but it is viewed to be associated with water absorption, secretion and prevent dessication of shoot. The members belonging to Homeophyllum type possess same type of leaves spirally arranged on the stem whereas the Heterophyllum type have two types of leaves- two dorsal rows of small leaves(Microphylls) and two ventral rows of large leaves(Megaphylls).

Internal structure

Root

The transverse section of the root reveals an outermost layer called epidermis. It is made up of tangentially elongated cells. The cortex is homogeneous made up of thin walled parenchyma . The innermost layer of cortex is called endodermis. The stele is a protostele, monarch and xylem is exarch (Figure 2.26).

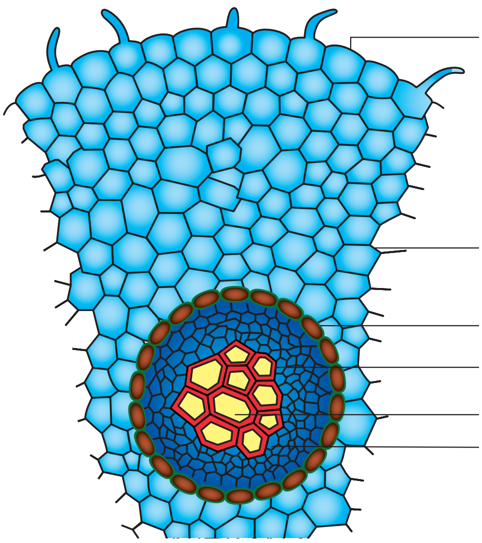


Figure 2.26: T.S. of root

Rhizophore

The outermost layer of Rhizophore is the epidermis. It is single layered and is covered with a thick cuticle. The cortex is differentiated into outer scelrenchymatous and inner parenchymatous layers. The innermost layer of cortex forms endodermis. The stele is a protostele Figure 2.37. It is monarch and exarch but it is centrifugal in *S. kraussiana* and crescent shaped in *S. atroviridis*.

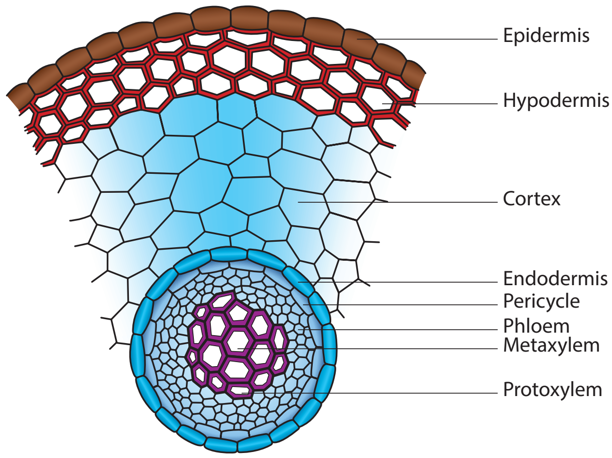


Figure 2.27: T.S. of Rhizophore

Stem

The anatomy of the stem reveals the presence of epidermis, cortex and stelar region (Figure 2.28).

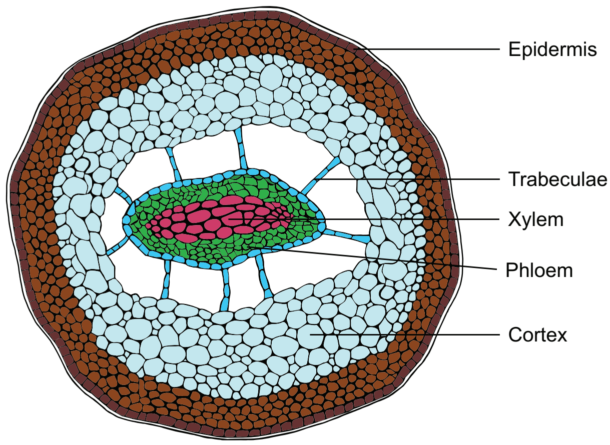


Figure 2.28: T.S. of Stem

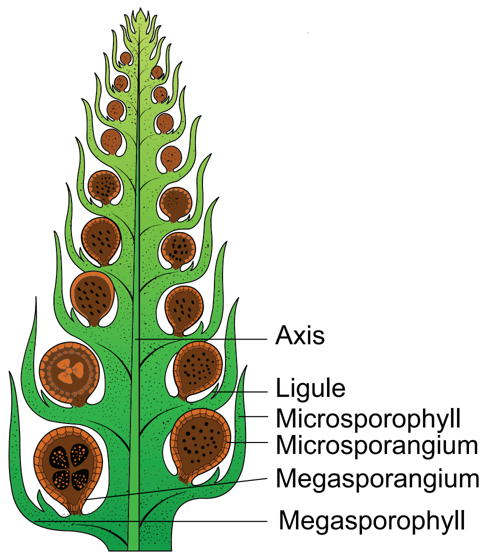
The epidermis is parenchymatous and is covered with a thick cuticle. The cortex is parenchymatous with cells arranged without intercellular spaces. A sclerenchymatous hypodermis is noticed in *Selaginella lepidophylla*. The presence of radially elongated endodermal cells called **trabeculae** is the characteristic feature of *Selaginella*. The casparian strips are found on the lateral walls. The rapid stretching of the innermost cortical cells in comparison with stele results in air spaces and stele appears to be suspended in air space with the help of trabeculae. The stele is a protostele and exarch. A variation in number of steles is found. It may be monostelic (*S. spinulosa*); distelic (*S. kraussiana*)or polystelic (*S. laevigata*). The xylem is monarch(*S. kraussiana*) or diarch (*S. oregana*). Tracheids are present but vessels are also noticed in *S. densa* and *S. rupestris*.

Leaf

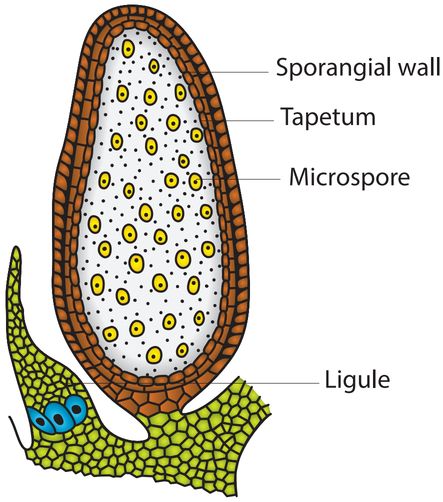
The leaf shows upper and lower epidermis. The epidermal cells have chloroplast. Stomata occur on both surfaces. The mesophyll is made up of loosely arranged thin walled cells with intercellular spaces. There is a median vascular bundle surrounded by a bundle sheath. In vascular bundle xylem is surrounded by phloem.

Reproduction

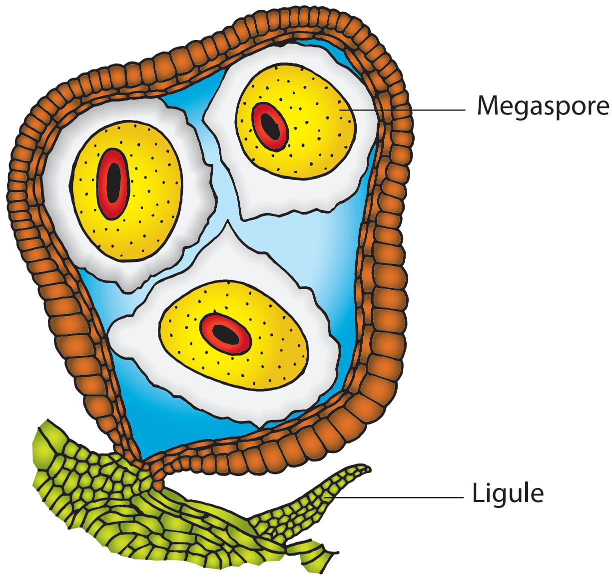
Selaginella shows both vegetative and asexual modes of reproduction.



a) L.S. of cone



b) A microsporangium enlarged



c) A megasporangium enlarged

Figure 2.29: Reproduction in *Selaginella*

Vegetative reproduction

Selaginella reproduces vegetatively by fragmentation, bulbil formation, tuber formation and resting buds.

Sexual reproduction

During sexual reproduction spores are produced (Figure 2.29). *Selaginella* is heterosporous and produces two types of spores namely microspores in microsporangium and megaspores in megasporangium. The sporangia are borne singly in the axils of microsporophyll and megasporophyll respectively. The sporophylls are arranged spirally around a central axis and aggregate to form strobili or cones. Variations in the distribution of microsporangia and megasporangia among the species are seen. In S. *selaginoides* and S. *rupestris* megasporangia are present in the basal part of the cone. *S. kraussiana* possesses a single megasporangium at the base of the strobilus. In S. *inaequifolia* one side of the strobilus bear only megasporangia and other microsporangia. Separate strobili for microsporangia and megasporangia are present in S. *gracilis*. and S. *atro-viridis*.

The development of sporangium is of eusporangiate type. The sporangial initial divides periclinally to form outer jacket initials and inner archesporial initials. The archesporial initials by repeated anticlinal and periclinal divisions form sporogenous cells. Microspore mother cells of microsporangium undergo reduction division to produce halpoid microspores. Similarly the megaspore mother cell undergoes reduction division to produce 4 haploid megaspores. The microspore and megaspore represent the male and female gametophyte and germinate inside the sporangium. The microspores produce biflagellate antherozoids. Archegonia develop in the megaspore. The antherozoids swim in water and reach the archegonium. Fertilization brings the fusion of male and female nucleus which result in the formation of a diploid zygote. The diploid zygote represents the first cell of sporophyte.

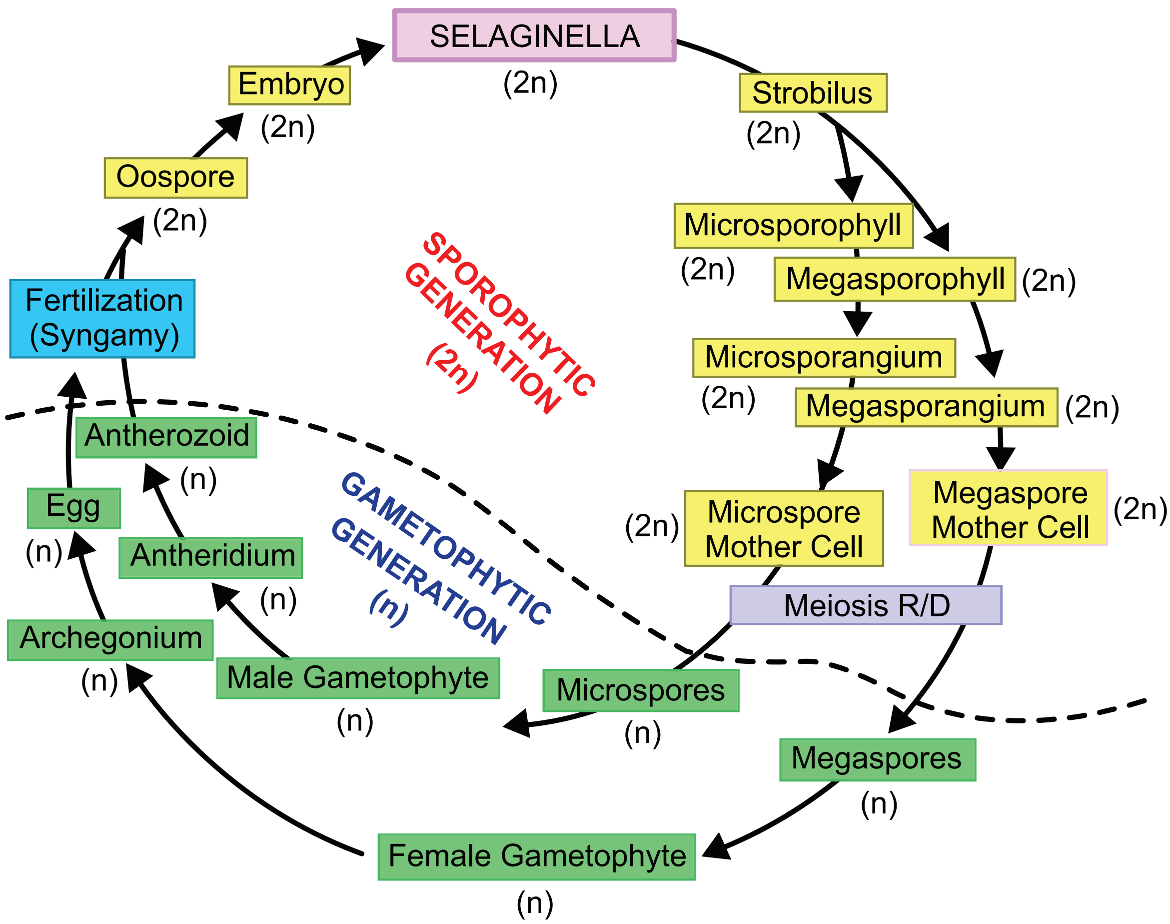


Figure 2.30: Life cycle of *Selaginella*

It undergoes several mitotic division to form embryo. The embryo develops into a mature sporophytic plant.

In the life cycle of *Selaginella* alternation of sporophytic and gametophytic generation is present (Figure 2.30).

2. 5.5 Adiantum

Division – Pteropsida
Class - Leptosporangiopsida
Order – Filicales
Family – Polypodiaceae
Genus – *Adiantum*

Adiantum is commonly known as 'Maiden hair fern' or 'Walking fern'. They are distributed in the tropical and temperate regions of the world. Some of the Indian species include *Adiantum capillus-veneris, Adiantum pedatum, Adiantum caudatum* and *Adiantum venustum*. The sporophyte is differentiated into rhizome, roots and leaves Figure 2.31.

External features

Rhizome

The rhizome is a perennial, subterranean dichotomously branched structure and is creeping in *A. capillus-veneris* or may be erect as in *A. caudatum*. It is covered with persistent leaf bases and hairy outgrowths called **ramenta**.

Root

The roots are adventitious and arise from the rhizome.

Leaf

The leaves are also called fronds and are pinnately compound (unipinnate- *A. caudatum*, bipinnate- *A. capillus-veneris*) the young leaves are circinately coiled. The petiole is long, black and shiny. The venation is free and dichotomous in all the species. The vein spread in a fan-like manner in the lamina. The leaves bear marginal sori which are covered by a **false indusium.**

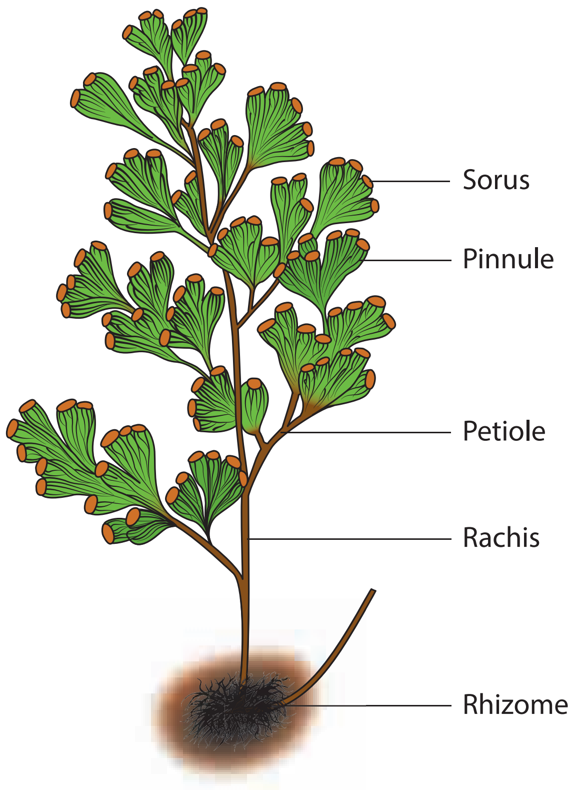


Figure 2.31: Adiantum Habit

Internal structure

Root

The root is differentiated into epidermis, cortex and central vascular cylinder.

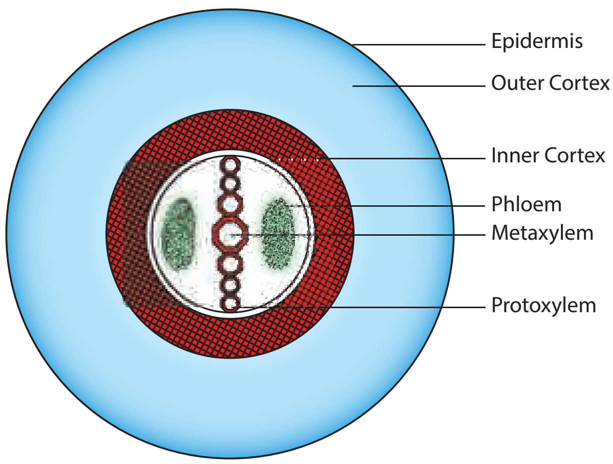


Figure 2.32: T.S. of root

The epidermis is the outermost layer and bears unicellular root hairs. The cortex is divided into outer wide parenchymatous and inner narrow sclerenchymatous layer. The stele is simple and possesses a central core of xylem in diarch condition with phloem on either side of it (Figure 2.32).

Rhizome

The rhizome in transverse section shows a single layered epidermis covered by cuticle. Some epidermal cells bear multicellular hairs. The Epidermis is followed by two to three layered hypodermis made up of sclerenchyma tissue. A parenchymatous ground tissue is present. The young rhizomes have amphiphloic siphonostele. The older rhizomes have solenostele or dictyostele (Figure 2.33).

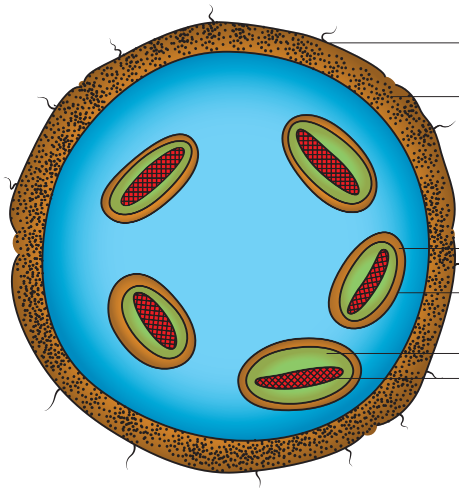


Figure 2.33: T.S. of Rhizome

Petiole

The petiole in T.S. shows a single layered epidermis with thick cuticle. Epidermis is followed by a sclerenchymatous hypodermis which provides mechanical support. There is an extensive parenchymatous ground tissue. The central region possesses a single large horse shoe shaped stele. Xylem forms central core surrounded by phloem (Figure 2.34).

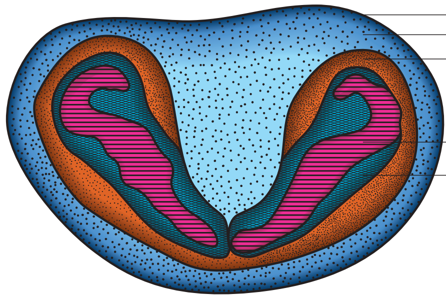


Figure 2.34: T.S. of Petiole

Pinnule

The Pinnule shows upper and lower epidermis. The cells contain chloroplasts. Stomata are confined to lower epidermis. The mesophyll is not differentiated into palisade and spongy parenchyma. The vascular bundle is surrounded by sclerenchymatous bundle sheath.

Reproduction

Adiantum is homosporous. The reproduction takes place by the production of spores. The spores are produced in sporangia. A group of sporangia forms sori. The sori are marginal but the reflex margins of the pinna form a protective membranous structure called *false indusium* (Figure 2.35). The development of sporangium is of leptosporangiate type.

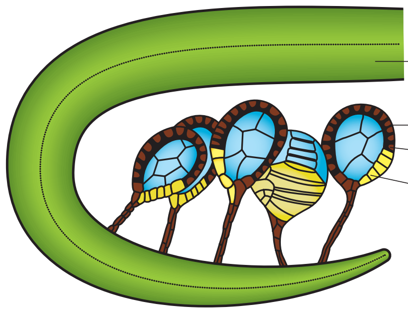


Figure 2.35: V.S. of Sporophyll

The sorus does not show any definite sequence hence fall under mixed type.

A mature sporangium bears a multicellular stalk and a spherical or elliptical single layered structure called **capsule**. The capsule contains haploid spores. The wall of the capsule is differentiated into thick walled annulus and thin walled **stomium**. On maturity the sporangium bursts and spores are released. The spores germinate and undergo repeated division to produce a **prothallus**. The prothallus is flat, green and heart shaped. It is monoecious and represents the gametophytic phase. Sex organs called **antheridia** and **archegonia** develop on the prothallus. Antheridia release multiflagellate antherozoids which swim in water and reach the egg of the archegonium to accomplish fertilization. The fertilization results in zygote(2n) and it represents the first cell of sporophytic generation. The zygote develops into embryo which further differentiates into sporophyte. Thus *Adiantum* shows alternation of generation (Figure 2.36).

2.5.6 Types of Stele

The term stele refers to the central cylinder of vascular tissues consisting of xylem, phloem, pericycle and sometimes medullary rays with pith (Figure 2.37).

There are two types of steles

1. Protostele
2. Siphonostele

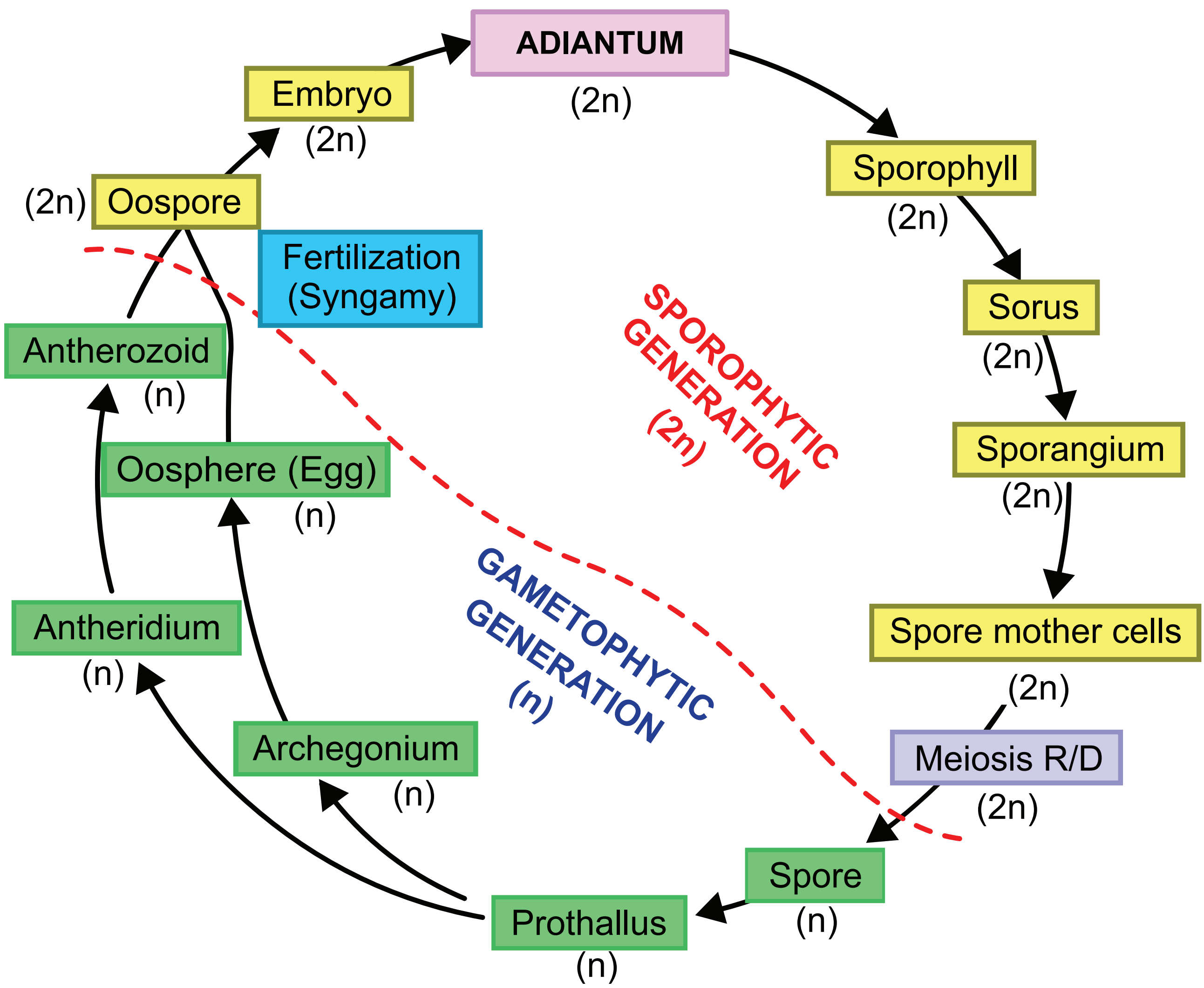


Figure 2.36: Life cycle of *Adiantum*

1. Protostele:

In protostele phloem surrounds xylem. The type includes Haplostele, Actinostele, Plectostele, and Mixed protostele.

(i) **Haplostele**: Xylem surrounded by phloem is known as haplostele. Example: *Selaginella.*

(ii) **Actinostele**: Star shaped xylem core is surrounded by phloem is known as actinostele. Example: *Lycopodium serratum.*

(iii) **Plectostele**: Xylem plates alternates with phloem plates. Example: *Lycopodium clavatum.*

(iv) **Mixed prototostele**: Xylem groups uniformly scattered in the phloem. Example: *Lycopodium cernuum.*

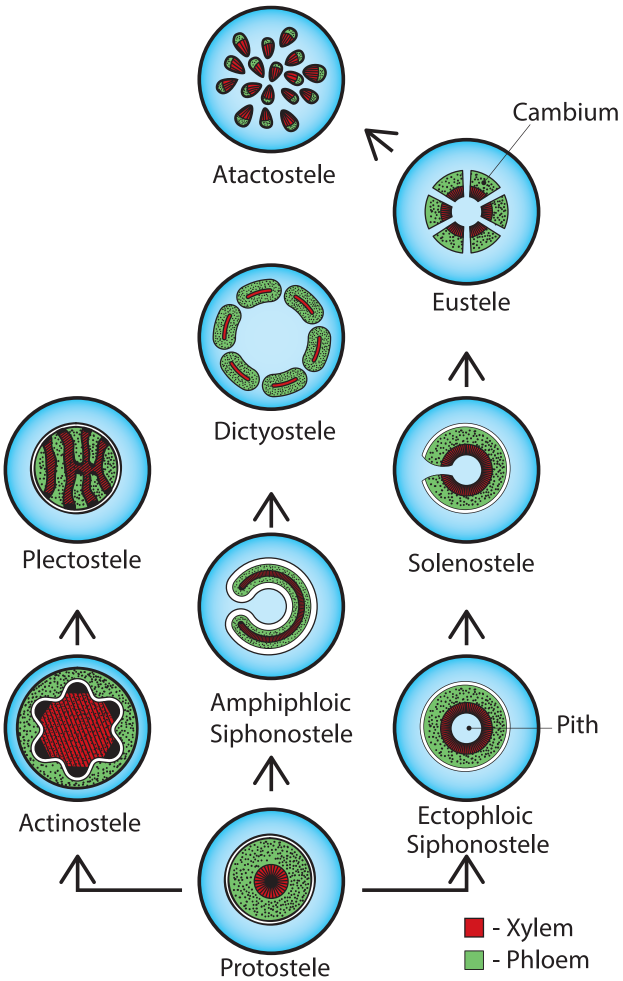


Figure 2.37: Types of Stele

2. Siphonostele:

In siphonostele xylem is surrounded by phloem with pith at the centre. It includes Ectophloic siphonostele, Amphiphloic siphonostele, Solenostele, Eustele, Atactostele and Polycylic stele.

(i) Ectophloic siphonostele: The phloem is restricted only on the external side of the xylem. Pith is in centre. Example: *Osmunda.*

(ii) Amphiphloic siphonostele: The phloem is present on both the sides of xylem. The pith is in the centre. Example: *Marsilea*.

(iii) Solenostele: The stele is perforated at a place or places corresponding the origin of the leaf trace.

(a) **Ectophloic solenostele** – Pith is in the centre and the xylem is surrounded by phloem Example *Osmunda*.

(b) **Amphiphloic solenostele** – Pith is in the centre and the phloem is present on both sides of the xylem. Example: *Adiantum pedatum*.

(c) **Dictyostele** – The stele is separated into several vascular strands and each one is called meristele. Example: *Adiantum capillus-veneris*.

(iv) Eustele: The stele is split into distinct collateral vascular bundles around the pith. Example: Dicot stem.

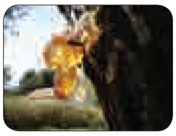
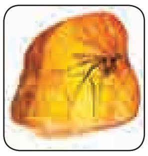
(v) **Atactostele**: The stele is split into distinct collateral vascular bundles and are scattered in the ground tissue Example: Monocot stem.

(vi) Polycyclicstele: The vascular tissues are present in the form of two or more concentric cylinders. Example: *Pteridium.*

2.6 Gymnosperms

Naked Seed producing Plants

Michael Crichton's Science fiction in a book transformed into a Film of Steven Spielberg (1993) called **Jurassic Park**. In this film you might have noticed insects embedded in a transparent substance called amber which preserves the extinct forms. What is amber? Which group of plants produces Amber?


Amber is a plant secretion that is a efficient preservative that doesn't get degraded and hence can preserve remains of extinct life forms. The amber is produced by ***Pinites succinifera***, a Gymnosperm.

In this chapter we shall discuss in detail about one group of seed producing plants called Gymnosperms.

Gymnosperms (Gr. Gymnos = naked; sperma= seed) are naked seed producing plants. They were dominant in the Jurassic and cretaceous periods of Mesozoic era. The members are distributed throughout the temperate and tropical region of the world

2.6.1 General characteristic features

- Most of the gymnosperms are evergreen woody trees or shrubs. Some are lianas (*Gnetum*)
- The plant body is sporophyte and is differentiated into root, stem and leaves.
- A well developed tap root system is present. Coralloid Roots of *Cycas* have symbiotic association with blue green algae. In *Pinus* the roots have mycorrhizae.
- The stem is aerial, erect and branched or unbranched (*Cycas*) with leaf scars.
- In conifers two types of branches namely branches of limited growth (Dwarf shoot) and Branches of unlimited growth (Long shoot) is present.
- Leaves are dimorphic, foliage and scale leaves are present. Foliage leaves are green, photosynthetic and borne on branches of limited growth. They show xerophytic features.
- The xylem consists of tracheids but in *Gnetum* and *Ephedra* Vessels are present.
- Secondary growth is present. The wood may be **Manoxylic** (Porous, soft, more parenchyma with wide medullary ray -*Cycas*) or **Pycnoxylic** (compact with narrow medullary ray-*Pinus*).
- They are heterosporous. The plant may be monoecious (*Pinus*) or dioecious (*Cycas*).
- Microsporangia and Megasporangia are produced on Microsporophyll and Megasporophyll respectively.
- Male and female cones are produced.
- Anemophilous pollination is present.
- Fertilization is siphonogamous and pollen tube helps in the transfer of male nuclei.
- Polyembryony (presence of many embryo) is Present. The naked ovule develops into seed. The **endosperm** is haploid and develop before fertilization.
- The life cycle shows alternation of generation. The sporophytic phase is dominant and gametophytic phase is highly reduced. The photograph of some of the Gymnosperms is given in Figure 2.38

a) *Cycas* b) *Thuja* c) *Taxus* d) *Ginkgo*

Figure 2.38: Gymnosperms

2.6.2 Classification of Gymnosperms

Sporne (1965) classified gymnosperms into 3 classes, 9 orders and 31 families. The classes include i) Cycadospsida ii) Coniferopsida iii) Gnetopsida.

GYMNOSPERMS		
Class-I	Class-II	Class-III
Cycadopsida	**Coniferopsida**	**Gnetopsida**
Orders: 1. Pteridospermales 2. Bennettitales 3. Pentoxylales 4. Cycadales	Orders: 1. Cordaitales 2. Coniferales 3. Taxales 4. Ginkgoales	Order: 1. Gnetales

General Characters of Main classes:

Class I – Cycadopsida

- Plants are palm-like or fern-like.
- Compound, frond-like pinnate leaves.
- Manoxylic wood.
- Sperms are motile.
- Flower like structures are absent. Strobili are simple.

  Example: *Cycas, Zamia*.

Class II – Coniferopsida

- Tall trees with simple leaves of varied shape.
- Wood is pycnoxylic.
- Cone like strobili are present.
- Motile sperms are absent (except *Ginkgo biloba*). Example: *Pinus*.

Class III – Gnetopsida

- Shrubs, trees and lianas.
- Leaves are elliptical or strap-shaped, simple, opposite or whorled.
- Motile sperms are absent.
- Wood contains vessels.
- Strobili is called as inflorescence.
- Flower like structure with perianth is present. Example: *Gnetum, Ephedra*.

2.6.2 Comparison of Gymnosperm with Angiosperms

Gymnosperms resemble with angiosperms in the following features

- Presence of well organised plant body which is differentiated into roots, stem and leaves.
- Presence of cambium in gymnosperms as in dicotyledons.
- Flowers in *Gnetum* resemble to the angiosperm male flower. The Zygote represent the first cell of sporophyte.
- Presence of integument around the ovule.
- Both plant groups produce seeds.
- Pollen tube helps in the transfer of male nucleus in both.
- Presence of Eustele.

The difference between Gymnosperms and Angiosperms were given in Table 2.5

Table 2.5: Difference between Gymnosperms and Angiosperms		
S.No	**Gymnosperms**	**Angiosperms**
1.	Vessels are absent [except Gnetales]	Vessels are present
2.	Phloem lacks companion cells	Companion cells are present
3.	Ovules are naked	Ovules are enclosed within the ovary
4.	Wind pollination only	Insects, wind, water, animals etc., act as pollinating agents
5.	Double fertilization is absent	Double fertilization is present
6.	Endosperm is haploid	Endosperm is triploid
7.	Fruit formation is absent	Fruit formation is present
8.	Flowers absent	Flowers present

2.6.3 Economic importance of Gymnosperms

Table 2.6: Economic importance of Gymnosperms			
S.No	**Plants**	**Products**	**uses**
1.	*Cycas circinalis, Cycas revoluta*	Sago	Starch used as food
2.	*Pinus gerardiana*	Roasted seed	Used as a food
3.	*Abies balsamea*	Resin (Canada balsam)	Used as mounting medium in permanent slide preparation
4.	*Pinus insularis, Pinus roxburghii*	Rosin and Turpentine	Paper sizing and varnishes
5.	*Araucaria* (Monkey's puzzle), *Picea* and *Phyllocladus*	Tannins	Bark yield tannins and is used in Leather industries
6.	*Taxus brevifolia*	Taxol	Drug used for cancer treatment
7.	*Ephedra gerardiana*	Ephedrine	For the treatment of asthma, bronchititis
8.	*Pinus roxburghii*	Oleoresin	Used to make soap, varnishes and printing ink
9.	*Pinus roxburghii, Picea smithiana*	Wood pulp	Used to make papers
10.	*Cedrus deodara*	wood	Used to make doors, boats and railway sleepers
11.	*Cedrus atlantica*	oil	Used in perfumery
12	*Thuja, Cupressus, Araucaria, and Cryptomeria*	whole plant	Ornamental plants/Floral Decoration

2.6.4 Cycas

Class – Cycadopsida
Order – Cycadales
Family- Cycadaceae
Genus - *Cycas*

It is widely distributed in tropical and sub tropical region of eastern hemisphere of the world. *Cycas revoluta*, *Cycas beddomei*, *Cycas circinalis, Cycas rumphii* are some of the common species. The plant body is sporophyte and resemble a small palm. The growth is very slow. It is evergreen and xerophytic in nature.

Sporophyte:-

The sporophyte is differentiated into root, stem and leaves. The stem is columnar bearing a crown of spirally arranged pinnately compound leaves (Figure 2.39).

External features

Figure 2.39: *Cycas* Habit

Root

Two types of roots are found in *Cycas*. They are the tap root and coralloid root.

The primary root persists and forms the tap root. Some of the lateral roots give rise to branches which grow vertically upward below the ground level. They branch repeatedly to form dichotomously branched coral- like roots called coralloid roots. The cortical region of the coralloid root contains the Blue green alga – *Anabaena* sp. which helps in nitrogen fixation (Figure 2.40).

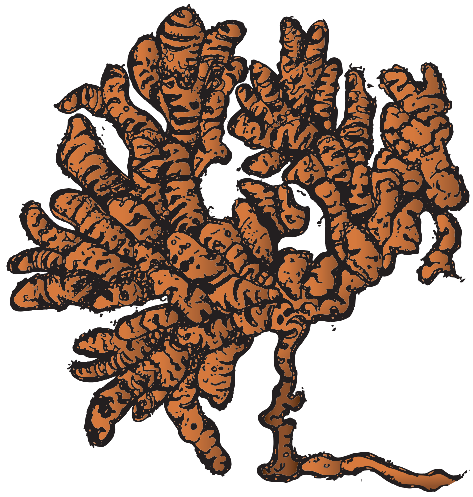


Figure 2.40: Coralloid root

Stem

The stem is columnar, unbranched and woody. It is covered with persistent woody leaf bases. The stem also bears adventitious buds at the base.

Leaves

Cycas has two types of leaves

(i) Foliage or assimilatory leaves
(ii) Scale leaves

(i) Foliage or assimilatory leaves

Foliage leaves are large, pinnately compound and form a crown at the top of the stem. Each leaf has 80-100 pairs of sessile leaflets. The apex is acute or spiny. The leaflet has a single midvein. Lateral veins are absent. Circinate vernation is present and young leaves are covered with **ramenta**.

(ii) Scale leaves

Scale leaves are brown, small, triangular and persistent which are protective in function. They are covered with ramenta.

Internal structure

T.S. of Root

The internal organization of the primary root reveals the following parts. 1. Epiblema, 2. Cortex 3. Vascular region (Figure 2.41). Epiblema is the outermost layer and is made up of single layered parenchyma. It is followed by thin walled parenchymatous cortex. The cortex is delimited by single layered endodermis. A multilayered parenchymatous pericycle is present and it surrounds the vascular tissue. The xylem is diarch in young root and tetrarch in older ones. Secondary growth is present. Coralloid root also shows similar structure but the middle cortex is characterized by the presence of Algal zone. Blue green alga called, *Anabaena* is found in this zone. The xylem is triarch and exarch.

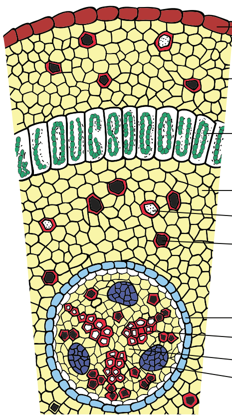


Figure 2.41: T.S. of Coralloid root

T.S. of Stem

The cross section of young stem is irregular in outline due to the presence of persistent leaf bases. It is differentiated into epidermis, cortex and vascular cylinder. It resembles the structure of a dicot stem (Figure 2.42).

The epidermis is the outermost layer and is covered with thick cuticle. It is discontinuous due to the presence of leaf bases. The cortex constitutes the major part and is made up of thin walled parenchymatous cells. The cells are filled with starch grains. Cortex also possesses several mucilage ducts and tannin cells. In young stem the vascular bundles are arranged in the form of a ring. A broad medullary ray is present. The vascular bundles are conjoint, collateral, endarch and open. Xylem is made up of tracheids and phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent. The cambium present in the vascular bundle is active for short period. The secondary cambium is formed from the pericycle or cortex and helps in secondary growth of the stem. The cortical region shows a large number of leaf traces. The presence of direct leaf traces and girdling leaf trace is the unique feature of *Cycas* stem. Secondary growth results in polyxylic condition. Phellogen and cork are formed and replace the epidermis.The wood formed belongs to manoxylic type.

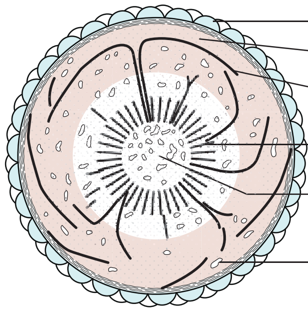


Figure 2.42: T.S. of stem

T.S. of Rachis

The outermost layer is epidermis and is covered by thick cuticle. The hypodermis is made up of two layers of sclerenchyma on the adaxial side and many layered on the abaxial side. The ground tissue is parenchymatous. The peculiar feature of the rachis is the arrangement of vascular bundle i.e., in an inverted Omega shape pattern (Figure 2.43). Each vascular bundle is covered by a single layered sclerenchymatous bundle sheath. Vascular bundles are collateral, endarch and open. A single layered endodermis and few layered pericycle surrounds the bundle. A diploxylic condition is present in the vascular bundles.(presence of both centripetal and centrifugal xylem).

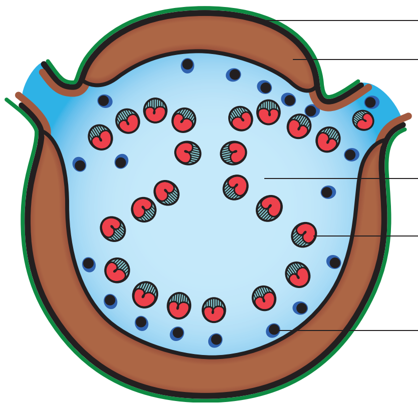


Figure 2.43: T.S. of Rachis

T.S. of Leaflet

The leaflet of *Cycas* in transverse section shows the presence of upper and lower epidermis. The epidermal cells are thick walled and are covered with thick cuticle. The lower epidermis is not continuous and is interrupted by sunken stomata. The hypodermis consists of sclerenchyma cells to prevent transpiration. The mesophyll is differentiated into palisade and spongy parenchyma. The cells of this layer are involved in photosynthesis. The spongy parenchyma present in close proximity to the lower epidermis bear large intercellular spaces which help in gaseous exchange.

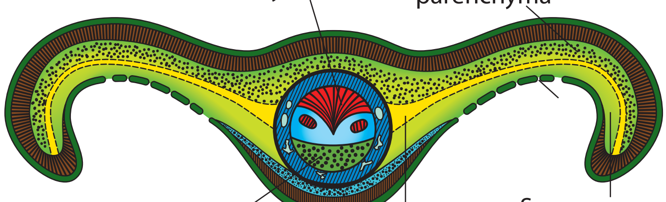


Figure 2.44: T.S. of leaflet

Layers of colourless, elongated cells which run parallel to the leaf surface from the midrib to the margin of the leaflet are seen. These constitute the **Transfusion tissue** that helps in the lateral conduction of water. The vascular bundle has xylem facing upper epidermis and phloem facing lower epidermis. The protoxylem occupies the centre, hence the bundle is mesarch. The vascular bundle has a sclerenchymatous bundle sheath (Figure 2.44).

Reproduction

Cycas reproduces by both vegetative and sexual methods

Vegetative reproduction

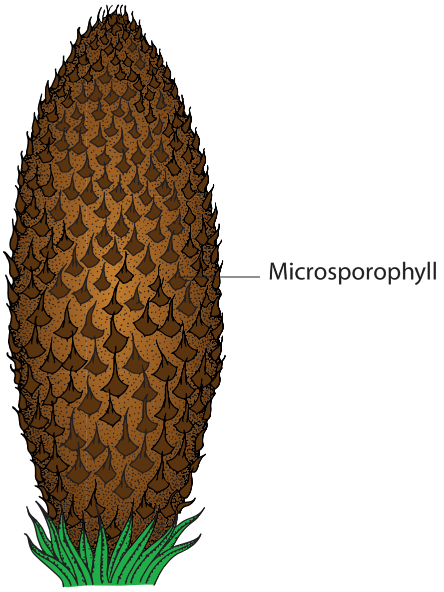
It takes place by adventitious buds or bulbils. They develop in the basal part of the stem. The bulbils on germination produce new plants.

Sexual reproduction

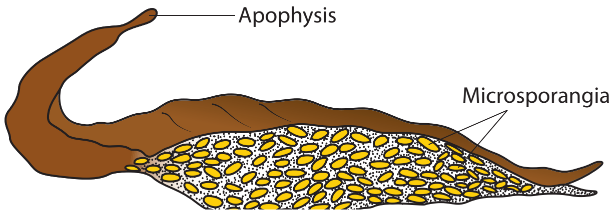
Cycas is dioecious i.e., male and female cones are produced in separate plants. It is heterosporous and produces two types of spores (Figure 2.45).

Male cone

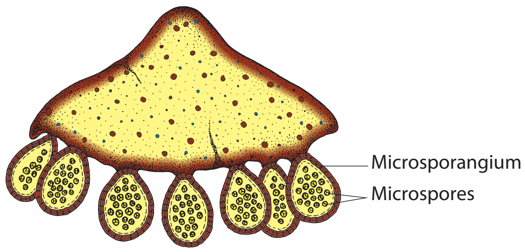
The male cone or staminate cone are borne singly on the terminal part of the stem. The growth of the stem is continued by the formation of axillary buds at the base of the cone. The male cone is displaced to one side showing sympodial growth in the stem. Male cones are stalked, compact, oval or conical and woody in structure. It consists of several microphylls which are arranged spirally around a central cone axis.



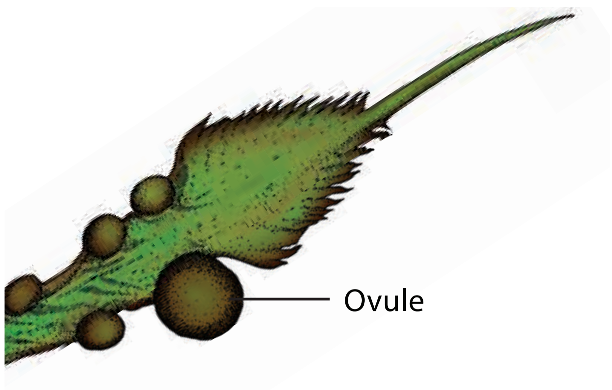
a) Male cone entire



b) A microsporophyll enlarged



c) T.S. of Microsporophyll



d) Megasporophyll

Figure 2.45: Reproduction in *Cycas*

Microsporophylls

Microsporophylls are flat, leaf-like and woody structures with narrow base and expanded upper portion. The upper expanded portion becomes pointed and is called apophysis. The narrow base is attached to the cone axis. Each microsporophyll contains thousands of microsporangia in groups called sori on abaxial (lower) surface. Development of sporangium is of Eusporangiate type. The spore mother cell undergoes meiosis to produce halpoid microspores. Each Microsporangium bears large number of microspores or pollen grains. Each sporangium is provided with a radial line of dehiscence, which helps in the dispersal of spores. Each microspore (Pollen grain) is a rounded, unicellular and uninucleate structure surrounded by outer thick exine and an inner thin intine. The microspore represents the male gametophyte.

Megasporophylls

The megasporophylls of *Cycas* are not organised into cones. They occur in close spirals around the tip of the stem of female plant. The megasporophylls are flat and measuring 15-30 cm in length. Each megasporophyll is differentiated into a basal stalk and an upper leaf like portion. The ovules are attached to the lateral side of the sporophyll. The ovules contain megaspore and it represent the female gametophyte.

Structure of Ovule

Cycas produces the largest ovule of the plant kingdom. The ovules are orthotropous, unitegmic and possess a short stalk. The single integument is very thick and covers the ovule leaving a small opening called *micropyle*. The integument consists of 3 layers, the outer and inner are fleshy (**sarcotesta**), the middle layer is stony called **sclerotesta**. The inner layer remains fused with the nucellus. The nucellus grows out into a beak-like structure and the upper part dissolves and forms a cavity-like structure called **pollen chamber**. A single megaspore mother cell undergoes meiosis to form four haploid megaspores. The lowermost becomes functional and others get degenerated. The nucellus gets reduced in the form of a thin papery layer in mature seeds and encloses the female gametophyte An enlarged megaspore or the embryo-sac is present within the nucellus. An archegonial chamber with 3-6 archegonia are present in the archegonial chamber below the pollen chamber (Figure 2.46).

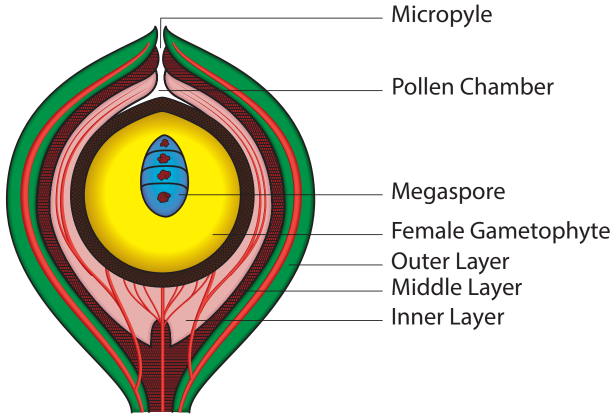


Figure 2.46: L.S. of Ovule

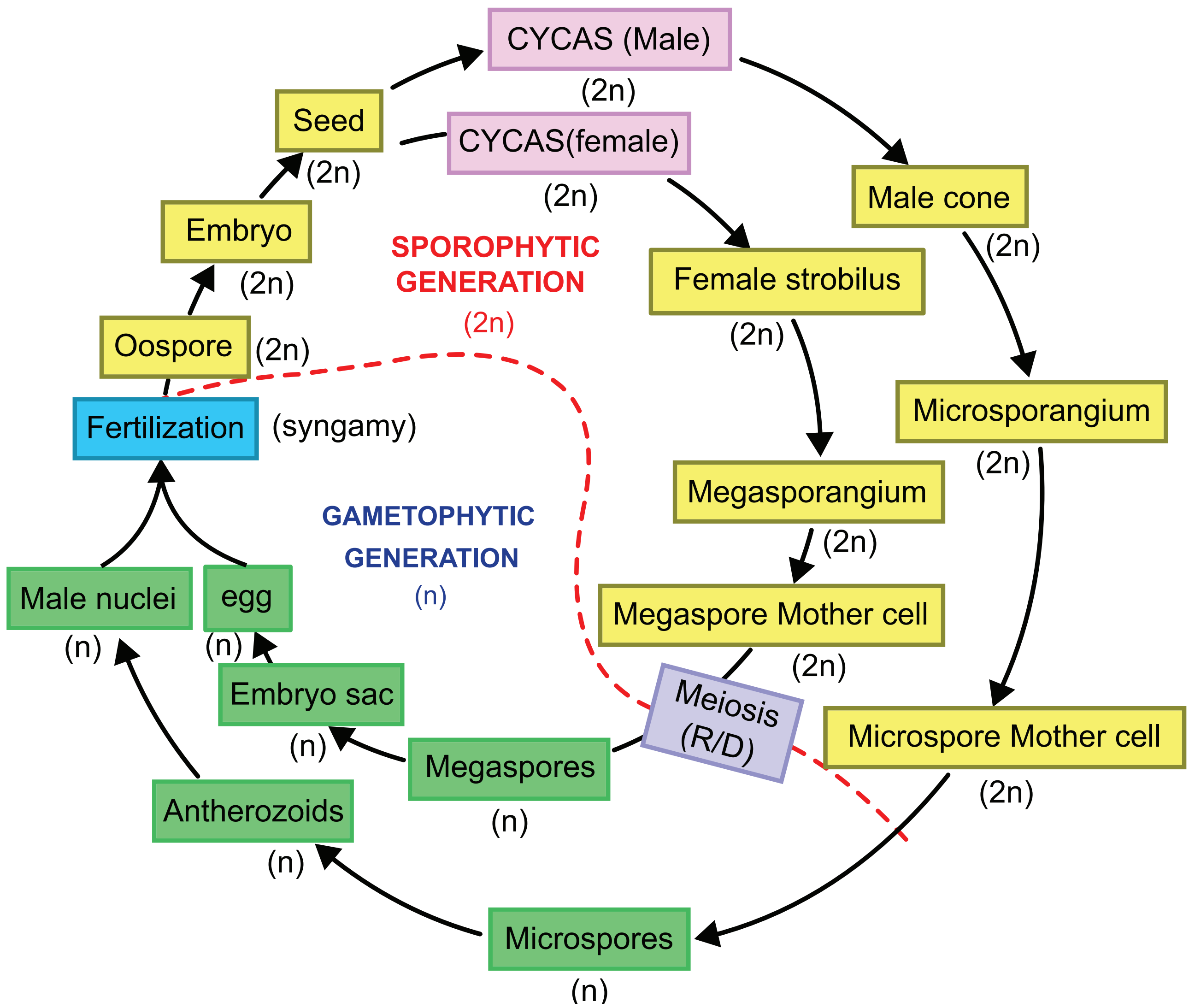


Figure 2.47: Life cycle of *Cycas*

Pollination and Fertilization.

Pollination is carried out by wind and occurs at 3 celled stage(a prothallial cell, a large tube cell and a small generative cell). Pollen grains gets lodged in the pollen chamber after pollination. The generative cell divides into a stalk and a body cell. The body cell divides to produce two large multiciliated antherozoids or sperms. During fertilization, one of the male gamete or multiciliated antherozoid fuses with the egg of the archegonium to form a diploid zygote (2n). The endosperm is haploid. The interval between pollination and fertilization is 4- 6 months. The zygote undergoes mitotic division and develops into embryo. The ovule is transformed into seed. The seed has two unequal cotyledons. Germination is hypogeal. The life cycle shows alternation of generations (Figure 2.47).

2.6.5 Pinus

Class – Coniferopsida

Order – Coniferales

Family –Pinaceae

Genus - *Pinus*

Pinus is a tall tree, looks conical in appearance and forms dense evergreen forest in the North temperate and sub-alpine regions of the world. They mostly grow in high altitudes (ranging from 1,200 to 3,000 metres). Some species of this genus include, *Pinus roxburghii, P. wallichiana, P. gerardiana* and *P. insularis.*

External features

The plant body is sporophyte and is differentiated into root, stem and leaves. The main stem is branched. The branches are dimorphic with long and short branches (Figure 2.48).

Figure 2.48: *Pinus* Habit

Root

Tap root system is found in *Pinus*. The root hairs are not well developed and the roots are covered with fungal hyphae called mycorrhizae.

Stem

The stem is cylindrical, erect, woody and branched. The branches are monopodial. The branches are of two types.

(i) Long shoots or branches of unlimited growth, (ii) Dwarf shoot or branches of limited growth

(i) Long shoots or branches of unlimited growth

The long shoot is present on the main trunk the apical buds grow indefinitely, They shorten gradually towards the tip, thus providing a pyramidal appearance to the tree. These branches bear scale leaves only.

(ii) Dwarf shoot or branches of limited growth

These branches do not have apical buds and hence show only limited growth. They develop in the axils of scale leaves and bear both scale and foliage leaves.

Leaves

There are two types of leaves 1. scale leaves, 2. foliage leaves

1. Scale leaves:

They are dark, brown, membranous, thin and small. They are present on both long and dwarf shoots. Their function is to protect young buds. The scale leaves on the dwarf shoots have a distinct midrib and are called "**Cataphylls**".

2. Foliage leaves:

The foliage leaves are green angular and needle like structures. They are borne on the dwarf shoot. A dwarf shoot with a group of needle like foliage leaves is known as **foliar spur**. The number of needles per dwarf shoot varies among the species. It may be one (*Pinus monophylla*), two (*P. sylvestris*), three (*P. geraradiana*), four (*P. quadrifolia*) and five (*P. excelsa*).

Internal Structure

T.S. of root

The internal structure of root reveals the presence of epiblema, cortex and stele.

The epiblema is made up of single layer of parenchymatous cells. Cortex is the wide zone and consists of parenchyma. Some of the cells have resin ducts. A single layered endodermis with suberised wall is present and is impregnated with tannins.A multilayered pericycle made up of parenchyma is present. Vascular tissue is radial, diarch with exarch xylem. The protoxylem bifurcates to form a 'Y' shaped structure and a resin duct lies in between the two arms of protoxylem. Secondary growth is present (Figure 2.49).

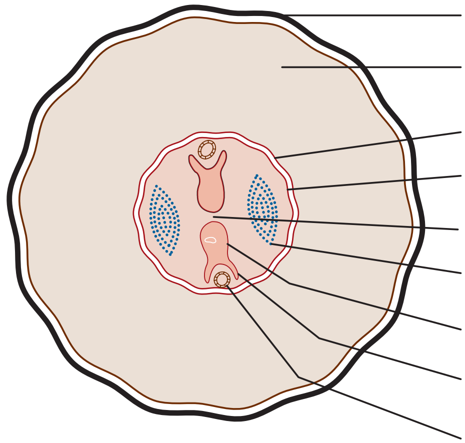


Figure 2.49: T.S. of *Pinus* root

T.S. of Stem

The internal organization of the stem shows three regions namely epidermis, Cortex and vascular tissue (Figure 2.50).

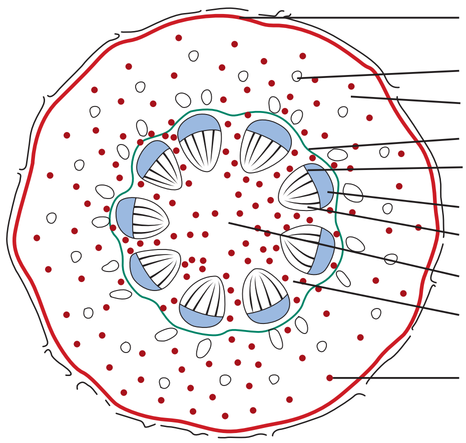


Figure 2.50: T.S. of *Pinus* stem

Epidermis is the outermost layer composed of compactly arranged and heavily cutinized cells. Epidermis is followed by few layers of sclerenchymatous hypodermis. The cortex consists of thin walled parenchyma cells. Resin canals and tannin filled cells are present in this region. Endodermis is indistinguishable from cortical cells. Vascular region is surrounded by pericycle. A ring consists of five or six vascular bundles are present. Vascular bundles are conjoint, collateral, open and endarch. Pith and medullary rays are present. Secondary growth is present and annual rings are formed.

T.S. of needle or foliage leaf

The internal structure of needle shows xerophytic adaptations. In cross section the outline appears more or less triangular and is divided into epidermis, mesophyll and vascular bundles. The epidermis is single layered and possesses thick cuticle and sunken stomata.Epidermis is followed by a few layers of sclerenchymatous hypodermis. It is interrupted by sub-stomatal cavities (Figure 2.51).

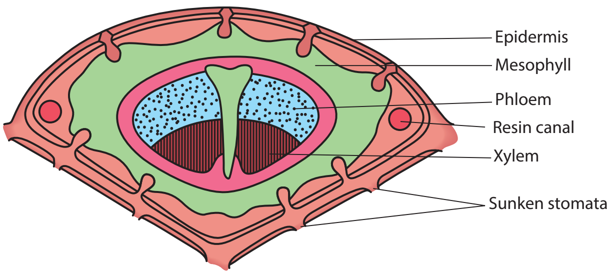


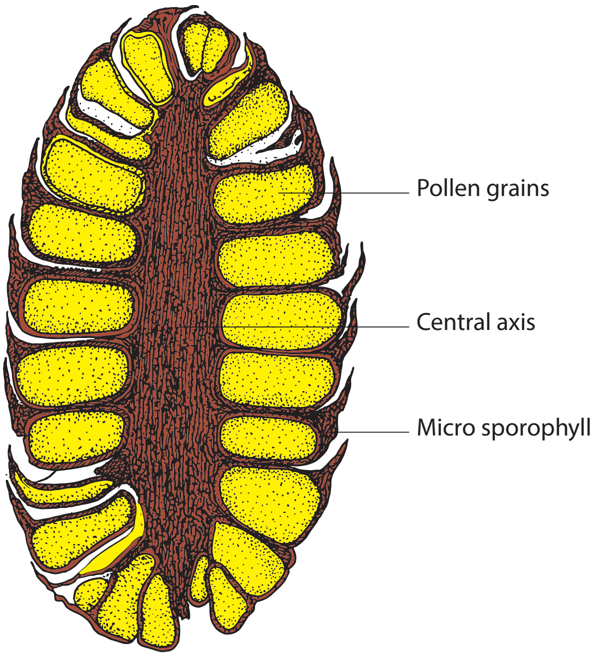
Figure 2.51: T.S. of *Pinus* needle leaf

Mesophyll is not differentiated into palisade and spongy parenchyma. Thin walled cells with chloroplasts are present. The cells are peculiar with numerous small infoldings which project into the cavities. The infoldings increase the photosynthetic area of the needle leaves Resin canal is present in the mesophyll. A single layered endodermis separates the vascular region from the cortex. A multilayered pericycle containing starch is present. Two types of specialised cells called **albuminous cells** and **tracheidal cells** are present. The former helps to pass substances from the mesophyll to the phloem while the latter helps in water conduction and constitutes transfusion tissue. Two vascular bundles are present. They are separated by sclerenchyma tissue. The Vascular bundles are conjoint, collateral and open.

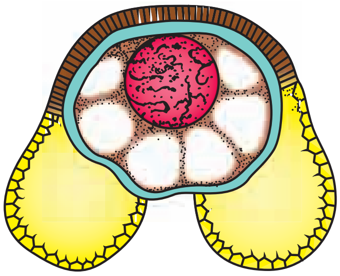
Reproduction

Pinus is heterosporous and produces two types of spores called. microspores and megaspores. The plants are monoecious. Both male and female cones or strobili develop on the different branches of the same plant (Figure 2.52).

a) *Pinus* - A twig with male cones

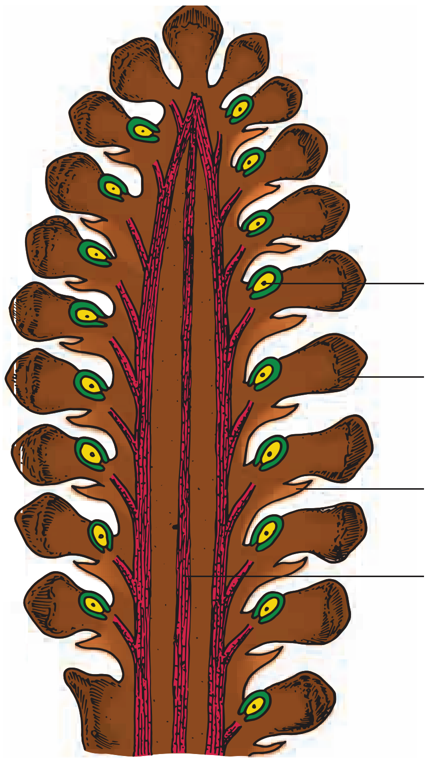


b) L.S. of male cone



c) A mature pollen grain

d) *Pinus* - A twig with female cone



e) L.S. of female cone

Figure 2.52: Reproduction in *Pinus*

Male cone

Male cones are produced in clusters on branches of unlimited growth. Each cone develops on the axil of scale leaf . The male cone consists of a centrally located cone axis surrounded by numerous spirally arranged microsporophyll. It bears two microsporangia at the base of the abaxial side of the microsporophyll. Each sporangium bears numerous winged microspores (n) or pollen grains. The microspores represent the male gametophyte

Female cone:-

Female cones are formed in the groups of 1 to 4 in the axils of the scale leaves. The female cone takes about three years to mature. It has the central axis around which megasporophylls are arranged spirally. The megasporophyll is the compound structure consisting of two types of scales. 1. Bract scale (sterile), and 2. Ovuliferous scales (fertile). The dorsal surface of each ovuliferous scale bears two ovules. Ovules bear megaspores which represent the female gametophyte.

Pollination and fertilization

In *Pinus* wind pollination takes place (Anemophilous). The microspore or pollen grain is released in the 4 celled stage(two prothallial cell, 1 generative and 1 tube cell). At the time of pollination a secretion oozes out from the micropyle of the ovule which entangles pollen grains which helps to lodge them in the pollen chamber. The tube cell protrudes to form pollen tube. The generative cell divides to produce stalk cell and body cell. The body cell divides into unequal male cells. Fertilization takes place after about a year of pollination. The pollen tube containing two male nuclei penetrates through the micropyle and reaches the egg. One of the male nuclei fuses with the egg forming diploid zygote and the remaning one gets degenerated. The fertilized egg

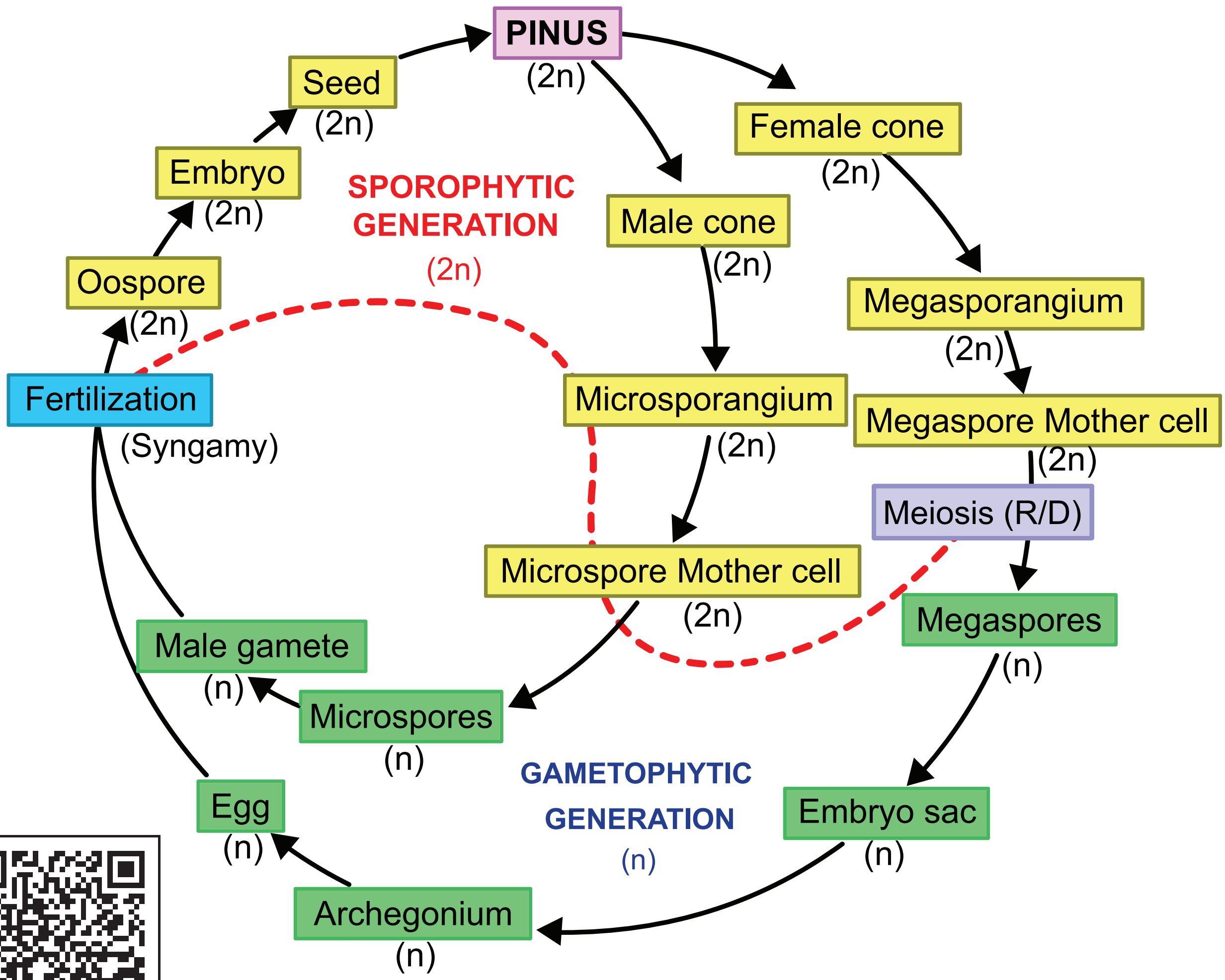


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Figure 2.53: Life cycle of *Pinus*

(zygote) undergoes mitotic division and develops into an embryo. Polyembryony is present. The embryo undergoes several changes and finally becomes a winged seed. The seed germination is epigeal. Life cycle of *Pinus* shows alternation of generation (Figure 2.53).

Know about Fossil plants

The National wood fossil park is situated in Tiruvakkarai, a Village of Villupuram district of Tamil Nadu. The park contains petrified wood fossils approximately 20 million years old. The term 'form genera' is used to name the fossil plants because the whole plant is not recovered as fossils instead organs or

Prof. Birbal Sahni (1891-1949)

Father of Indian Palaeobotany. He described Fossil plants from Rajmahal Hills of Eastern Bihar. *Pentoxylon sahnii*, *Nipanioxylon* are some of the form genera described by him. Birbal Sahni Institute of Palaebotany is located in Lucknow parts of the extinct plants are obtained in fragments. Shiwalik fossil park-Himachal Pradesh, Mandla Fossil park-Madhya Pradesh, Rajmahal Hills–Jharkhand, Ariyalur – Tamilnadu are some of the fossil rich sites of India.

Some of the fossil representatives of different plant groups are given below

Fossil algae - *Palaeoporella*, *Dimorphosiphon*

Fossil Bryophytes – *Naiadita, Hepaticites, Muscites*

Fossil Pteridophytes – *Cooksonia, Rhynia,, Baragwanthia, Calamites*

Fossil Gymnosperms – *Medullosa, Lepidocarpon, Williamsonia, Lepidodendron*

Fossil Angiosperms – *Archaeanthus, Furcula*

2.7 Angiosperms

In the previous lesson the characteristic features of one of the spermatophyte called Gymnosperms were discussed. Spermatophytes also include plants bearing ovules enclosed in a protective cover called ovary, such plants are called Angiosperms. They constitute major plant group of our earth and are adapted to the terrestrial mode of life. This group of plants appeared during the early cretaceous period (140 million years ago) and dominates the vegetation on a world scale. The sporophyte is the dominant phase and gametophyte is highly reduced.

2.7.1 Salient features of Angiosperms

- Vascular tissue (Xylem and Phloem) is well developed.
- Flowers are produced instead of cone
- The embryosac (Ovule) remains enclosed in the ovary.
- Pollen tube helps in fertilization, so water is not essential for fertilization.
- Double fertilization is present. The endosperm is triploid.
- Angiosperms are broadly classified into two classes namely Dicotyledons and Monocotyledons.

2.7.2 Characteristic features of Dicotyledons and Monocotyledons

Dicotyledons

Morphological features

Reticulate venation is present in the leaves. Presence of two cotyledons in the seed. Primary root radicle persists as Tap root.

Flowers tetramerous or pentamerous.

Tricolpate (3 furrow) pollen is present.

Anatomical features

- Vascular bundles are arranged in the form of a ring in stem.
- Vascular bundles are open (Cambium present).
- Secondary growth is present.

Monocotyledons

Morphological features

Parallel venation is present in the leaves. Presence of single cotyledon in the seed.

Radicle doesn't persist and fibrous root is present.

Flowers trimerous.

Monocolpate (1 furrow) Pollen is present.

Anatomical features

- Vascular bundles are scattered in the stem
- Vascular bundles are closed (Cambium absent).
- Secondary growth is absent.

Current Angiosperm Phylogeny Group (APG) System of classification doesn't recognize dicots as a monophyletic group. Plants that are traditionally classified under dicots are dispersed in several clades such as early Magnolids and Eudicots.

Summary

Plant Kingdom includes Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms

The life cycle in plants fall under three types 1. Haplontic,2. Diplontic and 3.Haplodiplontic

Algae are autotrophic, chlorophyll bearing organisms. The Plant body is not differentiated into root like, stem like or leaf like structures. A wide range of thallus organization is found in algae. They reproduce vegetatively through fragmentation, tuber and akinete formation. Zoospores , autospores and hypnospores are produced during asexual reproduction .and Sexual reproduction occurs through isogamy, anisogamy and oogamy.

Oedogonium is a fresh water, filamentous, multicellular alga. The presence of cap cell is the prominent characteristic feature in addition reticulate chloroplast is present. Asexual reproduction takes place through Zoospores. The sexual reproduction is Oogamous.

Chara is a fresh water alga and is popularly called "Stone worts". The plant body is multicellular, macroscopic and is differentiated into main axis and rhizoids. Sexual reproduction is Oogamous.

Bryophytes are simplest land plants. They are called amphibians of plant kingdom or nonvascular cryptogams. The plant body is gametophyte. The sporophyte depends upon gametophyte. Conducting tissues like xylem and phloem is absent. Vegetative reproduction takes place through fragmentation, formation of adventitious bud and Gemmae. Sexual reproduction is Oogamous. Water is essential for fertilization.

Marchantia belongs to the class Hepaticopsida. The thallus is dorsiventral and is attached to the substratum by means of rhizoids. The internal structure of the thallus reveals the presence of photosynthetic region and a storage region. Vegetative reproduction takes place through fragmentation and formation of Gemmae. The sexual reproduction is Oogamous. Sporophyte bears spores. Alternation of generation is present.

Funaria belongs to the class Bryopsida. The gametophyte is differentiated into leaf-like, stem-like structures with rhizoids. Gemmae, Protonema and bulbils help in asexual reproduction. Sexual reproduction is Oogamous. Alternation of generation is present.

Pteridophytes are also called vascular cryptogams. The plant body is sporophyte and is long lived ,which is differentiated into root, stem and leaves. They may be homosporous or heterosporous.

The sporangia with spores are found in sporophylls. The sporophylls organise to form cones or strobilus. The spores germinates to produce haploid, multicellular heart shaped independent gametophyte called prothallus. Sexual reproduction is Oogamous. The life cycle shows Alternation of generation.

The term stele includes central cylinder of vascular tissues comprising xylem, phloem, pericycle, endodermis and pith . There are two major types of stele namely Protostele and Siphonostele.

Selaginella belongs to the class Lycopsida. The plant body is sporophyte. It is differentiated into stem, leaf, rhizophore and roots. Heterospory is found and two types of spores namely microspores and megaspores are produced in sporangia. The microsporangia and megasporania are borne on sporophylls. The sporophylls are organized to form cone. Sexual reproduction is oogamous. Alternation of generation is present.

Adiantum belongs to Pteropsida. The sporophyte is differentiated into root, rhizome and leaves. The spores are produced in sporangia and is covered by false indusium. The sexual reproduction is oogamous and sex organs (antheridum and archegonium) are produced on prothallus. Alternation of generation is present.

Gymnosperms are naked seed producing plants. The plant body is sporophyte and it is the dominant phase. Coralloid roots are found in *Cycas*. The roots of *Pinus* possess Mycorrhizal association .Two types of branches called Long shoot and dwarf shoot are present. Stem shows secondary growth. Spores are produced in cones. Pollen tube helps in fertilization.. The endosperm is haploid . Alternation of generation is present

Cycas belongs to Cycadopsida. The plant body is sporophyte and looks like a small palm tree. Apart from Taproot Coralloid roots are present. It is dioecious, Microsporophylls are organized into male cone. Ovules are borne on megasporophylls which are not organized into cone. Fertilization results in zygote and it develops into embryo. Alternation of generation is present.

Pinus belongs to Coniferopsida.. The plant body is sporophyte and is differentiated into root, stem and leaves. The main stem is branched. The branches are dimorphic with long and short branches. It is monoecious, heterosporous and produces two types of spores called microspores and megaspores. Alternation of generation is present.

Angiosperms are highly evolved plant group and their ovules remain enclosed in an ovary. A wide range of habit is present.. These include trees, shrubs, herbs, climbers, lianas. Double fertilization is present. The endosperm is triploid. They are classified into Dicotyledons and Monocotyledons.

Evaluation

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1. Which of the plant group has gametophyte as a dominant phase?
   a. Pteridophytes
   b. Bryophytes
   c. Gymnosperm
   d. Angiosperm
2. Which of following represent gametophytic generation in pteridophytes?
   a. Prothallus
   b. Thallus

c. Cone

d. Rhizophore

3. The haploid number of chromosome for an Angiosperm is 14 , the number of chromosome in its endosperm would be

   a. 7   b. 14   c. 42   d. 28

4. Endosperm in Gymnosperm is formed
   a. At the time of fertilization
   b. Before fertilization
   c. After fertilization
   d. Along with the development of embryo
5. Differentiate halpontic and diplontic life cycle.
6. What is plectostele? give example.
7. What do you infer from the term pycnoxylic?
8. Mention two characters shared by gymnosperms and angiosperms.
9. Do you think shape of chloroplast is unique for algae. Justify your answer?
10. Do you agree with the statement 'Bryophytes need water for fertilization'? Justify your answer.
11. List the classes of algae.
12. Mention the pigments and storage food of Dinophyceae.
13. What are cap cells?
14. Name the flagellation found in the zoospore of *Oedogonium*
15. What is Nucule?
16. Differentiate nodal and internodal cells of *Chara*.
17. What are elaters?
18. What is protonema?
19. Where do we find false indusium?
20. Explain the internal structure of *Cycas* rachis.
21. Differentiate long and dwarf shoot.

ICT Corner

Different forms of plants

Is all the **plants** are same? →

Steps

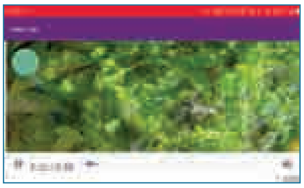
- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Characteristics of plants
- Click theory to know the basic about Characteristics of plants
- Register yourself with mail-id and create password to access online lab simulations

Activity

- Select video and record your observations of different forms of plant group.

Step 1

Step 2



Step 3

Step 4

URL:

https://play.google.com/store/apps/details?id=in.edu.olabs.olabs&hl=en

Alternate web:

http://www.phschool.com/atschool/phbio/active_art/plant_life_cycle/plantlifecycle.swf

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* Pictures are indicative only

Unit II: Plant Morphology and Taxonomy of Angiosperm

Chapter 3

Vegetative Morphology

Learning Objectives

The learner will be able to,

- *Explore the parts of the flowering plants*
- *Differentiate vegetative morphology and reproductive morphology*
- *Compare various root systems and their modifications*
- *Understand the stem modifications and functions*
- *Interpret the structure of leaf and functions of leaf*

Chapter Outline

3.1 Habit
3.2 Plant habitat
3.3 Life Span
3.4 Parts of a flowering plant
3.5 Root System
3.6 Shoot system
3.7 Leaf

The study of various external features of the organism is known as **morphology. Plant morphology** also known as **external morphology** deals with the study of shape, size and structure of plants and their parts (roots, stems, leaves, flowers, fruits and seeds). Study of morphology is important in taxonomy. Morphological features are important in determining productivity of crops. Morphological characters indicate the specific habitats of living as well as the fossil plants and help to correlate the distribution in space and time of fossil plants. Morphological features are also significant for phylogeny.

Plant Morphology can be studied under two broad categories:

A. **Vegetative morphology** – It includes shoot system and root system
B. **Reproductive morphology** – It includes Flower/inflorescence, Fruit and Seed

A. Vegetative morphology

Vegetative morphology deals with the study of shape, size and structure of plants and their parts roots, stems and leaves. To understand the vegetative morphology the following important components are to be studied. They are, 1) Habit, 2) Habitat and 3) Lifespan.

3.1 Habit

The general form of a plant is referred to as habit. Based on habit plants are classified into herbs, shrubs, climbers (vines) and trees.

I. Herbs

Herbs are soft stemmed plants with less wood or no wood. According to the duration of their life they may be classified as **annuals**, **biennials** and **perennials**. Perennial herbs having a bulb, corm, rhizome or tuber as the underground stem are termed as **geophytes.** Example: *Phyllanthus amarus, Cleome viscosa.*

II. Shrubs

A shrub is a perennial, woody plant with several main stems arising from the ground level. Example: *Hibiscus*

III. Climbers (Vine)

An elongated weak stem generally supported by means of climbing devices are called **Climbers** (vines) which may be annual or perennial, herbaceous or woody. **Liana** is a vine that is perennial and woody. Liana's are major components in the tree canopy layer of some tropical forests. Example: *Ventilago, Entada, Bougainvillea.*

IV. Trees

A tree is a stout, tall, perennial, woody plant having one main stem called **trunk** with many lateral branches. Example: mango, sapota, jack, fig, teak. If the trunk remains unbranched it is said to be **caudex.** Example: Palmyra, coconut.

3.2 Plant habitat

Depending upon where plants grow habitats may be classified into major categories: I. Terrestrial and II.Aquatic.

I. Terrestrial

Plants growing on land are called **terrestrial plants.** The following table illustrate the types of terrestrial plants classified based on their environmental adaptation.

II. Aquatic

Plants that are living in water environment are called **aquatic plants** or hydrophytes.

3.3 Life Span

Based on life span plants are classified into 3 types. They are annual, biennial and perennial

Terrestrial habitat		
Types	**Nature of environmental adaptation**	**Example**
Mesophytes	Growing in soils with sufficient water	*Azadirachta indica*
Xerophytes	Growing on dry habitats	*Opuntia*, *Euphorbia*
Psammophytes	Growing on sand	*Ipomoea pes-caprae, Spinifex littoralis*
Lithophytes	Growing on rock	Many algae and lichens, *Ficus spp*

Aquatic habitat		
Types	**Nature of environmental adaptation**	**Example**
Free Floating	Growing on water surface	*Eichhornia, Trapa, Pistia, Lemna*
Submerged	Plants growing completely under water	*Hydrilla, Vallisneria*
Emergent	Plants with roots or stems anchored to the substrate under water and aerial shoots growing above water	*Limnophyton, Typha*
Floating leaved	Anchored at bottom but with floating leaves	*Nelumbo, Nymphaea*
Mangroves	Plants growing emergent in marshy saline habitat	*Avicennia, Rhizophora*

I. Annual (Therophyte or Ephemerals)

A plant that completes its life cycle in one growing season. Example: Peas, maize, water melon, groundnut, sunflower, rice and so on.

II. Biennial

A plant that lives for two seasons, growing vegetatively during the first season and flowering and fruiting during the second season. Example: Onion, Lettuce, Fennel, Carrot, Radish, Cabbage and Spinach.

III. Perennial (Geophyte)

A plant that grows for many years that flowers and set fruits for several seasons during the life span. When they bear fruits every year, they are called **polycarpic.** Example: mango, sapota. Some plants produce flowers and fruits only once and die after a vegetative growth of several years. These plants are called **monocarpic**. Example: *Bamboo, Agave, Musa, Talipot palm.*

3.4 Parts of a flowering plant

Flowering plants are called **"Angiosperms"** or **Magnoliophytes**. They are sporophytes consisting of an axis with an underground **"Root system"** and an aerial **"Shoot System".** The shoot system has a stem, branches and leaves. The root system consists of root and its lateral branches.

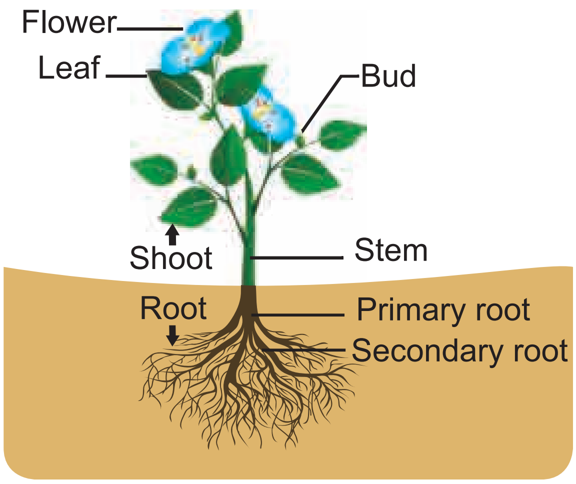


Figure: 3.1: Parts of a flowering plant

3.5 Root System

The root is non-green, cylindrical descending axis of the plant that usually grows into the soil (positively geotropic). It develops from the radicle which is the first structure that comes out when a seed is placed in the soil. Root is responsible for absorption of water and nutrients and anchoring the plant.

I. Characteristic features

- Root is the descending portion of the plant axis.
- Generally non-green in colour as it lacks chlorophyll.
- Does not possess nodes, internodes and buds (Exception in sweet potato and members of Rutaceae, roots bear buds which help in vegetative propagation)
- It bears root hairs (To absorb water and minerals from the soil)
- It is positively geotropic and negatively phototropic in nature.

II. Regions of root

Root tip is covered by a dome shaped parenchymatous cells called **root cap.** It protects the meristematic cells in the apex. In *Pandanus* multiple root cap is present. In *Pistia* instead of root cap root pocket is present. A few millimeters above the root cap the following three distinct zones have been classified based on their meristematic activity.

1. Meristematic Zone
2. Zone of Elongation
3. Zone of Maturation

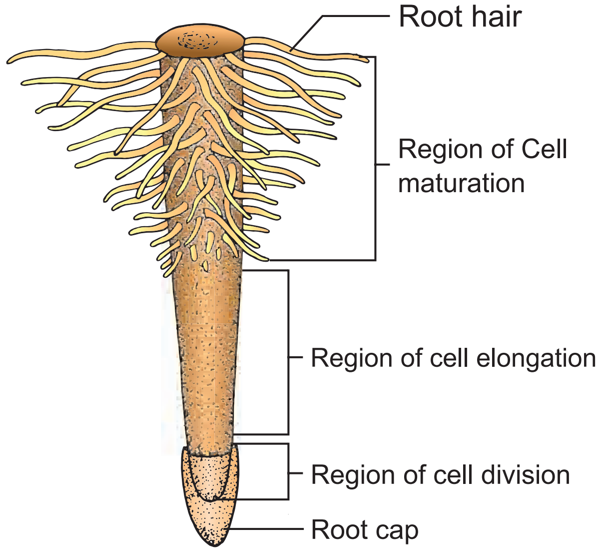


Figure 3.2: Regions of root

Table: Root zones			
Feature	**1. Meristematic Zone (Region of cell division)**	**2. Zone of Elongation**	**3. Zone of Maturation**
Position	It lies just above the root cap	It lies just above the meristematic zone	It lies above the zone of elongation.
Types of cells	Meristematic cells, actively divide and continuously increase in number	Elongated cells	Mature differentiated cells
Functions	This is the main growing tip of the root	The cells increase the length and cause enlargement of the root.	The cells differentiate into various tissues like epidermis, cortex and vascular bundles. It also produces root hairs which absorb water and minerals from the soil

3.5.1 Types of root

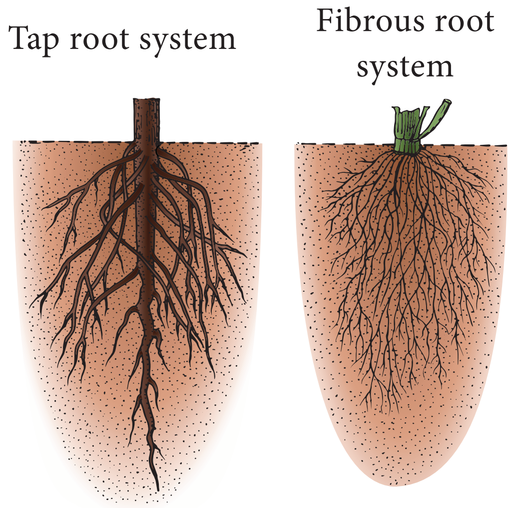


Figure 3.3: Types of root system

I. Tap root system

Primary root is the direct prolongation of the radicle. When the primary root persists and continues to grow as in dicotyledons, it forms the main root of the plant and is called the **tap root.** Tap root produces lateral roots that further branches into finer roots. Lateral roots along with its branches together called as **secondary roots**.

II. Adventitious root system

Root developing from any part of the plant other than radicle is called **adventitious** root. It may develop from the base of the stem or nodes or internodes. Example: *Monstera deliciosa, Ficus benghalensis, Piper nigrum*. In most of the monocots the primary root of the seedling is short lived and lateral roots arise from various regions of the plant body. These are bunch of thread-like roots equal in size which are collectively called **fibrous** root system generally found in grasses. Example: *Oryza sativa, Eleusine coracana, Pennisetum americanum*.

III. Functions of root

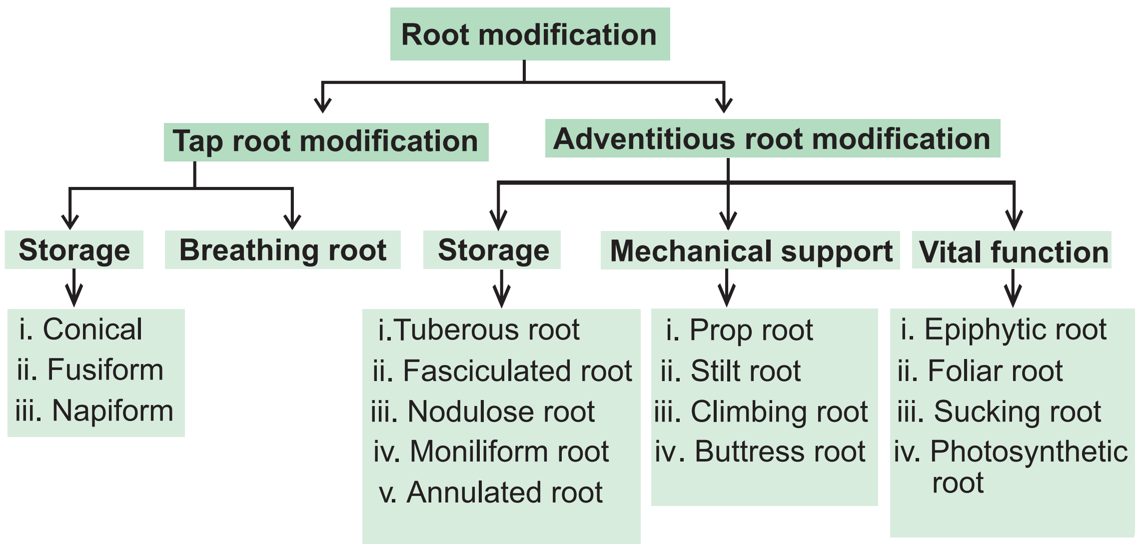
Root performs two kinds of functions namely primary and secondary functions.

Primary function

1. Absorb water and minerals from soil.
2. Help to anchor the plant firmly in the soil.

Secondary function

In some plants roots perform additional functions. These are called **secondary functions.** To perform additional functions, these roots are modified in their structure.



3.5.2 Modifications of root

I. Tap root modification

a. Storage roots

1. Conical Root

These are cone like, broad at the base and gradually tapering towards the apex. Example: *Daucus carota*.

2. Fusiform root

These roots are swollen in the middle and tapering towards both ends. Example: *Raphanus sativus*

3. Napiform root

It is very broad and suddenly tapers like a tail at the apex. Example: *Beta vulgaris*

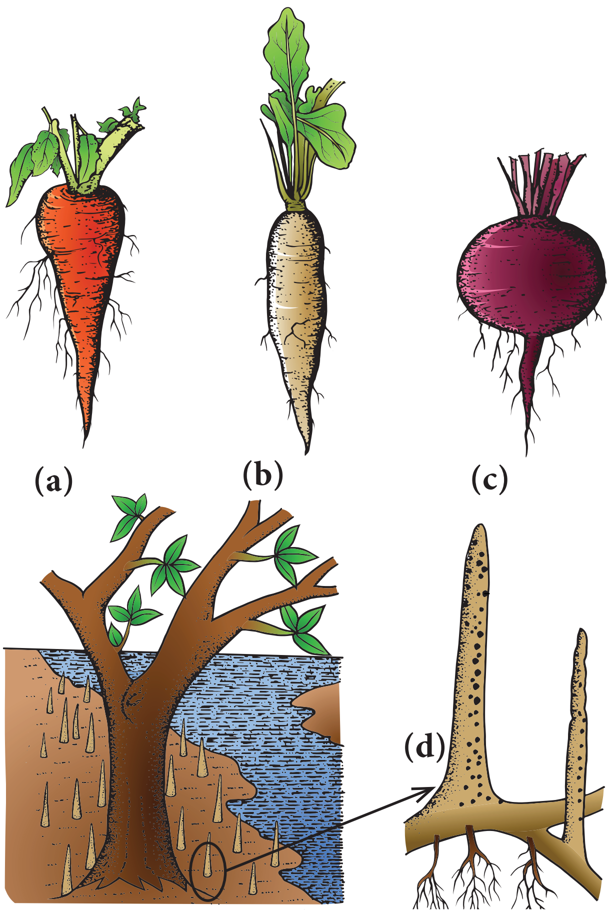


Figure 3.4: Tap root modification
(a) *Daucus carota* **(b)** *Raphanus sativus*
(c) *Beta vulgaris* **(d)** *Avicennia - pneumatophores*

b. Breathing root

Some mangrove plants like ***Avicennia, Rhizophora, Bruguiera*** develop special kinds of roots (Negatively geotropic) for respiration because the soil becomes saturated with water and aeration is very poor. They have a large number of breathing pores or pneumatophores for exchange of gases.

II. Adventitious root modification

a. Storage roots

1. Tuberous root

These roots are swollen without any definite shape. Tuberous roots are produced singly and not in clusters. Example: *Ipomoea batatas.*

2. Fasciculated root

These roots are in cluster from the base of the stem Example: *Dahlia, Asparagus, Ruellia.*

3. Nodulose root

In this type of roots swelling occurs only near the tips. Example: *Maranta* (arrow root) *Curcuma amada* (mango ginger), *Curcuma longa* (turmeric)

4. Moniliform or Beaded root

These roots swell at frequent intervals giving them a beaded appearance. Example: *Vitis, Portulaca, Momordica, Basella* (Indian spinach).

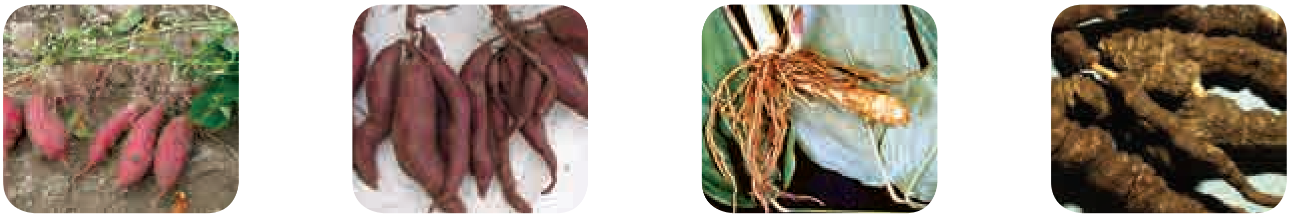
5. Annulated root

These roots have a series of ring- like swelling on their surface at regular intervals. Example: *Psychotria* (Ipecac)

b. Mechanical support

1. Prop (Pillar) root

These roots grow vertically downward from the lateral branches into the soil.



Ipomoea batatas *Dahlia* *Maranta* *Psychotria*

Figure 3.5: Adventitious Root Modification for Storage

Example: *Ficus benghalensis* (banyan tree), Indian rubber.

2. Stilt (Brace) root

These are thick roots growing obliquely from the basal nodes of the main stem. These provide mechanical support. Example: *Saccharum officinarum*, *Zeamays*, *Pandanus*, *Rhizophora*.

3. Climbing (clasping or clinging) roots

These roots are produced from the nodes of the stem which attach themselves to the support and help in climbing. To ensure a foothold on the support they secrete a sticky juice which dries up in air, attaching the roots to the support. Example: *Epipremnum pinnatum*, *Piper betel*, *Ficus pumila*.

4. Buttress root

In certain trees broad plank like outgrowths develop towards the base all around the trunk. They grow obliquely downwards and give support to huge trunks of trees. This is an adaptation for tall rain forest trees. Example: *Bombax ceiba* (Red silk cotton tree), *Ceiba pentandra* (white silk cotton tree), *Terminalia arjuna*, *Delonix regia*, *Pterygota alata*.

c. Vital functions

1. Epiphytic or velamen root

Some epiphytic orchids develop a special kind of aerial roots which hang freely in the air. These roots develop a spongy tissue called **velamen** which helps in absorption of moisture from the surrounding air. Example: *Vanda*, *Dendrobium*, *Aerides*.

2. Foliar root

Roots are produced from the veins or lamina of the leaf for the formation of new plant. Example: *Bryophyllum*, *Begonia*, *Zamioculcas*.

Ficus benghalensis *Saccharum officinarum* *Epipremnum pinnatum* *Bombax*

Figure 3.6: Adventitious root modification for mechanical support

3. Sucking or Haustorial roots

These roots are found in parasitic plants. Parasites develop adventitious roots from stem which penetrate into the tissue of the host plant and suck nutrients.

Example: *Cuscuta* (dodder), *Cassytha*, *Orobanche* (broomrape), *Viscum* (mistletoe), *Dendrophthoe*.

4. Photosynthetic or assimilatory roots

Roots of some climbing or epiphytic plants develop chlorophyll and turn green which help in photosynthesis. Example: *Tinospora*, *Trapa natans* (water chestnut), *Taeniophyllum*.

3.6 Shoot system

The plumule of the embryo of a germinating seed grows into stem. The epicotyl elongates after embryo growth into the axis (the stem) that bears leaves from its tip, which contain the actively dividing cells of the shoot called **apical meristem.** Further cell divisions and growth result in the formation of mass of tissue called **a leaf primordium.** The point from which the leaf arises is called **node**. The region between two adjacent nodes is called **internode.**

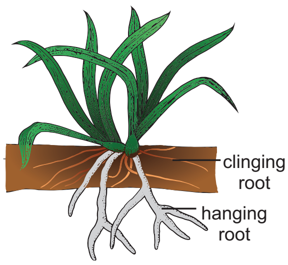
I. Characteristic features of the stem

1. The stem is usually the aerial portion of the plant
2. It is positively phototropic and negatively geotropic
3. It has nodes and internodes.
4. Stem bears vegetative bud for vegetative growth of the plant, and floral buds for reproduction, and ends in a terminal bud.
5. The young stem is green and thus carries out photosynthesis.
6. During reproductive growth stem bears flowers and fruits.
7. Branches arise exogenously
8. Some stems bears multicellular hairs of different kinds.

II. Functions of the stem

Primary functions

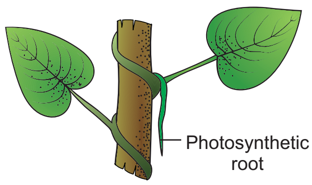
1. Provides support and bears leaves, flowers and fruits.
2. It transports water and mineral nutrients to the other parts from the root.
3. It transports food prepared by leaves to other parts of the plant body.



Vanda

Bryophyllum

Cuscuta



Tinospora

Figure 3.7: Adventitious Root Modification for Vital Functions

Secondary functions

1. **Food storage**- Example: *Solanum tuberosum, Colocasia* and *Zingiber officinale*
2. **Perennation / reproduction** – Example: *Zingiber officinale, Curcuma longa*
3. **Water storage** – Example: *Opuntia*
4. **Bouyancy** – Example: *Neptunia*
5. **Photosynthesis** – Example: *Opuntia, Ruscus, Casuarina, Euphorbia, Caralluma.*
6. **Protection** – Example: *Citrus, Duranta, Bougainvillea, Acacia, Fluggea, Carissa.*
7. **Support** - Example: *Passiflora, Bougainvillea, Vitis, Cissus quadrangularis.*

3.6.1 Buds

Buds are the growing points surrounded by protective scale leaves. The bud primordium matures into bud. They have compressed axis in which the internodes are not elongated and the young leaves are closed and crowded. When these buds develop, the internodes elongate and the leaves spread out. Buds have architecture identical to the original shoot and develop into lateral branches or may terminate by developing into a flower or inflorescence. Based on Origin Buds are classified into (a) Terminal or Apical bud (b) Lateral or Axillary or Axil bud. Based on Function Buds classified into (a) Vegetative bud (b) Floral or Reproductive bud

1. **Terminal bud or apical bud:** These buds are present at the apex of the main stem and at the tips of the branches.
2. **Lateral bud or Axillary bud:** These buds occur in the axil of the leaves and develop into a branch or flower.
3. **Extra axillary bud :** These buds are formed at nodes but outside the axil of the leaf as in *Solanum americanum.*
4. **Accessory bud :** An extra bud on either side (collateral bud) or above (superposed bud or serial bud) the axillary bud. Example: *Citrus* and *Duranta*
5. **Adventitious buds:** Buds arising at any part other than stem are known as **adventitious bud. Radical buds** are those that arises from the lateral roots which grow into plantlets. Example: *Millingtonia, Bergera koenigii (Murraya koenigii), Coffea arabica* and *Aegle marmelos*. **Foliar buds** are those that grow on leaves from veins or from margins of the leaves. Example: *Begonia* (Elephant ear plant) and *Bryophyllum* (Sprout leaf plant). **Cauline buds** arise directly from the stem either from cut, pruned ends or from branches. Adventitious buds function as propagules which are produced on the stem as tuberous structures. Example: *Dioscorea, Agave*.
6. **Bulbils (or specialized buds) :** Bulbils are modified and enlarged bud, meant for propagation. When bulbils detach from parent plant and fall on the ground, they germinate into new plants and serve as a means of vegetative propagation. In *Agave* and *Allium proliferum* floral buds get modified into bulbils. In *Lilium bulbiferum* and *Dioscorea bulbifera,* the bulbils develop in axil of leaves. In *Oxalis*, they develop just above the swollen root.

3.6.2 Types of Stem

Majority of angiosperm possess upright, vertically growing erect stem. They are (i) Excurrent, (ii) Decurrent, (iii) Caudex, (iv) Culm.

i. Excurrent

The main axis shows continuous growth and the lateral branches gradually becoming shorter towards the apex which gives a conical appearance to the trees. Example: *Polyalthia longifolia, Casuarina.*

ii. Decurrent

The growth of lateral branch is more vigorous than that of main axis. The tree has a rounded or spreading appearance. Example: *Mangifera indica, Azadirachta indica, Tamarindus indicus, Aegle marmelos*

iii. Caudex

It's an unbranched, stout, cylindrical stem, marked with scars of fallen leaves. Example: *Cocus nucifera, Borassus flabelliformis, Areca catechu*

iv. Culm

Erect stems with distinct nodes and usually hollow internodes clasped by leaf sheaths. Example: Majority of grasses including Bamboo.

3.6.3 Modification of Stem

I. Aerial modification of stem

1. Creepers

These are plants growing closer (horizontally) to the ground and produces roots at each node. Example: *Cynodon dactylon, Oxalis, Centella*

2. Trailers (Stragglers)

It is a weak stem that spreads over the surface of the ground without rooting at nodes. They are divided into 3 types,

i. **Prostrate (Procumbent):** A stem that grows flat on the ground. Example: *Evolvulus alsinoides, Indigofera prostrata.*

ii. **Decumbent:** A stem that grows flat but becomes erect during reproductive stage. Example: *Portulaca, Tridax, Lindenbergia*

iii. **Diffuse:** A trailing stem with spreading branches. Example: *Boerhaavia diffusa, Merremia tridentata*

3. Climbers

These plants have long weak stem and produce special organs for attachment for climbing over a support. Climbing helps to display the leaves towards sunlight and to position the flower for effective pollination.

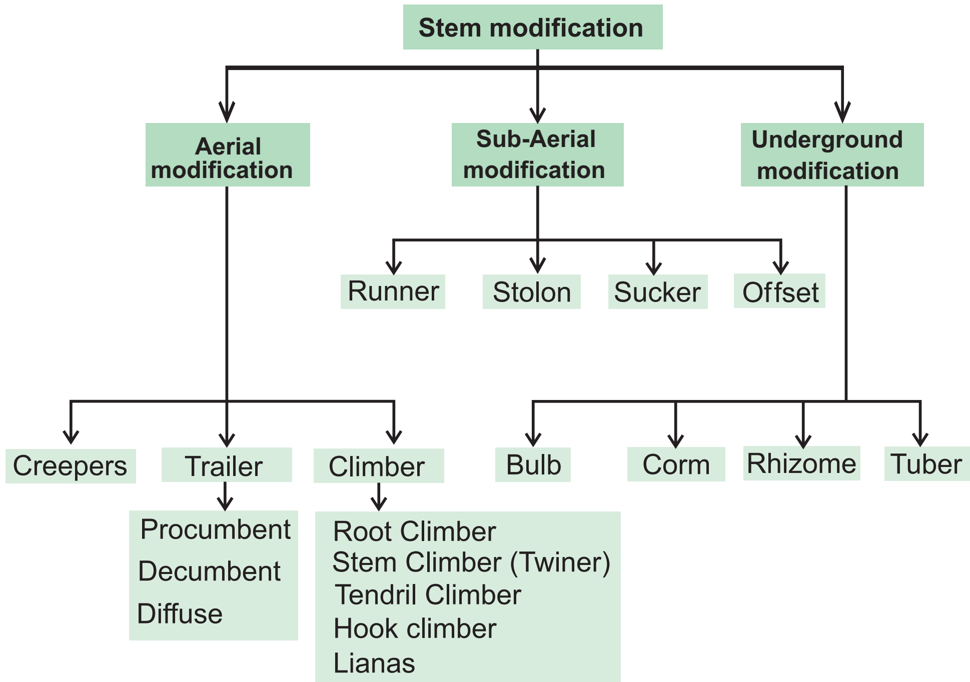
i. Root climbers

Plants climbing with the help of adventitious roots (arise from nodes) as in species of *Piper betel, Piper nigrum, Hedera helix, Pothos, Hoya.*

ii. Stem climbers (twiners)

These climbers lack specialised structure for climbing and the stem itself coils around the support. Example: *Ipomoea, Convolvulus, Dolichos, Clitoria, Quisqualis.*

Stem climbers may coil around the support clockwise or anti-clockwise. Clockwise coiling climbers are called **dextrose.** Example: *Dioscorea alata*. Anti-clockwise coiling climbers are called **sinistrose.** Example: *Dioscorea bulbifera*.



iii. Hook climbers

These plants produce specialized hook like structures which are the modification of various organs of the plant. In *Artabotrys* inflorescence axis is modified into hook. In *calamus* (curved hook) leaf tip is modified into hook. In *Bignonia unguis-cati* the leaflets are modified into curved hook (figure: 3.17). In *Hugonia* the axillary buds modified into hook.

iv. Thorn climbers

Climbing or reclining on the support with the help of thorns as in *Bougainvillea* and *Carissa*.

v. Lianas (woody stem climber)

Woody perennial climbers found in tropical forests are lianas. They twine themselves around tall trees to get light. Example: *Hiptage benghalensis, Bauhinia vahlii, Entada pursaetha.*

vi. Tendril climbers

Tendrils are thread-like coiling structures which help the plants in climbing. Tendrils may be modifications of Stem – as in *Passiflora*, *Vitis* and *Cissus quadrangularis;* Inflorescence axis – *Antigonon;* Leaf – *Lathyrus;* Leaflets - *Pisum sativum;* Petiole – *Clematis;* Leaftip – *Gloriosa;* Stipules – *Smilax*. In pitcher plant (*Nepenthes*) the midrib of the leaf often coils around a support like a tendril and holds the pitcher in a vertical position.

Phylloclade

This is a green, flattened cylindrical or angled stem or branch of unlimited growth, consisting of a series of nodes and internodes at long or short intervals. Phylloclade is characteristic adaptation of xerophytes where the leaves often fall off early and modified into spines or scales to reduce transpiration. The phylloclade takes over all the functions of leaves, particularly photosynthesis. The phylloclade is also called as **cladophyll.** Example: *Opuntia, Phyllocactus, Muehlenbeckia* (flattened phylloclade) *Casuarina, Euphorbia tirucalli, Euphorbia antiquorum* (cylindrical phylloclade).

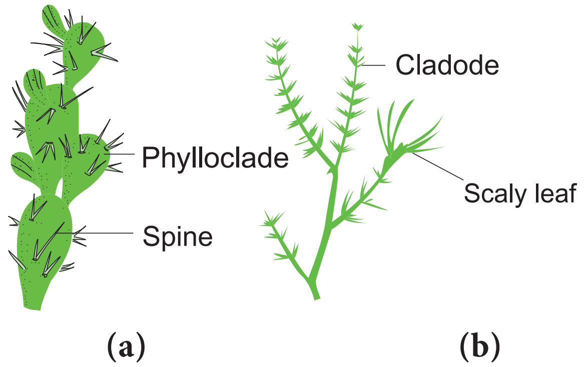


Figure 3.8: (a) Phylloclade-*Opuntia*
(b) Cladode-*Asparagus*

Cladode

Cladode is a flattened or cylindrical stem similar to Phylloclade but with one or two internodes only. Their stem nature is evident by the fact that they bear buds, scales and flowers. Example: *Asparagus* (cylindrical cladode), *Ruscus* (flattened Cladode).

Thorns

Thorn is a woody and sharp pointed modified stem. Either the axillary bud or the terminal bud gets modified into thorns. In *Carissa* apical bud modified into thorns. In *Citrus* and *Atalantia* axillary bud is modified into thorns.

II. Sub aerial stem modifications

Sub aerial stem found in plants with weak stem in which branches lie horizontally on the ground. These are meant for vegetative propagation. They may be sub aerial or partially sub terranean.

1. Runner

This is a slender, prostrate branch creeping on the ground and rooting at the nodes. Example: *Centella* (Indian pennywort), *Oxalis* (wood sorrel), lawn grass (*Cynodon dactylon*).

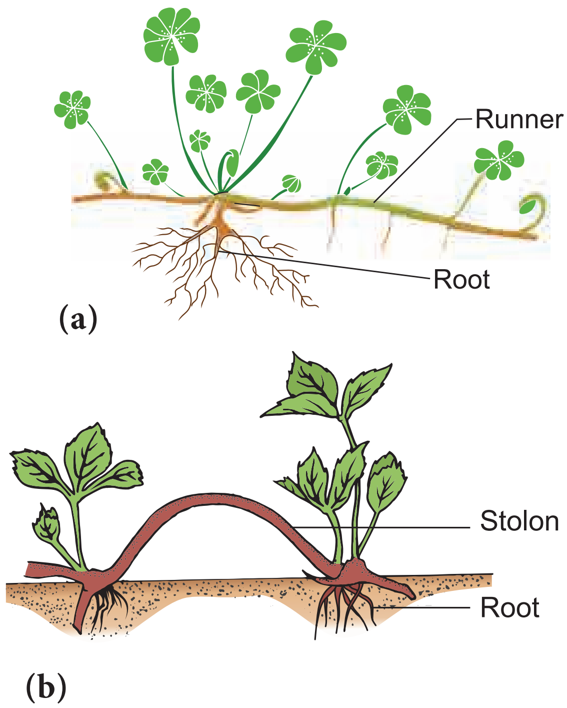


Figure 3.9: **(a)** Runner-*Oxalis*
(b) Stolon-*Fragaria*

2. Stolon

This is also a slender, lateral branch originating from the base of the stem. But it first grows obliquely above the ground, produces a loop and bends down towards the ground. When touches the ground it produces roots and becomes an independent plantlet. Example: *Mentha piperita* (peppermint), *Fragaria indica* (wild strawberry).

3. Sucker

Sucker develops from a underground stem and grows obliquely upwards and gives rise to a separate plantlet or new plant. Example: *Chrysanthemum, Musa*, *Bambusa*.

4. Offset

Offset is similar to runner but found in aquatic plants especially in rosette leaved forms. A short thick lateral branch arises from the lower axil and grows horizontally leafless for a short distance, then it produces a bunch of rosette leaves and root at nodes. Example: *Eichhornia* (water hyacinth), *Pistia* (water lettuce).

(c)

(d)

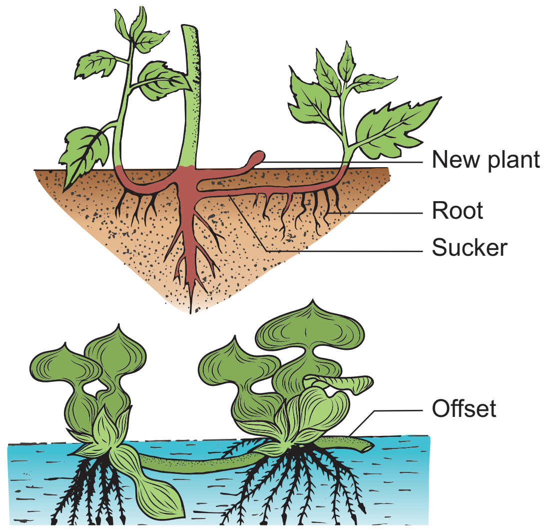


Figure 3.9: **(c)** Sucker-*Chrysanthemum*
(d) Offset-*Eichhornia*

III. Underground stem modifications

Perennial and some biennial herbs have underground stems, which are generally known as **root stocks**. Rootstock functions as a storage and protective organ. It remains alive below the ground during unfavourable conditions and resumes growth during the favourable conditions.

Underground stems are not roots because they possess nodes, internodes, scale-leaves and buds. Rootstock also lack root cap and root hairs but they possess terminal bud which is a characteristics of stem.

1. Bulb

It is a condensed conical or convex stem surrounded by fleshy scale leaves. They are of two types 1. Tunicated (coated) bulb: In which the stem is much condensed and surrounded by several concentric layers of scale leaves. The inner scales commonly fleshy, the outer ones dry. These are two types (a) Simple Tunicated bulb Example: *Allium cepa* (b) Compound Tunicated bulb. Example: *Allium sativum*. 2. Scaly bulb: They are narrow, partially overlap each other by their margins only. Example: *Tulipa spp*.

Pseudobulb is a short erect aerial storage or propagating stem of certain epiphytic and terrestrial sympodial orchids. Example: *Bulbophyllum*.

2. Corm

This is a succulent underground stem with an erect growing tip. The corm is surrounded by scale leaves and exhibit nodes and internodes. Example: *Amorphophallus, Gladiolus, Colocasia, Crocus, Colchicum*

Bulb-
Allium cepa

Rhizome
Zingiber officinale

Corm-*Colocasia*

Tuber
Solanum tuberosum

Figure 3.10: Underground Stem Modification

3. Rhizome

This is an underground stem growing horizontally with several lateral growing tips. Rhizome posses conspiquous nodes and internodes covered by scale leaves. Example: *Zingiber officinale, Canna, Curcuma longa, Maranta arundinacea, Nymphaea, Nelumbo.*

4. Tuber

This is a succulent underground spherical or globose stem with many embedded axillary buds called **"eyes".** Example: *Solanum tuberosum, Helianthus tuberosus*

IV. Stem Branching

Branching pattern is determined by the relative activity of apical meristems. The mode of arrangement of branches on a stem is known as **branching.** There are two main types of branching, 1. Lateral branching and 2. Dichotomous branching. Based on growth pattern stems may show indeterminate or determinate growth.

1. **Indeterminate:** The terminal bud grows uninterrupted and produce several lateral branches. This type of growth is also known as **monopodial branching.** Example: *Polyalthia, Swietenia, Antiaris.*
2. **Determinate:** The terminal bud caese to grow after a period of growth and the further growth is taken care by successive or several lateral meristem or buds. This type of growth is also known as **sympodial branching.** Example: *Cycas.*

3.7 Leaf

Leaves are green, thin flattened lateral outgrowths of the stem. Leaves are the primary photosynthetic organs and the main site of transpiration. All the leaves of a plant together are referred to as **phyllome**.

I. Characteristics of leaf

1. Leaf is a lateral appendage of the stem.
2. It is borne at the node of the stem.
3. It is exogenous in origin.
4. It has limited growth.
5. It does not posses apical bud.
6. It has three main parts namely, leaf base, petiole and lamina.
7. Lamina of the leaf is traversed by vascular strands, called **veins.**

II. Functions of the leaf

Primary functions

1. Photosynthesis
2. Transpiration
3. Gaseous exchange
4. Protection of buds
5. Conduction of water and dissolved solutes.

Secondary functions

1. Storage – Example: *Aloe, Agave, Kalanchoe, Sedum, Brassica oleracea.*
2. Protection – Example: *Berberis, Opuntia, Argemone mexicana.*
3. Support – Example: *Gloriosa, Nepenthes*
4. Reproduction - Example: *Bryophyllum, Begonia, Zamioculcas.*

3.7.1 Parts of the leaf

Three main parts of a typical leaf are:

i. Leaf base (Hypopodium)
ii. Petiole (Mesopodium)
iii. Lamina (Epipodium)

I. Leaf base (hypopodium)

The part of the leaf attached to the node of the stem is called **leaf base.** Usually it protects growing buds at its axil.

Pulvinus: In legumes leafbase become broad and swollen which is known as **pulvinus.** Example: *Clitoria, Lablab, Cassia, Erythrina, Butea, Peltophorum.*

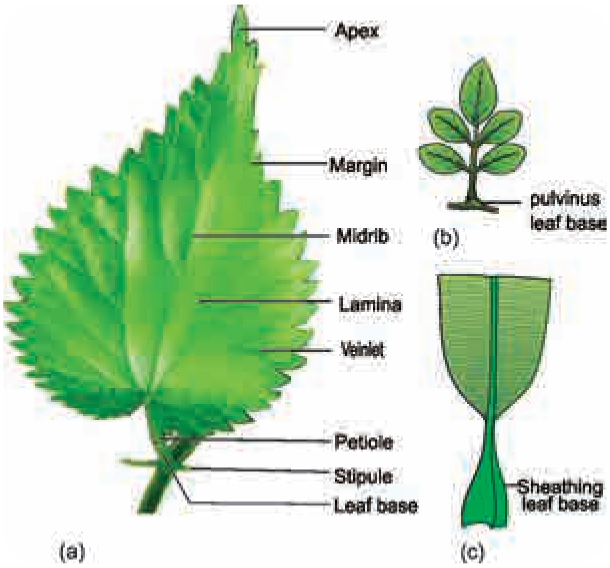


Figure 3.11: (a) Parts of the leaf **(b)** Pulvinus leaf base **(c)** Sheathing leaf base

Sheathing leafbase: In many monocot families such as Arecaceae, Musaceae, Zingiberaceae and Poaceae the leafbase extends into a sheath and clasps part or whole of the internode. Such leafbase also leave permanent scars on the stem when they fall.

II. Petiole (stipe or mesopodium)

It is the bridge between lamina and stem. Petiole or leaf stalk is a cylindrical or sub cylindrical or flattened structure of a leaf which joins the lamina with the stem. A leaf with petiole is said to be **petiolate.** Example: *Ficus, Hibiscus, Mangifera, Psidium*. Leaves that do not possess petiole is said to be **sessile**. Example: *Calotropis, Gloriosa.*

III. Lamina (Leaf blade)

The expanded flat green portion of the leaf is the blade or lamina. It is the seat of photosynthesis, gaseous exchange, transpiration and most of the metabolic reactions of the plant. The lamina is traversed by the midrib from which arise numerous lateral veins and thin veinlets. The lamina shows great variations in its shape, margin, surface, texture, colour, venation and incision.

Stipules

In most of the dicotyledonous plants, the leaf base bears one or two lateral appendages called the **stipules.** Leaves with stipules are called **stipulate**. The leaves without stipules are called **exstipulate or estipulate**. The stipules are commonly found in dicotyledons. In some grasses (Monocots) an additional out growth is present between leaf base and lamina. It is called **Ligule.** Sometimes, small stipule like outgrowths are found at the base of leaflets of a compound leaf. They are called **stipels.** The main function of the stipule is to protect the leaf in the bud condition.

3.7.2 Venation

The arrangement of veins and veinlets on the leaf blade or lamina is called **venation.** Internally, the vein contains vascular tissues. Conventionally venation is classified into two types namely, Reticulate venation and Parallel venation.

I. Reticulate venation

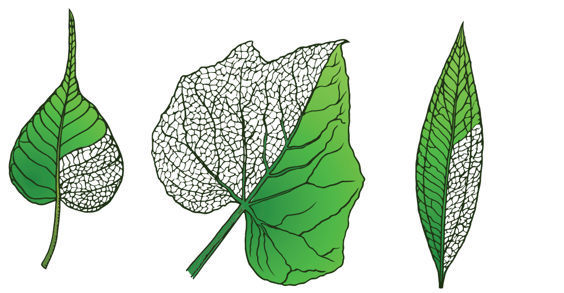
In this type of venation leaf contain a prominent midrib from which several secondary veins arise that branch and anastomose like a network. This type of venation is common in all dicot leaves. It is of two types.

1. **Pinnately reticulate venation (unicostate):** In this type of venation there is only one midrib in the centre which forms many lateral branches to form a network. Example: *Mangifera indica, Ficus religiosa, Nerium.*

2. **Palmately reticulate venation (multicostate):** In this type of venation there are two or more principal veins arising from a single point and they proceed outwards or upwards. The two types of palmate reticulate venation are

   i. **Divergent type:** When all principal veins originate from the base and diverge from one another towards the margin of the leaf as in *Cucurbita, Luffa, Carica papaya*, etc.,

   ii. **Convergent:** When the veins converge to the apex of the leaf, as in Indian plum (*Zizyphus*), bay leaf (*Cinnamomum*)



(a) *Ficus* **(b)** *Cucurbita* **(c)** *Cinnamomum*

Figure 3.12: Types of reticulate venation

(a) Pinnately reticulate
(b) Palmately reticulate (Divergent)
(c) Palmately reticulate (Convergent)

II. Parallel venation

Veins run parallel to each other and do not form a prominent reticulum. It is a characteristic feature of monocot leaves. It is classified into two sub types.

1. Pinnately Parallel Venation (Unicostate)

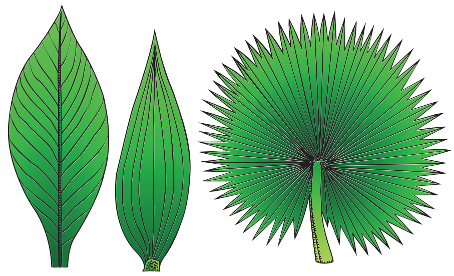
When there is a prominent midrib in the center, from which arise many veins perpendicularly and run parallel to each other. Example: *Musa*, Zinger, *Curcuma*, *Canna*.

2. Palmate Parallel Venation (Multicostate)

In this type several veins arise from the tip of the petiole and they all run parallel to each other and unite at the apex. It is of two sub types.

i. **Divergent type:** All principal veins originate from the base and diverge towards the margin, the margin of the leaf as in fan palm (*Borassus flabelliformis*)

ii. **Convergent type:** All principal veins run parallel to each other from the base of the lamina and join at the apex as in Bamboos, rice, water hyacinth.



(a) Canna **(b)** Bamboo **(c)** Borassus

Figure 3.13: Types of Parallel venation

(a) Pinnately parallel venation
(b) Palmately parallel(Convergent)
(c) Palmately parallel (Divergent)

3.7.3 Phyllotaxy

The mode of arrangement of leaves on the stem is known as **phyllotaxy (Gk. Phyllon = leaf ; taxis = arrangement).** Phyllotaxy is to avoid over crowding of leaves and expose the leaves maximum to the sunlight for photosynthesis. The four main types of phyllotaxy are (1) Alternate (2) Opposite (3) Ternate (4) Whorled.

5FPWZA

1. Alternate phyllotaxy

In this type there is only

DO YOU KNOW?

Modern morphologist Hickey (1973) and Hickey and Wolf (1975) classified the venation into following major types based on the pattern of primary, secondary and tertiary venation.

- Craspedodromous – In which secondary veins terminate at the leaf margin. (sub types are simplecraspedodromous, semicraspedodromous, mixed craspedodromous).
- Camptodromous – In which secondary veins do not terminate at the margin. (sub types are brochidodromous, eucamptodromous, cladodromous, reticulodromous).
- Hyphodromous – With only the primary midrib vein present or evident and secondary veins either absent, very reduced or hidden with the leaf mesophyll.
- Parallellodromous – Venation is equivalent to parallel in which two or more primary or secondary veins run parallel to one another, converging at the apex.
- Actinodromous – If three or more primary veins diverge from one point.
- Palinoactinodromous – Similar to actinodromous, but the primary veins have additional branch in above the main point of divergence of the primaries.
- Flabellate – Venation is that in which several equal, fine veins branch toward the apex of the leaf.
- Campylodromous – Venation is that in which several primary veins run in prominent, recurved arches at the base, curving upward to converge at the leaf apex.
- Acrodromous – If two or more primary veins run in convergent arches toward the leaf apex.

one leaf per node and the leaves on the successive nodes are arranged alternate to each other. Spiral arrangement of leaves show vertical rows are called **orthostichies**. They are two types.

a) **Alternate spiral:** In which the leaves are arranged alternatively in a spiral manner. Example: *Hibiscus, Ficus*.

b) **Alternate distichous** or **Bifarious**: In which the leaves are organized alternatively in two rows on either side of the stem. Example: *Monoon longifolium* (*Polyalthia longifolia*).

2. Opposite phyllotaxy

In this type each node possess two leaves opposite to each other. They are organized in two different types.

i. **Opposite superposed:** The pair of leaves arranged in succession are in the same direction, that is two opposite leaves at a node lie exactly above those at the lower node. Example: *Psidium* (Guava), *Eugenia jambolana* (Jamun), *Quisqualis* (Rangoon creeper).

ii. **Opposite decussate:** In this type of phyllotaxy one pair of leaves is placed at right angles to the next upper or lower pair of leaves. Example: *Calotropis, Zinnia, Ocimum*

3. Ternate phyllotaxy

In this type there are three leaves attached at each node. Example: *Nerium*

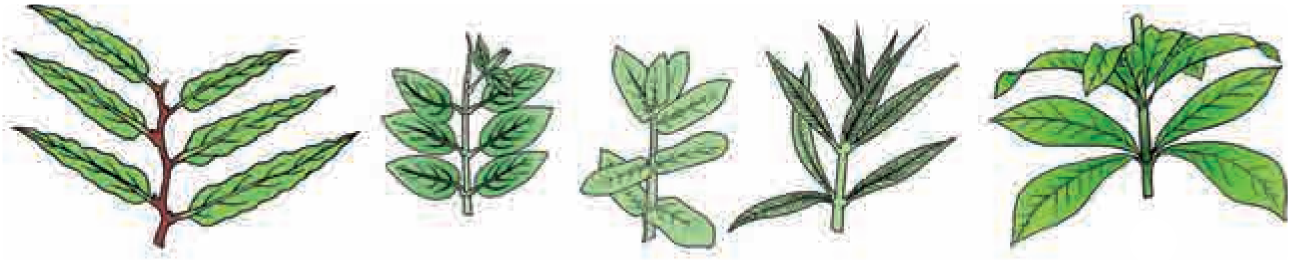


Figure 3.14: Phyllotaxy

4. Whorled (verticillate) type of phyllotaxy

In this type more than three leaves are present in a whorl at each node forming a circle or whorl. Example: *Allamanda, Alstonia scholaris.*

3.7.4 Leaf mosaic

In leaf mosaic leaves tend to fit in with one another and adjust themselves in such a way that they may secure the maximum amount of sunlight with minimum amount of overlapping. The lower leaves have longer petioles and successive upper leaves possess decreasing length petioles. Example: *Acalypha, Begonia.*

3.7.5 Leaf type

The pattern of division of a leaf into discrete components or segments is termed leaf type.

Based on the number of segments

I. Simple leaf

A leaf is said to be simple when the petiole bears a single lamina; lamina may be entire (undivided) Example: Mango or incised to any depth but not upto the midrib or petiole. Example: *Cucurbita*.

II. Compound leaf

Compound leaf is one in which the main rachis bears more than one lamina surface, called **leaflets.** Compound leaves have evolved to increase total lamina surface. There is one axillary bud in the axil of the whole compound leaf. The leaflets however, do not possess axillary buds.

1. Pinnately compound leaf

A pinnately compound leaf is defined as one in which the rachis, bears laterally a number of leaflets, arranged alternately or in an opposite manner, as in tamarind, *Cassia.*

i. **Unipinnate:** The rachis is simple and unbranched which bears leaflets directly on its sides in alternate or opposite manner. Example: *Rose*, *Neem*. Unipinnate leaves are of two types.
   a. when the leaflets are even in number, the leaf is said to be **paripinnate**. Example: *Tamarindus*, *Abrus, Sesbania, Saraca, Cassia*.
   b. when the leaflets are odd in number, the leaf is said to be **imparipinnate.** Example: *Rosa*, *Azadirachta* (Neem), (*Murraya* Chinese box).

ii. **Bipinnate:** The primary rachis produces secondary rachii which bear the leaflets. The secondary rachii are known as **pinnae.** Number of pinnae varies depending on the species. Example: *Delonix*, *Mimosa*, *Acacia nilotica, Caesalpinia*.

DO YOU KNOW?

- **Foliage leaves** — are ordinary green, flat, lateral appendages of the stem or the branch borne at the node.
- **Cotyledons or seed leaves** — are attached to the axis of the embryo of the seed. As the seed germinates, they usually turn green and become leaf-like.
- **Cataphylls or scale leaves** — are reduced forms of leaves, stalkless and often brownish. They are the bud-scales, scales on the rhizome (underground stems), and also on other parts of the plant body (Bamboo).
- **Prophylls** — the first formed leaves are called prophylls.
- **Floral leaves** — are members of a flower, forming into two accessory whorls (calyx and corolla), two essential whorls(androecium and gynoecium).
- **Hypsophylls or bract leaves** — these leaves cover the flower or an inflorescence in their axil. The main function of these leaves is to protect the flower buds.

iii. **Tripinnate:** When the rachis branches thrice the leaf is called **tripinnate.** (i.e) the secondary rachii produce the tertiary rachii which bear the leaflets. Example: *Moringa, Oroxylum*.

iv. **Decompound:** When the rachis of leaf is branched several times it is called **decompound.** Example: *Daucus carota, Coriandrum sativum, Foeniculum vulgare.*

2. Palmately compound leaf

A palmately compound leaf is defined as one in which the petiole bears terminally, one or more leaflets which seem to be radiating from a common point like fingers from the palm.

i. **Unifoliolate:** When a single leaflet is articulated to the petiole is said to be unifoliolate. Example: *Citrus, Des modium gangeticum.*

ii. **Bifoliolate:** When there are two leaflets articulated to the petiole it is said to be bifoliolate. Example: *Balanites roxburghii, Hardwickia binata, Zornia diphylla*

iii. **Trifoliolate:** There are three leaflets articulated to the petiole it is said to be trifoliolate. Example: wood apple (*Aegle marmelos*), Clover (*Trifolium*), *Lablab, Oxalis*

iv. **Quadrifoliolate:** There are four leaflets articulated to the petiole it is

(a) (b) (c) (d) (e)

Figure 3.15: Types of pinnately compound leaves

(a) Unipinnate (Paripinnate)-*Tamarindus* **(b)** Unipinnate (Imparipinnate)-*Azadirachta* **(c)** Bipinnate-*Caesalpinia* **(d)** Tripinnate-*Moringa* **(e)** Decompound-*Coriandrum*

(a) (b) (c) (d) (e)

Figure 3.16: Types of palmately compound leaves

(a) Unifoliolate - *Citrus* (b) Bifoliolate – *Zornia* **(c)** Trifoliolate – *Aegle marmelos* (d) Quadrifoliolate – *Paris quadrifolia* (e) Multifoliolate – *Bombax*

said to be quadrifoliolate. Example: *Paris quadrifolia, Marsilia*

v. **Multifoliolate or digitate:** Five or more leaflets are joined and spread like fingers from the palm, as in *Ceiba pentandra, Cleome pentaphylla, Bombax ceiba*

3.7.6 Modification of Leaf

The main function of the leaf is food preparation by photosynthesis. Leaves also modified to perform some specialized functions. They are described below.

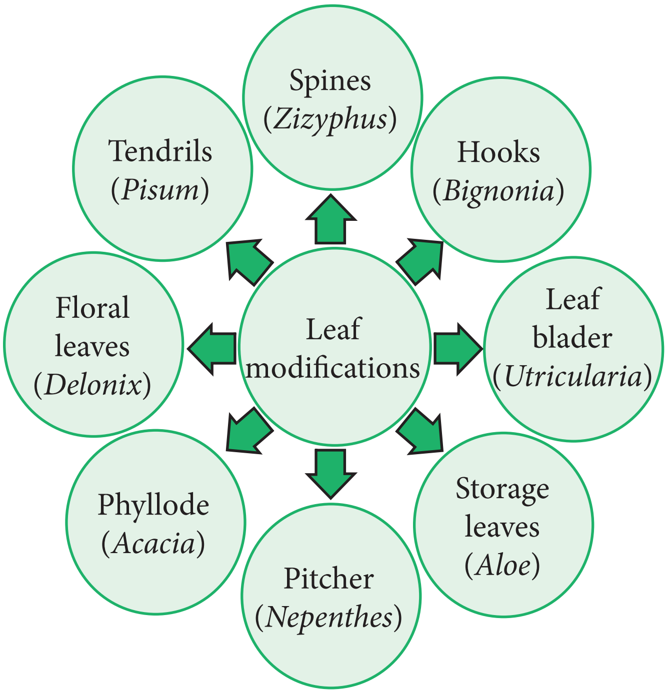
I. Leaf tendrils

In some plants Stem is very weak and hence they have some special organs for attachment to the support. So some leaves are partially or wholly modified into tendril. Tendril is a slender wiry coiled structure which helps in climbing the support. Some of the modification of leaf tendrils are given below:

Entire leaf—*Lathyrus*, stipules—*Smilax*, terminal leaflet—*Naravelia*, Leaf tip—*Gloriosa*, Apical leaflet—*Pisum*, petiole—*Clematis*.

II. Leaf hooks

In some plants, leaves are modified into hook-like structures and help the plant to climb. In cat's nail (*Bignonia unguis-cati)* an elegant climber, the terminal leaflets become modified into three, very sharp, stiff and curved hooks, very much like the nails of a cat. These hooks cling to the bark of a tree and act as organs of support for climbing. The leaf spines of *Asparagus* also act as hooks.



III. Leaf Spines and Prickles

Leaves of certain plants develop spinesent structures. Either on the surface or on the margins as an adaptation to herbivory and xeric conditions. Example: *Argemone mexicana* (Prickly poppy), *Solanum trilobatum, Solanum virginianum*. In xerophytes such as *Opuntia* (Prickly pear) and *Euphorbia* leaves and stipules are modified into spines.

Prickles are small, sharp structure which are the outgrowths from epidermal cells of stem or leaf. It helps the plant in scrambling over other plants. It is also protective against herbivory. Example: *Rosa spp, Rubus spp.*

IV. Storage Leaves

Some plants of saline and xerophytic habitats and members of the family Crassulaceae commonly have fleshy or swollen leaves. These succulent leaves store water, mucilage or food material. Such storage leaves resist desiccation. Example: *Aloe, Agave, Bryophyllum, Kalanchoe*, *Sedum, Sueada*, *Brassica oleracea* (cabbage-variety *capitata*).

V. Phyllode

Phyllodes are flat, green-coloured leaf-like modifications of petioles or rachis. The leaflets or lamina of the leaf are highly reduced or caducous. The phyllodes perform photosynthesis and other functions of leaf. Example: *Acacia auriculiformis* (Australian *Acacia*), *Parkinsonia.*

VI. Pitcher

The leaf becomes modified into a pitcher in *Nepenthes* and *Sarracenia*. In *Nepenthes* the basal part of the leaf is laminar and the midrib continues as a coiled tendrillar structure. The apical part of the leaf as modified into a pitcher the mouth of the pitcher is closed by a lid which is the modification of leaf apex.

VII. Bladder

In bladderwort (*Utricularia*), a rootless free-floating or slightly submerged plant common in many water bodies, the leaf is very much segmented. Some of these segments are modified to form bladder-like structures, with a trap-door entrance that traps aquatic animalcules.

VIII Floral leaves

Floral parts such as sepals, petals, stamens and carpels are modified leaves. Sepals and petals are leafy. They are protective in function and considered non-essential reproductive parts. Petals are usually coloured which attract the insects for pollination. Stamens are considered pollen bearing microsporophylls and carpels are ovule bearing megasporophylls.

3.7.7 Ptyxis

Rolling or folding of individual leaves may be as follows:

1. **Reclinate** - when the upper half of the leaf blade is bent upon the lower half as in loquat (*Eriobotrya japonica*).
2. **Conduplicate** - when the leaf is folded lengthwise along the mid-rib, as in guava, sweet potato and camel's foot tree (*Bauhinia*).

Leaf hooks-*Bignonia*

Leaf spines- *Zizyphus*

Phyllode-*Acacia*

Pitcher-*Nepenthes*

Figure 3.17: Leaf Modification

3. **Plicate or plaited** – when the leaf is repeatedly folded longitudinally along ribs in a zig-zag manner, as in *Borassus flabellifer*.
4. **Circinate** - when the leaf is rolled from the apex towards the base like the tail of a dog, as in ferns.
5. **Convolute** - when the leaf is rolled from one margin to the other, as in banana, aroids and Indian pennywort. *Musa* and members of Araceae.
6. **Involute** - when the two margins are rolled on the upper surface of the leaf towards the midrib or the centre of the leaf, as in water lily, lotus, Sandwich Island Climber (*Antigonon*) and *Plumbago*.
7. **Crumpled** - when the leaf is irregularly folded as in cabbage.

3.7.8 Leaf duration

Leaves may stay and function for few days to many years, largely determined by the adaptations to climatic conditions.

Cauducuous (Fagacious)

Falling off soon after formation. Example: *Opuntia, Cissus quadrangularis.*

Deciduous

Falling at the end of growing season so that the plant (tree or shrub) is leafless in winter/summer season. Example: *Maple, Plumeria, Launea, Erythrina.*

Evergreen

Leaves persist throughout the year, falling regularly so that tree is never leafless. Example: *Mimusops, Calophyllum.*

Marcescent

Leaves not falling but withering on the plant as in several members of Fagaceae.

3.7.9 Leaf symmetry

1. Dorsiventral leaf

When the leaf is flat, with the blade placed horizontally, showing a distinct upper surface and a lower surface, as in most dicotyledons, it is said to be dorsiventral. Example: *Tridax.*

2. Isobilateral leaf

When the leaf is directed vertically upwards, as in many monocotyledons, it is said to be isobilateral leaf. Example: *Grass.*

3. Centric leaf

When the leaf is more or less cylindrical and directed upwards or downwards, as in pine, onion, etc., the leaf is said to be centric.

4. Heterophylly

Occurrence of two different kinds of leaves in the same plant is called **heterophylly.** Heterophylly is found in many aquatic plants. Here, the floating or aerial leaves and the submerged leaves are of different kinds. The former are generally broad, often fully expanded, and undivided or merely lobed, while the latter are narrow, ribbon-shaped, linear or much dissected. Heterophylly in water plants is, thus, an adaptation to two different conditions of the environment. Example: water crowfoot (*Ranunculus aquatilis*), water plantain (*Alisma plantago*), arrowhead (*Sagittaria*), *Limnophila heterophylla.*

Terrestrial (land) plants also exhibit this phenomenon. Among them *Sterculia villosa*, jack (in early stages), *Ficus heterophylla* show leaves varying from entire to variously lobed structures during different developmental stages. Young leaves are usually lobed or dissected and the mature leaves are entire. Such type is known as **developmental heterophylly.** Example: *Eucalyptus, Artocarpus heterophyllus.*

Summary

Flowering plants consist of two major organ systems: Underground root system and aerial root system. Roots perform the functions of anchoring and absorbing nutrients from the soil. However some roots perform additional functions for which they undergo various modifications in shape, form and structure. Tap root continue the growth from the radical which further branches into secondary roots. Adventitious roots arise from different parts of the plant other than radical. Stem helps to display the leaves to get maximum sunlight and positioning flowers and fruits to attract pollination and dispersal agents. Apart from the normal functions the stems are modified to perform various functions such as food storage, perennation and protection. Leaves are exogenous in origin and function as food synthesizing and gaseous exchange sites. Some leaves also perform additional functions for which they are modified in their morphology. Leaves possess vascular tissues in the form of veins which render support to the lamina and help in transport of water, nutrients and food in and out of leaves. Phyllotaxy is the arrangement or distribution of leaves on the stem or its branches in such a way that they receive maximum sunlight to perform photosynthesis.

Activity

1. Collection of medicines prepared from root, stem, leaf of organic plants.
2. Prepare a report of traditional medicines.
3. Classroom level exhibition on Siddha and Ayurvedic medicine prepared from root, leaf, stem.
4. Growing micro greens in class room – project work. (Green seed sprouts)

Evaluation

5FYT1X

1. Which of the following is polycarpic plant?
   a. *Mangifera*
   b. *Bambusa*
   c. *Musa*
   d. *Agave*
2. Roots are
   a. Descending, negatively geotropic, positively phototropic
   b. Descending, positively geotropic, negatively phototropic
   c. Ascending, positively geotropic, negatively phototropic
   d. Ascending, negatively geotropic, positively phototropic
3. *Bryophyllum* and *Dioscorea* are example for
   a. Foliar bud, apical bud
   b. Foliar bud, cauline bud
   c. Cauline bud, apical bud
   d. Cauline bud, foliar bud
4. Which of the following is correct statement?
   a. In *Pisum sativum* leaflets modified into tendrils
   b. In *Atalantia* terminal bud is modified into thorns
   c. In *Nepenthes* midrib is modified into lid
   d. In *Smilax* inflorescence axis is modified into tendrils
5. Select the mismatch pair
   a. *Sagittaria* - Heterophylly
   b. *Lablab* - Trifoliolate
   c. *Begonia* - Leaf mosaic
   d. *Allamanda* - Ternate phyllotaxy

6. Draw and label the parts of regions of root.
7. Write the similarities and differences between
    1. *Avicennia* and *Trapa*
    2. Radical buds and foliar buds
    3. Phylloclade and cladode
8. How root climbers differ from stem climbers?
9. Compare sympodial branching with monopodial branching.
10. Differentiate pinnate unicostate with palmate multicostate venation

Climbers

Root climber - *Piper betel*

Stem climber - *Clitoria*

Thorn climber - *Bougainvillea*

Lianas - *Entada*

Tendril climber - *Cissus quadrangularis*

ICT Corner

Monocot and Dicot plants

Is plants differ **morphologically**?

Steps

- Scan the QR code or go to google play store
- Type online labs and install it.
- Select biology and select Characteristics of plants
- Click theory to know the basic about Characteristics of plants
- Register yourself with mail-id and create password to access online lab simulations

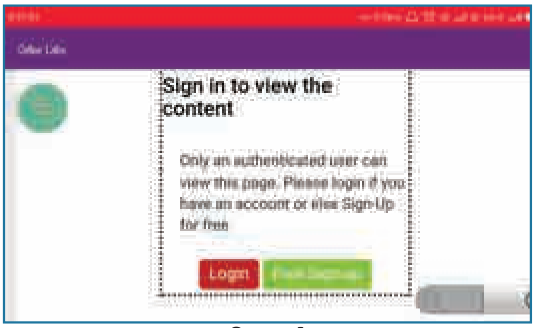
Activity

- Select video and record your observations of different forms of plant group.

Step 1

Step 2

Step 3



Step 4

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* Pictures are indicative only

Chapter 4

Reproductive Morphology

Learning Objectives

The learner will be able to,

- *List the types of inflorescence.*
- *Distinguish racemose and cymose inflorescence*
- *Dissect a flower and explore the parts of a flower.*
- *Compare various types of aestivation.*
- *Explore various types of placentation.*
- *Understands the types of fruits and seeds*

Chapter Outline

5G8P3K

Flowers of five types of land in tamil literature.

(a) (b) (c) (d) (e)

a. Kurinji (*Strobilanthus kunthianus*),
b. Mullai (*Jasminum auriculatum*),
c. Marutham (*Lagerstroemia speciosa*),
d. Neithal (*Nymphaea pubescens*),
e. Palai (*Wrightia tinctoria*)

Flowers have been a universal cultural object for millennia. They are an important aesthetic element in everyday life, and have played a highly symbolic role in our culture throughout the ages. Exchange of flowers marks respect, affection, happiness, and love. However, the biological purpose of the flower is very different from the way we use and perceive. Flower helps a plant to reproduce its own kind. This chapter discusses flowers, their arrangement, fruits and seeds which are the reproductive units of a plant.

Floriculture

Floriculture is a branch of Horticulture. It deals with the cultivation of flowers and ornamental crops. The Government of India has identified floriculture as a sunrise industry and accorded the status of 100% export oriented. Agriculture and Processed food product Export Development Authority (APEDA) is responsible for export promotion of agricultural and horticultural products from India.

4.1 Inflorescence

Have you seen a bouquet being used during functions? Group of flowers arranged together on our preference is a bouquet. But an inflorescence is a group of flowers arising from a branched or unbranched axis with a definite pattern. Function of inflorescence is to display the flowers for effective pollination and facilitate seed dispersal. The grouping of flowers in one place gives a better attraction to the visiting pollinators and maximize the energy of the plant.

4.1.1 Types of Inflorescence

Based On Position

Have you ever noticed the inflorescence arising from different positions? Where is the inflorescence present in a plant? Apex or axil?

Based on position of inflorescences, it may be classified into three major types. They are,

Terminal: Inflorescence grows as a part of the terminal shoot. Example: Raceme of *Nerium oleander*

Axillary: Inflorescence present in the axile of the nearest vegetative leaf. Example: *Hibiscus rosa-sinensis*

Cauliflorous: Inflorescence developed directly from a woody trunk. Example: *Theobroma cocoa, Couroupita guianensis*

Observe the inflorescence of Jackfruit and Canon ball tree. Where does it arise?

Figure 4.1: Cauliflorous inflorescence

4.1.2 Based on branching pattern and other characters

Inflorescences may also have classified based on branching, number and arrangement of flowers, and some specialized structures.

I. **Indeterminate (racemose)**

II. **Determinate (cymose)**

III. **Mixed inflorescence**: Inflorescence of some plants show a combination of indeterminate and determinate pattern

IV. **Special inflorescence**: Inflorescence which do not confined to these patterns

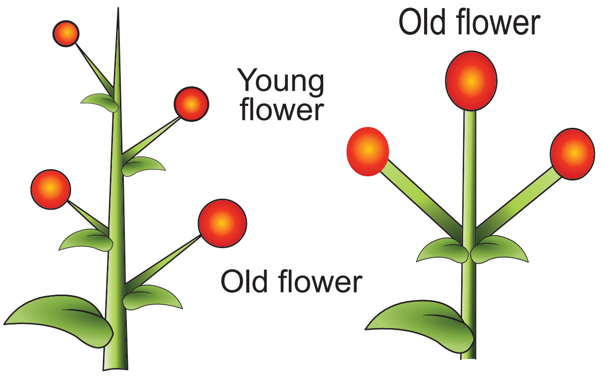


Figure 4.2: (a) Racemose

Figure 4.2: (b) Cymose inflorescence

Racemose	Cymose
Main axis of unlimited growth	Main axis of limited growth.
Flowers arranged in an acropetal succession	Flowers arranged in a basipetal succession
Opening of flowers is centripetal	Opening of flowers is centrifugal
Usually the oldest flower at the base of the inflorescence axis.	Usually the oldest flower at the top of the inflorescence axis.

I. Racemose

The central axis of the inflorescence (peduncle) possesses terminal bud which is capable of growing continuously and produce lateral flowers is called **racemose inflorescence**. Old flowers are at the base and younger flowers and buds are towards the apex. It is further divided into 3 types based on growth pattern of main axis.

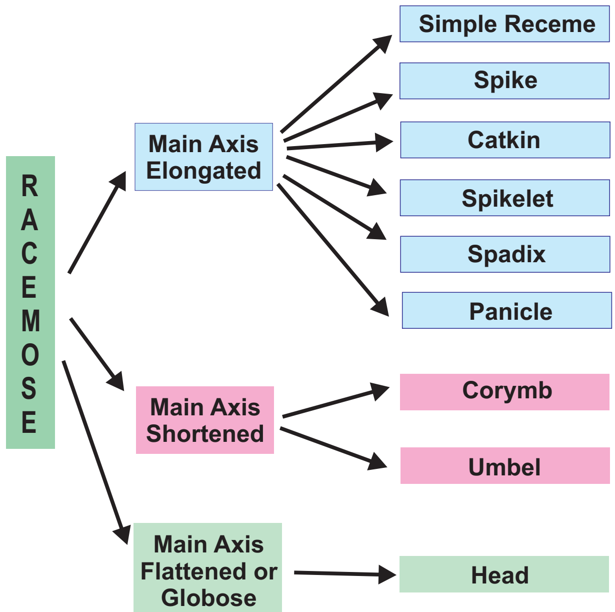


Figure 4.3: Racemose

1. Main axis elongated

The axis of inflorescence is elongated and contains pedicellate or sessile flowers on it. The following types are discussed under main axis elongated type.

a. Simple raceme: The inflorescence with an unbranched main axis bears **pedicellate flowers** in acropetal succession. Example: *Crotalaria retusa*, mustard and radish.

b. Spike: Spike is an unbranched indeterminate inflorescence with **sessile flowers**. Example: *Achyranthes*, *Stachytarpheta*.

c. Spikelet: Literally it is a small spike. The Inflorescence is with

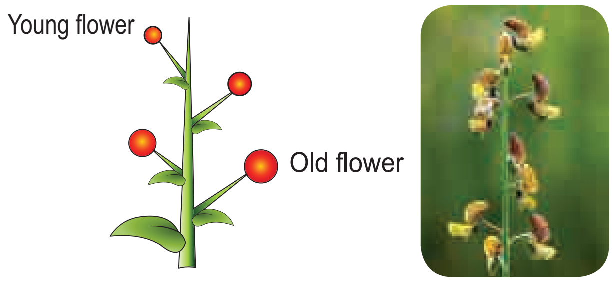


Figure 4.4: (a) diagrammatic, **(b)** Simple raceme

Figure 4.4: (c) diagrammatic, **(d)** Spike

branched central axis. Each branch is a **spikelet**. Sessile flowers are formed in acropetal succession on the axis. A pair of inflorescence bracts called **glumes** is present at the base. Each sessile flower has a **lemma** (bract) and a **palea** (bracteole). Tepals reduced to colourless scaly leaves (lodicule). Each flower has stamen and pistil only. Example: Paddy, Wheat, Barley, *Sorghum*.

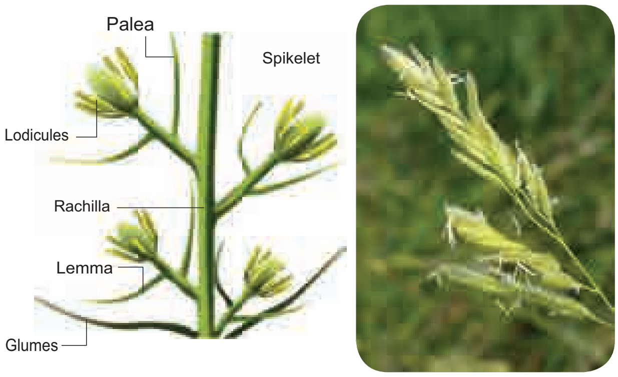


Figure 4.4: (e) diagrammatic, **(f)** Spikelet

d. Catkin: **Pendulous spikes** with a long and drooping axis bearing small unisexual or bisexual flowers. It is also called **ament**. Example: *Acalypha hispida*, *Prosopis juliflora*, *Piper nigrum*.

Figure 4.4: (g) diagrammatic, **(h)** Catkin

e. Spadix: An inflorescence with a fleshy or thickened central axis that possesses many unisexual sessile flowers in acropetal succession. Usually female flowers are found towards the base and male flowers are found at the apex. Entire inflorescence is covered by a brightly coloured or hard bract called a **spathe**. Example: *Amorphophallus*, *Colocasia*, *Phoenix*, *Cocos*.

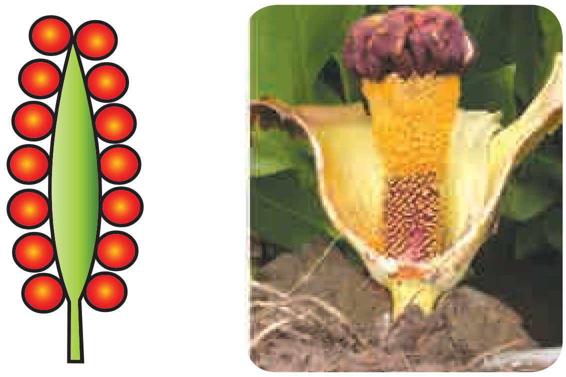


Figure 4.4: (i) diagrammatic, **(j)** Spadix

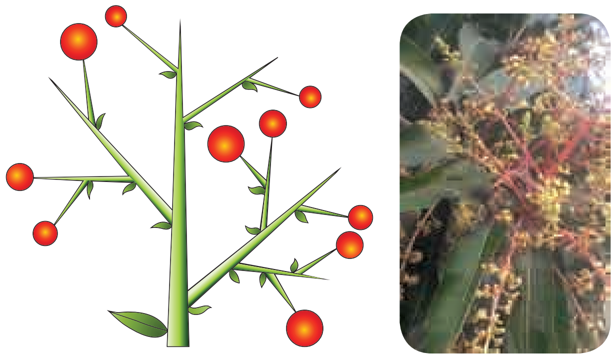


Figure 4.4: (k) diagrammatic, **(l)** Panicle

f. Panicle: A branched raceme is called **panicle**. Example: *Mangifera,* neem, *Delonix regia*. It is also called **Compound raceme** or **raceme of racemes**.

2. Main axis shortened:

Inflorescence with reduced growth of central axis. There are two types namely corymb and umbel.

a. Corymb: An inflorescence with shorter pedicellate flowers at the top and longer pedicellate flowers at the bottom. All flowers appear at the same level to form convex or flat topped racemose inflorescence. Example: *Caesalpinia*. **Compound corymb:** A branched corymb is called **compound corymb**. Example: Cauliflower.

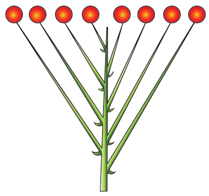


Figure 4.4: (m)
Corymb diagrammatic

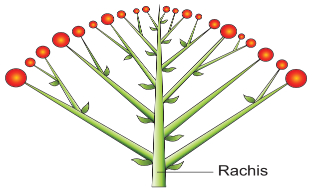


Figure 4.4: (n)
Compound corymb diagrammatic

Figure 4.4: (o)
Corymb

Figure 4.4: (p)
Compound corymb

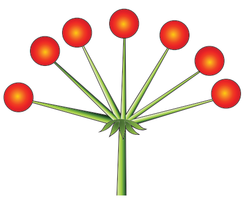


Figure 4.4: (q)
Umbel diagrammatic

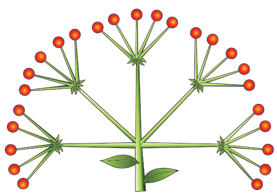


Figure 4.4: (r)
Compound umbel diagrammatic

b. Umbel: An inflorescence with indeterminate central axis and pedicellate flowers arise from a common point of peduncle at the apex. Example: *Allium cepa*, *Centella asiatica*, *Memecylon umbellatum*. **Compound umbel**: It is a branched umbel. Each smaller unit is called **umbellule**. Example: *Daucas carota*, *Coriandrum sativum, Memecylon edule*.

Figure 4.4: (s)
Umbel

Figure 4.4: (t)
Compound umbel

3. Main axis flattened:

The main axis of inflorescence is mostly flattened (convex or concave) or globose. A **head** or **capitulum** is a determinate or indeterminate, group of sessile or sub sessile flowers arising on a receptacle, often subtended by an involucre.

a. Head: A head is a characteristic inflorescence of Asteraceae and is also found in some members of Rubiaceae.

Figure 4.4: (u)
Neolamarkia cadamba head

Example: *Neolamarkia cadamba*, *Mitragyna parvifolia* and in some members of Fabaceae-Mimosoideae. Example:

Acacia nilotica, *Albizia lebbeck*, *Mimosa pudica* (sensitive plant).

Torus contains two types of florets: 1. Disc floret or tubular floret. 2. Ray floret or ligulate floret.

The flower and inflorescence are subtended by a lateral appendage called bract. In sunflower, you may notice that the whorl of bracts forms a cup like structure beneath mimicking the calyx. Such whorl of bracts is called involucre. A group of bracts present beneath the sub unit of inflorescence is known as Involucel.

Heads are classified into two types.

i. Homogamous head: This type of inflorescence exhibits single kind of florets. Inflorescence has disc florets alone. Example: *Vernonia, Ageratum* or Ray florets alone. Example: *Launaea, Sonchus*.

Figure 4.4: Homogamous head
(v) disc floret, **(w)** ray floret

ii. Heterogamous head: The inflorescence possesses both types of florets. Example: *Helianthus, Tridax*.

Disc florets at the centre of the head are tubular and bisexual whereas the **ray florets** found at the margin of the head which are ligulate pistilate (unisexual).

II. Cymose inflorescence.

Central axis stops growing and ends in a flower, further growth is by means of axillary buds. Old flowers present at apex and young flowers at base

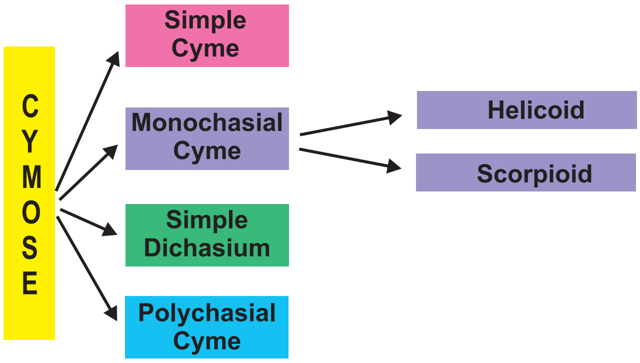


Figure 4.5: Cyme

1. Simple cyme (solitary): Determinate inflorescence consists of a single flower. It may be terminal or axillary. Example: terminal in *Trillium grandiflorum* and axillary in *Hibiscus*.

Figure 4.6: (a) Simple cyme

2. Monochasial Cyme (uniparous): The main axis ends with a flower. From two lateral bracts, only one branch grows further. It may be **helicoid (bostryx)** or **Scorpioid (cincinnus).**

a. Helicoid: Axis develops on only one side and forms a coil structure atleast at the earlier development stage. Example: *Hamelia*, potato.

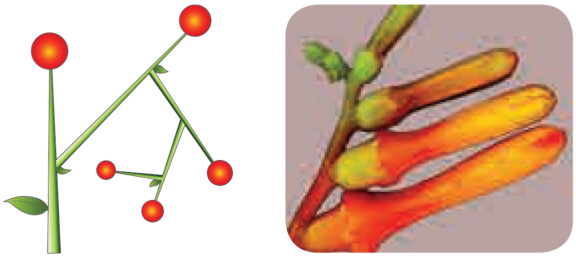


Figure 4.6: (b) diagrammatic,
(c) Monochasial Helicoid

b. Scorpioid: Axis develops on alternate sides and often becomes a coil structure. Example: *Heliotropium*.

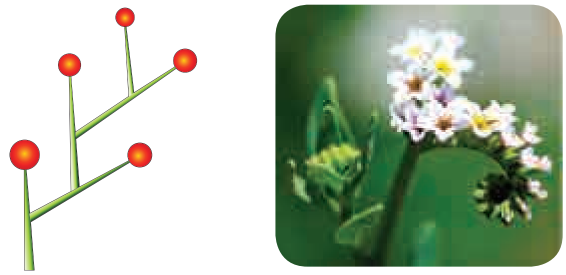


Figure 4.6: (d) diagrammatic,
(e) Monochasial Scorpioid

3. Simple dichasium (Biparous): A central axis ends in a terminal flower; further growth is produced by two lateral buds. Each cymose unit consists of three flowers of which central one is old one. This is **true cyme**. Example: *Jasminum*.

Figure 4.6: (f) diagrammatic,
(g) Simple dichasium

4. **Compound dichasium**: It has many flowers. A terminal old flower develops lateral simple dichasial cymes on both sides. Each compound dichasium consists of seven flowers. Example: *Clerodendron*.

A small,simple dichasium is called **cymule**

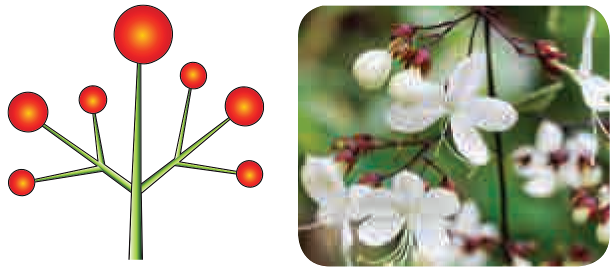


Figure 4.6: (h) diagrammatic,
(i) Compound dichasium

5. Polychasial Cyme (multiparous): The central axis ends with a flower. The lateral axes branches repeatedly. Example: *Nerium*

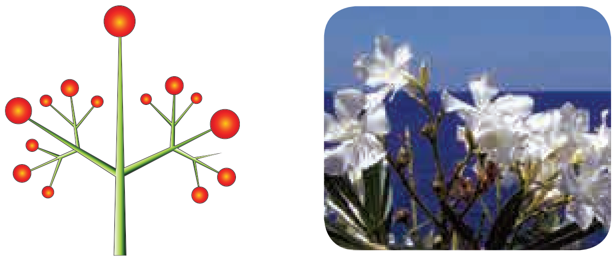
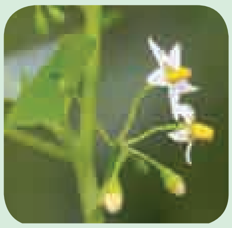


Figure 4.6: (j) diagrammatic,
(k) Polychasial cyme



Sympodial Cyme: In monochasial cyme, successive axes at first develop in a zigzag manner and later it develops into a straight pseudo axis. Example: *Solanum americanum*.

III. Mixed Inflorescence

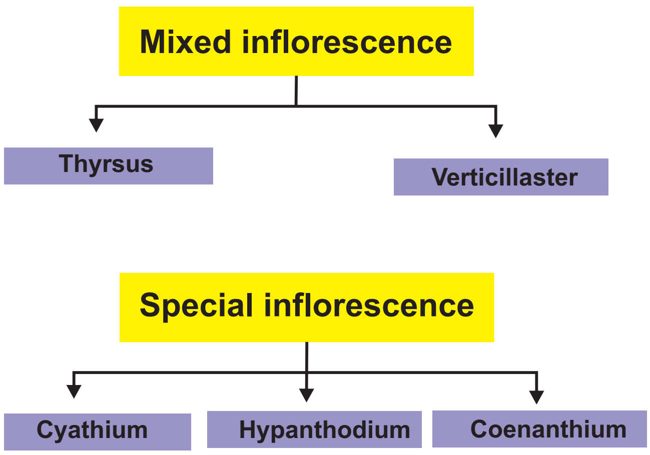


Figure 4.7: Mixed and special inflorescence

Inflorescences in which both racemose and cymose patterns of development occur in a mixed manner. It is of the following two types.

1. Thyrsus: It is a '**Raceme of cymes**'. Indefinite central axis bears lateral pedicellate cymes, (simple or compound dichasia). Example: *Ocimum*, *Anisomeles*.

Figure 4.8: (a) diagrammatic, **(b)** Thyrsus

2. Verticil or Verticillaster: Main axis bears two opposite lateral sessile cymes at the axil of the node,each of it produces monochasial scorpioid lateral branches so that flowers are crowded around the node. Example: *Leonotis, Leucas*.

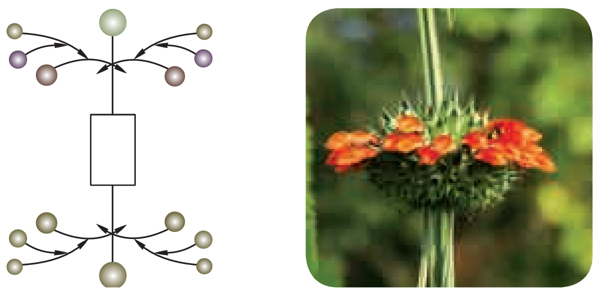


Figure 4.8: (c) diagrammatic,
(d) Verticillaster

IV. Special Inflorescence

The inflorescences do not show any of the development pattern types are classified under special type of inflorescence.

1. Cyathium: Cyathium inflorescence consists of small unisexual flowers enclosed by a common involucre which mimics a single flower. Male flowers are organised in a scorpioid manner. Female flower is solitary and centrally located on a long pedicel. Male flower is represented only by stamens and female flower is represented only by pistil. Cyathium may be actinomorphic (Example: *Euphorbia*) or zygomorphic (Example: *Pedilanthus*.). Nectar is present in involucre.

Figure 4.9: (a) diagrammatic,
(b) Cyathium

2. Hypanthodium: Receptacle is a hollow, globose structure consisting unisexual flowers present on the inner wall of the receptacle. Receptacle is closed except a small opening called **ostiole** which is covered by a series of bracts. Male flowers are present nearer to the ostiole, female and neutral flowers are found in a mixed manner from middle below. Example: *Ficus sp*. (Banyan and Pipal).

3. Coenanthium: Circular disc like fleshy open receptacle that bears pistillate flowers at the center and staminate flowers at the periphery. Example: *Dorstenia*

Figure 4.9: (c)
Hypanthodium

Figure 4.9: (d)
Coenanthium

4.2 Flower

In a plant, which part would you like the most? Of course, it is a flower, because of its colour and fragrance. The flower is a significant diagnostic feature of angiosperms. It is a modified condensed reproductive shoot. The growth of the flower shoot is determinate.

4.2.1 Whorls of flower

There are two whorls, accessory and essential. Accessory whorl consists of calyx and corolla and essential whorl comprises of androecium and gynoecium.

Flower is said to be **Complete** when it contains all four whorls. An **Incomplete** flower is devoid of one or more whorls.

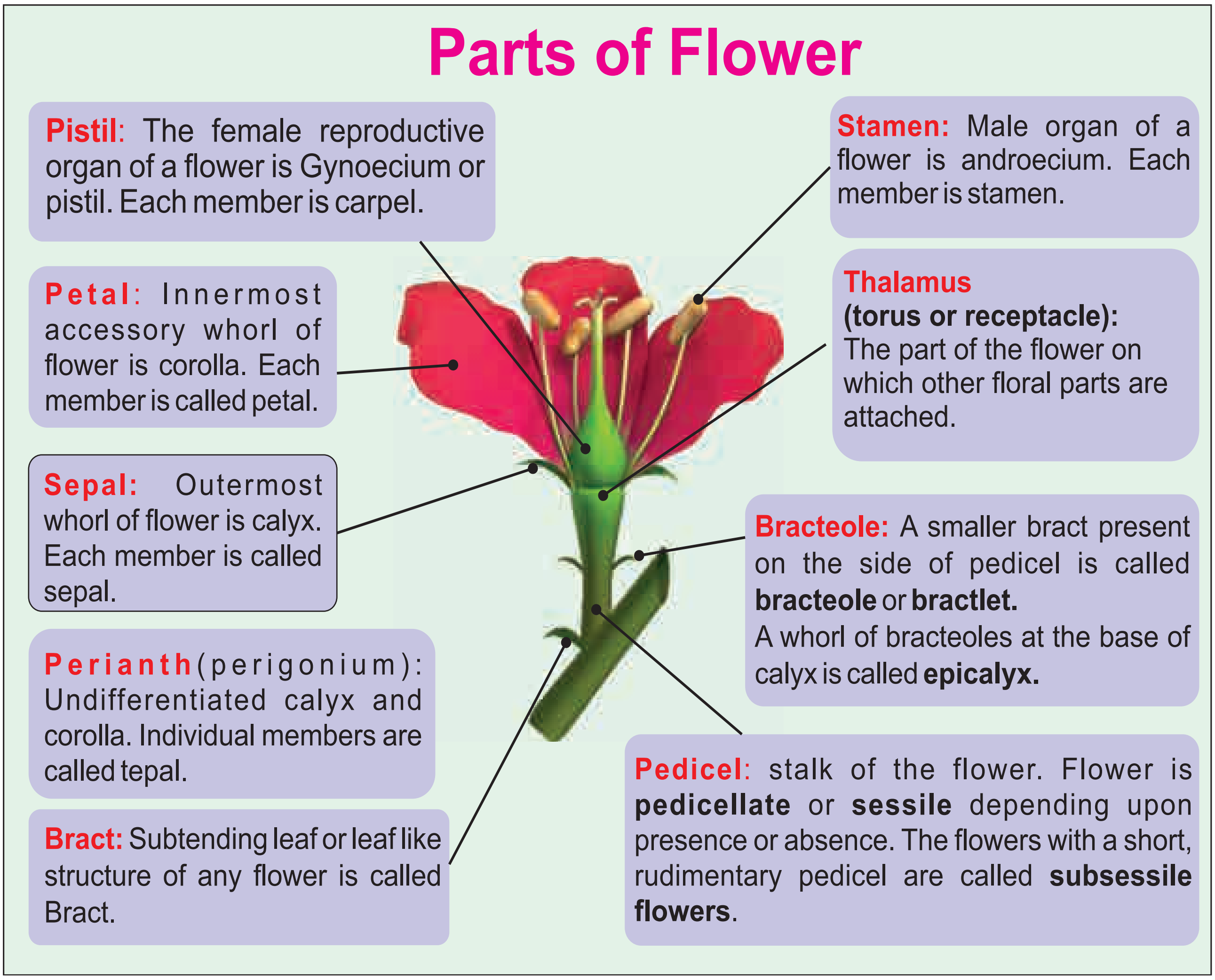


Figure 4.10: Parts of flower

4.2.2 Flower sex

Flower sex refers to the presence or absence of androecium and gynoecium within a flower.

1. Perfect or bisexual(monoclinous): When a flower contains both androecium and gynoecium is called **perfect flower**.

2. Imperfect or unisexual (diclinous): When the flower contains only one of the essential whorls is called **Imperfect flower**. It is of two types:

i) **Staminate flowers**: Flowers only with androecium alone are called **staminate flowers**.

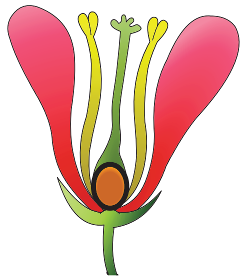


Figure 4.11: (a)
Bisexual flower

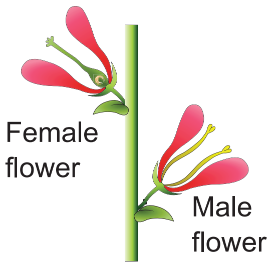


Figure 4.12: (a)
Monoecious

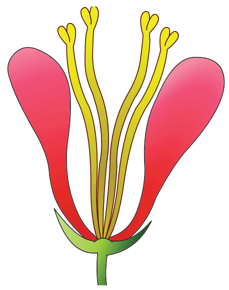


Figure 4.11: (b)
Male flower

Figure 4.12: (b)
Dioecious

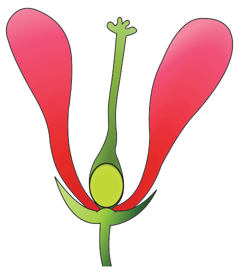


Figure 4.11: (c)
Female flower

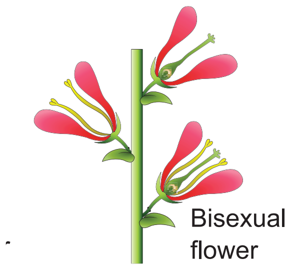


Figure 4.12: (c)
Polygamous

ii) Pistillate flowers: Flowers with only gynoecium are called **pistillate flowers**.

4.2.3 Plant sex

Plant sex refers to the presence and distribution of flowers with different sexes in an individual plant.

1. **Hermaphroditic**: All the flowers of the plant are bisexual.

2. **Monoecious** (*mono*-**one;** *oikos*-**house**): Both male and female flowers are present in the same plant Example: Coconut.

3. **Dioecious** (*di*-**two:** *oikos*-**house**): Male and Female flowers are present on separate plants. Example: Papaya, Palmyra.

Types of Polygamous:

Andromonoecious: A plant with both male flowers and bisexual flowers.

Gynomonoecious: A plant with both pistillate and bisexual flowers.

Polygamomonoecious: A plant with pistillate, staminate and bisexual flowers. It is also called trimonoecious.

Androdioecious: A plant with staminate flowers on one individual and bisexual flower on other individual

Gynodioecious: A plant with pistillate flowers on one individual and bisexual flowers on other individual.

Polygamodioecious: A plant with staminate flowers and bisexual in one individual and pistillate flowers and bisexual flowers in other individual.

Trioecious: A plant with staminate,pistillate and bisexual flowers on different individuals

4. **Polygamous**: The condition in which bisexual and unisexual (staminate/ pistillate) flowers occur in a same plant is called **polygamous**. It is of several types. See box. Example: Musa, *Mangifera*.

4.2.4 Flower symmetry

What is the radius of a circle? Cut a paper into round shape, fold it so as to get two equal halves. In how many planes will you get equal halves? In how many planes you can divide a cucumber in two equal halves? A flower is symmetrical when it is divided into equal halves in any plane running through the center. Flower symmetry