c. Theophrastus d. Linneaus

Q.4. The ovule is surrounded by two integuments in.....

a. *Cycas* b. *Thuja*

c. *Pinus* d. *Ephedra*

Q.5. In *Pinus* more than one embryo developed inside the single ovule is known as.......

a. Polyembryony b. Multiembryony

c. Nulliembryony d. Synembryony

Q.6. Chilgoza used as a dry fruit is the seeds of ....with high nutritious values.

a. *Pinus geradiana* b. *Abies balsamea*

c. *Zamia* d. *Cycas revoluta*

Q.7. An important drug ....is obtained from *Ephedra.*

a. Aconite b. Ephedrol

c. Ephidrine d. Belladona

Q.8.Canada balsam', a mounting medium used in biological laboratories isolated from.

a. *Ginkgo biloba* b. *Abies balsamea*

c. *Gnetum ula* d. *Cycas circinnalis*

Q. 9. *Cycas* is also known as

a. China Palm b. Indian Palm

c. Sago Palm d. Palm tree

Q.10. Pycnoxylic wood is found in ..

a. *Pinus* b. *Cycas*

c. All Gymnosperms d. *Cycas* and *Pinus* both

SHORT ANSWER TYPE QUESTIONS:

Q.1. Write down the characteristic features of Gymnosperms.

Q.2. How will you distinguish manoxylic and pycnoxylic wood?

Q.3. Describe the medicinal value of Gymnospermous plants by giving suitable examples.

Q.4 Give an out-line of the gymnosperm's classification proposed by Prof. D.D. Pant.

LONG ANSWER TYPE QUESTIONS:

Q.1. Write about the economic importance of Gymnosperms.

Q.2. Comment upon the various significant system of classification of Gymnosperms.
Q.3. What is the economic importance of gymnosperms?

1.7 ANSWERS

Objective type questions:
1.d 2.c 3.c 4.d 5.a 6.a 7.c 8.b 9.c 10.a

SAQ.1:
a. Ovary ***b.*** Gnetales ***c.*** Palaeozoic, Jurassic, Cretaceous, Mesozoic

SAQ.2:
a. Gnetales ***b.*** *Ephedra* ***c.*** *Pinus*

SAQ.3:
a. Bentham, Hooker ***b.*** Phyllosperms , Stachyosperms ***c.*** Prof. D. D. Pant, 1957

SAQ: 4
a. *Pinus geradiana* ***b.*** *Abies balsamea* ***c***. Ephidrine

UNIT 2: *CYCAS*

2.1 Introduction

Objectives
2.2 External Characteristics
2.1.1 Habit: Root
Stem
Leaf
2.3 Internal Characteristics
2.3.1 Normal Root
2.3.2 Coralloid Root
2.3.3 Stem
2.3.4 Rachis
2.3.5 Leaflet
2.4 Life Cycle
Reproduction
2.4.1 Vegetative reproduction
2.4.2 Sexual Reproduction
2.4.2.1 Male Cone or Strobilus
2.4.2.2 Development of microspores
2.4.2.3. Megasporophylls
2.4.2.4. The ovule
2.4.2.5 Megaspore and development of the Female Gametophyte
2.4.2.6 Pollination:
2.4.2.7 Development of Male Gametophyte after pollination
2.4.2.8 Fertilization
2.4.2.9 Development of Embryo
2.4.2.10 Germination of Seed
2.5 Summary
2.6 Terminal Question
2.7 Answer

2.1 INTRODUCTION

Cycas (Greek word *Kykas*= Cocopalm) is a genus of gymnosperm showing resemblance with pteridophytes. It is a slow-growing, long lived, ever-green, plam-like plant. Usually found wild or cultivated in the tropical and sub-tropical region of the world. It is dioecious i.e. male and female plants are separate in which female cone is absent and ovules are arranged at megasporophylls which are arranged spirally on the stem and alternating with cataphylls and foliage leaves. *Cycas* is considered as primitive gymnosperm showing some Pteridophytic or fern like characters which are as follows:

Objective:

After studying this unit you will be able to know :

- Primitive characters of *Cycas* along with there distribution.

- Extrenal morphology of the plant .
- Internal structure of various parts of the plant.
- The life cycle of *Cycas* plant.

Primitive or Fern-Like Characters:

1. Differentiation of the plant-body into root, stem and leaves.
2. Presence of a large crown of pinnate compound leaves at the apex as is seen in tree-ferns.
3. Presence of ramenta.
4. Presence of circinate vernation of the foliage leaves.
5. Absence of vessels in xylem.
6. Presence of tracheids and xylem-parenchyma representing xylem.
7. Absence of companion-cell in phloem.
8. Presence of sieve-tubes and phloem parenchyma representing phloem.
9. Presence of mesarch vascular bundles in rachis .
10. Presence of leaf-like megasporophylls.
11. Presence of microsporangia in soral group of 3-5 on the under-surface of the microsporophyll accompanied with indusial-hairs.
12. Structure and the eusporangiate development of sporangia with a large output of spores.
13. Presence of multiciliate motile sperms.

Systematic Position:

Division-CYCADOPHYTA
 Class-CYCADOPSIDA
  Order-CYCADALES
   Family-CYCADACEAE
    Genus-*Cycas*

Distribution:

It is indigenous to the orient and has about 17species widely distributed from Madagascar to Japan, including Australia. Out of which, about six species are distributed in India i.e. *C. circinalis, C. revoluta*, *C. beddomei, C. siamensis, C. rumphii* and *C. pectinata* reported from Andaman and Nicobar Island, Madras, Nepal, Sikkim, Bengal, Assam, and Southern India as cultivated or wild. Among these *C. revoluta* and *C. siamensis* are cultivated species. It is a popular conservatory plant in cold countries. In hot countries, the plant is usually found in open, sunny and well drained habitats. The plants are easy to culture. Their normal size ranges from 4 to 8 feet in height. *C.* media is the tallest species measuring about 20 feet in height.

. *C. revoluta*—the "Sago Palm", a native of China and Japan, is commonly cultivated in gardens all over the world.

SAQ:1

1. Plants of *Cycas* are ...., male and female plants are separate.
2. Presence of circinate vernation of the foliage leaves in *Cycas* is ....or....... like character
3. Male gamete or sperms of *Cycas* are ....

2.2 EXTERNAL CHARACTERISTICS

2.2.1 Habit

Cycas plants are evergreen, slow growing having palm-like shrubby habit (1.8-3 metre high).It has usually unbranched, a tuberous erect columnar stem bearing a crown of large compound foliage leaves in apparent whorls at the apex (Fig.2.1).

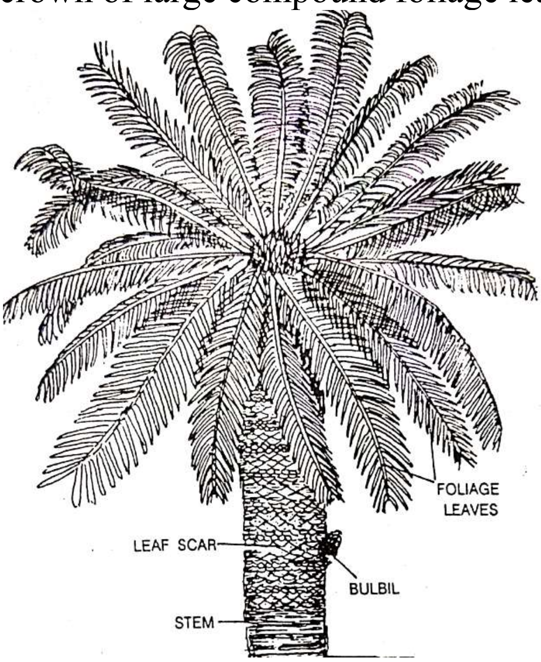


Fig. 2.1 *Cycas* Plant:Habit

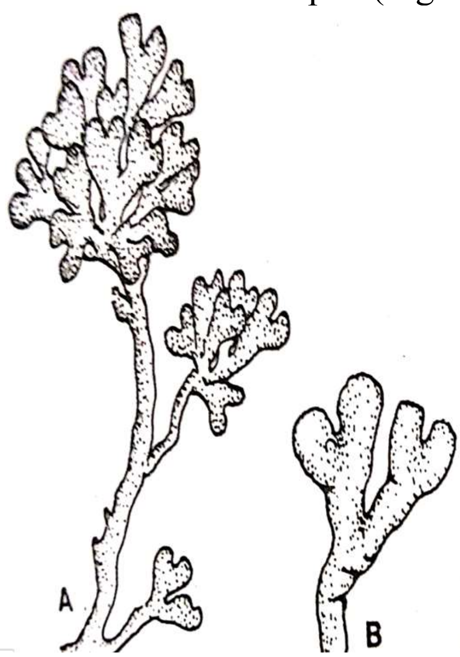


Fig. 2.2 A. *Cycas:* Coralloid Root
B. An enlarged portion

Root: The plant is provided with a deep, extensive short-lived tap-root system which is soon replaced by adventitious roots. In addition to these **normal roots**, are present vertical bunches of dwarf apogeotropic, dichotomously branched and stumpy roots known as **coralloid root** (Fig.2.2.A&B) which are meant as special organ for aeration..

Stem: Usually unbranched, sometimes, occurrence of dichotomous branching or irregular branching takes place by lateral-buds which arise on old trunks. The leaflets are strong, leathery and may keep their fresh green colour for a long time after being detached from the plant. The trunks are covered with woody bases of the petioles of the fallen leaves i.e. leaf scars (Fig.2.3).

Leaf: The pinnately compound leaves may be 0.6 to 1.8 meters long and show circinate vernation (Fig.2.4 C). there are two types of leaf : foliage leaf and scale leaf. The rachis is straight, stiff, thick, spiny in texture, quadrangular in form; sometimes reaching a length of 9 feet bearing two rows of hard and leathery leaflets (Fig. 2.4 A & B). They are numerous, sub-opposite, curved downwards, narrow, terminating in a spiny tip, stiff, shining dark green with revolute or flat margin. The number of leaflets varies with the species. The leaves are spirally arranged on the stem.

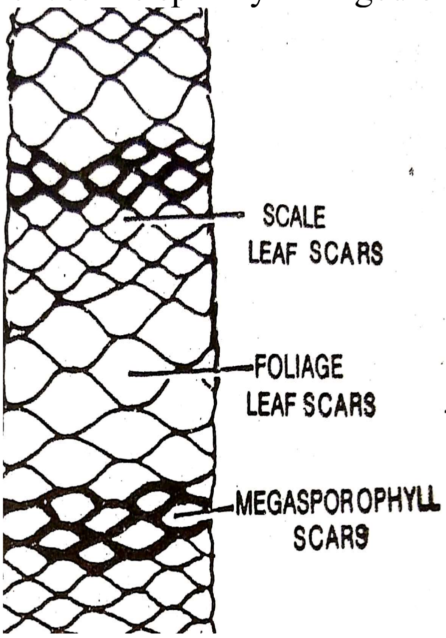
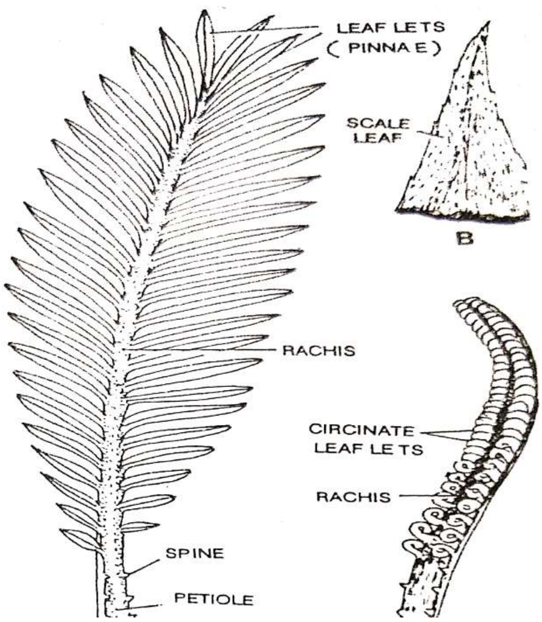


Fig. 2.3 Old stem showing leaf scars



A C

Fig. 2.4 A. Single Foliage leaf
B. Scale Leaf
C. Young Leaf showing Circinate Vernation

SAQ:2

1. Foliage leaves of *Cycas* are ....
2. ..... roots of *Cycas* act as special organ for aeration and are apogeotropic.
3. The old trunks of *Cycas* are covered with woody bases of the petioles of the fallen leaves i.e. ....

2.3 INTERNAL CHARACTERISTICS

2.3.1 Normal root

The normal root resembles to dicot structure showing secondary growth. It ranges from **diarch** to **tetrarch** exarch condition (Fig,2.5). Xylem and phloem bundles are **radial**, on alternate radii. The protoxylem shows spiral thickening whereas metaxylem shows scalariform or pitted thickening. Vascular-cambium formed from the pericycle region produces secondary xylem and secondary phloem as a result of secondary growth. The secondary xylem is traversed by numerous parenchymatous rays. Pith is reduced. Cork-cambium lies at periphery which cuts off cork on the outside.

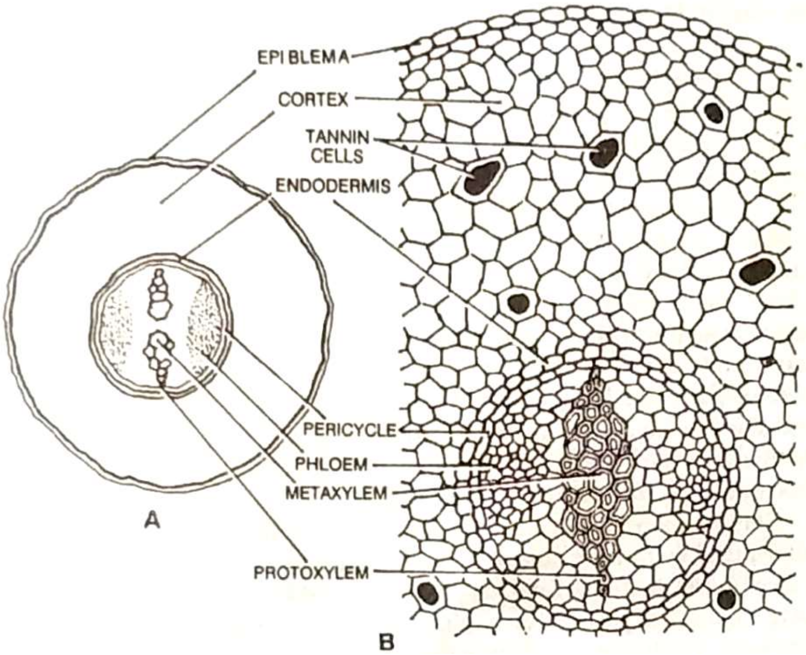


Fig.2.5: T.S. of normal root of *Cycas* showing diarch condition
A. Diagrammatic **B**. A part cellular

2.3.2 Coralloid root

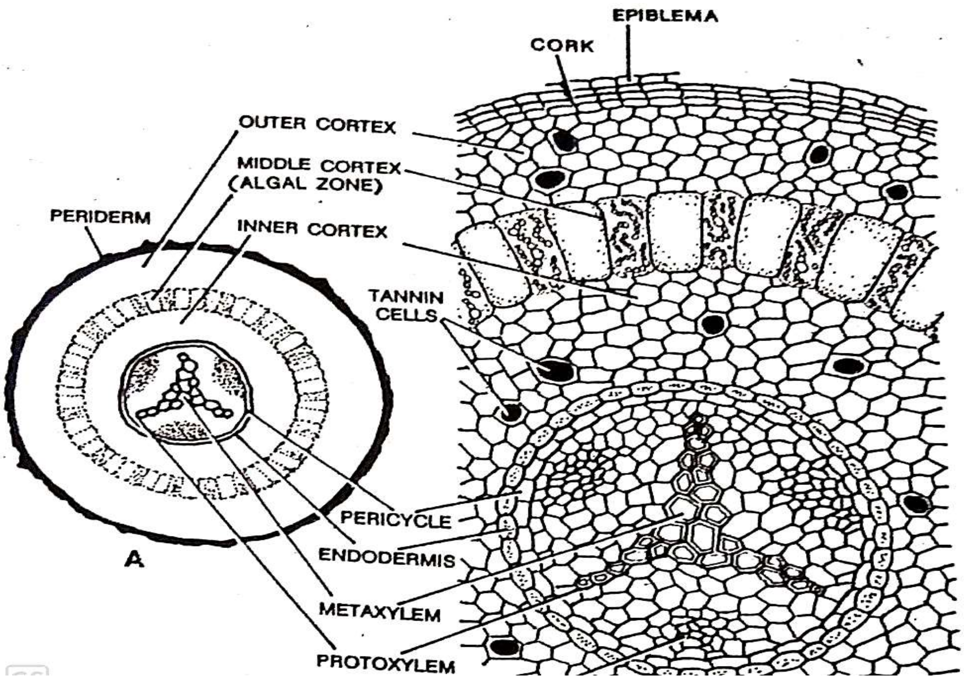


Fig.2.6: T.S. of coralloid root of *Cycas* showing triarch condition

A. Diagrammatic **B**. A part cellular

A transverse section of the coralloid root shows an outer zone of cork followed by cork-cambium. Below this lies the broad parenchymatous cortex which is divisible into an outer and inner regions due to the presence of a characteristic algal-zone in the middle (Fig 2.6). This zone is formed of large disorganised cells and contains *Anabena cycadaceae*, and *Nostoe punctiforme* the blue-green algae. The stele shows diarch to tetrarch structure. It is bounded by an endodermis which is followed by pericycle. Four bundles of xylem alternative with phloem lie in the conjunctive tissue. In some cases, these roots may show some secondary growth.

2.3.3 Stem

The outline of the stem is wavy due to armour of woody leaf-bases. The epidermis is not distinct. Large cortex and pith with narrow diameter of vascular cylinder. The cortex is multilayered; thin-walled parenchymatous cells filled-with starch-grains and a large number of mucilage-ducts which appear as dark-dots. Besides, these, a large number of leaf-traces are present. The leaf-traces are small and endarch but they become mesarch, as they enter the leaf due to the formation of centripetal xylem.

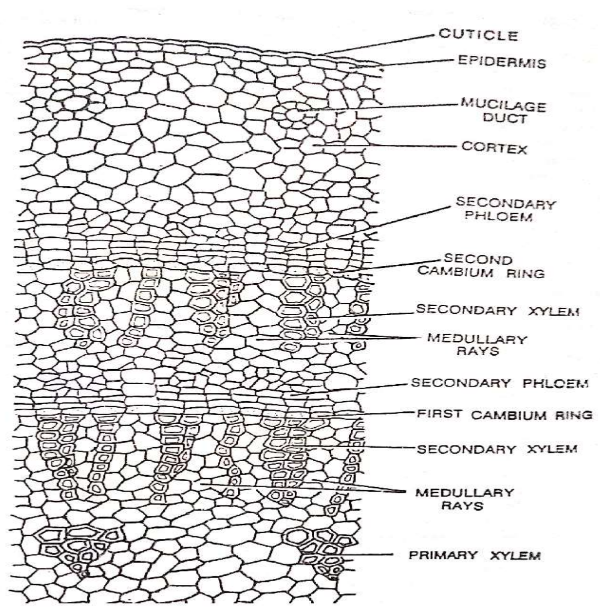


Fig.2.7 T.S of *Cycas* old Stem Showing Secondary Growth (A part Cellular)

The polyfascicular siphonostelic stele is surrounded by a single layered endodermis and inconspicuous pericycle. Large number of conjoint, collateral, endarch and open vascular bundles are arranged within this. The phloem consists of sieve-tubes and phloem parenchyma and is followed by cambium which in turn is followed by xylem formed of elongated tracheids. The primary vascular cambium is short lived; hence the secondary growth is not vigorous.

Secondary growth takes place by the formation of relatively small secondary vascular tissue. The secondary xylem is traversed by numerous broad parenchymatous rays. After sometimes, the vascular-cambium dies and may be superseded by a second cambium. The latter arises in the pericyclic region and procedure a vascular cylinder as prominent as the primary one. This after sometime, become inactive and a third vascular-cambium arises outside the secondary vascular ring and this process is repeated. The last cambium has been reported to produce concentric-bundles. The concentric rings of secondary tissue from a polyxylic structure, but these do not correspond to seasonal-growth or annual rings. Usually, a vascular ring arises when a new crown of leaves is produced by the terminal bud. Hence the vascular supply is surprisingly small, hardly 5 to 10mm in diameter. The soft, scanty wood is known as manoxylic. Meduallary rays containing "sago starch grains" are the prominent feature, hence the plant is called, "Sago palm". Like dictos corkcambium arises in the cortex developing about 10cm. thick periderm.

2.3.3 Rachis:

A transverse section of the stout petiole or rachis shows a biconvex outline (Fig2.8). The leaflets obtain their vascular supply from the margin of the upper adaxial part. The outermost layer is a thick single-layered, heavily cutinized epidermis having stomata. This is followed by a very narrow zone of chlorenchymatous cells. At the tip of the rachis they display an exarch structure. The direct and girdle traces branch freely and arrange themselves in omega-shaped manner as in the petiole. Below this lies a sclerenchymatous hypodermis. This is 2 to 3 cells on the abaxial surface and many cells thick on the adaxial surface, but it is poorly developed in the margins where leaflets arise. Within the sclerenchymatous hypodermis, lies the parenchymatous ground tissue. A number of mucilage-canals are seen in its peripheral region. Within the ground tissue are present, a varying number of vascular bundle arranged in a horse-shoe or omega-shaped manner. Each oval vascular bundle has a sclerenchymatous sheath having crystals of calcium oxalate. Within this lies pericycle of variable thickness ranging from one to many cells. This is followed by xylem, cambium, and phloem. The vascular bundles are conjoint, collateral and open. There is endarch (centrifugal) and exarch (centripetal) primary xylem present therefore called diploxylic condition.

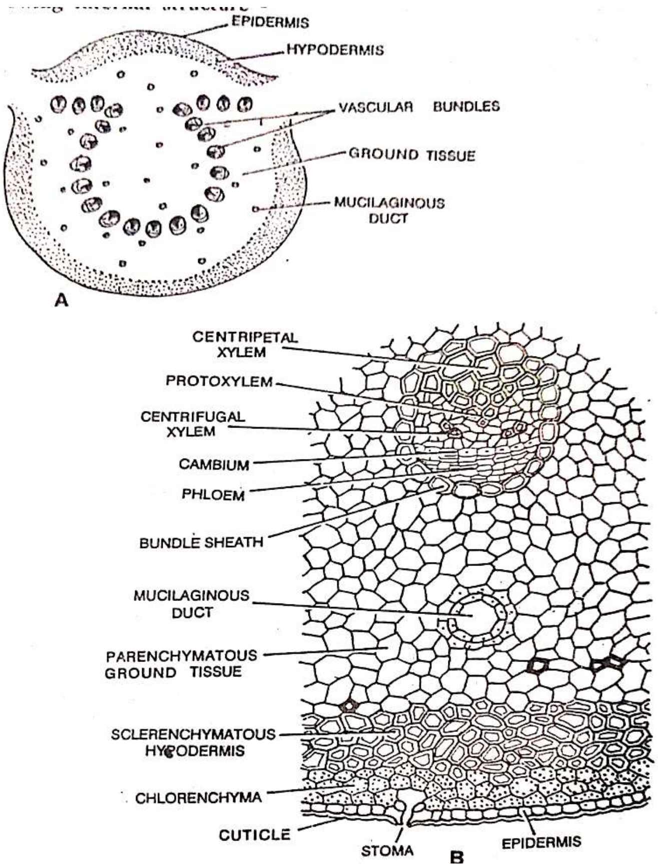


Fig 2.8 T.S. of rachis of *Cycas* **A.** Diagrammatic **B.** A part cellular

Petiole reveals a different structure at the base, centre, and the apex. At the base, the rachis, shows endarch bundle .The centrifugal protoxylem points towards the centre of the rachis. Near the middle of the rachis, the vascular bundle show pseudo mesarch structure in that some metaxylem tracheids develop, opposite the protoxylem groups. These are designated as centripetal metaxylem. This is formed in response to a functional change in the structure of rachis parenchymatous cells opposite the protoxylem. Hence the two metaxylem are of different origin. The centrifugal-metaxylem develops from the plerome of the apical primary-meristem. If sections are cut slightly above the middle region a cambium develops between the centripetal metaxylem and parenchymatous pericycle.

2.3.5 Leaflet

The dorsiventral leaflet, in a transverse section, reveals typical **xerophytic** characters. The leaflet shows a central bulged-portion which makes the position of a single prominent **mid-rib** (Fig2.9)

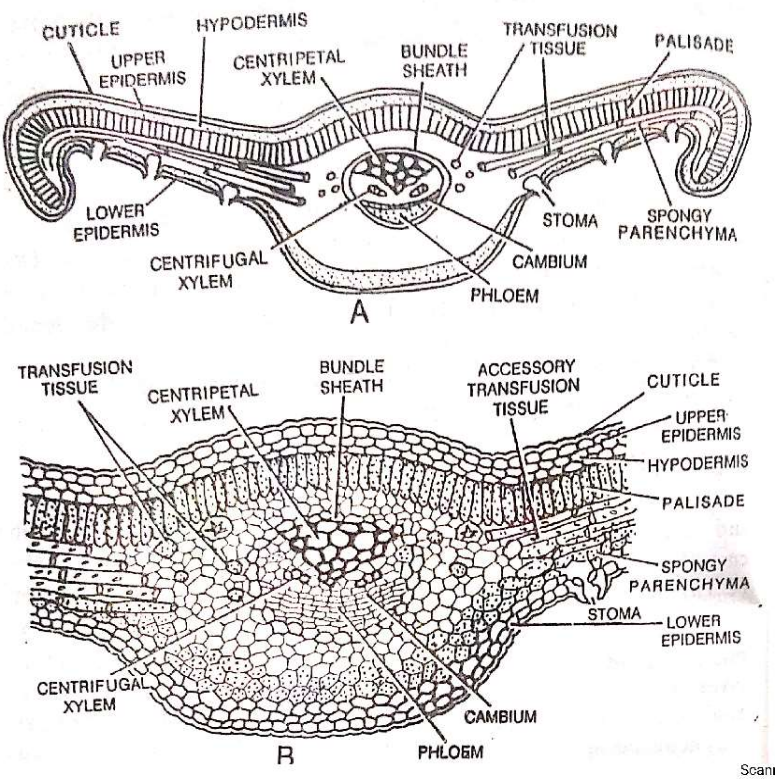


Fig.2.9 T.S. of *Cycas* leaflet **A.** Diagrammatic **B.** A part cellular

The vascular tissue of each leaflet is confined to the mid-rib only. The lamina halves are devoid of veins. On the outside is a thick layer of **cuticle** which protects the thick-walled continuous upper **epidermis** from desiccation and hence reduces transpiration. This is followed by sclerenchymatous **hypodermis** which is continuous in case of *C. revoluta* thicker in the region of mid-vein and the edge of leaflet. The sclerenchymatous hypodermis serves as a heat-screen in protecting the plant from excessive transpiration. The **mesophyll** tissue is very well differentiated into upper elongated **palisade** cells and lower loosely arranged cells forming the spongy tissue . This serves as the aerating and assimilatory tissue. The air-spaces of this region communicate with the outside through the stomata. The mid-rib bundles, like that of the rachis-bundle, show the occurrence of a broad primary xylem. This **diploxylic** structure is characteristic of the genus *Cycas*. Each mid-rib bundle is bounded by a thick-walled **endodermis**. This is followed by parenchymatous **pericycle** . The protoxylem points towards the lower epidermis and is surrounded by **centrifugal** patches of metaxylem. Below the patches of centrifugal xylem lies **cambium** and is followed by **phloem**, which lies in the lower part of the vascular bundle. The phloem consists of sieve-tubes and phloem-parenchyma cells. The remaining space of the vascular bundle is occupied by parenchyma. On either side of the vascular bundle are present a number of **tracheidal cell** with simple pits in an irregular manner. The vascular bundle is embedded in compact parenchymatous ground tissues which are impregnated with crystals of calcium oxalate. From this region, row of colourless elongated cells run laterally between the upper palisade and lower spongy-tissues. This tissue is known as the **transfusion tissue** and compensates for the unbranched nature of the mid-rib.

SAQ:3

1. In rachis of *Cycas* vascular bundles are arranged in a ....or ......shaped manner.
2. Presence of algal zone in the cortex of .... of *Cycas* which act as special organ for aeration and are apogeotropic.
3. Two types of xylem i.e. centripetal and centrifugal present in leaflet of *Cycas* is called as ....or....... condition.

2.4 LIFE CYCLE

REPRODUCTION

Cycas plants reproduce by vegetative and sexual methods .

2.4.1 VEGETATIVE REPRODUCTION

It takes place by adventitious **buds** or **bulbils** which develop on fairly old trunks in the cervices of the scale. These are formed as a result of the hypertrophy of the cortical-parenchyma and sometimes give an illusion of a branched stem as in *Cycas rumphii*. The bulbils have few scales and foliage-leaves and when detached develop a new plant.

It is also reported that *C. circinnalis* reproduces vegetatively by developing **suckers.** These develop from the roots which traverse the soil horizontally to a distance of several meters.

2.4.2 SEXUAL REPRODUCTION

In *Cycas*, as in all the seed bearing plants, the gametophytic phases are strictly **heterothallic.** The male and female gametophytes develop from different types of spores which are called the **microspores** and **megaspores.** These develop in micro and megasporangia respectively. *Cycas* is **dioecious** thus both the **sporangia** are segregated and develop on different plants.

2.4.2.1 Male Cone or Strobilus

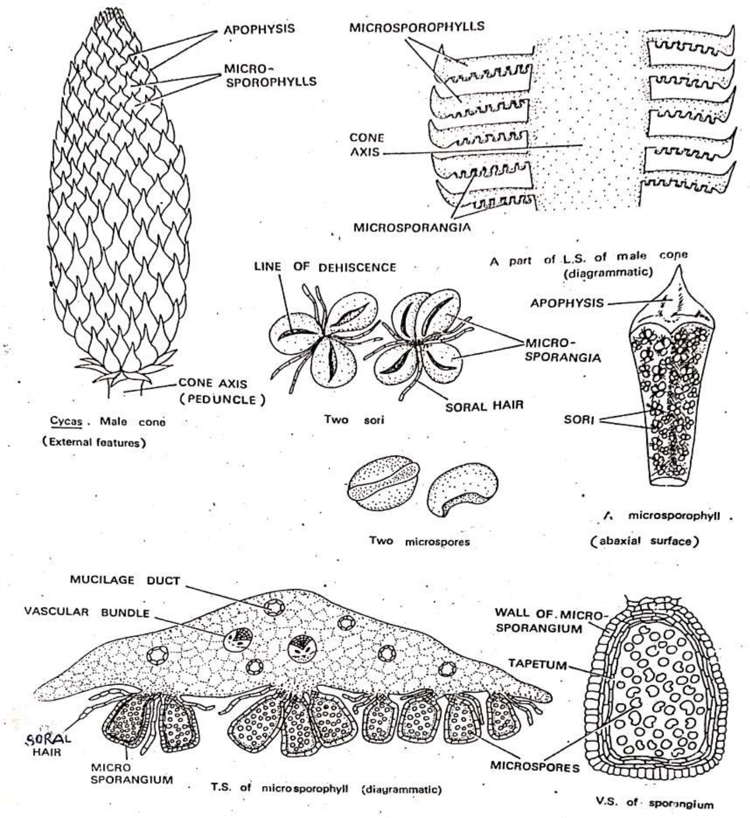


Fig 2.10 Male cone of *Cycas* along with microsporangia and microsporophyll

It develops at the apex of the stem usually singly and lies in the centre of the crown of leaves. The stem continues to add to its height by a lateral bud which arises at the base of the male-cone in the axil of a leaf showing the **sympodial** branching. The male-cone is a woody, wedge-shaped, blunt-ended structure about 50cm long. Each has an elongated axis on which are a number of spirally arranged woody **microsporophylls** or stamens. Each microsporophyll is a flattened structure narrow below and expanded above into an expanded sterile-disc drawn out in a sort of projection, the **apophysis**. The upper portion of the sporophyll is sterile, while on the lower abaxial part **microsporangia** are borne in soral group of three to six. The sporophylls at the base and apex of the cone are sterile. The microsporangia, may be 700-1000 in various species and lie in two depressed zones on either side of a median sterile ridge. They cover the entire abaxial surface of the sporophyll. The soral-group of microsporangia are surrounded by hairs (Fig.2.10).

2.4.2.2 Development of microspores

The microsporangia are **eusporangiate** in development, *i.e,* develop from hypodermal cell of the microsporophyll. The mature microsporangium is oval and attached by a short-stalk at one end. The microsporangial wall is massive and four to seven cell thick. The surface cells of the microsporangium are large and thick-walled except the point of dehiscence. Such cells are regarded as **annulus**. **Tapetum** below it is ill developed. The **archesporium** of the microsporangium develops a number of microspore mother cells which divide meiotically to give rise to tetrads of spores (Fig.2.11 A). This marks the end of the diploid sporophytic generation and number of **microspores** is thus produced in each sporangium. The haploid number *(n)* of chromosome in *Cycas* is eleven.

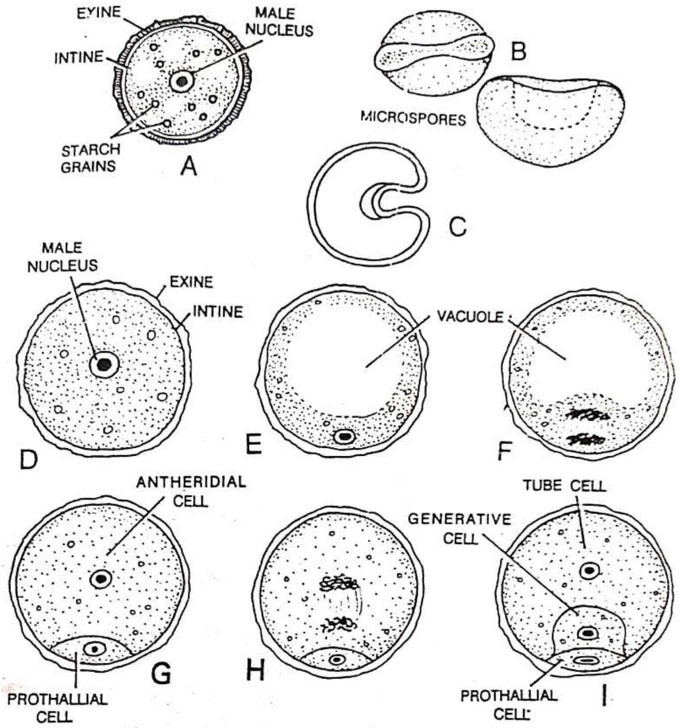


Fig.2.11 *Cycas* **A.** Microspore or Pollen grain **B.** Boat shaped Microspore or Pollen grain **C.** Optical section ofMicrospore or Pollen grain **D-I.** Development of male gametophyte after pollination

The microspores germinate in *situ*, much before the sporangium dehisces. Each has two coverings, the outer thick exine and an inner thin intine. The spore divides into a small **prothallial cell** at the lower end leaving a large **antheridial cell**. The antheridial cell divides forming a large **tube cell** and a small **generative cell** (Fig 2.11 D-I). Thus the male gametophyte is strictly endosporic and begins its development with the confines of the microsporangium. As a result of the loss of water, the sporangial will breaks-open along the lower side, so that the microsporangia become boat-shaped and the three celled microspores are liberated in air for pollination, (Fig.2.11 B). When this takes place the axis of the male cone elongates and the microsporophylls get separated from one another.

2.4.2.3 Megasporophylls

The genus *Cycas* does not possess female cone or strobilus. Instead of forming a female cone, the **megasporophylls** are arranged spirally in acropetal succession forming **rosettes** or a crown having the apical meristem unaffected to grow and form future leaves and sporophylls. The megasporophylls develop when plant is quite old and a crown of megasporophylls is formed each year between successive crowns of foliage leaves. They are far more numerous than the foliage leaves.

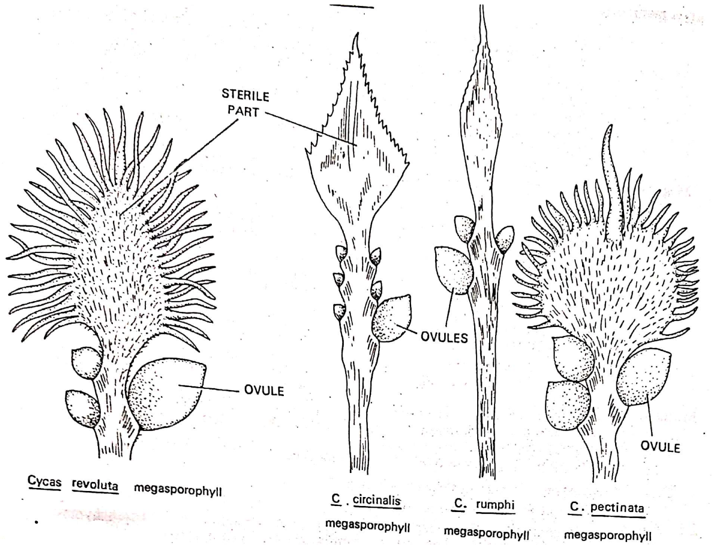


Fig.2.12 Megasopophylls in different species of *Cycas*

The megasporophylls differ in shape and size in different species (Fig 2.12). The ovules of *Cycas circinalis* are the largest in the plant kingdom, about 6cm long. When mature they are red in colour and may be as larger as hen's egg

2.4.2.4 Ovule

The ovules are **orthotropous** in position. Each ovule has a very thick integument. It is in close association to the nucellus except at the apical region where it form a nucellar-beak and a micropylar-opening. The micropyles of the ovules are turned obliquely outward. Within the beak-like portion develops a hallow chamber called the **pollen-chamber** (Fig 2.13). When mature the integument differentiate into an outer green or orange fleshly-layer, the *sarcotesta* the middle yellow stony-layer, the *sclerotesta* and an inner fleshy layer. The inner fleshy layer is absorbed as the female gametophyte matures and is left as a dry papery membrane closely applied to the embryo-sac. The outer fleshy-layer remains fleshy throughout. Usually two vascular strands enter the ovules from the megasporophyll. The outer strand enters the outer fleshy-layer and consists of about a dozen vascular bundles which extend right unto the micropyle. The second strand transverses the inner fleshy-layer and consists of numerous vascular bundles. Each ovule arises as a hypodermal mass of cell. The sterile cells above it divide rapidly so that the sporogenous cells become deep seated at the base of a large nucellus.

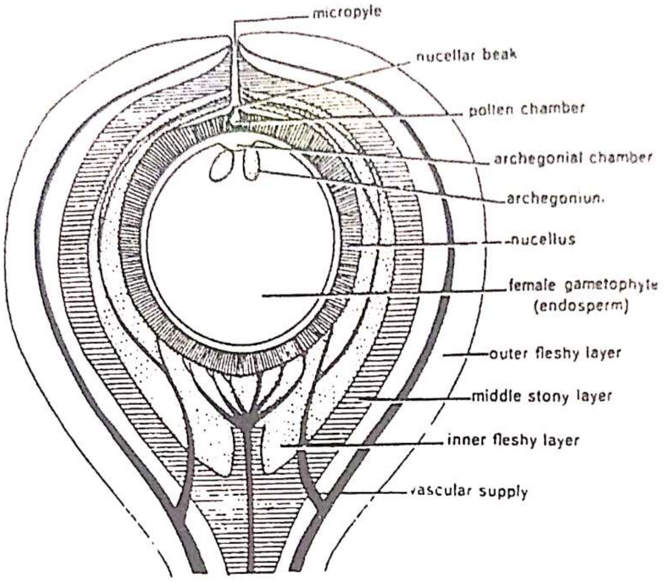


Fig.2.13 L.S. of Mature ovule of *Cycas*:

2.4.2.5 Megaspore and development of the Female Gametophyte

At first, the thin-walled parenchymatous cells of the nucellus are all alike, but soon one cell in the central region become more prominent.This larger cell is called the **megaspore mother cell.** It divides meiotically developing a linear tetrad of four haploid **megaspores** (Fig2.14). This marks the end of diploid sporophytic generation and the initiation of the haploid female gametophytic phases. The upper three megaspores are non-functional and soon degenerate. The basal megaspore becomes large in size. This functional megaspore is known as **embryo-sac.**

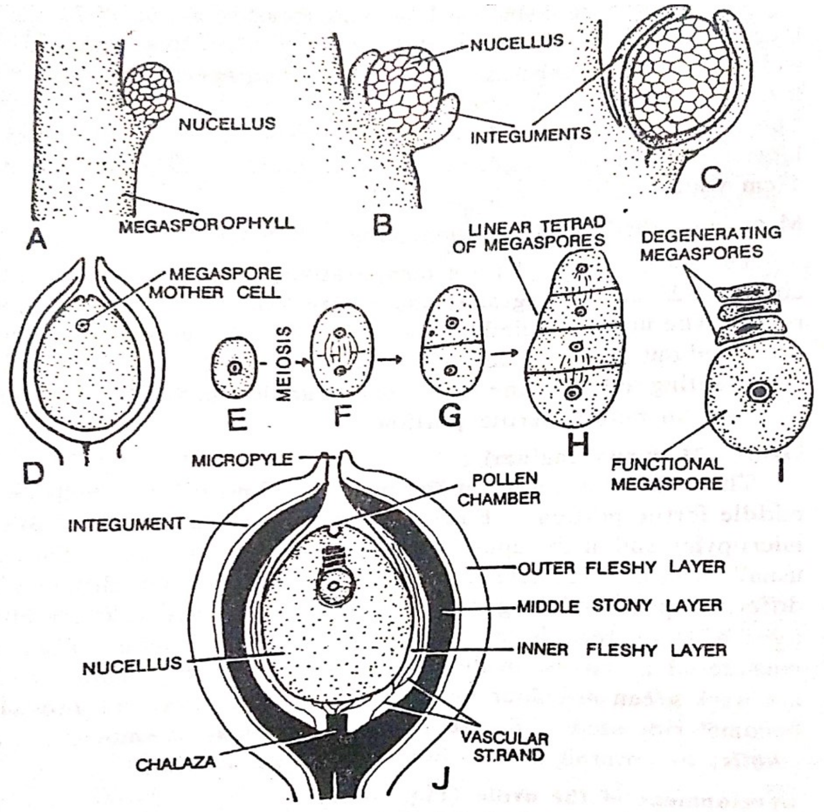


Fig.2.14 Development of ovule and megasporogenesis in *Cycas*

Like megaspores of all spermatophytes, the megaspore of *Cycas* is permanently retained in the megasporangium or ovule. The megaspore has a thick papillate exospores and a fibrillar inner endospore. It enlarges considerably and a vacuole appears in the centre which pushes the nucleus to the lower side. The nucleus divides by free nuclear division resulting in the production of more than a thousand nuclei. As free nuclear division continue, additional cytoplasm is synthesized and the vacuole is gradually obliterated. At this time wall formation is initiated, at first between the peripheral nuclei and it continues in a centripetal direction until the female gametophyte is entirely cellular (Fig 2.15). This is known as the **female prothallus** or **endosperm** and consists of uninucleate cells which are smaller above and larger below. A well-defined megaspore wall clearly demarcates the gametophyte from the adjacent tissue of the nucellus (Fig 2.15). Outside this is developed a nutritive jacket of two cells thick which is called **endosperm jacket.** This seems to function like the tapetum. Some of the surface cells near the micropylar end of the female gametophyte enlarge and form two to five **archegonial-initials**. Each develops into an extremely large **archegonium.** The superficial initial divides transversely into a **primary neck cell** and a **central cell**. The primary neck cell usually divides once longitudinally to form two neck cells. These lie side by side forming a very small neck. The neck cells become turgid, enlarge and protrude into the archegonial chamber. Neck canal cells are absent in *Cycas.* The central cell, at this stage is considerably enlarged and becomes highly vacuolated. It gets surrounded with a nutritive jacket of cells called the **archegonial jacket.**

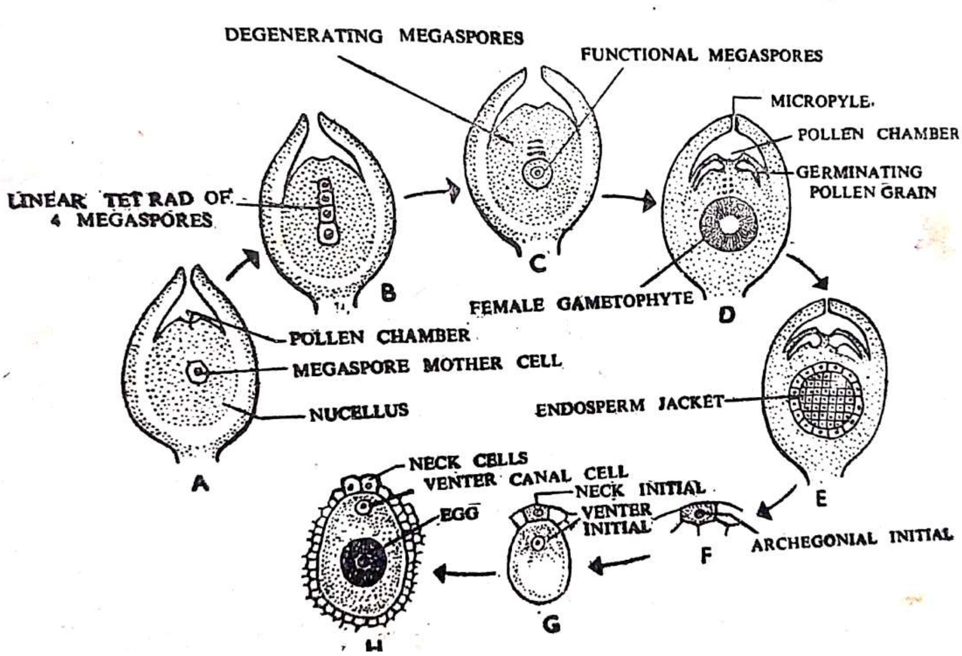


Fig . 2.15 Development of female gametophyte of *Cycas*

After sometimes jacket cells become depleted of its contents and the pores between the central and jacket cells become occupied by the formation of plug-like thickenings.

While the egg is losing its originally and become large central-vacuole with densely cytoplasmic by the intake of the content of the surrounding cells, the upper portion of the gametophyte which contains the archegonia loses its contact with the nucellus forming a small space, the **archegonial chamber.** According to Chamberlain (1935), this phenomenon is caused by an upward growth of the tissue surrounding the archegonia. The egg of *Cycas* and its nucleus are the largest in the plant kingdom at this stage the egg awaits fertilization.

2.4.2.6 Pollination

Pollination is **anemophilous** i.e.the wind helps to transfer some of the three-celled, large, dry, microspores in the micropylar region of the ovules. At this stage, some of the cells of the nucellus disorganise forming the pollen-chamber and the mucilaginous product so formed, fills the micropyle and is exuded as the **"pollination drop".** A large number of pollen-grains are entangled in this, and as it dries up, the pollen-grains are drawn into the pollen-chamber; further drying seals the pollen chamber and the top become very hard. This process leads the pollen-grain to their destination.

2.4.2.7 Development of Male Gametophyte after pollination

Four months after pollination in *C. revoluta,* the pollen-grains germinates in the pollen-chamber. The tube-cell enlarges soon and this results in the bursting of the exine at the upper end and the intine comes out in the form of a **pollen-tube** . The end of the pollen-grain from which pollen-tube is given off, is called **haustorial-end.** This end penetrates in the nucellus, so that the pollen-tube grows down in the tissue of the nucellar-beak serving as haustorium. The pollen-tube is not sperm carrier. At this stage, the generative cell divides into a **stalk cell** and a **body cell.** The stalk cell is sterile and remains attached to the persistent prothallial cell (Fig2.16).

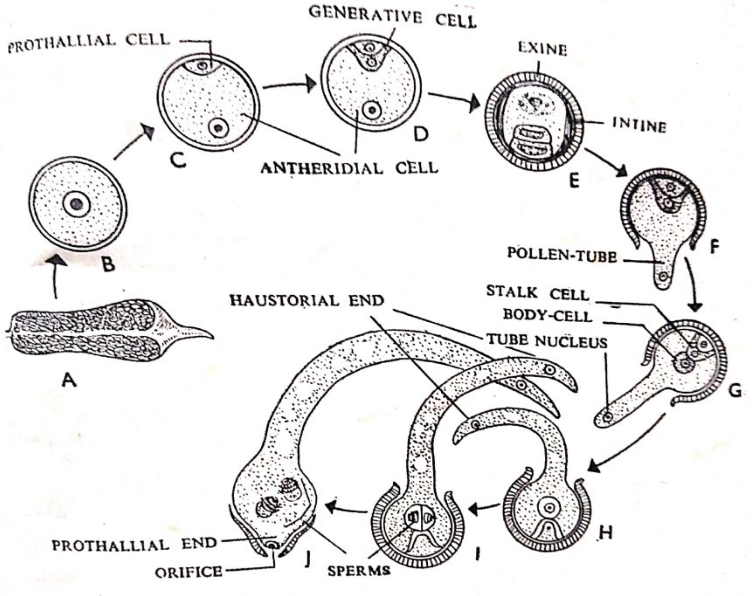


Fig. 2.16 Microsporophyll and development of male gametophyte of *Cycas*

No further development takes place until the archegonia are mature. For further development, a period of four months is needed, after which the full-grown tubes hang freely in a cavity which is partly pollen-chamber and partly archegonial-chamber. Meanwhile, the prothallial cell penetrates into the stalk cell, reducing it to the form of a ring. When the fertilization time approaches, the body cell enlarged enormously in the direction of the long axis of the elongating pollen-tube. In the body cell, two star-shaped protoplasmic bodies appear. These are known as the **blepharoplasts**. They are concerned in the production of cilia and breakup into granular mass forming five to six spiral bands. The nucleus completely divides and each of its part is attached to the centre of the ciliated spiral bands. The body-cell divides into two and thus two **antherozoids** are formed. These are liberated from the body-cell, become motile and swim actively in the pollen-tube. The sperms of *Cycas* are the largest known in the plant kingdom and may attain a diameter of 300 microns and are thus visible to the naked eyes.

2.4.2. 8 Fertilization

The interval between pollination and fertilization is **4-6 months.** During fertilization, the pollen-tubes are extremely turgid probably because of high osmotic value of the substance which have been digested and absorbed by it. There is no liquid water in the archegonial chamber at fertilization time. It has that the turgid end of the pollen-tube does not burst but spermatozoids are just squeezed out by amoeboid movements helps the sperms to enter into the egg. After the libration of sperms, a liquid of high osmotic pressure is given out from the pollen tube. This draws water from the neck cells and from the egg, and then a portion of the egg cytoplasm protrudes into the archegonial chamber. When a sperm touches neck cells, it is sucked violently with a sufficient force so as to sever the blepharoplasts and the naked male nucleus migrates to the vicinity of egg nucleus, which is now of tremendous size. This results in the union of male and female nuclei, the **fertilization.**

It is the beginning of the diploid sporophytic generation which initiates its development by the formation of a diploid **oospore** or **zygote.** This type of fertilization which is achieved by the help of pollen-tube is called **siphonogamy.** Since the sperms are motile, the process is called **zoodiogamy**.

2.4.2.9 Development of Embryo

The diploid oospore undergoes rapid free nuclear divisions resulting in the production of about 200 to 300 nuclei. These are distributed throughout the cytoplasm of the oospore. The period of free nuclear division continues longest at the base of the oospore. Some of the nuclei in the centre along with some cytoplasm disorganise forming a large central vacuole which pushed the surviving nuclei towards the periphery. Later on wall formation is initiated among the free nuclei in the oospore at its base and extends gradually towards the neck end of the archegonium. Some of the free nuclei may remain unenclosed by walls. This region is called **proembryo** and functions as meristematic zone.

The cells of the proembryo are differentiated into three region: the upper region of **haustorial cells,** the central region of **suspensor cells,** and the basal region of **embryonal cells**. (Fig 2.17). The uppermost region of haustorial cells is directly in contact with the free nuclear part of the oospore and serves to absorb food for the embryo. The suspensor cells elongate considerably and push the embryo cells deep into the tissue of the female prothallus. All the archegonia of one female gametophyte may be fertilized but only one embryo normally is present in the mature seed. All the suspensor from different oospores which come from different archegonia twist together and form a compound structure 'several cms long' supporting the functional embryo. This thrust the embryo in the middle of the nutritive prothallus.

The embryonal cells enlarge and divide rapidly. The growth, at the centre, soon stops whereas the margins grow vigorously and protrude out forming two **unequal cotyledons.** Schuster (1932) reported occurrence of one or 3 cotyledons in *C.circinnalis.* Between the depression of the two cotyledons lies the terminal **plumule**, The cell above the plumule elongate and form the axis of the embryo which soon differentiates into a **hypocotyl** and a **radical.** Development of embryo is slow and when mature, the embryo reaches the whole length of seed. At this stage the suspensor are pushed back against the micropylar end forming a hard pad, called the **coleorhiza seed.** The mature fleshy seed consists of an outer, thick, red or orange testa which is formed from the three-layered integument of the ovule. Within this lies a thin layer of nucellus, the female prothallus or endosperm and a functional straight embryo consisting of two unequal cotyledons. These conceal a plumule between them. The axis of the embryo is very well marked out into hypocotyls and radical.

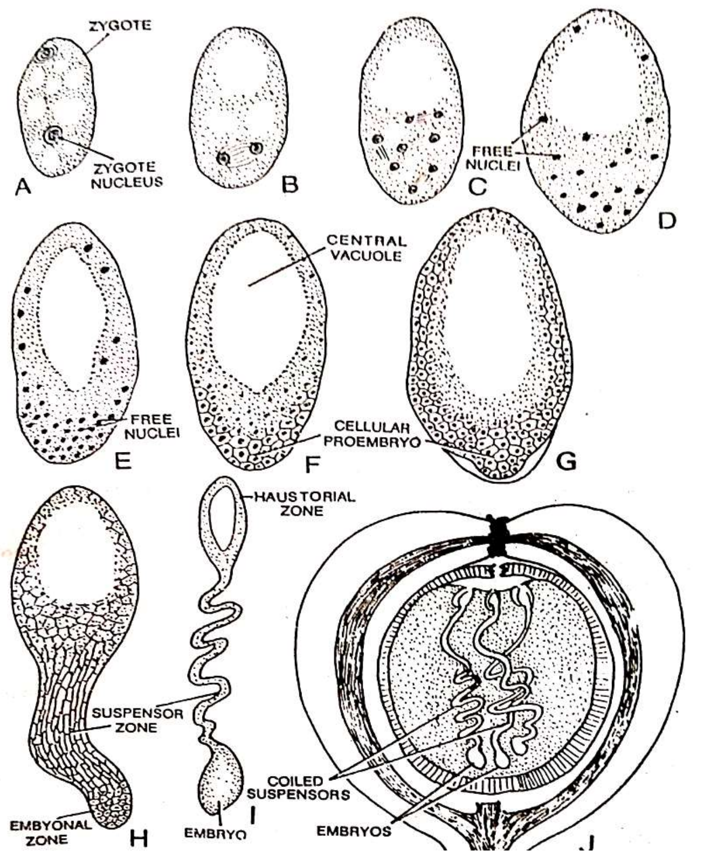


Fig. 2.17 A- I. Develpomental stages of *Cycas* embryo

2.4.2.10 Germination of Seed

The seeds of *Cycas* germinate immediately and have no resting period (Fig.2.18). In any case, they do not keep their viability for more than a few months. The seed-coat on germination is broken up by the stony coleorhizae, which makes the passage for the delicate radical.

The unequal cotyledons remains within the seed below the ground where they function in absorbing food stored, in the female gametophyte cells or endosperm. When the food is finished, the cotyledons dry up and are followed by the appearance of the first foliage leaf with a few leaflets. The seedling stem is very short and its vascular system forms a plate rather than a column. The seed is an **autonomous** organization and develop new plant during favourable conditions.

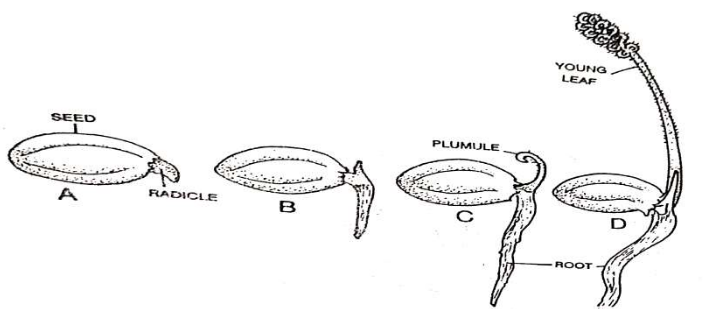


Fig. 2.18 A-D. Different stages of seed germination in *Cycas*

2.5 SUMMARY

Cycas is widely distributed genus found all over the world. There is 17 species out of which 7 species reported in India in North-East and Southern region.

External Characteristics:

- Plants are differentiated into root, stem and leaves .It is slow growing, long lived evergreen.

Root

- Roots are two types : Normal and Coralloid
- Primary root is short lived tap root replaced by adventitious root.
- **Normal roots** are well developed with conical root caps and positively geotropic.
- Some of primary root grow vertically towards soil and negatively geotropic known as **Coralloid roots**. These are dichotomously branched, green and coral like without root cap inhabited by Cyanobacteria for N_2 fixation.

Stem

- Stem is woody erect and usually unbranched bears crown of leaves at apex
- Stem shows leaf scars of leaf bases alternating large and small leaf scars of foliage and scale leaves respectively.
- It represents the age of the plant.

Leaf

- Crown of leaves arranged at the apex of stem.
- Leaves are dimorphic i.e. two types: Foliage and Scale leaves
- Foliage leaves are large and pinnately compound with long stout rachis.
- Young foliage leaves are circinately coiled and covered with ramenta (hairs). Pinnae are sessile with prominent mid rib.
- Scale leaves are small, simple , brown and covered with ramenta.

Bulbils

- These are small ovoid adventitious vegetative buds on main stem. On germination may grow into a new plant.

Internal Characteristics:

Root

Normal Root:

- It shows typical dicot features with circular outline, single layred thin walled epidermis with unicellular hairs, parenchymatous cortex filled with starch and tannin cells.
- Endodermis not clear, multilayered pericycle.
- Central stele is radial, exarch, di to tri arch, pith small
- Older roots show secondary growth, epidermis ruptured due to development of periderm
- Cambium develops between primary xylem and primary phloem, which cuts xylem inside and phloem outside
- Primary medullary rays form opposite to protoxylem and secondary medullary rays between secondary xylem

Coralloid Root:

- Similar to normal root but differs in having algal zone in cortex and ill development of secondary growth

Stem

- Irregular outline, outer most layer is epidermis. Large parenchymatous cortex with leaf traces
- Stele ectophloic siphonostele consisting of many conjoint, collateral, open, endarch vascular bundles arranged in a ring each of them separated by medullary rays
- Old stem shows several rings of vascular bundles which are secondary in origin.
- It is manoxylic i.e. large pith and cortex, scanty secondary growth.

Rachis

- Outline biconvex type of flattened with two lateral depressions of leaflet on both sides.
- Thick cuticle outside as well as thick walled unicellular epidermis with sunken stomata showing xerophytic characters.
- Number of vascular bundles embedded in ground tissue arranged in an inverted omega (℧) shape
- Each bundle is surrounded by its own single layered thick walled bundle sheath.
- Vascular bundles are conjoint, collateral and open, diploxylic (centripetal and centrifugal xylem).

Leaflet

- Dorsiventral with swollen mid rib and flat or revolute margin.

- Both upper and lower epidermis is thick walled and highly cuticularised having sunken stomata.
- Transfusion tissues are present for lateral transport.
- Lateral veins absent.
- Diploxylic or pseudomesarch condition of vascular bundle.

Life Cycle

- *Cycas* plants reproduce by vegetative and sexual methods.
- Vegetative reproduction takes place by adventitious **buds** or **bulbils** and sometimes by **suckers** which develop from the roots which traverse the soil horizontally to a distance of several meters.
- The gametophytic phases are strictly **heterothallic.**
- The male and female gametophytes develop from different types of spores which are called the **microspores** and **megaspores.** These develop in micro and megasporangia respectively.
- *Cycas* is **dioecious** thus both the **sporangia** are segregated and develop on different plants.
- Diagrammatic representation of life cycle of *Cycas* is shown in (Fig.2.19).

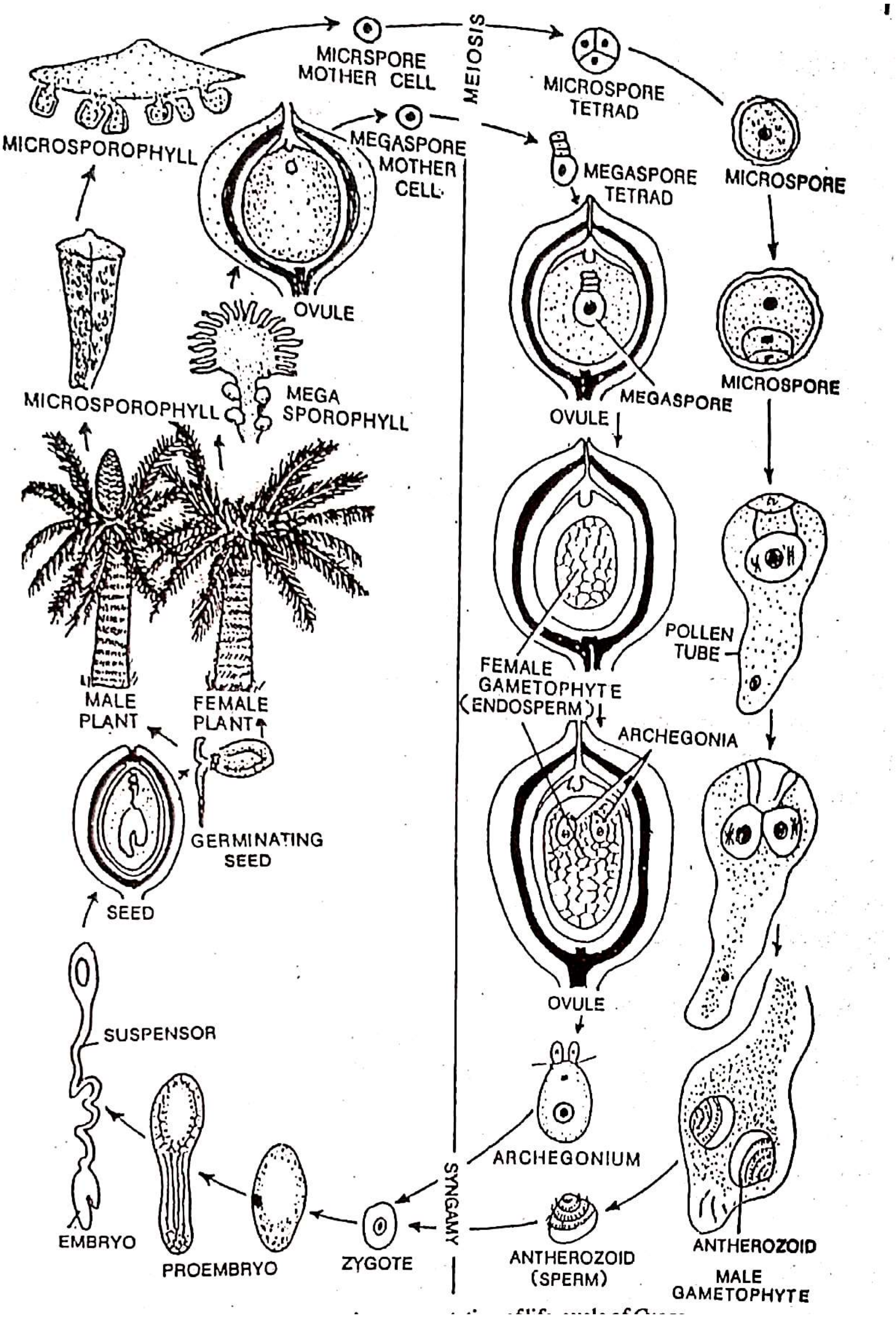


Fig. 2.19. Diagrammatic representation of life cycle of *Cycas*

2.6 TERMINAL QUESTIONS

VERY SHORT ANSEWER TYPE QUESTIONS:

1. Which type of wood is present in *Cycas*?
2. Name of the plant which bears coralloid root.
3. Which type of association occurs between *Nostoc* and *Cycas* root?
4. What is the name of tracheid like cells occurring outside the vascular bundles in *Cycas* leaflets?
5. What is the condition when xylem is arranged in two patches like centripetal and centrifugal?
6. What is the arrangement of vascular bundles in *Cycas* rachis?
7. Which type of stomata presents in *Cycas* leaflet and where does they found?
8. What is the shape of *Cycas* pollen grains?
9. Which plant is commonly Known as Sago Palm?
10. What is the function of pollen tube in *Cycas*?
11. How many cells are present in pollen grain of *Cycas* at the time of pollination?

SHORT ANSEWER TYPE QUESTIONS:

Q 1. Point out the differences between Normal and coralloid roots of *Cycas.*
Q.2. Draw well labelled diagrams of following:
a. T.S. of *Cycas* leaflet b. T.S. of *Cycas* rachis
Q.3. Write short notes on following:
a. Mature ovule of *Cycas.* b. Transfusion tissue c. Microsporophylls of *Cycas*

LONG ANSEWER TYPE QUESTIONS:

Q.1 Describe briefly about the habit, habitat and external morphology of *Cycas.*
Q.2. With the help of suitable diagram explain the structure of *Cycas* stem.
Q.3. Describe the post fertilization development of ovule of *Cycas.*
Q. 4. Give a diagrammatic representation of life cycle of *Cycas.*

2.7 Answers

SAQ:1

1. Dioecious 2. Primitive or Fern 3. Multiciliated motile

SAQ:2

1. Pinnately compound 2. Coralloid 3. Leaf Scars

SAQ:3

1. horse-shoe or omega 2. Coralloid roots 3. Diploxylic or pseudomesarch

VERY SHORT ANSEWER TYPE QUESTIONS:

1.Manoxylic 2. *Cycas* 3. Symbiotic 4. Transfusion tissues 5. Diploxylic 6. Inverted omega (℧) shape 7. Sunken , Ventral surface of leaflet 8. Boat shaped 9. *Cycas* 10. Haustorial as well as carries sperms 11. Three celled: prothalial, generative and tube cell

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UNIT 3: *PINUS*

3.1 Introduction

Objectives

3.2 External Morphology of Plant (Sporophyte)

3.2 .1 Root

3.2.2 Stem

3.2.3 Leaf

3.3 Internal Characteristics

3.2.1 Root

3.2.2 Stem

3.2.3 Leaf

3.4 Life Cycle: Reproduction

3.4.1 Male Cone or Strobilus

Microspophylls or Stamens

Development of Microsporangium
Structure of Microsporangium
Dehiscence of Microsporangium and Dispersal of Microspores or Pollen Grains
3.4.2 Female Cone or Strobilus (Ovulate Stronilus)
Development of Megasporangium or Ovule
Structure of Megasporangium or Ovule
3.4.3 The Gametophyte
3.4.3.1 Male Gametophyte
Development of Male Gametophyte with in Microsporangium
Pollination in *Pinus*
Development of Male Gametophyte after Pollination
3.4.3.2 Female gametophyte
Development of Female Gametophyte
Development of Archegonium
3.4.4 Fertilization
3.4.5 The New Sporophyte
3.4.6 Seed Formation
3.4.7 Seed Germination
3.5 Summary
3.6 Terminal Question
3.7 Answer

3.1 INTRODUCTION

Pinus is one of the oldest evergreen conifer of Pine family having about 150 species. The species of *Pinus* often dominate the natural vegetation type in which they occur and provide some of the most important timber tree in the world.

Objectives:
After studying this unit you will be able to know :

- External and internal characteristics of various parts like root ,stem and leaf of sporophyte.
- Structure and development of male and female gametophyte.
- Process of fertilization, formation of seed and new sporophyte .

HABIT
The plants of *Pinus* are perennial , evergreen tree and xerophytes. The plant gives an appearance of pyramid in young stage as conifers. The sporophytic plant body is differentiated into root, stem and leaf.

SYSTEMATIC POSITION

Division - *Gymnospermae*
Class - *Coniferopsida*
Order - *Coniferales*
Family - *Pinaceae*
Genus – *Pinus*

OCCURRENCE

Pinus is an important dominant genus of conifers and about 105 species reported, distributed throughout northern hemisphere, forming dense evergreen forest of north temperate and subalpine regions. About six species of them known from different part of our country are as follows (Table 3.1):

S.N.	Name of species	Common name	Location in India
1.	*Pinus gerardiana*	Chilgoza Pine	Kashmir and Kinnur of Himachal Pradesh
2.	*Pinus excellsa* or *wallichiana*	Blue Pine	Kashmir Hills, Himachal Pradesh and Punjab
3.	*Pinus roxburghii* or *longifolia*	Chir Pine	Kashmir, Punjab, Himachal Pradesh and Uttar Pradesh
4.	*Pinus merkusii*	Merkus Pine	East India, Bengal, Burma
5.	*Pinus insularis*	Khasi Pine	Khasi, Naga hills, Manipur
6.	*Pinus armondi*	Armand's pine	NEFA

Table 3.1 Distribution of different species of *Pinus* in India

Some more species also introduced in India as exotic pines and growing wildly are *P.montana, P.laricio, P.sylvestris, P.canariensis, P.caribaea, P.pinester, P.radiata, P.thumbergii* etc.

SAQ 1:

1. Out of 105 species of *Pinus*....... are reported from India.
2. Chigoza is obtained from...........
3. .... is known as Chir Pine.

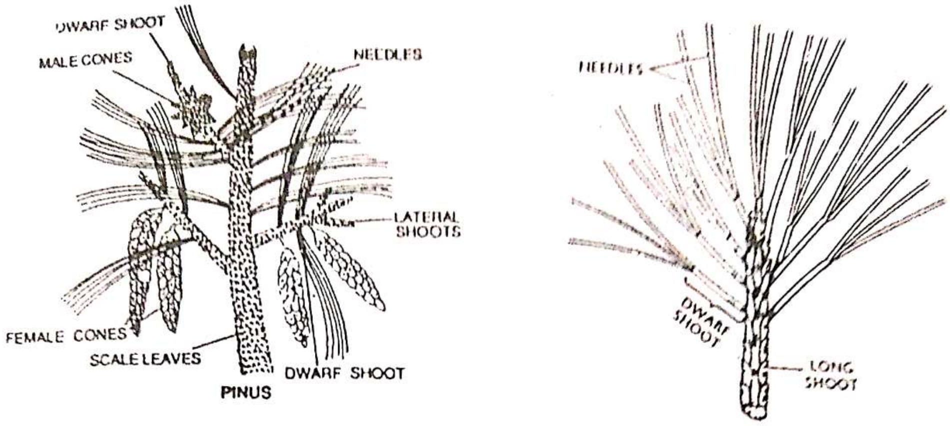
3.2 EXTERNAL MORPHOLOGY OF PLANT (Sporophyte)

3.2.1 ROOT

The primary root is a prominent tap root that does not penetrate deep into the soil with ill developed root hairs. The lateral roots develop later on, grow extensively and help in anchoring the plant in the soil. The roots are covered with an ectotrophic symbiotic fungus i.e. mycorrhiza.

3.2.2 STEM

The stem is cylindrical, erect and branched monopodially. The main stem is covered with bark. The branching is confined to the upper part of the stem, giving a pyramid or cone like appearance to the plant.



A B

Fig. 3.1 *Pinus* **A.** External features of Plant with cones
B. A part of Stem showing long and dwarf shoot

The stem has two types of branches: i. Long shoots or Branches of unlimited growth and ii. Dwarf shoots or Branches of limited growth (Fig.3.1).

i. Long shoots or Branches of unlimited growth:

They develop in the axils of scaly leaves and spread horizontally. The main trunk develops a large number of radial long shoots to give the plant pyramid look. The apical buds of these branches grow indefinitely hence these branches called as branches of unlimited growth.

ii. Dwarf shoots or Branches of limited growth :

These branches lack apical buds and grow for short period. They develop in axils of scaly leaves and bear both scaly and foliage leaves or needles. The dwarf shoot with needle is called foliar spur.

3.2.3 LEAF

Pinus plants possess two types of leaves: Scale leaves and Foliage leaves.

i. Scale leaves:

These are small, brown, membranous and borne on both long and dwarf shoot. These leaves are also known as cataphylls. They help in keeping branches moist by conserving water. At maturity of branches these leaves fall off.

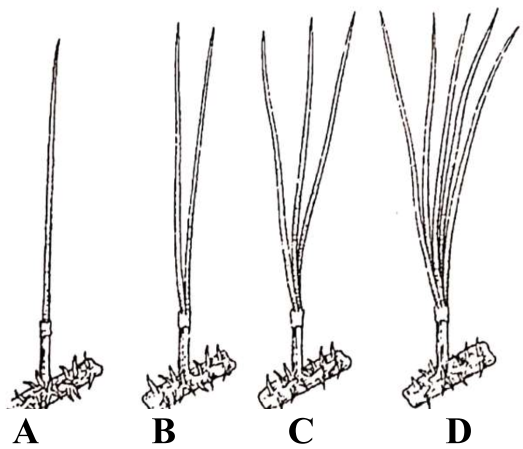


Fig. 3.2 Different types of foliar spur in *Pinus*
A. *P.monophylla* (monofoliar) **B.** *P..sylvestris* (bifoliar)
C. *P.gerardiana* (trifoliar) **D.** *P.excelsa* (Pentafoliar)

ii. Foliage leaves:

These leaves develop only on dwarf shoots. These are needle like, long acicular, smooth and green, photosynthetic and remain persistent for several years. The structure of leaves showing xerophytic adaption of the plant. The dwarf shoot with needle like foliage leaf is known as foliar spur. The number of needle in a spur varies from 1-5 in different species (Fig.3.2), as for example, *P.monophylla* is monofoliar , with single needle, *P.sylvestris* and *P.merkussi* are biofoliar with two needles *P. Longifolia* and *P.geradiana* are trifoliate with three needles, *P.quadrifolia* is quadrifoliar with four needles and *P.wallichiana* are pentafoliar with five needles.

SAQ 2:

1. Primary roots of *Pinus* covered by fungal hyphae i.e. ....which is..........
2. The stem of *Pinus* has two types of branches known as.........shoots or branches of ....growth and........shoots or branches of ....
3. .... of *Pinus* is also known as foliar spur.

3.3 INTERNAL CHARACTERISTICS

3.3.1 ROOT

The internal structure of young root is similar to that of a dicotyledonous root is as follows:

Epidermis: The root is surrounded by an outer piliferous layer, the epiblema, bearing unicellular root hairs. In young roots there is fungal growth of ectophytic mycorrhiza.

Cortex: Epiblema is followed by a wider zone of parenchymatous cortex made up of 4 to 5 or more layers.
Endodermis: The inner-most layer of cortex is single layered endodermis, have typical thickening bands on their radial walls of cells.
Pericycle: Multilayered pericycle is present just below the endodermis containing tannin and starch grains.
Vascular tissue: Vascular cylinder may be diarch to tetrarch. Radial vascular bundles are present. The protoxylem is exarch and slightly form 'Y' shaped structure and resin canal lies in between the two arms of the protoxylem. Xylem lacks vessels and phloem is lacking companion cells. The pith is parenchymatous if present usually ill developed. (Fig.3.3)

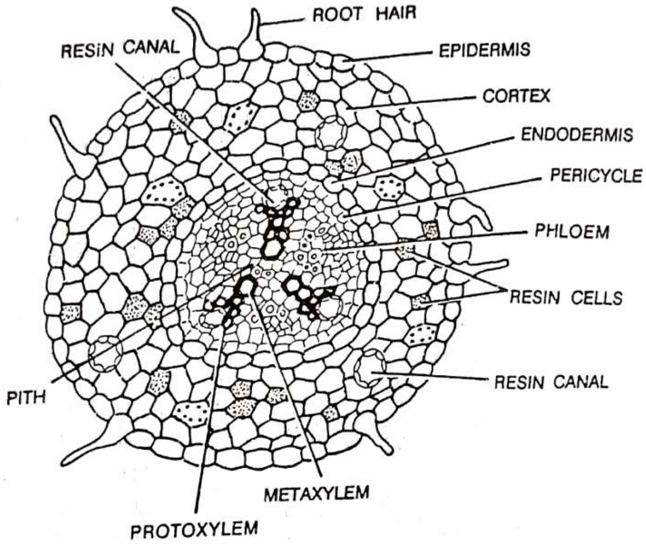


Fig. 3.3 T.S. of *Pinus* young root

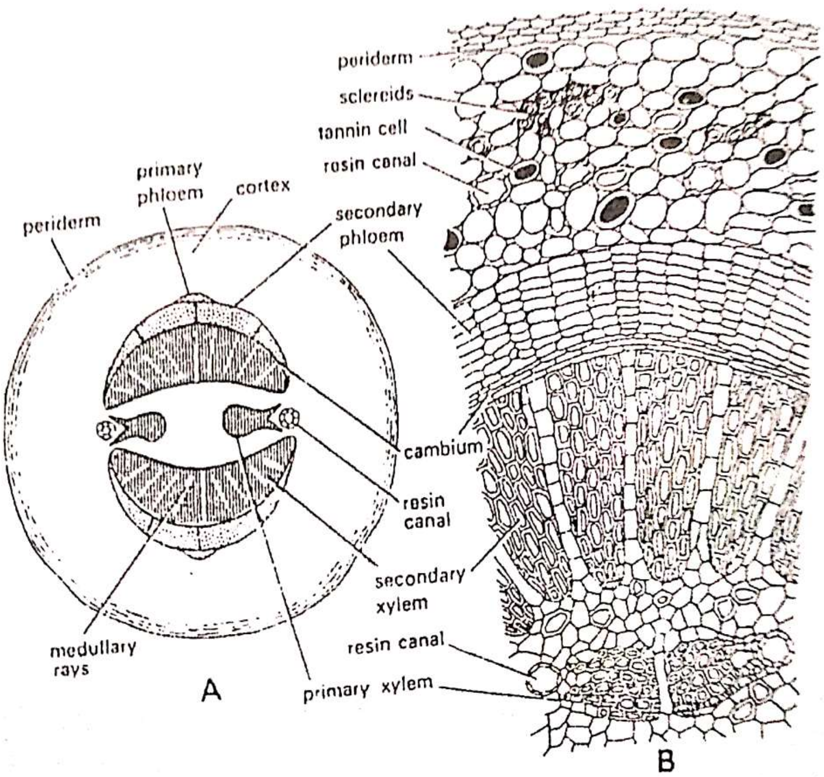


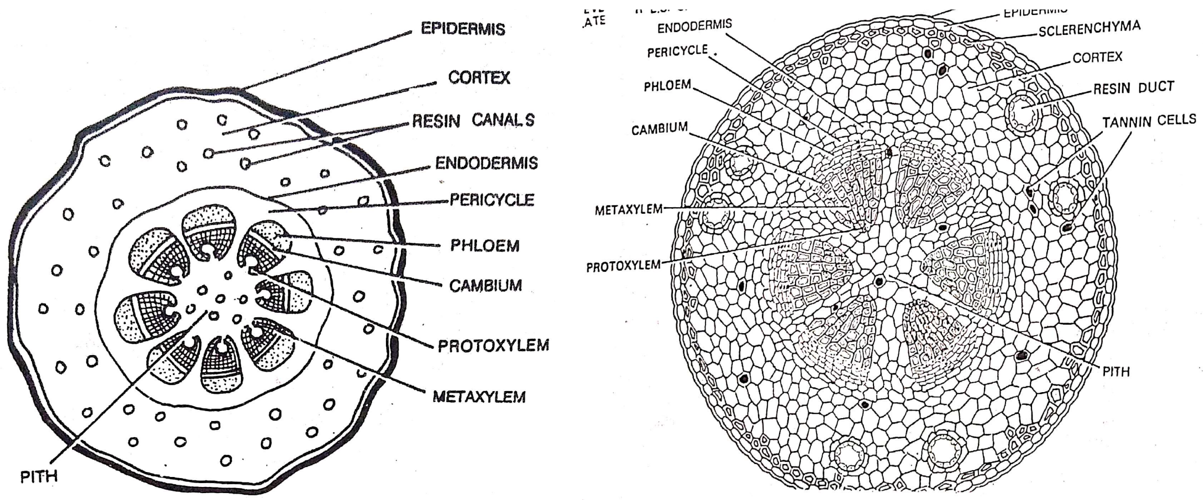
Fig. 3.4 T.S. of *Pinus* mature root showing secondary growth
A. Diagrammatic **B.** A part cellular

Secondary growth in root:

Secondary growth of root in *Pinus* resembles with dicotyledonous root. A band of cambium develops from parenchymatous cells in between the phloem and metaxylem. This cambium cuts secondary xylem toward inside and secondary phloem outside. Simultaneously cork cambium is formed from outer layer of pericycle, i.e. extra stelar secondary growth. The cork cambium (phellogen) cut off cork cells (phellem) on its outer side and secondary cortex (phelloderm) on its lower side. Periderm is constituted by phellem, phellogen and phelloderm. Lateral roots arise from inner layer of pericycle (Fig 3.4).

3.3.2 STEM

The internal structure of young stem of *Pinus* is more or less similar to dicot stem. In transverse section stem appears wavy or irregular in outline due to presence of leaf bases of the dwarf shoots. It is as follows (Fig.3.5):



A **B**

Fig.3.5 T.S. of *Pinus* Young Stem **A.** Diagrammatic **B.** Cellular

Epidermis: It is outermost layer composed of compactly arranged and heavily cutinised cells.

Cortex: Just below the epidermis there is broad zone of cortex. It may be differentiated into outer sclerenchymatous hypodermis consisting of lignified cells and inner parenchymatous cells containing chloroplast and resin canals. Each resin canal is bounded by 2-layered envelop of sclerotic cell followed by a layer of glandular, resin secreting epithelial cells.

Endodermis: It is the innermost layer of cortex. Next to endodermis is 2-3 layered indistinct pericycle.

Vascular tissue: The vascular cylinder is eustelic or polyfascicular siphonostelic type. It consists of a ring of 5 to 7 or more closely arranged conjoint, collateral open and endarch vascular bundles. The medullary rays lie between vascular bundles, which are narrow. The xylem consists of trachieds, vessels are absent. The protoxylem is endarch. The phloem consists of sieve cells with sieve plates and phloem parenchyma. Some albuminous cells are also present in the phloem. Companion cells are absent. Cambium cells are present between xylem and phloem.

Pith: A parenchymatous pith is present in the centre of the stem. Some of the pith cells are filled with resinous substances.

Secondary growth in stem:

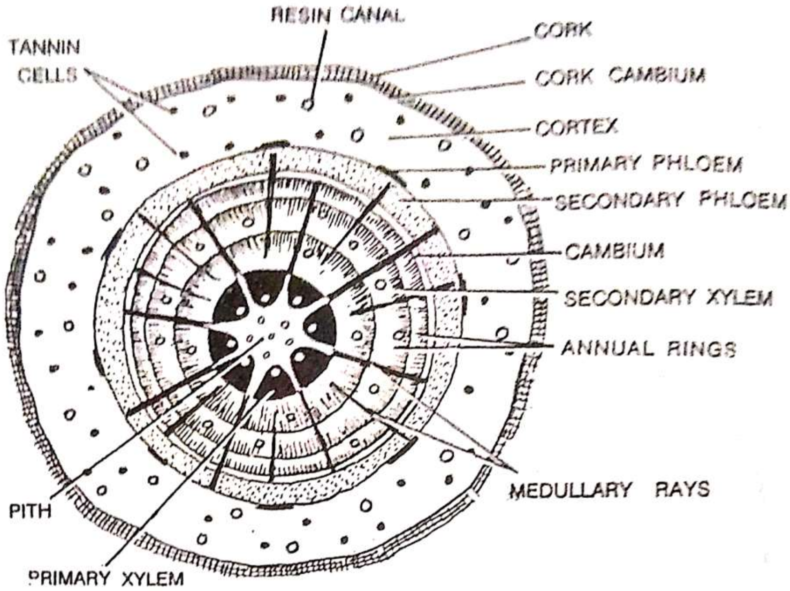


Fig.3.6. T.S. of *Pinus* old Stem showing secondary growth (Diagrammatic)

Secondary growth in the *pinus* stem takes place more or less in the same way as in dicot stem (Fig.3.6). Intrafascicular cambium develops in the medullary rays in between vascular bundles. The strip of inter fascicular cambium joins with intra fascicular cambium present in vascular bundles and form a complete ring of cambium. Cambium cuts of secondary xylem on its inner and secondary phloem on its outerside (Fig3.7). These zones are traversed by medullary rays. The secondary wood shows well marked growth rings which are formed annually due to seasonal impact. Each annual ring possesses a zone of spring and autumn wood. In autumn, there is less supply of food material and therefore, the tracheids formed in autumn are quite smaller in size while in spring there is abundant supply of food material and larger trachieds are formed. The wall of autumn tracheids is much thicker than those of spring tracheids.

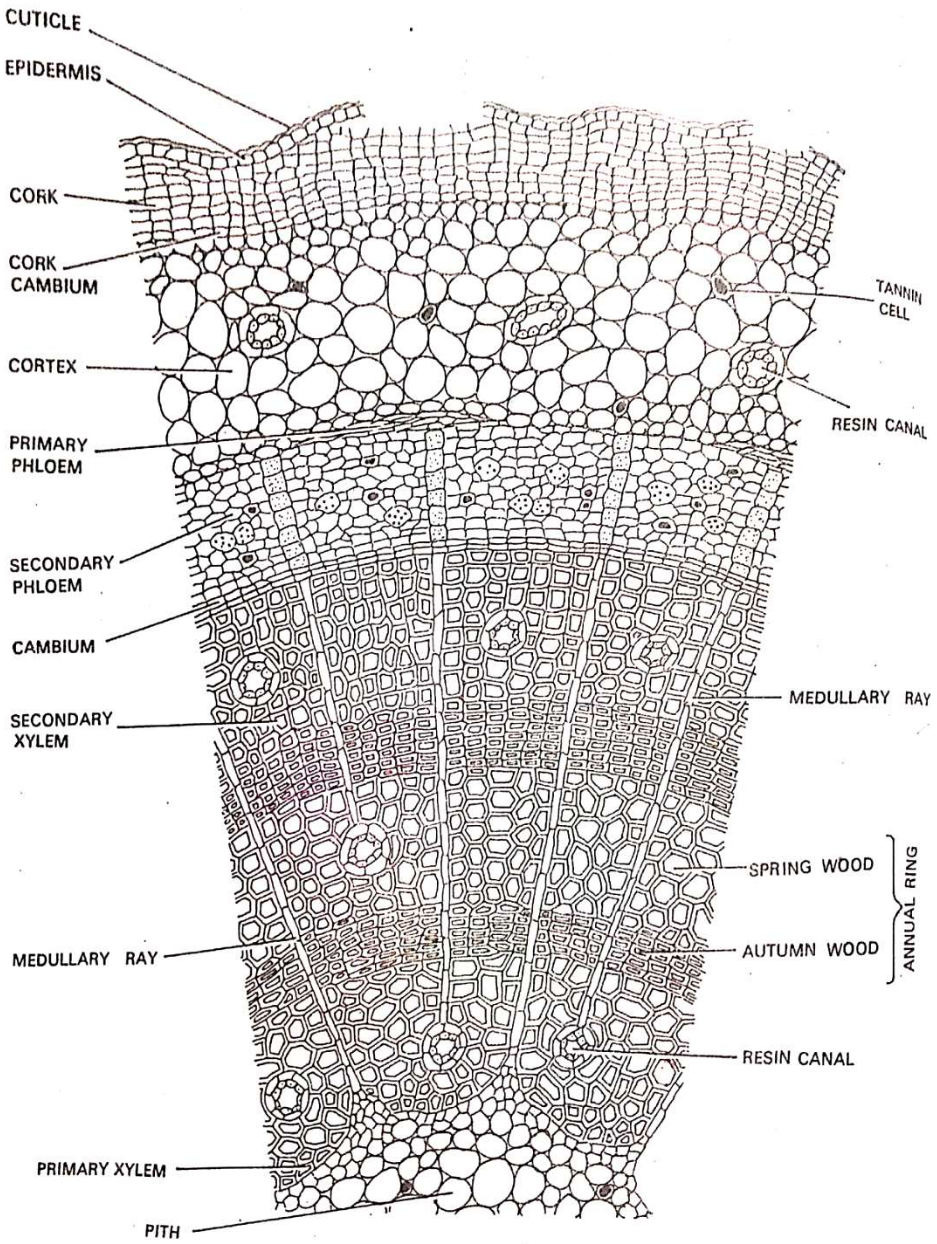


Fig. 3.7 T.S. of *Pinus* old stem showing secondary growth (a part cellular)

The age of plant can be estimated by counting the annual rings. The wood is dense and massive and known as pycnoxylic wood.

Secondary wood consist of tracheids, traversed by rays. Resin canals occur frequently in secondary wood. (Fig.3.7). Each resin canal has its outer layer of sclerenchymatous cells and an inner layer of glandular epithelial cells. Epithelial cells secrete resinous substance like turpentine etc. Resin canals are also present in multiseriate xylem rays.

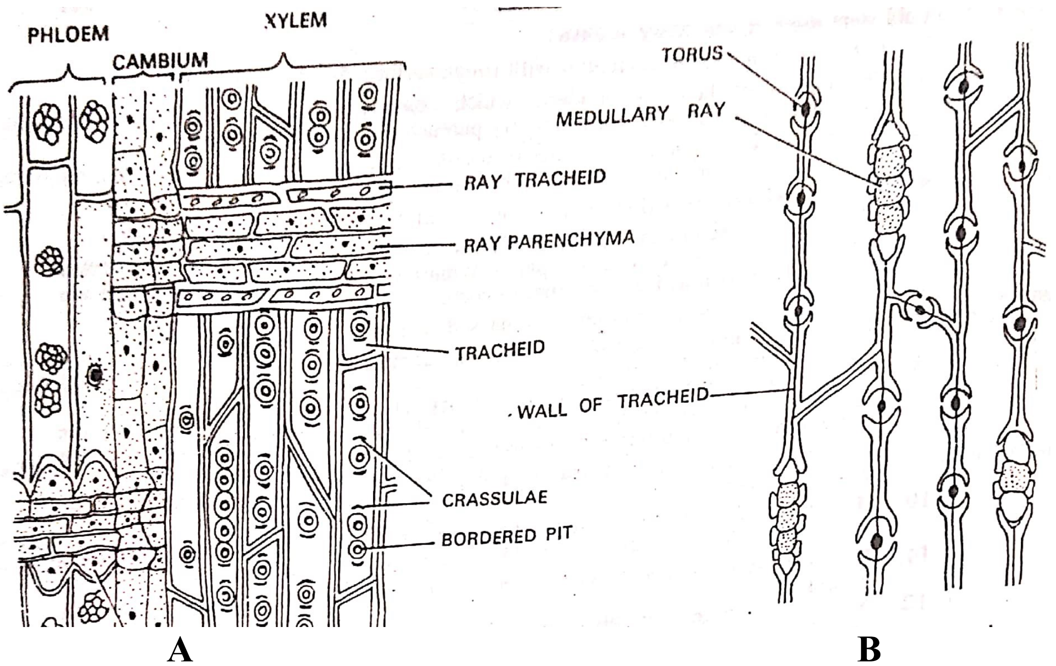


Fig. 3.8 A. R.L.S. of *Pinus* Long Shoot **B**. T.L.S. of *Pinus* Long Shoot

A meristematic layer also develops (like cambium) in the cortex known as cork cambium (phellogen). It cuts off cork (phellem) on its outer and secondary cortex (phelloderm) on its inner side. The cork is impervious to water and serves as bark to protect the stem.

An important characteristic feature of wood of *Pinus* is presence of bars of sanio or crassullae. They occur in the form of crescentic bars in between the pits. These bars are formed by the deposition of cellulose and pectin on tracheid walls. As the wood matures, these bars are separated from the pits; the bars of the adjacent pits are fused to forms bars of sanio.

The secondary vascular tissues are traversed by parenchymatous secondary medullary rays which extend from the pith to cortex. They formed by cambial cells. The medullary rays are uniseriated and when they are associated with resin canals are multiserriate. In radial longitudinal sections (R.L.S) medullary rays are cut length wise and thus revealing their length and height (Fig.3.8 A). In tangential longitudinal section, (T.L.S) they are cut transversely and their height and breath can thus be noticed (Fig.3.8B). The structure of medullary rays is different in secondary xylem and secondary phloem region. In secondary xylem, the rays consist of thin-walled a starch-filled living cell, having simple pits. On both the side of these cell are present radially elongated thick, walled cell, with simple pits called tracheidal cells which help in the diffusion of the sap. The structure of medullary rays in the phloem is slightly different. In this region medullary rays consist of usual rectangular medullary ray cells containing starch bounded on the upper and lower side by albuminous cells. The rays tracheids as found in xylem region are absent here.

3.2.3 LEAF (NEEDLE)

In transverse section the outline of the foliage leaf varies i.e. circular in (monofoliar) *P. monophila*, semicircular in bifoliar and triangular in trifoliar, and pentagonal in pentafoliar spurs. The needle of trifoliar spur of *P.roxburghii* is triangular in transverse section. (Fig.3.9).

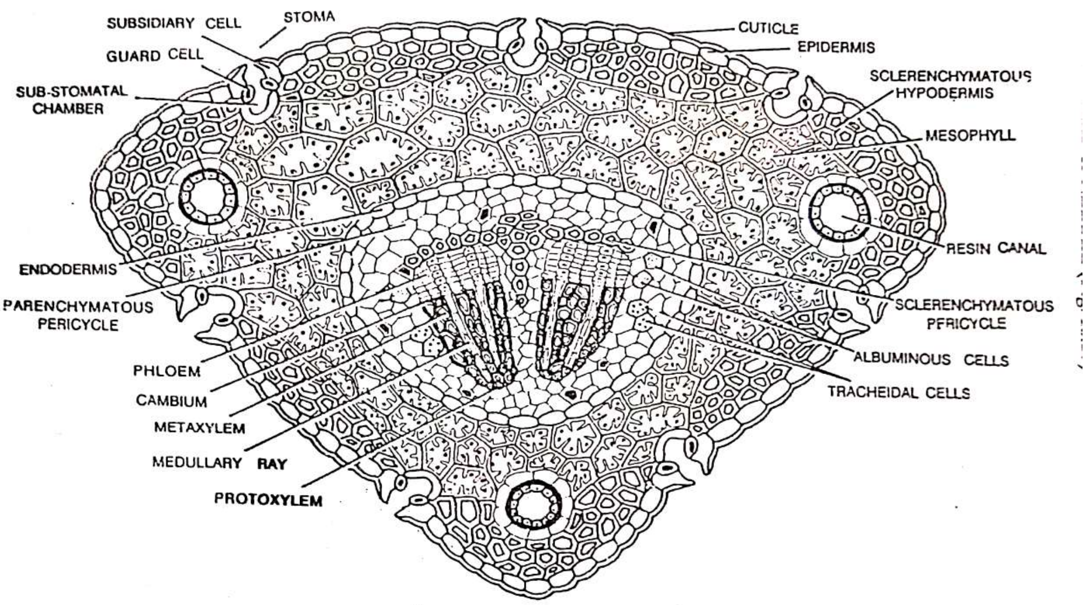


Fig.3.9 T.S. of *Pinus* needle (foliage leaf)

Epidermis: It is single layered and consists of heavily cutinised thick walled cells and deeply sunken stomata. The guard cells are sunken and covered by subsidiary cells which have modified epidermal cells. Stomata are haplochelic.

Hypodermis: 2-3 layered sclerenchymatous hypodermis is present below the epidermis which is interrupted by presence of substomatal cavities. The hypodermis is several layered at the corners.

Mesophyll: It is parenchymatous and not differentiated into palisade and spongy tissues between hypodermis and endodermis. These cells contain a large number of chloroplasts and starch grains. The walls of mesophyll cells give rise to many peg-like infoldings which increases photosynthetic area of these cells. Some mesophyll cells have resins.

Endodermis: Endodermis is quite prominent and is composed of barrel shaped cells with casparian strips.

Pericycle: Multilayered pericycle lies just below the endodermis. Most of the pericycle cells composed of parenchymatous cells rich in protein and known as albuminous cells which are present above the phloem of vascular bundles. The remaining tissues within the sheath is the *'transfussion tissue'* which consist of the two type of cells: I- trachiedial cells that have broderd pits and lie adjacent to the xylem and extending further, serve to conduct water from xylem to mesophyll and II- parenchymatous cells which are intermediate in between the mesophyll and the phloem, help in transfer of food.

Vascular bundles: The central portion of needle is occupied by vascular cylinder. Each bundle is collateral, open, and endarch with abaxial phloem and adaxial xylem. Xylem consists of radial rows of cells and phloem of sieve tubes and phloem parenchyma. Companion cells are absent.

SAQ 3:

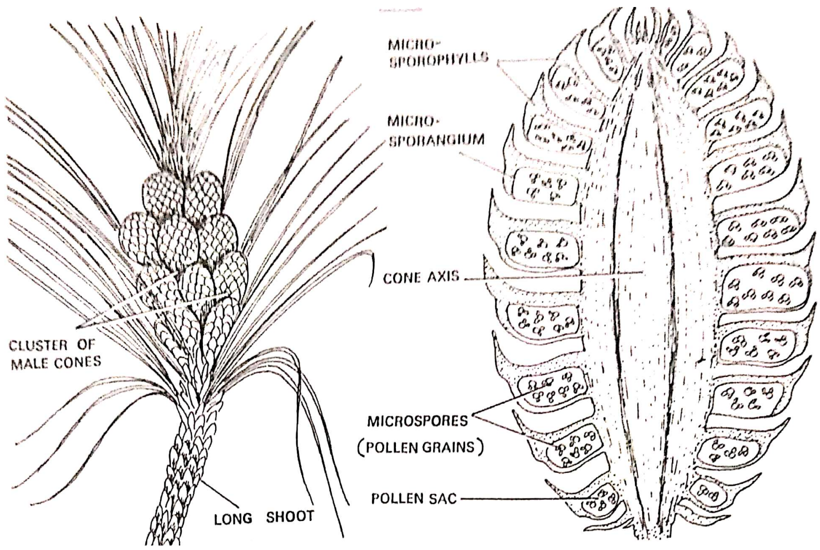
1. In case of *Pinus* xylem lacks .... and phloem is lacking of ....
2. An important characteristic feature of wood of *Pinus* is presence of bars of ....or........
3. The stomata of *Pinus* needle are ....

3.4 LIFE CYCLE: REPRODUCTION

Pinus plants are monoecious i.e., both male and female strobili (cones) are produced on the same plant but on different branches. It is heterosporous i.e. two type of spores microspores and megaspores which are present inside microporangia and megasporangia on male and female sporophylls arranged in male and female strobili or cone respectively. Cones are usually monospornagiate (with one type of sporangia) but rarely bisporangiate strobilus i.e. with both micro and megasporophylls are present together as in some species e.g., *P.roxburghii, P.montana.*

3.4.1 MALE CONE OR STROBILUS

The male strobili (cones) are produced earlier than the female strobili, in January on plains and in March on hills. Male strobili or staminate strobili develop in cluster from the branches of unlimited growth (long shoots) in place of branches of limited growth (dwarf or spur shoots) arise separately in the axil of scale leave which falls of later . They are produced just behind the apical bud of the lower branches; the apical growth may persist even after their production. Each male strobilus is a small ovoid structure and is about 3 to 4 cm long and 0.65cm in diameter (*P.roxburghii*) at younger stage and covered externally by bracts. Each strobilus has large number of scaly microsporophylls arranged in a spiral manner around the short central axis forming a compact structure called male cone (Fig 3.10).



A. **B.**

Fig. 3.10 *Pinus* **A.** Branch showing cluster of male cone
B. L.S. of a male cone (Diagrammatic)

MICROSPOROPHYLLS (STAMENS)

Each microsporophyll is a small, brown, scaly and triangular structure consisting of a short stalk and leaf like expansion with two microsporangia (pollen sac) on the lower (abaxial) surface. The terminal part of expanded structure of the microsporophyll, the apophysis, extends overlapping the above lying microsporophyll and downwards covering the microsporangia. Microsporophylls arise at the right angle to the central axis of male strobilus. Some of the basal microsporophylls of the male strobilus are fertile while the remaining upper ones are sterile (Fig.3.11).

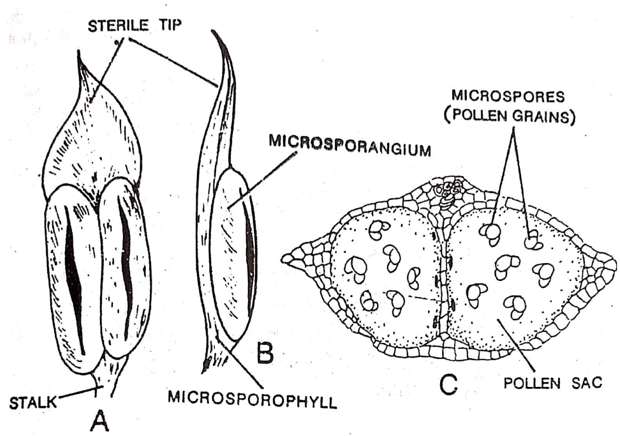


Fig.3.11 *Pinus* Microsporophyll **A.** Front view **B.** Side view **C.** T. S. through microsporangia

DEVELOPMENT OF MICROSPORANGIUM

Microsporangia are eusporangiate in development. Each sporangium develops from a small group of hypodermal cells known as archesporium. Archesporium devides periclinally and differentiated into outer primary wall cell and inner sporogenous cells. The primary wall cells undergo several division and formed 2-4 layered sporangial wall. The inner most layer of sporangium wall is differentiated into nutritive layer, known as tapetum. The cells of sporogenous tissue separate from each other and function as microspore mother cells. Each microspore mother cell divides meiotically to form four haploid microspores or pollen grains (Fig 3.12).

STRUCTURE OF MATURE MICROSPORANGIUM

A pair of microsporangia (pollen sacs) occurs on the lower (abaxial) surface of the microsporophyll. Each microsporangium is a small sessile and elongated sac like structure having two layered wall surrounded by epidermis. Tapetum the nourishing tissue is the innermost layered enclosing a cavity of the microsporangium in which large number of the dusty and two winged microspore (pollen grains) are present (Fig.3.12 H). Microsporangia on their dorsal side have longitudinal slit for dehiscence.

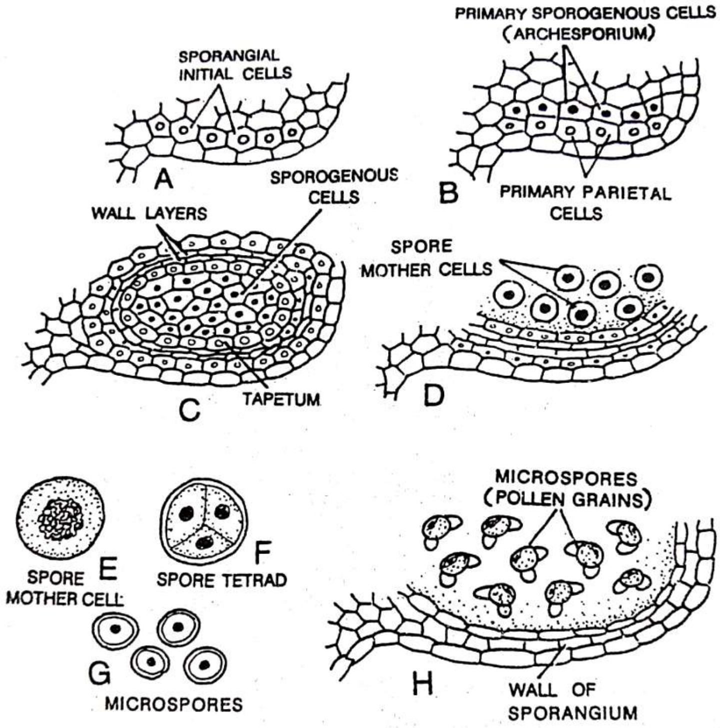


Fig.3.12 *Pinus* **A-H** Development of Microspores

DEHISCENCE OF MICROSPORANGIUM AND DISPERSAL OF MICROSPORES (POLLEN GRAINS)

The wall of microsporangium bursts at maturity from underside thus forming a longitudinal slit. A large number of pale yellow winged pollen grains are released from the slit forming yellow cloud which is called 'Shower of Sulphur'. Their dispersal takes place in hot dry weather from March to beginning of June in our country. When the microsporangia become empty, the male strobilus withers and falls off.

3.4.2 FEMALE CONE OR STROBILUS (OVULATE STROBILUS).

The female strobili (cones) take three years to become completely mature. They are initiated in the month of February in plains and in May on the hills. The female strobilus unlike the male strobilus is a complicated structure produced laterally in the axil of the scale leaf on the branches that lack male strobili. One or clusters of two to four cones are borne on a shoot from places where normally dwarf or spur shoots would have developed. These strobili begin to develop during winter and are ready for pollination in the following spring. One year old cone is very small and redish green structure about 1cm long (Fig.3.13A). In the second year it enlarges but the sporophylls remain intact (Fig.3.13B). In the third year it becomes fully mature and at the end of the third year it forms the seeds (Fig.3.13C). After that the central axis elongates as a result of which sporophylls, get separated from the each other leaving the space through which pollen grain reach the ovules.

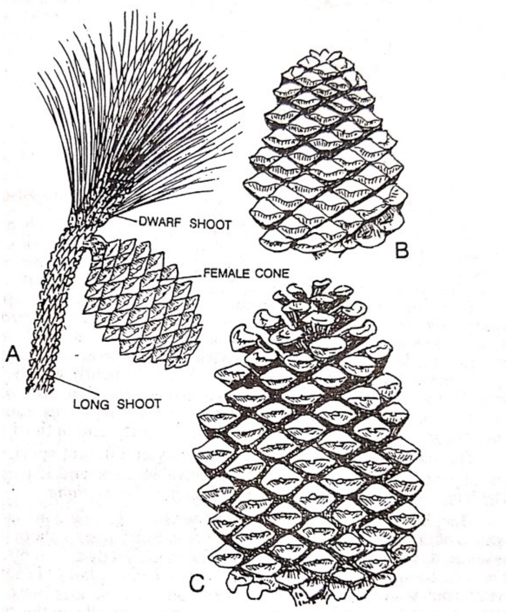
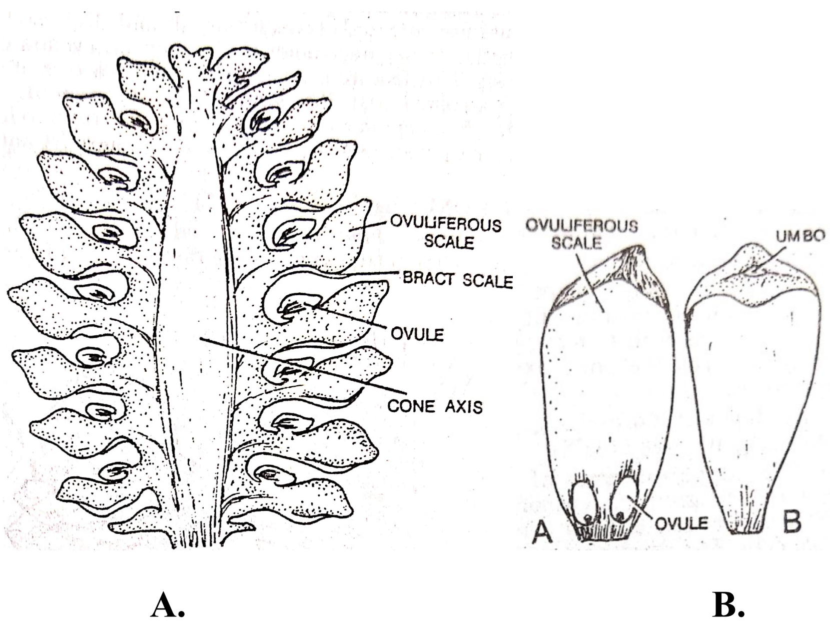


Fig.3.13 *Pinus* Female Cone **A.** One year old **B.** Two years old **C.** Three years old

Each female strobilus is somewhat elongated cylindrical structure with an elongated central axis, round which are present a large number of megasporophylls arrange in spiral manner acropetally. Some of the megasporophylls lying at the base are smaller and sterile. The female strobilus represents inflorescence because the ovule bearing structure (ovuliferous scales) are not borne, directly upon the central axis of the strobilus but the scaly structure, the bract scales which turn are borne on the central axis and are arranged spirally. The female cones are about 15-20 cm long (Fig.3.14).

Each megasporophyll is differentiated into two parts:

1. ***Bract Scale (lower part):*** This is small dry membranous structure which is directly attached with the cone axis. It occurs just below the ovuliferous scale. They are also named as carpellary or cover scales. When the strobilus matures these become rolled up and help in the dispersal of seed.
2. ***Ovuliferous scales (upper part):*** This is a stout woody and brownish structure borne on dorsal side of bract scales. Each ovuliferous scale is more or less triangular with a terminal border portion, the apophysis and a narrow basal part. The apophysis appear to be rhomboidal when viewed from the outside and possesses a small central point known as umbo. Each ovuiferous scale on the dorsal side near the base possesses two ovules with their micropyle directed towards the strobilus axis (Fig.3.14B).



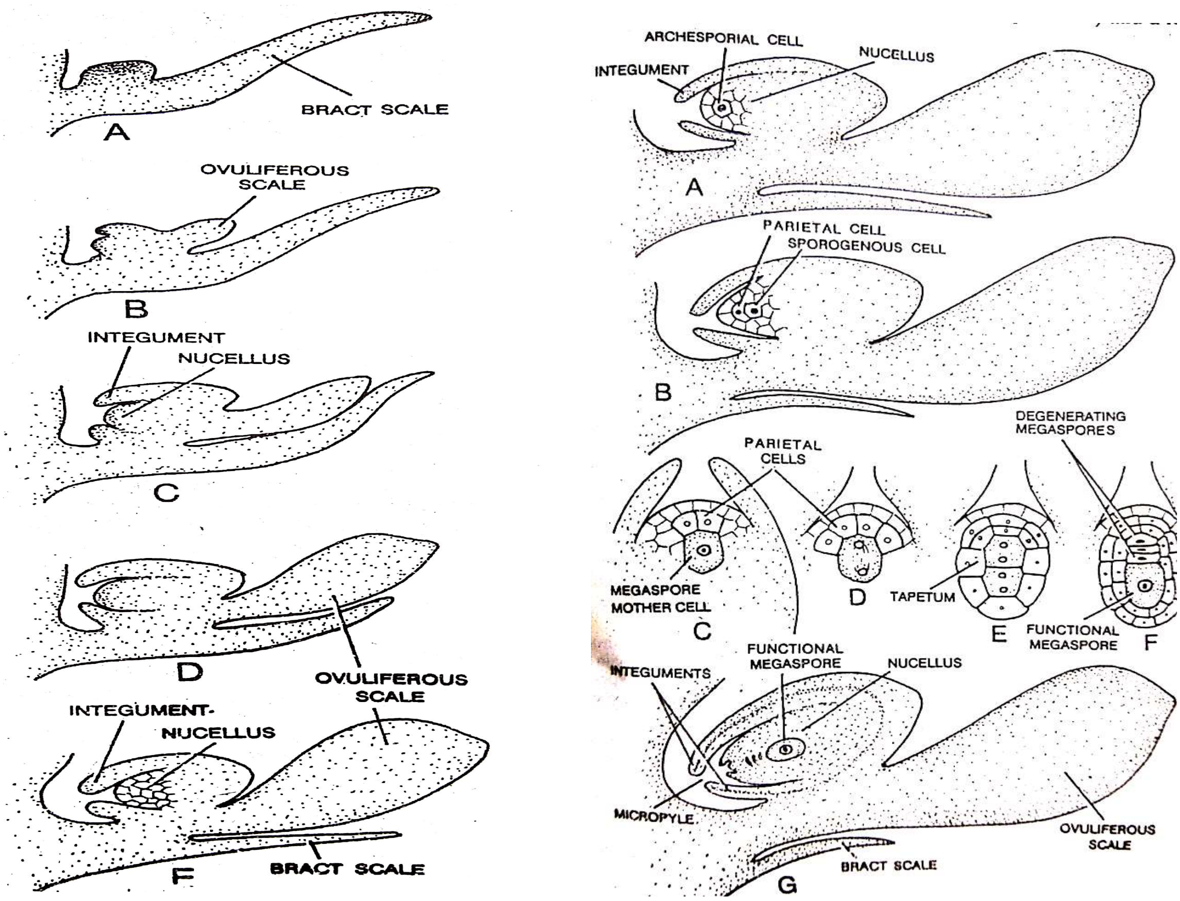
A. **B.**

Fig. 3.14 A. L.S. of Female cone of *Pinus* (Diagrammatic)
B. Ovuliferous Scale A. Dorsal side B. Ventral Side

Before the pollination bract scales are longer than ovuliferous scales but the later soon outgrows the former. Soon after pollination female strobilus slowly turns upside down causing the megasporophylls to come very close to each other. Thus the strobilus becomes closed and soon enlarged. When the strobilus are young the double nature of the scale can be easily marked out but in adult condition the two are closely appressed.

DEVELOPMENT OF MEGASPORANGIUM OR OVULE

The development of ovule is eusporangiate type i.e. it develops from the group of superficial initial cells. Ovules arise on the dorsal surface of ovuliferous scale as a small protuberance which increases in size and becomes the nucellus. The neighbouring cells at the base of the nucellus become meristematic, they grow upwards and form integument (Fig.3.15A). The integument surrounds the nucellus except at the top, where a small pore is left known as micropyle. The micropyle is directed toward the base of ovuliferous scale.



A. **B.**

Fig.3.15 A. Early stages of development of ovule (A-F)
B. Development of megaspore and ovule (A-G)

At the apex of the nucellus a hypodermal cell become enlarged and differentiated from other cells. It is called archesporial cell. It divides by periclinal wall to form an upper parietal cell and lower megaspore mother cell. The parietal cell divides to form a nutritive layer, known as tapetum. The megaspore mother cell divide meiotically and four haploid megaspore are formed. The three megaspores towards micropylar end degenerate and the remaining one is functional megaspore (fig.3.15 B).

STRUCTURE OF OVULE OR MEGASPORANGIUM

Pinus ovule is orthotropous like other gymnosperms has following structure: (Fig.3.16)

a. *Nucellus* – It is the massive and parenchymatous region of the ovule.
b. *Integument*- It is the thick protective covering around the nucellus. It has very narrow aperture at the apex of nucellus known as micropyle. The integument is differentiated into the three layer; the outer and inner layers are fleshy and the middle layer is stony. In upper part of ovule a space is formed in between integument and nucellus. This space is known as pollen chamber.

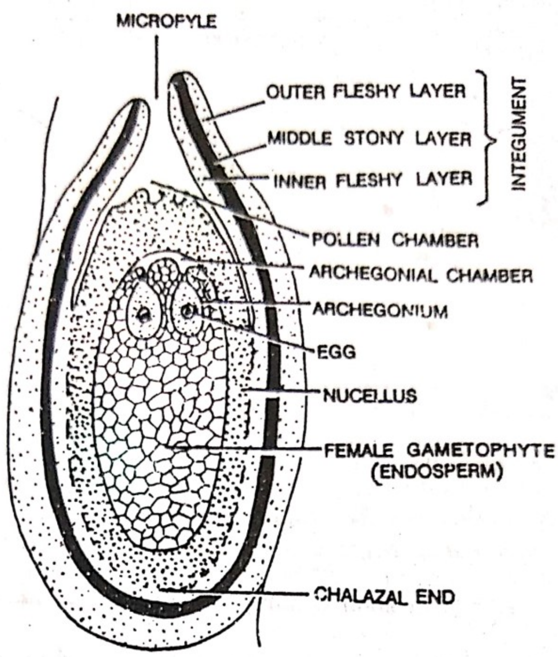


Fig.3.16 L.S. of mature ovule of *Pinus*

3.4.3 THE GAMETOPHYE

Pinus is a heterosporous plant bearing microspores (pollen grain) and megaspores which develop in microporangium and megasporangium respectively. Both generation, divide reductionally while still in the sporangium to produce large number of functional microspore and four megaspores. Microspore and megaspore represent the first stage of the gametophytic generation.

3.4.3.1 MALE GAMETOPHYTE

The microspores (pollen grains) the initial stage or unit of male gametophyte, is a uninucleate structure with two asymmetrically placed air-bladder. The air bladder which is also known as wing or saccus arises on the lateral sides. Each pollen grain has a cuticularised outer layer exine and an inner thin layer called intine. The outer wall of the wing has a reticulate sculpture. Male gametophyte partially develops in the microsporangium and partially in the ovule.

DEVELOPMENT OF MALE GAMETOPHYTE WITHIN THE MICROSPORANGIUM: (BEFORE POLLINATION)

The nucleus of microspore divides and a wall is laid forming a small lens shaped cell called first prothallial cell and a large apical cell. The apical cell divides again to form a second prothallial cell covering the first prothallial cell and a large cell called antheridial cell. The antheridial cell divides into two a generative cell adjacent to second prothallial cell and tube cell (Fig.3.17A-G).

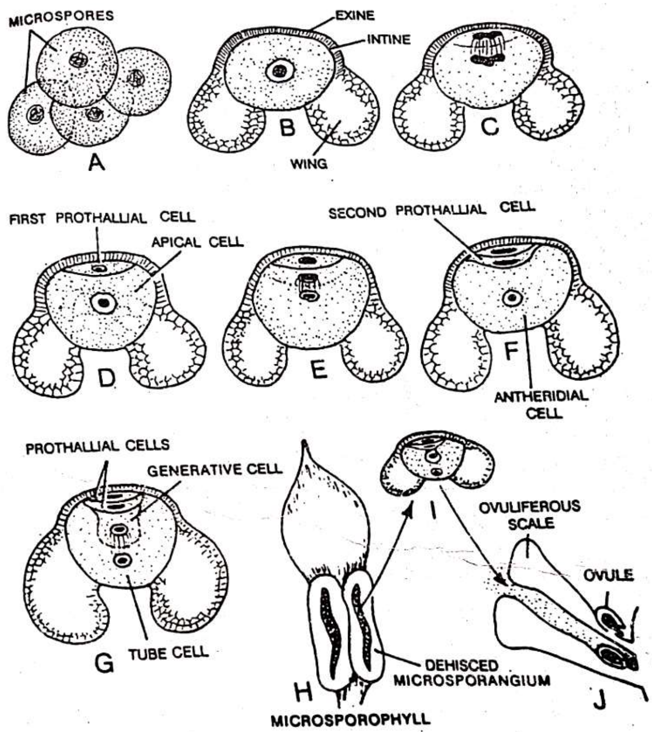


Fig.3.17 *Pinus*: **A-G** Development of male gametophyte before pollination **H-J** Pollination

POLLINATION IN *PINUS*

The pollination is anemophilous i.e. pollen grains are carried to ovule through wind. A secretion oozing out of the micropyle entangles the pollengrains. Then it is sucked inside along with the pollen grains. The pollen grains are thus collected in the pollenchamber at the tip of nucellus. Pollen grains are shed in four celled stage and further development takes place in the ovule (Fig.3.17H-J) and remain inactive for about 11months. Thereafter the mouth of micropyle is closed.

DEVELOPMENT OF MALE GAMETOPHYTE AFTER POLLINATION

The exine of the male gametophyte ruptures and intine protrudes out to form a tube called pollen tube. The tube nucleus moves down into pollen tube tip. The generative cell divides into two cells, stalk cell and body cell. The body cell passes into the pollen tube. The wall of stalk cell disintegrates and its nucleus also passes into pollen tube (Fig.3.18).

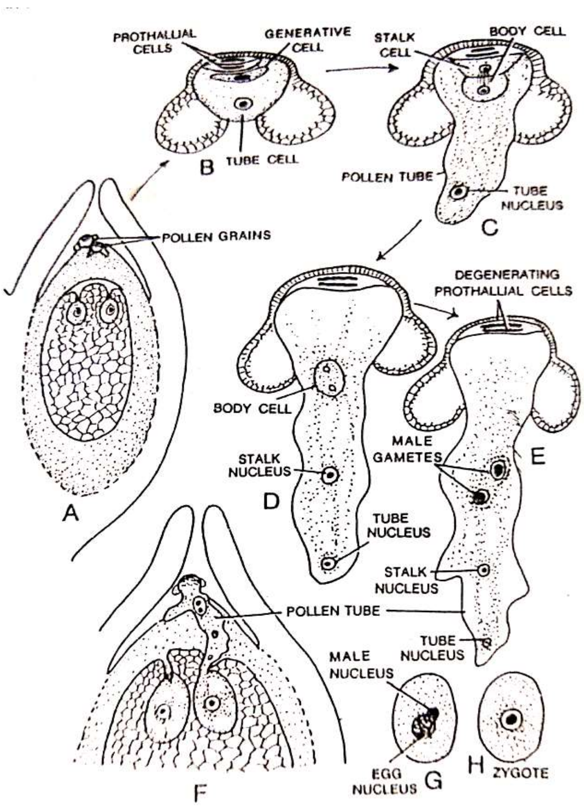


Fig.3.18 *Pinus*: **A-E.** Development of male gametophyte after pollination **F-G** Fertilization **H.** Zygote

Just before fertilization the body cell divides to produce two male gametes which are small non cilliated and short lived. The pollen tube apex may be unbranched or branched.

3.4.3.2 FEMALE GAMETOPHYTE

DEVELOPMENT OF FEMALE GAMETOPHYTE

The functional megaspore is the first cell of the female gametophytic generation. The megaspore increase in size and its nucleus undergoes many free nuclear division producing about 2000 free nuclei. Avacuole appear in the centre. Later this vacuole disappears and wall formation starts centripetally. Thus by these division a multicellular tissue is differentiated. This is female prothallus or endosperm (Fig.3.19A-I),

As in other gymnosperms the development of endosperm in *Pinus* occur before fertilization and hence it is haploid structure (in angiosperms it is triploid structure).

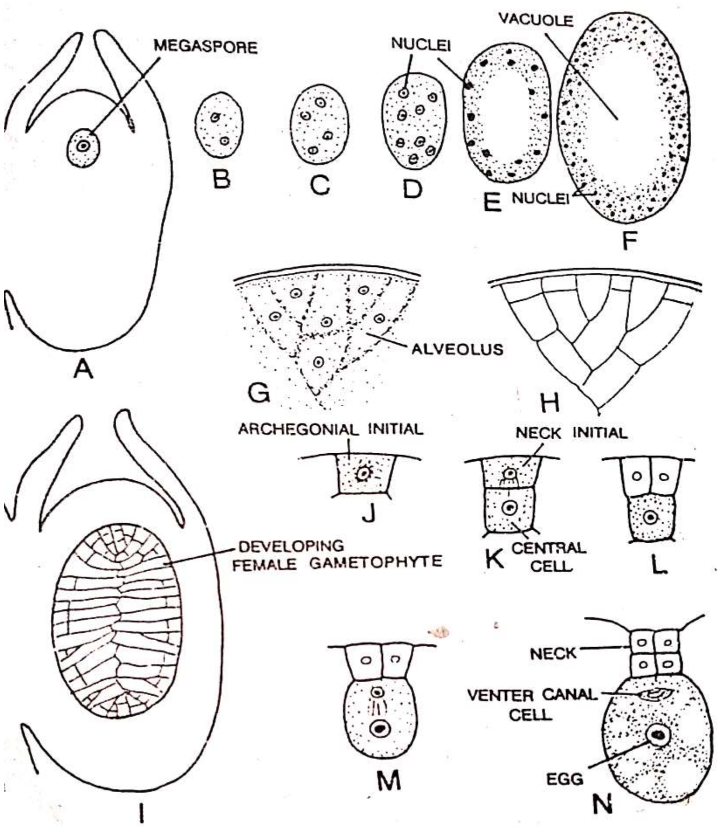


Fig.3.19 *Pinus* **A-I** Development of Female Gametophyte
J-N Development of Archegonium

DEVELOPMENT OF ARCHEGONIUM

Usually 2-5 archegonia develop at micropylar end from the superficial cells of female gametophyte. These cells become enlarged and are called archegonial initial. Each archegonial initial divides to form a neck cell and a large central cell. The primary neck cell divides by successive vertical division at right angles to each other followed by transverse division of each cell forming an eight celled neck arranged in two tier. The central cell divides to form a small ventral canal cell which seperates by wall from a large egg (Fig.3.19J-N).The division takes place just before fertilization. The nucleus of venter canal cell degenerates just before fertilization.

3.4.4 FERTILIZATION

Fertilization takes place after about an year of pollination. The pollen tube laden with a nucleus, one stalk nucleus and two sperms, gradually elongates and digests its way finally reaching near the tip of archegonia. It forcibly penetrates the neck and reaches near the egg. The tip of the pollen tube soon bursts and both the male gametes (sperms) become free. Only one of the male gamete, however, fuses with the egg and forms the zygote (oospores) the other gamete along with tube and stalk cell disintegrates. Fertilization is usually completed by the end of June. The diploid oospore represents the first cell of sporophytic generation (3.18F-G).

3.4.5 THE NEW SPOROPHYTE (EMBRYO)

The Development of young sporophyte (embryo) from oospore or zygote:

The oospore nucleus divides twice mitotically into four nuclei, which migrate toward the base. They arrange in one plane (only two are seen laterally) and divides again forming eight free nuclei, which become arranged in two tier of four nuclei each . Wall formation takes place forming lower (apical) tier and upper (open) tier. Both the tiers divide again giving rise to four tiered peoembryo. At this stage proembryo consists of 16 cells arranged in the four tier (Fig.3.20). Each tier has a specific function:

1. Embryonal tier (four cells): is the lower most tier and its cells divide to form embryo.
2. Suspensor tier (four cells above the lower tier): which elongates and gives rise to long suspensor.
3. Rossete tier (four cells above the suspensor tier), which conduct nourishment to embryo.
4. Nutritive tier: It is uppermost tier remain open above and provide nutrition to the remaining proembryo.

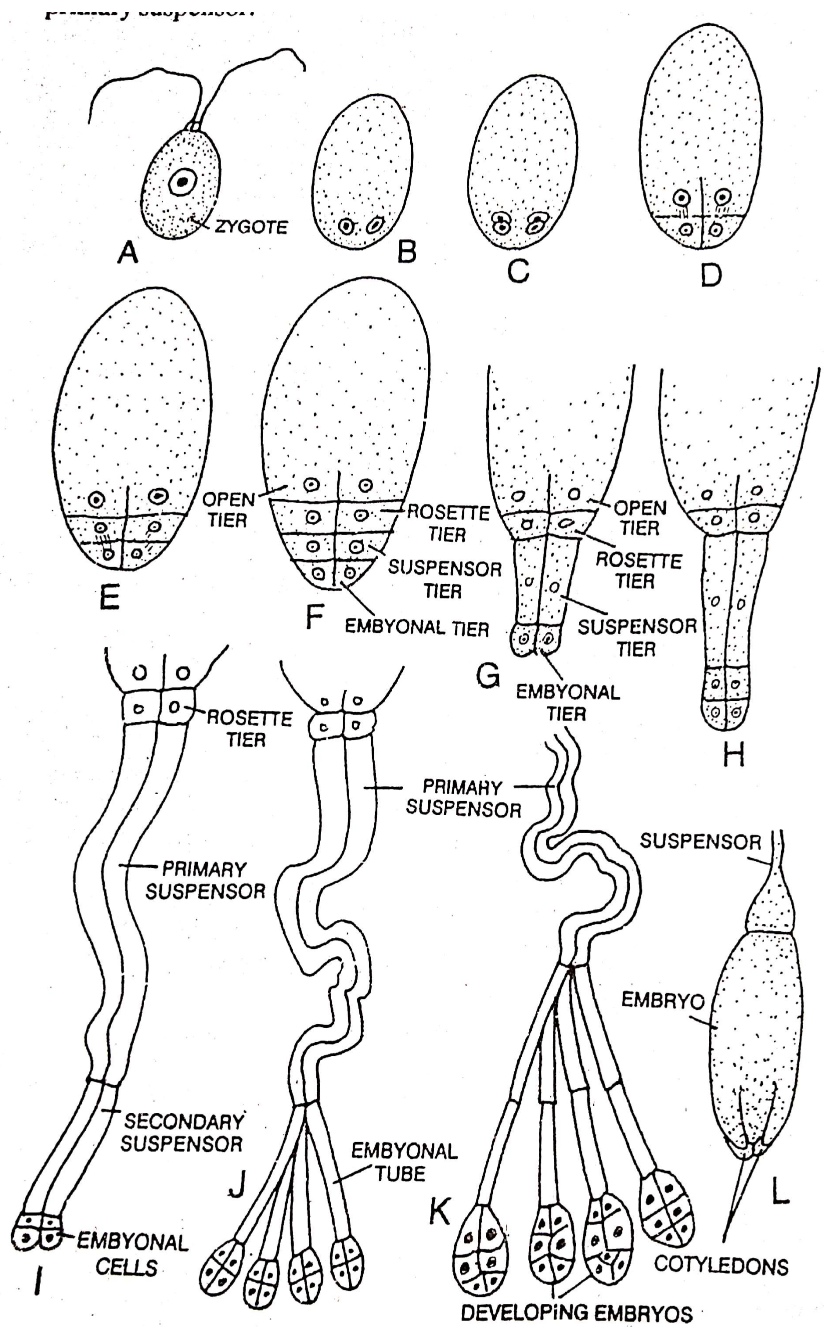


Fig. 3.20 *Pinus*: Development of Embryo

All the four cells of the suspensor tier elongate very much and soon become very long and tortuous .The embryonal cells are thrust down into food containing cells of endosperm.

The cells of the embryonal tier divide and interpose another tier between them and primary suspensor cells thus forming secondary suspensor cells (embryonal tubes). All the four cells of embryonal tier separate from one another and develop into four independent embryos. The formation of the more than one embryos from one oospore is called **cleavage polyembryony.** In *Pinus,* as the polyembryony occurs by splitting of zygote, it is known as cleavage polyembryony. Another type of polyembrony found in *Pinus* is simple polyembryony (when more than one emboryos are developed as a result of fertilization of different archegonia). In *Pinus* both types of polyembryony are found but at maturity seed contains only one embryo as food is not sufficient for the survival of many embryos.

The mature embryo is differentiated into the following parts (Fig.3.21A)

(a) Cotyledons: Three to eighteen cotyledons
(b) Plumule: Remain hidden in between the cotyledon and gives rise to shoot.
(c) Radicle; Lies towards the micropyle and gives rise to root.
(d) Hypocotyls, present in between plumule and radical

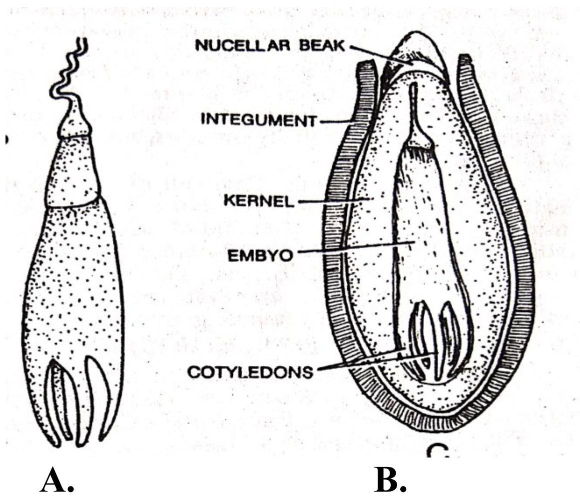


Fig.3.21 *Pinus*: **A.** Mature Embryo **B.** L.S. of Seed

3.4.6 SEED FORMATION

The seed is covered over with a hard shell (seed coat). The outer part of seed coat is testa (developed from middle stony layer: (outer integument disintegrates). Testa encloses a brown papery tegmen developed from inner fleshy layer. The tegmen surrounds white fleshy endosperm (female gametophyte). A nuclear cap is present toward the pointed end of endosperm and represents the remains of nucellus. Embryo is enclosed by the endosperm.

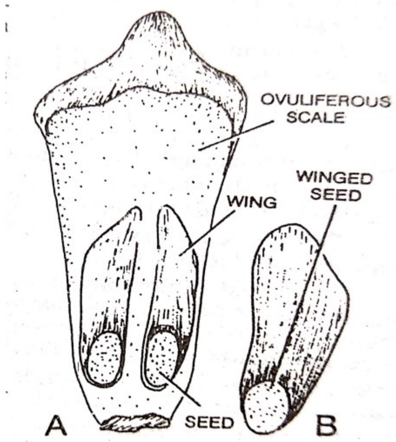


Fig.3.22 *Pinus*: **A.** Two Winged Seeds with Ovuliferous Scale **B.** Single Seed

As the seed matures a thin layer of ovuliferous scale fused with the testa of the seed in the form of a wing (Fig.3.22) helps in the dispersal of seed. At maturity the axis of the female cone enlarges and cone dries due to which scales are separated which help in the dispersal of seed by wind. The mature seed thus represent three generations

1. Old sporophyte: Testa, tegmen and nucellus.
2. Gametophyte : Endosperm (Female gametophyte)
3. New sporophyte Embryo.

3.4.7 SEED GERMINATION

Seeds of *Pinus* may germinate immediately without undergoing resting period during favourable conditions. Though they may remain viable and dormant for several years under unfavourable conditions. The cotyledons come outside the soil surface by elongation of hypocotyls i.e. germination is epigeal (Fig.3.14). The seed coat ruptures by absorbing water,radical comes out through the micropyler aperture and entres the soil. The radical forms primary tap root. Thereafter plumule emerges out and develops a shoot with spirally arranged juvenile leaves.

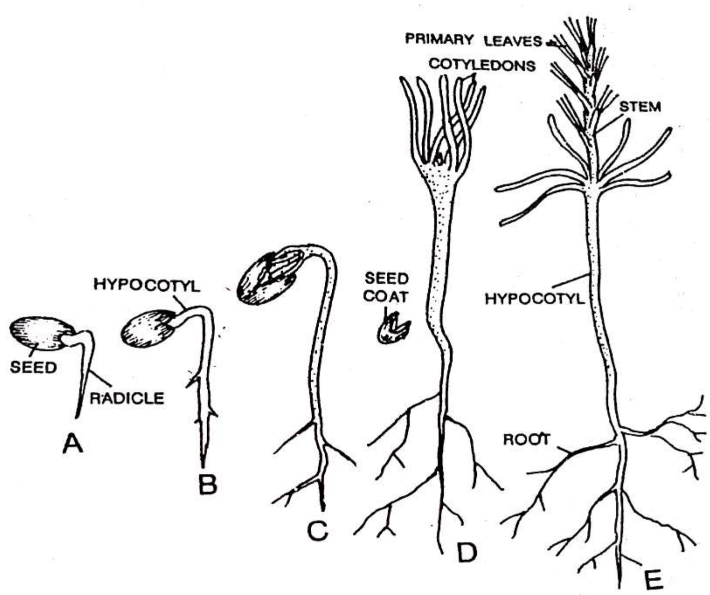


Fig.3.23 *Pinus*: **A-E** Germination of Seed

SAQ 4:

1. In *Pinus* pollen grains are .... and carried to ovule through wind called ....
2. Pollen grains are shed in ..... celled stage at the time of pollination and further development takes place in the ovule
3. Each megasporophyll is differentiated into two parts lower.........scale and upper.......... scale.
4. The formation of the more than one embryos from one oospore or zygote is called ....
5. The germination of seeds in *Pinus* is........

3.5 SUMMARY

- *Pinus* is an important genus of conifers having about 150 species reported
- It is distributed throughout northern hemisphere, forming dense evergreen forest of north temperate and subalpine regions.
- The sporophytic plant body is an evergreen tree differentiated into root stem and leaf.
- Primary root is tap root with ill developed root hairs and covered by fungal hyphae i.e. **mycorrhiza**.
- Stem is cylindrical, erect, woody and monopodially branched.

- **Dimorphic** branches i.e. **long shoot** of unlimited growth and **dwarf shoots** of limited growth.
- Dwarf shoots bear both **foliage leaves** and **scale leaves**.

Internal structure

- **Root:** The internal structure of young root is similar to a dicotyledonous root.
- **Epidermis:** The root is surrounded by an outer piliferous layer, the epiblema, bearing unicellular root hairs. In young roots there is fungal growth of ectophytic mycorrhiza.
- **Cortex:** Epiblema is followed by a wide zone of cortex made up of 4 to 5 or more layers of Parenchymatous cells.
- **Endodermis:** The inner-most layer of cortex is single layered endodermis. The cells of this layer have typical thickening bands on their radial walls.
- **Pericycle:** Just below the endodermis there is multilayered pericycle containing tannin and starch grains
- **Vascular tissue:** Vascular cylinder may be diarch to tetrarch. Vascular bundles are radial. The protoxylem is exarch and slightly forced to from Y shaped structure and resin canal lies in between the two arms of the protoxylem. Xylem lacks vessls and phloem is devoid of companion cells. The pith is poorly developed or if present made up of parenchymatous cells.
- A dwarf shoot with a group of foliage leaves or needles known as 'foliar spur' which are green photosynthetic and persistent showing xerophytic characters.
- The no. of needles in a spur may varies from 1-5 in different species of *Pinus*.
- Plant is sporophytic bearing two types of cone: Male and female on separate branches of same plants.
- Microsporophyll is membranous, stalked and roughly triangular with two microsporangia on base of its abaxial side.
- Microsporangium has microspore mother cells each of which produces haploid microspores or pollen grain by reduction division.
- Microspores or pollen grains have two wings on either side and pale yellow in colour so that at the time of dehiscence pine forests appear yellow dusty appearance called '**Sulphur Rain**'.
- Megasporophyll consisting of two types of scales: **Bract** or **Cone scale** and **Ovuliferous scale.**
- Bract scale is small membranous attached to cone axis just below the ovuliferous scale which is thick, large and woody, brownish and roughly triangular.

- Ovules are **orthotropus** and **unitegmic,** present at the base of each ovuliferous scale on dorsal side.
- Megaspore mother cell in ovule divides meiotically into 4 haploid megaspores, arranged in a linear tetrad. Out of them three ovules towards the micropylar end degenerate and only one remains functional.
- Both micro and megaspore develop male and female gametophyte respectively.
- Microspores released from microsporangium after partial development of male gametophyte and rest is developed in pollen chamber of the ovule.
- Megaspore develops female gametophyte after resting period inside nucellus.
- At the micropylar end of female gametophyte 2-5 **archegonia** develop, each of which consists of swollen **venter** and short **neck** with 8 **neck cells.** Neck canal cells are absent**.** Venter encloses a large **egg cell** and a **venter canal cell** which soon disorganise.
- Pollination by wind i.e. anemophilous during first year of cone's development.
- Fertilization takes place after the growth of pollen tube in spring.
- Fertilized ovules becomes in winged seed.
- It matures during second year and dispersed during third year by then female cones become large and woody and scales bend outwards to expose the seeds and dispersed by wind.
- Seeds germinate soon after their dissamination under favourable condition to develop young plants.
- Complete life cycle of *Pinus* shown in Fig.3.24.

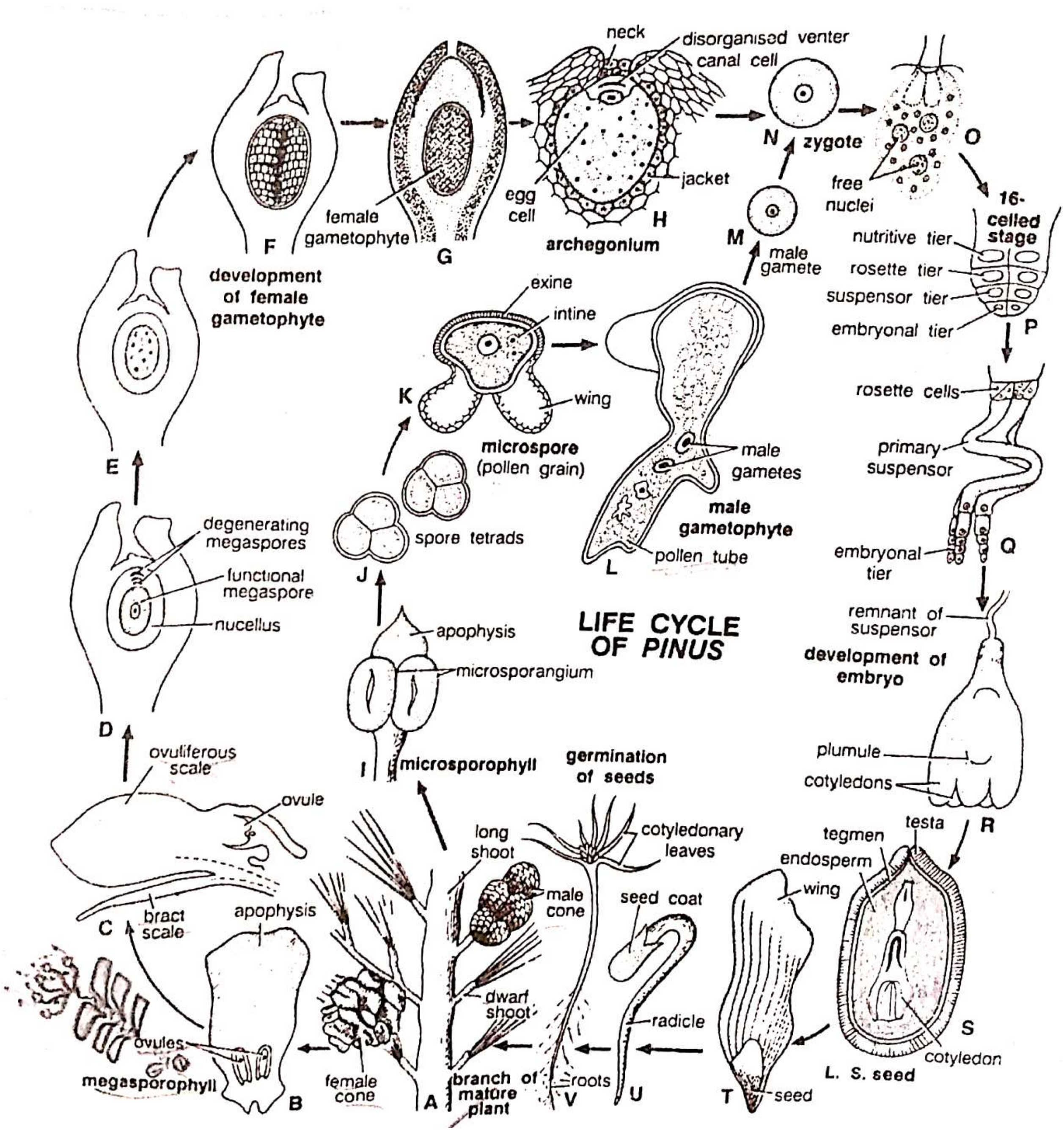


Fig.3.24 Life Cycle of *Pinus*

3.6 TERMINAL QUESTIONS

VERY SHORT ANSWER TYPE OF QUESTIONS:

Q.1 Name of a plant which produces seeds but no fruits.

Q.2.What happens during April and May yellow sulpur like dust blown in Himalayan pine forest?

Q.3. From which part of the female cone wing on the seeds of *Pinus* formed?

Q.4. How many cells are present in pollen grains at the time of pollination?

Q.5. Which type of pollen grains are produced in *Pinus*?

Q.6. What is the common name of foliage leaves of *Pinus*?

Q.7. What type of wood is found in *Pinus*?

Q. 8. Give the name of plant which has ectomycorrhiza.

Q.9. Which plant is commonly known as chir pine and blue pine?

Q.10. Why it becomes difficult to extinguish fire in pine forest?

SHORT ANSWER TYPE OF QUESTIONS:

Q.1. What do you know about the distribution of different species of *Pinus* in India?

Q.2. Briefly discuss about the comparative account of following:

a. Dwarf shoot and long shoot
b. Scale leaves and foliage leaves
c. Systematic position of *Pinus*
d. Bract scale and ovuliferous scale

LONG ANSWER TYPE OF QUESTIONS

Q.1. With the help of labelled diagrams explain the secondary growth in *Pinus* wood.

Q.2. Describe the structure and development of male gametophyte of *Pinus.*

Q.3. Describe the structure and development of female gametophyte of *Pinus.*

Q.4. Explain about the following structures *Pinus* with the help of labelled diagrams:

a. T.S. of Needle
b. L.S. of mature ovule
c. T.L.S. and R.L.S.of wood
d. T.S. of young and old stem

e. T.S. of young and old root

f. L.S. of Male and female Cone

Q.5. Give an illustrated account of post fertilization development up to the formation of seed in *Pinus.*

3.7 ANSWERS

SAQ 1:

1. Six   2. *Pinus gerardiana*   3. *Pinus roxburghii* or *longifolia*

SAQ 2:

1. Mycorrhiza, ectotrophic   2. Long, unlimited; Dwarf, limited
   3.Foliage leaf

SAQ 3:

1. Vessels, Companion cells   2. sanio or crassullae   3. haplochelic

SAQ 4:

1. Winged, Anemophilous   2. Four   3. Bract , Ovuliferous
   4. Polyembryony   5. Epigeal

VERY SHORT ANSWER:

1 *Pinus*   2. Due to dissemination of pollen grains of pines   3. Ovuliferous Scale   4. Four celled: 2 Prothalial, 1 Generative and 1tube cell   5. Winged 6. Needle   7. Pycnoxylic   8. *Pinus*   9. *Pinus excelsa* and *Pinus roxburghii*   10. Due to the presence of resins in wood which is highly inflammable.

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Block- II

Plant Anatomy

Plant anatomy or Phytotomy is the general term which focuses on the structural or body parts and systems that make up a plant. A typical plant body consists of three major vegetative organs: the root, the stem and the leaf as well as a set of reproductive parts that includes flowers, fruits and seeds. Plant's root like the foundation of sky scraper, help it to stay upright, absorb water and minerals from the ground and give the plant to make its own food. The stem supports the parts of the plant above ground and carry water and food from place to place within the plant itself. Leaf is highly specialized part of the plant as it manufactures food for the plant. Flower is the reproductive part of the plant which produces seed.

The knowledge of anatomy is required to the students for understanding relationship between structure, function, taxonomy, ecology and developmental genetics.

Keeping this in mind the block is divided into four units:

Unit IV- Tissue system: This unit covers epidermal, ground and vascular tissue. It also has description of meristematic and permanent tissue.

Unit V- Root: This unit covers the primary and secondary structure of root.

Unit VI- Stem: This unit describes primary and secondary structure of stem.

Unit VII- Anomalous Secondary Growth: This unit covers anomalous secondary growth in dicot stem like *Bignonia, Boerhaavia* and monocot stem *Dracaena*.

Objective:

After studying this block, you will be able to:

- Know tissue system of the plant.
- Understand vascular system.
- Describe internal structure of root and stem.
- Know the process of anomalous secondary growth in dicot and monocot stem.

Unit- IV

Tissue System

Structure

4.1 Introduction

Objectives

4.2 Tissue system

- **Epidermal tissue system**
- **Ground tissue system**
- **Vascular tissue system**

4.3 Meristematic tissue

4.4 Simple permanent tissues

- **Parenchyma**
- **Collenchyma**
- **Sclerenchyma**

4.5 Complex permanent tissues

- **Xylem**
- **Phloem**

4.6 Summary

4.7 Terminal Questions

4.8 Answers

4.1 Introduction

Plant anatomy is the study of plant tissues and cells in order to learn more about the way these organisms are constructed and how they work. These studies are very important because they lead to a better understanding of how to care for plants and fight plant diseases. Plant anatomy is also known as phytotomy.

A plant is a complex structure that consists of a number of parts which constitute the whole plant. If you learn to identify each individual part, you will gain a much greater understanding as to how the plant works as a whole. This can be helpful to aromatherapists who need to be aware of the part of the plant an essential oil was derived from because there is often a connection between the oils location in a plant and its therapeutic action. Understanding plant anatomy also helps everyone appreciate the art of distillation and extraction.

Students as you know that Plant anatomy or Phytotomy is the general term for the study of the internal structure of plants. The science of the structure of the organized plant body learned by dissection is called Plant Anatomy (anatomy-dissection). In general, Plant Anatomy refers to study of internal morphology, pertaining to different tissues. The subject of this chapter is internal structure of Angiosperms, with emphasis on primary tissues. While originally it included plant morphology, which is the description of the physical form and external structure of plants, since the mid-20th century the investigations of plant anatomy are considered a separate, distinct field, and plant anatomy refers to just the internal plant structures.

In higher plants the plant body is more complex and the cells differ in their kind, form and origin. A study of internal structure shows that the vascular cryptogams and the spermatophyte have many types of cells that cluster together to form various types of tissue system. Plant body in Angiosperms is differentiated into root, stem, leaf and flower. All these parts are made up of different types of tissues containing different cell types. A tissue is a mass of similar or dissimilar cells performing a common function.

The first developed plant body is known as primary plant body and its tissue as primary tissue. In lower plants and monocotyledons the plant body remains primary throughout the life span. While in the Gymnosperms, in most dicots and in some monocots secondary thickening in stem and roots or secondary growth takes place and its tissues are known as secondary tissues. The secondary growth does not fundamentally change the primary structure. The primary plant structures root, stem and leaves are distinguished by relative distribution of vascular and ground tissue system.

Objectives

After studying this unit, you will be able to:

- Document facts about structure of plant and its morphology.
- Know function of every parts of plant.
- Study major types of plant cells and their function.
- Differentiate the various types of cells.
- Study the relationship between the distribution of tissues in the various parts of plants.
- Describes the ground tissue system (cortex and pith) and vascular systems.

4.2 Tissue system

As you have learnt, the plant cells are organised into tissues, in turn the tissues are organised into organs. Different organs in a plant show differences in their internal structure. This part of chapter deals with the different type of internal structure of various plant organs and its adaptations to diverse environments. A group of tissues performing a similar function, irrespective of its position in the plant body, is called a tissue system. In 1875, German Scientist Julius von Sachs recognized three tissue systems in the plants **(Figure 4.1)**. They are:

1. Epidermal tissue system (derived from protoderm)
2. Ground tissue system (derived from ground meristem)
3. Vascular tissue system (derived from procambium)

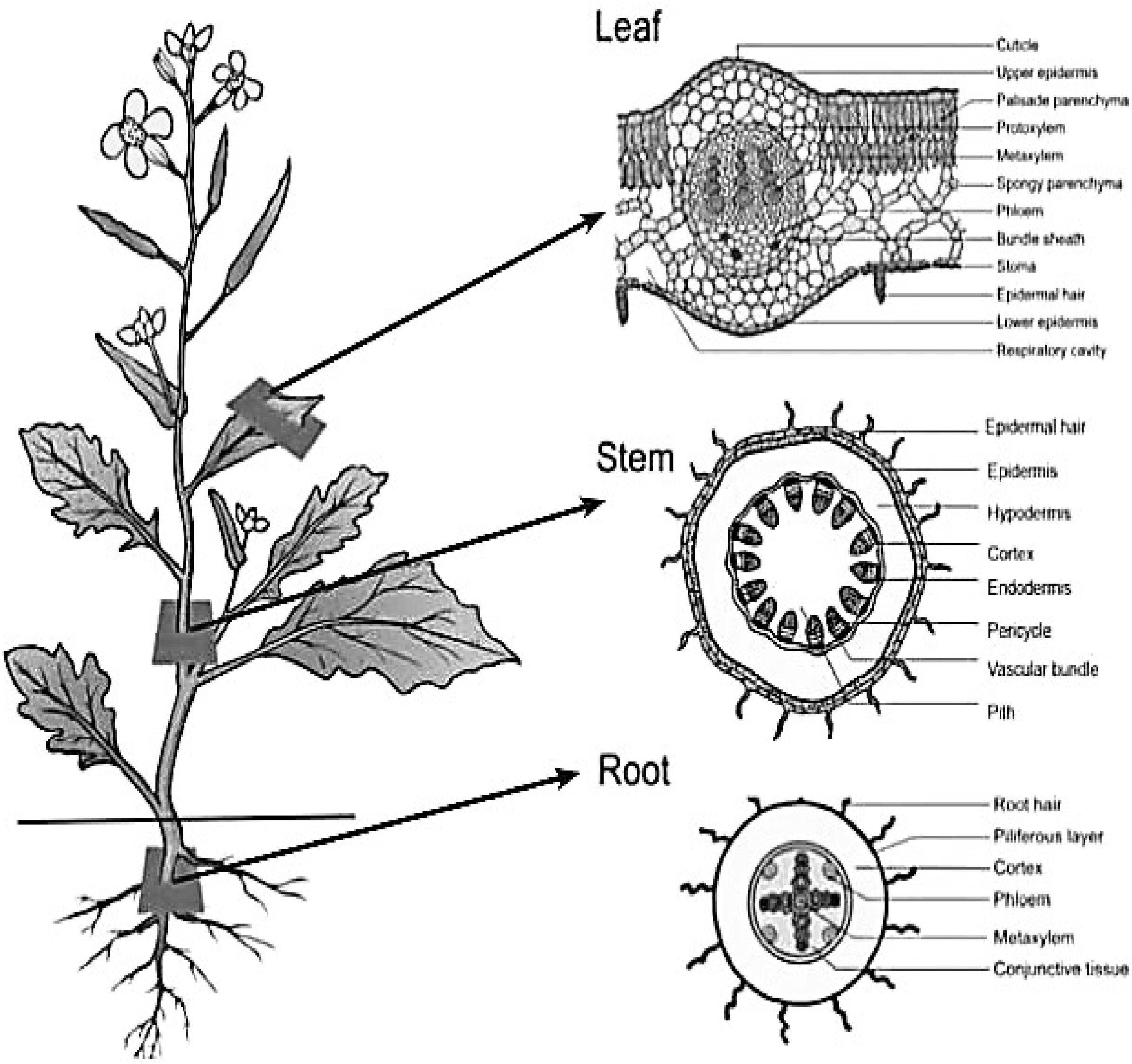


Figure 4.1 Tissue system

- **Epidermal tissue system**

Epidermal tissue system is the outer most covering of plants. It is in direct contact with external environment. It consists of epidermis derived from protoderm. Epidermis is derived from two Greek words, namely 'Epi' and 'Derma'. 'Epi' means upon and 'Derma' means skin. Although epidermis is a continuous outer layer, it is interrupted by stomata in many plants.

Root Epidermis

The outer layer of the root is known as piliferous layer or epiblema. It is made up of single layer of parenchyma cells which are arranged compactly without intercellular spaces. It is devoid of epidermal pores and cuticle. Root hair is always single celled, it absorbs water and mineral salts from the soil. The another important function of piliferous layer is protection.

Stem Epidermis

It is protective in function and forms the outermost layer of the stem. It is a single layer of parenchymatous rectangular cells. The cells are compactly arranged without intercellular cells. The outer walls of epidermal cells have a layer called cuticle. The cuticle checks transpiration. The cuticle is made up of cutin. In many plants it is also mixed wax to form epicuticular wax. Epidermal pores may be present here and there. Epidermal cells are living. Chloroplasts are usually absent except in guard cells of stomata. In many plants a large number of epidermal hairs occur on the epidermis.

Leaf Epidermis

The leaf is generally dorsiventral. It has upper and lower epidermis. The epidermis is usually made up of a single layer of cells that are closely packed. Generally, the cuticle on the upper epidermis is thicker than that of lower epidermis. The minute openings found on the epidermis are called stomata (singular: stoma). Usually, stomata are more in number on the lower epidermis than on the upper epidermis **(Figure 4.2)**. A stoma is surrounded by a pair of specialised epidermal cells called guard cells. In most dicots and monocots, the guard cells are bean-shaped. While in grasses and sedges, the guard cells are dumb-bell shaped. The guard cells contain chloroplasts, whereas the other epidermal cells normally do not have them.

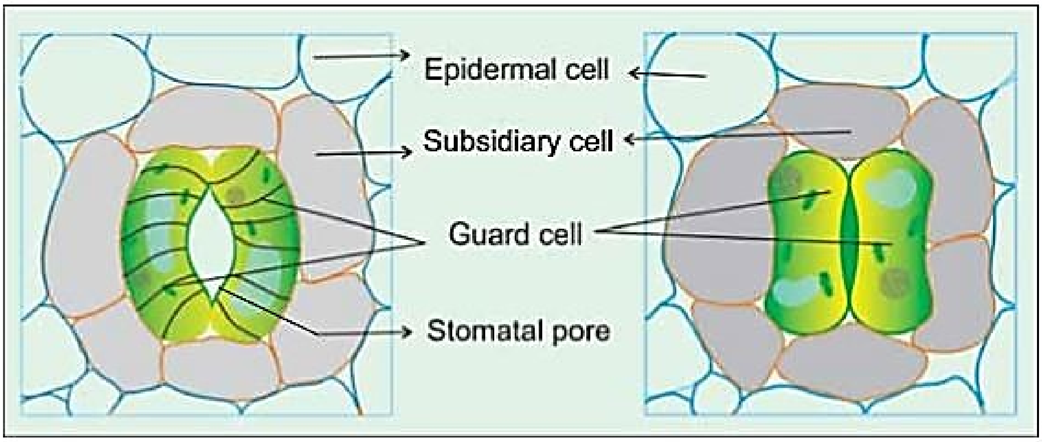


Figure: 4.2 (a) Stoma with bean-shaped guard cells. (b) Stoma with dumb-bell shaped guard cells

Some cells of upper epidermis (Example: Grasses) are larger and thin walled. They are called bulliform cells or motor cells. These cells are helpful for the rolling and unrolling of the leaf according to the weather change. Some of the epidermal cells of the grasses are filled with silica. They are called silica cells.

Subsidiary Cells

Stomata are minute pores surrounded by two guard cells. The stomata occur mainly in the epidermis of leaves. In some plants addition to guard cells, specialised epidermal cells are present which are distinct from other epidermal cells. They are called Subsidiary cells. Based on the number and arrangement of subsidiary cells around the guard cells, the various types of stomata are recognised. The guard cells and subsidiary cells help in opening and closing of stomata during gaseous exchange and transpiration.

Sunken Stomata

In some Xerophytic plants (Examples: *Cycas, Nerium*), stomata are sunken beneath the abaxial leaf surface within stomatal crypts. The sunken stomata reduce water loss by transpiration.

Multilayered or Multiseriate Epidermis **(Figure 4.3)**

Generally, epidermis is single layered, but in certain leaves, multi layered upper epidermis is present, Example: *Ficus, Nerium and Peperomea.*

In *Ficus*, upper epidermal layer contains cystoliths made up of calcium carbonate crystals.

In *Nerium,* the multilayered epidermis, the outer layer alone is cutinized.

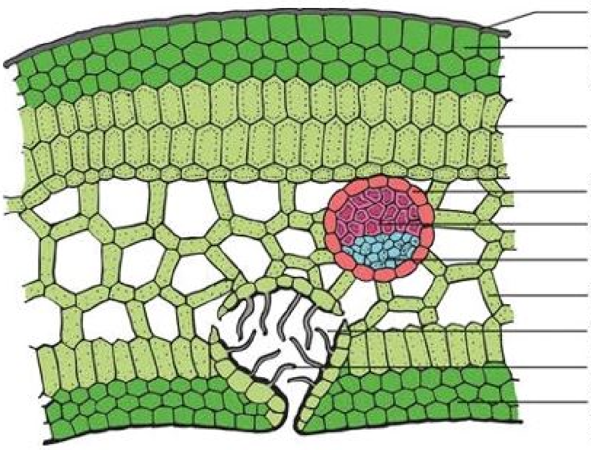


Figure 4.3: T.S. of *Nerium* Leaf

Epidermal Outgrowths

There are many types of epidermal outgrowths in stems. The unicellular or multicellular appendages that originate from the epidermal cells are called trichomes. Trichomes may be branched or unbranched and are one or more one celled thick. They assume many shapes and sizes. They may also be glandular (Example: *Rose, Ocimum*) or non-glandular **(Figure 4.4)**.

Trichoblasts are elongate into root hairs. Epidermal hairs can also be in the form of stellate hairs (star shaped) present in plants. Example: many members of Malvaceae and Solanaceae.

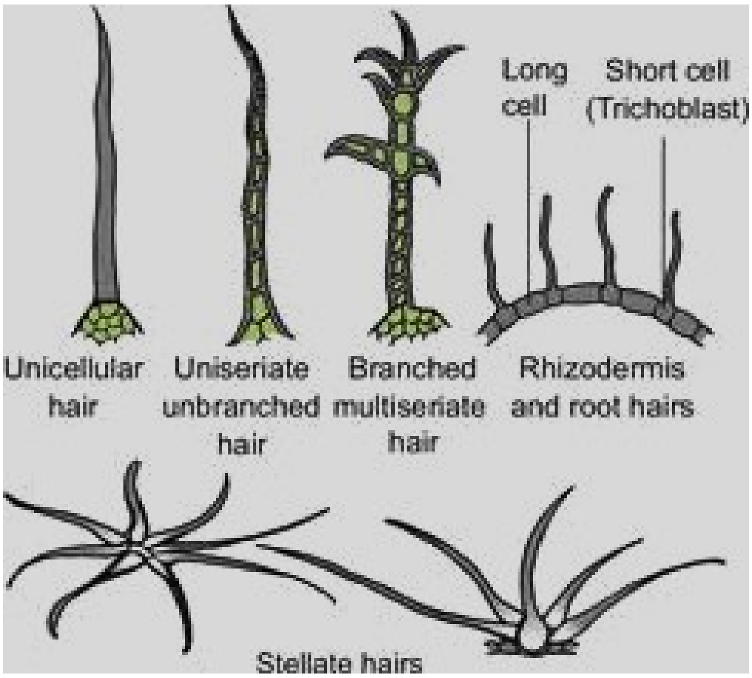


Figure 4.4 Types of Trichomes

Prickles

Prickles, are one type of epidermal emergences with no vascular supply. They are stiff and sharp in apperance. (Example: Rose).

Functions of Epidermal Tissue System-

1. This system in the shoot checks excessive loss of water due to the presence of cuticle.
2. Epidermis protects the underlying tissues.
3. Stomata is involved in transpiration and gaseous exchange.
4. Trichomes are also helpful in the dispersal of seeds and fruits, and provide protection against animals.
5. Prickles also provide protection against animals and they also check excessive transpiration
6. In some rose plants they also help in climbing.
7. Glandular hairs repel herbivorous animals.

SAQ.1

---

a. German Scientist_____________recognized three tissue systems in the plants.
b. Epidermal tissue system derived from_____________.
c. The sunken stomata reduce water loss by________________.

d. In *Ficus*, upper epidermal layer contains cystoliths made up of________________.
e. Stomata is involved in transpiration and_______________.

- **Ground tissue system**

The ground tissue system constitutes the main body of the plants. It includes all the tissues except epidermis and vascular tissues. In monocot stem, ground tissue system is a continuous mass of parenchymatous tissue in which vascular bundles are found scattered. Hence ground tissue is not differentiated into cortex, endodermis, pericycle and pith. Generally, in dicot stem, ground tissue system is differentiated into three main zones – cortex, pericycle and pith. It is classified into extrastelar ground tissue (Examples: cortex and endodermis) and intrastelar ground tissue (Examples: pericycle, medullary ray and pith).

Extrastelar Ground Tissue

The ground tissues present outside the stele is called extrastelar ground tissue. (Cortex)

Intrastelar Ground Tissue

The ground tissues present within the stele are called intrastelar ground tissues. (pericycle, medullary rays and pith).

Different Components of Ground Tissue Systems are as follows-

Hypodermis

One or two layers of continuous or discontinuous tissue present below the epidermis, is called hypodermis. It is protective in function.

In dicot stem, hypodermis is generally collenchymatous, whereas in monocot stem, it is generally sclerenchymatous. In many plants collenchyma forms the hypodermis.

General Cortex

The Cortex occurs between the epidermis and pericycle. Cortex is a few to many layers in thickness, In most cases, it is made up of parenchymatous tissues. Intercellular spaces may or may not be present.

The cortical cells may contain non-living inclusions of starch grains, oil, tannins and crystals. Sometimes in young stem, chloroplasts develop in peripheral cortical cells, which is called chlorenchyma.

In the leaves, the ground tissue consists of chlorenchyma tissues. This region is called mesophyll. In hydrophytes, cortex is aerenchymatous (with air cavities). Its general function is storage of food as well as providing mechanical support to organs.

Endodermis

The cells of this layer are barrel shaped and arranged compactly without intercellular spaces.

Endodermis is the innermost cortical layer that separates cortex from the stele. This layer may be a true endodermis as in root or it is an endodermis like layer in stems. This layer is morphologically homologous to the endodermis found in the root.

The cells of endodermis like layer had living cells containing starch grains. Hence it is known as starch sheath. In true root endodermis, radial and inner tangential walls of endodermal cells possess thickenings of lignin, suberin and some other carbohydrates in the form of strips they are called casparian strips.

The endodermal cells, which are opposite to the protoxylem elements, are thin walled without casparian strips. These cells are called passage cells. Their function is to transport water and dissolved salts from the cortex to the protoxylem.

Water cannot pass through other endodermal cells due to casparian strips. The main function of casparian strips in the endodermal cells is to prevent the re-entry of water into the cortex once water entered the xylem tissue. The other suberized cells act as water-tight layer between vascular and nonvascular regions to check the loss of water.

Pericycle

Pericycle is single or few layered parenchymatous found inner to the endodermis. It is the outermost layer of the stele. Rarely thick walled sclerenchymatous. In angiosperms, pericycle gives rise to lateral roots.

Pith or Medulla

The central part of the ground tissue is known as pith or medulla. Generally, this is made up of thin walled parenchyma cells with intercellular spaces. The cells in the pith generally stores starch, fatty substances, tannins, phenols, calcium oxalate crystals, etc.

SAQ.2

---

1. In monocot stem, ground tissue system is a continuous mass of__________tissue in which vascular bundles are found_______________.
2. In dicot stem, ground tissue system is differentiated into three main zones: ___________, ___________ and________.
3. The hypodermis is ____________ in function.
4. Pericycle is the outermost layer of the___________.
5. The central part of the ground tissue is known as_______or_____________.

- **Vascular tissue system (Figure 4.5)**

This section deals with the vascular tissue system of gymnosperms and angiosperms stems and roots. The vascular tissue system consists of xylem and phloem. The elements of xylem and phloem are always organized in groups. They are called vascular bundles.

The stems of both groups have an eustele while roots are protostele. In eustelic organization, the stele contains usually a ring of vascular bundles separated by interfascicular region or medullary ray.

The structural and organizational variation in vascular bundles is shown below.

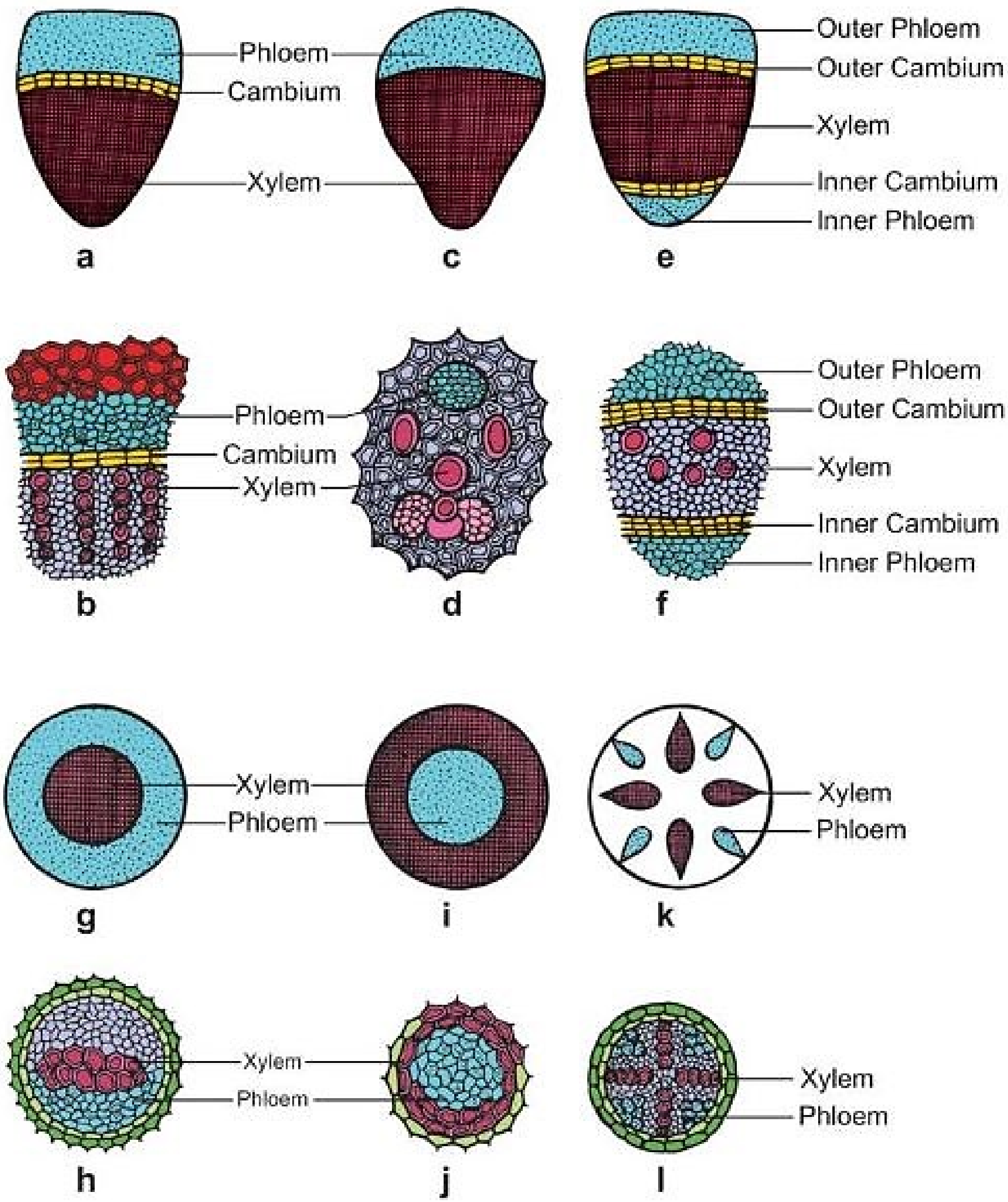
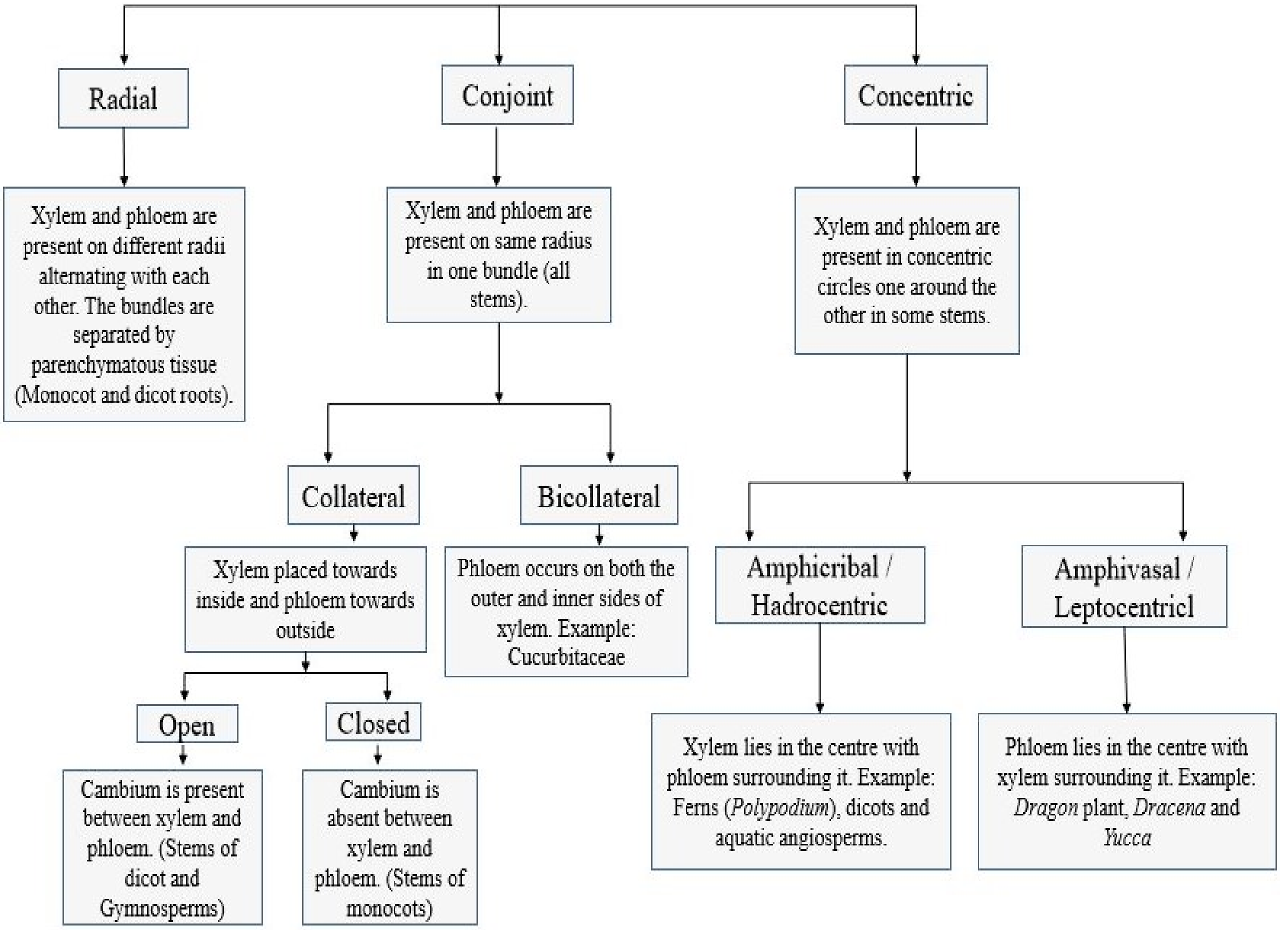


Figure 4.5: Types of vascular bundles

(a) and (b) - Conjoint, collateral and open; (c) and (d) - Conjoint, collateral and closed (e) and (f) - Conjoint, bicollateral and open; (g) and (h) - Concentric and amphicribral; (i) and (j) - Concentric and amphivasal; (k) and (1) – Radial

Types of vascular bundles illustrate-



SAQ.3

a. The vascular tissue system consists of____________and___________.

b. In eustelic organization, the stele contains usually a _______of vascular bundles separated by ____________or medullary ray.

c. Xylem lies in the centre with phloem surrounding it. This is called__________vascular bundle.

d. Xylem and phloem is present on same radius called__________.

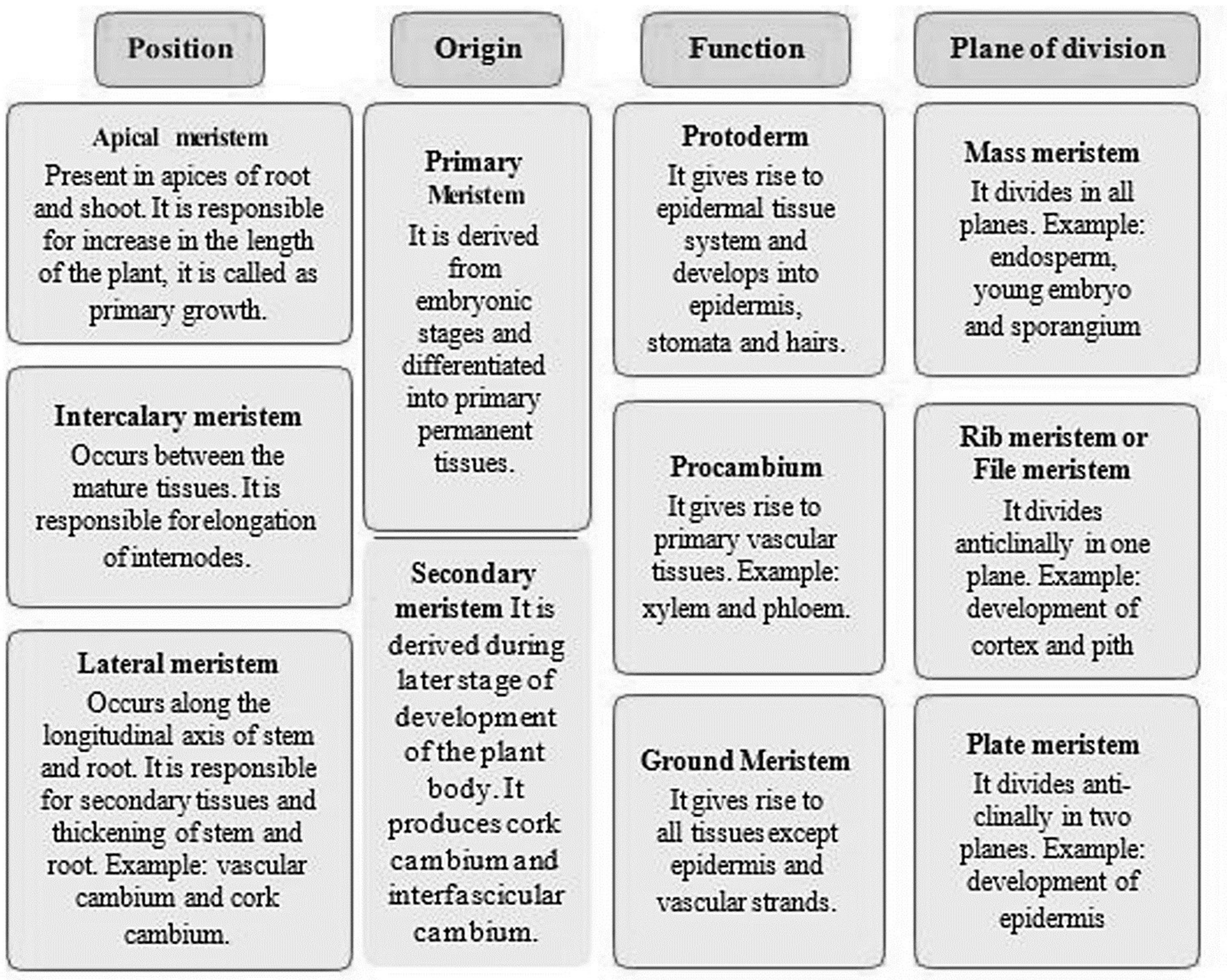
e. Closed type of collateral vascular bundle is found in stems of___________.

4.3 Meristematic tissues

The term meristem is coined by **C. Nageli** in 1858. The meristematic cells are isodiametric and they may be, oval, spherical or polygonal in shape. They have generally dense cytoplasm with prominent nucleus. Generally, the vacuoles in them are either small or absent. Their cell wall is thin, elastic and essentially made up of cellulose. These are most actively dividing cells. Meristematic cells areself-perpetuating.

Classification of Meristem

Meristem has been classified into several types on the basis of position, origin, function and division which are as follows **(Figure 4.6)**-



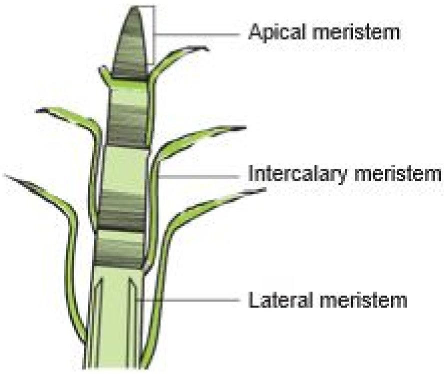


Figure 4.6: Different types of meristems on the basis of position in plant body

SAQ.4

a. The term meristem is coined by______________in 1858.
b. Intercalary meristem occurs between the____________tissues.
c. Lateral meristem occurs along the_____________axis of stem and root.
d. Vascular and cork cambium are the examples of________________meristem.
e. ____________meristem gives rise to all tissues except epidermis and vascular strands.

4.4 Simple permanent tissues

Simple tissues are composed of one type of cells only. The cells are structurally and functionally similar. It is of three types

1. Parenchyma
2. Collenchyma
3. Sclerenchyma

1. Parenchyma

Parenchyma is generally present in all organs of the plant. It forms the ground tissue in a plant. Parenchyma is a living tissue and made up of thin walled cells. The cell wall is made up of cellulose. Parenchyma cells may be oval, polyhedral, cylindrical, irregular, elongated or armed. Parenchyma tissue normally has prominent intercellular spaces. Parenchyma may store various types of materials like, water, air, ergastic substances. It is usually colourless. The turgid parenchyma cells help in giving rigidity to the plant body. Partial conduction of water is also maintained through parenchymatous cells **(Figure 4.7)**.

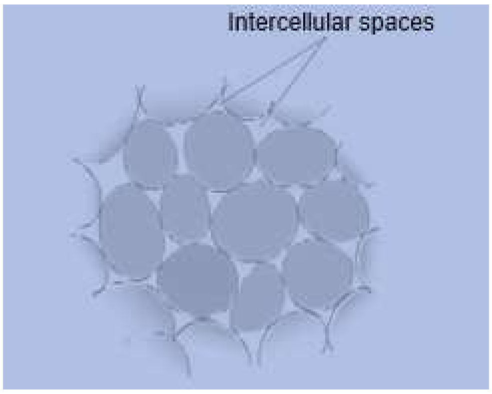


Figure 4.7 Parenchyma

Occasionally Parenchyma cells which store resin, tannins, crystals of calcium carbonate, calcium oxalate are called idioblasts. Parenchyma is of different types and some of them are discussed as follows.

Types of Parenchyma (Figure 4.8)-

1. **Aerenchyma-** Parenchyma which contains air in its intercellular spaces. It helps in aeration and buoyancy. Example: *Nymphae and Hydrilla.*
2. **Storage Parechyma-** Parenchyma stores food materials. Example: Root and stem tubers.
3. **Stellate Parenchyma-** Star shaped parenchyma. Example: Petioles of *Banana and Canna*.
4. **Chlorenchyma-** Parenchyma cells with chlorophyll. Function is photosynthesis. Example: Mesophyll of leaves.
5. **Prosenchyma-** Parenchyma cells became elongated, pointed and slightly thick walled. It provides mechanical support.

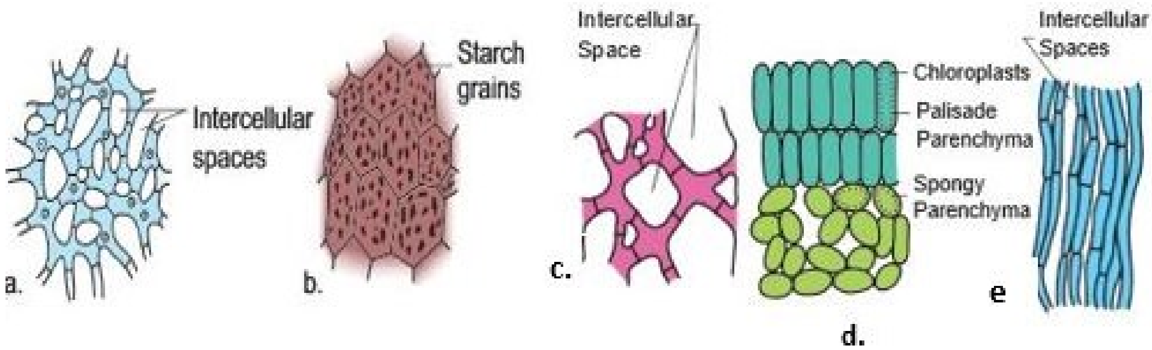


Figure 4.8: a. Aerenchyma, b. Storage parenchyma, c. Stellate parenchyma, d. Chlorenchyma, e. Prosenchyma

2. **Collenchyma**

Collenchyma is a simple, living mechanical tissue. Collenchyma generally occurs in hypodermis of dicot stem. It is absent in the roots and also occurs in petioles and pedicels. The cells are elongated and appear polygonal in cross section. The cell wall is unevenly thickened. It contains more of hemicellulose and pectin besides cellulose. It provides mechanical support and elasticity to the growing parts of the plant. Collenchyma consists of narrow cells. It has only a few small chloroplast or none. Tannin maybe present in collenchyma. Based on pattern of pectinisation of the cell wall, there are three types of collenchyma

Types of Collenchyma (Figure 4.9)-

1. **Angular collenchyma-** It is the most common type of collenchyma with irregular arrangement and thickening at the angles where cells meets. Example: Hypodermis of *Datura* and *Nicotiana*
2. **Lacunar collenchyma-** The collenchyma cells are irregularly arranged. Cell wall is thickened on the walls bordering intercellular spaces. Example: Hypodermis of *Ipomoea*
3. **Lamellar collenchyma-** The collenchyma cells are arranged compactly in layers(rows). The Cell wall thickening is at tangential walls. These thickening appear as successive tangential layers. Example: Hypodermis of*Helianthus.*

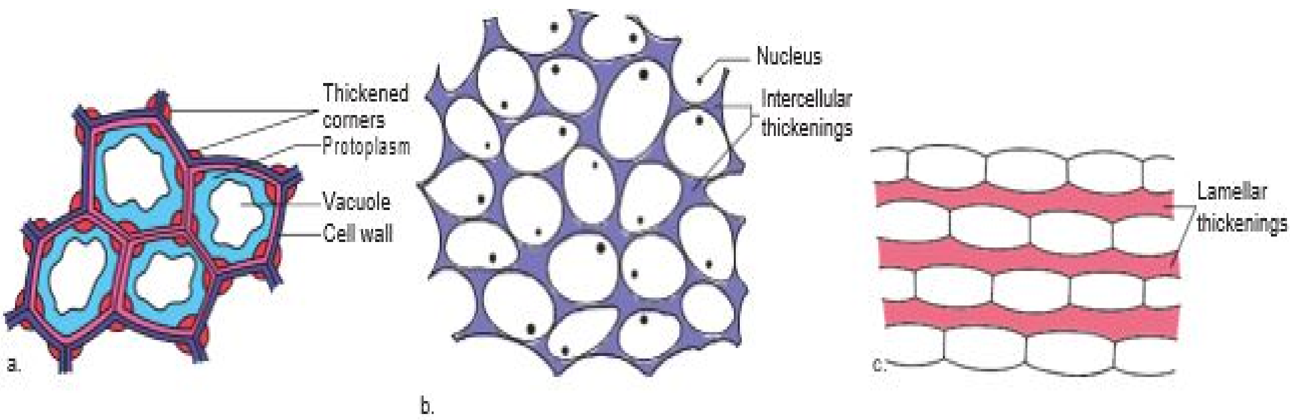


Figure 4.9: Types of Collenchyma a) Angular collenchyma, b) Lacunar collenchyma and c) Lamellar collenchyma

3. **Sclerenchyma**

The sclerenchyma is dead cell and lacks protoplasm. The cells are long or short, narrow thick walled and lignified secondary walls. The cell walls of these cells are uniformly and strongly thickened. The sclerenchymatous cells are of two types:

1. Sclereids
2. Fibres

1. Sclereids (Stone cells)

Sclereids are dead cells, usually these are isodiametric but some are elongated too. The cell wall is very thick due to lignification. Lumen is very much reduced. The pits may be simple or branched. Sclereids are mechanical in function. They give hard texture to the seed coats, endosperms etc., Sclereids are classified into the following types **(Figure 4.10)**.

i. **Branchysclereids or Stone cells:** Isodiametric sclereids, with hard cell wall. It is found in bark, pith cortex, hard endosperm and fleshy portion of some fruits. Example: - Pulp of*Pyrus*.

ii. **Macrosclereids:** Elongated and rod shaped cells, found in the outer seed coat of leguminous plants. Example: *Crotalaria and Pisum sativum*.

iii. **Osteosclereids (Bone cells):** Rod shaped with dilated ends. They occur in leaves and seed coats. Example: seed coat of *Pisum and Hakea*

iv. **Astrosclereids:** Star cells with lobes or arms diverging from a central body. They occur in petioles and leaves. Example: *Tea, Nymphae and Trochodendron.*

v. **Trichosclereids:** Hair like thin walled sclereids. Numerous small angular crystals are embedded in the wall of these sclereids, present in stems and leaves of hydrophytes. Example: *Nymphaea leaf* and Aerial roots of*Monstera.*

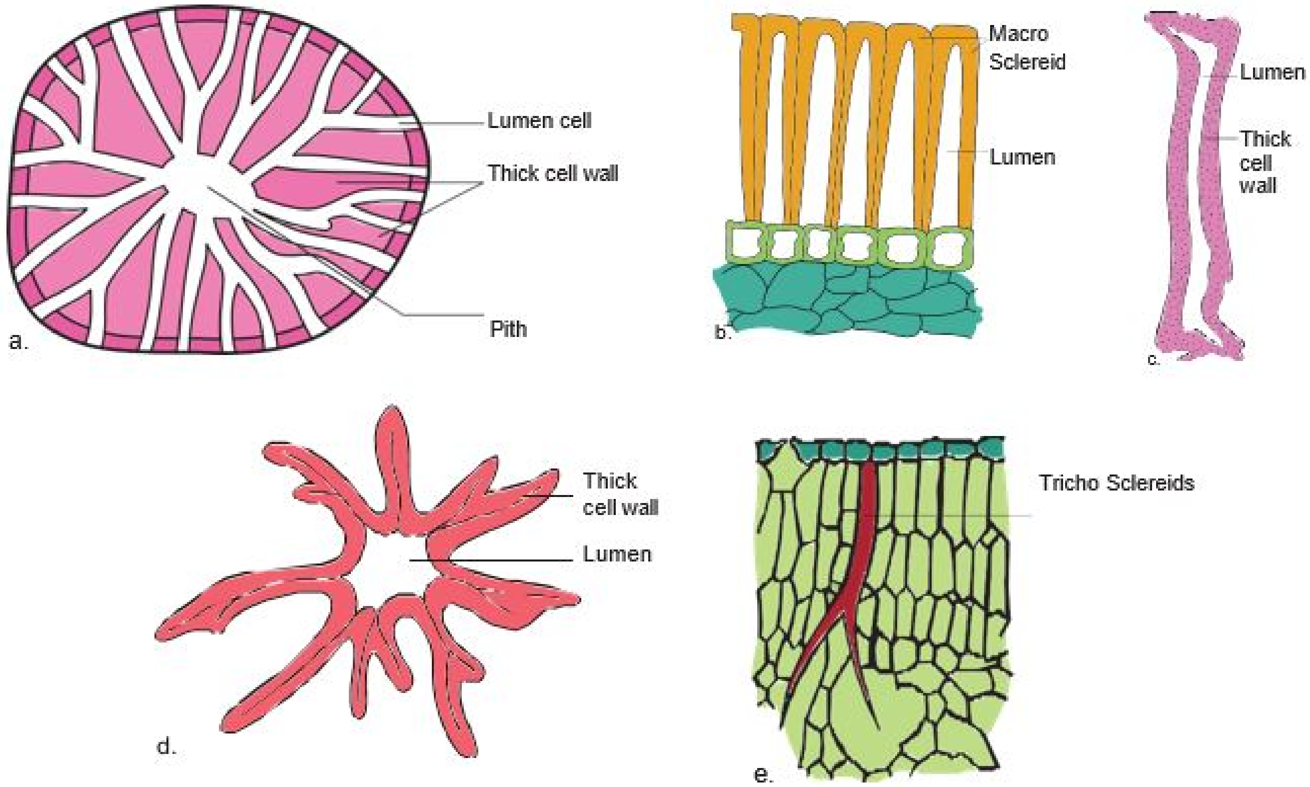


Figure 4.10: Types of Sclereids a) Brachysclereids, b) Macrosclereids, c) Osteosclereids, d) Astrosclereids, e) Trichosclereids

2. Fibres

Fibres are very much elongated sclerenchyma cells with pointed tips. Fibres are dead cells and have lignified walls with narrow lumen. They have simple pits. They provide mechanical strength and protect them from the strong wind. It is also called supporting tissues. Fibres have a great commercial value in cottage and textile industries **(Figure 4.11)**.

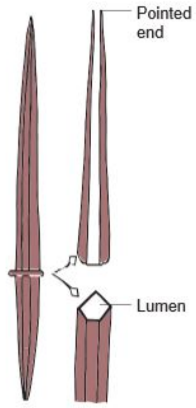


Figure 4.11 T.S. of fibre

Fibres are of five types-

1. **Wood Fibres or Xylary Fibres**

These fibres are associated with the secondary xylem tissue. They are also called xylary fibres. These fibres are derived from the vascular cambium. These are of four types which are as follows-

a. **Libriform fibres:** These fibres have slightly lignified secondary walls with simple pits. These fibres are long and narrow.
b. **Fibre tracheids:** These are shorter than the libriform fibres with moderate secondary thickenings in the cell walls. Pits are simple or bordered.
c. **Septate fibres:** Fibres that have thin septa separating the lumen into distinct chambers. Example: Teak
d. **Gelatinous fibres:** Fibres in which lignin is less in amount and cellulose is more in this cell walls.

These fibres are characteristic of tension wood which is formed in the underside of leaning stems and branches.

2. **Bast fibres or Extra Xylary Fibres**

These fibres are present in the phloem. Natural Bast fibres are strong and cellulosic. Fibres obtaining from the phloem or outer bark of jute, kenaf, flax and hemp plants. The so called pericyclic fibres are actually phloem fibres.

3. **Surface Fibres**

These fibres are produced from the surface of the plant organs. Cotton and silk cotton are the examples. They occur in the testa of seeds.

4. **Mesocarp Fibres**

Fibres obtained from the mesocarp of drupes like Coconut.

5. **Leaf Fibres**

Fibres obtained from the leaf of *Musa, Agave and Sensciveria.*

SAQ.5

---

a. Parenchyma is a___________tissue and made up of _______walled cells.

b. ______________collenchyma is the most common type of collenchyma with irregular arrangement and thickening at the angles where cells meets.

c. Collenchyma generally occurs in hypodermis of __________ stem.

d. The sclerenchyma is________ cell and lacks protoplasm.

e. Bast fibre of extra xylary fibres are present in the______________.

4.5 Complex permanent tissues

A complex tissue is a tissue with several types of cells but all of them function together as a single unit. It is of two types – xylem and phloem.

1. Xylem

The xylem is the principal water conducting tissue in a vascular plant. The term xylem was introduced by **Nageli** (1858) and is derived from the Gk. *Xylos* – wood. The xylem which is derived from Procambium is called **primary xylem** and the xylem which is derived from vascular cambium is called **secondary xylem**. Early formed primary xylem elements are called protoxylem, whereas the later formed primary xylem elements are called metaxylem.

Protoxylem lies towards the periphery and metaxylem that lies towards the centre is called **Exarch.** It is common in *roots.*

Protoxylem lies towards the centre and meta xylem towards the periphery this condition is called **Endarch**. It is seen in *stems.*

Protoxylem is located in the centre surrounded by the metaxylem is called **Centrarch**. In this type only one vascular strand is developed. Example: *Selaginella sp.*

Protoxylem is located in the centre surrounded by the metaxylem is called **Mesarch**.In this type several vascular strands are developed. Example: *Ophioglossum sp.*

Xylem consist of four type of cells-

i. Tracheids

ii. Vessels or Trachea

iii. Xylem Parenchyma

iv. Xylem Fibres

i. Tracheids

Tracheids are dead, lignified and elongated cells with tapering ends. Its lumen is broader than that of fibres. In cross section, the tracheids are polygonal.

There are different types of cell wall thickenings due to the deposition of secondary wall substances. They are annular (ring like), spiral (spring like), scalariform (ladder like) reticulate (net like) and pitted (uniformly thick except at pits) **(Figure 4.12)**. Tracheids are imperforated cells with bordered pits on their side walls. Only through this conduction takes place in Gymnosperms. They are arranged one above the other. Tracheids are chief water conducting elements in Gymnosperms and Pteridophytes. They also offer mechanical support to the plants.

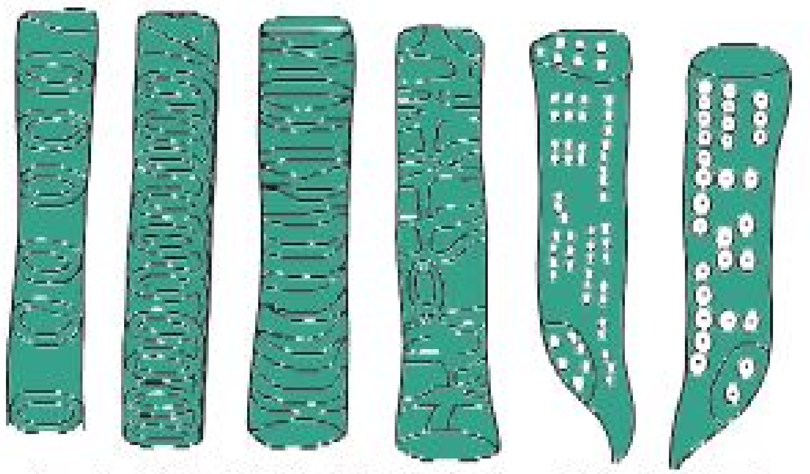


Figure 4.12: Types of secondary wall thickenings in tracheids and vessels

ii. Vessels or Trachea

Vessels are elongated tube like structure. They are dead cells formed from a row of vessel elements placed end to end. They are perforated at the end walls. Their lumen is wider than Tracheids. Due to the dissolution of entire cell wall, a single pore is formed at the perforation plate. It is called **simple perforation plate**, Example: *Mangifera*. If the perforation plate has many pores, it is called **multiple perforation plate**. Example *Liriodendron.* The secondary wall thickening of vessels are annular, spiral, scalariform, reticulate, or pitted as in tracheids, Vessels are chief water conducting elements in Angiosperms and absent in Pteridophytes and Gymnosperms. In G*netum* of Gymnosperm, vessels occur. The main function is conduction of water, minerals and also offers mechanical strength.

iii. Xylem Fibre

The fibres of sclerenchyma associated with the xylem are known as xylem fibres. Xylem fibres are dead cells and have lignified walls with narrow lumen. They cannot conduct water but being stronger provide mechanical strength. They are present in both primary and secondary xylem. Xylem fibres are also called libriform fibres.

The fibres are abundantly found in many plants. They occur in patches, in continuous bands and sometimes singly among other cells. Between fibres and normal tracheids, there are many transitional forms which are neither typical fibres nor typical tracheids. The transitional types are designated as **fibre-tracheids**. The pits of fibre-tracheids are smaller than those of vessels and typical tracheids.

iv. Xylem Parenchyma

The parenchyma cells associated with the xylem are known as xylem parenchyma. These are the only living cells in xylem tissue. The cell wall is thin and made up of cellulose. Parenchyma arranged longitudinally along the long axis is called **axial parenchyma**. Ray parenchyma is arranged in radial rows. Secondary xylem consists of both axial and ray parenchyma, Parenchyma stores food materials and also helps in conduction of water.

2. Phloem

Phloem is the food conducting complex tissues of vascular plants. The term phloem was coined by **C. Nageli** (1858) The Phloem which is derived from procambium is called primary phloem and the phloem which is derived from vascular cambium is called secondary phloem. Early formed primary phloem elements are called **protophloem** whereas the later formed primary phloem elements are called **metaphloem**. Protophloem is short lived. It gets crushed by the developing metaphloem **(Figure 4.13)**.

Phloem is of four types-

i. Sieve elements

ii. Companion cells

iii. Phloem parenchyma

iv. Phloem fibres

i. Sieve elements

Sieve elements are the conducting elements of the phloem. They are of two types, namely sieve cells and sieve tubes.

Sieve Cells: These are primitive type of conducting elements found in Pteridophytes and Gym nosperms. Sieve cell have sieve areas on their lateral walls only. They are not associated with companion cells.

Sieve Tubes: Sieve tubes are long tube like conducting elements in the phloem. These are formed from a series of cells called sieve tube elements. The sieve tube elements are arranged one above the other and form vertical sieve tube. The end wall contains a number of pores and it looks like a sieve. So it is called as sieve plate. The sieve elements show nacreous thickenings on their lateral walls. They may possess simple or compound sieve plates. The function of sieve tubes are believed to be controlled by companion cells.

In mature sieve tube, Nucleus is absent. It contains a lining layer of cytoplasm. A special protein (P. Protein = Phloem Protein) called slime body is seen in it. In mature Sieve tubes, the pores in the Sieve plate are blocked by a substance called **callose** (callose plug). The conduction of food material takes place through cytoplasmic strands. Sieve tubes occur only in Angiosperms.

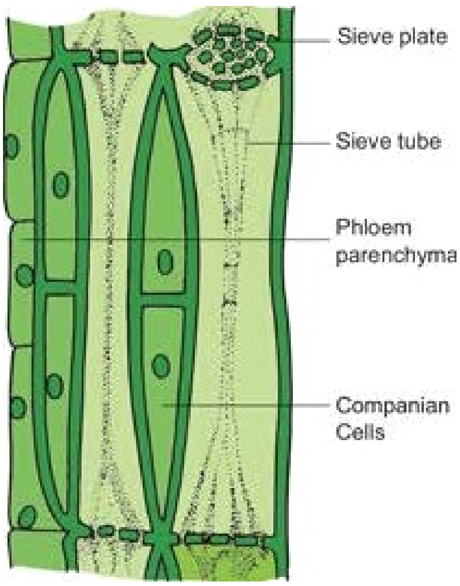


Figure 4.13: Different types of phloem elements

ii. Companion Cells

The thin walled, elongated, specialized parenchyma cells, which are associated with the sieve elements, are called companion cells. These cells are living and they have cytoplasm and a prominent nucleus. They are connected to the sieve tubes through pits found in the lateral walls. Through these pits cytoplasmic connections are maintained between these elements. These cells are helpful in maintaining the pressure gradient in the sieve tubes. Usually the nuclei of the companion cells serve for the nuclei of Sieve tubes as they lack them. The companion cells are present only in Angiosperms and absent in Gymnosperms and Pteridophytes. They assist the sieve tubes in the conduction of food materials.

iii. Phloem Parenchyma

The parenchyma cells associated with the phloem are called phloem parenchyma. These are living cells. They store starch and fats. They also contain resins and tannins in some plants. Primary phloem consists of axial parenchyma and secondary phloem consists of both axial and ray parenchyma. They are present in Pteridophytes, Gymnosperms and Dicots.

iv. Phloem Fibres (or) Bast Fibres

The fibres of sclerenchyma associated with phloem are called phloem fibres or bast fibres. They are narrow, vertically elongated cells with very thick walls and a small lumen. Among the four phloem elements, phloem fibres are the only dead tissue. These are the strengthening aswell as supporting cells.

4.6 Summary

In this unit you have learnt that:

- The tissues can be classified on the basis of their function, structure and location into epidermal tissue system, ground tissue system and vascular tissue system.
- Epidermal tissue system develops as the outermost covering of the entire plant body. It consists of epidermal cells and associated structures.
- All tissues except epidermis and vascular tissues constitute the ground tissue.
- The vascular tissue system is formed of vascular bundles.
- A Tissue is a group of cells that are alike in origin, structure and function. There are two principal groups: (1) Meristematic tissues and (2) Permanent tissues.

- Meristematic tissues comprise of self-perpetuating cells. Meristems are classified into several types on the basis of position, origin, function and activity.
- The permanent tissues normally develop from apical meristem. They are classified into two types: 1) Simple permanent tissues and 2) Complex permanent tissues.
- Simple tissues are composed of a single type of cells only. It is of three types: (1) Parenchyma, (2) Collenchyma and (3) Sclerenchyma.
- *Parenchyma* is generally present in all organs of the plant. It forms the ground tissue in a plant. Parenchyma is a living tissue and made up of thin walled cells.
- Collenchyma is a simple, living mechanical tissue. Collenchyma generally occurs in hypodermis of dicot stem. It is absent in the roots and also occurs in petioles and pedicels.
- The sclerenchyma is dead cell and lacks protoplasm. The cells are long or short, narrow thick walled and lignified secondary walls
- A complex tissue is a tissue with several types of cells but all of them function together as a single unit. It is of two types – xylem and phloem.
- The xylem is the principal water conducting tissue in a vascular plant. The term xylem was introduced by **Nageli** (1858) and is derived from the Gk. *Xylos* – wood.
- Xylem is of four type- Tracheids, Vessels or Trachea, Xylem Parenchyma and Xylem Fibres.
- Phloem is of four types- Sieve elements, Companion cells, Phloem parenchyma and Phloem fibres.
- Secretory tissues produce different types of chemicals. Some are in the form of enzymes, hormones, rubber, gum etc.

4.7 Terminal Question

Q.1 What is tissue system? Give a detailed account of it.

Answer:--

Q.2 Describe the meristematic tissue. Discuss its classification also.

Answer:--

Q.3 What is permanent tissue? Explain its different types.

Answer:--

Q.4 Describe the types of xylem and phloem.

Answer:--

Short Questions

Q.6 Write short notes on:

1. Intercalary meristem
2. Ground tissue system
3. Epidermal tissue system
4. Sclereids
5. Types of Parenchyma
6. Collenchyma
7. Xylem tracheids
8. Sieve elements

Q.7 Multiple choice question:

1. Which of the following are not belongs to xylem types?
   i. Tracheids
   ii. Companion cells
   iii. Xylem fibres
   iv. Vessels
2. Which sentence is correct about parenchyma cells-
   i. Dead cells
   ii. Thick walled cells
   iii. Suberized and lignified
   iv. Living and thin walled cells
3. The correct statements are-

i. Xylem is food conducting cells.

ii. Phloem consist of companion cells, sieve element and xylem tracheids.

iii. The sclerenchyma is dead lignified cell and lacks protoplasm.

iv. All of the above

4. The term meristem is coined by-

i. C. Nageli

ii. Theophrastus

iii. Haekal

iv. Darwin

5. Tracheids are-

i. Dead

ii. Lignified

iii. Elongated with tapering ends.

iv. All the above

4.8 Answers

1. ii 2. iv 3. iii 4. i 5. iv

Self-assessment questions

SAQ.1

a. Julius Von Sachs **b.** Protoderm **c.** Transpiration **d.** Calcium carbonate crystals **e.** Gasseous exchange

SAQ.2

a. Parenchymatous, scattered **b.** Cortex, pericycle, pith **c.** Protective **d.** Stele **e.** Pith, medulla

SAQ.3

a. Xylem, phloem **b.** Ring, inter-fascicular cambium **c.** Amphicribal or hadrocentric **d.** Conjoint **e.** Monocots

SAQ.4

a. C. Nageli **b.** Mature **c.** Longitudinal **d.** Lateral **e.** Ground

SAQ.5

b. Living, thin **b.** Angular **c.** *Ipomea* **d.** Dead **e.** Phloem

Unit- V

Root

Structure

5.1 Introduction

Objectives

5.2 Primary structure of root

5.3 Secondary structure of root

5.4 Summary

5.5 Terminal Questions

5.6 Answers

9.1 Introduction

Root constitutes the lower part of the plant axis which typically grows towards gravity. It is usually sub-cylindrical, tapering towards the tip. Roots are usually much more crooked (zig-zag) than stem as their direction of growth is influenced by a number of obstructions and moisture content of the soil. On the basis of external form, root system can be sub-divided into the following two categories-

1. **Tap root system-** It consists of primary root (the root formed by direct elongation of the radicle) and its lateral branches. Most of the Dicotyledons have a tap root system.
2. **Adventitious root system-** It includes those roots which develop from any part of the plant other than the radicle. Fibrous roots of monocotyledons, foliar roots of *Bryophyllum*, aerial roots of *Ficus, Oxalis* etc., tuberous roots of sweet potato and prop roots of mangroves are some example of adventitious roots.

Evolutionarily, the root seemed to be the last of the three main vegetative organs to evolve, perhaps since early land plants grew on or near the water and so much of their early innovations were geared toward maximizing photosynthesis through development of stems and leaves. There are generally two very different developmental and structural aspects to Angiosperm root systems. The primary root system is derived from the radicle and tends to be dominant in dicots, and gives rise to lateral roots with various degrees of branching. In monocots, the primary root is often ephemeral, and so adventitious roots (derived usually from stems and leaves) and seminal roots (derived from mesocotyl) comprise their root systems where they also produce lateral roots. The root system also has an apical meristem, known as the root apical meristem. This acts in much the same way as the shoot apical meristem, causing extension growth. The main difference is the growth goes down into the ground, and roots, not leaves and branches come from the root apical meristem. Roots have really important jobs, and they do not get due credit for their hard work because they remain underground all the time.

The main functions of the root are:

i. **Anchorage** of plant in the soil.

ii. **Adsorption** of water and minerals

iii. **Storage** of food material.

As roots grow, they travel downward through the soil, dodging rocks and other obstacles that might be in their way. Just as you should wear a helmet when riding a motorcycle or playing hockey, roots have their own type of helmet: a root cap. The root cap protects the root apical meristem as the root pushes its way through the soil. It also secretes slimy ooze that lubricates the soil around the tip of the root, aiding the root on its journey through the harsh soil.

Anatomy of root is simpler than stem and show some characteristic features by which we can determine roots. They lack chlorophyll and are positively geotropic and they are not susceptible to light. Roots have root cap at the apex with root hairs near the apex. Vascular bundles are radial and exarch type i.e. xylem and phloem in different radii and protoxylem towards periphery and metaxylem towards center.

Objectives

After studying this unit, you will be able to:

- To become familiar about roots of different plants.
- To know monocot and dicot root features

- To study of primary structure of monocot and dicot root in various aspects.
- To know about secondary structure of monocot and dicot root in various aspects.
- To differentiate monocot and dicot root.

5.2 Primary structure of root

In different parts of the plants, the various tissues are distributed in characteristic patterns. This is best understood by studying their internal structure by cutting sections (transverse or longitudinal or both) of the part to be studied.

- **Dicot Root (Bean Root)**

The transverse section of the dicot root (Bean) shows the following plan of arrangement of tissues from the periphery to the centre **(Figure 5.1)**.

Piliferous Layer or Epiblema

The outermost layer of the root is called piliferous layer or epiblema. It is made up of single layer of parenchyma cells which are arranged compactly without intercellular spaces. It is devoid of epidermal pores and cuticle. It possesses root hairs which are single celled. It absorbs water and mineral salts from the soil. The chief function of piliferous layer is protection.

Cortex

Cortex consists of only parenchyma cells. These cells are loosely arranged with intercellular spaces to make gaseous exchange easier. These cells may store food reserves. The cells are oval or rounded in shape. Sometimes they are polygonal due to mutual pressure. Though chloroplasts are absent in the cortical cells, starch grain are stored in them. The cells also possess leucoplasts. The innermost layer of the cortex is endodermis. Endodermis is made up of single layer of barrel shaped parenchymatous cells. Stele is completely surrounded by endodermis. The radial and the inner tangential walls of endodermal cells are thickened with suberin and lignin. This thickening was first noted by Robert Casparay in 1965. So these thickenings are called casparian strips. But these casparian strips are absent in the endodermis cells which are located opposite the protoxylem elements. These thin-walled cells without casparian strips are called passage cells through which water and mineral salts are conducted from the cortex to the xylem elements. Water cannot pass through other endodermal cells due to the presence of casparian thickenings.

Stele

All the tissues present inside endodermis comprise the stele. It includes pericycle and vascular system.

Pericycle

Pericycle is generally a single layer of parenchymatous cells found inner to the endodermis. It is the outermost layer of the stele. Lateral roots originate from the pericycle. Thus, the lateral roots are endogenous in origin.

Vascular System

Vascular tissues are in radial arrangement. The tissue by which xylem and phloem are separated is called conjunctive tissue. In bean, the conjunctive tissue is composed of parenchyma tissue. Xylem is in exarch condition. The number of protoxylem points is four and so the xylem is called tetrarch. Each phloem patch consists of sieve tubes, companion cells and phloem parenchyma. Metaxylem vessels are generally polygonal in shape. But in monocot roots they arecircular.

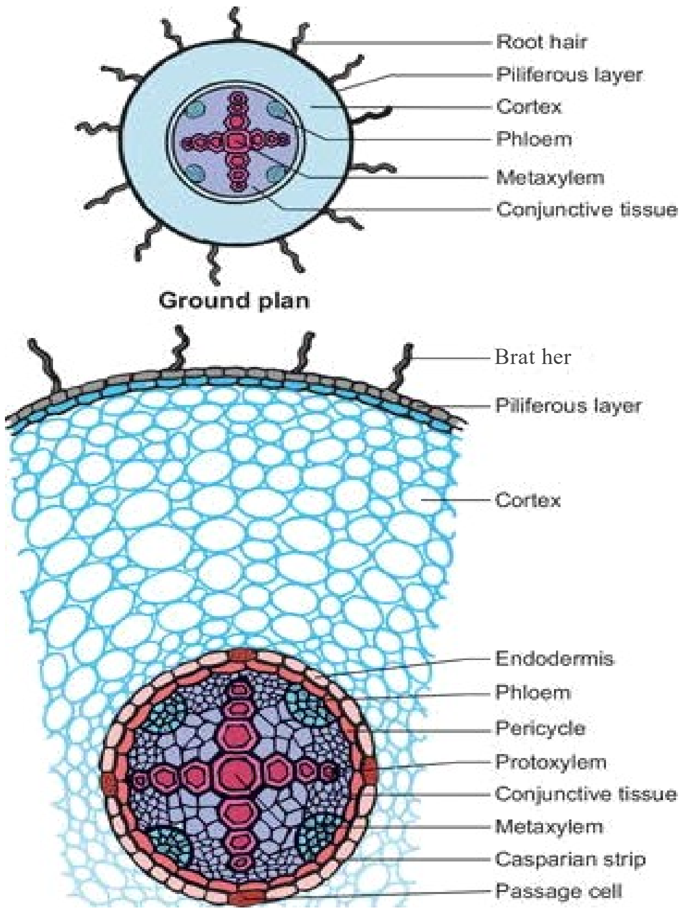


Figure 5.1: T.S. of Dicot root (Bean root)

- **Monocot root (maize Root)**

The transverse section of the monocot root (maize) shows the following plan of arrangement of tissues from the periphery to the centre **(Figure 5.2)**.

Piliferous Layer or Epiblema

The outermost layer of the root is known as piliferous layer. It consists of a single row of thin-walled parenchymatous cells without any intercellular space. Epidermal pores and cuticle are absent in the piliferous layer. Root hairs that are found in the piliferous layers are always unicellular. They absorb water and mineral salts from the soil. Root hairs are generally short lived. The main function of piliferous layer is protection of the inner tissues.

Cortex

The cortex is homogenous. i.e. the cortex is made up of only one type of tissue called parenchyma. It consists of many layers of thin-walled parenchyma cells with lot of intercellular spaces. The function of cortical cells is storage. Cortical cells are generally oval or rounded in shape. Chloroplasts are absent in the cortical cells, but they store starch. The cells are living and possess **leucoplasts.** The inner layer of the cortex is endodermis. It is composed of single layer of barrel shaped parenchymatous cells. This forms a complete ring around the stele. There is a band like structure made of**suberin** and **lignin** present in the radial and inner tangential walls of the endodermal cells. They are called **casparian strips** named after **casparay** who first noted the strips. The endodermal cells, which are opposite the protoxylem elements, are thin walled without casparian strips. These cells are called passage cells. Their function is to transport water and dissolved salts from the cortex to the xylem. Water cannot pass through other endodermal cells due to casparian strips. The main function of casparian strips in the endodermal cells is to prevent the re-entry of water into the cortex once water entered the xylem tissue.

Stele

All the tissues inside the endodermis comprise the stele. This includes pericycle, vascular system and pith.

Pericycle

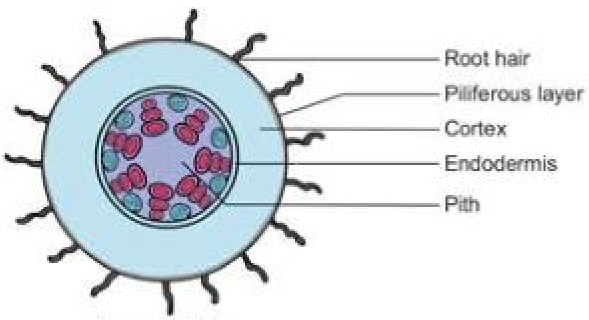
Pericycle is the outermost layer of the stele and lies inner to the endodermis. It consists of single layer of parenchymatous cells.

Vascular System

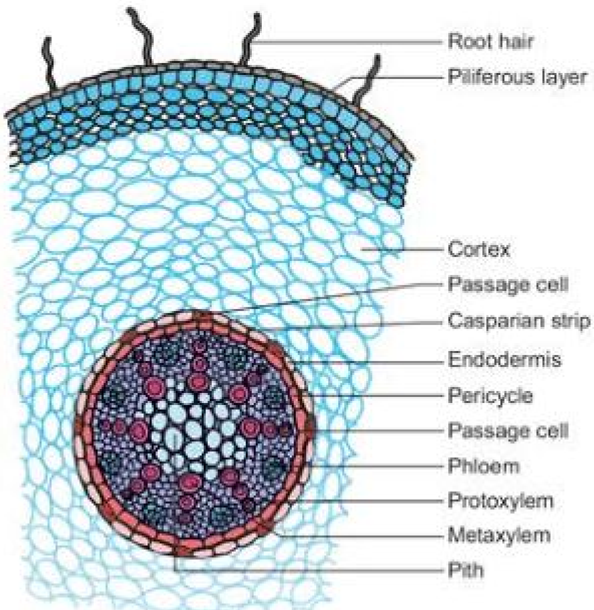
Vascular tissues are seen in radial arrangement. The number of protoxylem groups is many. This arrangement of xylem is called polyarch. Xylem is in exarch condition, the tissue which is present between the xylem and the phloem, is called conjunctive tissue. In maize, the conjunctive tissue is made up of sclerenchymatous tissue.

Pith

The central portion is occupied by a large pith. It consists of thin-walled parenchyma cells with intercellular spaces. These cells are filled with abundant starch grains.



Ground plan



A sector enlarged

Figure 5.2: T.S of Monocot root (Maize root)

SAQ.1

a. The outermost layer of the root is called_________layer or__________.
b. The chief function of piliferous layer is___________.
c. Lateral roots originate from the____________.
d. In dicots, vascular tissues are in____________ arrangement
e. The function of endodermis is to transport ___________and ________from the cortex to the xylem.

5.3 Secondary structure of root

Secondary growth occurs normally in the roots of gymnosperms and Dicotyledons to support the spreading shoot system and to meet the growing needs of absorption and conduction of food materials. Roots of most monocotyledons do not show secondary growth and remain in primary state throughout their life. Some monocots. However, do show secondary thickenings in roots (Example- *Dracaena*).

Though the process of secondary growth in the root is initiated in a different manner, the fundamental structure of secondary tissues formed is similar to that of the stem. The two secondary meristems responsible for secondary growth in roots are-

1. **Fascicular or vascular cambium-** It lies in the stelar region and its activity results in the formation of secondary xylem and secondary phloem.
2. **Phellogen or cork cambium-** It develops in the extra-stelar region and its activity results in the formation of periderm.

The initiation and activity of vascular cambium starts much earlier than that of cork cambium.

- **Dicot roots-**

Secondary growth takes place in all dicotyledonous woody plants. The root increases in girth by the activity of stelar and extrastelar cambium. This growth starts to takes place slightly behind the apex of root **(Figure 5.3)**.

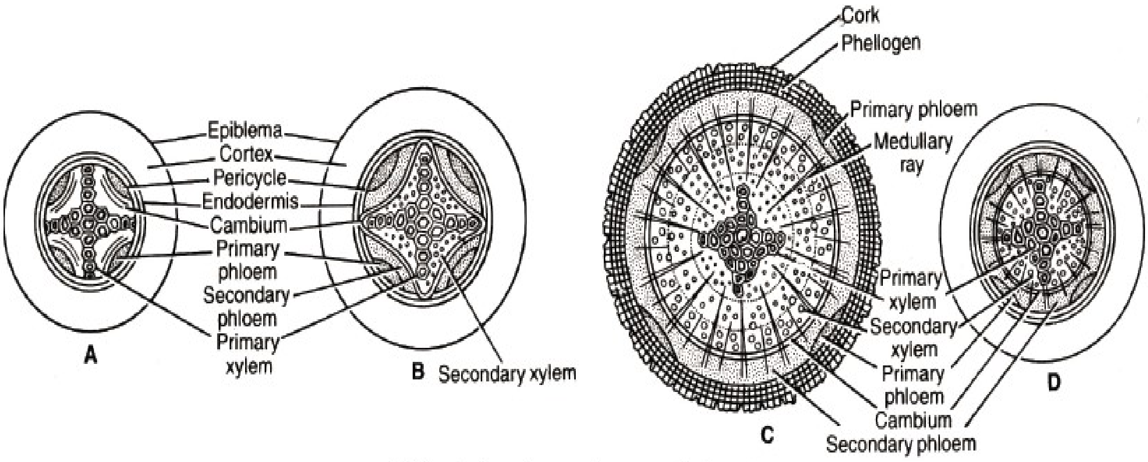


Figure 5.3: Dicot root

1. Origin and Activity of Vascular Cambium

In dicot roots, the arrangement of vascular bundles is radial and xylem is exarch. Cambium is absent but develops at the time of secondary growth. First of all, parenchyma cells interior to the phloem (towards pith) become meristematic, thus in a tetarch root four separate strips of cambia are formed. Later, these strips become continuous laterally as a result of tangential divisions of pericycle cells opposite to each protoxylem. Thus, a wavy continuous cambium ring is produced. This ring is present below the phloem but above the protoxylem. This meristem is thus, an absolutely **secondary meristem**. First the strips of cambia below the phloem cut of secondary xylem towards the inner side. The cells cut-off toward the outer face mature into secondary phloem. By this activity of these strips of cambium, the cambium become circular and cuts-off secondary xylem internally at all places and secondary phloem at all places externally. Thus, after stelar secondary growth a solid central cylinder of wood is formed which is surrounded by bast.

2. Origin and Activity of Cork Cambium

Cork cambium arises as a result of the tangential division of the outer cells of pericycle. The activity of cork cambium is similar to that found in dicot stem so it produces cork cells on the outer side and parenchyma on the inner side. The protoplast of cork cells secretes a fat-like substance called **suberin** which is deposited in the walls. Due to further deposition of suberin these cells die. As the cork cambium in dicot root originates from the cells of pericycle so all tissues lying outside the cork (endodermis, cortex, epiblema) are completely sloughed off. **(Figure 5.4)**.

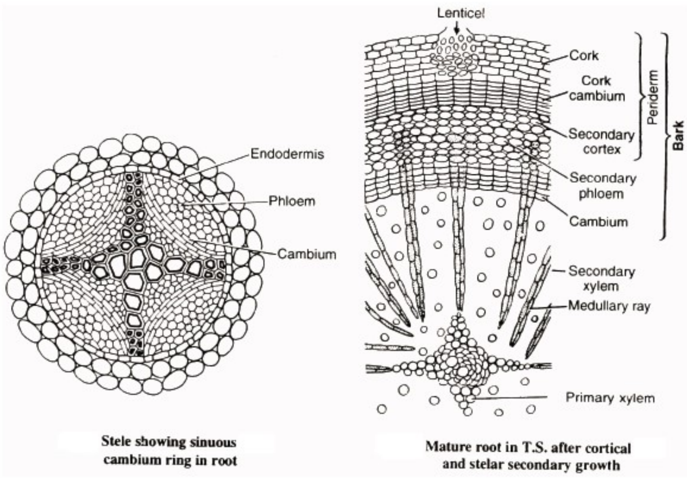


Figure 5.4

- **Monocot roots-**

  In stem of some monocots there occur abnormal secondary growth. Eg. *Dracena*, *Yucca sansi viera*, *Agave Americana*, *Kingia*, *Lomendra*, *Aloe arborescenae*. In all these monocots ring of V.C. is derived from outer part of ground tissue. Vascular cambium produces parenchyma towards outside and secondary xylem and secondary phloem both are produced towards inner side.

  In some other monocots like Date palm, Coconut palm, Tulipa, Musa. Width increases without cambium in these plants. Apical meristem is of special type and is called primary thickening meristem. Due to its activity width and length both increases. Increase in width of plant organ in these monocots is the example of primary growth.

SAQ.2

---

a. Secondary growth occurs normally in the roots of__________and____________.

b. _________ cambium lies in the stelar region and its activity results in the formation of secondary xylem and secondary phloem.

c. The initiation and activity of vascular cambium starts much earlier than that of________.

d. In dicot roots, the arrangement of vascular bundles is_______and xylem is________.

e. Apical meristem is of special type and is called_____________________meristem.

5.4 Summary

- Root constitutes the lower part of the plant axis which typically grows towards gravity. It is usually sub-cylindrical, tapering towards the tip.
- On the basis of external form, root system can be sub-divided into the two categories: **i.** Tap root system, **ii.** Adventitious root system.
- Tap root system consists of primary root and its lateral branches. Most of the Dicotyledons have a tap root system.
- Adventitious root system includes those roots which develop from any part of the plant other than the radicle.
- The main functions of the root are:

  i. Anchorage of plant in the soil

  ii. Adsorption of water and minerals

  iii. Storage of food material.
- Anatomical differences in dicot and monocot root are as follows-

S.No.	Characters	Dicot root	Monocot root
1.	Pericyle	Gives rise to lateral roots, phellogen and a part of vascular cambium.	Gives rise to lateral roots only.
2.	Vascular tissue	Usually limited number of xylem and phloem strips.	Usually more number of xylem and phloem strips,
3.	Conjunctiv e tissue	Parenchymatous; Its cells are differentiated into vascular cambium.	Mostly sclerenchymatous but sometimes parenchymatous. It is never differentiated into vascular cambium.
4.	Cambium	It appears as a secondary meristem at the time of secondary growth.	It is altogether absent.
5.	xylem	Usually tetrarch	Usually polyarch

5.5 Terminal Question

Q.1 Describe the role of root in plants.

Answer:---

Q.2 Discuss the primary structure of dicot root in detail.

Answer:---

Q.3 Describe the primary structure of monocot root in detail.

Answer:---

Q.4 Discuss the secondary structure of monocot and dicot root.

Answer:---

Q.5 Differentiate the monocot and dicot root.

Answer:---

Short Questions

Q.6 Write short notes on:

1. Tap root system
2. Adventitious root system
3. T.S. of *Maize* root

4. Primary structure of dicot root
5. Secondary growth of dicot root
6. Epiblema
7. Vasculature in monocots
8. Endodermis of dicot and monocot root

Q.7 Multiple choice questions:

1. Tetrarch vascular bundle is characteristic of-
   i. Bengal gram root
   ii. Sunflower stem
   iii. Maize stem
   iv. Maize root
2. Root hairs arises from-
   i. Epiblema
   ii. Cortex
   iii. Endodermis
   iv. Pericycle
3. Which of the following can be seen in a monocot root?
   i. A large pith
   ii. No or poorly developed pith
   iii. Medullary ray
   iv. Endarch xylem
4. A dicot root differs from monocot root in the presence of-
   i. Piliferous layer
   ii. Exodermis
   iii. Ill developed pith
   iv. Radial vascular bundles
5. A transverse section of the young dicot root can be distinguished from that of a young monocot stem by the presence of-
   i. Interfascicular cambium
   ii. Intrafascicular cambium
   iii. Collateral arrangement of xylem and phloem
   iv. Radial arrangement of xylem and phloem

5.6 Answers

1. i.   2. i   3. i   4. iii   5. iv

Self-assessment questions

SAQ.1

b. Piliferous, epiblema **b.** Protection of the inner tissues **c.** Pericycle **d.** Radial **e.** Water, mineral salt

SAQ.2

b. Gymnosperms, dicotyledons **b.** Fascicular or vascular cambium **c.** Cork-cambium **d.** Radial, exarch **e.** Primary thickening

Unit- VI

Stem

Structure

6.1 Introduction

Objectives

6.2 Primary structure of stem

6.3 Secondary structure of stem

6.4 Summary

6.5 Terminal Questions

6.6 Answers

6.1 Introduction

Stems are usually above ground organs and grow towards light (positively phototropic) and away from the ground (negatively geotropic), except in the case of certain metamorphic (modified) stems. The main stem develops from the plumule of the embryo, while lateral branches develop from auxillary buds or from adventitious buds. In normal stems clearly defined internodes and nodes can be distinguished, the latter being the regions where the leaves are attached. In younger stems stomata are found in the epidermis while in the mature stems lenticels are evident. Depending on the hardness of the stem one can also distinguish between herbaceous and woody stems. In this section we will discuss the internal structures of young dicotyledonous and monocotyledonous stems, secondary thickening in the stems of dicot, and differences in the internal structures of dicots and monocots.

Stem is one of two main structural axes of a vascular plant, the other being the root. The stem is normally divided into nodes and internodes: The nodes hold one or more leaves, as well as buds which can grow into branches (with leaves, conifer cones, or inflorescences (flowers)). Adventitious roots may also be produced from the nodes.

The term "shoots" is often confused with "stems"; "shoots" generally refers to new fresh plant growth including both stems and other structures like leaves or flowers. In most plants stems are located above the soil surface but some plants have underground stems. The stems have four main functions which are:

- Support for and the elevation of leaves, flowers and fruits
- The stems keep the leaves in the light and provide a place for the plant to keep its flowers and fruits
- Transport of fluid between the root and shoot by the xylem and phloem
- Storage of nutrients

Production of new living tissue i.e. stems have cells called meristems that annually generate new living tissue. Shoots consist of stems including their appendages, the leaves and lateral buds, flowering stems and flower buds. The new growth from seed germination that grows upward is a shoot where leaves will develop. In the spring, perennial plant shoots are the new growth that grows from the ground in herbaceous plants or the new stem and flower growth that grows on woody plants.

In everyday speech, shoots are often synonymous with stems. Stems, which are an integral component of shoots, provide an axis for buds, fruits, and leaves. Young shoots are often eaten by animals because the fibers in the new growth have not yet completed secondary cell wall development, making the young shoots softer and easier to chew and digest. As shoots grow and age, the cells develop secondary cell walls that have a hard and tough structure. Some plants (e.g. bracken) produce toxins that make their shoots inedible or less palatable

Stem usually consist of three tissues, dermal tissue, ground tissue and vascular tissue. The dermal tissue covers the outer surface of the stem and usually functions to water proof, protect and control gas exchange. The ground tissue usually consists mainly of parenchyma cells and fills in around the vascular tissue. It sometimes functions in photosynthesis. Vascular tissue provides long distance transport and structural support. Most or all ground tissue may be lost in woody stems. The dermal tissue in aquatic plants, stems may lack the waterproofing as found in aerial stems. The arrangement of the vascular tissues varies widely among plant species.

Stem is divided into nodes and internodes. Parts of the stem where one or more leaves are attached are called nodes and the regions between two successive nodes as internodes. The stem increases in length mainly due to the activity in the sub-apical region, known as primary elongation meristem. Both cell division and cell elongation taking place in this region contribute to the growth of the stem in length. Stems of many monocotyledons elongate also by an intercalary meristem- a meristem intercalated between the two regions of differentiated tissue.

Objectives

After studying this unit, you will be able:

- Familiar about stem of different plants.
- To know monocot and dicot stem features
- About various aspects of primary structure of monocot and dicot stem in various aspects.
- To know about secondary structure of monocot and dicot stem.
- To differentiate monocot and dicot stem.

6.2 Primary structure of stem

- **Dicot stem (Sunflower)-**

The transverse section of the dicot stem (sunflower) shows the following plan of arrangement of tissues from the periphery to the centre **(Figure 6.1)**.

Epidermis

It is protective in function and forms the outermost layer of the stem. It is a single layer of parenchymatous rectangular cells. The cells are compactly arranged without intercellular spaces. The outer walls of epidermal cells have a layer called cuticle. The cuticle checks the transpiration. The cuticle is made up of waxy substance known as cutin. Stomata may be present here and there. Epidermal cells are living. Chloroplasts are usually absent. A large number of multicellular hairs occur on the epidermis.

Cortex

Cortex lies below the epidermis. The cortex is differentiated into three zones. Below the epidermis, there are few layers of collenchyma cells. This zone is called **hypodermis.** It gives mechanical strength of the Stem. These cells are living and thickened at the corners.

Inner to the hypodermis, a few layers of collenchyma cells are present. This zone is called hypodermis. It gives mechanical strength to the stem. These cells are living and thickened at the corners. Inner to the hypodermis, a few layers of chlorenchyma cells are present with conspicuous intercellular spaces. This region performs photosynthesis. Some resin ducts also occur here. The third zone is made up of parenchyma cells. These cells store food materials. The innermost layer of the cortex is called **endodermis**. The cells of this layer are barrel shaped and arrange compactly without intercellular spaces. Since starch grains are abundant in these cells. Therefore, this layer is also known as **starch sheath**. This layer is morphologically homologous to the endodermis found in the root. In most of the dicot stems, endodermis with casparian strips is not developed.

Stele

The central part of the stem inner to the endodermis is known as **stele**. It consists of pericyle, vascular bundles and pith. In dicot stem, vascular bundles are arranged in a ring around the pith. This type of stele is called **eustele.**

Pericycle

Pericycle is the layers of cells that occur between the endodermis and vascular bundles. In the stem of **sunflower** (*Hellianthus*), a few layers of sclerenchyma cell occur in patches outside the phloem in each vascular bundle. This patch of sclerenchyma cell is called Bundle cap. The bundle caps and the parenchyma cells between them constitute the pericycle in the stem of sunflower.

Vascular bundle

The vascular bundles consist of xylem, phloem and cambium. Xylem and phloem in the stem occur together and form the vascular bundles. These vascular bundles are Wedge shaped. They are arranged in the form of a ring. Each vascular bundle is conjoint, collateral, open and endarch.

Phloem

Primary phloem lies towards the periphery. It consists of proto phloem and meta phloem. Phloem consists of sieve tubes, companion cells and phloem parenchyma. Phloem fibres are absent in the primary phloem. Phloem conducts organic food materials from the leaves to other parts of the plant body.

Cambium

Cambium consists of brick shaped and thin walled meristematic cells. It is one to four layers in thickness. These cells are capable of forming new cells during secondary growth.

Xylem

Xylem consists of xylem fibres, xylem parenchyma vessels and tracheids. Vessels are thick walled and arranged in a few rows. Xylem conducts water and minerals from the root to the other parts of the plant body.

Pith

The large central portion of the stem is called pith. It is composed of parenchyma cells with intercellular spaces. The pith is also known as medulla. The pith extends between the vascular bundles. These extensions of the pith between the vascular bundles are called primary pith rays or primary medullary rays. Function of the pith is storage of food.

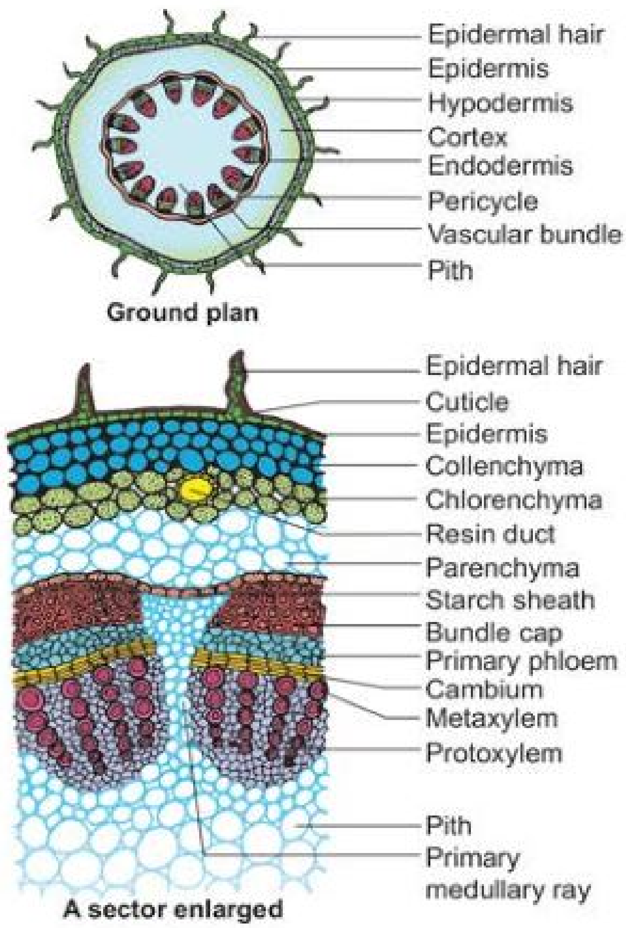


Figure 6.1: T.S of Dicot Stem (Sunflower stem)

- **Monocot stem (Maize)-**

The outline of the maize in transverse section is more or less circular. The transverse section of the monocot stem (maize) shows the following plan of arrangement of tissues from the periphery to the centre **(Figure 6.2)**.

Epidermis

It 1s the outermost layer of the stem. It is made up of single layer of tightly packed parenchymatous cells. Their outer walls are covered with thick cuticle. The continuity of this layer may be broken here and there by the presence of a few stomata. There is no epidermal outgrowth.

Hypodermis

A few layer of sclerenchymatous cells lying below the epidermis constitute the hypodermis. This layer gives mechanical strength to the plant. It is interrupted here and there by chlorenchyma cells.

Ground tissue

There is no distinction into cortex, endodermis, pericycle and pith. The entire mass of parenchyma cells lying inner to the hypodermis forms the ground tissue.

The cell wall is a made up of cellulose. The cells contain reserve food material starch. The cells of the ground tissue next to the hypodermis are smaller in size, polygonal in shape and compactly arranged.

Towards the centre, the cells are loosely arranged, rounded in shape and bigger in size. The vascular bundles lie embedded in this tissue. The ground tissue stores food and performs gaseous exchange.

Vascular bundles

Vascular bundles are scattered (atactostele) in the parenchymatous ground tissue. Each vascular bundle is surrounded by a sheath of sclerenchymatous fibres called bundle sheath. The vascular bundles art conjoint, collateral, endarch and closed. They are numerous, small and closely arranged in the peripheral portion. Towards the centre, the bundles are comparatively large in size and loosely arranged. Vascular bundles are skull or oval shaped.

Phloem

The phloem in the monocot stem consists of sieve tubes and companion cells. Phloem parenchyma and phloem fibres are absent. It can be distinguished into an outer crushed protophloem and an inner metaphloem.

Xylem

Xylem vessels are arranged in the form of 'Y' the two metaxylem vessels are located at the upper two arms and one or two protoxylem vessels at the base. In a mature bundle, the lowest protoxylem disintegrates and forms a cavity known as protoxylem lacuna.

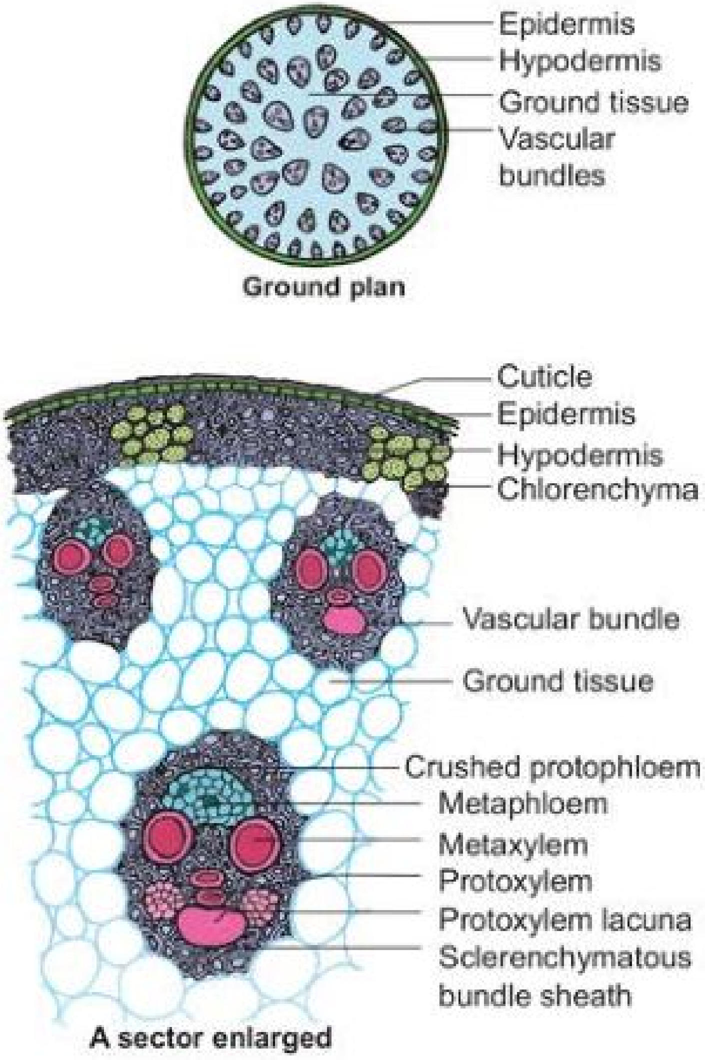


Figure 6.2: T.S. Monocot stem (Maize stem)

SAQ.1

a. The______________checks the transpiration.

b. The innermost layer of the cortex is called____________.

c. In the stem of ______________ a few layers of sclerenchyma cell occur in patches outside the phloem in each vascular bundle.

d. In monocots, vascular bundles are____________in the______________ground tissue.

e. The phloem in the monocot stem consists of______________and_____________cells.

6.3 Secondary structure of stem

Secondary growth occurs in perennial gymnosperms and dicots such as trees and shrubs. It is also found in the woody stems of some herbs. In such cases, the secondary growth is equivalent to one annual ring, e.g., Sunflower.

A. Formation of Secondary Vascular Tissues (Figure 6.3):

They are formed by the vascular cambium. Vascular cambium is produced by two types of meristems, fascicular or intra-fascicular and inter-fascicular cambium. Intra-fascicular cambium is a primary meristem which occurs as strips in vascular bundles. Inter-fascicular cambium arises secondarily from the cells of medullary rays which occur at the level of intra-fascicular strips.

These two types of meristematic tissues get connected to form a ring of vascular cambium. Vascular cambium is truly single layered but appears to be a few layers (2-5) in thickness due to presence of its immediate derivatives. Cells of vascular cambium divide periclinally both on the outer and inner sides (bipolar divisions) to form secondary permanent tissues.

The cells of vascular cambium are of two types, elongated spindle-shaped fusiform initials and shorter isodiametric ray initials. Both appear rectangular in T.S. Ray initials give rise to vascular rays.

Fusiform initials divide to form secondary phloem on the outer side and secondary xylem on the inner side. With the formation of secondary xylem on the inner side, the vascular cambium moves gradually to the outside by adding new cells.

The phenomenon is called dilation. New ray cells are also added. They form additional rays every year. The vascular cambium undergoes two types of divisions—additive (periclinal divisions for formation of secondary tissues) and multiplicative (anticlinal divisions for dilation).

Ray initials produce radial system (= horizontal or transverse system) while fusiform initials form axial system (= vertical system) of secondary vascular tissues.

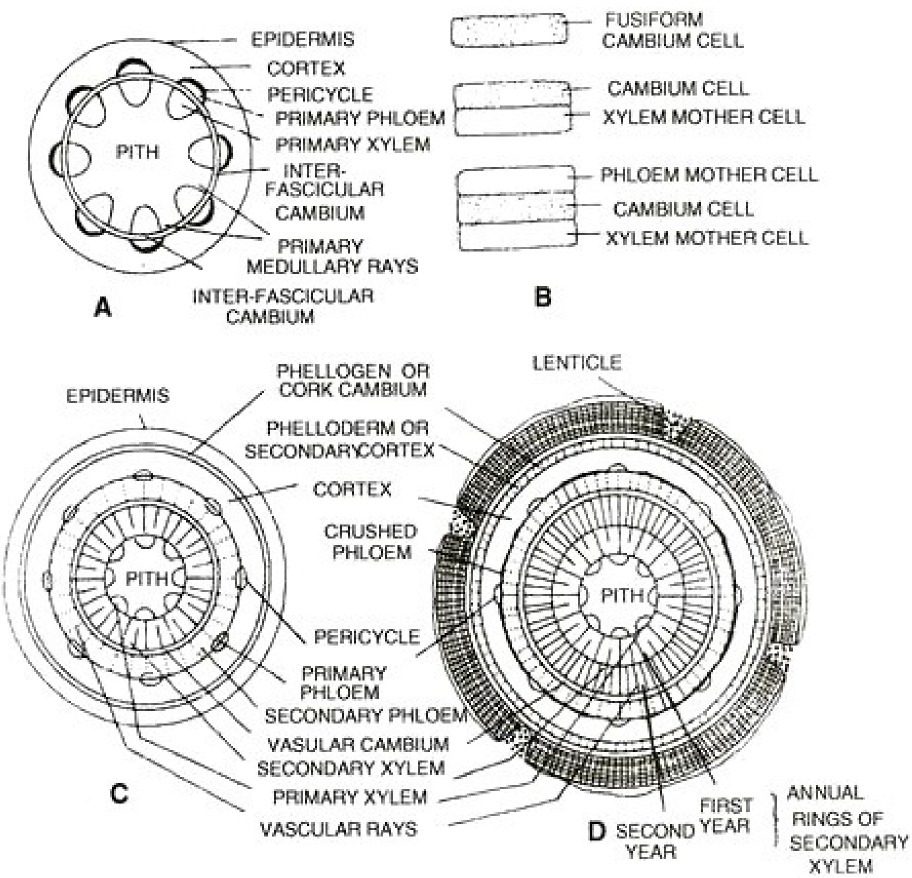


Figure 6.3 **A.** complete ring of vascular cambium formed by strips of intra-fascicular cambium and inter- fascicular cambium, **B.** Formation of secondary vascular tissue mother cells, **C.** The beginning of secondary growth (mostly made up of secondary vascular tissues) of dicot stem (diagrammatic), **D.** Two –year stage of secondary growth of a dicot stem.

B. Formation of Periderm:

In order to provide for increase in girth and prevent harm on the rupturing of the outer ground tissues due to the formation of secondary vascular tissues, dicot stems produce a cork cambium or phellogen in the outer cortical cells. Rarely it may arise from the epidermis (e.g., Teak, Oleander), hypodermis (e.g., Pear) or phloem parenchyma.

Phellogen cells divide on both the outer side as well as the inner side (bipolar) to form secondary tissues. The secondary tissue produced on the inner side of the phellogen is parenchymatous or collenchymatous. It is called secondary cortex or phelloderm. Its cells show radial arrangement.

Phellogen produces cork or phellem on the outer side. It consists of dead and compactly arranged rectangular cells that possess suberised cell walls. The cork cells contain tannins. Hence, they appear brown or dark brown in colour. The cork cells of some plants are filled with air e.g., *Quercus suber* (Cork Oak or Bottle Cork). The phelloderm, phellogen and phellem together constitute the periderm.

Cork prevents the loss of water by evaporation. It also protects the interior against entry of harmful micro-organisms, mechanical injury and extremes of temperature. Cork is light, compressible, nonreactive and sufficiently resistant to fire.

It is used as stopper for bottles, shock absorption and insulation. At places phellogen produces aerating pores instead of cork. These pores are called lenticels. Each lenticel is filled by a mass of somewhat loosely arranged suberised cells called complementary cells.

SAQ.2

1. In Sunflower, the secondary growth is equivalent to___________annual ring.
2. _________________is a primary meristem which occurs as strips in vascular bundles.
3. Fusiform initials divide to form______________on the outer side and_____________on the inner side.
4. The cells of phelloderm show_____________arrangement.
5. The phelloderm, phellogen and phellem together constitute the____________.

6.4 Summary

- The shoot system of the flowering plants, which develops from the plumule, consists of an axis, the stem, bearing lateral organs.
- Stem is divided into nodes and internodes.
- Parts of the stem when one or more leaves are attached are called nodes and the regions between two successive nodes as internodes.
- The stem increases in length mainly due to the activity in the sub-apical region, known as primary elongation meristem.

- The innermost layer of the cortex is called endodermis. The cells of this layer are barrel shaped and arrange compactly without intercellular spaces. Since starch grains are abundant in these cells, this layer is also known a starch sheath.
- Secondary growth occurs in perennial gymnosperms and dicots such as trees and shrubs. It is also found in the woody stems of some herbs. It occurs due to formation of secondary vascular tissues or formation of periderm.
- The phelloderm, phellogen and phellem together constitute the periderm.
- Anatomical differences in dicot and monocot stem are as follows-

S.No.	Characters	Dicot Stem	Monocot Stem
1.	Hypodermis	Collenchymatous	Sclerenchymatous
2.	Ground tissue	Differentiated into cortex, endodermis and pericycle and pith	Not differentiated, but it is a continuous mass of parenchyma.
3.	Starch Sheath	Present	Absent
4.	Medullary rays	Present	Absent
5.	Vascular bundles	(a) Collateral and open	(a) Collateral and closed
		(b) Arranged in a ring	(b) Scattered in ground tissue
		(c) Secondary growth occurs	(c) Secondary growth usually does not occur.

6.5 Terminal Question

Q.1 Describe the primary structure of a normal dicot stem with the help of labelled diagram.

Answer:--

Q.2 Discuss the primary structure of a normal monocot stem with the help of labelled diagram.

Answer:--

Q.3 Discuss the vascular bundles of dicot and monocot stem.

Answer:---

Q.4 Describe the secondary structure of stem.

Answer:---

Q.5 Differentiate the monocot and dicot stem.

Answer:---

Short Questions

Q.6 Write short notes on:

1. Ground tissue of dicot and monocot stem
2. Starch sheath
3. Xylem and phloem of dicot stem
4. T.S. stem of Monocot
5. Secondary growth in dicot stem
6. Pith cavity of monocot and dicot stem
7. Casparian strips

Q.7 Multiple choice questions:

1. In a dicot stem-
    i. The vascular bundles are scattered and lack cambium
    ii. The vascular bundles are usually arranged in a ring and have cambium
    iii. Xylem and phloem occur in separate bundles
    iv. Xylem is always exarch
2. Conjoint, collateral and open vascular bundles are found in-
    i. Dicot stem
    ii. Monocot stem
    iii. Dicot root
    iv. Monocot root

3. In monocot stems, the hypodermis is-
    i. Parenchymatous
    ii. Chlorenchymatous
    iii. Collenchymatous
    iv. Sclerenchymatous
4. Bundle sheath is present in-
    i. Dicot stem
    ii. Monocot root
    iii. Monocot stem
    iv. Both i and ii
5. The layer between vascular bundles and endodermis is known as-
    i. Epidermis
    ii. Hypodermis
    iii. Bundle sheath
    iv. Pericycle

6.6 Answers

1. ii 2. i 3. iii 4. iii 5. iv

Self-assessment questions

SAQ.1

c. Cuticle **b.** Endodermis **c.** Sunflower **d.** Scattered, parenchymatous **e.** Sieve tubes, companion

SAQ.2

c. One **b.** Intra-fascicular cambium **c.** Secondary phloem, secondary xylem **d.** Radial **e.** Periderm

Unit- VII

Anomalous Secondary Growth

Structure

7.1 Introduction

Objectives

7.2 Anomalous secondary growth in *Bignonia* (Dicot)

7.3 Anomalous secondary growth in *Boerhaavia* (Dicot)

7.4 Anomalous secondary growth in *Dracaena* (Monocot)

7.5 Summary

7.6 Terminal Questions

7.7 Answers

7.1 Introduction

Increase in plant girth due to the vascular cambium or cork cambium is called secondary growth. whereas the development, arrangement and activity of the vascular cambium in most woody dicotyledonous and gymnosperm plants tends to be very similar, there are some alternatives or deviation, which produce new secondary tissues that do not follow a normal pattern. As a result, the secondary plant structures are formed which are termed anomalous.

The word Anomalous means" deviating from the normal or common type or order". The term Anomalous secondary growth is given for the deviation or variation. The pattern of the secondary thickening show deviation from the normal type is regard as abnormal or anomalous secondary growth.

Remember that all plant stem growth occurs at the meristems of the shoot system because this is where cell division occurs. There are two types of meristem in the plant stem: apical and lateral. As we just reviewed, primary growth occurs at the apical meristem and increases plant stem length. We have previously looked at the basic structures of the shoot system as well as primary growth of the stem. We will now look at another form of growth known as secondary growth of the stem. Before we do, let us review a few key components of the shoot system, which is the above ground structures of plants, including the leaves, buds, stems, flowers and fruits.

Primary growth occurs at the apical meristem and allows the plant stem to increase in length. However, some plants need more than just growth in the length of the stem. We will now look at this type of growth. Remember that all plant stem growth occurs at the meristems of the shoot system because this is where cell division occurs. There are two types of meristem in the plant stem: apical and lateral. As we just reviewed, primary growth occurs at the apical meristem and increases plant stem length. Primary growth occurs when plants grow toward the sunlight necessary for photosynthesis and also sink roots deep into the soil to anchor them and enable them to absorb water and nutrients. This 'up and down' growth is possible due to apical meristem, stem cell like tissue that, upon division, creates an undifferentiated cell that will become either a new root or shoot tip.

Secondary growth happens when stems or branches grow outward (get thicker) This type of growth is possible because some plants (like trees and shrubs) have lateral meristem, another stem cell like tissue. Instead of causing the plant to grow up or down, lateral meristematic tissue causes the plant to increase in girth by adding rings of growth. Now we know how a plant gets taller and its roots get longer. But what about being wider? Even a big tree with an enormous trunk starts out as a puny seedling. So when the width of a plant or its girth increases is called secondary growth and it arises from the lateral meristems in stems and roots.

As with apical meristems, lateral meristems are regions of high cell division activity. However, the cells they make grow outward rather than upward or downward. Dicots use lateral meristems to add to their width; monocots, however, do not experience secondary growth. We will come back to them later. The lateral meristems that produce secondary growth are called cambiam, which just mean a tissue layer that adds to plant growth. The two important ones for secondary growth are the vascular cambium and the cork cambium. The vascular cambium produces more vascular tissue (xylem and phloem), which provide support for the shoot system in addition to transporting water and nutrients. Because the xylem and phloem that come from the vascular cambium replace the original (primary) xylem and phloem, and add to the width of the plant, they are called secondary xylem and secondary phloem.

Secondary growth is growth at the lateral meristem and increases the girth of the stem. This type of growth is only found in dicots and is not found in monocots. In order to understand why it does not occur in monocots, let us review the structure of vascular tissue in both types of flowering plants. There are two types of vascular tissue: xylem, which moves water and dissolved minerals, and phloem, which moves food in the plant stem. In monocots and dicots, these structures are organized a bit differently.

In monocots, the xylem and phloem are found in paired bundles and are scattered throughout the stem. Remember that monocots are simple flowering plants such as grasses. However, in dicots - which are more advanced flowering plants such as roses and apple trees

- the xylem and phloem are found in rings with the xylem on the inside and the phloem on the outside. This organization allows for secondary growth of plant stems.

Cambium

Meristematic tissue responsible for lateral (outward) growth in plants is known as cambium. There are two kinds of cambium in woody plant stems, both of which increase the diameter of stems. First type of cambium is vascular cambium found in the center of the stem; its division produces the plant's secondary vascular tissue (xylem and phloem cells.) The outer ring or near the epidermis the bark of a woody plant also contains a cambium called secondary cambium or cork cambium, which creates cork cells of the outer layer and responsible to give rise the bark **(Figure 7.1)**.

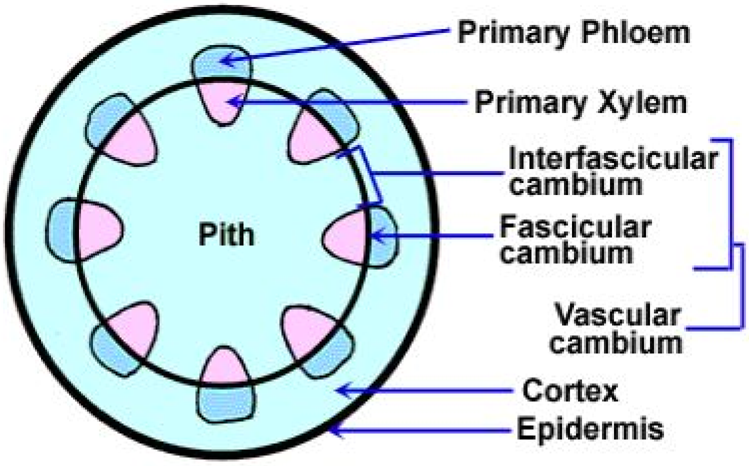


Figure 7.1 Structure of cambium

The cambium layer consists of a single layer of cell and these cells divide in a direction parallel with epidermis. Each time it divides into two cells and one of the two new cells one remains meristematic and the other differentiates into permanent tissue. If the newly formed cell is near the xylem it will form secondary xylem and if newly formed cell is towards phloem it will develop in secondary phloem. The activity of cambium thus increases and the enlargement of stem takes place. This activity of cambium remains for a considerable long period of time.

Haberlandlt classified anomalous secondary growth into –

1) Adaptive Anomaly - Anomalies as regards secondary growth in many case notable being those of some climbers, lianas and storage organ such as beet root, are environmental, since they are morphologically and physiologically different from the normal types and, they are thus adaptive (environmental).

2) Non Adaptive Anomaly - At the same time there are cases of anomalous condition which are non-environmental and appear to be merely cases of variations of the design.

The Anomalies may be listed as follows –

1. Anomalous position of vascular cambium
2. Abnormal behaviour of normal cambium.
3. Accessory cambium formation and its activity.
4. Extrastelar cambium.
5. Interxylary or Included phloem.
6. Presence of medullary bundles along with normal cambial activity.
7. Presence of cortical bundles along with normal cambial activity.
8. Intraxylary or Internal phloem.
9. Secondary growth in monocotyledons. e.g. *Dracaena.*
10. Scattered vascular bundles in dicotyledons.
11. Anomalous primary growth –

a) Absence of vessels in the xylem.

b) Scattered vascular bundles along with cambial activity in dicots.

Objectives

After studying this unit, you will be able to:

- Analyse primary and secondary growth.
- Discuss the increase in length and width of the plant.
- Explain secondary growth in dicotstems.
- Understand the normal and abnormal activity of cambium.
- Explain secondary growth in monocot stems
- Discuss anomalous secondary growth in dicots and monocots.

7.2 Anomalous secondary growth in *Bignonia* (Dicot)

Bignonia stem

Bignonia is a member of Bignoniaceae family. Transverse section through the young stem of *Bignonia* show following tissue **(Figure 7.2)**: -

Epidermis:

It is uniseriate and cuticularised. The young stem shows wavy outline with prominent ridges and furrows.

Cortex:

It is parenchymatous and bounded internally by a starch sheath layer.

Perivascular Region:

There are scattered patches of sclerenchymatous cells, particularly under the ridges of the stem.

Vascular Bundles:

In young stem vascular bundles are arranged in a ring and cambium is normal in disposition. Soon secondary growth starts, the cambial ring is formed and then it cuts-off different proportions of xylem and phloem at different points.

At four points, the formation of secondary xylem is reduced and that of secondary phloem correspondingly increased. As a result of this, a peculiar structure with ridged and furrowed xylem cylinder is formed.

Pith:

It is parenchymatous.

Anomalous Structure in *Bignonia* –

The most interesting anatomical feature in *Bignonia* is the occurrence of anomalous secondary structure. This is as follows –

Anomalous secondary thickening is due to the abnormal functioning of cambium. Cambium is normal in disposition and abnormal in function (adaptive type).

A) Presence of Phloem Wedges in the Xylem -

The young stems which exhibits this type of structure when mature are provided with a normal ring of vascular bundles. The origin, position and function of cambium ring is normal in the initial stage of growth. Cambium function normally producing more secondary xylem towards inner side and less secondary phloem to the outer side. But after sometime, the cambium cuts off different proportion of xylem and phloem at different points.

At four diagonal point arranged in cross shaped order, formation of secondary xylem is reduced and that of secondary phloem correspondingly increase, so that secondary phloem with transverse bands of bast fibre gets penetrated within the mass of xylem in the form of phloem pocket. Hence, the woody cylinder appears to have four longitudinal grooves which become increasingly deeper with secondary growth.

As a result of these four furrows at four equidistant points appear in the xylem, extending almost to the pith. The cambium breaks up into a number of strips, widest ones occurring opposite the four projecting ridges of wood and the narrow ones at the base of the grooves. Cambium is not found on the radial surface. Peculiar structure with ridged and furrowed xylem cylinder is formed (Anomalous structure in stelar region). The four radial groups of the phloem are united by medullary rays seen traversing the phloem of furrows.

B) Presence of Fissured Xylem –

The fissured xylem may only be seen in fairly old stems. First of all wedges of phloem are formed and thereafter the xylem strand becomes fissured by dilation and cell division in wood parenchyma and pith.

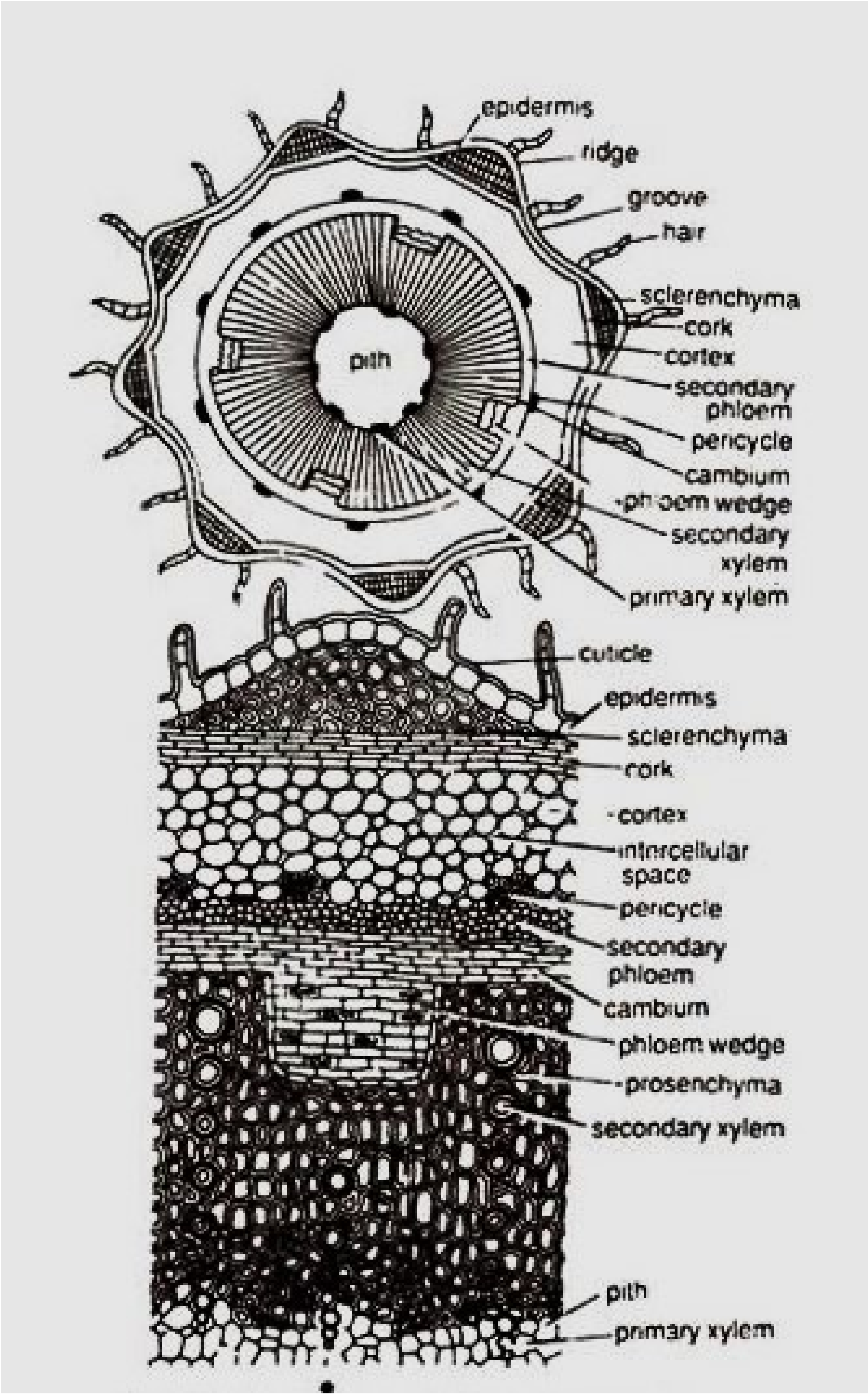


Figure 7.2 T.S. stem of *Bignonia*: Upper (diagrammatic), lower (A part cellular)

SAQ.1

a. Cork is formed from______________.

b. Anomalous secondary thickening is due to the abnormal functioning of _________in *Bignonia.*

c. The__________radial groups of the phloem are united by medullary rays seen traversing the phloem of furrows.

d. During anomalous secondary growth, sclrenchymatous bar is formed in the stem of _____________.

e. The fissured xylem may only be seen in fairly________stems.

7.3 Anomalous secondary growth in *Boerhaavia* (Dicot)

***Boerhaavia* Stem**

Boerhaavia is a member of family, Nyctaginaceae. They are generally herbaceous plant. Transverse section through the young stem of *Boerhaavia* show following tissues **(Figure 7.3)**: -

Epidermis –

1) Epidermis is single layered and consists of small, radially elongated parenchymatous cells.

2) Multi-cellular epidermal hairs arise from some cell.

3) A thick cuticle is present on the epidermis.

4) Some stomata are also present.

Cortex –

1) Cortex is well differentiated and consists of few layered collenchymatous hypodermis followed by parenchyma.

2) Collenchyma is 3-4 cells deep, but generally near stomata it is only one layered.

3) Parenchyma is present inner to collenchyma in the form of 3 to 7 layers.

4) Parenchymatous cells are thin walled, oval, full of chloroplast and enclose many intercellular spaces.

Endodermis is Clearly developed and made up of many tubular thick walled cells.

Pericycle - Inner to the endodermis is present parenchymatous pericycle but at some place it is represented by isolated patches of sclerenchyma.

Pith - Well developed, parenchymatous, present in the centre.

Vascular System –

Vascular bundles are collateral, conjoint and open with endarch xylem and are arranged in three rings –

1) Two large centrally placed medullary vascular bundles.

2) A middle ring of 6 to 14 loosely arranged and medium sized vascular bundles.

3) The outer ring of 15 to 20 small vascular bundles just beneath the pericycle.

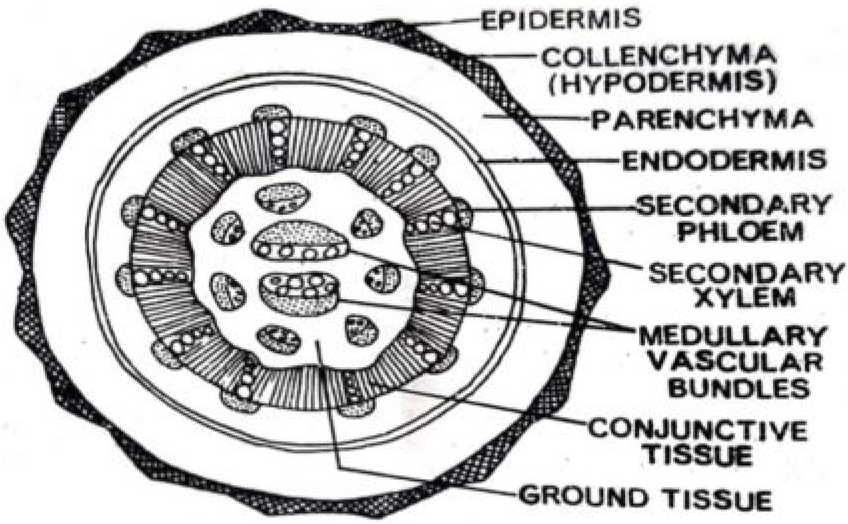


Figure 7.3 ***Boerhaavia*** **Stem - T.S. of Stem of** ***Boerhaavia*** **sp. (Diagrammatic)**

Anomalous Structure in ***Boerhaavia*** **(Figure 7.4) –**

a) **Primary Anomaly -** Presence of two large central medullary vascular bundles encircled with a second ring of 6 to 14 loosely arranged vascular bundles lying in the ground tissue.

b) **Non-adaptive type Anomaly -** Normal indisposition of cambium with its unusual activity.

Anomalous Secondary Growth –

The stem of *Boerhaavia* contain well defined anomalous secondary growth which is characterized by the presence of successive rings of xylem and phloem (vascular bundles).

After primary growth, the secondary growth is limited in the inner (Two medullary vascular bundles) and the middle ring of vascular bundles (6 to 14) by a fascicular cambium. As a result, they slightly increase their size.

Two vascular bundles (medullary vascular bundles) of the inner most ring are Large, oval and lie opposite to each other with their xylem facing towards centre and phloem outwards.

In the stem, the secondary growth occurs by the activity of a complete cambium ring formed in the outer ring of the vascular bundles in the normal position. Outer most ring of the vascular bundles contains inter-fascicular cambium which is absent in other two rings.

The outer ring consists of 15-20 vascular bundles, here the inter fascicular and intra fascicular cambium strips join together to form a continuous cambial ring. The cambial ring is functionally segmented into fascicular and intra fascicular region. This cambial ring produce –

Internally: - Secondary xylem in the intra fascicular region and lignified conjunctive tissue in the inter fascicular region on the inner side.

Externally: - Secondary phloem in the intra fascicular region and parenchyma from the inter fascicular region opposite the conjunctive tissue.

After the formation of secondary tissue, the cambium ceases its activity and a new fresh cambial ring is arising by the joining of secondary parenchyma cells opposite to the conjunctive tissue and the cells of pericycle outside the phloem. This accessory cambial ring functions in a similar manner to the previous cambium. It produces secondary xylem alternating with lignified conjunctive tissue on the inner side and secondary phloem opposite to the secondary xylem and parenchyma above the conjunctive tissue. After sometime, the activity of this cambium also cease.

One or more cambium gets differentiated which also functions in similar manner. During the process, several such cambial rings may be formed. As a result of these successive cambial differentiation several concentric rings of vascular bundles get embedded in the thick walled lignified conjunctive tissue separated by thin walled parenchymatous zone give the appearance of growth rings.

The cambium is composed of fusiform initials only which gives to ray-less secondary vascular tissue. Each successive ring of cambium is originated from the outer most phloem parenchyma cell. This Anomalous type of secondary growth thickness takes place by the means of successive ring of collateral vascular bundles.

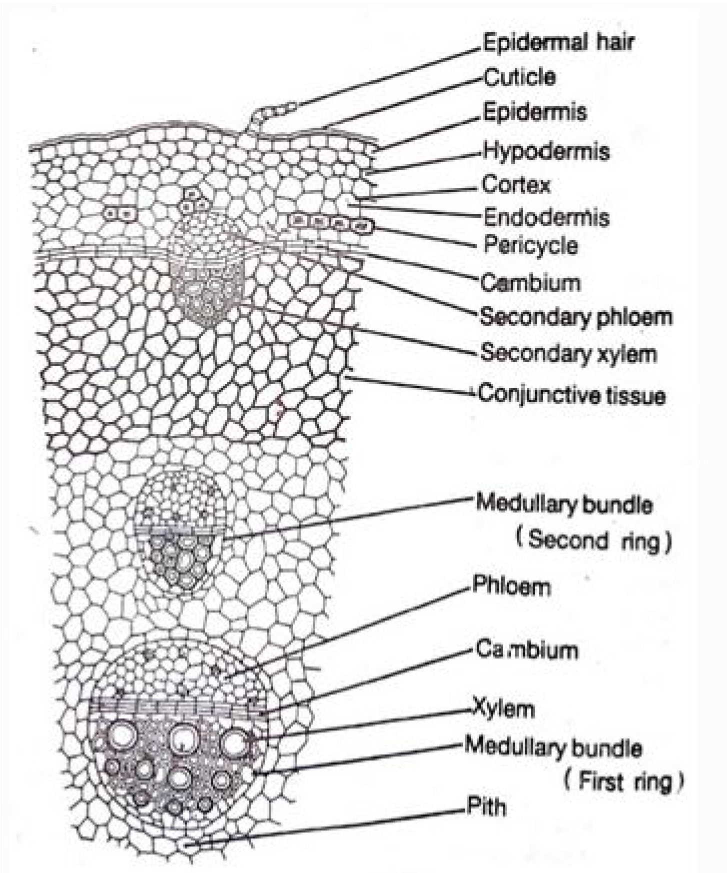


Figure 7.4: The Stem Anomalous Structure - T.S. of stem of *Boerhaavia* showing anomalous secondary growth, thick-walled conjunctive tissue, and medullary bundles.

SAQ.2

a. *Boerhaavia* is a member of family___________.

b. The stem of *Boerhaavia* contain well defined anomalous secondary growth which is characterized by the presence of successive rings of_____________.

c. *Boerhaavia* consists of___________groups of vascular bundles.

d. The abnormal activity of cambium firstly occurs in the___________group of vascular bundle.

e. Each successive ring of cambium is originated from the outer most___________cell.

7.4 Anomalous secondary growth in *Dracaena* (Monocot)

The vascular bundles of the monocotyledonous stems are usually closed ones. Thus due to absence of the cambium, they lack secondary growth in thickness and the vascular system is wholly composed of primary tissues.

The bundles remain irregularly scattered in the ground tissues, forming an atactostele, where the limits of cortex and other ground tissues can be hardly discerned.

Some monocotyledons belonging to the family Liliaceae, such as *Dracaena, Yucca, Agave, Aloe* and others exhibit a peculiar type of secondary growth in thickness, that may be called anomalous because of unusual phenomenon.

Dracaena is a typical example of anomalous secondary thickening (growth) in monocots.

***Dracaena* Stem: -**

The young stem of *Dracaena* is typical monocot stem. The cross-section of *Dracaena* stem shows the following structure **(Figure 7.5 A)**.

Epidermis –

Outer most single layer consist of parenchymatous cells remains covered with thick cuticle. The lenticels are also visible on the epidermis.

Hypodermis –

Situated just below the epidermis composed of sclerenchymatous cells.

Ground Tissue –

Ground tissues is undifferentiated parenchymatous. It is not divisible into cortex and pith due to absence of endodermis and pericycle.

Vascular Bundles –

Several amphivasal closed vascular bundles lie scattered on the ground.

Anomalous Structure in *Dracaena* –

In Dracaena secondary growth is due to –

a) Extrastelar cambial ring in a monocots stem at the cortex.

b) Abnormal activity of cambium.

During Secondary Thickening –

Dracaena shows anomalous secondary growth **(Figure 7.5 B)**. The cambium appears in the parenchyma outside the outermost vascular bundles. In the regions which have ceased to elongate some cells occurring outside the vascular bundles become meristematic and form the cambium. The secondary meristem originates in the cortex, in fact, deep layers of cortex or pericycle. Here the meristem will be named as secondary thickening meristem (STM).

The cambial cells are fusiform or rectangular in shape. The activity of the cambium is abnormal. Instead of forming phloem and xylem on the outer and inner sides, as in normal condition, the cambial ring producing large number of secondary tissues to the inner side first, and later small amount of new tissues are cut off on the outer side as well.

The tissues cut off by the cambial cells on the outer side are scanty in amount and are parenchymatous in nature. The tissues those produced on the inner side of the cambium are partially parenchymatous and partially vascular in nature.

The parenchymatous cells produced internally to the cambium developed into lignified conjunctive tissue. The radial arrangement of the parenchyma cells of conjunctive tissue is due to their origin by tangential divisions of the cambial cells. So they may be easily distinguished from the irregularly arranged parenchyma of the primary ground tissues.

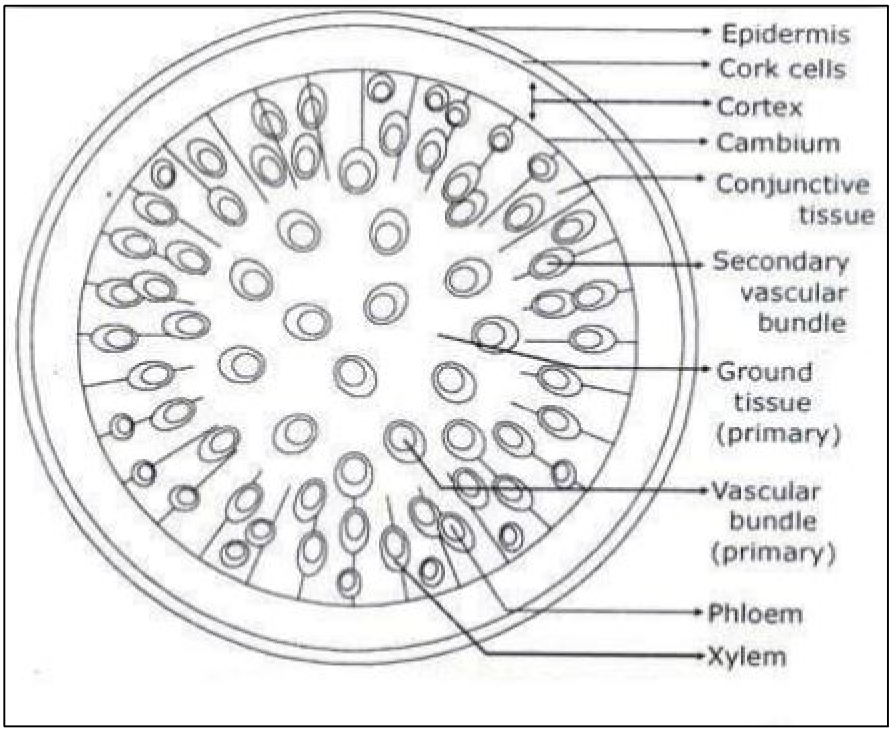
Usually, the secondary vascular bundles arise from a single cell called vascular bundle initial. The vascular bundle initial cell divides by two anticlinal divisions to form a row of two or three cells. All these cells then undergo a periclinal division to form peripheral cells. Later divisions are irregular and form a mass of cells. In this mass of cells, the centrally placed cell metamorphoses into phloem cells. The peripheral cells differentiated into xylem. Thus, the newly formed secondary vascular bundles consists of a centrally placed phloem which is surrounded by the xylem (amphivasal type). The secondary vascular bundles are amphivasal.

Secondary vascular bundles differ from the primary ones in presence of small amount of phloem and in absence of annular and spiral protoxylem elements. The small amount of phloem consists of short sieve tubes, companion cells and parenchyma. The Xylem is made of only tracheids, usually with scalariform thickening and small amount of xylem parenchyma which have lignified walls.

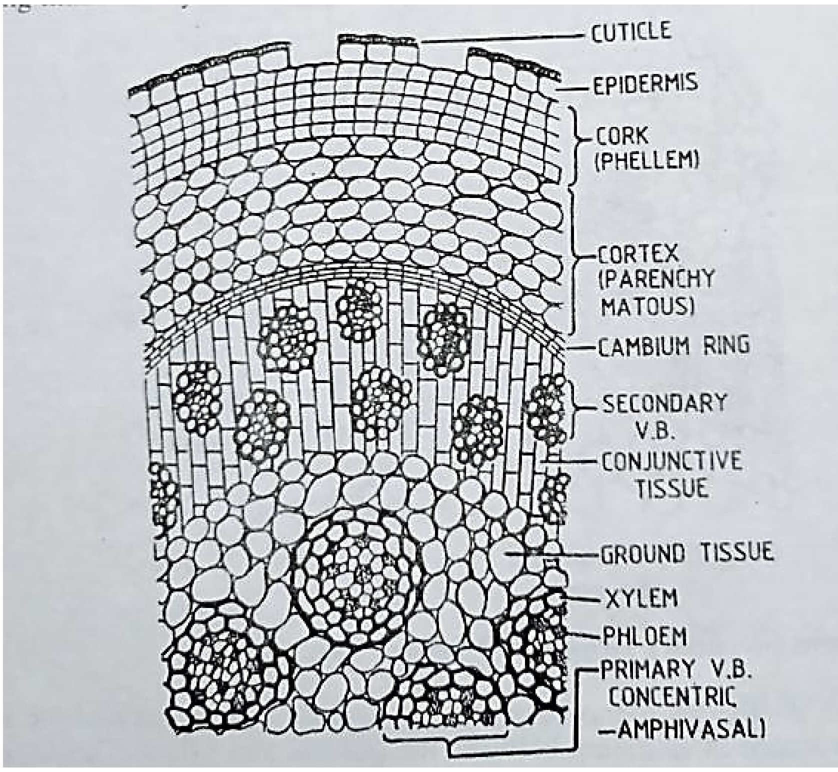
The cambium then cut parenchyma cells internally. The newly formed parenchyma cells push the vascular bundles towards the central region.

After some time, the cambium again behaves abnormally to produce another ring of vascular bundles. This process continues and many rings of concentrically arranged vascular bundles are formed. The last ring of vascular bundles is embedded in a mass of lignified conjunctive tissue.

In the extrastelar region the periderm is formed because of the repeated periclinal divisions of the cortical cells. Here the cork cells, formed without the appearance of cork cambium, are called storied-cork.



A. Diagrammatic



B. Cellular

Fig 7.5 *Dracaena* Stem - Transverse Section of *Dracaena* Showing Anomalous Secondary Growth

SAQ.3

a. In *Dracaena*, several amphivasal closed vascular bundles lie___________on the ground.
b. In *Dracaena* secondary growth is due __________cambial ring in a monocots stem at the cortex or abnormal activity of_____________.
c. The parenchymatous cells produced internally to the cambium developed into lignified__________tissue.
d. The_____________ring of vascular bundles is embedded in a mass of lignified conjunctive tissue.
e. _____________type of vascular bundle is formed in *Dracaena*.

7.5 Summary

- In plant science, secondary growth refers to the growth that results from cell division in the cambia or lateral meristems and that causes the stems and roots to thicken, while primary growth is growth that occurs as a result of cell division at the tips of stems and roots, causing them to elongate, and gives rise to primary tissue. Secondary growth occurs in most seed plants, but monocots usually lack secondary growth. If they do have secondary growth, it differs from the typical pattern of other seed plants.
- In many vascular plants, secondary growth is the result of the activity of the two lateral meristems, the cork cambium and vascular cambium. Arising from lateral meristems, secondary growth increases the girth of the plant root or stem, rather than its length. As long as the lateral meristems continue to produce new cells, the stem or root will continue to grow in diameter. In woody plants, this process produces wood, and shapes the plant into a tree with a thickened trunk.
- Because this growth usually ruptures the epidermis of the stems or roots, plants with secondary growth usually also develop a cork cambium. The cork cambium gives rise to thickened cork cells to protect the surface of the plant and reduce water loss. If this is kept up over many years, this process may produce a layer of cork. In the case of the cork oak it will yield harvestable cork. Secondary growth also occurs in many non-woody plants e.g. tomato, potato tuber, carrot taproot and sweet potato tuberous root. A few long-lived leaves also have secondary growth.

- **Haberlandlt** classified anomalous secondary growth into: 1) Adaptive anomaly, 2) Non Adaptive anomaly.
- Adaptive anomalies as regards secondary growth in many case notable being those of some climbers, lianas and storage organ such as beet root, are environmental, since they are morphologically and physiologically different from the normal types and, they are thus adaptive (environmental).
- Non Adaptive anomaly, at the same time there are cases of anomalous condition which are non-environmental and which appear to be merely cases of variations of the design.
- In *Bignonia*, anomalous secondary thickening is due to the abnormal functioning of cambium. Cambium is normal in disposition and abnormal in function (adaptive type). At four diagonal point arranged in cross shaped order, formation of secondary xylem is reduced and that of secondary phloem correspondingly increase, so that secondary phloem with transverse bands of bast fibre gets penetrated within the mass of xylem in the form of phloem pocket.
- The stem of *Boerhaavia* contain well defined anomalous secondary growth which is characterized by the presence of successive rings of xylem and phloem (vascular bundles). After primary growth, the secondary growth is limited in the inner (Two medullary vascular bundles) and the middle ring of vascular bundles (6 to 14) by a fascicular cambium. As a result, they slightly increase their size.
- In Dracaena secondary growth is due to –

  a) Extrastelar cambial ring in a monocots stem at the cortex.

  b) Abnormal activity of cambium.

7.6 Terminal Question

Q.1 What are the various reasons of anomalous secondary growth in dicotyledons?

Answer:---

Q.2 Describe anomalous secondary growth in *Bignonia.*

Answer:---

Q.3 Discuss the anomalous secondary growth in *Boerhaavia* stem.

Answer:--

Q.4 What type of anomalous secondary growth found in *Dracaena*? Discuss briefly.

Answer:--

Q.5 What is the significance of anomalous secondary growth in monocots?

Answer:--

Short Questions

Q.6 Write short notes on:

1. Medullary bundle
2. Inter-fascicular and Intra-fascicular cambium
3. Cambium rings
4. T. S. of normal stem of *Boerhaavia*
5. Abnormal behaviour of normal cambium in *Bignonia*
6. Amphivasal vascular bundle
7. Sclenchymatous bar and Phloem wedges

Q.7 Multiple choice questions:

1. Intraxylary phloem is also known as-
    i. Included phloem
    ii. External phloem
    iii. Internal phloem
    iv. Vestigial phloem
2. Interxylary phloem is formed due to-
    i. Formation of accessory strips of cambium

ii. Abnormal behaviour of normal cambium
iii. Anomalous position of cambium
iv. Anomalous behaviour of abnormal cambium

3. Four phloem wedges formed during anomalous secondary growth in-
   i. *Bignonia*
   ii. *Boerhaavia*
   iii. *Dracaena*
   iv. All of the above
4. Three rings of vascular bundle are present in the stem of-
   i. *Boerhaavia*
   ii. *Dracaena*
   iii. *Bignonia*
   iv. None of the above
5. During anomalous secondary growth, four inverted cortical bundles are present in the stem of-
   i. *Nyctanthus*
   ii. *Bignonia*
   iii. *Boerhaavia*
   iv. *Dracaena*

7.7 Answers

1. iii 2. ii 3. i 4. i 5. i

Self-assessment questions

SAQ.1

d. Phellogen **b.** Cambium **c.** 4 **d.** *Bignonia* **e.** Old

SAQ.2

d. Nyctaginaceae **b.** Xylem and phloem **c.** 3 **d.** Outer **e.** Phloem parenchymatous

SAQ.3

c. Scattered **b.** Extra stellar, cambium **c.** Conjunctive **d.** Last **e.** Amphivasal closed

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Block-III
Plant Taxonomy

This block deals with plant taxonomy which is closely allied to plant systematic and there is no sharp boundary between the two. It can be defined as the branch of botany which deals with characterisation, identification, classification and nomenclature of plants based on their similarities and differences. Identification means to identify the unknown species based on its characteristics and comparing with already existing species. Characterization is to describe all the characteristics of the newly identified species. Classification is placing and arranging the unknown species into different groups or taxa according to similarities and dissimilarities. Nomenclature means giving up scientific name according to the convention.

This block has two units VIII and IX.

Unit VIII is **plant taxonomy I**, which deals with introduction of taxonomy, history of economic botany with special reference to India as well as Bentham and Hooker's system of classification.

Unit IX is **plant taxonomy II** which has description of some important families of dicots as well as monocots. .

Objectives:

After studying this block you should be able to:

- Know the history of economic botany in India.
- Understand and Bentham and Hooker's system of classification.
- Use the terminology to describe the characteristics of taxa and classify them.
- Know the characteristic features of some important families of dicots and monocots.

Unit- VIII

Plant Taxonomy I

Structure

8.1 Introduction

Objectives

8.2 History of Economic botany with special reference to India

8.3 Bentham and Hooker's System of Classification

- **Merits**
- **Demerits**

8.3 Summary
8.4 Terminal Questions
8.5 Answers

8.1 Introduction

The Plant taxonomy (Syn. Systematic Botany) is a functional science concerned with the identification, nomenclature and classification of various kinds of plants all over the world. Identification consist of determining that a particular plant is similar or not to some other known. individual. Nomenclature is the application of correct names to the individuals or groups of individuals. Plants themselves not have any name. The name by which they are called are the names which we have applied to them. These names serve two very important purposes (1) they are for convenience in referring to them and (2) they indicate relationships. Classification is the disposition of these plants or groups of plants into categories according to some particular plan.

The principles of taxonomy began with the period of descriptive taxonomy that had its main period of development on a scientific level in the 19^{th} century. It was mainly concerned with the observation of the similarities and the differences in the gross morphological characters of the plants discovered at that time all over the earth. This descriptive taxonomy began with the works of Tournfort, de Jussieu and Linnaeus and was followed by Robert Brown, the Hookers, John Lindley, George Bentham, de Candolles and several others. Mostly the plants were described and classified according to the morphological characters. During this period different principles of taxonomy were published, the first of these being by Linnaeus in his *Critica botanica*. Afterwards by Adanson, John Lindley, de Candolles and Sir Joseph Hooker. Most of these principles were accepted by contemporary workers, but the present day taxonomists consider that the gross morphological characters are not always sufficient to provide means of differentiation in determining the genetical relationships between taxa. Accordingly, the present day taxonomy is based on the morphological characters, affinity, the findings of anatomy, cytology and genetics. Classification proposed in the earlier part of this period were called "*natural systems*" as they were based on one's understanding of the nature at that time. Later on the acceptance of the theory of evolution led taxonomists to classify plants on the basis of actual genetic and ancestral relationships. The successive generations, the offspring of ancestral plants has occurred an evolution of plant characters in such a way that the surviving plants usually are of increased structural complexity and genetic organization over their ancestors. The systems of classification based on such characters are called "*phylogenetic systems*"

Now-a-days Modern taxonomists of 20th century use methods such as experiment taxonomy which makes use of data not only from old fields of morphology, ecology, plant geography, but also from modern fields of genetics, cytology, physiology and Embryology.

Objectives

After studying this unit, you will be:

- To document facts about plant use and plant management.
- To create awareness about role of plants in cultural, social and health of people.
- To train people or student for utilization of medicinal plants.
- To know all plants on the earth with their names
- To build up a reference system for plants for easy identification, naming and classification
- To understand the facts of evolution of different plants
- To give every plant a universal name to avoid confusions in naming of plants.

8.2 History of Economic botany with special reference to India

The history of economic botany is briefly discussed. Economic Botany is the interaction of people with plants. Economic botany is closely related to the field of ethnobotany - that word is based on two Greek roots: ethnos (race: people: cultural group) and botanikos (of herbs) and can mean the plant lore of a race or people as well as the study of that lore.

Economic botanists are scientists who study the interactions between humans and plants. That makes the field of Economic Botany as far flung and diverse as both the human and plant life on our planet. Economic botanists study human-plant interactions from a variety of different angles. These skilled researchers rely on a variety of disciplines including archeology, sociology, and ecology in addition to basic botany to help them explain these interactions and their effects on plants, society and our dynamic planet.

Economic plants are defined as those plants utilized either directly or indirectly for the benefit of man. Indirect usage includes the need of man's livestock and the maintenance of the environment, the benefits may be domestic, commercial, environmental, or aesthetic.

The word "**herb**" has been derived from the Latin word, *"herba"* and an old French word *"herbe"*. Now a day, herb refers to any part of the plant like fruit, seed, stem, bark, flower, leaf, stigma or a root, as well as a non-woody plant. Earlier, the term "herb" was only applied to non-woody plants, including those that come from trees and shrubs. These medicinal plants are also used as food, flavonoid, medicine or perfume and also in certain spiritual activities.

The term "**medicinal plant**" include various types of plants used in herbalism ("herbology" or "herbal medicine"). It is the use of plants for medicinal purposes, and the study of such uses.

Plants have been used for medicinal purposes long before prehistoric period. Ancient Unani manuscripts, Egyptian papyrus and Chinese writings described the use of herbs. Evidence exist that Unani Hakims, Indian Vaids and European and Mediterranean cultures were using herbs for over 4000 years as medicine. Indigenous cultures such as Rome, Egypt, Iran, Africa and America used herbs in their healing rituals, while other developed traditional medical systems such as Unani, Ayurveda and Chinese Medicine in which herbal therapies were used systematically.

Traditional systems of medicine continue to be widely practised on many accounts. Population rise, inadequate supply of drugs, prohibitive cost of treatments, side effects of several synthetic drugs and development of resistance to currently used drugs for infectious diseases have led to increased emphasis on the use of plant materials as a source of medicines for a wide variety of human ailments.

Among ancient civilisations, India has been known to be rich repository of medicinal plants. The forest in India is the principal repository of large number of medicinal and aromatic plants, which are largely collected as raw materials for manufacture of drugs and perfumery products. About 8,000 herbal remedies have been codified in AYUSH systems in INDIA. Ayurveda, Unani, Siddha and Folk (tribal) medicines are the major systems of indigenous medicines. Among these systems, Ayurveda and Unani Medicine are most developed and widely practised in India.

In India, earliest references to medicinal plants appear in the Rigveda, written between 3500 and 1600 B.C. In *Itharvaveda* too, detailed descriptions of several medicinal plants were given. In Ayurveda, definite properties of drugs obtained from plants and their uses have been given in some details, *Charaka-Samhita* and *Susruta-Samhita* are two important works dealing with' some medicinal plants of India.

Most of the drug plants are wild and only a few of them have been cultivated. Studies of medicinal plants based on ancient literature and investigation in the modem light is known as ethnology. The branch of medic dealing with the history, botany, identification, preservation and commerce of crude drugs is known as Pharmacognosy. Pharmacology is the study of the action of drugs on an organ or organism.

The medicinal importance of a plant is due to the presence of some special substances like alkaloids, glycosides, resins, volatile oils, gums, tannins etc. These active principles usually remain concentrated in the storage organs of the plant, viz., roots, seeds, bark, leaves, etc. Since time immemorial plants have been used for the treatment of various ailments. Even today several important drugs used in the modem system of medicine are obtained from plants. The use of medicinal plants has figured in several ancient manuscripts like the Rigveda, the Bible, the Iliad, the Odyssey, and the History of Herodotus. As far back as 4000 B.C. the ancient Chinese were using drug plants. The earliest reference to the use of medicinal plants as a cure for diseases is found in the manuscript of 'Eber Papyrus,' written in 1600 B.C. The Greeks and Romans were also familiar with many of the present day Drugs as is evident from the work of Hippocrates (460-370 B.C.), Aristotle (384- 322 B.C.), Theophrastus (370-287 B.C.), Pliny the Elder (23-79 A.D.), Dioscorides (50-100 A.D.) and Galan (131-201 A.D.). Hippocrates, known as the father of medicine, was the first person who tried to explain the diseases on a scientific basis. Dioscorides *De Materia Medica* was an invaluable and authoritative book on medicinal plants. In the 16th century, several herbals were published; the important being those of Brunfels (1530), Bock (1539), Fuchs (1542), Cordus (1561) and L'Obel (1576). At about the same time Paracelsus (1493-1541) advanced *Doctrine of signatures*, which advocated that all plants useful for man possessed certain forms and shapes that indicated their specific use in the treatment of similarly shaped organs in the human body. For instance, plants with heart-shaped leaves were used for cardiac disorder, walnut as brain tonic and pomegranate seeds for dental disease. With the advancement of our knowledge, such superstitions were gradually lost.

Recently, WHO (World Health Organization) estimated that 80 percent of people worldwide rely on herbal medicines for some aspect of their primary health care needs. According to WHO, around 21,000 plant species have the potential for being used as medicinal plants.

As per data available over three-quarters of the world population relies mainly on plants and plant extracts for their health care needs. More than 30% of the entire plant species, at one time or other were used for medicinal purposes. It has been estimated, that in developed countries such as United States, plant drugs constitute as much as 25% of the total drugs, while in fast developing countries such as India and China, the contribution is as much as 80%. Thus, the economic importance of medicinal plants is much more to countries such as India than to rest of the world. These countries provide two third of the plants used in modern system of medicine and the health care system of rural population depend on indigenous systems of medicine.

Treatment with medicinal plants is considered very safe as there is no or minimal side effects. These remedies are in sync with nature, which is the biggest advantage. The golden fact is that, use of herbal treatments is independent of any age groups and the sexes.

The ancient scholars only believed that herbs are only solutions to cure a number of health related problems and diseases. They conducted thorough study about the same, experimented to arrive at accurate conclusions about the efficacy of different herbs that have medicinal value. Most of the drugs, thus formulated, are free of side effects or reactions. This is the reason why herbal treatment is growing in popularity across the globe. These herbs that have medicinal quality provide rational means for the treatment of many internal diseases, which are otherwise considered difficult to cure.

Medicinal plants such as *Aloe, Tulsi, Neem, Turmeric* and *Ginger* cure several common ailments. These are considered as home remedies in many parts of the country. It is known fact that lots of consumers are using Basil (*Tulsi*) for making medicines, black tea, in *pooja* and other activities in their day to day life.

In several parts of the world many herbs are used to honour their kings showing it as a symbol of luck. Now, after finding the role of herbs in medicine, lots of consumers started the plantation of tulsi and other medicinal plants in their home gardens.

Medicinal plants are considered as a rich resources of ingredients which can be used in drug development either pharmacopoeial, non- pharmacopoeial or synthetic drugs. A part from that, these plants play a critical role in the development of human cultures around the whole world. Moreover, some plants are considered as important source of nutrition and as a result of that they are recommended for their therapeutic values. Some of these plants include ginger, green tea, walnuts, aloe, pepper and turmeric etc. Some plants and their derivatives are considered as important source for active ingredients which are used in aspirin and toothpaste etc.

Apart from the medicinal uses, herbs are also used in natural dye, pest control, food, perfume, tea and so on. In many countries different kinds of medicinal plants/ herbs are used to keep ants, flies, mice and flee away from homes and offices. Now a day’s medicinal herbs are important sources for pharmaceutical manufacturing.

Recipes for the treatment of common ailments such as diarrhoea, constipation, hypertension, low sperm count, dysentery and weak penile erection, piles, coated tongue, menstrual disorders, bronchial asthma, leucorrhoea and fevers are given by the traditional medicine practitioners very effectively.

Over the past two decades, there has been a tremendous increase in the use of herbal medicine; however, there is still a significant lack of research data in this field. Therefore, since 1999, WHO has published three volumes of the WHO monographs on selected medicinal plants.

Importance of some herbs with their medicinal values

- Herbs such as black pepper, cinnamon, myrrh, aloe, sandalwood, ginseng, red clover, burdock, bayberry, and safflower are used to heal wounds, sores and boils.
- Basil, Fennel, Chives, Cilantro, Apple Mint, Thyme, Golden Oregano, Variegated Lemon Balm, Rosemary, Variegated Sage are some important medicinal herbs and can be planted in kitchen garden. These herbs are easy to grow, look good, taste and smell amazing and many of them are magnets for bees and butterflies.
- Many herbs are used as blood purifiers to alter or change a long-standing condition by eliminating the metabolic toxins. These are also known as 'blood cleansers'. Certain herbs improve the immunity of the person, thereby reducing conditions such as fever.
- To reduce fever and the production of heat caused by the condition, certain antipyretic herbs such as *Chirayta*, black pepper, sandal wood and safflower are recommended by traditional Indian medicine practitioners.
- Sandalwood and Cinnamon are great astringents apart from being aromatic. Sandalwood is especially used in arresting the discharge of blood, mucus etc.
- Some herbs are used to neutralize the acid produced by the stomach. Herbs such as marshmallow root and leaf. They serve as antacids. The healthy gastric acid needed for proper digestion is retained by such herbs.
- Indian sages were known to have remedies from plants which act against poisons from animals and snake bites.
- Herbs like Cardamom and Coriander are renowned for their appetizing qualities. Other aromatic herbs such as peppermint, cloves and turmeric add a pleasant aroma to the food, thereby increasing the taste of the meal.
- Some herbs like aloe, sandalwood, turmeric, sheetraj hindi and khare khasak are commonly used as antiseptic and are very high in their medicinal values.
- Ginger and cloves are used in certain cough syrups. They are known for their expectorant property, which promotes the thinning and ejection of mucus from the

lungs, trachea and bronchi. Eucalyptus, Cardamom, Wild cherry and cloves are also expectorants.

- Herbs such as Chamomile, Calamus, Ajwain, Basil, Cardamom, Chrysanthemum, Coriander, Fennel, Peppermint and Spearmint, Cinnamon, Ginger and Turmeric are helpful in promoting good blood circulation. Therefore, they are used as cardiac stimulants.
- Certain aromatic plants such as Aloe, Golden seal, Barberry and Chirayata are used as mild tonics. The bitter taste of such plants reduces toxins in blood. They are helpful in destroying infection as well.
- Certain herbs are used as stimulants to increase the activity of a system or an organ, for example herbs like Cayenne (Lal Mirch, Myrrh, Camphor and Guggul).
- A wide variety of herbs including Giloe, Golden seal, Aloe and Barberry are used as tonics. They can also be nutritive and rejuvenate a healthy as well as diseased individual.
- Honey, turmeric, marshmallow and liquorice can effectively treat a fresh cut and wound. They are termed as vulnerary herbs.

The following points highlight the top eight medicinal plants that are chiefly found in India. The plant are as follows:

- ***Rauwolfia serpentina* (L.) Benth.ex Kurz.**

  Family: Apocynaceae

1. It is a small shrub with long leaves, white or pinkish flowers, and small dark purple to black fruits.
2. It is an age-old well-known medicinal plant in the Indian medicine, mentioned even in *Charak-Samhita.*
3. The drug is obtained from air died roots.
4. It is well known for reducing high blood pressure and also as a sedative and hypnotic. The alkaloids found in its roots have tranquillizing effects.
5. Due to the tranquillizing effects of the drug it is also used for chronic mental illness.
6. Extracts of roots are useful for treatment of intestinal disorders.
7. Roots mixed with some other plant extracts, are used in the treatment of cholera and fever.
8. Its roots stimulate uterine contraction and are thus used during child birth.
9. Plants are widely distributed in Sub-Himalayan tracts from Punjab to Nepal, Sikkim, Bhutan, Assam, Western Ghats and Andamans.

- ***Papaver somniferum* L. (Opium Poppy):**

  Family: Papaveraceae

1. It is a herb, now grown on a large scale in UP., Jullundur and Hoshiarpur districts of Punjab, M.P. and Rajasthan.
2. Opium is the dried juice which exudes from the injured immature capsules of this plant.
3. It is highly useful for mankind in relieving the pain, if used in limited doses, mainly due to the presence of some alkaloids. But its heavy doses and to take it as a habit can be so fatal that no other drug has caused so much corruption and tragedy as opium.
4. Opium is used to induce sleep, relieve pain and relax spasm.
5. Besides other resins and oils, the important alkaloids obtained from the dried latex of the opium plant are morphine, codeine, papaverine and narcotine.
6. Morphine is a powerful analgesic, narcotic and stimulant.
7. Besides many European countries, India and China are two great sufferors of opium.

- ***Atropa belladona* L. (Belladona):**

  Family: Solanaceae

1. The roots of the plant are used as sedative, stimulant and antispasmodic, is cultivated in Kashmir and some other Indian states.
2. Roots and leaves are also used as tonic.
3. The drug atropine, obtained from this plant, is used to dilate pupils of eye at the time of eye testing.
4. In certain poisoning cases of snakebites and scorpionbites, it is used as an antidote.
5. Two famous alkaloids found in this drug are atropine and hyoscyamine.

- ***Datura stramonium* L. (Datura):**

  Family: Solanaceae

1. It is an annual plant, the leaves and seeds of which are narcotic.
2. The drug, obtained from its dried leaves, flowering tops and seeds, is used in treatment of asthma.
3. Atropine, an alkaloid obtained from Stramonium, is used to stimulate central nervous system and also for dilating the pupils of the eye in eye testing.
4. Leaves and seeds are used sometimes for criminal poisoning.
5. Kanaka Asava, an Ayurvedic medicine prepared from Stramonium, is used as an antispasmodic, expectorant and demulcent.
6. Its seeds are smoked by the patients suffering from asthma.

- ***Cinchona* sp. (Cinchona):**

  Family: Rubiaceae

1. Quinine, a well-known medicine for malarial fever, is obtained from the dried bark of *Cinchona calisaya, C. officinalis, C. ledgeriana and C. succirubra*.
2. In India, *C. calisaya* is found in Nilgiris and Sikkim, *C. ledgeriana* in West Bengal, Khasi Hills and South India, and *C. succirubra* in hilly regions of Sikkim and South India.
3. Quinine also checks certain bacterial infections, and some of its preparations are useful in amoebic dysentry.
4. Quinine, if used in high quantity, may cause deafness, blindness and nausea.
5. Its use should be avoided by heart patients and pregnant women.

- ***Withania somnifera* L. Dunal. (Ashvagandha):**

  Family: Solanaceae

1. It is a small under-shrub with ovate leaves and pale green small flowers arranged in axillary clusters.
2. From the roots of the plant, the drug Ashvagandha is obtained.
3. It is useful for sexual weakness.
4. It is also used in rheumatism and general weakness, and functions as a narcotic and diuretic.
5. Roots and leaves are antibacterial and antibiotic in activity.

- ***Ocimum sanctum* L. (Tulsi):**

  Family: Labiatae or Lamiaceae

1. The Sacred basil or Holy basil is a well-known sacred plant of Indian houses, gardens and temples all over the country.
2. An infusion of its leaves in hot water, and specially along with tea, is useful in cold, bronchitis and digestive disorders.
3. The oil present in its leaves has the ability to destroy bacteria and some insects.
4. A poultice of its fresh leaves is applied on ringworm and other diseases of skin.
5. Its seeds are used in disorders of the urinary system.
6. Seeds are also useful in dysentery and chronic diarrhoea.

- ***Ephedra gerardiana* Wall., E. major Host. (Khanda):**

  Family: Ephedraceae (Gnetales, Gymnosperms)

1. *Ephedra* is a small xerophytic shrub of Gymnosperms found in the drier regions of Himalayas from Kashmir to Sikkim.

2. The plants resemble *Equisetum* in their external morphology and bear profusely branched jointed stem which bears nodes and internodes. Foliage leaves are absent. Scaly leaves are present only on the nodes.
3. The famous antibiotic drug ephedrine, is obtained from its dried stems.
4. Ephedrine is used to treat asthma, cold and hay fever.
5. It is also effective as a good cardiac stimulant.
6. Nasal spray, prepared from ephedrine, is effective in inflammation of mucous membrane and also in asthmatic attacks.
7. Stems of *E. major* are the richest source of ephedrine.

As our lifestyle is now getting techno-savvy, we are moving away from nature. While we cannot escape from nature because we are part of nature. As herbs are natural products they are free from side effects, they are comparatively safe, eco-friendly and locally available. Traditionally there are lot of herbs used for the ailments related to different seasons. There is a need to promote them to save the human lives.

These herbal products are today being the symbol of safety in contrast to the synthetic drugs, that are regarded as unsafe to human being and environment. Although herbs had been priced for their medicinal, flavouring and aromatic qualities for centuries, the synthetic products of the modern age surpassed their importance, for a while. However, the blind dependence on synthetics is over and people are returning to the naturals with hope of safety and security. It's time to promote them globally.

SAQ.1

f. Opium poppy is belonging to family_________________.
g. The botanical name of tulsi is___________________.
h. The roots and leaves of Asvagandha shows___________and_____________activity.
i. Ehpedrine is obtained from__________________.
j. Quinine is obtained from______________and belong to__________________ family.

8.3 Bentham and Hooker's System of Classification

George Bentham (1800-1884) and **Joseph Dalton Hooker** (1817-1911), the two British botanists who were associated with the **Royal Botanic Garden, Kew, England** joined their forces to bring out a **Genera Plantarum** (1862-1883), wherein they presented their outstanding system of classification. This was the greatest taxonomic work ever produced in the United Kingdom and has "ever since been an inspiration to generations of Kew botanists". This three volume monumental work which required quarter of a century, comprised description of all genera of seed plants known to science at that time and they were classified according to the system proposed by them. The first part of ***Genera Plantarum*** appeared in July 1862 and the last part in April 1883. They have provided first rate descriptions of the families and genera of seed plants then known. This was a major landmark in Botany, for its system as well as for its quality. The geographical distribution of each genus was given.

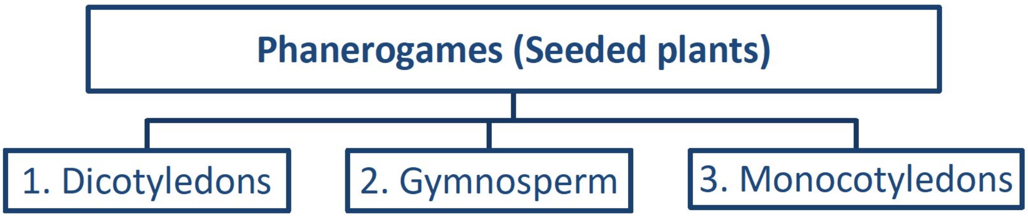
Table 1 gives a summary of the number of families, genera and species of flowering plants known at the time of the publication of Genera Plantarum.

Table.1 A synopsis of Bentham and Hooker's system of classification:

	Orders (Families)	**Genera**	**Species**
Polypetalae	82	2,610	31,874
Gamopetalae	45	2,619	34,556
Monochlamydae	36	801	11,784
Gymnosperm	3	44	415
Monocotyledonns	34	1,495	18,576
Total	200	7,569	97,205

Although Bentham and Hooker's system of classification was based on that of de Candolle, it was certainly a refinement over the latter. Bentham and Hooker divided all seed plants into 3 classes, 3 sub-classes, 21 series, 25 cohorts and 200 orders. They divided theseed plants into Dicotyledons, Gymnosperm and Monocotyledons. They placed Ranales in the beginning and grasses at the end. The gymnosperms are a distint group from the angiosperms and their placement between Dicotyledons and Monocotyledons is consistent with our current understanding of this group. The position of Apocyanceae among cotyledons is incorrect and they should have been placed at the beginning of the Monocotyledons.

The following is the summary of Bentham and Hooker's system:



1. **Dicotyledons-** Embryo with two cotyledons, reticulate venation, ovule enclosed in ovary. It has 3 divisions-
   i. Polypetalae
   ii. Gamopetalae
   iii. Monochlamydae

i. Polypetalae (Petals free):

Series I Thalmiflorae- Hypogynous, stamens and pistils many, indefinite mostly free. It includes the following **six** orders (34 families). Some important families are mentioned below in their order-

Order Families

Ranales- Ranunculaceae

Caryophyllineae- Caryophyllaceae

Parietales- Papaveraceae, Brassicaceae, Capparidaceae

Guttiflorales- Guttiferae

Polygalineae- Polygaleae

Malvales- Malavaceae

Series II Disciflorae- Hypogynous, calyx consisting free or united sepals which are free from ovary. A nectariferous disc surrounds the base of the ovary. It contains the following **four** orders (22 families). Some important families are -

Order Families

Geraniales- Rutaceae

Celastrales-Celastrineae

Olacales- Olacineae

Sapindales- Anacardiaceae

Series III Calyciflorae- Perigynous or sometimes epigynous. Calyx consists of united sepals, rarely free and adenate to ovary. It includes the following **five** orders (27 families). Some important families are –

Order Families

Rosales- Rosaceae, Leguminosae

Ficoidales- Ficoideae

Myrtales- Myrtaceae

Umbellales- Apiaceae

Passiflorales- Cucurbitaceae

ii. **Gamopetalae (Petals united):**

Series I Inferae- Ovary inferior, stamens as many as corolla lobes or fewer. it includes the following **three** orders (9 families). Some important families are -

Order Families

Rubiales- Rubiaceae

Campanales- Campanulaceae

Asterales- Asteraceae

Series II Heteromerae- Ovary superior, stamens as many or twice as many as corolla lobes, carpels more than two. It includes the following **three** orders (12 families). Some important families are -

Order Families

Ericales- Ericaceae

Ebenales- Sapotaceae, Ebenaceae

Primulales- Plumbagineae, Primulaceae

Series III Bicarpellatae- Ovary superior, stamens as many as the corolla lobes or fewer, carpels usually two. It has the following **four** orders (23 families). Some important families are -

Order Families

Gentianales- Apocyanaceae, Ascleipiadaceae

Personales-Scrophulariaceae, Acathaceae

Polemoniales- Solanaceae, Convolulaceae

Lamiales- Labiateae, Verbenaceae

iii. **Monochlamydae (Petals absent):**

Series I Curvembryae (6 families)**-** Embryo curved round the endosperm, ovule usually one. The families Polygonaceae, Nyctagineae, Chenopodiaceae, Amaranthaceae etc. belongs to it.

Series II Multiovulatae aquaticae (1 family)**-** Aquatics with numerous ovules. The family Podostemaceae belongs to it.

Series III Multiovulatae terrestris (3 families)**-** Terrsitrial plants with numerous ovules. The families Nepenthaceae, Cytinaceae and Aristolochieae belongs to it.

Series IV Microembryeae (4 families)**-** Embryo very small in copious endosperm. The families Piperaceae, Moniaceae etc. belongs to it.

Series V Daphnales (5 families)**-** Ovary usually with one carpel and single ovule. The families Penaeceae, Protenceae etc. belongs to it.

Series VI Achlamydosporae (3 families)**-** Ovay usually inferior, unilocular and one to three ovuled. The families Loranthaceae, Santalaceae etc. belongs to it.

Series VII Unisexuales (9 families)**-** Flowers unisexuales.The families Urticaceae, Casuarineae, Euphorbiaceae etc. belongs to it.

Series VIII Ordines anomaly (9 families)**-** The families of uncertain relationship were placed in this series. The family Salicaceae belongs to it.

2. **Gymnospermae**
3. **Monocotyledons**

Series I Microspermae (3 families)**-** Ovary inferior, seeds very small. The family Orchidaceae belongs to it.

Series II Epigynae (7families)**-** Ovary usually inferior, seeds large. The families Scitamineae, Irideae belongs to it.

Series III Coronarieae (8 families)**-** Perianth petaloid, ovary superior. The family Liliaceae belongs to it.

Series IV Calycinae (5 families)**-** Perianth sepaloid, ovary superior. The family Palmae belongs to it.

Series V Nudiflorae (5 families)**-** Perianth mostly lacking, ovary superior. The family Typhaceae belongs to it.

Series VI Apocarpeae (3 families)**-** Carpels free. The family Najadaceae belongs to it.

Series VII Glumaceae (5 families)**-** Perianth small, scale like or chaffy. The families Cyperaceae, Graminae belongs to it.

Merits and Demerits of Bentham and Hooker's system- The classification of Bentham and Hooker's can be considered as natural. Its profound accuracy and masterly descriptions of plants provided valuable material to their successors. The merits and demerits of Bentham and Hooker's system are given below.

- **Merits-**

1. Bentham and Hooker provided first rate descriptions of the families and genera of seed plants then known.

2. Their system is of great practical value for identification of plants.
3. The system is widely followed for the arrangement of specimens in the herbaria of many countries, including India and Britain.
4. Although Bentham and Hooker's system of classification was based on that of de Candolle, it is certainly a refinement over the latter. For example, in the Polypetalae they introduced a new series Disciflorae between the Thalmiflorae and the Calyciforae, and the classification of apetalous taxa was revised.
5. Bentham and Hooker considered gymnosperms a separate group from the angiosperms.
6. They placed Ranales in the beginning and grasses at the end. Their treatment is in line with our present understanding of these groups.
7. Dicotyledons are placed before the Monocotyledons.
8. The arrangement of taxa is based on overall natural affinities decided on the basis of morphological features.

- **Demerits-**

Although Bentham and Hooker's system of classification is a natural one, yet it has several shortcomings. Some of them are mentioned below-

1. The gymnosperms are a distinct group from the angiosperms and their placement between the Dicotyledons and Monocotyledons is inconsistent with our current understanding of this group. They also did not recognize the phylogenetic importance of naked seeds.
2. The position of Apocarpae among Monocotyledons is incorrect and they should have been placed at the first place in the Monocotyledons.
3. Monochlamydae is an unnatural assemblage of taxa. The creation of this group has resulted in the separation of many closely related families. For instance, Caryophyllaceae, Illecebraceae and Chenopodiaceae are closely related families to the extent that they are placed in the same order in all major classification. In Bentham and Hooker's system, however, Caryophyllaceae are placed in Polypetalae, and the other two in Monochlamydae. Similarly, the family Podostemaceae which is placed in a separate series Multiovulatae aquaticae, better belong to the order Ranales.
4. In Monochlamydae, there are no orders and instead there are only eight series of unequal values. In this group, Curvembryae is a natural series while Unisexuales contains families with different affinities.

5. They have given unique importance to the habit of the plant in creating the two series namely Multiovulatae aquaticae and Multiovulatae terrestris.
6. The classification of Gamopetalae ignores the fundamental basis of polypetalous groupings. Bentham and Hooker, in Polypetalae, placed the epigynous families at the end. But in Gamopetalae they start with the series Inferae which includes order Rubiales and Asterales having epigynous flowers whereas the latter families of Heteromerae and Bicarpellatae have hypogynous flowers.
7. The classification of Monocotyledons is very unnatural. It is divided into seven series, there being no orders. The first series, the Microspermae and Epigynae have epigynous families and they should have been at the end instead of at the beginning of Monocots.
8. The family Orchidaceae is an advanced family with inferior ovary and zygomorphic flowers; but the family is given a primitive position.
9. In Monocotyledons, Liliaceae and Amaryllidaceae are generally regarded as closely related but Bentham and Hooker placed these families under different series, Amaryllidaceae under Epigynae and Liliaceae under Coronarieae.
10. Bentham and Hooker could not tell the affinities of the families placed in order Ordines anomali.
11. Several large families like Euphorbiaceae, Liliaceae, Saxifragaceae and Urticaceae are unnatural assemblages and represent polyphyletic groups.

8.3 Summary

In this unit you have learnt that:

- The Plant taxonomy is a functional science concerned with the identification, nomenclature and classification of various kinds of plants all over the world.
- Economic Botany is the interaction of people with plants which is closely related to the field of ethnobotany.
- Medicinal plants are considered as a rich resources of ingredients which can be used in drug development either pharmacopoeial, non- pharmacopoeial or synthetic drugs.
- ***Rauwolfia serpentine*** (Apocyanaceae) is well known for reducing high blood pressure and also as a sedative and hypnotic. The alkaloids found in its roots have tranquillizing effects.
- ***Papaver somniferum*** (Papaveraceae) is highly useful for mankind in relieving the pain, if used in limited doses, mainly due to the presence of some alkaloids. But its

heavy doses and to take it as a habit can be so fatal that no other drug has caused so much corruption and tragedy as opium. Morphine is a powerful analgesic, narcotic and stimulant which is also obtained from this plant.

- The drug atropine, obtained from ***Atropa belladonna*** (Solanaceae), is used to dilate pupils of eye at the time of eye testing. In certain poisoning cases of snakebites and scorpionbites, it is used as an antidote.
- Atropine, an alkaloid obtained from ***Datura stramonium*** (Solanaceae), is used to stimulate central nervous system and also for dilating the pupils of the eye in eye testing. Its seeds are smoked by the patients suffering from asthma.
- ***Withania somnifera*** (Solanaceae) is also used in rheumatism and general weakness. It functions as a narcotic and diuretic. From the roots of this plant, the drug Ashvagandha is obtained.
- ***Ocimum sanctum*** (Labiatae) is a well-known sacred plant of Indian houses, gardens and temples all over the country. An infusion of its leaves in hot water, and specially along with tea, is useful in cold, bronchitis and digestive disorders. Its seeds are also useful in dysentery and chronic diarrhoea.
- The famous antibiotic drug ephedrine, is obtained from its dried stems of ***Ephedra gerardiana*** (Ephedraceae). Ephedrine is used to treat asthma, cold and hay fever. It is also effective as a good cardiac stimulant. Nasal spray, prepared from ephedrine, is effective in inflammation of mucous membrane and also in asthmatic attacks.
- Bentham and Hooker classified the plants based on natural characters.
- Bentham and Hooker classified the plants in the book called **Genera Plantarum** (1862-1883).
- Bentham and Hooker classification is a classification of only seed plants.
- Merit-
    1. It is simple and easy to use for practical purpose.
    2. Every genus and species were studied from the actual specimens.
    3. Ranales is placed first in the dicot which is very reasonable.
    4. Monocots followed dicots
    5. Gymnosperms were treated as a third taxon and placed between Dicots and Monocots
- Demerit-
    1. Placing of Gymnosperms between dicot and monocot is not accepted.

2. Artificial characters are considered here and there.
3. Monochylamydeae is considered to be the most highly evolved among polypetalae is the most primitive groups among dicots.
4. Some of the related orders are widely separated from each other.
5. There is no uniformity in the arrangement of groups.
6. In the classification of monocotyledon, importance is not given to all natural characters.

8.4 Terminal Question

Q.1 What is economic Botany? Give a detailed account of five medicinal plants.

Answer:---

Q.2 Describe history of medicinal plant and discuss the uses of Ephedrine and Aswagandha also.

Answer:---

Q.3 Define the Thalimiflorae, Disciflorae and Calyciflorae.

Answer:---

Q.4 Discuss the classification of Bentham and Hooker in detail.

Answer:---

Short Questions

Q.6 Write short notes on:

9. Polypetalae
10. Gamopetalae
11. Monochlamydae

12. Monocotyledons
13. Merits and demerits of Bentham and Hooker's classification
14. Natural and Phylogenetic classification
15. Monochlamydae
16. Genera Plantarum

Q.7 Multiple choice question:

6. Number of series in Polypetalae are-
   v. 2
   vi. 3
   vii. 4
   viii. 5
7. Bentham and Hooker's classification is a-
   v. phylogenetic system of classification
   vi. artificial system of classification
   vii. natural system of classification
   viii. None of the above
8. Difference between the natural system of plant classification and artificial system of classification is-
   v. considers only one vegetative character
   vi. considers all the similarities between plants
   vii. considers only one floral character
   viii. All of the above
9. The chief merit of Bentham and Hooker's classification is that-
   v. It is a natural system of classification of all groups of plant
   vi. A system based on evolutionary aspects
   vii. It is also considering the phylogenetic aspects
   viii. The description of taxa is based on actual examination of the specimen
10. Genera Plantarum was published by
    i. Engler and Prantle
    ii. Carolus Linnaeus
    iii. Bentham and Hooker
    iv. Darwin

8.5 Answers

2. ii 2. iii 3. ii 4. i 5. iii

Self-assessment questions

SAQ.1

a. Papaveraceae **b.** *Ocimum sanctm* **c.** Antibacterial, antibiotic **d.** *Ephedra gerardiana* **e.** *Cinchona sp*., Rubiaceae

Unit- IX

Plant Taxonomy II

Structure

9.1 Introduction

Objectives

9.2 Terminology

9.3 Dicot families

9.3.1 Asteraceae

9.3.2 Ranunculaceae

9.3.3 Brassicaceae

9.3.4 Solanaceae

9.3.5 Malvaceae

9.3.6 Mimosoideae

9.3.7 Caesalpinioideae

9.3.8 Papilionoideae

9.4 Monocot families

9.4.1 Liliaceae

9.4.2 Orchidaceae

9.4.3 Poaceae

9.5 Summary
9.6 Terminal Questions
9.7 Answers

9.1 Introduction

Angiosperms are divided into two subgroups, dicotyledonous and monocotyledonous plants, mainly on the basis of number of embryonic leaves or cotyledons. The two are commonly spoken as monocots and dicots.

Monocots:

They are angiospermic or flowering plants which are characterised by the presence of a single cotyledon in the seed, generally parallel venation in the leaves (exception S*milax, Colocasia* and relatives), scattered closed vascular bundles in the stem and trimerous flowers. Monocot seedlings tend to grow a cluster of several roots spreading out from the site of germination, which branch further to form a fibrous root system **(Figure 9.1 A)**. e.g., Banana, Cereals, Palms, Grasses, Bamboo, Lilies, Orchids. About 50,000 species of monocots are known.

Dicots:

They are angiospermic or flowering plants which are characterised by the presence of two cotyledons in the seed, generally reticulate venation in leaves (with a few exceptions), concentric tissues in the stem with open vascular bundles arranged in a ring, penta- or tetramerous flowers. Dicot seedlings usually have a distinct primary root, which grows vertically down into the soil, sometimes becoming a taproot as the plant grows **(Figure 9.1 B)**. e.g., Pea, Rose, Eucalyptus, Mustard, Cotton, Acacia, Sunflower. The number of dicot species is over 200,000.

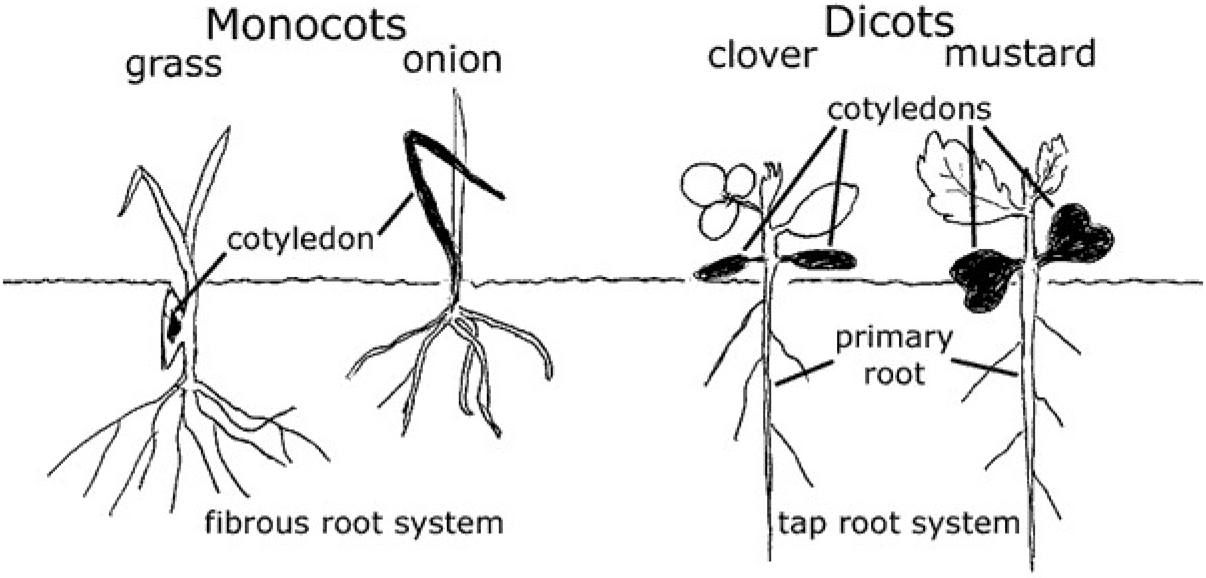


Figure 9.1 (A and B) *Seedlings of a grass, onion, clover, and mustard. The first two are monocots, in which the cotyledon most often remains below ground, though onion family cotyledons emerge. The last two are dicots, whose cotyledons and growing points usually emerge above the ground, although the cotyledons of peas and vetches remain below ground while the growing points and shoots emerge. Root systems are typically fibrous in monocots, and tap-rooted to a greater or lesser degree in dicots.*

**(Figure credits: Mark Schonbeck, Virginia Association for Biological Farming).*

The criteria of the classification are the characters on which the classification is based. The characters of an organism are all the features or attributes (leaf width, stamen number, corolla length, locule number, placentation, etc) possessed by the organism that may be composed, measured, counted, described or otherwise assessed. This means that indifferences, similarities and discontinuities between plants and taxa are reflected in their character. The characters of a taxon are determined by observing or analyzing samples of individuals and recording the observations or by conducting controlled experiments.

Certain characters which are used in description, delimitation or identification are called Diagnostic characters, whereas the characters of constant nature which are used to help define a group are termed as synthetic characters. A character may be qualitative character when it refers to such things as flower colour, odour, leaf shape etc. or quantitative character when it expresses the features that can be counted or measured such as size, length, and breadth, etc.

Objectives

- To become familiar with basic plant morphology.

- To begin to identify plants using morphological characteristics
- To study of monocot and dicot features through various families.
- To study of different plant parts in various aspects.
- To know about primitive and advance character of plant families.
- To introduce plant nomenclature and classification.

9.2 Terminology

Taxonomists need descriptive terminology to efficiently and accurately communicate information. This is particularly important because taxonomy is, in large part, a descriptive science (*vs.* experimental science). It is similar to anatomy and related disciplines in regard to the number of terms used.

Since all the systems of classification and nomenclature of plants are based on morphological and anatomical features, it is necessary for a student of systematic botany to attain ability to recognize the characters by which one kind of plant may be distinguished from another. This requires knowledge of plant structures and familiarity with the technical terms by which they and their components are known.

Such a study, which is known as phytography, constitutes an important part of taxonomy. Though the terminology used in describing the plant structures is extensive and unduly technical, but they are concise and do give accuracy to the description. Since we are concerned here only with the angiosperm plants, terminology used to describe them is given below. A plant is described in a set sequence, starting from its habit and roots and going up to its floral diagram and floral formula.

A. Plant Type (Habit and Habitat):

1. **Annual-** A plant that completes its entire life cycle, from seed to reproduction and death, in one single layer.
2. **Biennial-** A plant that completes its entire life cycle in two years.
3. **Perennial-** A plant that grows and reproduces for many years.
4. **Herb-** A small, usually annual plant, with no wood in its stems or roots.
5. **Shrub-** A much branched, small, woody perennial plant with several branches from ground level upwards.
6. **Tree-** A tall, woody, perennial plant with a single trunk which usually bears branches.

7. **Climber-** A weak- stemmed plant with roots in the ground and climbing the other plants etc. to support itself with the help of its tendrils or adventitious roots, etc. Usually climbers twist around their support.
8. **Liana-** An annual or perennial, elongate plant, with weak stem, which is often climbing.
9. **Creeper-** A plant which is unable to support itself, and spreads along the ground.
10. **Epiphytes-** A plant, growing on stems or branches of other plants, with no roots in the ground, but not taking nutrients on which it is growing.
11. **Parasites-** An organism which takes all its nutrients from the tissues of another organism, usually with harmful effects.
12. **Aquatic-** Organisms growing in water.
13. **Xerophytes-** A plant that lives in dry habitats or in a desert.

B. Root:

Whether tap root or adventitious root, or some specialized roots such as-

1. **Annulated-** Root having a series of ring like swellings.
2. **Fibrous-** Fine, thread-like roots.
3. **Tuberous-** Fleshy roots appearing like stem tubers.
4. **Stilt-** Supportive roots which grow out from the bottom of the trunk into the ground.
5. **Aerial-** A root arising from a part of the plant which is above the ground.
6. **Climbing-** These arises on the nodes of weak-stemmed plants, and help them to climb or fix on the support.
7. **Nodulose-** Root bearing a small knot at or near the apex.

C. STEM:

1. **Aerial-** Stem which remains above the ground.
2. **Erect-** Growing upright.
3. **Angular-** Stem showing many angles in a transverse section.
4. **Arborescent-** Woody and tree like.
5. **Branched-** Stem with many branches.
6. **Bulb-** An underground, short, erect stem covered by fleshy leaves.
7. **Caudex-** A short, hard, overwintering base of perennial herb.
8. **Cladode-** A phylloclade in which a branch of a single internode becomes flat or leaf like.
9. **Corm-** Solid, round, bulblike, fleshy, underground stem, usually surrounded by membranous scales.

10. **Cylindrical-** Stem showing circular outline in transverse section.
11. **Herbaceous-** Soft, non-woody, dying to the ground at the end of the growing season.
12. **Internode-** Region of stem between any two nodes.
13. **Phylloclade-** A flat or round, green, succulent stem with leaves either ill-developed or modified into spines.
14. **Phyllode-** A flattened, green, leaf like modification of the petiole which takes up the functions of the leaf blade which is reduced or absent.
15. **Rhizome-** A horizontal, prostrate, or underground stem bearing scale-like leaves.
16. **Tendril-** Long, twisting appendages, adapted for climbing.
17. **Woody-** Hard in texture and possessing secondary xylem.
18. **Prickle-** A sharp, pointed extension of epidermis or cortex.

(I) Branching of stem:

1. **Dichotomous-** Stem dividing equally into two.

2. **Monopodial-** When the main axis continuous growing and also giving off lateral branches which do not exceed it in size.

3. **Sympodial-** When the main axis either stops growing due to destruction of the apical bud or its development into a flower or it grows comparatively very slow so that the growth of its branches for exceed that of the main axis. It may be of following kinds:

    a. **Uniparous-** When each successive branch bears upon itself one new branch only.
    b. **Biparous-** When two branches arise simultaneously from their axes, thus giving a symmetrical form.
    c. **Multiparous-** When each relative main axis of the cyme produces more than two branches.

(II) Surface of the stem:

1. **Glaucous-** Shining and smooth.
2. **Glabrous-** Smooth, or without hairs.
3. **Hairy-** Thread like structure present on the stem.
4. **Spiny-** A strong and sharp-pointed woody body mostly arising from the wood of the stem.

D. Leaves:

(I) Apex of Leaf (Figure 9.2):

1. **Acuminate-** Drawn out in the form of a long slender tail, or tapers to a protracted point.
2. **Acute-** Ending into a sharp point in the form of an acute angle but not drawn out.
3. **Apiculate-** Ending into a short, sharp, flexible point, or an apicula.
4. **Aristate-** Tappering to a very narrow, much elongated apex, or bearing a stiff awn.
5. **Caudate-** Containing a tail-like appendages.
6. **Cirrhose-** Apex ending into tendril like structure.
7. **Caspidate-** Abruptly and sharply concavely constricted into a sharp and elongated pointed tip.
8. **Emarginate-** Containing a deep or shallow notch at the apex.
9. **Mucronate-** Terminating abruptly into a short and sharp point.
10. **Mucronulate-** Smaller form of mucronate.
11. **Obcordate-** Deeply lobed at the apex.
12. **Obtuse-** Blunt or rounded.
13. **Retuse-** Slightly notched obtuse apex.

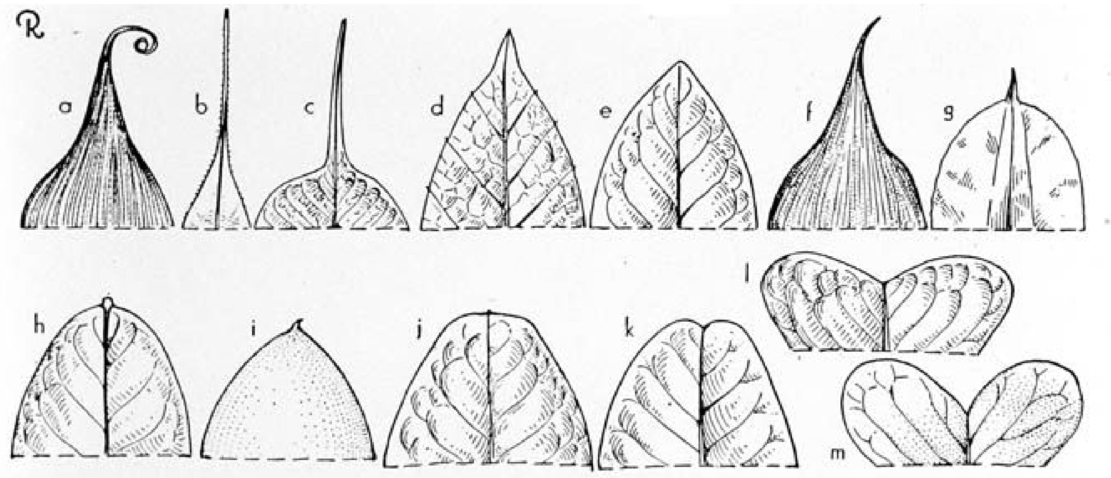


Figure 9.2 Apex of leaf: *a. Cirrhose, b. Aristate, c. Caudate, d. Acuminate, e. Acute, f. Cuspidate, g. Mucronate, h. Mucronulate, i. Apiculate, j. Obtuse, k. Retuse, l. Emarginate, m. Obcordate*

(II) Leaf Base (Figure 9.3):

1. **Auriculate-** Bearing an appendages or ear-shaped part at the base.
2. **Perfoliate-** Sessile leaf whose base completely surrounds the stem.
3. **Clasping-**The leaves covering the stem which appears passing through them.
4. **Attenuate-** Base showing a long gradual taper.
5. **Oblique-** Two sides of base being unequal-sized.

6. **Truncate-** Blunt, or appearing as if cut off at the end.
7. **Cordate-** Heart shaped
8. **Saggitate-** Base like an arrowhead, or triangular.
9. **Hastate-** Resembling with an arrowhead, hlberd-shaped
10. **Peltate-** Attached to its stalk inside the margin.
11. **Cuneate-** Wedge-shaped, triangular with the narrow end at the attaching point.
12. **Rounded-** The leaf base round in shape.

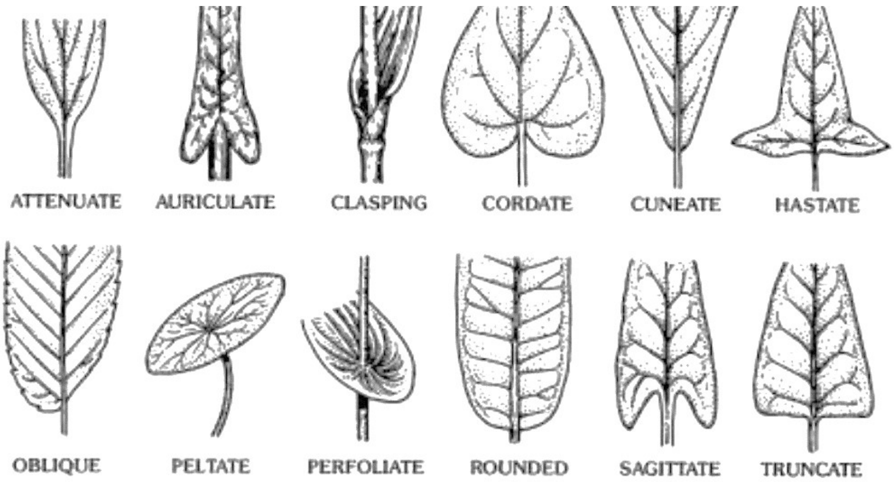


Figure 9.3 Leaf Base

(III) Kinds, modification and parts of Leaf:

1. **Bract-**Reduced and modified leaf found in inflorescence.
2. **Bracteole-** Small leaf found on the pedicel of flower.
3. **Cauline-** Leaf arising only on the main axis.
4. **Radical-** Leaves arising from bulb or other underground stem.
5. **Epicalyx-** Leaves present below the true calyx.
6. **Evergreen-** Persistent.
7. **Exstipulate-** Without stipules.
8. **Fugacious-** Falling soon.
9. **Glume-** Bract of the spikelets of sedges and grasses.
10. **Incomplete-** Leaf without one or more parts.
11. **Leaflet-** A distinct or separate segment of leaf.
12. **Ligule-** Finger-like small part present at the upper end of leaf sheath.
13. **Petiolate-** Leaf with a distinct stalk.

14. **Pitcher-** Tubular or pitcher-shaped leaf of insectivorous plants.
15. **Pulvinus-** Swollen base of petiole.
16. **Rachilla-** Secondary axis of a compound leaf.
17. **Rachis-** Main axis of a pinnately compound leaf.
18. **Scaly leaf-** Small, non-green leaf
19. **Sessile-** Without petiole.
20. **Spathe-** An enlarged bract enclosing an inflorescence.
21. **Sporophyll-** Spore-bearing leaves.
22. **Stipule-** Scale, gland or blade-like structure at the base of petiole of leaf.

(IV) Margin of Leaf (Figure 9.4):

1. **Biserrate-** When each tooth of the serrated margin is again serrated.
2. **Ciliate-** Margin bearing hairs.
3. **Crenate-** With blunt, low rounded teeth
4. **Crispate-** Curled and extremely undulate.
5. **Dentate-** With sharp, marginal teeth pointing outward.
6. **Dissected-** Cut or deeply divided into many segments
7. **Entire-** With a continuous smooth margin, lacking any teeth, lobes or indentations.
8. **Incised-** Provided with sharp and irregular incisions.
9. **Lacearate-** Torn or irregularly cut.
10. **Lobed-** Provided with many lobes extending one third to one-half the distance between the midrib and the margin.
11. **Parted-** Dissected or cut almost to the midrib.
12. **Pinnatifid-** Parted in a pinnate way, or divided almost to the midrib.
13. **Revolute-**With the margin rolling inward i.e. towards the underside of the leaf.
14. **Serrate-**With the marginal teeth pointing towards the apex.
15. **Serrulate-**When the teeth in the serrated margin are very minute.
16. **Undulate-**With a slightly wavy margin.

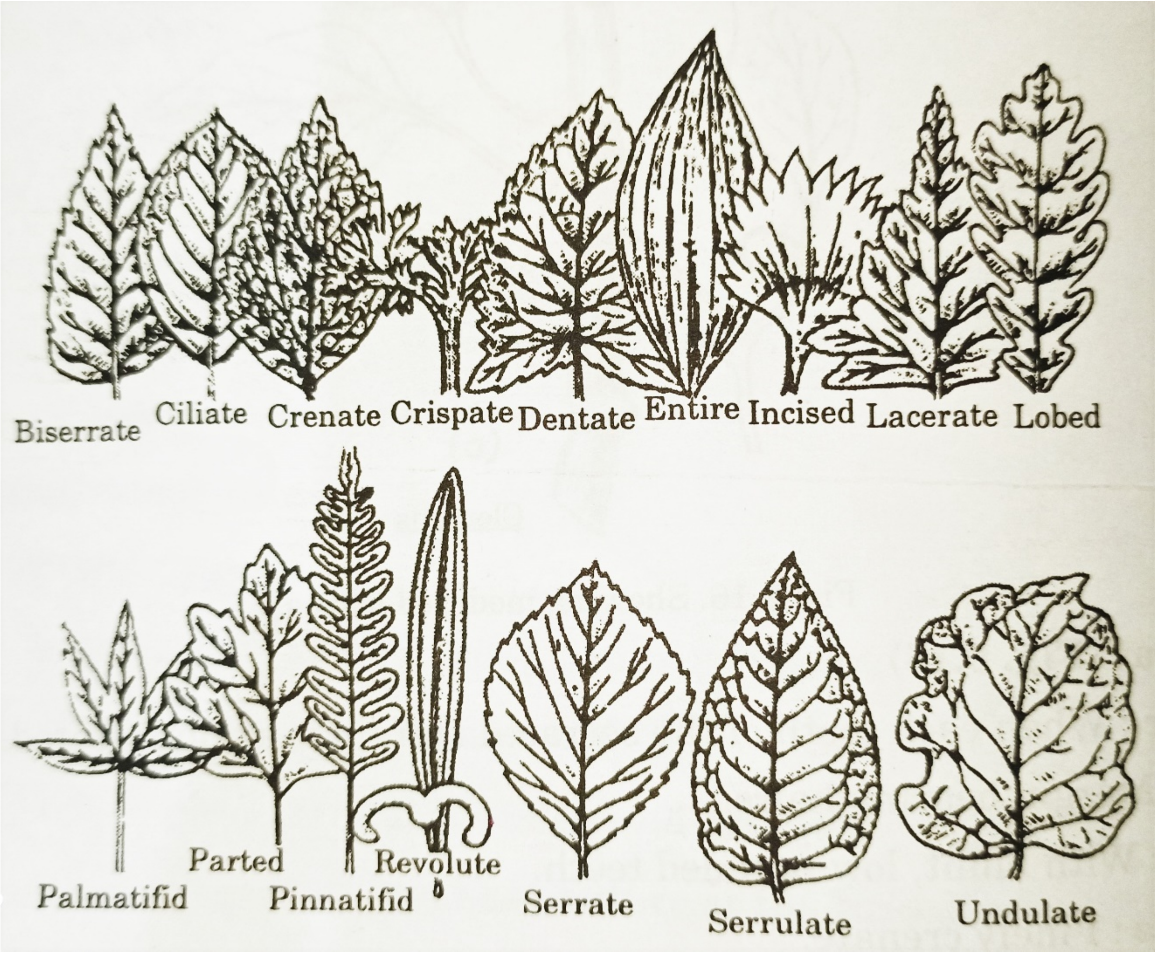


Figure 9.4 Margin of Leaf

(V) Leaf Arrangement:

1. **Opposite-** Bearing leaves paired at each node on opposite side.
2. **Decussate-** When two successive opposite pairs of leaves occur at right angle to each other.
3. **Alternate-** Bearing one leaf at each node.
4. **Distichous-** When alternate leaves appear on just two sides of the stem.
5. **Whorled-** Bearing three or more leaves at each node.
6. **Rosette-** An arrangement of leaves radiating from a crown or center and usually at or close to the earth.

(VI) Shape of Leaf (Figure 9.5):

1. **Acicular-** Needle shaped.
2. **Auriculate-** Ear shaped.
3. **Cordate-** Heart shaped.

4. **Cuneate-** Wedge shaped with lower end narrow.
5. **Deltoid-** Delta-like or triangular.
6. **Elliptical-** Oval in outline, being narrowed to form rounded ends and widest at the middle.
7. **Falcate-** Sickle shaped.
8. **Filiform-** Long, slender and thread like.
9. **Hastate-** Like an arrow head.
10. **Lanceolate-** Much longer than broad, or widening above the base and tapering towards the tip.
11. **Linear-** Long, flat, and narrow with almost parallel sides.
12. **Lorate-** Strap shaped, or like a narrow strip of leather.
13. **Lyrate-** Like a lyre, i.e. having a big terminal lobe and several smaller lateral lobes.
14. **Obcordate-** Inversely cordate.
15. **Oblique-** When two halves of the lamina are unequal.
16. **Oblong-** Long, wide with the parallel margin.
17. **Obovate-** Upper terminal half broader than the lower basal half; opposite to ovate.
18. **Ovate-** Egg shaped; broad at the base and narrowing towards apex.
19. **Pedate-**Like the claw of a bird; or palmately lobed.
20. **Reniform-** Kidney-shaped
21. **Rhomboid-** Rhombic-shaped
22. **Rotund-** Nearly circular.
23. **Sagitate-** Like an arrowhead; or triangular.
24. **Spathulate-** Spoon shaped.
25. **Subulate-** Tapering from the base to apex; awi shaped.

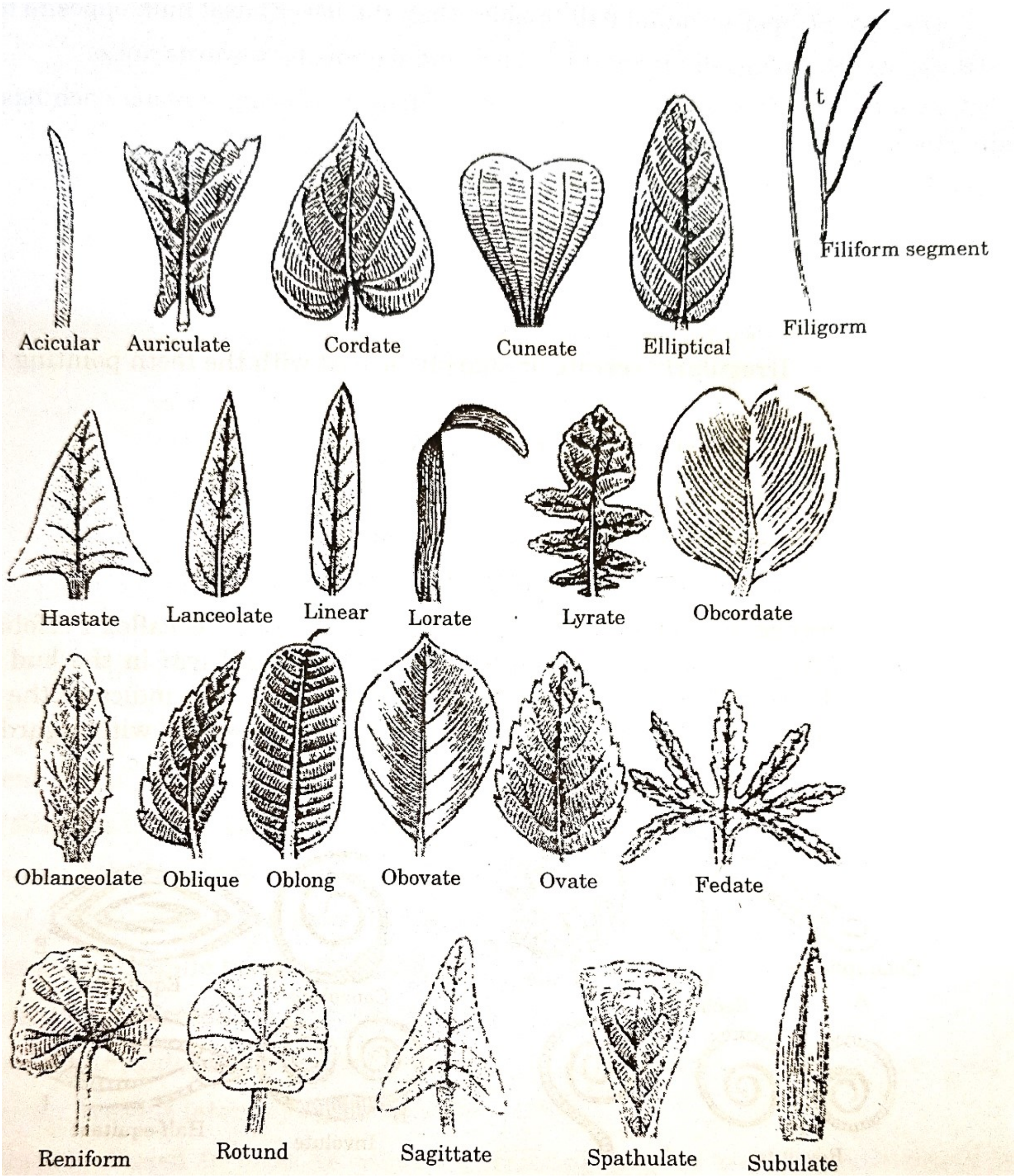


Figure 9.5 Shape of leaf

(VI) Stipules:

1. **Vestigial-** Very small, minute, or remnant.
2. **Scaly-** Dry, small and membranous stipule
3. **Adnate-** Attached fully to petiole as wings.
4. **Interpetiolar-** Presnt in between the petioles of opposite leaves.
5. **Intrapetiolar-** Situated in the axil of leaves, and their margins fuse above the petiole.
6. **Basal-** Stipules attached near the base of petiole.
7. **Lateral-** Present laterally on the petiole.
8. **Spinous-**Stipule in the form of a hard spine.

9. **Ochreate-** Fused to form an ochrea or a fused tubular nodal sheath round the internode.
10. **Foliaceous-** Stipule resembling with a large leaf.
11. **Ventral-** Present on the ventral side of the petiole.

(VII) Venation of the Leaf:

1. **Parallel-** When the veins run parallel to each other in the lamina of the leaf.
2. **Reticulate-** When the pattern of the veins in the lamina of the leaf is like a network.

(VIII) Types of Leaf:

1. **Simple leaf-** A leaf with the blade in a single part is called simple leaf. The single blade may, however, be variously divided.
    a. ***Trifoliate-*** Three leaved as in *Trillium*.
    b. ***Trifoliolate-*** Having a leaf or leaves of 3 leaflets, as most clovers.
2. **Compound leaf-** A leaf, in which the leaf blade or lamina remains divided into smaller, blade like parts or leaflets is called compound leaf. A compound leaf may be palmately compound or pinnately compound.
    a. ***Palmately compound leaf-*** If the leaflets diverge from a common point at the end of the petiole, in the same way as the fingers from the palm of the hand, the leaf is called palmately compound.
    b. ***Pinnately compound leaf-*** If the leaflets are attached on both sides of one central rachis.

E. Inflorescence:

(A) Racemose- In this type, the main axis does not terminate into a flower, but it keeps on growing continually and gives off flowers laterally in acropetal succession. Here the youngest flower is present at the apex and the older flowers towards the base. The examples are as follows **(Figure 9.6)**:

1. ***Raceme-***An indeterminate, unbranched inflorescence with a single axis and the flowers arranged along the main axis on pedicels.
2. ***Spike-*** Elongated, unbranched, indeterminate inflorescence with sessile flowers.
3. ***Spikelet-*** A small spike or the basic inflorescence unit of Cyperaceae and Gramineae.
4. ***Panicle-*** Branched inflorescence with pedicellate flowers arranged in the form of number of recemes.

5. ***Spadix-*** A fleshy or thick, spike like inflorescence with very small flowers usually in a spathe.
6. ***Corymb-*** A raceme whose lower stalks are longer than the upper ones, so the inflorescence has a flat top.
7. ***Compound corymb-*** A branched corymb having pedicellate flowers.
8. ***Umbel-*** An inflorescence in which all the pedicels are of the same length and arise from the same point.
9. ***Capitulum or Head-*** A dense cluster of several sessile or sub sessile flowers on a compound receptacle or torus.

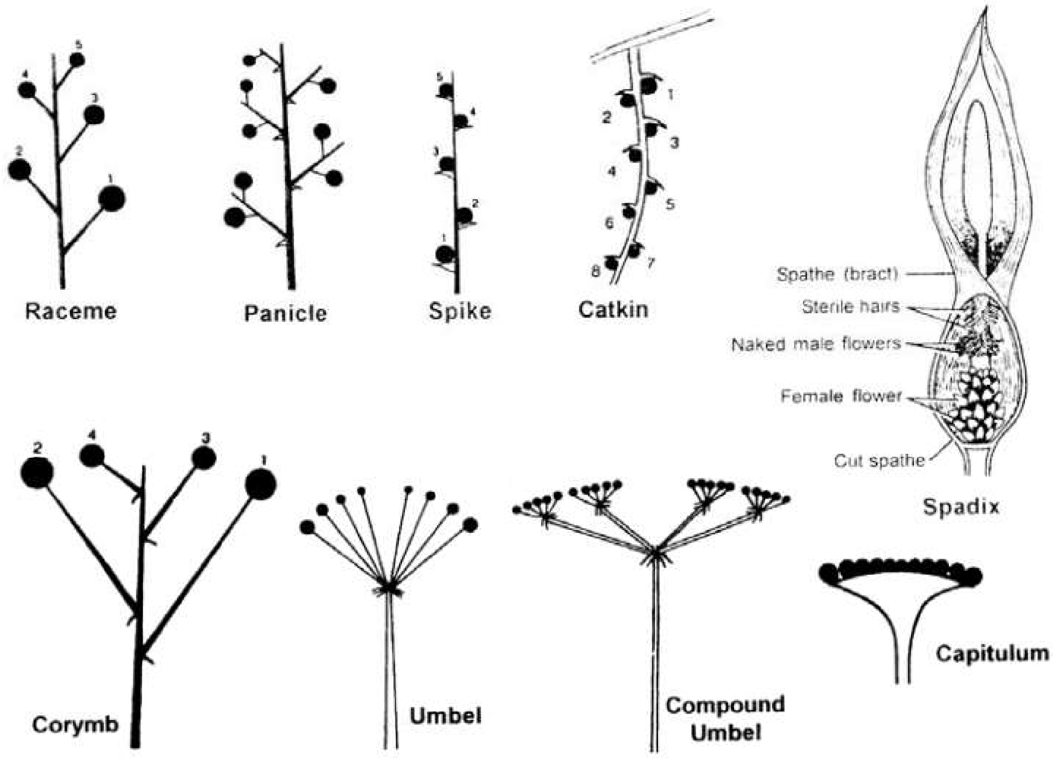


Figure 9.6 Types of Racemose inflorescence

(B) Cymose- In this type the growth of the main axis is checked soon by the development of a flower at the apex, and the lateral axis below the terminal flower also ends in a flower, and thus its growth is also checked. In cymose inflorescence, the terminal flower is the oldest and the young flowers are present on the lower side. The examples are as follows **(Figure 9.7)**:

1. **Uniperous-**
   a. ***Helicoid-*** Curved and unbranched inflorescence of pedicellate flowers having the branches on one side.

b. ***Scorpoid-*** A zig-zag cymose inflorescence that appears to coil like a scorpion's tail. In this type, the branches develop alternately on opposite side of the rachis.

2. Biperous

3. Multiperous

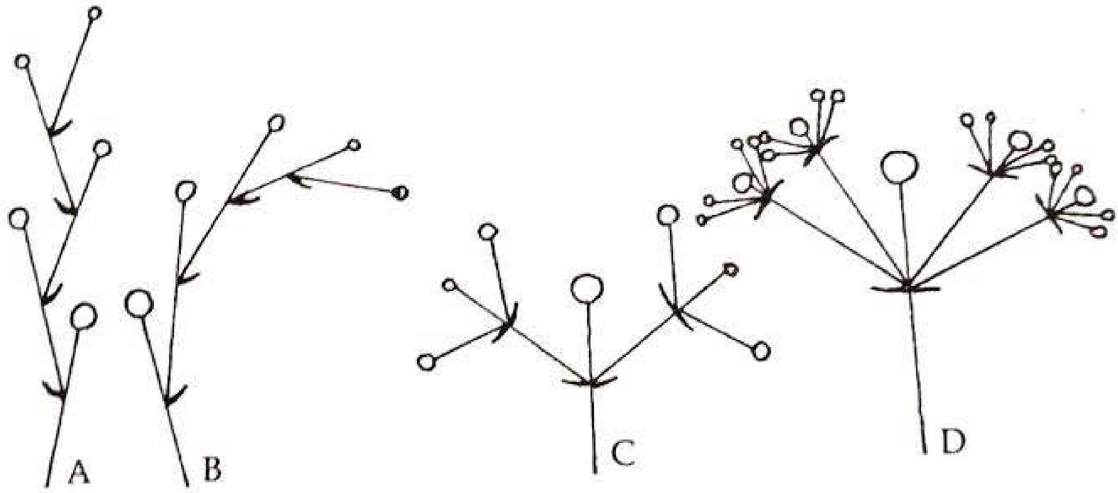


Figure 9.7 Types of Cymose inflorescence: A. Uniparous scorpoid cyme, B. Uniparous helicoids cyme, C. Biparous cyme, D. Multiparous cyme

(C) Some special type (Figure 9.8)-

a. **Cyathium-** A cup shaped involucre containing nectar-secreting glands, a centrally placed large female flower and many male flowers.

b. **Hypanthodium-** An inflorescence having sessile flowers on a wall of a concave Capitulum, opening by a small ostiole. Male flowers are situated near the periphery and female flowers in the centre.

c. **Verticillaster-** Whorled dichasial cyme arranged at the nodes of an elongate axis.

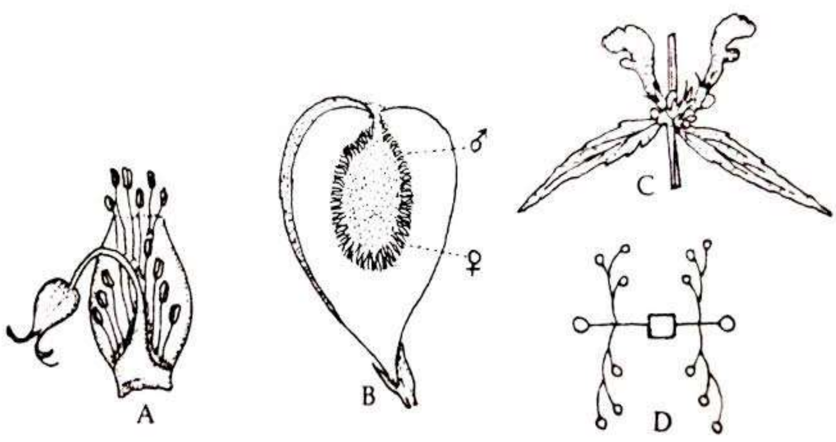


Figure 9.8 Special types of inflorescence: A. Cyathium of *Euphorbia*, B. Hypanthodium of *Ficus*, C. Verticilaster of *Oscimum* (D. Diagrammatic)

F. The Flower (Figure 9.9):

1. **Actinomorphic-** Flowers with radial symmetry; or flowers which can be bisected into similar halves along two or more planes.
2. **Zygomorphic-** Flowers which can be bisected into similar halves only in one vertical plane.
3. **Hermaphrodite-** Flowers having both the sex organs.
4. **Androphore-** Elongated intermodal part between corolla and androecium.
5. **Anthopore-** Elongated intermodal part between calyx and corolla.
6. **Gynophore-** Elongated intermodal part between androecium and gynoecium.
7. **Androgynophore-** Stripe bearing both androphore and gynophore together.
8. **Amorphic-** Flowers without symmetry.

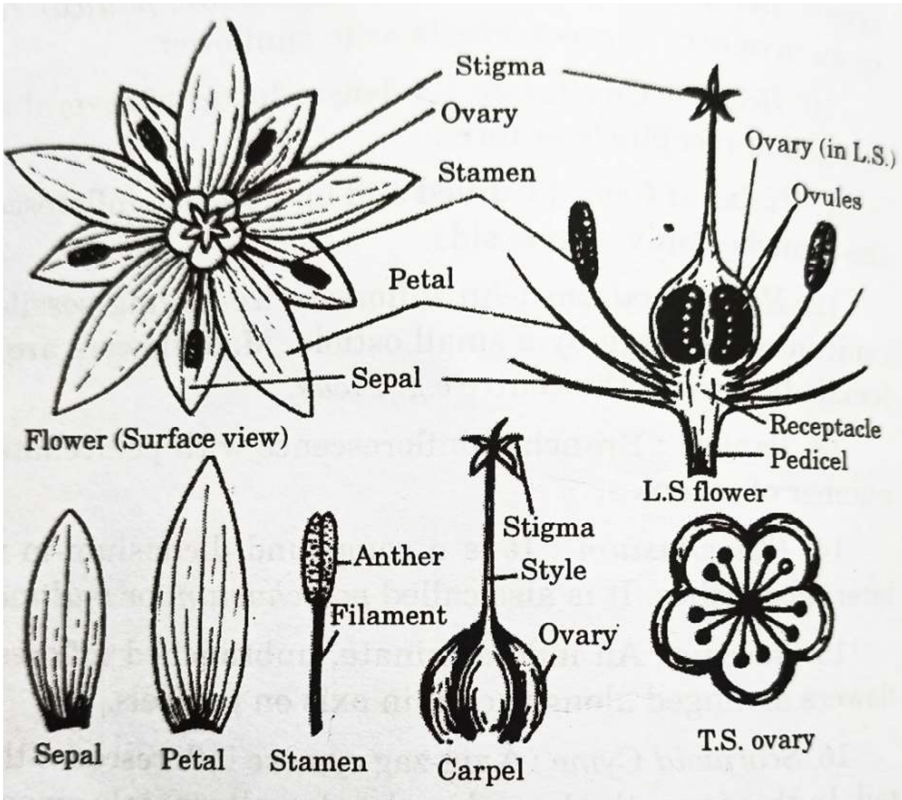


Figure 9.9 Showing parts of a typical flower

(i) Arrangement of floral appendages on the receptacle (Figure 9.10):

1. **Hypogynous-** The condition in which sepals, petals and androecium are attached to the floral tube below the ovary.
2. **Perigynous-** The condition in which sepals, petals and androecium are attached to the floral tube around the ovary.
3. **Epigynous-** The condition in which the sepals, petals and androecium are attached to the floral tube above the ovary.

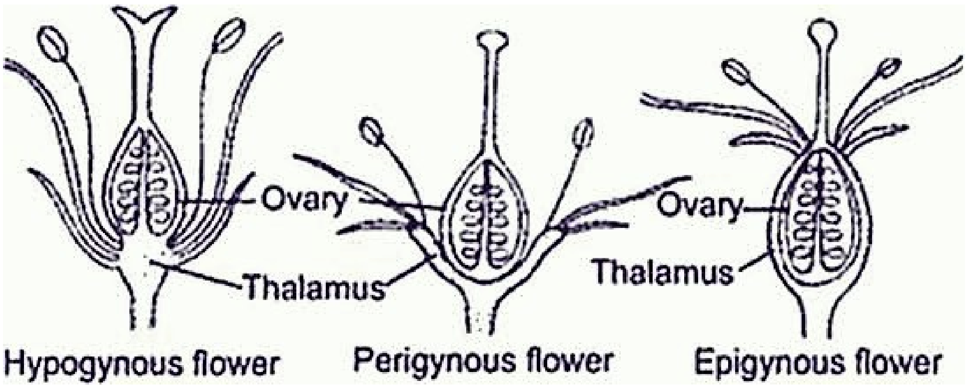


Figure 9.10 Arrangement of floral appendages on the receptacle

(ii) The Calyx:

1. **Asepalous-** Without sepals.
2. **Petalloid-** Coloured sepals except green.
3. **Bilabiate-** Consisting of two lips.
4. **Polysepalous-** When sepals are free.
5. **Gamosepalous-** When sepals are fused.
6. **Caducous-** Falling off when the flower opens.
7. **Deciduous-** Falling off when the flower withers.
8. **Persistent-** Persisting even at the fruiting stage of the flower.

(iii) The Corolla:

1. **Apetalous-** Without petals.
2. **Polypetalous-** When petals are free.
3. **Gamopetalous-** When petals are fused.
4. **Wing-** Lateral petals.

(iv) Aestivation of Calyx and Corolla (Figure 9.11):

1. **Valvate aestivation-** When the sepals or petals meet edge to edge without overlapping each other.

2. **Twisted aestivation-** When margins of each part are overlapped regularly, i.e. one edge of the sepal or petal are overlapped by the preceding part.
3. **Imbricate aestivation-** Out of the five sepals or petals, one external, one internal, and other three are partly external and partly internal.
4. **Quincuncial aestivation-** Out of the five sepals or petals, two external, two internal and remaining one is partly external and partly internal.
5. **Vexillary aestivation-** Out of the five sepals or petals the posterior one is the largest and covers the two lateral sepals or petals, and the latter in turn overlap the two smallest and anterior sepals or petals.

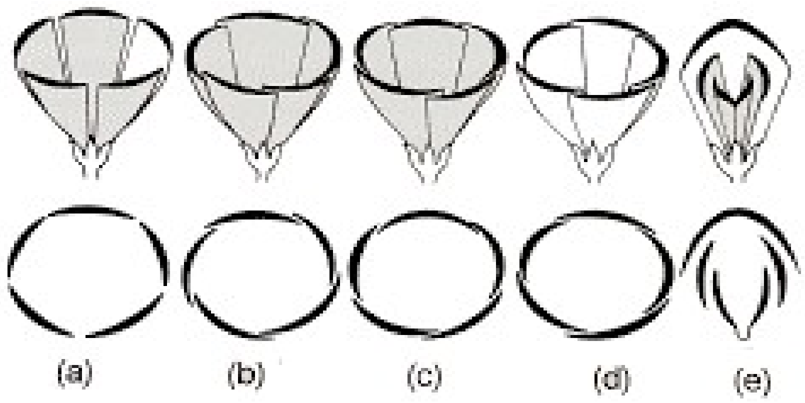


Figure 9.11 Different types of aestivation of calyx and corolla: a. Valvate, b. Twisted, c. Imbricate, d. Quincuncial, e. Vexillary

(v) The Androecium:

(A) Attachment of the filament to the anther (Figure 9.12):

1. **Basifixed-** Filament attached with the base of the anther lobe.
2. **Adnate-** When filament runs throughout the entire length of the anther from the base of the top.
3. **Dorsifixed-** When the filament attached on the dorsal side of the anther lobes.
4. **Versatile-**Dorsifixed but it appears as if the anther is swinging freely on the filament.

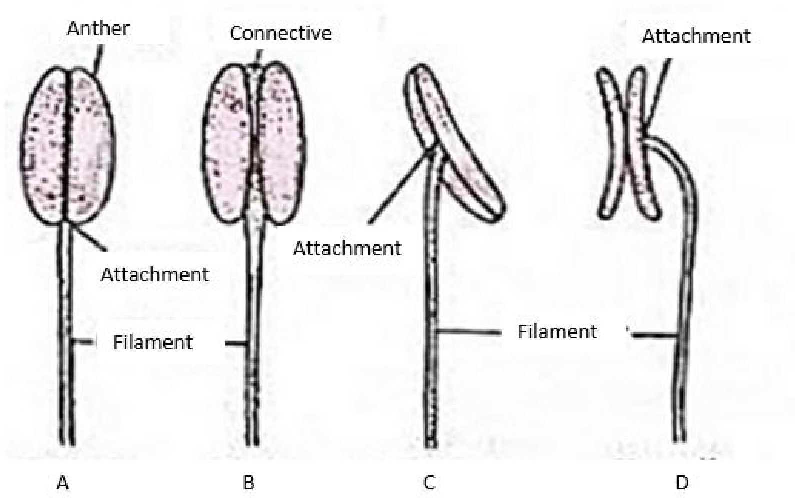


Figure 9.12 Attachment of the filament to the anther: A. Basified, B. Adnate, C. Dorsifixed, D. Versatile

(B) Cohesion of stamens (Figure 9.13):

1. **Monoadelphous-**When filaments of one group of stamens are fused but their anthers are free.
2. **Diadelphous-** The filaments of stamens united or connate in two groups with their anthers being free.
3. **Polyadelphous-** The filaments are united in several groups with their anthers remaining free.
4. **Syngenesious-** With fused anthers and free filaments.
5. **Synandrous-** Anthers as well as their filaments being united in the form of one group.

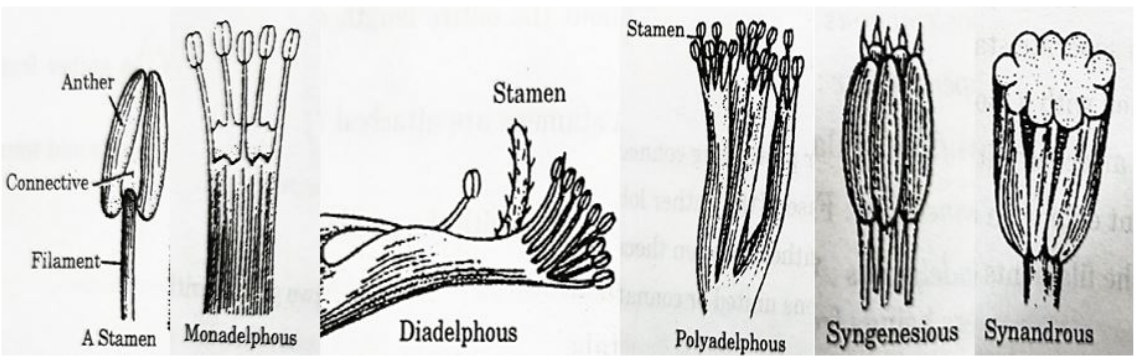


Figure 9.13 Cohesion of stamens

(C) Adhesion of Stamens:

1. **Epipetalous-** When the stamens remain attached to the petals.

2. **Epiphyllous-** When the stamens remain attached with the petals.
3. **Gynandrous-** When stamens are fused with gynoecium.

(D) Length of Stamens (Figure 9.14):

1. **Didynamous-** When two out of the four stamens are larger and remaining two are smaller in size.
2. **Tetradynamous-** Two out of a total of six stamens are short while the remaining four are long.

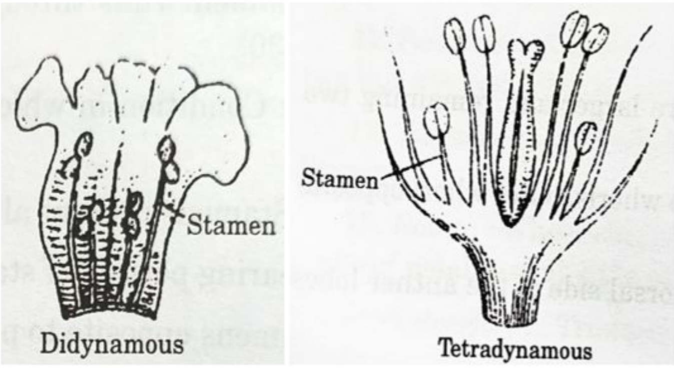


Figure 9.14 Length of stamens

(vi) Gynoecium:

1. **Syncarpous-** With fused carpels.
2. **Apocarpous-** With free or separate carpels.
3. **Pistillode-** A sterile carpel.

(a) Stigma (Figure 9.15):

1. **Capitate-** Like a cap or head.
2. **Clavate-** Club-shaped.
3. **Crested-** Possessing a terminal tuft or ridge.
4. **Decurrent-** Long and extending downward.
5. **Diffuse-** Spread over a wide surface.
6. **Discoid-** Like a disc.
7. **Fimbriate-** Fringed.
8. **Lineate-** In the form of small lines.
9. **Lobed-** Divided into some lobes.
10. **Plumose-** Like a feather.
11. **Terete-** Elongate and cylindrical.

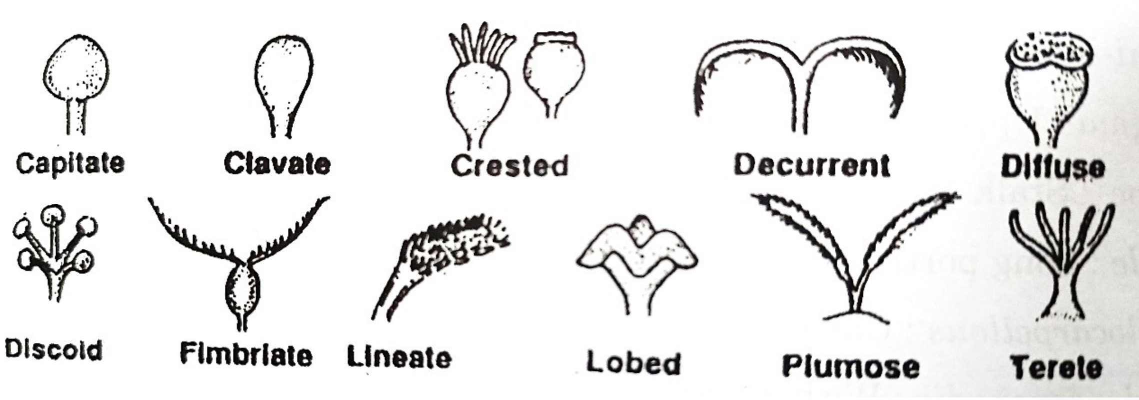


Figure 9.15 Types of stigma

(b) Style:

1. **Gericulate-** The style which bents abruptly.
2. **Gynobasic style-** The style which is attached at the base of the ovary in central depression.
3. **Heterostylous-** With styles of different shapes or length.
4. **Homostylous-** With styles of same shapes or length.

(c) Placentation (Figure 9.16):

1. **Axile-** The placentae develop along the central axis in a compound ovary with septa. It occurs in a bilocular to multilocular ovary.
2. **Basal-** The placenta develops at the base of the ovary, i.e. directly on the thalamus. It occurs in a unilocular ovary.
3. **Free-central-** The placenta develops along the central axis in a compound ovary without septa. It occurs in unilocular ovary.
4. **Superficial-** The placenta develops over the inner surface of the ovary wall. It occurs in a multicarpellary ovary.
5. **Marginal-** The placenta develops along the margin of the simple ovary. It occurs in monocarpellary and unilocular ovary.
6. **Parietal-** The placentae develop on the wall or intruding portions of a compound ovary. It occurs in bicarpellary to multicarpellary but unilocular ovary.
7. **Apical or Pendulous-** The placenta develops at the top of the ovary and the ovules remain suspended in a pendulous manner.

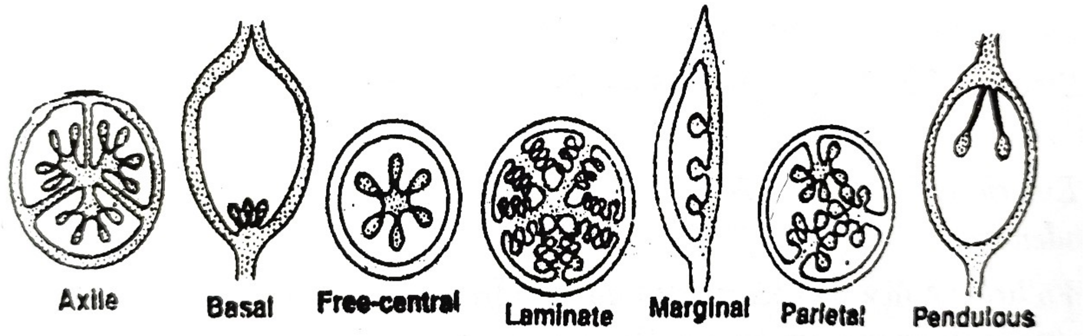


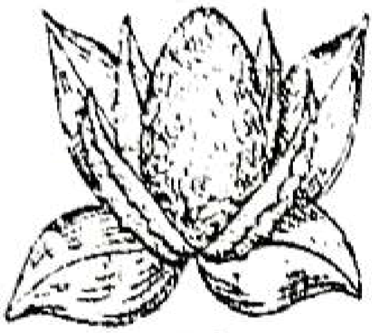
Figure 9.16 Types of placentation

G. The Fruit (Figure 9. 17: I, II, III):

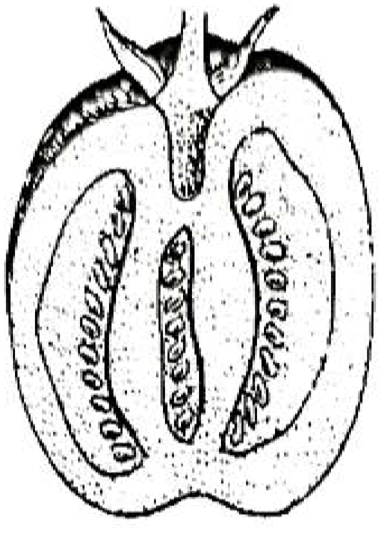
1. **Achene-** Developing from a monocarpellary superior ovary, the achene is one-seeded, dry, indehiscent, simple fruit having its seed attached to fruit wall only at one point, e.g. *Mirabilis, Clematis.*
2. **Amphisarca-** A fleshy simple berry-like fruit with a woody rind, e.g. *Lagenaria.*
3. **Balausta-** A simple, dry, many-seeded and many-loculed indehiscent fruit with a tough pericarp, e.g. *Punica*.
4. **Berry-** Fleshy simple fruit with succulent pericarp, e.g. tomato, banana, *Vitis.*
5. **Bibacca-** A multiple type of fruit formed as a fused double berry, e.g. *Lonicera.*
6. **Cacervulus-** A dry schizocarpic fruit which develops from bi-to multicarpellary, syncarpous, superior ovary with many locules, e.g. Labiatae.
7. **Calybium-** A hard, unichambered dry indehiscent fruit derived from an inferior ovary, e.g. *Quercus.*
8. **Capsule-** A dry dehiscent fruit derived from a bi-to multicarpellary superior or inferior ovary, e.g. *Papaver*.
9. **Caryopsis-** A dry indehiscent fruit derived from monocarpellary ovary in which pericarp is inseparably fused with testa, e.g. Gramineae.
10. **Cremocarp-** A dry schizocarpic fruit derived from bicarpellary, syncarpous inferior ovary with one ovule in each locule. It dehisces from two indehiscent, single-seeded mericarps attached with carpophore, e.g. Umbelliferae.
11. **Cypsela-** A dry indehiscent achene type of fruit derived from unilocular, inferior ovary, e.g. *Helianthus.*
12. **Drupe-** A fleshy fruit with a stony endocarp and edible mesocarp, e.g. mango, *Prunus.*
13. **Druplet-** A small drupe, e.g. *Rubus.*

14. **Etaerio of Achenes-** Also called achenecetum, it is an aggregation of achenes, e.g. *Ranunculus.*
15. **Etaerio of Berries-** Also called baccacetum, it is an aggregation of berries, e.g *Artabotrys. Olinu*
16. **Etaerio of Drupes-** Also called drupecetum, it is an aggregation of drupes, e.g *Rubus*
17. **Etaerio of Follicles-** Also called follicetum, it is an aggregation of follicles, e.g *Delphinium.*
18. **Etaerio of Samaras-** Also called samaracetum, it is an aggregation of samaras, e.g *Liriodendron*.
19. **Follicle-** A dry, dehiscent fruit derived from a monocarpellary, superior ovary, and dehisces only along one suture, e.g. *Delphinium.*
20. **Hesperidium-** A fleshly, thick-skinned berry with hard and leathery pericarp. It is derived from a polycarpellary, multilocular, superior ovary. Bulk of this fruit is derived from glandular hairs, e.g. *Citrus*.
21. **Legume-** A dry, dehiscent fruit derived from monocarpellary, superior ovary with marginal placentation. It dehisces along two sutures, e.g. *Pisum.*
22. **Lomentum-** A dry dehiscent legume that separates transversely between seed sections, e.g. *Acacia*.
23. **Nut-** A dry indehiscent, one-seeded fruit with a hard pericarp. It is derived from unilocular ovary, e.g. *Anacardium*.
24. **Nutlet-** A small nut.
25. **Pepo-** A berry with a leathery nonseptate rind, developing from tricarpellary, syncarpous, inferior ovary with parietal placentation, e.g. Cucurbitaceae.
26. **Pome-** A fleshy fruit surrounded by the fleshy thalamus and developing from a two or more called, syncarpous, inferior ovary, e.g. apple.
27. **Pyrene-** Fleshy fruit with each seed covered by a bony endocarp, e.g. *Ilex.*
28. **Regma-** Dry, schizocarpic fruit derived from tricarpellary, syncarpous, superior, trilocular ovary, and bears many spinous tubercles, e.g. *Ricinus.*
29. **Samara-** Dry, indehiscent simple fruit derived from bicarpellary, syncarpous ovary Its pericarp is winged, eg. *Elm*.
30. **Silicula-** Dry, dehiscent fruit derived from two or more carpels. It dehisces along two sutures and leaves a persistent partition after dehiscence. It is as broad as, or even broader, than long, e.g. *Iberis.*

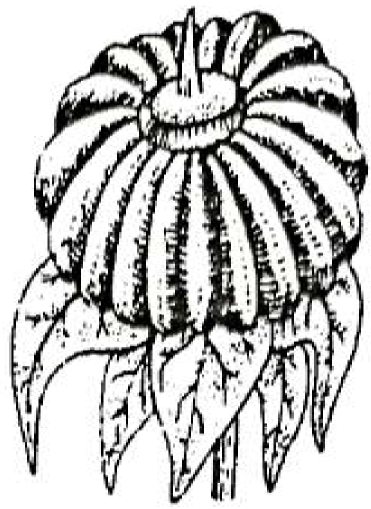
31. **Siliqua-** Dry, dehiscent fruit derived from bicarpellary, syncarpous ovary with Parietal placentation and a false septum. It is longer than broad, e.g. *Brassica*.
32. **Sorosis-** A multiple fruit developing from the spadix or spike in which the flowers Usually fuse by their succulent sepals, and axis bearing them becomes woody or fleshy Forming a compact mass, e.g. pineapple.
33. **Syconus-** A multiple fruit derived from hypanthodium type of inflorescence. Here The achenes develop on the inside of a hollowed-out fleshy receptacle, e.g. *Ficus*.



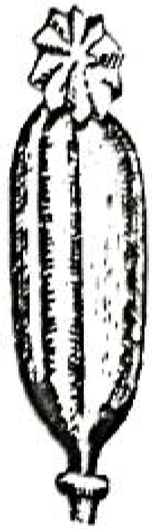
Achene
(*Mirabilis*)



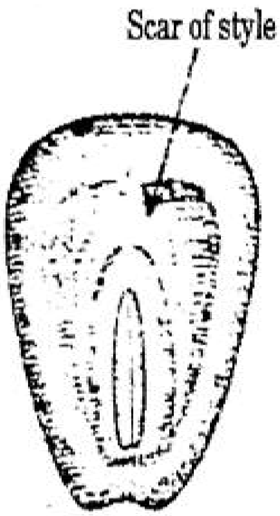
Berry
(*Tomato*)



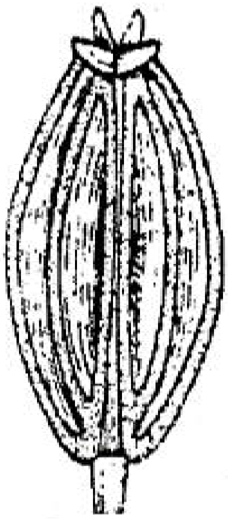
Cacervulus
(*Althea*)



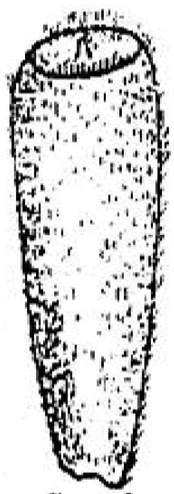
Capsule
(*Papaver*)



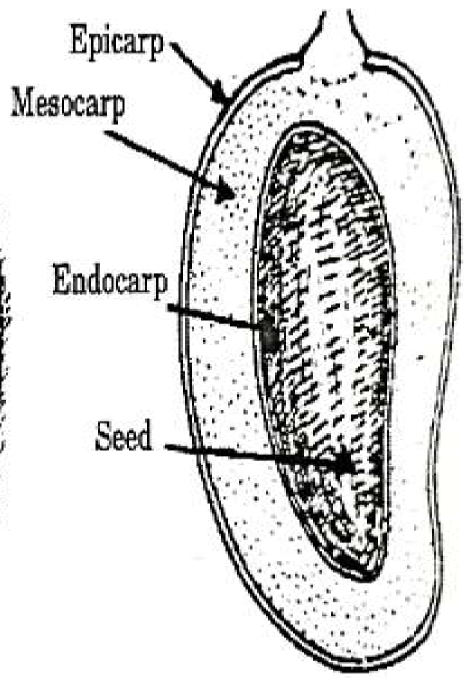
Caryopsis
(*Zea mays*)



Cremocarp
(*Coriandrum*)



Cypsela
(*Helianthus*)



Drupe
(Mango)

Figure 9.17-I: Types of fruit

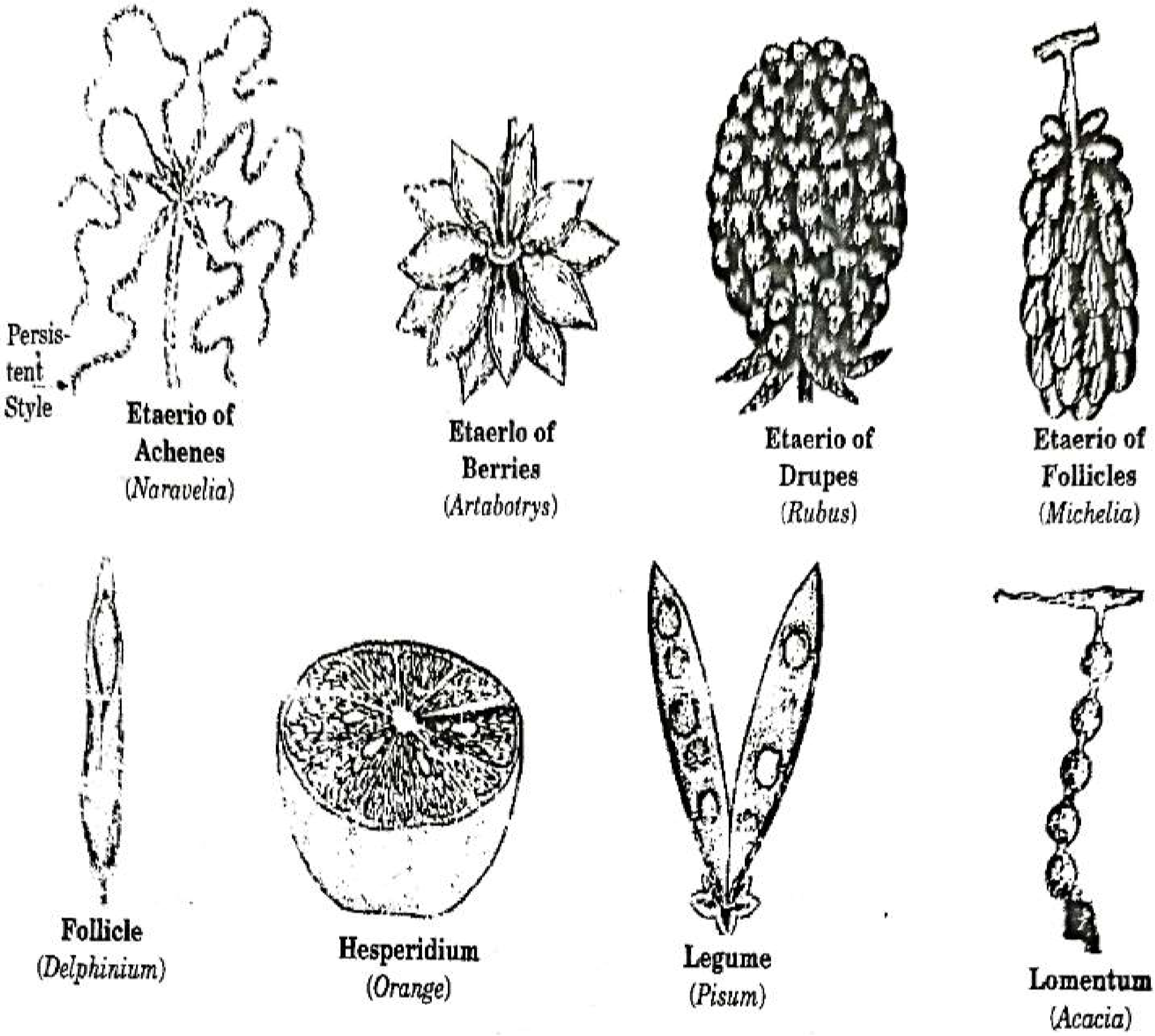


Figure 9.17-II: Types of fruit

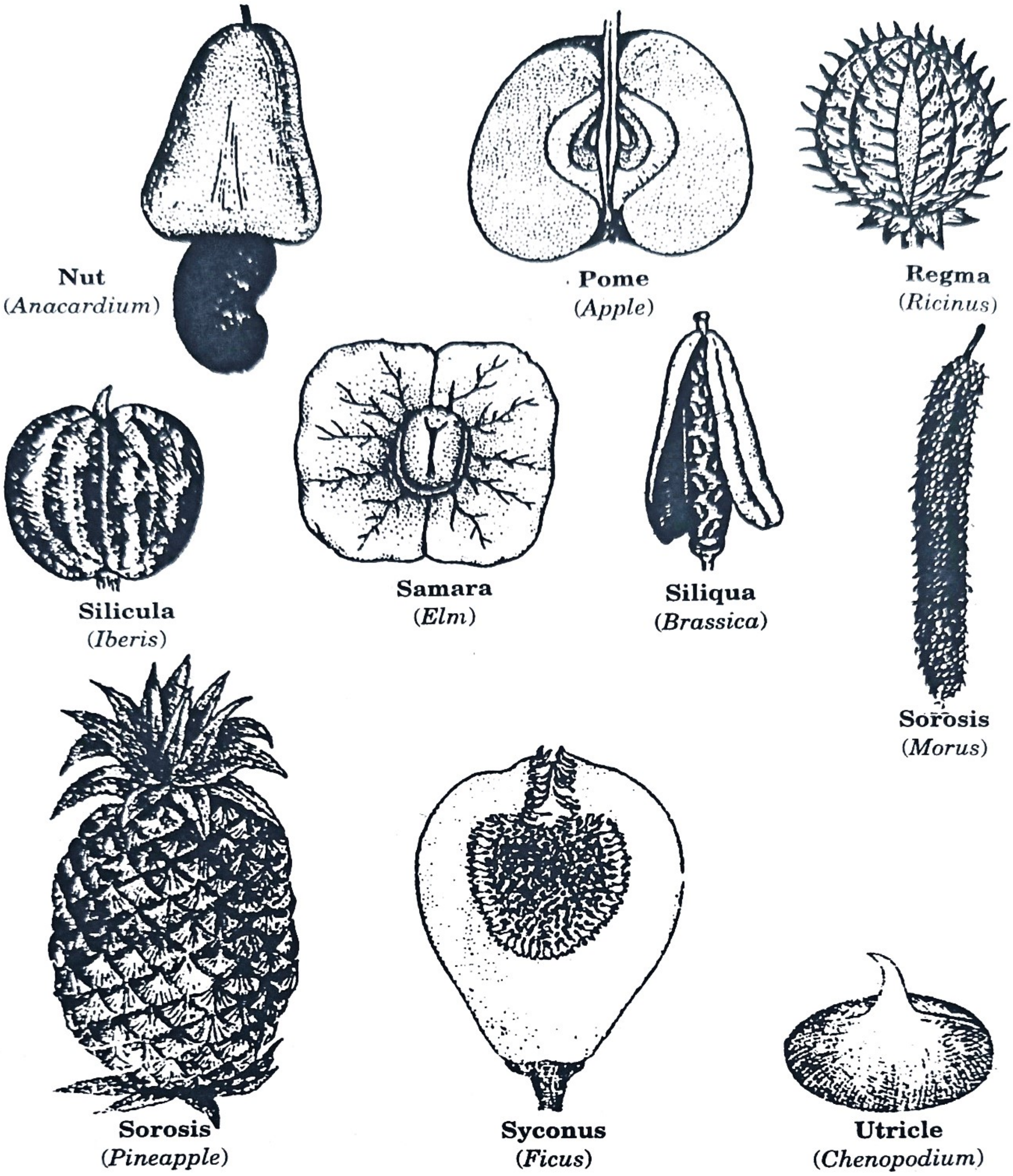
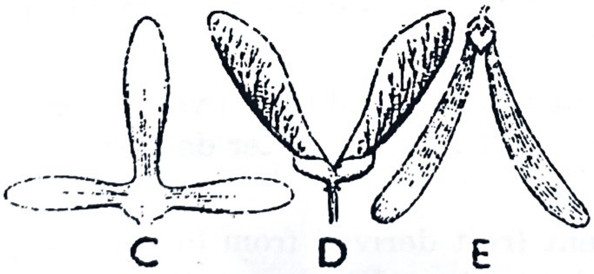


Fig. 9.40. Types of fruit (Arranged alphabetically).



C, samara; D, double samara; E, samarpod.

Figure 9.17-III: Types of fruit

Floral diagram:

The diagram, that illustrates the relative position and number of parts in each of the sets of organ comprising a flower, is called floral diagram. It is an ideal ground plan of a flower which represents all floral parts in a project manner.

The floral diagram visually depicts the essential features of a flower in cross section. The parts of the flower are drawn by semi-diagrammatic symbols or ideographs. The number of the whorls and floral parts are both illustrated in floral diagram. This also illustrates the fusion of the floral parts as well as the flower symmetry.

Floral Formula:

It is a simple device to describe morphological features of various floral pans with the help of certain standard symbols. These symbols, when combined, constitute the so called floral formula for a particular flower. The main symbols are as follows:

[I]	**Bracts (Br)**			
	Br	Bracteate	Ebr	Ebracteate
[II]	**Bracteoles (Brl)**			
	Brl	Bracteolate	Ebrl	Ebracteolate
[III]	**Symmetry of the flower**			
	⊕	Actinomorphic	⦶ or †	Zygomorphic
[IV]	**Sex**			
	♂	Staminate (male)	♀	Pistillate (female)
	⚥	Hermaphrodite (Bisexual)		
[V]	**Calyx (K)**			
	K_4	4 sepals, polysepalous	$K_{(4)}$	4 sepals, gamosepalous
	K_{2+2}	4 sepals in 2 whorls of 2 each		
[VI]	**Corolla (C)**			
	C_4	4 petals, polypetalous	$C_{(4)}$	4 petals, gamopetalous
	C_{2+2}	4 petals in 2 whorls of, 2 each		
[VII]	**Perianth (P)**			
	P_6	6 tepals, polytepalous/polyphyllous		
	P_{3+3}	6 tepals, in 2 whorls of 3 each		
	$P_{(3)+(3)}$	6 tepals, gamotepalous/gamophyllous		
[VIII]	**Androecium (A)**			
	A_6	6 stamens, polyandrous		
	A_{2+4}	6 stamens in 2 whorls of 2 and 4 each, Tetradynamous		
	A_0	stamens absent	A_α	stamens indefinite
	$A_{(\alpha)}$	monadelphous	$A_{1+(9)}$	diadelphous
	$A_{(5)}$	syngenesious	$A_{(5)}$	synandrous
	$\overset{\frown}{C\ A}$	epipetalous	PA	epitepalous/Epiphyllous

SAQ.1

f. Ovary is superior in Hypogynous / Perigynous / Epigynous condition.
g. When corolla is free, this condition is known as__________________.
h. Helicoid and scorpoid condition comes under______________type of inflorescence.
i. Axile placentation refers____.
j. When stamens are fused and anthers are free, is known as_____________________.

9.3 Dicot families

The description of some important dicot families is mentioned below-

9.3.1 Asteraceae (Compositae)

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Gamopetalae

Inferae

Asterales

Asteraceae

Distribution:

This is the largest family of the flowering plants containing about 950 genera and nearly 20,000 species (Lawrence).

Habit: A large number of cultivated garden plants such as *Helianthus annus* (Sunflower), *Tagetes erecta* (Marigold), *Lactuca sativa* (Lettuce) etc., are annual herb. *Sonchus*, *Launaea*, *Ageratum* are either annual or perennial herbs. *Cotula* is an aquatic herb. Various habits are exhibited by different species of *Senecio* (*S. walker*- a climber, *S. hastate*- shrub, *S. johnstoni*- a tree, *S. articulate*-a succulent, *S. aquatic*- a marsh plant).

Vegetative characters (Figure 9.18):

Root system is normal. Roots are tuberous in *Dahlia*.

Stem tubers are produced in Helianthus tuberosus and *Crepis bulbosa*. The stem is leaf like in *Baccharis*. Stem is slender, covered by different types of trichomes. Laticiferous vessels are present in tribe Cichoreae. Oil passage are present in stems.

Radical buds of *Taraxacum*, stolons of *Achillea* and suckers of *Chrysanthemum* are helpful in vegetative propagation.

Leaves are radial or cauline, opposite or alternate,leaves succulent in *Notonia*, scaly in *Haplophyllum*, stipules absent, venation is pinnately reticulate. In *Corymbium* the leaves parallel veined.

Floral characters: Inflorescence is a capitulum or head with distinct involucral cup formed of bracts. The capitulum may be solitary (Tridax) or they may be arranged into cymes or form profusely branched paniculate cyme (Blumea). The marginal sterile (neutral) or female flowers are called ray florets, these are ligulate. The central bisexual flowers are called disc florets.

Disc florets: These are actinomorphic, hermaphrodite, tubular and epigynous, bisexual.

Calyx: Usually represented by a ring of small teeth of numerous hairs or scales, they so called pappus.

Corolla: Consists of 5 petals, gamopetalous and tubular.

Androceium: Consists of 5 stamens, epipetalous, syngenesious, anthers fused in a tube.

Gynoecium: Bicarpellary, syncarpous, inferior, unilocular, with single anatropous ovule, style is simple and stigma bifid.

Ray florets: These are zygomorphic, pistillate (female) or neuter, ligulate and epigynous. Each floret is arising in the axil of the bracteole.

Calyx: Like disc floret, pappus.

Corolla: Consists of 5 petals, gamopetalous, strap shaped (ligulate).

Gynoecium: Bicarpellary, syncarpous,ovary inferior, unilocular with single anatropous ovule.

Fruit: Cypsela, often crowned by persistent pappus.

Seeds: Non-endospermic, embryo straight with inferior radicle.

Important characteristics:

1. Annual herbaceous nature
2. Head inflorescence
3. Presence of ray and disc florets
4. Calyx reduced to pappus
5. Epigynous flowers
6. Syngenesious anthers
7. Inferior unilocular ovary with a solitary ovule on basal placentation
8. Cypsela fruit

Floral formula:

Ray floret- Br % ☿ K_{pappus} $C_{(5)}$ A_0 $G_{\overline{(2)}}$

Disc floret- Br % ☿ $K_{pappus}\ \widehat{C_{(5)}\ A_0}\ G_{\overline{(2)}}$

Common plants: *Acanthospermum hispidum* L., *Ageratum conyzoides*, *Artemisia vulgaris*, *Calandula officinalis* L., *Cosmos bipinnatus* Cav., *Chrysanthemum coronarium* L., *Cichorium intybus*, *Eclipta prostrata*, *Helianthus annus* L., *Sphaeranthus indicus*, *Tridax procumbens*, *Vernonia cinera*, *Xanthium strumarium*, *Zinnia elegans* L., *Tagetes erecta* L.

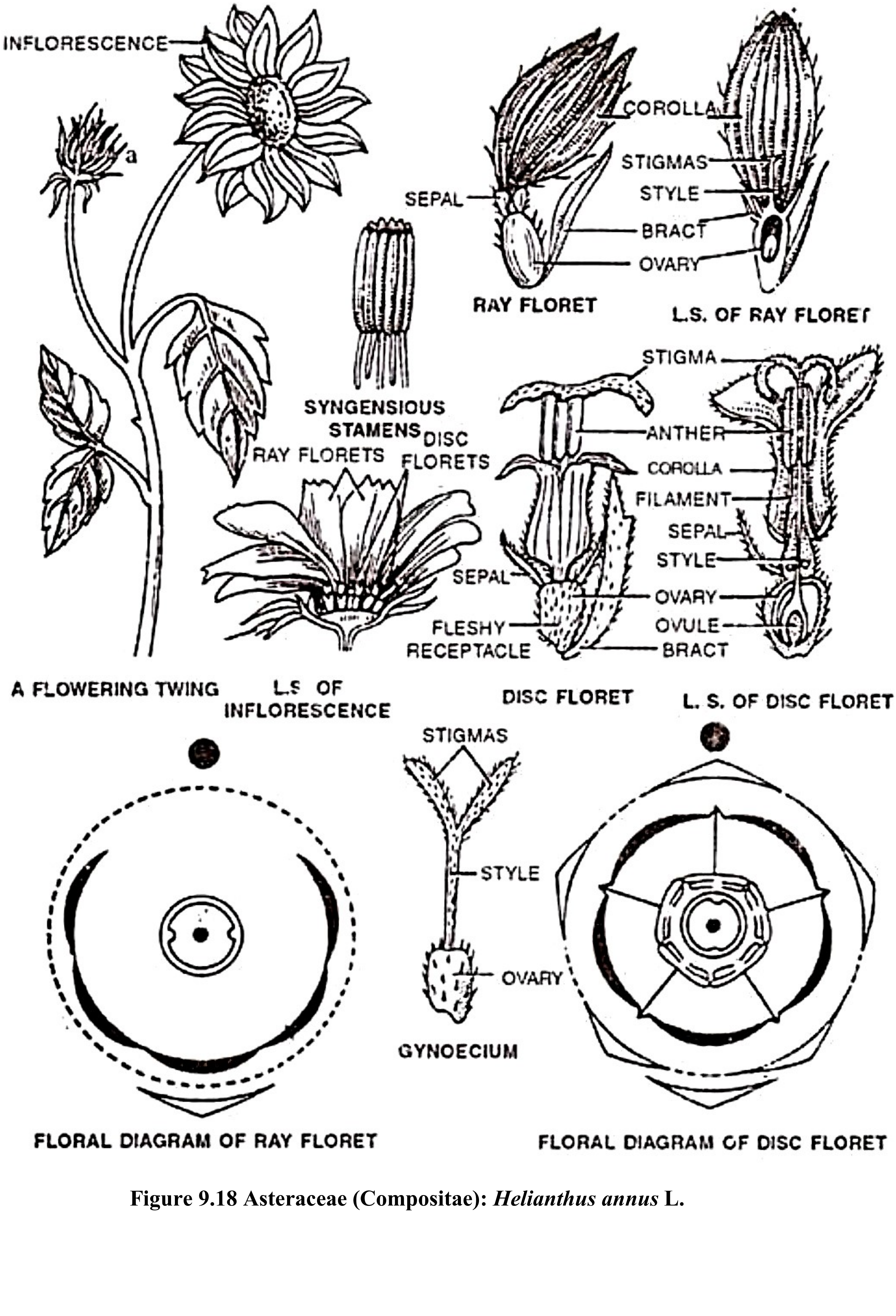


Figure 9.18 Asteraceae (Compositae): ***Helianthus annus*** **L.**

SAQ.2

a. The old name of Asteraceae family is____________________.

b. _________________inflorescence found in Asteraceae.

c. In Asteraceae family, ______________placentation is present.

d. Calyx is reduced to_________________.

e. _____________anthers are present in Asteraceae.

9.3.2 Ranunculaceae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Polypetalae

Thalamiflorae

Ranales

Ranunculaceae

Distribution:

This is a small family containing about 35 genera and 1500 species (Lawrence), mostly found in North temperate regions. In India, the members are found on the Himalayas.

Habit: Annual or perennial herbs; perennials perennate by means of rhizome (*Helleborus, Cimicifuga*) or by means of tuberous roots (*Aconitum*). *Clematis* is a climbing undershrub. *Naravelia* is a climbing shrub. *Ranunculus aquatilis* is aquatic.

Vegetative characters (Figure 9.19): In aquatic and marshy forms the tap root soon perishes and it is replaced by adventitious roots.

Leaves are altermate (opposite in *Clematis*), exstipulate; radical leaves found in *Anemone* and *Callianthemum*. In *Thalictrum* leaf base is elongated into a pair of lateral stipular lobes. *Ranunculus aquatilis* shows heterophylly. In *Delphinium* leaves are palmately lobed and finely dissected.

Floral characters: Inflorescence is a raceme in *Aconitum, Delphinium, Thalictrum*.

Flowers are bisexual (unisexual in *Thalictrum*), actinomorphic (zygomorphic in *Aconitum*, *Delphinium*), hypogynous, typically spiral or spirocyclic.

Perianth is represented by petaloid calyx in *Caltha*, *Clematis*. True corolla is formed only in *Anemone* and *Clematis*. Petals are horn-like and function as nectaries (honey leaves) and honey leaves pass into stamens gradually. In *Helleborus* tubular honey leaves are present. In *Actaeo, Cimicifuga* petal-like honey leaves are present.

Androecium consists of numerous stamens; stamens free and arranged in whorls or spirally on the torus; in *Aquilegi*a there are 50 stamens arranged in radial rows; in *Nigella* 32 stamens in 8 rows.

Gynoecium is 3 to many carpellary, usually apocarpous (syncarpous in *Nigella*); Carpels are arranged spirally on the torus; ovary is unilocular with one (*Clematis*) to many (*Caltha*) ovules on marginal or basal placentas; ovules are anatropous.

Fruit aggregate of follicles, achenes or rarely berry-like.

Seeds with copious oily endosperm; embryo small.

Important characteristics:

1. Herbaceous nature,
2. Alternate radical or cauline leaves with palmately reticulate venation.
3. Hemicyclic flowers with numerous essential organs on elongated torus.
4. Honey petals.
5. Numerous stamens with extrorse anthers.
6. Apocarpous pistil.
7. Fruit a follicle achene or berry.
8. Endospermic seed; embryo minute and oily endosperm.

Floral formula: Br Brl ⊕ ☿ K_5 C_5 A_∞ $G_{\underline{\infty}}$

Common Plants: *Ranunculus sceleratus* L.; *Clematis gouriana* Roxb; *Naravelia zeylanica* DC.; *Nigella sativa* L.; *Thalictrum javanicum* Bl.

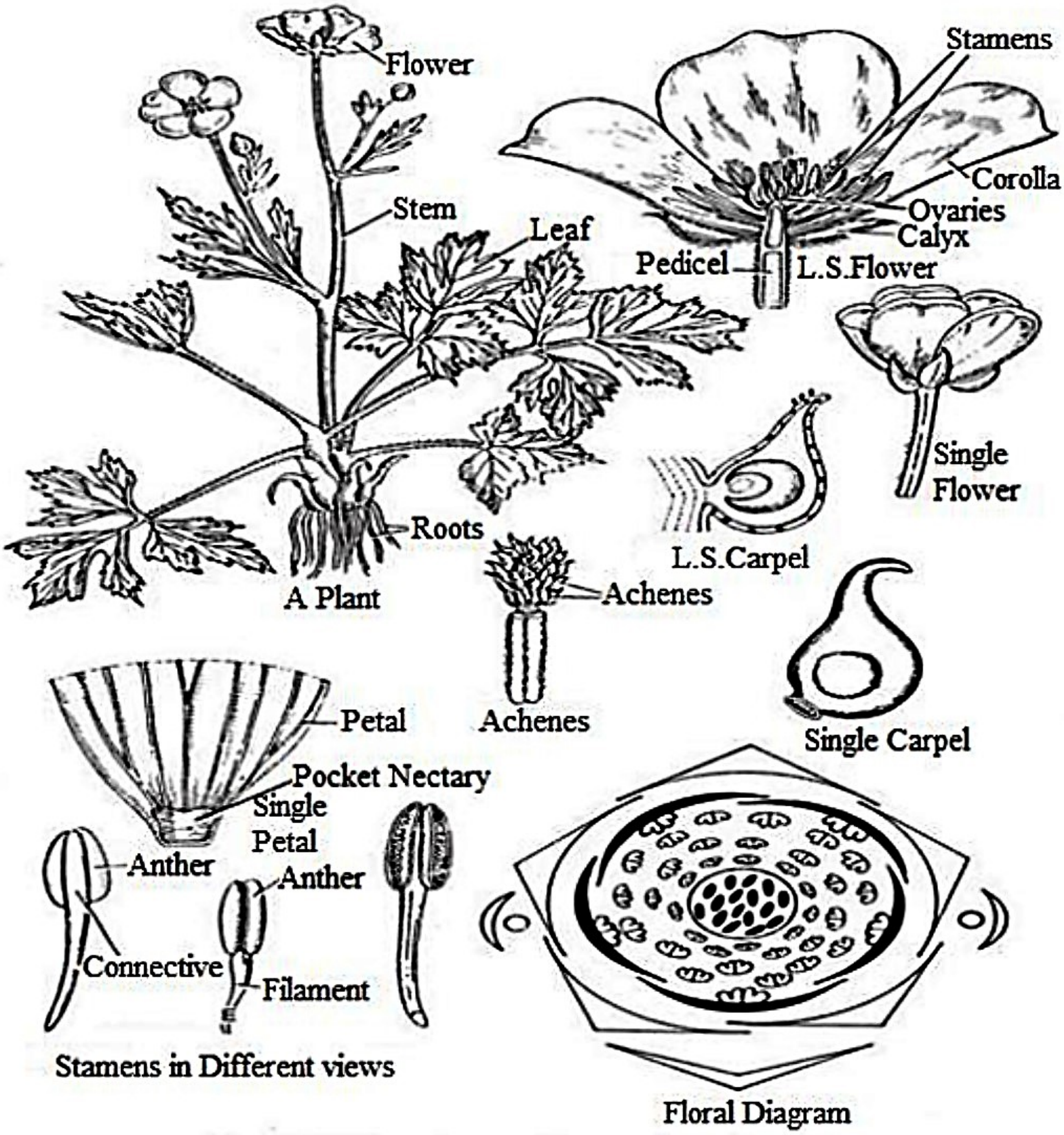


Figure 9.19 Ranunculaceae: *Ranunculus sceleratus* L.

SAQ.3

1. Apocarpous condition is found in family____________________.
2. _________________inflorescence found in Ranunculaceae.
3. In Ranunculaceae family, ______________fruit is present.
4. The number of anther are _________________in Ranunculaceae family.
5. The floral formula of Ranunculus is_______________.

9.3.3 Cruciferae (Brassicaceae)

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Polypetalae

Thalamiflorae

Parietales

Brassicaceae

Distribution:

This is a fairly large family containing 350 genera and about 2500 species (Lawrence) which are world-wide in distribution but the major centres of distribution are North temperate regions especially the Mediterranean region.

Habit: Mostly mesophytic, annual or biennial herbs or rarely shrubs. *Subularia aquatica* is a hydrophyte. *Cheiranthus* is perennial.

Vegetative characters (Figure 9.20): Root normal tap root. In turnip and radish, the tap root is a storage organ.

Stem is soft, slender covered by hairs; in knol-kohl, the aerial stem is swollen; in *Brassica oleracea* form capitata (cabbāge) stem is thickened to form a corn like structure.

Leaves are cauline in annuals, but radical in biennials (turnip, radish), alternate exstipulate, lyrate covered by simple or branched hairs.

Inflorescence typically racemose and corymbose towards the apex.

Floral characters: Flowers are ebracteate, complete, bisexual, actinomorphic, hypogynous and perigynous (in *Lepidium*), zygomorphic (in *Iberis* and *Teesdalia*).

Calyx: Sepalš 4, polysepalous, imbricate, öuter ones anterioposterior.

Corolla: Cruciform (in the form of Greek cross), clawed, aestivation valvate. absent in *Lepidium*, *Nasturtium* and *Rorippa*.

Androecium: Stamens 6, (2+4) free arranged in two whorls, outer two shorter, inner stamens longer (tetradynamous). In *Senebiera* stamens are 2 only; stamens 16 in *Megacarpaea*. Anthers bithecous, basifixed or dorsifixed, dehiscence longitudinal, extrorse or introrse.

Gynoecium bicarpcllary, syncarpous, ovary superior, unilocular, becomes bilocular due to appearance of false septum (replum), parietal placentation; style short, stigma simple or bifid.

Fruit a siliqua or silicula.

Seeds numerous, round, non-endospermic with large embryo; cotyledons oily; testa is mucilaginous.

Floral formula: Ebr ⊕ ☿ K_{2+2} C_4 A_{2+4} $G_{\underline{(2)}}$

Important characteristics:

1. Simple, exstipulate, lyrate leaves.
2. Corymb inflorescence
3. Ebracteate, dimerous or tetramerous flowers.
4. Cruciform and clawed Petals.
5. Tetradynamous stamens.
6. Transversely placed carpels.
7. Parietal placentation of ovules.
8. Commissural stigma.
9. Sliqua or silicula fruit.

Common plants: *Brassica juncea* (L.) Czer and Cass.; *B. campestris* var. *dichotomna* Watt; *B. campestris* var. *toria* Duth.; *B. nira* Koch.; *Raphanus sativus* L.; *Eruca sativa* Lamk; *Iberis amara* L.; *Rorippa indica* (L. Hochr. (syn. *Nasturtiun indicum* (L.) DC.

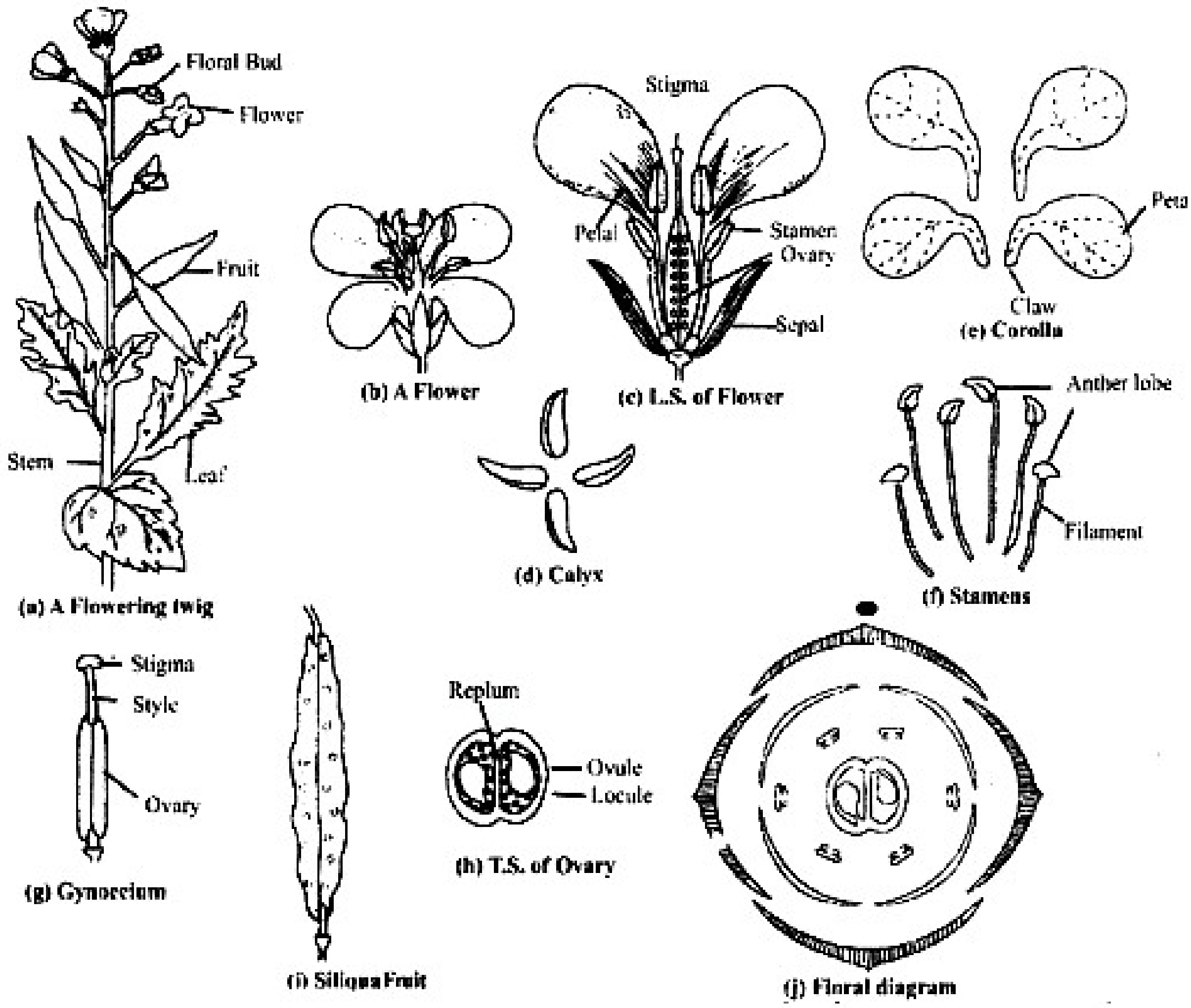


Figure 9.20 Brassicaceae (Cruciferae): *Brassica campestris* L.

SAQ.4

a. ________________inflorescence present in Brassicaceae.

b. The old name of Brassicaceae family is____________________.

c. The_______________fruit is present in Brassicaceae family.

d. ______________stamens are found in Brassicaceae family.

e. The Placentation of Brassicaceae family is___________________.

9.3.4 Solanaceae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Gamopetalae

Bicarpellatae

Polemoniales

Solanaceae

Distribution:

Family Solanaceae is fairly large, including about 85 genera and 2,000 species, of wide geographical distribution in temperate regions and very abundant in tropical countries.

Habit: Mostly annual or perennial herbs sometimes small shrub or trees. Some may be climbing shrubs (*Solanun trilabatum*). The chief anatomical character of the family is the presence of bicolleteral vascular bundles in the stem.

Vegetative characters (Figure 9.21):

Root: tap root, branched.

Stem: herbaceous, erect, branched, hairy or prickly, underground in potato forming tubers.

Leaf: Simple, exstipulate, alternate in vegetative region and opposite in the floral region.

Floral characters:

Inflorescence is usually terminal, sometimes axillary or extra- axillary. It is usually of the cymose type, tending to monochasial condition in the ultimate branches. In *Nicotiana*, it is a panicle.

Flowcrs are bisexual, hypogynous, pentamerous with a reduction to two members in the innermost whorl. In *Nicandra*, flowers are pentamerous throughout. The flowers are almost regular but for the oblique position of the ovary. Hence, they are described as obliquely zygomorphic. Flower is extremely zygomorphic in *Schizanthus* which has an irregular bilobed corolla.

Corolla: is rotate, infundibuliform (*Datura*), or campanulate (*Atropa*). It is usually regular but strongly two lipped in *Schizanthus*. Petals are 5, united, twisted.

Androecium consists of 5 free stamens which are epipetalous and alternating with the lobes of the corolla. In *Schizanthus* only 2 are fertile, others being reduced to staminodes. The filaments bear large dithecous anthers which usually liberate pollen by apical pores (porous dehiscence) as in species of *Solanum*. However, dehiscence may be longiudinal as in *Datura*.

Gynoecium is bicarpellary (pentacarpellary in *Nicandra*) syncarpous. Ovary is superior with a terminal style that ends in a capitate stigma. The anatropous, (rarely amphitropous) ovules are arranged on swollen, axile placentas of the bilocular ovary that may be rendered tetralocular by the formation of a false septum as in *Datura*. Due to the imperfect development of the cross wall in *Capsicum*, the ovary is unilocular in the upper part.

The arrangement of the carpels is peculiar. The posterior carpel is tilted towards the right and the anterior one is tilted to the other end and so the septum occupies an oblique position, whereas in the normal condition, it occupies the horizontal position. So it is often described as an obliquely zygomorphic flower.

Fruit is either a berry (tomato) or a capsule (*Datura*); sepals may be inflated and remain with the fruit helping in dispersal (*Physalis, Solanum*). In *Datura*, the fruit is a septifragal Capsule dehiscing into four parts.

Seeds are flattened, endospermic, with a curved embryo. Embryo is straight in *Nicotiana*.

Important characteristics:

1. Simple, exstipulate leaves.
2. Adnation of leaves to the Stem (axis).
3. Pentamerous, hypogynous and obliquely zygomorphic flowers.
4. Epipetalous stamens.
5. Oblique twisting of the ovary.
6. Ovules on swollen, axile placentation.
7. Curved embryo.

Floral formula: $\oplus$ ☿ $K_{(5)}\ \overbrace{C_{(5)}\ A_5}\ G_{\underline{(2)}}$

Common plants: *Solanum torvum* Swartz; *S. surattense* Burm. (*S. xanthoçarpum* Schrad and Wendl.): *S. nigrum* L.; *S. trilobatum* L.; *Datura metel* L.; *D. stramonium*, *Withania somnifera* Dunal.; *Nicotiana tabacum* L.; *Lyconersicon esculentum* Mill.; *Cestrum nocturnum* L.; *C. diurnum* L, *Browallia alata* L.

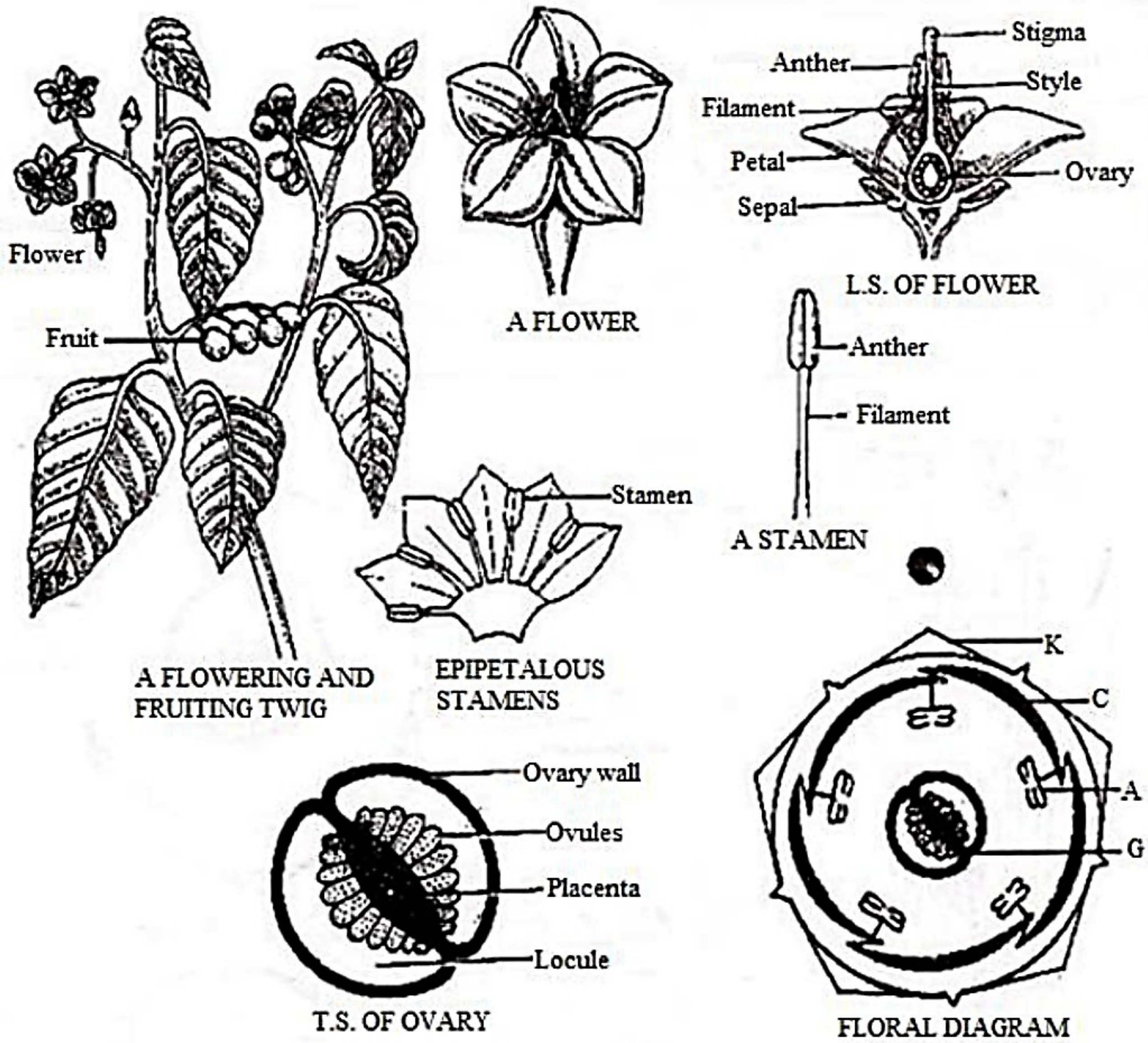


Figure 9.21 Solanaceae: *Solanum nigrum* L.

SAQ.5

a. ________________inflorescence present in Solanaceae.

b. The position of ovary is __________________in Solanaceae.

c. Epipetalous stamens are present in_________________family.

d. ______________fruit is found in Solanaceae family.

e. The______________ placentation is present in Solanaceae family.

9.3.5 Malvaceae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Polypetalae

Thalamiflorae

Malvales

Malvaceae

Distribution:

This is a small family containing 82 genera and 1500 species (Lawrence). The family is cosmopolitan, being distributed nearly throughout the word.

Habit: The plants are herbs (*Abutilon, Malva, Malvastrum*) etc., shrubs (*Sida, Hibscus*).

Vegetative characters (Figure 9.22):

Root: Tap root, branched.

Stem: Erect, herbaceous or woody, branched and pubescent, decumbent in *Malva* and *Sida*.

Leaves: Simple, large, broad, palmately veincd, petiolate, alternate, mostly stipulate, stipules caducous.

Floral characters:

Inflorescence: Solitary axillary or solitary terminal or cymose.

Flowers: Regular, pentamerous, bisexual, hypogynous, often showy and beautifully coloured, ebracteate.

Epicalyx: A whorl of 2 or more involucral bracteoles form epicalyx except in few genera such as *Sida*, *Abutilon*.

Calyx consists of 5 sepals which may be free or united at the base, aestivation is valvate

Corolla consists of 5 petals which are either free or slightly united at the base, aestivation is mostly twisted, but sometimes imbricate.

Androecium consists of numerous stamens which are monadelphous. The staminal tube is formed by the union of the filaments. The tube is divided into numerous filaments at the top (*Malva* and *Sida*). In *Hibiscus* the filaments of the stamens are given off at all levels from the staminal tube. It is considered that numerous stamens have arisen due to multiplication of the original 5 epipetalous stamens. Anthers are reniform, monothecous and dehiscence is by transverse slits at the top. This divides the anther into two halves liberating the spinous and large pollengrains.

Gynoecium is 3 to many carpellary, syncarpous. Ovary is superior, style is terminal, single or divided apically to bear as many or twice as many stigmas as the carpels. The chambers in the ovary are as many as the carpels. There are 1 to many anatropous ovules in each chamber in 1 or 2 rows on axile placenta. Ovules are horizontal or pendulous.

Pollination is mostly through the agency of insects, which come for the honey secreted in pits at the base of the petals,

Fruit is mostly a loculicidal capsule. Sometimes the mature carpels separate from each other and form the axis (*Althaea, Malva, Malvastrum, Abutilon*). In *Malvaviscus*, fruit is a berry.

Seeds may be renifom (kidney-shaped) or ovoid, and glabrous hairy or woody. The Embryo may be straight or curved surrounded by the endosperm which is often oily.

The epidermal outgrowths on the seeds of cotton help in dispersal by wind. To facilitate dispersal through the agency of animals, hooks are produced on the mericarps in *Sida* and *Urena*. The loculicidal capsules break open violently to disperse the seeds.

Floral formula: Br Brl ⊕ ☿ $K_{(5)}$ C_5 $A_{(\infty)}$ $G_{\underline{(5)}}$

Important characteristics:

1. Stellate hairs on vegetative parts.
2. Mucilage in the cortex and pith.
3. Stipulate, alternate leaves with multicostate reticulate venation.
4. Showey flowers.
5. Presence of epicalyx.
6. Monadelphous stamens.
7. Monothecous, reniform, extrorse anthers.
8. Spinous pollen.
9. Ovules on axile placentation.

Common plants: *Hibiscus rosa-sinensis* L; *H. mutabilis* L.; *Gossypium herbaceum* L. *Abelmoschus esculentus* Moçnch (Syn. *Hibiscus esculentus* L.); *Abutilon indicum* Don. *Sida cordifolia* L.; *S. rhombifolia* L.; *S. alba* L. (Syn. *S. spinosa* L.); *Malachra capitata* L; *Thespesia populnea* (L.) Soland. ex Cor.; *Urena lobata* L.

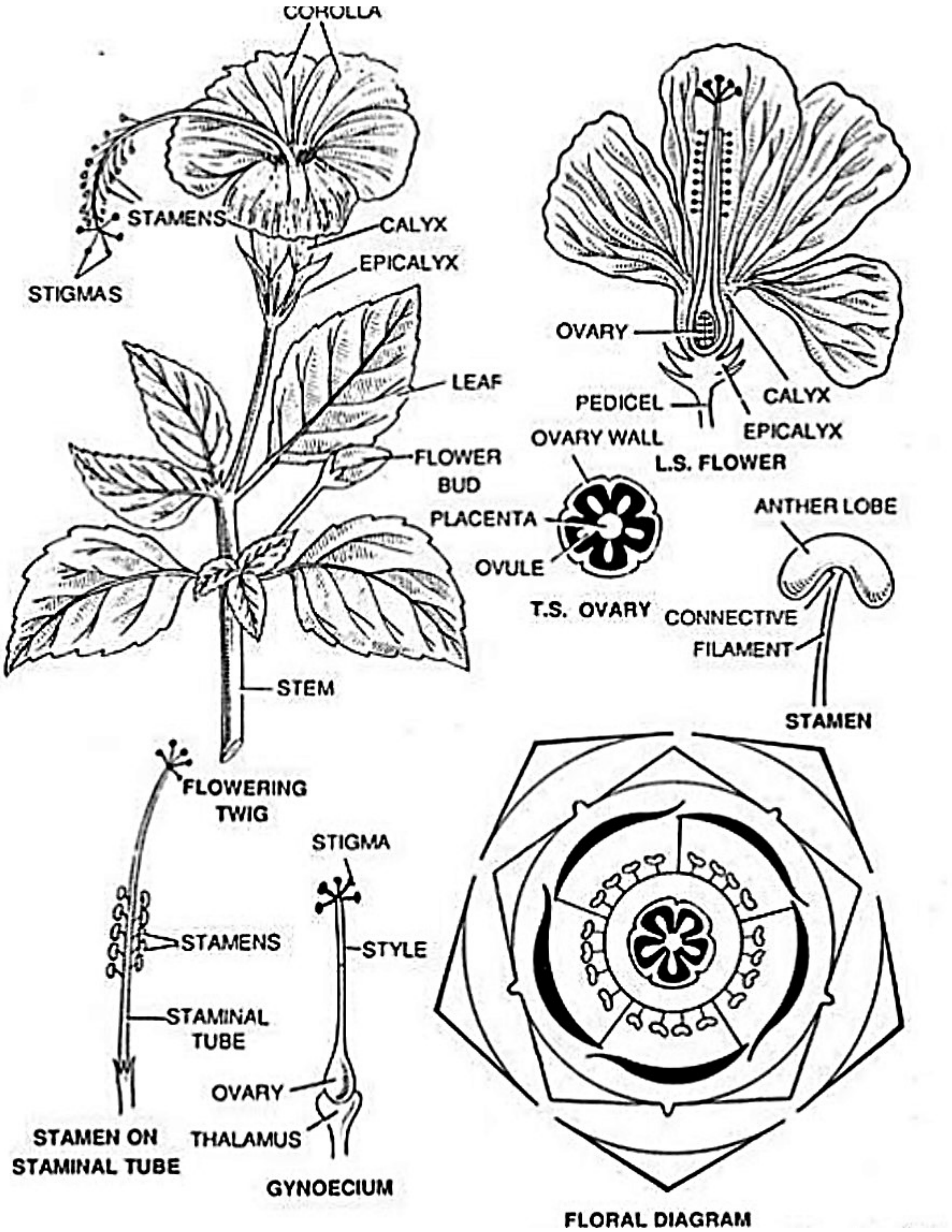


Figure 9.22 Malvaceae: *Hibiscus rosa sinensis* L.

SAQ.6

a. ________________reticulate venation is present in Malvaceae.

b. _____________stamens are found in Malvaceae.

c. Monothecous anthers are present in________________family.

d. _____________hairs are found in Malvaceae. family.

e. The______________ placentation is present in Malvaceae family.

9.3.6 Mimosaceae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Polypetalae

Calyciflorae

Rosales

Leguminosae

Mimosoideae

Habit: Mostly shubs or trees; herbs (*Mimosa*) shrubs (*Acacia*) or trees (*Enterolobium, Xylia*). *Enterolobium* is a mesophyte. *Prosopis* and *Acacia*' are xerophytes; *Neptunia* is a hydrophyte. *Entada* is tendril climber.

Vegetative characters (Figure 9.23):

Leaves alternate, stipulate, (stipules modified into spines in *Acacia arabica*; myrmecophilous spines in *A. sphaerocephala*) bipinnately compound; in *A. Melanoxylon* petiole is flattened into phyllode and leaflets are suppressed; leaves of *Mimosa pudica* and *Neptunia oleracea* exhibit movements when touched.

Floral characters:

Inflorescence is usually globose head; pedunculate, elongated spike (*Prosopis*) or condensed cymose head (*Enterolobium, Albizzia*).

Flowers bracteate, bracteolate, bisexual (polygamous in *Entada*), actinomorphic, regular, pentamerous and perigynoys; flowers of *Mimosa* are tetramerous.

Calyx consists of 4 or 5 sepals gamosepalous, clearly toothed, valvate. In *Mimosa*, calyx is minutely toothed.

Corolla: petals 5 (4 in *Mimosa*) united, valvate, tubular; in *Prosopis* petals are connate at the base,

Stamens are 10 to infinite; free (*Acacia*); in *Prosopis* stamens 10, free and slightly exserted; in *Albizzia* numerous stamens are united at the base by means of filaments; stamens 4 in *Mimosa*. Anthers dithecous, small and longitudinally dehiscent.

Gynoecium monocarpellary, ovary sessile or stalked, style filiform and stigma minute. Usually many ovules are present in the unilocular ovary on marginal placenta.

Fruit is a legume or lomentum (*Inga dulcis*).

Seed is non endospermic.

Floral formula: Br Brl ⊕ ☿ $K_{(5)}$ $C_{(5)}$ A_{∞} $G_{\underline{1}}$

Important Characteristics:

1. Plants are mostly trees.
2. Bicompound leaves.
3. Spike or globose head inflorescence.; Flowers regular, bisexual, perigynous and symmetrical.
4. Corolla lobes are sepaloid.
5. Numerous stamens with attractive coloured filaments
6. Fruit is a legume or lomentum.

Common Plants: *Mimosa pudica* L.; *Acacia auriculiformis* A. Cunn.; *Acacia suma* Buch.-Ham.; *Acacia nilotica* Del.; *Entada pursaetha* DC.; *Samanea saman* (Jacq.) Merr.; *Inga dulcis* Willd. (Syn. *Pithecellobium dulce* Benth.); *Xylia xylocarpa* Taub. (syn. X. *Dolabriformis* Benth.).

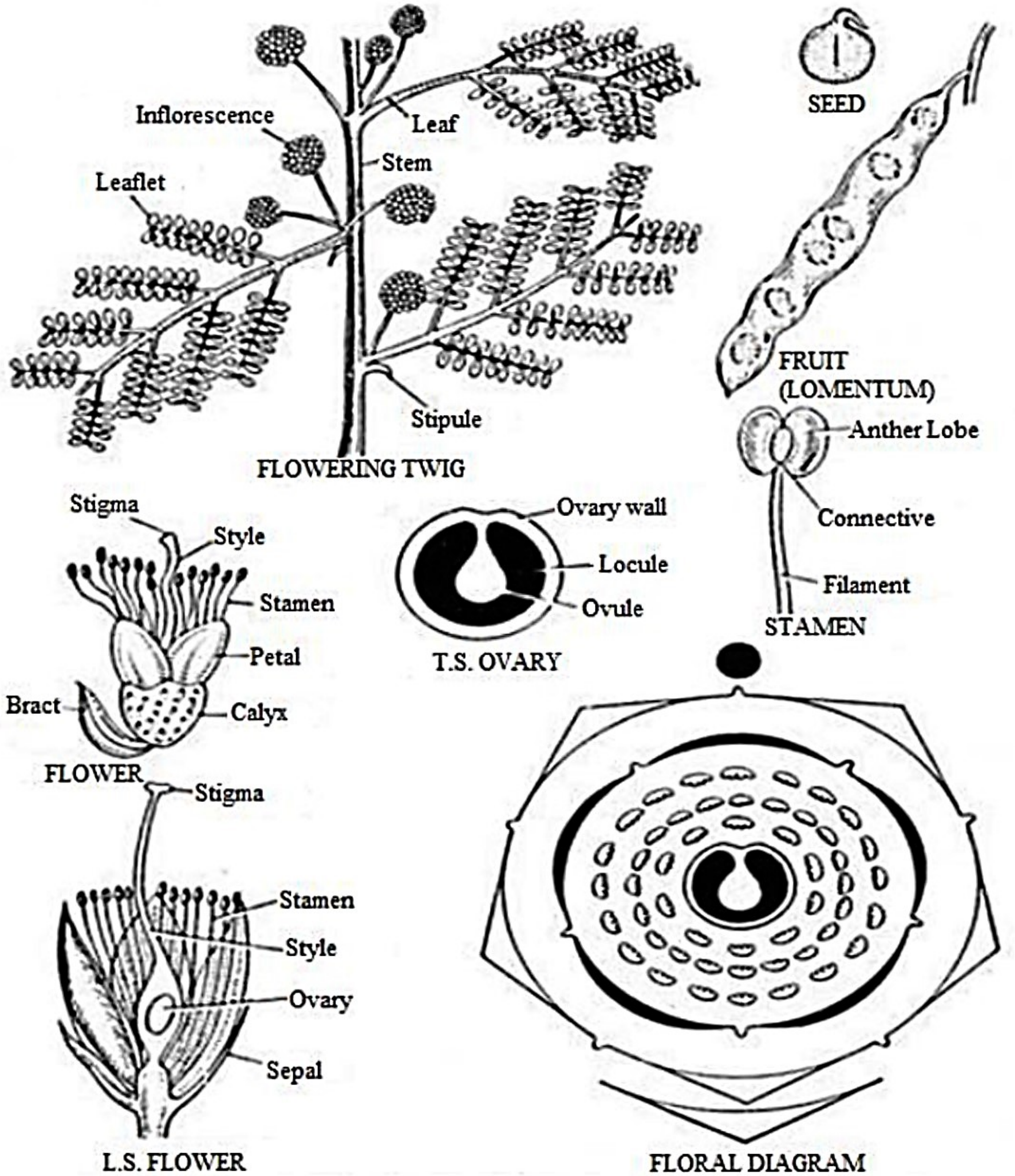


Figure 9.23 Mimosaceae: ***Acacia nilotica*** **L.**

SAQ.7

a. _______________leaves are present in Mimosaceae.

b. ____________fruit is found in Mimosaceae.

c. ____________stamens with attractive_________filaments are present in Mimosaceae.

d. ____________inflorescence is found in Mimosaceae family.

e. The_____________ placentation is present in Mimosaceae family.

9.3.7 Caesalpinoidae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Polypetalae

Calyciflorae

Leguminosae

Caesalpinoideae

Habit: Mostly shrubs or trees; mesophytes (*Parkinsonia* shows xerophytic features) *Cassia* are under shrubs (*C. occidentalis*); shrubs (*C. auriculata*) *Parkinsonia* is a shrub; trees are very common (*Tamarindus, Hardwickia*). *Caesalpinia sepiaria* is a climber. *Bauhinia vahlii* is a gigantic climber and it is a *liane*. Climbing species of *Bauhinia* may show coiled tendrils formed from the axillary buds.

Vegetative characters (Figure 9.24):

Stem is round or flattened as in climbing species of *Bauhinia* exhibiting anomalous secondary thickening.

Leaves: Large, pinnately or bipinately compound and stipulate. Stipules are either small or auriculate (*Cassia auriculata*); spiny (*Parkinsonia*), or leafy as in *Delonix*. In *Parkinsonia*, the main rachis is modified into a spine and the flattened secondary rachises or phyllodes arise on it. In *Bauhinia vahlii* conspicuous circinately coiled branched tendrils are present in the axils of the leaves which are simple; leaf base is typically swollen and pulvinate.

Floral characters

Inflorescence: A many flowered raceme, terminal corymbs (*Delonix*) or like corymbose panicles (*Saraca*).

Flowers: Flowers are big and showy forming cluster; bracteate, ebracteolate, complete bisexual, perigynous, pentamerous,

Calyx consists of 5 green sepals, united or free, may be only 4 in some (*Sarcra,. Tamarindus*). Sepals are petaloid in genera where petals are completely absent (*Saraca, Dialium*); valvate in aestivation (*Delonix*) or imbricate (*Cassia, Saraca*)

Corolla consists of 5-4 petals, free aestivation is ascending imbricate; anterior two petals are completely suppressed or represented by glands or bristles in *Amherstia* and *Tamarindus*. Petals are absent in *Saraca*.

Androecium consists of 10 stamens, diplostemonous, (haplostemonous in *Ceratonia*) usually free, but diadelphous (as in Papilionaceae) in *Amherstia*, monadelphous in *Tamarindus*. Only 3 fertile stamens are produced in *Tamarindus*. Anthers are dithecous, basifixed or versatile, dehiscing by longitudinal slits (by pores in *Cassia* sps). In some species of *Cassia* some of the posterior stamens are sterile.

Gyoecium is monocarpellary (rarely bicarpellary, apocarpous in *Saraca*), ovary is cylindrical with terminal style and capitate stigma; ovary is unilocular with numerous ovules; placentation is marginal.

Flowers are entomophilous. Flowers of *Poinciana* are visited by small birds.

Fruit is a legume, but rarely a samara as in *Pterolobium.*

Seeds non-endospermic or endospermic.

Important Characteristics:

1. Compound leaves.
2. Inflorescence is a corymb or Corymbose raceme.
3. Flower perigynous, pentamerous and slightly zygomorphic.
4. Ascendingly imbricate aestivation of petals.
5. Ten stamens in two rings.

Floral formula: Br % ☿ K_5 C_5 $A_{10 \text{ or } 7+3\text{std}}$ $G_{\underline{1}}$

Common plants:

Tamarindus indica (imli tamarind), *Parkinsonia aculeata* (vilayati kikar), *Acrocarpus*, *Cassia fistula* (amalas), *Cassia occidentalis* (kasunda), *Cassia tora*, *Bauhinia purpurea*, *Haematoxylon campechianum*, *Cassia occidentalis*, *Poinciana regia* (gulmohar), *Caesalpinia pulcherrima* (peacock flower), *Bauhinia variegata* (kachnar), *B. purpurea*, *B. galpini*, *Cassia fistula* (amaltas), *Saraca indica* (ashok).

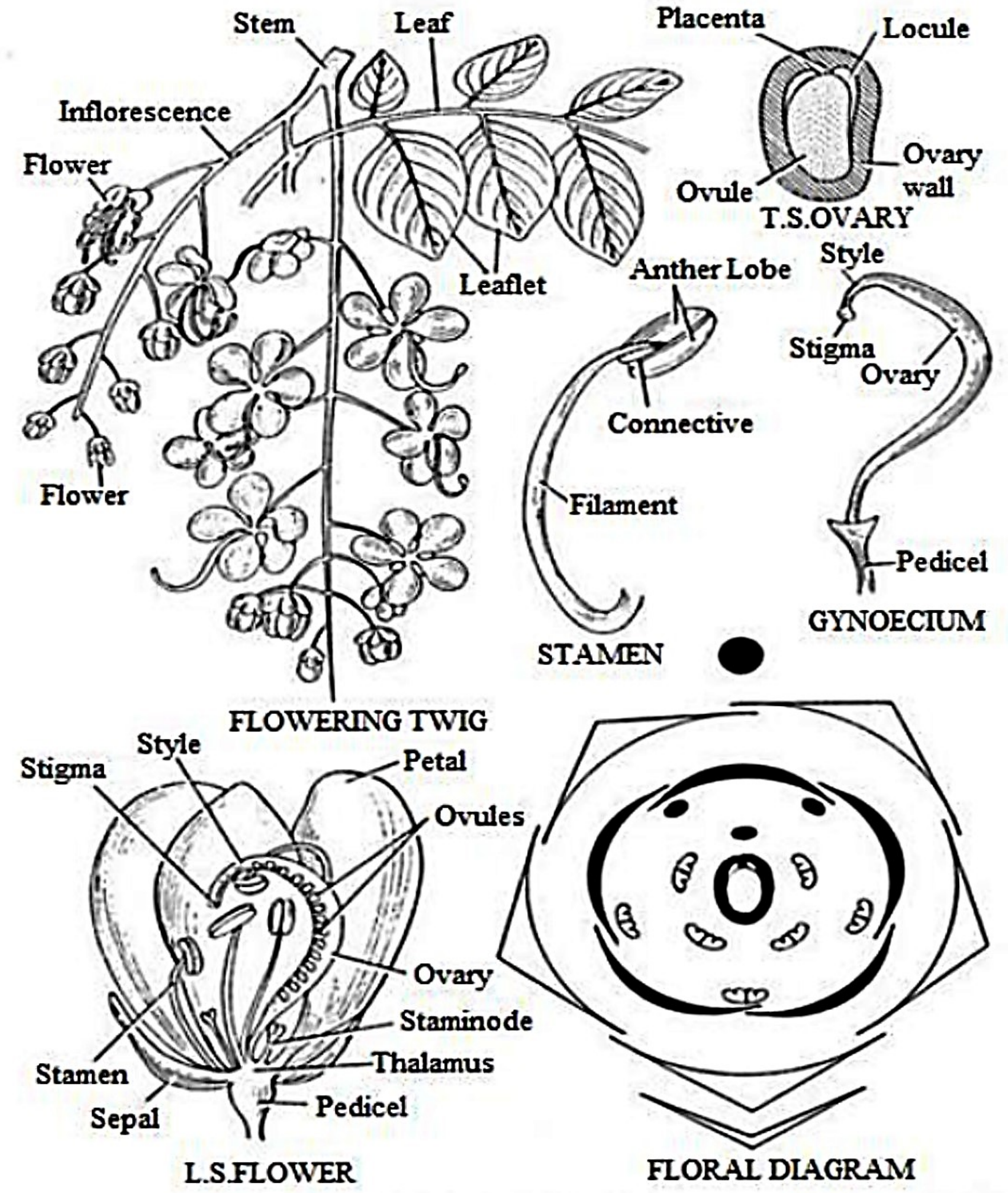


Figure 9.24 Caesalpinoidae: *Cassia fistula* L.

SAQ.8

a. _______________stamens in two ring is present in Caesalpinoidae.

b. ____________aestivation is found in Caesalpinoidae.

c. Flower condition in Caesalpinoidae is_________________.

d. ____________inflorescence is found in Caesalpinoidae family.

e. The_____________ placentation is present in Caesalpinoidae family.

9.3.8 Papilionaceae (Fabaceae)

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Dicotyledons

Polypetalae

Calyciflorae

Rosales

Leguminosae

Papilionaceae

Habit: Mostly herbs, a few trees; mesophytes. *Ulex* show xerophytic adaptations. *Aeschynomene aspera* is a perennial shrub growing near the margins of ponds. Some of the plants are annual herbs (*Tephrosia*) or shrubs (*Sesbania*). *Dolichos* and *Clitoria* are climbers. *Lathyrus* and *Pisum* are tendril climbers. *Abrus* is a climbing shrub. *Pterocarpus, Pongamia* are trees. *Rhynchosia* is a liana.

Vegetative characters (Figure 9.25):

Roots are normal tap root type and show root nodules Containing Rhizobium bacteria which fix atmospheric nitrogen (symbiosis).

Leaves are simple or compound imparipinnate, alternate, stipulate, stipules leaf like (foliaceous) in *Pisum* and *Lathyrus*; leaf-base is swollen (pulvinate). Leaves of *Desmodium* Show turgor movements. Leaves are spinous in *Ulex*. The entire leaf in *Lathyrus*, and terminal1 Leaflets of *Pisum sativum* are modified into tendrils.

Inflorescence usually of racemose type (*Melilotus, Cajanus, Trigonella*). In *Crotalaria*, the lowers are arranged in terminal or leaf opposed racemes; in *Cajanus* flowers are arranged in corymbose racemes or from a terminal panicle; in *Cicer* flowers are solitary axillary; in *Dalbergia* a terminal or lateral panicle; in *Neptunia*, an aquatic herb, flowers are arranged in dense heads.

Flowers are bisexual, strongly zygomorphic, perigynous, pentamerous

Calyx consists of 5 sepals, gamosepalous, iregular, aestivation is valvate. Calyx 2-lipped in *Aeschynomene*.

Corolla consists of 5 petals, free, irregular; aestivation descendingly imbricate (vexillaryy It is papilionaceous i.e. there is an erect, posterior petal, standard, overlapping along the edges of 2 lateral petals, wings and these in turn overlap the 2 lower ones along lower margin to form the keel.; odd petal largest, posterior and outermost.

Androecium consists of 10 stamens which are diadelphous having 9 stamens united into a bundle, with the 10^{th} one in a free condition (*Tephrosia, Dolichos*); stamens are opposite to the standard petal. In *Crotalaria*, all the 10 stamens are united into a single bundle (monadelphous), all the 10 stamens free (*Sophoa*). Sometimes stamens are only (9) in *Dalbergia*; filaments become free towards the apex of the tube and bear dithecous anthers.

Gynoecium consists of single carpel that has a short stalk, flattened ovary, terminal style that ends in capitate stigma. Ovary is unilocular. Several anatropous or amphitropous ovules are arranged alternately on marginal placenta. In *Arachis*, ovules are 24.

Pollination: The flowers show interesting floral construction and efficient pollination mechanisms. The flowers are horizontally disposed on the axis and each flower has an erect brightly coloured standard petal. Nectar is stored round the base of the ovary and it is protected by the thalamus. Wing petals which are horizontally arranged form the landing place for the insect visitor. The claws of the keel petals and claws of the wing petals are firmly morticled due to the inter-locking of the hairs on the opposite faces. So, the weight of the insect on the wings is brought to bear on the keel also. Consequently, the essential organs which are safely covered and protected by the keel are exposed and the stigma first touches The lower part of the insect's body and the pollen is shed later. When the insect leaves the flower, due to absence of pressure, the keel and wings resume their positions. This is therefore Called the piston mechanism; e.g., *Mellotus, Trifolium, Crotalaria*.

Fruit is a small legume which is straight or twisted (bean, *Abrus*). In *Desmodium* it is a lomentum. Seed non-endospermic.

Important Characteristics:

1. Tap root with nodules.
2. Pinnately compound leaves with pulvinus leaf base.
3. Racemose inflorescence.
4. Pentamerous, perigynous and strongly zygomorphic flower.
5. Papilionaceous corolla, descendingly imbricate aestivation.
6. 10 stamens, mono or diadelphous.
7. Monocarpellary, superior ovary, with ovules on marginal placentation.
8. Fruit is a legume.

Floral formula: Br % ☿ $K_{(5)}$ $C_{1+2+(2)}$ $A_{1+(9)}$ $G_{\underline{1}}$

Common Plants: *Butea monosperma* (Lam.) Taub.; *Desmodium gyrans* in *Pongamia pinnata* (L.) Pierre; *Tephrosia purpurea* Pers; *Aeschynomune aspera, Dalbergia sissoo* Roxb; *Indigofera tinctoria* L; *Abrus precatorius* L.; *Clitorea ternata* L, *Crotalaria pallida* Aiton (syn. *C. striata* DC).

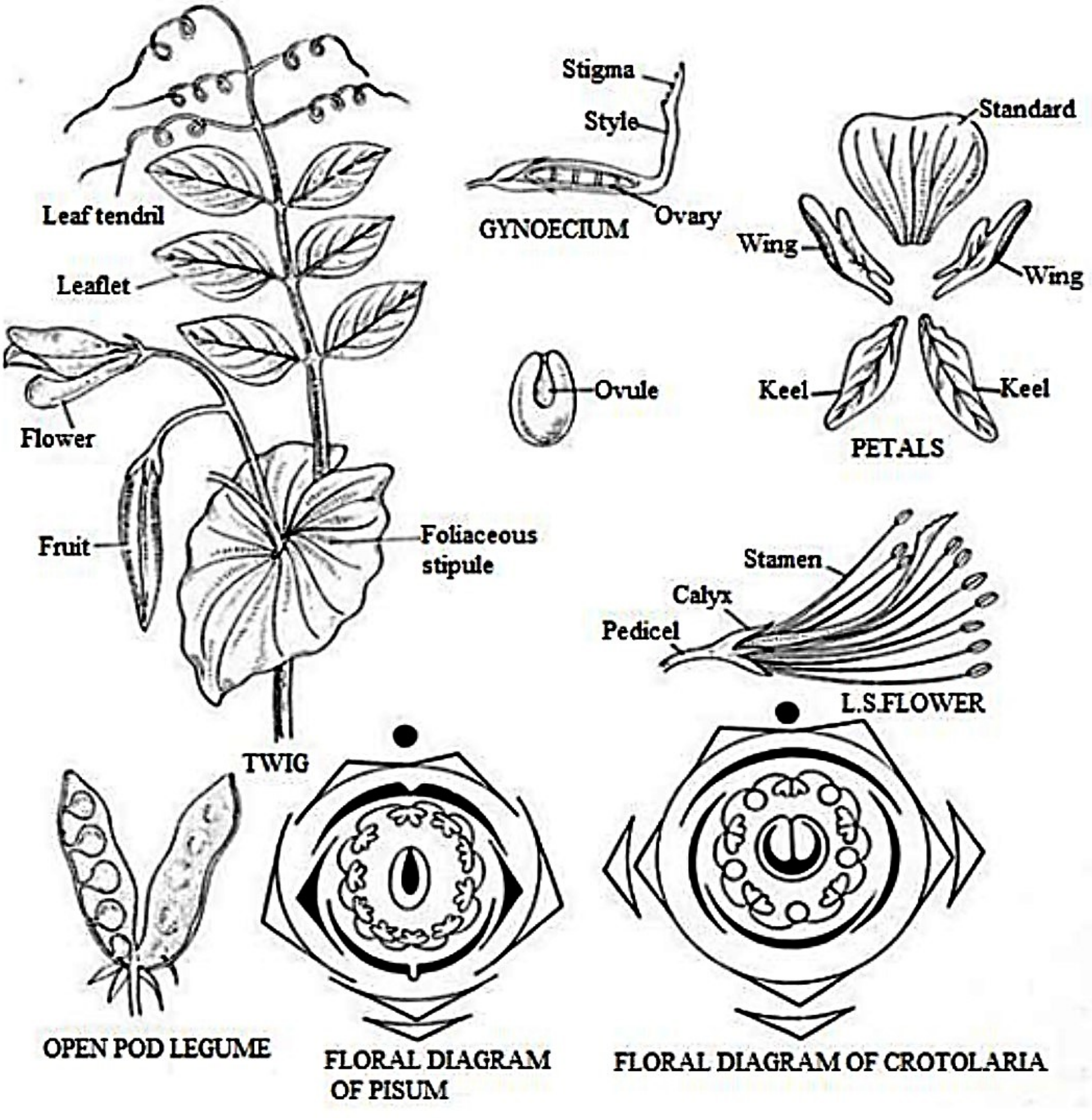


Figure 9.25 Papilionaceae (Leguminosae): *Pisum sativum* L.

SAQ.9

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a. ________________compound leaves are present in Papilionaceae.

b. _____________aestivation is found in Papilionaceae.

c. Diadelphous condition is found in family____________________.

d. The_____________placentation is found in Papilionaceae family.

e. Flower condition is Actinomorphic/ Zygomorphic in Papilionaceae family.

9.4 Monocot families

The description of some important dicot families is mentioned below-

9.4.1 Liliaceae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Monocotyledons

Coronarieae

Liliaceae

Distribution:

This is a large family contain 250 genera and 3, 760 species (Willis). The plants are cosmopolitan being distributed almost throughout the world.

Habit (Figure 9.26): Mostly herbs with fibrous roots persisting from season to season by means of sympodial rhizomes (*Polygonatum*), bulbs (tulip, lily), bulbils from leaf axils (*Lilium bulbiferum*), corm (*Colchicum*). Species of *Aloes, Yucca, Dracaena* may be either shrubs or trees with perennial aerial stems. Several plants are xerophytic (*Aloe, Gastera*), possessing succulent leaves having water storage tissues which arc well protected by a thick cuticle. In *Dasylirion*, stem is tuberous with narrow hard leaves. In *Bowiea* a large underground corm gives off, from year to year, a branched climbing stem having small leaves which soon drop off and the green stem performs photosynthesis. Species of *Smilax, Asparagus, Gloriosa* arc climbing plants. Species of *Asparagus*, *Ruscus* exhibit phylloclades. The stems are underground bulbs or rhizomes.

Leaves: Radical or cauline, alternate, (opposite in *Scolyopus*), fleshy (*Aloe, Yucca, Dracaena*) or reduced to scales (*Ruscus, Asparagus*); venation parallel (net-veined in *Smilax, Trillium*).

Inflorescence is terminal or axillary scape; solitary (*Tulipa, Fritillaria*). Panicled raceme (*Asphodelus*), cymose umbel (*Allium, Smilax*) and solitary axillary (*Gloriosa*).

Flower: Pedicellate, actinomorphic or zygomorphic (*Lilium*), bisexual (unisexual in *Smilax*, *Ruscus*), hypogynous, complete or in complete (in unisexual flowers.) trimerous rarely 2 or 4-merous (*Maianthemum, Paris*).

Perianth: 6 in two whorls of 3 each, polyphyllous (*Lilium, Tulipa*) or gamophyllous (*Aloe*, *Asparagus*), petaloid.

Androecium: Stamens 6, epiphyllous (attached to perianth segments) and arranged in two whorls of 3 each (*Allium, Yucca*). In *Ruscus* only 3 stamens of outer whorl are present and filaments are united to form a staminal column. In *Paris quadrifolia* there are 8 stamens in two whorls and in *Maianthemum bifolium* only 4 stamens are present. Anthers are dithecous, dehiscing by longitudinal slits.

Gynoecium: Superior, tricarpellary and syncarpous; ovary is lobed, trilocular with one or more ovules in each locules on axile placentae; style is entire or divided into 3 branches ending in separate stigmas.

Fruit a loculicidal capsule (*Asphodelus*) or a berry (*Dracaena, Asparagus, Smilax*).

Seed is endospermic; embryo is straight. Polyembryony is seen in some members. Additional embryos are produced by nucellar budding in *Northoscordum* while in *Allium* they are from antipodals.

Pollination: Entomophilous; in *Yucca, Gloriosa* takes place through the agency of a moth *Pronuba yuccasella*. Flowers are protandrous in *Allium* and protogynous in *Colchicum*.

Important characteristics:

1. Mostly herbs, perennating by rhizomes, bulbs etc.,
2. Regular, hypogynous, trimerous flowers
3. Perianth lobes are mostly petaloid.
4. Six stamens in two whorls
5. Tricarpellary, syncarpous, superior ovary.

Floral formula: Br or Ebr $\oplus$ ☿ $\overparen{P_{(3+3)}\,A}_{3+3}$ $G_{\underline{(3)}}$

Common plants: *Allium, Aloe, Ruscus, Tulipa*

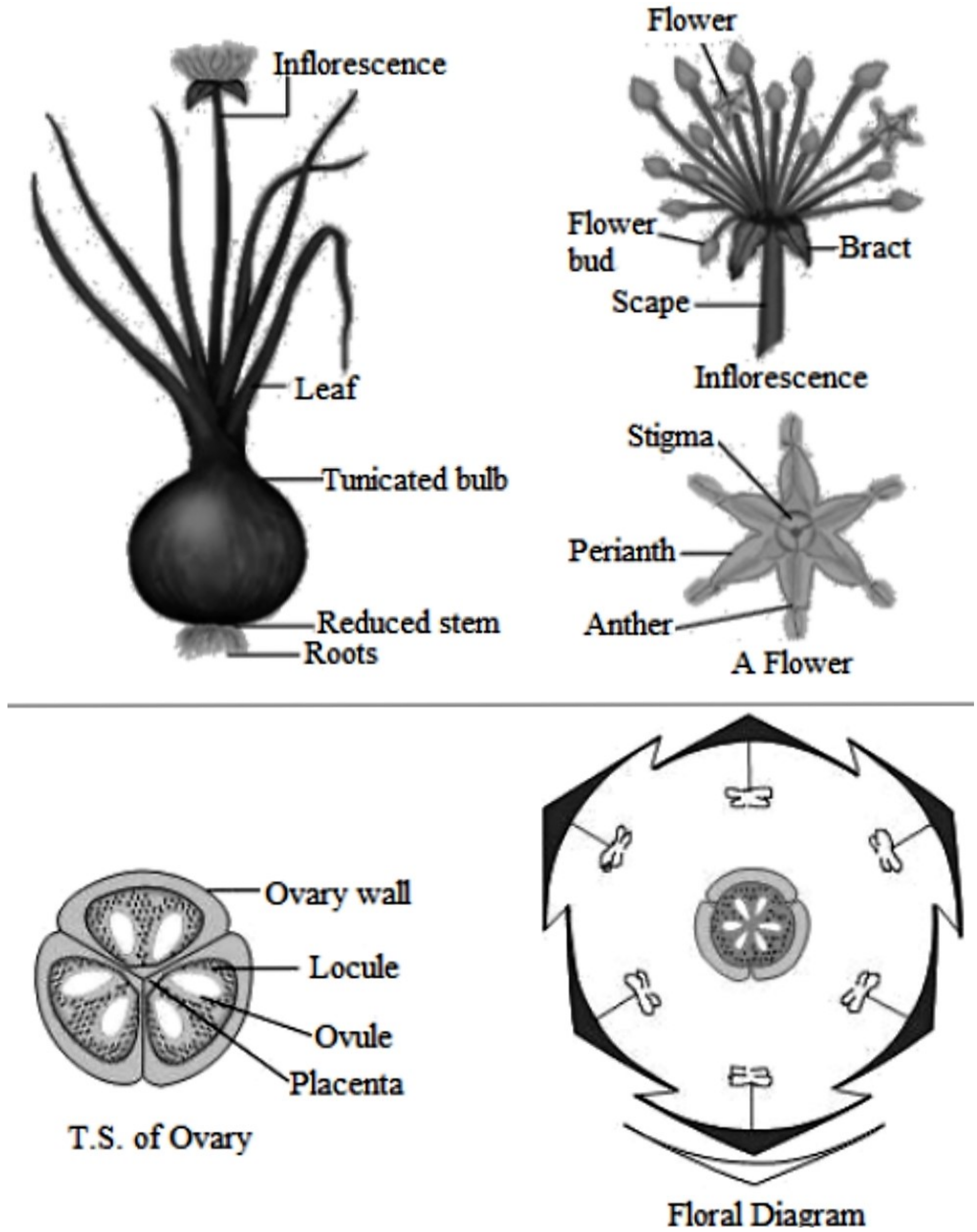

Figure 9.26 Liliaceae: *Allium cepa* L.

SAQ.10

a. ________________flowers are present in Liliaceae.

b. _____________stamens in two whorls is present in Liliaceae.

c. Perianth lobe is__________________in Liliaceae family.

d. _____________ovary is found in Liliaceae family.

e. ______________placentation is present in Liliaceae family.

9.4.2 Orchidaceae

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Monocotyledons

Microspermae

Orchideae

Orchidaceae

Distribution:

This is the second largest family of flowering plants containing 450 genera (Willis and Lawrence), and nearly 17,000 species (Rendle). The family is cosmopolitan being distributed almost throughout the world. It is very well represented in the tropics, but is however rare in arctic regions. In India there are nearly 1,600 species representing this family found on Himalayas and other hills.

Habit (Figure 9.27): These are perennial herbs existing as epiphytes, terrestrial plants, or saprophytes. The epiphytes have clinging roots for fixation and velamen roots for absorbing water trickling on them e.g. *Vanda, Oberonia* etc. Some epiphytes have no leaves and photosynthesis takes place with the help of stem and hanging aerial roots (*Polyrrhiza*). The roots are photosynthetic, leaves are dropped and the plant perennates by pseudobulbs which are swollen internodes with reserve foods and water e.g. *Phajus, Eria, Bulbophyllum, Peristeria*.

Terrestrial orchids have tubers, rhizomes or even storage roots for perennation. In Several genera, leaves appear after producing flowers. They may be small herbs or may be climbing (*Vanilla*). Internodes are tuberous in *Nervilia*. The leaves are often succulent and spread as radical rosettes.

Saprophytic orchids are few and they grow in soils rich in humus. The leaves are not green. The plants are perennial herbs with fleshy rhizomes and may be with or without roots (*Epipogon, Didymoplexis*). The rhizome as well as roots are often associated with fungus (mycorrhiza). The mycorrhiza is endotrophic. The roots on the rhizome may form a network (*Neottia*). In *Corallorhiza*, rhizome is branched, coral-like and there are no roots.

Growth: Most of the orchids show sympodial growth (the main axis shows limited growth) which is of two types:

1. *Acranthous sympodium* in which the axis of each year's growth ends in an inflorescence e.g. *Vanda*.

2. *Pleuranthous sympodium* in which the axis of each year's growth never ends in an inflorescence but becomes arrested and flowers are borne on the lateral axis.

Leaves: The leaves are often succulent and may spread around on the soil or may be opposite, whorled or alternate on the aerial stem. Venation parallel, usually margin is entire. The leaves have a thick cuticle and water storage tissue below the epidermis.

Inflorescence: Mostly racemose, often a spike; panicle in *Oncidium*. The inflorescence may either be short-lived or perennial, producing new flowers throughout the year. It may be small or as large as 4 m. in length as in *Renanthera lowii*. The inflorescence axis sometimes is fleshy and flattened as in *Bulbophyllum* with flowers almost sunk in it. Spicate or solitary flowers occur in *Cypripedium*.

Flower: Usually bracteate, appear after few years of growth of the plant e.g., in *Dendrobium* after 3-4 years and in *Cottleya* after 10-12 years of growth. They are generally large, brightly coloured and sweetly scented. Small and inconspicuous flowers occur in *Pleurothallis*. Flowers are incomplete, bracteate, pedicellate or sessile, generally bisexual sometimes unisexual (heteromorphic unisexual flowers occur in *Catasetum*); zygomorphic, epigynous. The flower, before maturation, often twists by 180° so that what is anterior in the bud becomes posterior at the flowering stage. This phenomenon of reverse orientation is called 'resupination'.

Perianth: Usually 6 tepals in two whorls of 3 each, free or slightly coherent, superior; the outer whorl is sometimes green then this series may be regarded as the sepals but mostly coloured and petaloid. Sepals usually smaller but may be larger than the inner they are much series as in *Masdevallia*. The odd member is anterior and is sometimes larger or smaller than the other two; it is spurred in *Disa*. The inner whorl is generally more conspicuous and large, of which the median tepal (i.e., the anterior in the resupinated flower) is variously coloured it is the Labellum' or the 'lip'. It may be flat or tubular and generally differs from the other two tepals in shape and size. The two lateral tepals of the inner whorl are generally smaller than the labellum (bigger in *Oncidium*). In *Cypripedium*, they may be about 1 m. long while they are completely absent in *Coryysanthes*. These along with the odd sepal form a hood like structure in *Haemaria*. A very large variety of form and colour is met with in the tepals of the inner whorl. A spur is sometimes present this develops from the lip or also partly from the axis, it stores honey as in *Orchis, Listera* etc.

Androecium: Represented by 2 fused, lateral stamens or 1 terminal stamen, Anthers dithecous, introrse, pollen grains granular or bound together by viscin threads into masses called pollinia or stamen generally 1, terminal opposite the odd sepal i.e., anterior (before resupination). This is supposed to belong to the outer whorl while the inner whorl represented by two lateral staminodes; the other members having been lost (i.e. A1+2 Std.), while

Cypripedium, the outer whorl is represented by one anterior fleshy petaloid staminode and the two lateral fertile stamens belong to the inner whorl (i.e. A 1 Std.+2). The staminodes, when present offer a great variety of forms, they may be foliaceous as in *Diuris* or in the form of small auricles as in *Orchis*. They are often glandular, variously coloured and attractive. The anthers are basically 2-celled, introrse and the pollen grains may be glandular and powdery (*Cephalanthera*) or in tetrads (*Listera*) but generally they are aggregated to form a 'pollinium' (*Zeuxine Orchis* etc). The pollinia may be waxy, bony or mealy masses of pollen grains; 2-8 per anther and may either be free within the anther cell or may be united to each other. The sterile end of the pollinium forms a slender stalk, the 'caudicle', at the base of which usually is present a flat and sticky gland sometimes called the 'corpusculum'.

Gynoecium: Tricarpellary, syncarpous, inferior, unilocular, ovules numerous, small, anatropous and are attached in double rows on three parietal placentae. Axile placentation (Apostasia). The ovary is generally cylindrical or spindle shaped marked with longitudinal lines or ridges, it is sometimes confused for the pedicel because of its inferior position. The style, stigma and the stamen together form a complex structure called the 'column' or the 'gynostegium'. It is an elongated, fleshy structure arising above the ovary. The vascular supply of the column is on the same pattern as is to be found supplying the androecium and the gynoecium in general.

Morphologically, therefore, it is not an axial structure. The column is sometimes absent as in *Diuris* in which the stamen and the staminodes arise directly on the ovary. The stylar portion of the column is generally stout and the stigma lobes are, 3 of which usually only the two lateral lobes are functionally fertile (all three functional in *Cypripedium*) and the third terminal lobe is sterile and modified forming the 'rostellum' (absent in *Cephalanthera*). The rostellum aids in pollination because it is variously associated with the pollinium, usually becoming its integral part and forms a viscid disc like structure.

Fruit: Usually a dry capsule dehiscing by six (sometimes by 1, 2 or 3) longitudinal slits which open the fruit only in its middle, the apex and the base remaining intact. In *Vanilla*, the fruit is fleshy and bean-like, opening partially by two unequal valves.

Seeds: Generally, very numerous and minute with a few-celled, small, undifferentiated Embryo surrounded by a membranous coat. The seeds are ejected out by hairy structure which are hygroscopic and are developed on the inside of the valves. Sticky gland at the base of the caudicle, the viscid nature of the rostellum' size and the waxy pollen masses. When the insect visits another flower, it may, while searching for the honey, deposit the pollen on the viscid fertile stigmatic surface below the rostellum, thus causing cross pollination.

Self-pollination usually may also occur in *Cephalanthera* while in *Epidendrum* the flowers are cleistogamic.

Floral Formula: $\uparrow K_3\ C_{2+1}\ [A_{1+2}{}^{0}\ \hat{G}_{(3)}]$ or $K_{(2):1}\downarrow\ C_{1\ \mathrm{labellum}:2}\downarrow\ [A_3{}^{0}{}_{+2:1}\downarrow\ \hat{G}_{(3)}*]\ Vp_{\infty}$

Common plants: *Cattleya, Habenaria, Vanilla planifolia, Eulophia epidendrae, Geodrum densiflora, Vanda.*

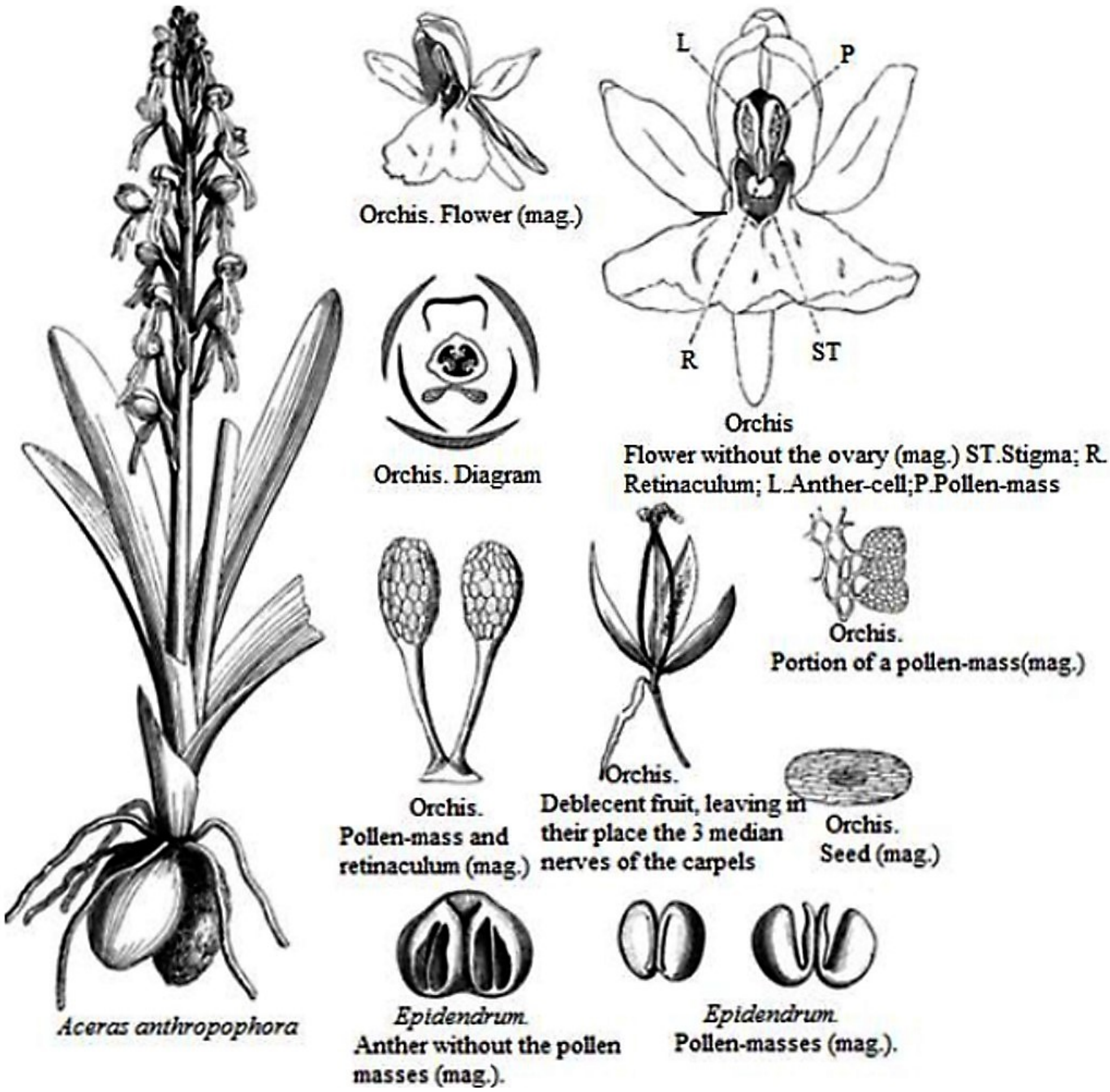

Figure 9.27 Orchidaceae I: Floral details of some orchids

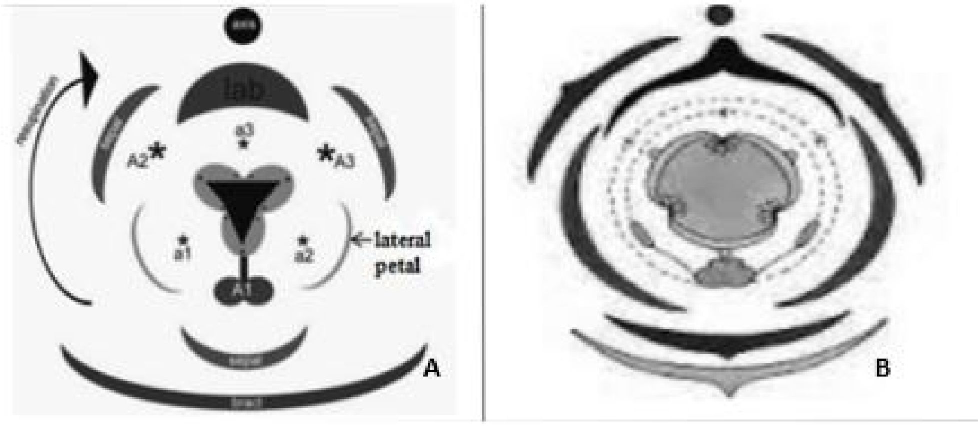

Figure 9.27 Orchidaceae II: A. Floral diagram of Monandrous orchid, B. Floral diagram of Diandrous orchid

SAQ.11

a. In Orchidaceae family, the growth is__________________.
b. Pollinia formation is present in_______________family.
c. ______________________flowers occur in *Cypripedium*.
d. The____________placentation is found in Orchidaceae family.
e. _____________pollination occurs in *Cephalanthera*.

9.4.3 Gramineae (Poaceae)

Systematic position:

Bentham and Hooker (1862)

Phanerogames

Monocotyledons

Glumaceae

Graminae

Distribution:

This is one of the largest and most widely distributed family of the flowering plants containing nearly 600 genera and 10,000 species. The family is cosmopolitan being distributed almost throughout the world. In temperate regions however, the plants form a very conspicuous vegetation developing into prairies, steppes etc.

Habit (Figure 9.28): Annual or perennial herbs, sometimes they become woody and attain large size such as *Bambusa, Dendrocalamus* etc.,

Roots are fibrous and many plants possess rhizomes. The perennial grasses persist by means of a sympodial rhizome formed by the lower internodes of the stem.

Stem (culm) is mostly fistular (hollow), rarely solid (*Zea mays, Saccharum officinale*). *Sorghum* stem is erect, prostrate or creeping, stem in divided into nodes and internodes. Runners and suckers are produced by some grasses.

Leaves are alternate, simple, distichous, exstipulate, sessile, ligulate (ligule absent in *Echinochloa*) leaf base forming tubular sheath, parallel veined, cylindrical petiole present in *Bambusa*; auriculate structures are produced in *Oryza* and *Hordeum*. Anatomically, in the epidermis stomata are present in regular linear rows along the sides of the ridges. The guard cells are dumb-bell shaped.

Floral characters:

Inflorescence: Compound spike which may be sessile or stalked. The unit of structure is taken as a spikelet. The spikelets are variously arranged on the rachis. Each spikelet may have only bisexual flowers, or may have bisexual and male florets or may have male and female flowers only. Each spikelet has, very short of minute axis (*rachilla*) on which glumes or bracts are present in two vertical rows. The lowest glumes which are 2 are sterile and bear nothing in their axils, the lowest glume may be larger than the upper one. The upper ones are fertile and each one subtends a simple flower in its axil, this fertile bract or glume is the lemma. The fertile glumes (lemma) are closely similar to the sterile glumes (*Eragrostis*) or differ from them in shape, size and texture (*Avena*). Palea is membranous structure present between the glume and the rachilla. The flower is enclosed by the palea from above and this is considered to be bracteole. Thus the flower is enclosed by the lemma from below and the palea from above. Each floret is typically trimerous plan with great variation in the reduction of its parts.

Flower: Small, inconspicous, bracteate (palea and lemma), bracteolate, sessile, complete, bisexual (rice) or unisexual (maize), irregular, zygomorphic, hypogynous, cyclic.

Perianth: Usually represented by two membranous scales called the lodicules. The lodicules are situated above and opposite the palea. 3 lodicules are present in *Bambusa*.

Androecium: Stamens are commonly 3 and they belong to the outer whorl. The inner whorl of stamens is completely absent. Rarely this whorl also may be present making the number 6 (*Bambusa, Oryza*). Stamens are numerous in *Pariana.* Anthers are dithecous, versatile, introrse opening by a longitudinal slit.

Gynoecium is superior, monocarpellary with a solitary, erect, anatropous ovule; styles short or absent; (styles 3 in *Bambusa*); stigmas 2, feathery, papillate and branched.

Fruit: Caryopsis (achene with pericarp completely united or adherent with the seed coat), Fruit is a nut in *Dendrocalamus*, berry in *Bambusa*. or utricle (*Eleusine*).

Seed: Endospermic; embryo is small, straight and situated to a side of the massive endosperm;

Important characteristics:

1. Cylindrical hollow stem with distichously arranged leaves
2. Open leaf-sheath and the ligule
3. Spikelet inflorescence
4. Lodicule
5. Versatile anthers.
6. Feathery stigmas.
7. Fruits, a caryopsis, with the embryo situated towards a side at the base
8. Presence of coleoptile (plumule) and coleorhiza (radicle); hypogeal germination.

Primitive characters: Arboreal habit of some members; all florets in a spikelet are fertile; glumes persistent; herbaceous and leafy lemmas; three stigmas; simple, alternate leaves; hypogynous bisexual flowers; endospermic seed.

Advanced characters: Herbaceous annuals and perennials; exstipulate leaves; flowers arranged in distinct inflorescence; small, inconspicuous, zygomorphic flowers; perianth represented by lodicules; stamens reduced to 3; monocarpellary, unilocular gynoecium; basal placentation; caryopsis fruit; small seeds.

Floral Formula: % ☿ $P_{2\ (lodicules)}$ A_3 $G_{\underline{1}}$

Common plants: Wheat (*Triticum vulgare*), rice (*Oryza sativa*), maize (*Zea mays*), bajra (*Pennisetum typhoides*), jowar (*Sorghum vulgare*), barley (*Hordeum vulgare*), oats (Jai; *Avena sativa*), ragi (*Eleusine coracana*), rye (*Secale cereale*), Sugarcane (ganna, ponda; *Saccharum officinale*), *Bambusa, Dendrocalamus, Andropogon odoratus* (ginger grass), *Cymbopogon nardus* (citronella grass), *C. citronella* (lemon grass), *C. martini* (geranium oil Grass), *Elymus arenarius*, *Lolium, Dactylis*, *Cynodon* (doob, Bermuda grass), *Agrostis* (fiorin grass), Poa (meadow grass), *Festuca* (fescu grass), Stenotaphrum (schrank grass), *Zoisia* (zoisia grass of New Zealand), *Saccharun munja* (munj).

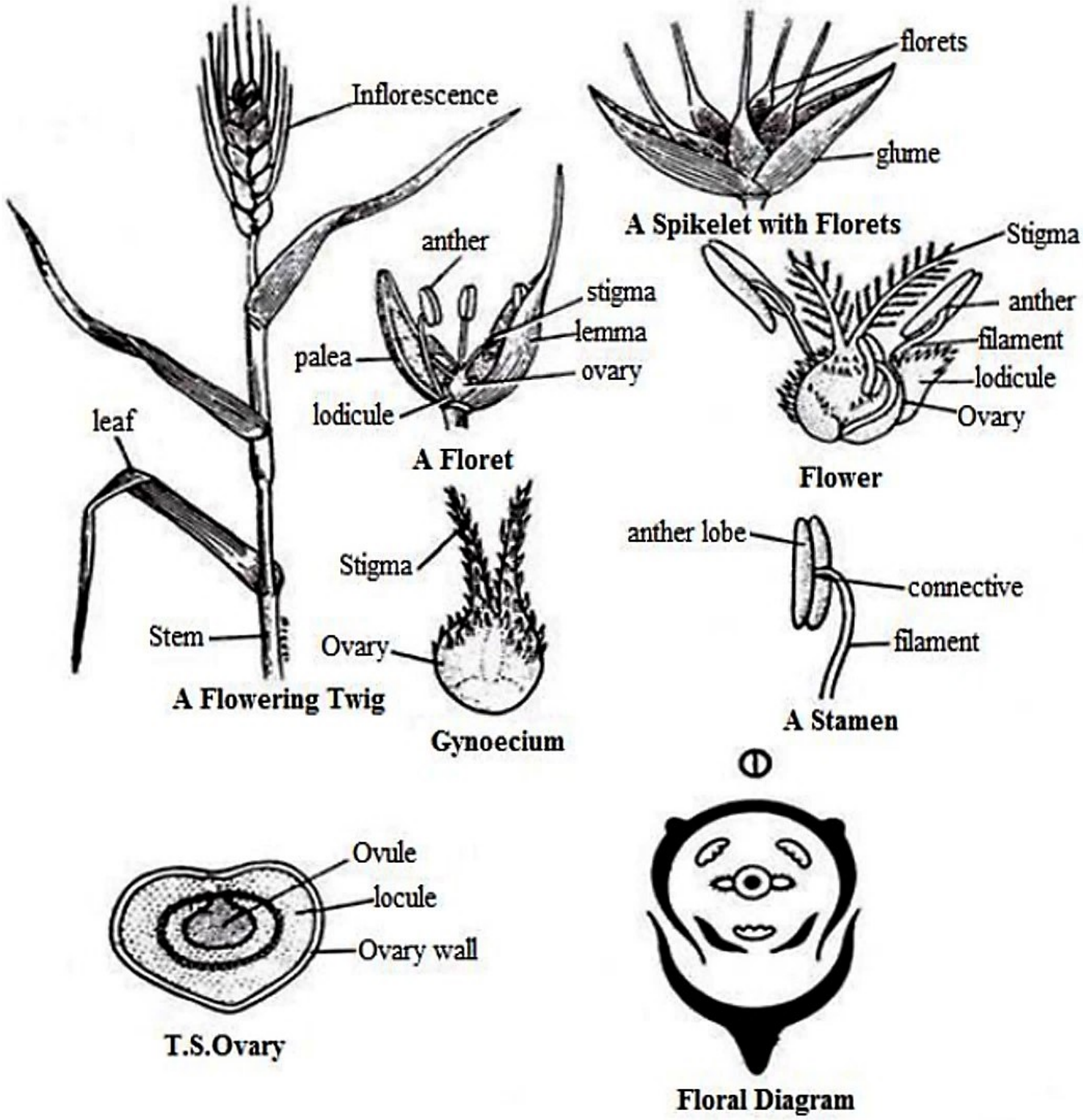

Figure 9.28 Graminae (Poaceae): *Triticum aestivum* L.

SAQ.12

a. In Graminae family, the inflorescence is__________________.

b. The alternate name of Graminae family is _______________.

c. _________anthers and ____________stigma is present in Graminae.

d. ____________fruit is found in Graminae family.

e. The_____________placentation is present in Graminae.

8.3 Summary

- Angiosperms are divided into two subgroups: dicotyledonous and monocotyledonous plants, mainly on the basis of number of embryonic leaves or cotyledons.
- The dicot plants are characterised by the presence of two cotyledons in the seed, generally reticulate venation in leaves, concentric tissues in the stem with open vascular bundles arranged in a ring.
- The monocot plants are characterised by the presence of a single cotyledon in the seed, generally parallel venation in the leaves, scattered closed vascular bundles in the stem.
- In racemose type inflorescence, the main axis does not terminate into a flower, but it keeps on growing continually and gives off flowers laterally in acropetal succession. Here the youngest flower is present at the apex and the older flowers towards the base.
- In cymose inflorescence, the terminal flower is the oldest and the young flowers are present on the lower side.
- In Cyathium inflorescence, a cup shaped involucre containing nectar-secreting glands, a centrally placed large female flower and many male flowers. E.g., *Euphorbia*
- In Verticillaster inflorescence, whorled dichasial cyme arranged at the nodes of an elongate axis. e.g., *Oscimum*
- The Hypanthodium inflorescence has sessile flowers on the wall of a concave Capitulum, opening by a small ostiole. Male flowers are situated near the periphery and female flowers in the centre. e.g., *Ficus*
- The style which is attached at the base of the ovary in central depression, called gynobasic style.
- In axile placentation, the placentae develop along the central axis in a compound ovary with septa. It occurs in a bilocular to multilocular ovary.
- In caryopsis fruit, a dry indehiscent fruit derived from monocarpellary ovary in which pericarp is inseparably fused with testa, e.g. Gramineae.
- In cremocarp, a dry schizocarpic fruit derived from bicarpellary, syncarpous inferior ovary with one ovule in each locule. It dehisces from two indehiscent, single-seeded mericarps attached with carpophore, e.g. Umbelliferae.
- In etaerio of achenes, also called achenecetum, it is an aggregation of achenes, e.g. *Ranunculus.*
- The diagram, that illustrates the relative position and number of parts in each of the sets of organ comprising a flower, is called floral diagram.

- Asteraceae is the largest and advanced family of the flowering plants. The plants of this family showing peculiar feature like annual, herbaceous in nature, Head or capitulum inflorescence, presence of ray and disc florets, calyx reduced to pappus, epigynous flowers, syngenesious anthers, inferior unilocular ovary with a solitary ovule on basal placentation and cypsela fruit.
- The peculiar characteristics of Ranunculaceae family are herbaceous in nature, alternate radical or cauline leaves with palmately reticulate venation, hemicyclic flowers with numerous essential organs on elongated torus, honey petals, numerous stamens with extrorse anthers, apocarpous pistil, fruit a follicle achene or berry, endospermic seed; embryo minute and oily endosperm.
- In Brassicaceae, plants show important features such as simple, exstipulate, lyrate leaves, corymb inflorescence, ebracteate, dimerous or tetramerous flowers, cruciform and clawed petals, tetradynamous stamens, transversely placed carpels, parietal placentation of ovules, commissural stigma, sliqua or silicula fruit.
- The unique features of Solanaceae family are simple, exstipulate leaves, adnation of leaves to the Stem (axis), pentamerous, hypogynous and obliguely zygomorphic flowers, epipetalous stamens, oblique twisting of the ovary, ovules on swollen axile placenta, curved embryo.
- The characteristic features of Malvaceae family are stellate hairs on vegetative parts, mucilage in the cortex and pith, stipulate, alternate leaves with multicostate reticulate venation, showey flowers, presence of epicalyx, monadelphous stamens, monothecous, reniform, extrorse anthers, spinous pollen, ovules on axile placentation.
- The peculiar characteristics of Mimosaceae family are bicompound leaves, spike or globose head inflorescence.; Flowers regular, bisexual, perigynous and symmetrical, corolla lobes are sepaloid, numerous stamens with attractive coloured filaments, legume or lomentum type fruit.
- The characteristic features of Caesalpinoidae family are compound leaves, corymb or Corymbose raceme type inflorescence, flower perigynous, pentamerous and slightly zygomorphic, ascendingly imbricate aestivation of petals, ten stamens in two rings.
- The unique features of Papilionaceae family are tap root with nodules, pinnately compound leaves with pulvinus leaf base, racemose inflorescence, pentamerous, perigynous and strongly zygomorphic flower, papilionaceous corolla, descendingly

imbricate aestivation, 10 stamens, mono or diadelphous, monocarpellary, superior ovary, with ovules on marginal placentation, legume type fruit.

- The characteristic features of Liliaceae family are mostly herbs, perennating by rhizomes, bulbs etc., regular, hypogynous, trimerous flowers, perianth lobes are mostly petaloid, six stamens in two whorls, tricarpellary, syncarpous, superior ovary.
- In Orchidaceae, plants show important features such as perennial herbs existing as epiphytes, terrestrial plants, or saprophytes, sympodial growth, pollinia formation, sticky gland corpusculum, stamen together form a complex structure 'column' or the 'gynostegium', rostellum aids in pollination, dry capsule.
- In Graminae, plants show important features like cylindrical hollow stem with distichously arranged leaves, open leaf-sheath and the ligule, spikelet inflorescence, lodicule, versatile anthers, feathery stigmas, fruits- a caryopsis, with the embryo situated towards a side at the base, presence of coleoptile (plumule) and coleorhiza (radicle); hypogeal germination.

8.4 Terminal Question

Q.1 Differentiate the hypogynous, perigynous and epigynous condition.

Answer:---

Q.2 Discuss the vegetative and reproductive characteristic features of family Asteraceae in detail.

Answer:---

Q.3 Describe the general characters of family Graminae with suitable examples.

Answer:---

Q.4 What is plant taxonomy? Discuss the role of it in scientific area.

Answer:---

Q.5 Describe the characteristics of family Brassicaceae and write its economic importance.

Answer:---

Short Questions

Q.6 Write short notes on:

9. Racemose and cymose inflorescence
10. Aestivation
11. Placentation
12. Cythium inflorescence
13. Hypanthodium inflorescence
14. Head or Capitulum inflorescence
15. Important characteristics of family Papilionaceae
16. Resupination

Q.7 Multiple choice questions:

6. Vertisilaster inflorescence found in the family-
    v. Brassicaceae
    vi. Asteraceae
    vii. Lamiaceae
    viii. Orchidaceae
7. Spike of spikelet inflorescence is the characteristics features of the family-
    v. Liliaceae
    vi. Orchidaceae
    vii. Graminae
    viii. Ranunculaceae
8. Pollinia formation and resupination occurs in the family of-
    v. Orchidaceae
    vi. Ranunculaceae
    vii. Brassicaceae

viii. None of the above

9. Basal placentation is the features of family-
   v. Asteraceae
   vi. Liliaceae
   vii. Malvaceae
   viii. Brassicaceae
10. Caryopsis type of fruit is found in the family-
   v. Graminae
   vi. Solanaceae
   vii. Liliaceae
   viii. None of the above

8.6 Answers

6. iii. 2. iii 3. i 4. i 5. i

Self-assessment questions

SAQ.1

a. Hypogynous **b.** Polypetalae **c.** Cymose **d.** Placentae develop along the central axis in a compound ovary **e.** Adelphous condition

SAQ.2

a. Compositae **b.** Head or capitulum **c.** Basal **d.** Pappus **e.** Fused

SAQ.3

a. Ranunculaceae **b.** Raceme **c.** Aggregate of follicle, achenes or rarely berry **d.** Numerous **e.** Br Brl ⊕ ☿ K_5 C_5 A_∞ $G_{\underline{\infty}}$

SAQ.4

a. Typically racemose **b.** Cruciferae **c.** Siliqua **d.** 6 (2+4) **e.** Parietal

SAQ.5

a. Cymose **b.** Superior **c.** Solanaceae **d.** Berry or capsule **e.** Axile

SAQ.6

a. Multicostate **b.** Monoadelphous **c.** Malvaceae **d.** Stellate **e.** Axile

SAQ.7

a. Bicompound **b.** Legume or lomntum **c.** Numerous, coloured **d.** Spike or globose head **e.** Marginal

SAQ.8

a. Ten **b.** Imbricate **c.** Perigynous, pentamerous and zygomorphic **d.** Corymb or corymbose raceme **e.** Marginal

SAQ.9

a. Pinnately **b.** Imbricate **c.** Papilionaceae **d.** Marginal **e.** Zygomorphic

SAQ.10

a. Trimerous **b.** 6 **c.** Mostly petaloid **d.** Superior **e.** Axile

SAQ.11

b. Sympodial **b.** Orchidaceae **c.** Spicate or solitary **d.** Axile **e.** Self

SAQ.12

a. Spike of spikelet **b.** Poaceae **c.** Versatile, feathery **d.** Caryopsis **e.** Basal

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