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GYMNOSPERMS AND SYSTEMATICS OF ANGIOSPERMS

SC-124

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U N I T – I

CHAPTER

1

GENERAL ACCOUNT OF GYMNOSPERMS

STRUCTURE

LEARNING OBJECTIVES

After reading this chapter you should be able to know the general account and affinities of Gymnosperms.

1.0 INTRODUCTION

Gymnosperms is the sub-division of Spermatophyta (Gr. *Sperma* = seed; *Phyton* = plant). It is a very ancient and small group of plants reaching back 2 to 3 hundred million years. The word **Gymnosperms** was first used by **Theophrastus** (300 BC). He described them as plants whose seeds are unprotected. It is evident that members of **Gymnosperms** did not originate as seed plants in nature. **Pteridophytes** are looked for the immediate origin of these plants.

Robert Brown (1827), was the first to define the female flower of Cycads and Conifers as a naked ovule. Due to this remarkable discovery, the Cycads and Conifers, which were previously regarded as the members of Dicotyledons, were grouped under **Gymnosperms** because the word Gymnosperm has been derived from the two Greek words, *Gymnos* = naked, *Sperma* = seed *i.e.*, plants with naked seeds. They differ from Angiosperms (*Angios* = vessel, *Sperma* = seed), where the seeds are encoded in a vessel or carpel. **Goebel** (1887) described the Gymnosperms as "Phanerogams with out ovary".

Gymnosperms are represented by a comparatively small group of present day plants comprising of about 70 genera and 725 species, yet it is very ancient and includes *the most primitive sed plants and* it is presumed that these ancient forms were once the predominant flora as the Angiosperms are predominant today.

1.1. GEOLOGICAL HISTORY OF GYMNOSPERMS

The Gymnosperms of **upper Devonian** (Palaeozoic) dominated the world during **Mesozoic** and early members of this group have become extinct today. The Gymnosperm's line is of extreme age reaching back to **upper Devonian**, roughly about 300 million years back. The fruitifications of the earliest fossils grouped under Gymnosperms are not known but several undoubted Gymnosperms had already come into existance during the lower **Carboniferous** period. From 150 millions years back right upto the end of **Cretaceous** period *i.e.*, about 70 millions years back, they formed the ruling class of the plant kingdom. Only after the **Cretaceous** period they were shifted to the second position because of Angiosperms (Fig. 1.1).

The Gymnosperms are also primitive than Angiosperms as far as the structure of vascular element is concerned. In case of primitive Gymnosperms the vessels and wood fibres are lacking from the wood. It is only composed of xylem tracheids and xylem parenchyma, where as in case of angiosperms the vessels and wood fibres have originated through the specialization of tracheids. In Gymnosperms the companion cells are absent while they are present in Angiosperms.

The above mentioned differences indicate that Gymnosperms are more primitive than Angiosperms.

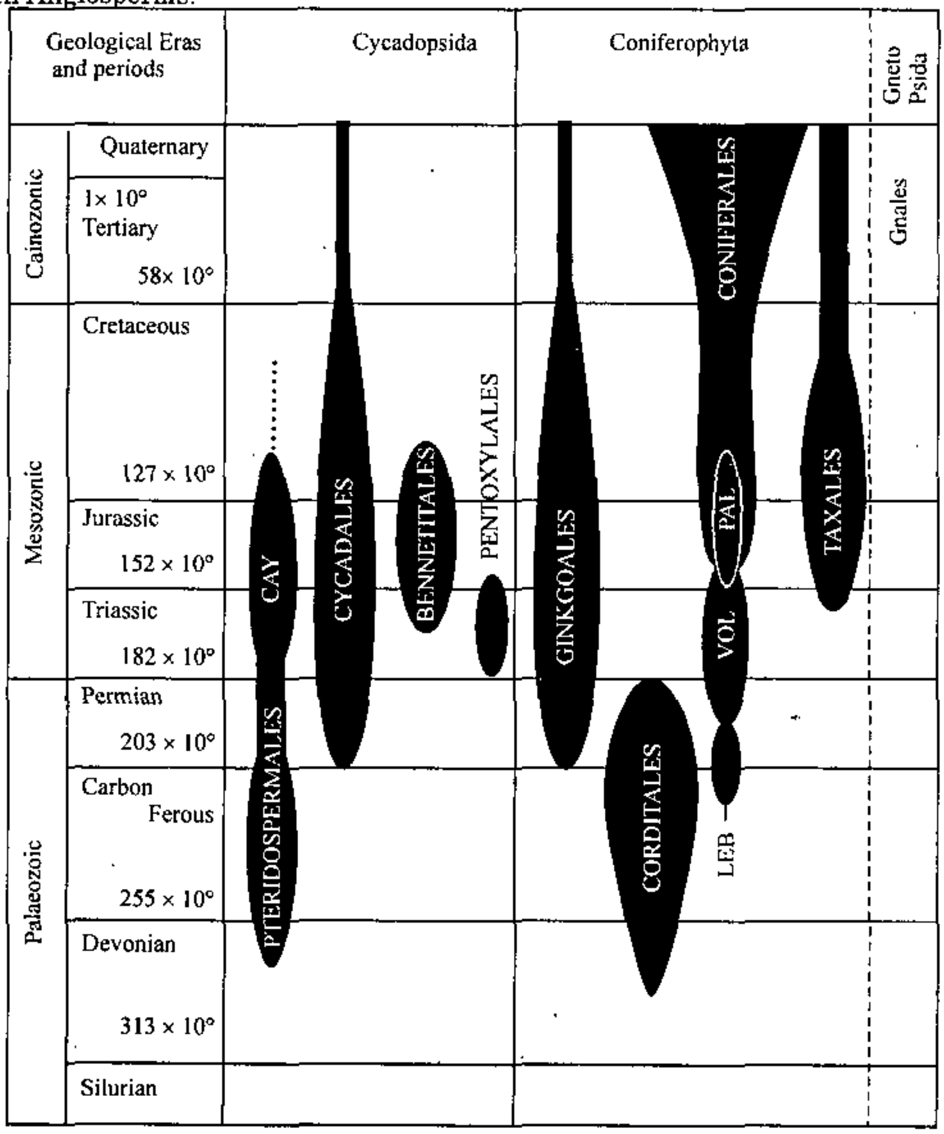


Fig. 1.1. Geological history of Gymnosperms (Modified from Melchior and Werdermann 1954) (Cay = Caytonibeae, Leb = Lebachiaceae, Vol = Voltziaceae)

The class Gymnospermae includes most ancient seed bearing plants, which in those times have flourished like dominant flora and now finally became extinct. It includes the most important **Cycadofilicales** which have characteristic fern like leavs and bear primitive type of seeds. This extinct group shows its possible origin from Pteridophytes. Besides this, there are few more ancient groups viz., **Cordaitales** and **Bennettitales**. **Cordaitales** were predominant in the Palaeozoic period and are considered as the fossil **Coniferales** and might have given rise to present day **Coniferales** and **Gnetales** (**Eames**, 1952). The order **Bennettitales** were quite dominant in the

Mesozoic and are known as fossil **Cycads** because of their resemblance with the modern **Cycads**.

The rest of the members are placed in the orders, which are forming the main flora of present day Gymnosperms *e.g.* **Cycadales, Ginkgoales, Coniferales** and **Gnetales**. Among these four orders of the modern Gymnosperms, the **Coniferales** is by far the largest and widely distributed with quite familiar and economically important plants like *Pines, Firs, Cedars*, and *Spruces*. *Sequoia gigantea* is a conifer which is a giant tree and may live up to 4000 years. The members of the order *Cycadales* are found in tropical and sub-tropical areas *e.g. Cycas, Microcycas, Zamia, Dioon, Encephalartos etc.* The other **Ginkgoales** has a sole representative, the *Ginkgo biloba*, which is known as living fossil. The last order of living Gymnosperms is the *Gnetales* which because of its members, is quite interesting and phylogenetically important. It includes three genera *viz. Gnetum, Ephedra*, and *Welwitschia*, which all differ among themselves sharply and show gradual evolutionary tendency towards the angiospermic side. It is often regarded as the connecting link between Gymnosperms and Angiosperms.

1.2. GENERAL CHARACTERS OF GYMNOSPERMS

1. Mature plants are tall, woody, perennial trees or shrubs and show xerophytic characters. Most of the members of the orders like **Cycadales, Coniferales,** *Ginkgoales,* and *Gnetales,* are living while those of the orders like **Cycadofilicales, Cordaitales**, Pentoxylales and **Bennettitales** are represented by fossil members.
2. Plant body is **sporophytic** which is distinctly differentiated into root, stem and leaves. *Zamia pygmea* is the smallest gymnosprm and *sequoiadendron gigantium* is the tallest.
3. There is a tap root system with **diarch** to **polyarch** and **exarch** stele.
4. The stem is branched but unbranched in *Cycas. Sequoia semipervience and, Sequoiadendron giganteum* are living trees measuring upto 120 meters in height.
5. The leaves are **dimorphic** *i.e.* **scale leaves** and **foliage leaves.** The foliage leaves may be quite big **(megaphyllous)** or small **(microphyllous)** in size.
6. Usually the leaves are arranged in a spiral and acropetal manner except in Cupressaceae and Gnetales where they are arranged in a cyclic manner.
7. The leaves have a thick cuticle and sunken stomata.
8. The mesophyll of the leaves is undiffersentiated (*e.g. Pinus, Cedrus*) or differentiated into palisade tissue and spongy parenchyma (*e.g. Cycas*).
9. Most gymnosperms have do not have lateral veins and lateral translocation of nutrients takes place with the help of transfusion tissue.
10. The vascular bundles in the stem are **conjoint, collateral, open, endarch** and are arranged in a ring.
11. Secondary growth is prominent and distinct. Annual rings are formed is secondary wood.
12. The **xylem** is composed of **xylem parenchyma** and **xylem tracheids** with **bordered pits.** Xylem vessels and fibres are absent except in **Gnetales.**
13. Phloem is composed of **sieve tubes** and **phloem parenchyma. Companion cells** are completely absent.
14. Secondary wood is of two types *i.e.* **manoxylic** (loose and soft) *e.g., Cycas* and **pycnoxylic** (compact and hard) *e.g., Pinus.*
15. The reproductive organs in living Gymnosperms are arranged compactly to form cones or strobili except the female reproductive organ in some genera like *Cycas.*
16. Usually the cones are **monosporangiate** (unisexual) but in certain members **bisporangiate** (bisexual) cones have also been reported.
17. The members are **heterosporous** *i.e.,* they produce two types of spores which are called as **microspores** (pollen grains) and **megaspores**.

18. The male cones are composed of a number of **microsporophylls** arranged spirally and compactly around the central axis. Each microsporophyll has many **microsporangia** (pollen sacs) on the abaxial side (lower surface) which contain many **microspores** or pollen grains. The microsporophylls may be flattened dorsiventral structures as in *Cycas* or peltate struture as in *Taxus*, *Dioon* etc.
19. The development of sporangium is of **eusporangiate** type *i.e.* they develop from a group of cells. The wall of sporangium is multilayered.
20. During the development of male gametophyte either only one prothallial cell *e.g., Cycas* or two *e.g.,* Pinus. are formed..
21. The female cones are also composed of a number of **megasporophylls** arranged spirally and compactly around a central axis, except in *Cycas* where they are loosely arranged. The megasporophylls bear **ovules (megasporangia).**
22. The megasporophylls may be similar to nomal foliage leaves (*e.g., Cycas*) or **Cauline** (*e.g., Pinus*).
23. The ovule is usually covered externally by a single integument (unitegmic) as in *Cycas, Pinus* etc. but in some cases ovule is surrounded by two integuments *e.g.; Ephedra*. An additional covering in the form of **aril** or **cupule** is also present outside the integument in *Taxus*. They are **orthotropus**.
24. The ovules are naked structures *i.e.* they are not enclosed in the ovary.
25. Archegonia are developed in female gametophyte except in *Gnetum and Welwitschia*. The archegonium has a single egg and a venter canal cell. Neck canal cells are absent in the neck of archegonia.
26. The pollination is of direct type i.e., Pollen grains directly come in contact with the ovule. Pollens are deposited in the pollen chamber where they germinate. All gymnosperms are wind pollinated.
27. Fertilization is siphonogamic and the pollen tube may function as **haustorial** (*e.g. Cycas*) or **sperm carrier** (*e.g.; Pinus*).
28. Development of embryo is of **meroblastic** type *i.e.;* the embryo develops from the lower part of the zygote.
29. Development of endosperm takes place before fertilization and hence the endospesm is **haploid.**
30. The embryo is straight and embedded in the endosperm except in order **Bennettitales**.
31. Some time several embryos are developed inside a ovule. This phenomenon is termed as **polyembryony** *e.g., Pinus*.
32. A true fruit is lacking because of the absence of ovary.
33. The ovule after fertilization and embryo formation turns into **seed.** The integument of the ovule acts as seed coat.
34. Number of **cotyledons** vary in different members. Cotyledons are two in *Cycas*, many in *Pinus* and are green while still enclosed in the seed.
35. The **sporophytic** or diploid phase is long lived, dominant and independent while the **gametophytic** or haploid phase is short lived and dependent on sporophytic phase.
36. The plants show alternations of generation. The diploid phase is dominant, whereas the haploid gametophytic phase is reduced. The gametophytic phase is dependent on the sporophytic phase.
37. The seeds represent three generations :
    (i) Integument and nucellus represent the parent sporophytic stage.
    (ii) Endosperm represents the gametophytic stage.
    (iii) Embryo represents the new gametophytic stage.

1.3. AFFINITIES OF GYMNOSPERMS

The group **Gymnosperms** shows great affinity with higher **Cryptogams (Pteriodophytes)** on one hand and with **Angiosperms** on the other hand and thus act as an intermediate group of connecting link between the two from evolutionary point of view.

Resemblances with Pteridophytes

1. Both the groups are identical in the alternation of generation. *i.e.* show regular alternation of generation of sporophytic and gametophytic generations.
2. Plant body is differentiated into root, stem and leaves in both the groups.
3. Main plant body is sporophytic in nature.
4. Young leaves show circinate vernation (*e.g., Cycas*), like those of ferns. In both groups leaves are pinnately compound.
5. Xylem is devoid of xylem vessels and phloem is without companian cells (except **Gnetales**).
6. Formation of micro- and megaspores in micro- and megasporangia, borne on micro- and megasporophylls respectively.
7. Sporangia are grouped in sori (*e.g., Cycas*).
8. Formation of male and female cones.
9. Sperms are ciliated (*e.g., Cycas* and *Ginkgo*).
10. Sporophytic generation is long independent and dominent while gametophytic generation is short and dependent on sporophytic generation.
11. Suspensor formation is common.

Differences with Pteridophytes

1. Gymnosperms are mostly trees whereas pteridophytes are perennial herbs or shrubs.
2. Pteridophytes usually grow in moist, shady and terrestrial places, while gymnosperms occur in xerophytic habitats.
3. In Gymnosperms typical tap root system is present while in Pteridophytes adventitious roots are present.
4. Cambium is absent thus no secondary growth takes place in Pteridophytes, while it is prominent in Gymnosperms.
5. Development of ovule and seed formation is absent in Pteridophytes while present in Gymnosperms.
6. In heterosporous members of Pteridophytes both micro- and megaspores are shed from their sporangia, while in case of Gymnosperms only microspores are shed from microsporangia and the megaspore remains inside the ovule.
7. Archegonia are well developed with neck canal cells in Pteridophytes while in Gymnosperms the archegonia are very simple with short neck and no neck canal cells.
8. In Gymnosperms pollen tube is formed for carrying sperms to archegonia while in Pteridophytes it is absent

Resemblances with Angiosperms

1. Both are shrubs and trees with differentiation into root, stem and leaves.
2. Xylem and phloem are quite prominent. Secondary growth also takes place (expect monocots).
3. Flowers are present in both the groups.
4. Pollen tubes are developed in both the groups, which help in fertilization (siphonogamy).
5. The megaspore permanently remains inside the megasporangium and develops into female gametophyte.
6. Seed formation take place in both the groups.
7. General life history is similar in both the groups.

Differences with Angiosperms

1. Vessels in xylem element and companion cells in phloem are completely absent in Gymnosperms (except Gnetales), while they are present in Angiosperms.
2. The flowers in Gymnosperms are unisexual and simple without calyx and corolla, while in Angiosperms the calyx and corolla are present and may be unisexual or bisexual.
3. Cones are present in Gymnosperms while absent in Angiosperms.

4. The seeds are naked in Gymnosperms and are enclosed in carpel or ovary in Angiosperms.
5. Fruit formation is absent in Gymnosperms.
6. Pollination in Gymnosperms takes place by means of air currents while in Angiosperms through various agencies.
7. Archegonia are present in Gymnosperms and absent in Angiosperms.
8. In Gymnosperms the endosperm is formed before fertilization from the vegetative tissues of prothallus while in Angiosperms, it is formed after fertilization.
9. Endosperm is triploid in Angiosperms while haploid in Gymnosperms.
10. Angiosperms shows double fertilization where as this phenomenon is absent in Gymnosperms.
11. Polyembryony of Gymnosperms is not common in Angiosperms.

Phylogenetic relationships of Gymnosperms

The class **Gymnospermae** has been segregated into two main divisions the **Cycadophyta** and **Coniferophyta.** There is no doubt about their possible origin from the **Filicineae** but the matter is still on the carpet as to whether the two divisions had a common origin from Filicineae or have originated separately from different groups of Filicineae. The discovery of **Cycadofilicales** (Pteridosperms) or the seed ferns, which have close resemblance with ferns in many features, strongly supports the possible origin from Pteridophytes. It was also presumed that **Cycadales** and **Cycadeoidales** have been evolved from **Cycadofilicales.** The fossil order **Cordaitales** irrespective of the fact whether it had originated along with **Cycadofilicales** or had an independent origin, has given rise to present day **Conifers** and **Ginkgoales.** The **Gnetales** represents a sepearate shoot from the Conifers and show gradual evolutionary tendency towards angiospermic side. No ancestors are available for **Gnetum,** *Welwitschia* and *Ephedra.* More over none of these members are closely allied to other Gymnosperms. It is therefore concluded that like ferns the Gymnosperms are also polyphyletic in origin.

1.4. ECONOMIC IMPORTANCE OF GYMNOSPERMS

The gymnosperms plants are of great economic value. Some of the major uses are detailed here under.

(i) As ornamentals : Some of the gymnosperms are grown in in gardens in different parts of the world for *e.g. Cycas, Pinus, Thuja, Agathis alba, , Cryptomeria, Cupressus, Metaseuquoia, Taxus, Taxodium, Larix, Podocarpus, Ginkgo biloba etc.* These plants are having botanical importance.

(ii) Wood : Several plants of this group yield useful timber, for *e.g.,*

(a) *Cedrus deodara :* Wood is used in making railway sleepers, making bridges, doors, furniture, electric poles, flooring in houses etc.

(b) *Juniperus virginiana :* Wood is used in making high quality pencils.

(c) *Agathis austrilis :* Rrailway sleepers, boats, poles etc.

(d) *Larix :* Railway sleepers.

(e) *Cryptomeria Japonica :* Construction of buildings.

(f) *Abies :* Boxes, packing cases and roof in the hill houses.

(g) *Pinus wallichiana :* **Kail wood,** building, construction

(h) *Pinus roxburghii :* **Chir pine** wood is used for various purposes and a good source of resin.

(iii) Resins : Several conifers yield resins which are obtained by tapping. Resins cannot dissolve in water. They are soluble in organic solvents. Most of the resins are used in paint and varnish industry in medicines and in biological preparations. Some resins obtained from living and fossil conifers are as under.

(a) **Kopal :** Obtained from *Agathis australis;* also called candle gum or green gum, used in paint industry, making of plastics, *etc.*

(b) **Amber :** Obtained from fossil conifer *Pinites succinifera*-making of beads and jewellery etc.

(c) **Sondarac :** Obtained from *Callitris quadrivalis* and *Tetraclinis articulata*, used as metal varnish.

(d) **Turpentines :** Obtained from different species of *Pinus* for *e.g., P. australis, P. ponderosa, P. caribeae, P. wallichiana, P. merkusii etc.* used in varnish industry.

(e) **Canada balsum :** Obtained from *Abies balsamea,* mounting agent.

(f) **Spruce gum :** Obtained from *Picea rubens.*

(g) **Venetian turpentine :** Obtained from *Larix deciduà,* used in preparation of special type of varnish and veterinary medicines.

(iv) Essential oils : Different species of gymnosperms are the source of essential oils. These oils are used mainly in perfumery, soap industry *etc.* Some of the important oil yielding gymnosperms are *Tsuga canadensis, Picea glauca, Abies siberica* and *Cedrus deodara.* Cedar wood oil is obtained from *Juniperus virginiana.* It is used in microscopic work. Terpentine oil is obtained from *Pinus* spp. It is used as thinner *(solvent) in paint and varnish industry.*

(v) Paper industry : The wood of several gymnosperms particular those of conifers is used in paper industry *e.g. Abis, Picea, Cryptomeria, Pinus, Psuga etc.*

(vi) Edible :

(a) **Sago** : Starch is obtained from stem of *Cycas revoluta.*

(b) **Chilgoza :** Seeds of *Pinus gerardiana,* nutritious and edible.

(c) **Vegetable :** Young leaves of *Gnetum* are cooked as vegetable.

(vii) Medicines : An important alkaline **ephedrine** is obtained from *Ephedra* and is widely used in the treatment of cough, cold and other respiratory disorders. An oil is obtained from *Gnetum ula,* which is used as massage in reumatic pains. Leaf decoction of *Biota (Thuja)* is used as medicine in case of intermittent fever, cough, scurvy and rheumatisun. A volatile oil is extracted from the shoots and leaves of *Thuja,* and it is often used as vermifuge.

(viii) Miscellaneous : Many gymnosperms for *e.g. Pinus* are used as fuel. *Gnetum latifolium* yields fibre which is used in making ropes and nests. From the leaves of Cycas *circinalis* hat, and baskets are prepared.

1.5. DISTRIBUTION OF GYMNOSPERMS IN INDIA

As mentioned earlier out of total population of 70 genera and 725 species of gymnosperms in world, only 16 genera and about 53 species have been reported from India (Raizada and Sahni, 1960). It is as follows :

The Indian gymnosperm flora is mainly represented by Cycadales, Coniferales and Gnetales. With this some gymnosperms are cultivated *(Ginkgo biloba)* in Indian gardens. It does not occur naturally in our country.

Cycadales : *Only Cycas occurs in India and represented* by fire species :

1. *C. beddomei :* Dry hills of Cuddapah district of Andhra Pradesh and Calicut.
2. *C. circinalis :* Dry deciduous forests of Mysore, Tamil Nadu and Orissa.
3. *C. pectinata* : Plains and eastern hills of Assam.
4. *C. rumphii* : Coasts of Andman and Nicobar Islands.
5. *C. revoluta* : A native of Japan, culturated commonly in Indian gardens.

Ginkgoales : represented by 1 species, *Ginkgo biloba,* a native of china, occur in India in cultivated gardens.

Coniferales : Out of 54 living genera of coniferales in the world, about 10 genera have been reported from India. They are found predominantly in the Himalayas and particular rich in the north-west Himalayas. Their distribution is mainly governed by altitude.

Abies : 4 species (*A, pindrow, A spectabilis, A. delevayi, A. densa),* an altitude ranging from 2300 to 4300 meters

Cedrus : 1 species (*C. deodera*)- Western Himalays between 1200-3300 meters.

Larix : 1 specie (*L. griffithiana*) Estern Himalayas 2400-3700 meters.

Picea : 2 species (*P. smithiana, P. spinulosa*) Western, Central and Eastern Himalayas.

Pinus : 6 species-distributed throughout in Himalayas.

P. roxburghii (Vern. Chir) : 2000-5000 feet.

P. wallichiana : North west Himalayas-5000-12000 feet.

P. gerardiana (vern. Chilgoza) : Kashmir and Kinnaur district of Himachal Pradesh at an altitude of 5000-12000 feet.

P. merkusii : Hillocks in East Bengal, 450 to 1800 feet.

P. insularis : Knasya regions of Assam, 2000-5400 feet.

Tsuga : 1 species (*T. dumosa*)–Central and Eastern Himalayas at an altitude ranging from 5000 – 9000 feet.

Cupressus : 2 species (*C. torulosa, C. cashmeriana*), distributed widely in Himalayas.

Juniperus : 6 species (*J. communis, J. recurva, J. wallichiana, J. squamata, J. macropoda and J. coxii*). present in alpine ranges of the Himalayas.

Cephalotaxus : 2 species (*C. griffithii, C. mannii*) evergreen forests of the Eastern Himalayas, Arunachal Pradesh, and Naga and Khashi Hills.

Taxus : One species– *T. baccata,* distributed in all along the Himalayas at an elevation from 5000 – 9000 feet.

Podocarpus : Two species– *P. neriifolius, P. wallichianus*– distributed in Assam. East Himalays, Andmans and Nicobar Islands. With this some coniferales are also cultivated as ornamentals in Indian gardens. These include *Araucaria cooki, A. cunninghamii, Thuja occidentalis, Cupressus cashmeriana, Cryptomeria japonica etc.*

Gnetales : Indian Gnetales include species of *Gnetum* and *Ephedra.*

Gnetum : Represented by six species.

G. gnemon var. *brunonianum* ⎤ Assam, Nilgiris
G. gnemon var *griffithi* ⎦ and shimla hills

G. montana– Assam, Sikkim and parts of Orissa

G. ula– West and east coast of India in Kerala, Kanara, Coorg, Orissa *etc.*

G. oblongum– West Bengal.

G. latifolium– Andman and Nicobar Islands

G. contactrum– Kerala, Nilgiris.

Ephedra : Represented by 7 species :

E. pachyclada *E. intermedia* *E. saxatilis* *E. gerardiana* *E. nebrodensis* *E. major* *E. regeliana*	All species are confined to the North-west Himalayan region.

1.6. SUMMARY

The term gymnosperm was introduced by **Theophrastus** in 300 B.C. It is a small group of plants comprising about 70 genera and 725 species. Sixteen genera of gymnosperms are reported from India. The geological history reveals that gymnosperms are more primitive than angiosperms. Few gymnosperms for *e.g. Gnetum, Ephedra* and *Welwitschia* show gradual evolutionary tendency towards the angiosperm side. It is often regarded as the connecting link between gymnosperms and angiosperms.

In gymnosperms both living and fossil genera are present. The order Cycadales and Ginkgoales having a long fossil history and regarded as living fossils. Gymnosperms are tall, woody, perennial trees or shrubs and show xerophytic characters. Plant body is sporophytic and differentiated into root, stem and leaves. Plants possess well-developed tap root system. Steins are crect woody and branched or unbranched. Leaves are dimorphic or monomorphic. Roots are di-to polyarch. In xylem vessels are absent. Phloem consists sieve tubes and phloem parenchyna. Companion cells are absent. Wood is manoxylic or pycnoxylic. Mesophyll is undifferentiated or differentiated into spongy parenchyma and palisade tissues. Lateral veins are absent in the leaves. The lateral translocation of nutrients tales place with the help of *transfusion tissue*.

Gymnosperms are heterosporous. In most of the living gymnosperms reproductive organs are arranged in the form of compact cones or strobilii. Cones are monosporangiate or bisporangiate. Male cones bear microsporophylls which are similar to stamens. Female cones are formed by the aggregation of megasporopylls which are similar to carpel. Microporophylls bear microsporangia, which develop on the abaxial side. The development of the microsporangium is eusporangiate type. Megasporophylls bear naked megasporangia (ovules). Ovules are generally orthrotropus and unitegmic. Generally 3-4 celled male gametophyte (pollen) is formed. Prothallial cells may be formed or all together absent. The functional megaspore by gemetogenesis first forms a free nuclear female gametophyte (endosperm) which later on becomes cellular. The number of archegonia in female gametophyte is variable. Pollinate is anemophilous and fertilization is siphonogamous. As a result of fertilization zygote is formed which soon develops into embryo. The development of zygote is meroblastic. Embryo soon shows distinction of radicle, hypocotyl, cotyledons, plumule and a long suspensor. The seed comprises tissues of three generations namely parent sporophytic, gametophytic and second sporophyte. The germination is usually epigeal, sometimes hypogeal and rarely viviparous.

The gymnosperm plants are of great economic importance. They are source of wood, medicines, resins, essential oil and food. Several gymnosperms are ornamental. Gymnosperms are poorly represented in the Indian flora. A total of 16 genera and 53 species of gymnosperms occur in India.

1.7. STUDENT ACTIVITY

1. Describe the economic importance of Gymnosperms.

2. Describe the general characters of Gymnosperms.

1.8. TEST YOURSELF

1. Who was the first to use the term gymnosperm?
2. What is the main character of gymnosperms?
3. What is the major difference between gymnosperms and angiosperms?
4. Name the tallest gymnosperm.
5. The wood of the which gymnosperm is used in making high quality pencils?
6. Name the gymnosperm from which canada balsam is obtained.
7. What is the main character in which gymnosperm resemble with angiosperms?
8. Name the gymnosperm from which spruce gum is obtained.

ANSWERS

1. Theophrastus, **2.** Naked ovule **3.** In gymnosperms fruit is absent
4. *Sequoiadendron* **5.** *Juniperus virginiana* **6.** *Abies balsamea*
7. Presence of seeds. **8.** *Larix decidua.*

UNIT - I

CHAPTER

2

CLASSIFICATION OF GYMNOSPERMS

STRUCTURE

- Introduction
- Some old systems of classification
- Classification proposed by Coulter and Chamberlin (1910)
- Classification proposed by Birbal sahni (1920)
- Classification proposed by Chamberlin (1935)
- Classification proposed by Arnold (1948)
- Classification proposed by Pilger and Melchior (1954)
- *Classification proposed by D.D. Pant (1957)*
- Classification proposed by Raizada and Sahni (1960)
- Classification proposed by A. Cronquist, A. Takhtajan and Zimmermann (1966)
- Classification proposed by D.W. Bierhorst (1971)
- Modern classification of Gymnnosperms
- Classification proposed by Taylor (1981)
- Classification proposed by Stewart (1983)
- Classification proposed by Sandra Holmes (1986)
- Important characters of different groups of gymnosperms.
- Summary
  - Student activity
  - Test yourself
  - Answers

LEARNING OBJECTIVES

After reading this chapter you will be able to classify the gymnosperms and important characters of different groups of gymnosperms.

1.0 INTRODUCTION

Classification is a process in which various organisms are placed in various phyla, classes, orders and families on the basis of their similarities and dissimilarities in order to make the study of organisms possible. Because of various controversies regarding their position in the plant kingdom and the presence of large number of fossil genera, the classification of Gymnosperms is continuously in the state of changes. This topic is quite interesting and controversial. Various classifications were proposed by different workers from time to time. Some of the important classifications are discussed below :

1.1. SOME OLD SYSTEMS OF CLASSIFICATION

It was **Robert Brown,** who for the first time in 1827 recognised these plants and placed them in a distinct group Gymnosperms. **Bentham** and **Hooker** (1862-1883) kept this group in between dicotyledons and monocotyledons.

Van Tieghem (1898) placed Gymnosperms as one of the two divisions of **Spermatophyta** and further divided it as follows :

- **Spermatophyta**
  - Gymnosperms
    - Cycadales
    - Gnetales
    - Coniferales
  - Angiosperms

Afterwards due to the discovery of large number of fossil genera three more orders viz. **Cycadofilicales, Bennettitales** and **Cordaitales** were included in this group.

Engler (1897) placed this group under Embryophyta and due to the discovery of motile sperms in *Ginkgo* (**Hirase** 1896) a separate order **Ginkgoales** was established. The class Gymnospermae has been classified into seven orders as follows :

- **Embryophyta**
  - (Class) Gymnospermae
    - (Orders)
      1. Cycadofilicales
      2. Cycadales
      3. Bennettitales
      4. Ginkgoales
      5. Coniferales
      6. Cordaitales
      7. Gnetales
  - Angiospermae

1.2. CLASSIFICATION PROPOSED BY COULTER AND CHAMBERLIN (1910)

Coulter and Chamberlain (1910) proposed a system of classification and divided this group into seven orders as follows :

- Gymnosperms
  1. Cycadofilicales
  2. Cycadales
  3. Bennettitales
  4. Ginkgoales
  5. Coniferales
  6. Cordaitales
  7. Gnetales

1.3. CLASSIFICATION PROPOSED BY BIRBAL SAHNI (1920)

Prof. Birbal Sahni (1920) classified the group Gymnosperms as follows on the basis of morphological nature of ovule bearing organs :

- *Gymnosperms*
  - Divisions
    - **Phyllosperms** (Seeds developed on leaves)
      - Orders
        1. **Cycadofilicales**
        2. **Coniferales**
        3. **Bennettitales**
    - **Stachyosperms** (Seeds developed on stem)
      - Orders
        1. **Cordaitales**
        2. **Coniferales**
        3. **Ginkgoales**
        4. **Taxales**

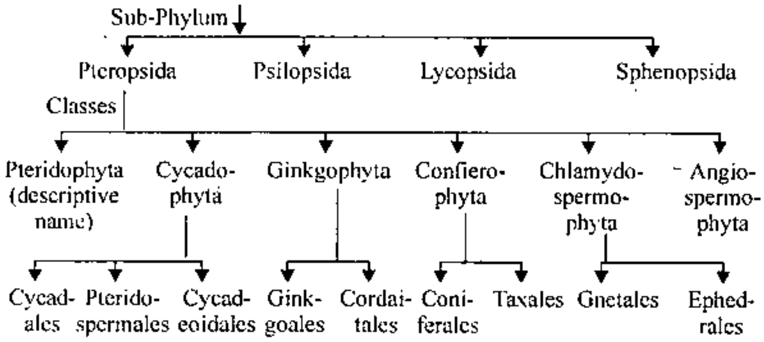
1.4. CLASSIFICATION PROPOSED BY CHAMBERLIN (1935)

Chamberlain (1935) divided the class Gymnosperms into two sub classes and further classified as follows. He supported the system of classification given by **Sahni** (1920) but he changed the names of divisions as **Cycadophytae** and **Coniferophytae**.

- **Gymnosperms**
  - (Sub-classes)
    - **Cycadophytae** (wood monoxylic)
      - Orders
        - **Cycadofilicales**
        - **Coniferales**
        - **Bennettitales**
    - **Coniferophytae** (wood pycnoxylic)
      - Orders
        - **Cordaitales**
        - **Coniferales**
        - **Ginkgoales**
        - **Gnetales**

1.5. CLASSIFICATION PROPOSED BY ARNOLD (1948)

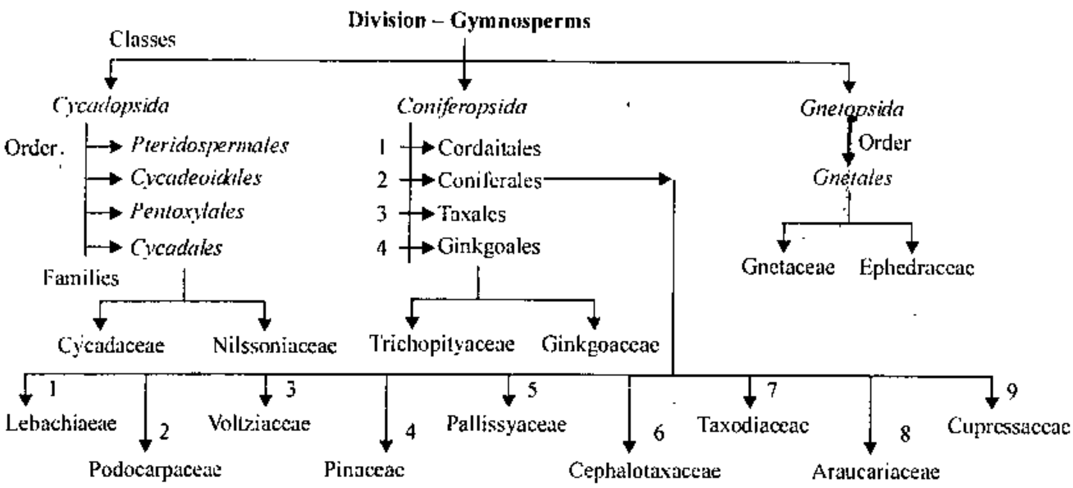
Arnold (1948) gave his scheme of classification as follows. He proposed the separation of *Taxus* from Coniferophyta and *Ephedra* into a separate order **Ephedrales** under Chlamydospermophyta. He grouped all plants above the level of **Bryophytes** in phylum **Tracheophyta** as follows :



Phylum Tracheophyta (all plants above the level of Bryophytes)

Pearson (1922), **Florin** (1931-34), **Eames** (1952) etc. questioned the inclusion of *Gnetum*, *Ephedra* and *Welwitschia* in the order *Gnetales*. According to **Eames** (1952) *Ephedra* is widely separated from *Welwitschia* and *Gnetum*. He also stated about the separation of *Gnetum* and *Welwitschia* into separate order **Gnetales** and **Welwitschiales** respectively.

1.6. CLASSIFICATION PROPOSED BY PILGER AND MELCHIOR (1954)



Pilger and **Melchior** (1954) classified the division Gymnosperm as follows ;

In this text the classification of **Pilger** and **Melchior** (1954) is being followed. **Sporne (1965)** also followed the above system of classification in his book **"Morphology of Gymnosperms"**.

1.7. CLASSIFICATION PROPOSED BY D.D. PANT (1957)

D.D. Pant (1957) modified the **Arnold's** classification and classified the group **Gymnosperms** into three divisions as follows :

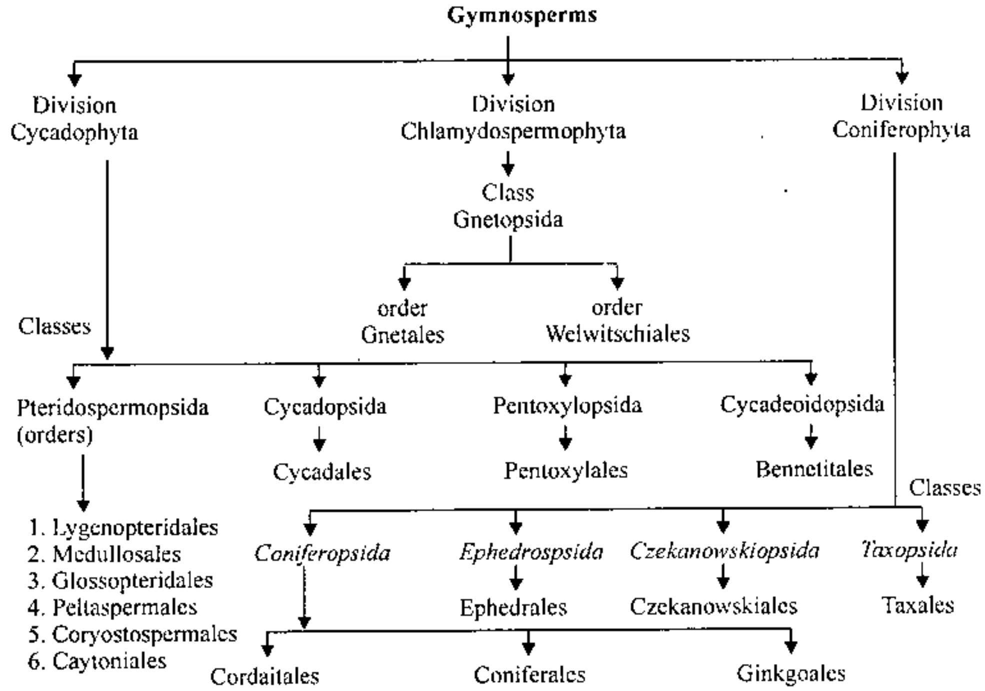
He proposed the following modifications in **Arnold's** system and strictly followed the recommendations of **International Code of Botanical Nomenclature 1956.**

(i) A new class **Ephedropsida** with a single order **Ephedrales** has been included under division **Coniferophyta.**

(ii) A new class **Czekanowskiopsida** with a single order **Czekanowskiales** has been established with the discovery of new genus **Czekanowskia.**

(iii) The class **Pento xylopsida** with order **Pentoxylales** has been included under division **Cycadophyta.**

(iv) Orders like **Glossopeteridales**, **Peltaspermales**, **Coryostospermales**, **Caytoniales** have also been included under class **Pteridospermopsida**.



1.8. CLASSIFICATION PROPOSED BY RAIZADA AND SAHNI (1960)

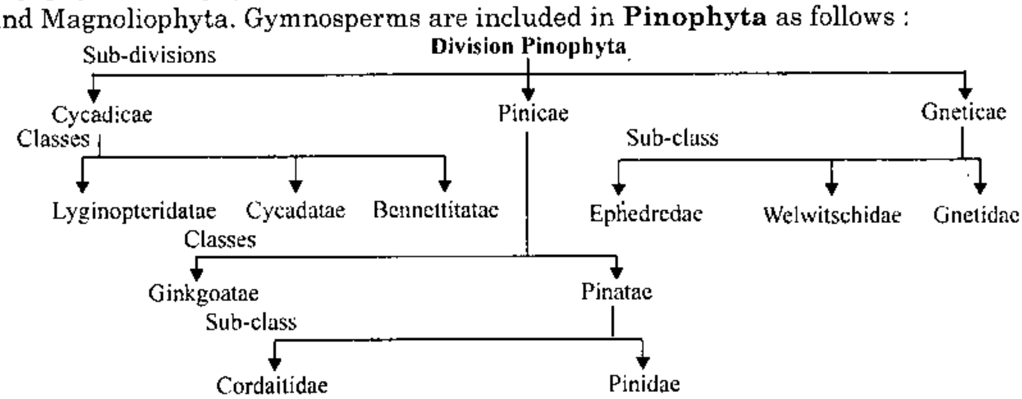
Raizada and Sahni (1960) in view of the discovery of **Pentoxylon** (**Sahni** 1948) classified the group **Gymnosperms** as follows :

Gymnosperms —
1. Pteridospermales } **Cycadophyta**
2. Cycadeoidales
3. Cycadales
4. Pantoxylales — **Pentoxylales**
5. Cordaitales
6. Ginkgoales } **Coniferophyta**
7. Coniferales
8. Gnetales (?)

1.9. CLASSIFICATION PROPOSED BY A. CRONQUIST, A. TAKHTAJAN AND ZIMMERMAN (1966)

Cronquist, A. Takhtajan and Zimmerman (1966) also gave their scheme of classification which is as follows :

All embryo bearing plants have been placed in eight divisions viz Rhiniophyta, Bryophyta, Psilophyta, Lycopodiophyta, Equistophyta, Polypodiophyta, Pinophyta, and Magnoliophyta. Gymnosperms are included in **Pinophyta** as follows :



1.10. MODERN CLASSIFICATION OF GYMNOSPERMS

The class Gymnospermae has been classified into the following orders as given by **Otto** and **Towle** (1965) in their book "Modern Biology".

1. **Order Cycadales :** Primitive fern like Gymnosperms and Cycads (*Cycas, Dioon, Zamia*)
2. **Order Ginkgoales :** *Ginkgo biloba.*
3. **Order Coniferales :** Cone bearing Gymnosperms, ever green, foliage leaves in the form of needles. (Pines, Cedars, Spruces, Firs, Yews).
4. **Order Gnetales :** Possible forerunners of flowering plants, wood having vessels, (*Ephedra, Gnetum and Welwitschia*)

Engler, Melchior & Werdermann (1954) discussed another system of classification in *Syllabus der Pflanzen familien* which is based on wood anatomy, leaf type & seed structure. This was similar to that given by **Pilger** and **Melchior (1954)**.

1.11. CLASSIFICATION PROPOSED BY D.W. BIERHORST (1971)

He divided gymnosperms into 3 classes :

Class 1 : Cycadopsida (6 orders)

Order 1 : Pteridospermales
Order 2 : Caytoniales
Order 3 : Cycadeoidales
Order 4 : Cycadales
Order 5 : Pentoxylales
Order 6 : Glossopteridales

Class 2 : Coniferopsida (5 orders)

Order 1 : Cordaitales
Order 2 : Protopityales
Order 3 : Ginkgoales
Order 4 : Coniferales
Order 5 : Taxales

Class 3 : Gnetosida (3 orders)

Order 1 : Ephederales
Order 2 : Gnetales
Order 3 : Welwitchiales

1.12. CLASSIFICATION PROPOSED BY SPORNE (1974)

He recognized 3 classes and nine orders of gymnospems :

Class 1 : Cycadopside

Order 1: Pteridospermales
Order 2: Bennettitales
Order 3: Pentoxylales
Order 4: Cycadales

Class 2 : Coniferopsida

Order 1: Cordaitales
Order 2: Coniferales
Order 3: Taxales
Order 4: Ginkgoales

Class 3 : Gnetopsida

Order 1: Gnetales

1.13. CLASSIFICATION PROPOSED BY TAYLOR (1981)

Taylor (1981) divided gymnosperms into six major divisions (Progymnospermophyta, Pteridospermophyta, Cycadophyta, Cycadeoidophyta, Ginkgophyta and Coniferophyta) as under :

1. Division Progymnospermophyta (Progymnosperms)

2. Division Pteridospermophyta (Seed ferns)
   1. Lyginopteridales 2. Medullosales 3. Callistophytales
   4. Calamopityales 5. Caytoniales 6. Corystospermales
   7. Peltaspermales 8. Glossopteridales
3. Division Cycadophyta (Cycads)
4. Division Cycadeoidophyta (Cycadeoids)
5. Division Ginkgophyta (Ginkgophytes)
6. Division Coniferophyta
   1. Cordaitopsida (Cordaites)
   2. Coniferopsida (Conifers)
      1 Voltziales 2. Coniferales 3. Taxales

According to **Taylor** (1981) Gnetales, Vojnovskyales and Pentoxylales are the problematic gymnosperms.

1.14. CLASSIFICATION PROPOSED BY STEWART (1983)

Stewart (1983) classified the gymnosperms mainly on the basis of the evidences available from the fossil records. He divided gymnosperms into three classes (Progymnospermopsida, Gymnospermopsida and Gnetopsida) as under.

1. Progymnospermopsida
   1. Aneurophytales 2. Archaeopteridales 3. Protopityales
2. Gymnospermopsida
   1. Pteridospermales 2. Cycadales 3. Cycadeoidales
   4. Caytoniales 5. Glossopteridales 6. Pentoxylales
   7. Czekanowskiales 8. Ginkgoales 9. Cordaitales
   10. Voltziales 11. Coniferales 12. Taxales
3. *Gnetopsida (Gnetum, Ephedra, Welwitschia)*

1.15. CLASSIFICATION PROPOSED BY SANDRA HOLMES (1986)

Holmes (1986), in her book entitled "Outline of Plant Classification", divided gymnosperms into three classes (Cycadopsida, Gnetopsida and Coniferopsida) but also described some fossil ancestors in a separate class Progymnospermopsida. An outline of her classification is undermentioned :

Division SPERMATOPHYTA

Sub-divisuon Gymnospermae

Class Cycadopsida (Cycadatae)

- Order Lyginopteridales (Cycadofilicales, Pteridospermales)
- Order Caytoniales
- Order Bennettitales
- Order Pentoxylales
- Order Cycadales
- Order Nilssoniales

Class Gnetopsida (Gnetatae, Chlamydospermae)

- Order Welwitschiales
- Order Ephedrales
- Order Gnetales

Class Coniferopsida

- Order Ginkgoales
- Order Cordaitales
- Order Coniferales (Pinales)
- Order Voltziales
- Order Taxales

Class Progymnospermopsida (Fossils which are now thought to be nearer to gymnosperms although not of full gymnospermous status)

Order Pityales

Order Aneurophtales

Order Protopityales

1.16. IMPORTANT CHARACTERS OF DIFFERENT GROUPS OF GYMNOSPERMS

Class 1. Cycadopsida (Manoxylic wood)

Order 1. Cycadofilicales (Seed ferns) : This order is also known as Pteridospermales. It includes all fossil members of late Palaeozoic age, most dominant in the Carboniferous period. They were the plants with a moderate size, stem bearing frond of leaves. Foliage leaves were similar to those of ferns. The members act as connecting link between Cycads and ferns. In some features they resemble the ferns i.e., sporangia found on leaves, seeds and microsporangia developed on more or less modified leaves, which never form cones or strobili. Stem is with large central pith, Primary vascular bundles were mesarch *e.g. Lyginopteris, Medullosa etc.*

Order 2. Cycadeoidales (Fossil Cycads) : This order is also known as **Benettitales**. It includes the members found in Mesozoic age, which is known as "age of fossil Cycads." Members are also known as fossil Cycads as they very much resemble Cycads, Plants were tree like with slender columnar stem covered by an armour of persistant leaf bases. Leaves were large and pinnately compound. Wood is manoxylic. Plants were monoecious with cones or strobili developed at the apex of lateral small shoots. *Megasporophylls and microsporophylls form flower like structures e.g., Williamsonia, Williamsoniella, Cycadeoidea etc.*

Order 3. Cycadales (Cycads) : It includes all the present day living members, which are known as "*Cycads*". The members are perennial woody palm like trees with a columnar stem, which is usually unbranched. The stem is covered by an armour of persistant leaf bases and megasporophylls. The stem at its apex bears a frond of leaves. The foliage leaves are pinnately compound and large in size. Wood is manoxylic with *mucilage canals*. Plants are dioecious. Male gametes are large and multiciliate *e.g, Cycas, Zamia, Bowenia, Stangeria, Encephalartos, Microcycas etc.*

Order 4. Pentoxylales : Exclusively fossil group, shrub or small tree in habit. Stem polystelic. Leaves simple thick, lanceolate and spirally arranged. Female cones at the top of dwarf shoots protected by leaves. Male flowers also at the top of dwarf shoots in the form of branched microspophylls forming a disc.

Class 2. Coniferopsida (Pycnoxylic wood)

Order 1. Cordaitales : *It is an extinct group of Palaeozoic arborescent* gymnosperms, commonly known as fossil coniferales. The members were tall trees with slender stem. At the apex of the stem, was present a crown of branches bearing simple strap shaped leaves with parallel venation. Plants may be monoecious or dioecious. Reproductive organs were found aggregated into cones. Wood pycnoxylic *i.e.* compact and hard. Some time pith is very small *e.g. Callixylon, Pitys, Poroxylon, Cordaites* etc.

Order 2 Coniferales : It includes the members, which are commonly known as ***Conifers*** *and constitute* the largest order of present day Gymnosperms. The members are tall woody perennial trees with dimorphic branches. Foliage leaves are characteristically needle shaped or filiform.

Wood is pycnoxylic *i.e.* it is quite hard and compact. Xylem tracheids are provided with bordered pits on their radial walls. Plants may be monoecious or dioecious with male and female cones. Male gametes are non motile *e.g. Pinus, Thuja, Taxus, Araucaria, Podocarpus, Cupressus* etc.

Order 3. Taxales : *Members are shrubs or small trees.* Stem, woody branched with spirally arranged linear leaves. Resin cannals absent. Male cones are small with scale like peltate microsporangiophores. Ovules are solitary with a distinct aril. It includes a single family Taxaceae *e.g. Taxus.*

Order 4. Ginkgoales : It includes all the extinct forms of Palaeozoic age except a single living genus **Ginkgo**, which is among the present day Gymnosperms. The living genus is known as maiden hair tree. It is tall woody perennial tree with dimorphic branches. The foliage leaves are deeply bilobed, flat, leathery with open dichotomous venation. Plants are dioecious. Male and female reproductive organs are axillary in position. Microsporangia are pendulous. Sperms are motile with an spiral band of cilia like Cycads. *e.g. Ginkgo* (living), *Ginkgodium, Ginkgoites, Baiera, Tricopitis, Sphenobaiera, Stephanophytlum* (all extinct).

Class 3. Gnetopsida : This is a very interesting class comprising of only 3 genera, included in a single order *Gnetales* which differ widely from each other. This class, because of diversity in character, acts as a connecting link between Gymnosperms and Angiosperms. Wood is quite compact and hard. Resin canals are absent. Medullary rays are multiseriate. Vessels are quite conspicuous in the wood. Archegonia may or may not be present. Motile male gametes are lacking *e.g. Ephedra, Gnetum and Welwitschia.*

1.17. SUMMARY

Robert Brown (1827) recognised the gymnosperms as a group distinct from angiosperms. However, **Bentham** and **Hooker** (1862-83) in their 'Genera plantarum' placed them between Dicotyledonae and Monocotylidonae. Engler (1897) Placed this group under Embryophyte. **Coulter** and **Chamber** (1910) classified gymnosperms into 7 orders. **Sahni** (1920) created two sub divisions in gymnosperms and included 7 orders in its. **Chamberlain** (1935) supported the system of classification given by Sahni (1920), but he changed the names of divisions. **Arnold** (1948) gave his scheme of classification. He grouped all plants above the level of Bryophytes in Phylum Tracheophyta. **Pilger** and **Melchoir** (1954) classified the gymnosperms in three classes pant (1957) classefied the gymnosperms in three divisions. **A. Cronquist, A. Takhtajan** and **Zimmerman** (1966) classified all embryo bearing plants in eight divisions **Bierhorst** (1971) classified gymnosperms in three classes and further into fourteen orders. Recently **Sandra Holmes classifed** (1986) the gymnosperms into four classes and 17 orders.

1.18. STUDENT ACTIVITY

1. Write important charcters of Gnetopsida.

2. Write briefly the classification of gymnosperms proposed by **Pilger** and **Melchoir**.

1.19. TEST YOUR SELF

1. **Bierhorst** classified the gymnosperms into how many classes?
2. Who was the first botanist to recognise the gymnosperms as a group distinct from Angiosperms?
3. Name the book in which Bentham and Hooker placed the gymnosperms between Dicotyledonae and Monocotyledonase.
4. Name the order in which fossil Cycads are included.
5. Name the order which includes all the extinct forms of palaeozic age except a single living genus.

ANSWERS

1. Three	**2. Robert Brown**	**3.** *Cenera Plantarum*
4. Cycadeoidales	**5.** Ginkgoales	

UNIT-I

CHAPTER

3

CYCAS

STRUCTURE

- Introduction
- *Distribution*
- Morphology
- Anatomy
- Reproduction
- Embryology
- Seed structure
- Relationships
- *Cycas* is a living fossil
- Graphic life cycle
- Economic Importance
- Systematic position
  - Summary
  - Student activity
  - Test yourself
  - Answers

LEARNING OBJECTIVES

After reading this chapter you will be able to know the morphology, anatomy, reproduction and life cycle of *Cycas*.

1.0 INTRODUCTION

*Cycas** is a member of order Cycadales. It is one of the largest order of present day gymnosperms. The members of the order occur from mesozoic period to the present day with a worldwide distribution. The order Cycadales includes about 9 genera and 95 species.

1.1. DISTRIBUTION

It is the only genus of the family Cycadaceae, which is represented in India. It has got about 15 species (**Sporne,** 1965) or 20 species (**Willis**, 1966) which are widely distributed in Eastern as well as Western hemisphere from Madagascar, Eastern coast of Africa to Japan and Australia touching China and India. In our country a few of the species are found growing abundantly in the South in Andaman and Nicobar, islands, Madras, Mysore, Malabar and in North East in East Bengal, Assam, Nepal and Sikkim. A few of the species are also found in Burma and Ceylon. The following species are found in India (Fig. 3) :

**Cycas* is commonly known as 'Sago palm' because of the presence of sago grains (Starch in stem). In Japan it is crushed and bread is prepared and therefore it is also known as 'bread palm'.

C. circinalis Linn : Plants are about 12 to 15 feet tall. Leaves are 5 to 9 feet long. It is distributed in westerm part of peninsular India, Malabar. Orissa hills, Andhra, Madras to Ceylon upto 3500 ft. The plants are also cultivated in Indian gardens. In Hindi it is called as *Jangli-Madan mast-ka-phul.* (Fig. 1)

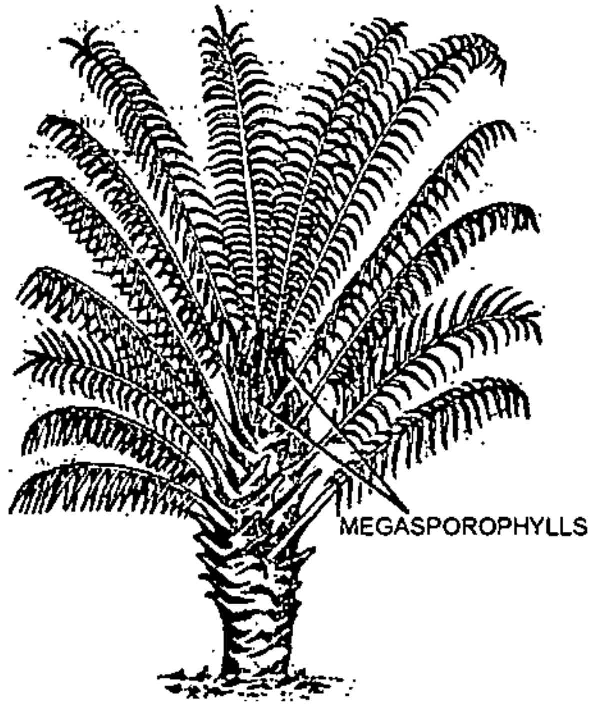


Fig. 1. *Cycas circinalis*—A female plant.

C. pectinata, Griff : Plants are about 8 to 10 feet tall. Leaves are 4 to 6 feet long. It is commonly found growing in Nepal, Sikkim, in Assam Khasia Hill, East Bengal and Burma (Fig. 3). In Nepal it is commonly called as *Thankal* (Fig. 3).

C. beddomel Dyer : Plants are about 40 cm. tall. Leaves 3 feet long. It is naturally found growing on dry hills of Cuddapah in Andhra Pradesh, Madras, Malabar Java. Locally it is called as *Pers. ita*,

Fig. 2. *Cycas rumphii*—A female plant

C. rumphii Miq : Plants are more than 12 feet tall. Leaves 4 to 5 feet long. It is found growing in Andaman and Nicobar islands, Ceylon, Burma etc. It is also cultivated in Indian gardens. In Tamil it is called as *Kama, Paiyindu* (Fig. 2).

C. revoluta Thumb : Plants are upto 10 feet tall. Leaves 3 to 5 feet long. It is a native of China and Japan and locally called as Tesso. In our country it is mostly cultivated in gardens and locally called as Sago palm. Due to its primitive characters it is also known as living fossil. Exceptionally it has reached a height of about 200 feet in gardens of Taj Mahal Agra (India).

C. siamensis Miq. : Trunk geophilous, tuberous but at times 6 feet tall. Leaves upto 4 feet long. It is a native of Burma Siam, Cochin, China etc, and locally in Burma it is called as Mondaing. **Pant** and **Nautial** (1963) considered *C. siamensis and C. pectinata* similar on the basis of epidermal and anatomical studies.

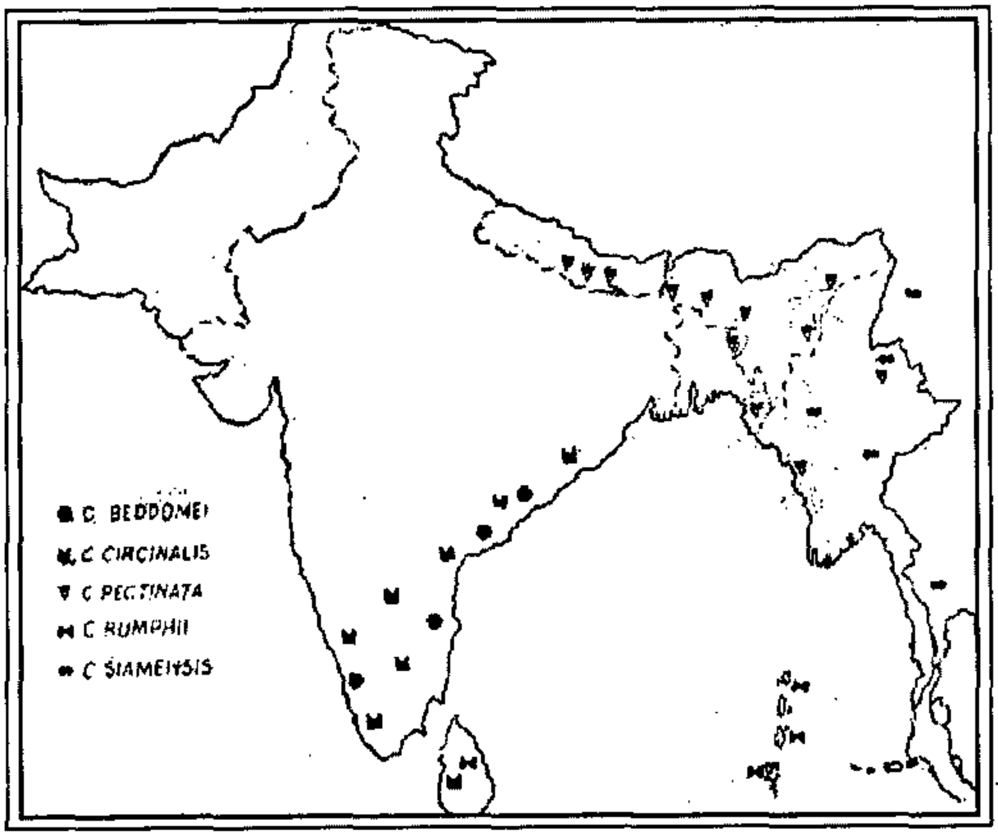


Fig. 3. Geographical distribution of Cycas Sps. in India and adjoining countries (modified from Pant)

1.2. MORPHOLOGY

The *Cycas* plant is perennial and the lowest form of the seed plants. Commonly plants are called as "Palm plants & ferns" *etc. although neither they are palms nor* ferns but superficially resemble palms or tree ferns. The plant body is sporophytic (2x) and 8 to 14 feet tall. The tallest among the Cycas species is *C. media* with 20 feet height. On the basis of anatomical studies of stem made by **Brongniart** (1829) *Cycas* was *treated to be different from palms*. The plant body may be distintly differentiated in to following three parts :

(1) Roots, (2) Stem and (3) Leaves.

ROOT :

They are of two types :

(i) Normal roots, (ii) Coralloid roots.

Normal root

It forms a primary tap root system in the beginning which is later on replaced by branched adventitious roots. It grows deep into the soil. They are not green, positively geotropic with no root hair. Their function is to anchor the plant into the soil and absorption of water and minerals from the soil.

Coralloid root

From the lateral branches of the normal roots, are given out vertical aerial roots, which are **negatively geotropic (apogeotropic)**, fleshy, dichotomously branched and green or brownish dwarf structures. They are formed just below the soil surface and are coral like in appearance and hence called as **corallorrhiza or coralloid roots**. (Fig. 4) Their vascular structure is similar to normal roots except that they are mostly infected with endophytic algae *i.e. Anabaena cycadacearum, Nostoc* and bacteria *etc.*

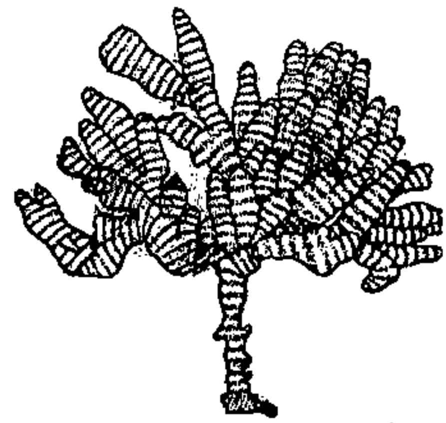


Fig. 4. *Cycas*—coralloid roots.

Formation of coralloid roots : Generally these roots develop in the soil which is rich in bacteria and blue green algae. Bacteria attack the roots and get inside through the lenticl. They damage the cortical tissue forming a space, which is filled up (with the endophytic algae. *i.e. Anabaena cycadacearum* and *Nostoc*, already present in the soil. The endophytic algae later on form a complete zone in the middle cortex and become swollen giving the appearance of a coral that is why it is called as coralloid root. As the endophytic algae require light, air and carbon di-oxide for carbon assimilation, the roots containing them become (negatively geotropic) **apogeotropic**, According to recent researches the blue green algae are capable of fixing atmospheric nitrogen hence, their presence also helps in nitrogen fixation.

Stem

It is subterranean, short and tuberous when young but becomes erect, aerial and columnar on maturity. The plants are about 8 to 14 feet tall. *C. media* is tallest among all species *i.e.* about 20 meters **Schuster** (1932). It is mostly unbranched but branched specimens have also been reported. The branching is due to

Fig. 5. Cycas *revoluta*—plant showing branched stem.

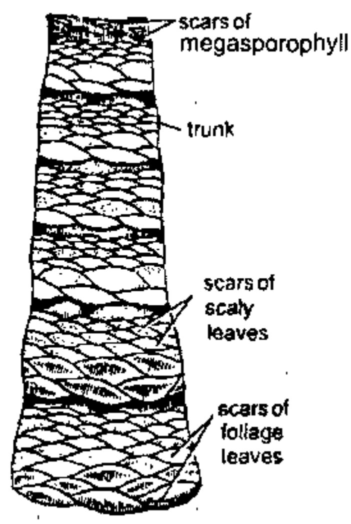


Fig. 6. Cycas—Stem showing alternate bands of larger foliage leaf bases and smaller scaly leaves and megasporophyll's bases.

injury or development of adventitious buds. (Fig. 5). Surface of stem is rough due to the presence of persistant woody leaf bases. At the top is present a crown of leaves. The persistant leaf bases form a thick armour around the stem. In the armour are distinctly visible the alternating bands of large and small rhomboidal leaf bases. Larger ones are of foliage leaves and smaller ones are of scally leaves and megasporophylls in the female plant. The leaf bases are spirally and compactly arranged with each other (Fig.6). By counting the numbers of leaves per crown, the duration of crown and total numbers of leaf bases, the age of the plant can be calculated. In older plant, the stem base is smooth as the armour is not so persistant. *C. circinalis* can grow upto 100 years (**Brandis**, 1907).

Leaves

Leaves are dimorphic *i.e.,* of two types : (i) Scale leaves (ii) Foliage leaves.

Both these types of leaves form a crown at the top of the stem. The crown of scale and foliage leaves periodically alternate with each other. The bases of both these type of leaves are persistant and form the armour around the stem. The zones of persistant scale and foliage leaf bases are quite distinct on the stem surface as the scale leaves have got smaller rhomboidal persistant bases where as the foliage leaves have got bigger rhomboidal persistant bases. (Fig. 6).

Fig. 7. Cycas—A scale leaf.

Scale leaves : The reduced form of foliage leaves without lamella are formed yearly in crown at the apex of stem (Fig. 7). They cover the stem apex (growing point) and help in protecting the young developing foliage leaves. They are arranged in a compact spiral and alternate manner. A single scale leaf is a brown dry, woody, triangular structure with a thick covering of brown *hair or* ***ramenta***.

Foliage leaves : They are green in colour and meant for photosynthesis (Fig. 8). They are also produced in a crown at the apex of the stem. According to **Coulter** and **Chamberian** (1910) one crown of foliage leaves is formed yearly while **D.D. Pant** (1953) observed the formation of two crowns per year in *C. circinalis.* In case of *C. revoluta* the leaves are 3 to 5 feet long but in case of *C. circinalis* they are up to *9* feet long. *A single foliage leaf is unipinnately* peripinnate compound leaf. The rachis or petiole of the leaf has two rows of pinna attached on both the sides of the adaxial groove. The rachis is spiny below (Fig. 8) with a sheathing leaf base. These spines are modified leaflets. The

Fig. 8. *Cycas revoluta*—A foliage leaf.

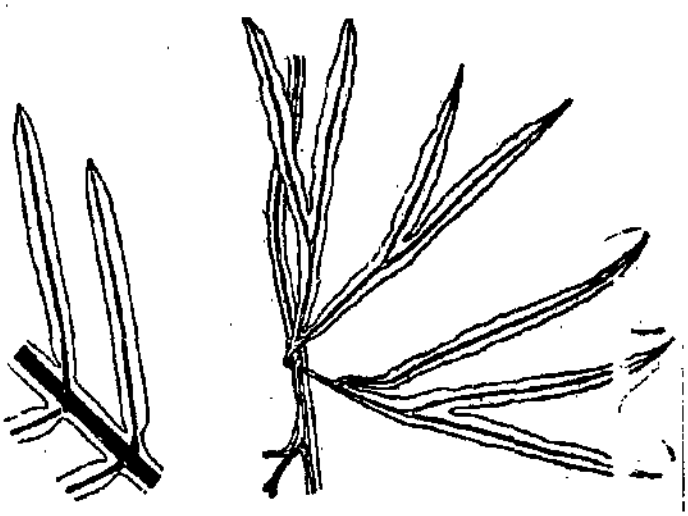


Fig. 9. (A, B) *Cycas-sp.* (A) Leaf showing margin, venation and mode of insertion of insertion of pinnae. (B) *C. micholizii*, the leaflets are repeatedly and deeply branched.

spines are usually arranged in two rows like leaflets but **Pant** (1953) has reported 4 rows of spines on the rachis.

Each leaflet is sub-sessile, lanceolate, in shape, thick and leathery in texture, entire margin with acute apex. Each leaflet has got only a single midrib *i.e.,* unicostate with no lateral branching (9A). In the lower portion of rachis the leaflets appear to be oppositely arranged due to irregular growth. In *C. micholizii* the leaflet is repeatedly and deeply dichotomised (9B). Abnormal forked pinnae have also been observed in *C. rumphii var. bifida* (**Thiselton-Dyre**, 1902). In *C. circinalis* branched leaflets with two to three veins have been observed by **Dublish** *et al* (1976). In *C. revoluta* and *C. beddomii* the margins of the leaflets are curved downwards and inwards, where as in *C. rumphii* and *C. circinalis* the margins are flat and the pinnae are bigger in size.

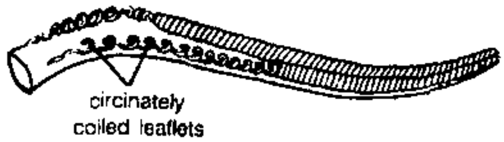


Fig. 10. *Cycas sp.* **young leaf showing circinate vernation**

In a crown the number of leaves is more than ten but in young seedlings only one leaf is produced per year for a number of years. In young developing condition, the rachis is straight and pinnae show circinate vernation (Fig. 10) but according to **D.D. Pant** in *C. circinalis* the rachis incurved and pinnae are inrolled. Deeply bilobed rachis has been observed in *C. circinalis* (**Dublish** *et al*, 1976). Young leaves show circinate vernation similar to ferns and are also covered by hairs or ramenta.

1.3. ANATOMY

Anatomy of normal root : In internal structure the normal root of *Cycas* is exactly similar to that of dictoyledonous root (Angiosperms). It is some what circular in out line (Fig. 11) and reveals the following structures :

Epiblema : It is the outer most limiting layer and is single layered thick. It consists of tangentially elongated cells. (Fig. 12).

Cortex : Next to the epiblema, is a wide zone of cortex consisting of thin walled parenchymatous cells with numerous intercellular spaces or air spaces. The cells of the cortex contain starch. Dark brown tannin cells are interspersed all over the cortex. Few cells of the cortex may contain sphear-raphides (Fig. 12).

Endodermis : It is the inner most layer of the cortex and consists of single layer of barrel shaped cells with conspicuous casparian strips.

Pericycle : Endodermis is followed by multilayered parenchymatous pericycle.

Vascular tissue : The central portion is occupied by the vascular tissue, which

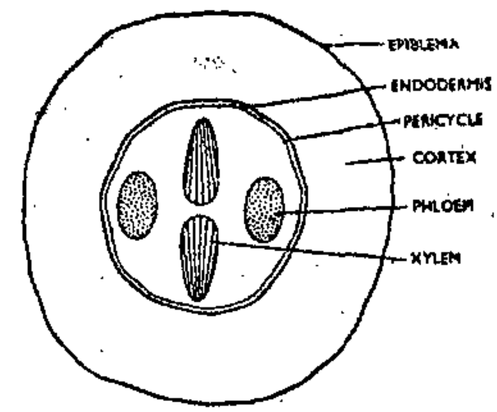


Fig. 11. ***Cycas*** **T.S. normal root with primary structures. (diagrammatic)**

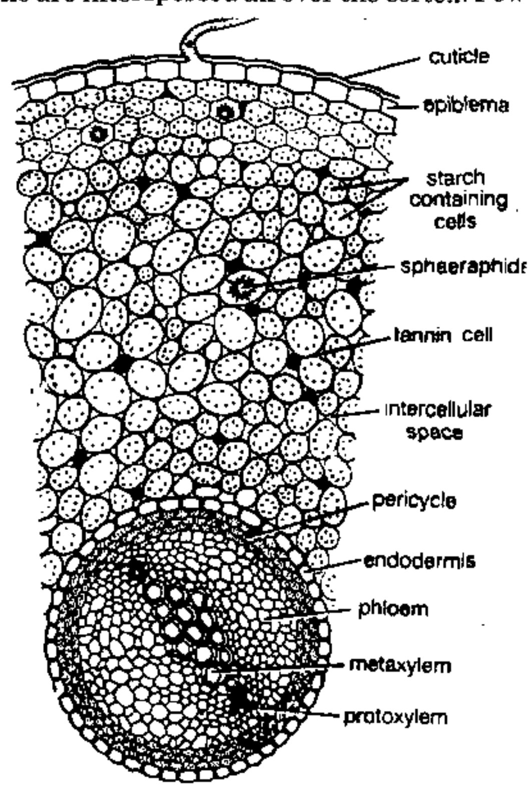


Fig. 12. ***Cycas*****—T.S. normal root with primary structures (A portion cellular)**

consists of xylem and phloem. They are radially arranged *i.e.*, xylem and phloem are arranged on different radii (Fig. 11).

Xylem : It is usually situated in the middle and is generally diarch and exarch *i.e.*, protoxylem is towards the periphery. Young roots are usually diarch whereas is the older portion protoxylem strands may be 2 to 8 in number. The Protoxylem consist of spiral tracheids where as the metaxylem usually consist of scalariform tracheids but some time of pitted elements. Vessels are completely absent from the xylem.

Phloem : Alternating with the protoxylem groups, are present pholem cells consisting of sieve tubes and phloem parenchyma. The companion cells are completely lacking.

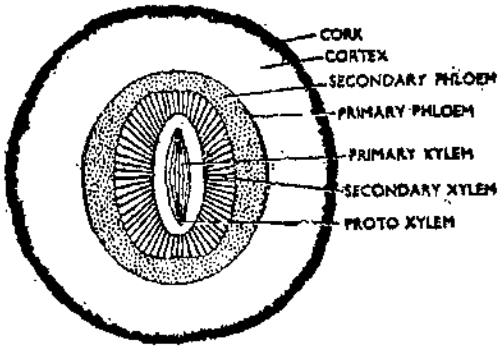


Fig. 13. Cycas. T.S. normal root with secondary growth.

Pith. It is generally absent and if present, very little and is made up of parenchymatous cells.

Secondary growth in normal roots : In the older part of the roots on both the lateral sides of primary xylem along with the inner side of primary phloem, develops the cambium. This cuts of secondary phloem on the outer side and secondary xylem on the inner side. After some time the cells of the pericycle opposite to the protoxylem strands also become meristematic and behave as cambium, cutting phloem on the outer side and xylem on the inner side. Thus a complete ring of cambium is formed, which forms a complete ring of secondary xylem on the inner side and complete ring of secondary phloem on the outer side. This secondary xylem consists of radial rows of tracheids separated by parenchymatous cells. The primary phloem is crushed in due course of development and appears in the form of crushed layer above the secondary pholem (Fig.13, 14).

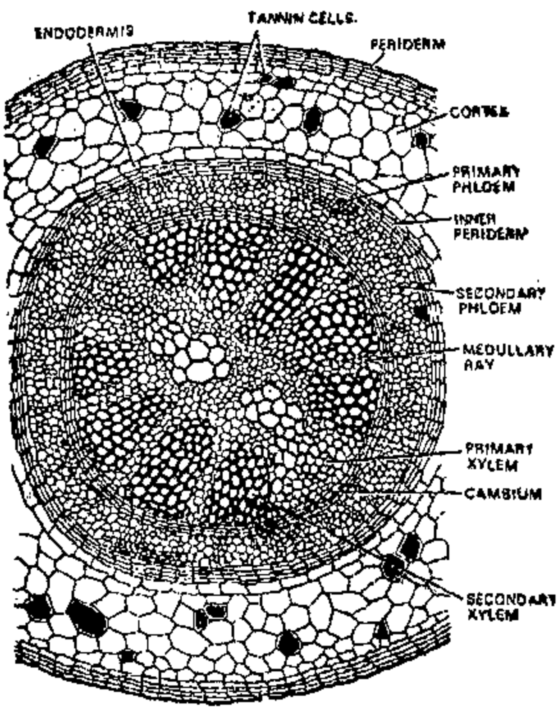


Fig. 14. *Cycas.* T.S. normal root with secondary structures (Cellular)

Periderm formation : Along with the course of formation of secondary xylem and secondary phloem, the formation of periderm starts in the cortex. The cells of the outer most layer of cortex become meristematic and start cutting cork cells on the outer side and secondary cortex on the inner side. This layer of meristematic cells is called as cork cambium. The cells of the cork are dead and full of suberin. They are impermeable to water and protect from the outer injury. In the course of the formation of cork, the cells of the epiblema are crushed.

Anatomy of the coralloid root : The cross section of the coralloid root is circular in out line and reveals the following structure :

Cork (Periderm) : It is the outer most tissue like normal root, with secondary growth and consists of 2 to 5 layers of dead cells. This is also known as periderm. The cork is followed by cork cambium and then by secondary cortex.

Cortex : It is exactly similar to that of normal root except that it has got a greenish algal zone almost in the middle of the cortex thus dividing it into outer cortex and inner cortex. The algal zone (Fig. 15, 16) consists of loosely connected radially elongated thin walled cells with abundant large intercellular space occupied by algae (Fig. 16) usually *Anabaena cycadacearum* and *Nostoc punctiformis* and some time by *Oscillatoria* sp. (**Fritsch,** 1945). These spaces are formed as a result of infection of fungi and bacteria

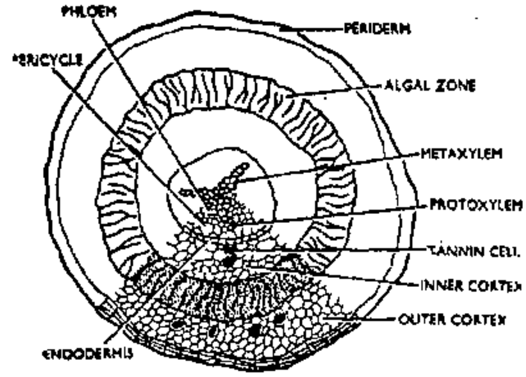


Fig. 15. ***Cycas.*** **T.S. coralloid root (diagrammatic)**

and ultimately occupied by algae. According to **Chaudhary** and **Akhtar** (1931) spaces are formed as a result of algae. Some times this algal zone may be absent from the deep seated coralloid roots. The main function of these roots is nitrogen fixation because of the presence of algal members (**Pant,** 1973).

Endodermis **Pericycle** **Vaseular tissues**	All these structures are exactly similar to that of normal root or *Cycas.*

Secondary growth is absent or very little. No secondary xylem and secondary phloem are developed although cork and cork cambium are present.

Atanomy of the Stem : In anatomical features the stem of *Cycas* resembles more or less with the dicot stem (Fig. 18). It shows a large pith, thin vascular cyclinder and thick cortex. The pith and cortex are full of mucilage canals and sago grains. Girdle shaped leaf traces are also present in the cortex. Woody tissue increases in width by secondary thickenings. Vascular bundles are compactly arranged. They are conjoint, collateral and open. Xylem is endarch. In a cross section the following structure are clearly visible :

Epidermis : It is the outer most layer of the stem and is made up of compactly arranged thick walled cells. The epidermis is wavy and ruptured due to the presence of armour of presistant leaf bases and woody scales on the stem.

Cortex : Just below the epidermis there is wide zone of

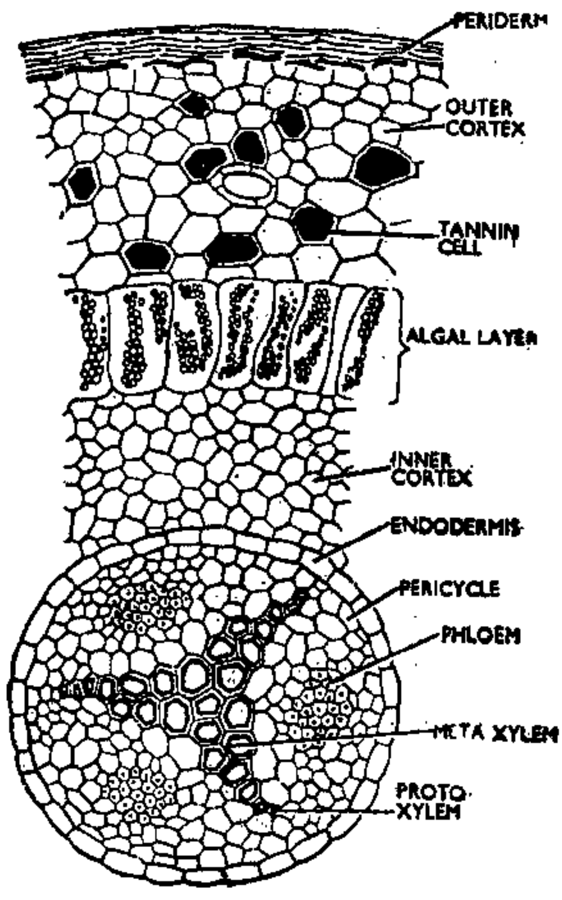


Fig. 16. ***Cycas.*** **T.S.—coralloid root (A portion cellular)**

thin walled parenchymatous cells forming cortex. The cortical cells are filled with large number of starch grains in the form of sago grains. Scattered in the cortex are several **mucilage canals** (Fig. 18). Each mucilage canal is lined by radially elongated epithelial cells, (Fig. 17) or secretory cells, which secrete mucilage. These mucilage canals communicate with those present in the pith through medullary rays.

Endodermis and Pericycle : These layers are not very conspicuous and therefore, the inner limit of the cortex can not be made out easily although the endodermis is single layered and pericycle is multilayered thick.

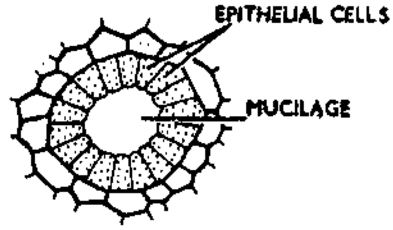


Fig. 17. *Cycas*. **A mucilage canal**

Vascular cylinder (Stele) : It is of ectophloic siphonostelic type and consists of a ring of numerous small closely arranged vascular bundles.

Vascular Bundles : They are conjoint, collateral and open. The xylem is endarch. It consists of tracheids and xylem parenchyma. Vessels are absent. The phloem is present on the outer of the vascular bundles and consists of sieve cells and phloem parenchyma. The companion cells are lacking. The xylem is separated from the phloem with the help of primary cambium. The cells of the cambium are brick shaped. Sieve cells are much elongated and have sieve plates on oblique terminal end on the lateral walls.

Medullary Rays : The cells lying between the vascular bundles form the medullary rays. They are parenchymatous and connect the pith with the cortex. Usually they are one celled wide and 1 to 20 cells long. The cells contain sago starch grains and crystals of calcium oxalate.

Pith : In the centre of the stem is present a large massive pith consisting of parenchymatous cells which are rich in starch (Sago). A large number of mucilage canals are also present, which are exactly similar in structure to that found in the cortex region.

Leaf traces or Girdles : There are several girdles present in the cortex (Fig. 18). They really are the vascular supplies of the leaves given by the main vascular cylinder. Each leaf receives four traces, two of which are direct traces and other two are given out

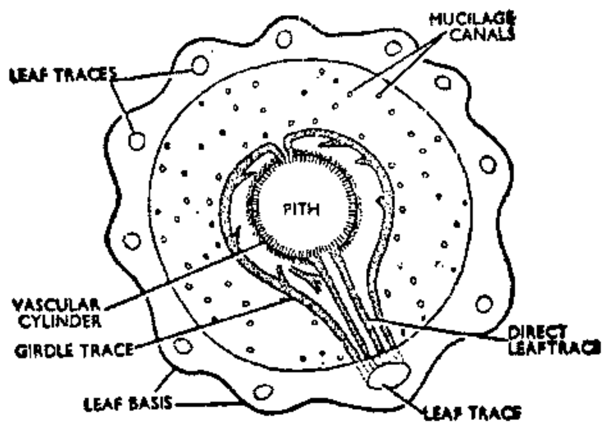


Fig. 18. ***Cycas.*** **T.S. Stem showing origin of leaf traces from the vascular cylinder.**

from the opposite side of direct traces and each takes a round around the main vascular cylinder in opposite direction through cortex and then enters the leaf base of opposite side from the point of their origin from the stele. These leaf traces are known as girdle traces (Fig. 18) or indirect traces and are peculiar structures in the stem of *Cycas*.

Secondary growth in stem : It is a slow process. At first a complete ring of cambium is formed by the development of inter-fascicular cambium in between the adjacent vascular bundles. The cambium ring starts cutting secondary xylem on the inner side and secondary phloem on the outer side. Gradually the patches of primary phloem get crushed. This ring of primary cambium remains active only for a short duration. Secondary growth now takes places by successive secondary cambium formed out side the previous one. Secondary cambium may arise in pericycle or cortex and cuts off secondary tissue on either side. The vascular cylinder thus formed is identical that of primary vascular cylinder. After somè time cambium becomes inactive and another cambium is formed, cutting secondary tissues on either side. This process may be repeated several times forming a number of rings of successive vascular cylinders (Figs, 19, 20)-**Chamberlain** (1935) reported as many as 14 concentric cylinders in *C. pectinata.* The size of the vascular cylinder diminishes as we go out. The peripheral vascular bundles are concentric and not collateral with mesarch xylem, a character resembling ferns.

In the beginning the stem of *Cycas* is **monoxylic** *i.e.,* having only one vascular cylinder but later on becomes **polyxylic** due to development of number of secondary vascular cylinders. The development of successive rings is irregular and not like that of annular rings of dicotyledons, as a result of which the age of the plant can not be calculated by counting the number of rings, Secondary phloem possesses fibres and sieve cells. These fibres add to the mechanical strength of stem. Bordered pits are present in secondary xylem tracheids. The girdles are also a source of strength to the stem.

Anatomy of the Rachis : The traces (direct or indirect) given out from the vascular cylinder of the stem, branch freely as they enter the rachis of the leaf and arrange themselves in an omega (Ω) manner. A cross section of the rachis at the very base is some what rhomboidal in outline (Fig. 21), but a little higher up it is shield shaped *i.e.* biconvex in outline with 2 adaxially lateral grove and two bases of leaflets. The basal portion of rachis is soft whereas most of the portion is hard with well developed sclerenchyma. A cross section of the rachis reveals the following structure. (Fig. 22, 23, 24A):

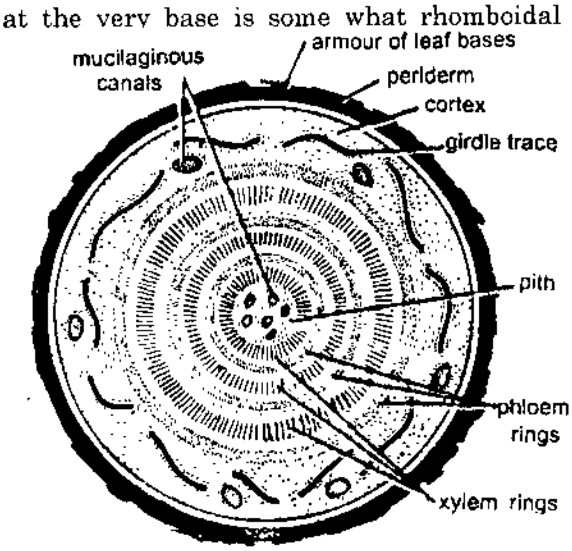


Fig. 19. *Cycas*—**T.S. mature stem.**

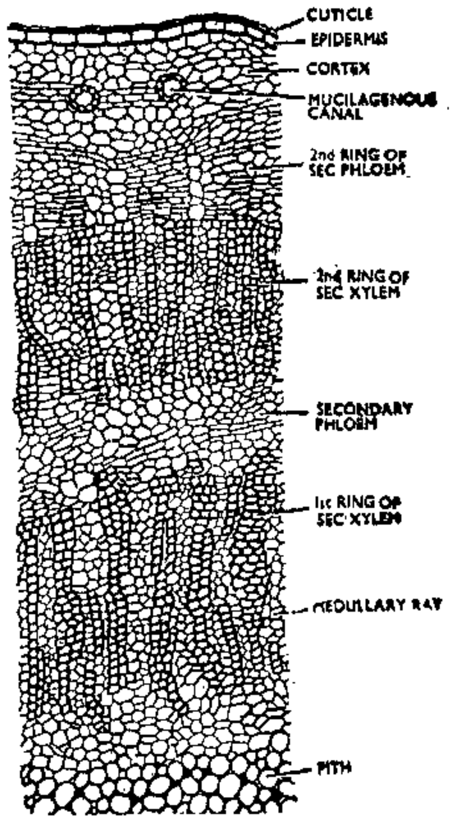


Fig. 20. *Cycas*—**T.S. Stem with sec. growth (A part cellular)**

Epidermis : All around the rachis, there is a single layered epidermis made up of compactly arranged thick walled cells. It is heavily cuticularised and interrupted by stomata on its upper as well as lower side.

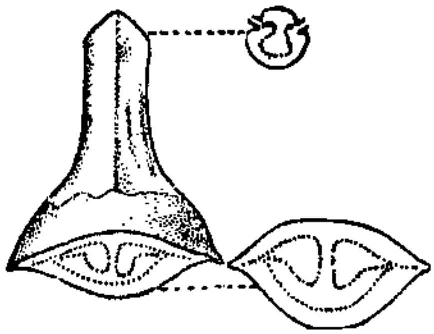


Fig. 21. *Cycas*—**basal portion of rachis and the form and arrangement of vascular bundles at the base and upper level.**

Hypodermis : Epidermis is followed by a well developed hypodermis, differentiated into outer chlorenchymatous and inner sclerenchymatous regions.

Chlorenchyma : There are two or there layers of chlorophyll containing short thin walled cells. On the adaxial side, the chlorenchyma is comparatively more developed.

Sclerenchyma : Inner to the chlorenchyma, are four or more layers of thick walled cells with lignified thickenings. Sclerenchyma is poorly developed on the lateral sides.

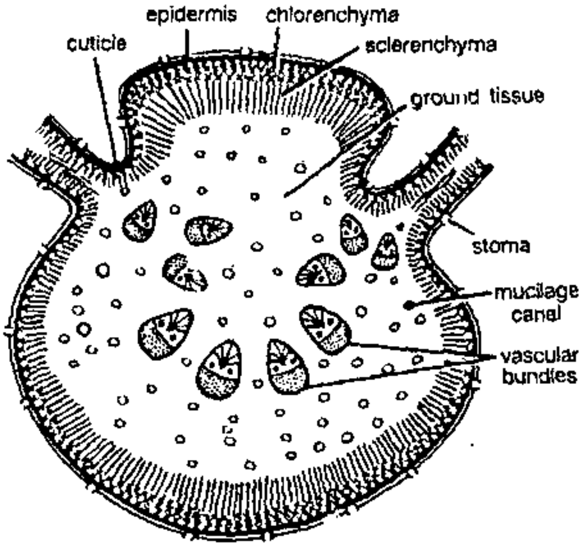


Fig. 22. *Cycas*—T.S. rachis (diagrammatic)

Ground tissue : The hypodermis gradually joins a zone of tin walled parenchymatous cells in which, ae embedded the vascular bundles and several mucilage canals.

Vascular bundles : There is a variable number of vascular bundles, which are arranged in a `Omega' (Ω) shaped manner (Fig. 22). Each vascular bundle is conjoint, collateral and open and is bounded by a fibrous bundle sheath of sclerenchymatous cells. The vascular bundle shows diploxylic condition, consists of xylem towards the inner side phloem on the outer side separated by an arc of inactive cambium.

Xylem : It consists of tracheids and xylem parenchyma. Vessels are lacking.

Phloem : It is arc shaped and consists of sieve cells and phloem parenchyma. The companion cells are completely lacking.

Mucilage canals : In between the vascular bundles and sclerenchymatous hypodermis, is a variable number of mucilage canals. The canals

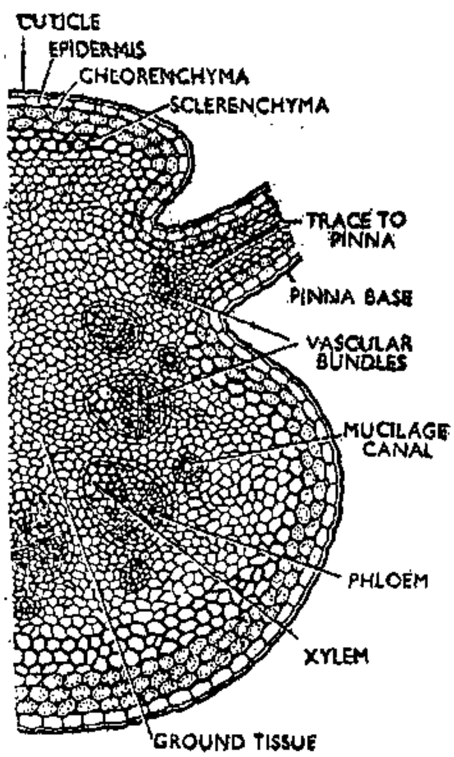


Fig. 23. *Cycas T.S.* rachis (A portion cellular)

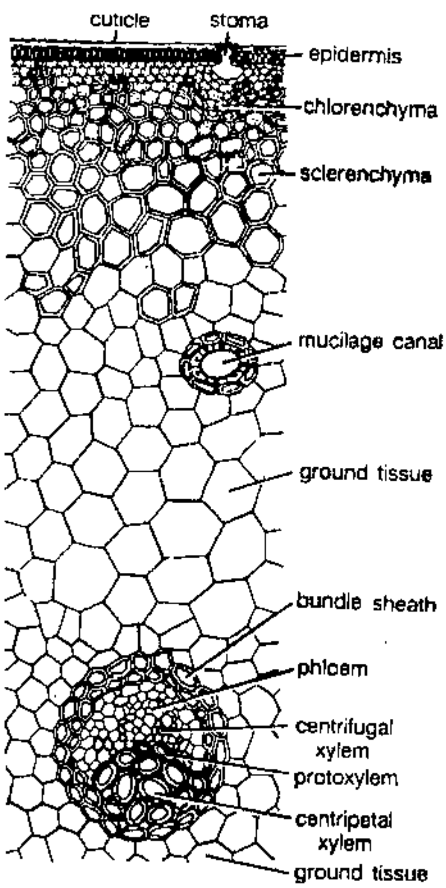


Fig. 24A. *Cycas*. T.S. rachis (A portion enlarged) are double walled with inner layer of epithelial cells and an outer wall of tangentially stretched sclerenchymatous cells.

Detailed structure of vascular bundle : It is interesting to note that the structure of vascular bundles shows a gradual transition from the base as we proceed upwards upto the tip of rachis from endarch to extrach condition through pseudomesarch *i.e.*, diploxylic condition in the middle. In the basal portion of the rachis all the xylem is centrifugal and protoxylem is endarch. (It is partly primary and partly secondary in origin.) As we proceed higher up the rachis, this endarch xylem diminishes gradually and another mass of xylem appears on the other side of the diminishing centrifugal xylem. In the greater part of the rachis the vascular bundles contain a large part of centripetal xylem and with the little of centrifugal xylem. In the upper middle portion the centrifugal xylem is represented only by two metaxylem tracheids, one on each side of the centripetal protoxylem (Fig. 24B). Such a condition is called as pseudomesarch or diploxylic as it is having both centripetal and centrifugal xylem, which are developed separately at different times.

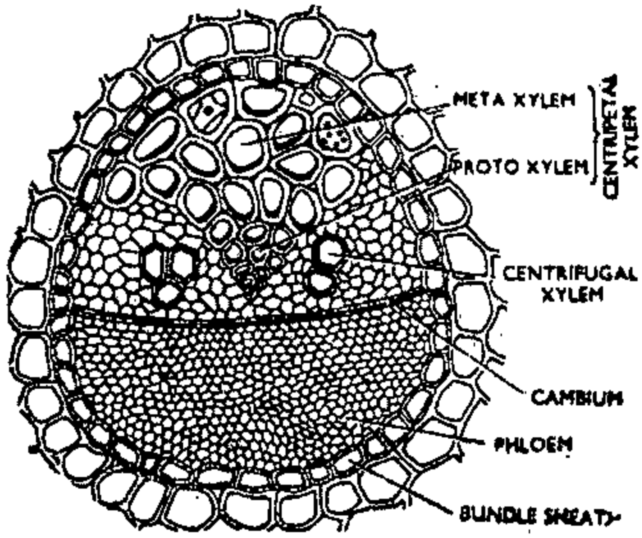


Fig. 24 B. *Cycas*-single vascular bundle of rachis (enlarged)

Centrifugal and Centripetal Xylem : The genus *Cycas* possess a number of features which may be considered as sign post, pointing out possible course of evolution. The peculiar structure of the vascular bundles is its double xylem arrangement (one portion is centripetal and other is centrifugal in position). There are differences in opinion among various writers. Some consider these foliar bundles as **mesarch.** Another class opposes this view on the ground that this fact is based on mere appearence. These bundles are apparently and not strictly mesarch. It is due to inversion of normal primary xylem. Some authors like **chodal** recorded the observations which were limited to the cycadean leaf and are restricted to the relation of centripetal xylem and centrifugal xylem with one another and with other tissues as well.

The foliar bundles form may be simple and collateral or concentric with the parenchyma in the centre but in the variety of form, there is a distribution of the element, which remains constant at the base of the petiole. The xylem is entirely endarch or centrifugal (Fig. 25). An internal protoxylem is succeeded by numerous lignified cells continued by cambium and phloem cells. The cells in

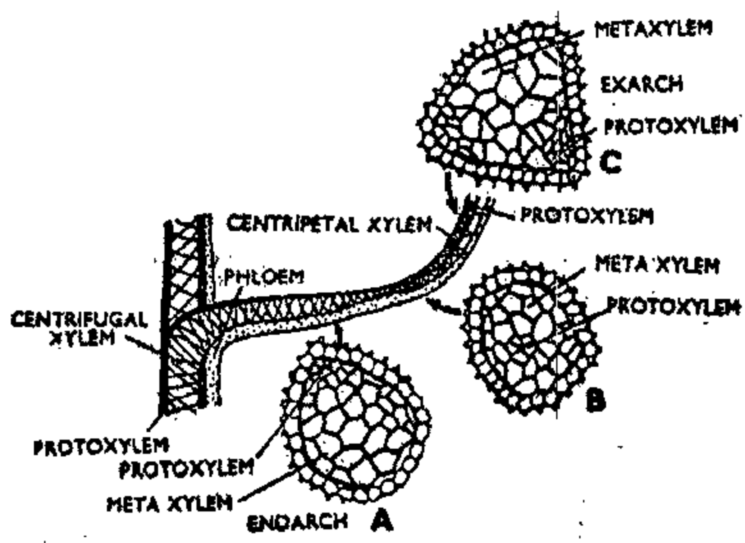


Fig. 25. *Cycas*—Diagrammatic representation of the course of bundles in the reachis.

connection with protoxylem are no longer centrifugal but seem to run in the lateral direction. Only the central row remains properly centrifugal, normal to the pith, undergoing however, a process of reduction. The reduction is more and more prominent as we proceed up to the petiole. The lateral rows possess new independent groups of lignified cells which are scattered and thus centripetal xylem is initiated.

At the higher level the centripetal xylem is more abundant than the centrifugal xylem. The gap which is observed behind between the two lateral segments is entirely closed and a complete ring is formed, which soon breaks up on both the sides. There remains only a few centrifugal cells scattered in small groups and without any visible characters with the centripetal xylem except that of parenchymatous tissue of the thin walled cells.

A stage may be reached in which no trace of centrifugal xylem is present but this is very rare *i.e.* small groups of centrifugal may be found (Fig. 26).

Some scientists are of opinion that centrifugal xylem is secondary in nature while according to **Scott** (1897) it is primary in nature. The two xylem are completely separated by a layer of thin walled cells.

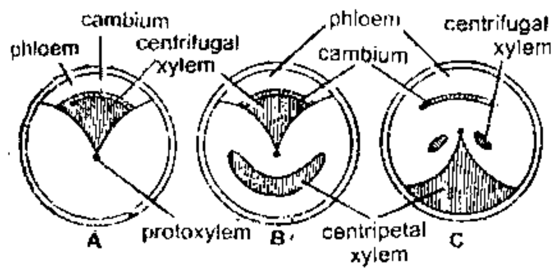


Fig. 26. (A-C). *Cycas*. Diagrammatic representation of vascular bundles of rachis at different levels. A. At the base B. In the middle, C. At the apex.

The protoxylem is in contact with centripetal xylem but not with centrifugal xylem. No centrifugal xylem is found in young petioles at the level where centripetal xylem is well developed.

There is no definite boundary between the large amount of secondary centrifugal xylem at the base of the petiole and much smaller amount found at the higher levels.

The final findings are therefore,

1. At the base of the petiole, the structure of the vascular bundle is entirely centrifugal which is indicated by regular rows of xylem. Cambium and phloem separated by medullary rays and has been proved with the study of petiole at different levels.

2. The centripetal xylem is primary structure.

3. The centrifugal and centripetal xylem are separate in origin.

4. During most of the course, along the petiole, the two xylem remain distinct, therefore the vescular bundles may be pseudomesarch or diploxylic.

5. The two xylem overlaps at the end the remains of the centripetal xylem scattered at the base might point to a time when it ran further down perhaps into the stem.

Anatomy of the Leaflet : A cross section of the leaflet of *Cycas* exhibits a **hypostomatic** dorsiventral structure (Fig. 28) with a prominent unbranched mid rib, and is like a flying bird in outer appearance. In case of *Cycas revoluta* the margins are curved downwards and inwards but in *C. circinalis* the margins are flat. The following tissues can be differentiated :

Epidermis : It is single layered structure and consists of more or less squarish cells. The outer wall of epidermal cells is highly thickened. The upper epidermis is complete whereas the lower epidermis is interrupted by several stomata present only in the region of blade **(Hypostomatic).** The upper as well as lower epidermis is covered by a thick layer of cuticle. The cuticle acts as a mechanical tissue to some extent and helps in checking transpiration.

Stomata : They are situated on the lower epidermis only in the blade region. At the place where the stomata are situated, the epidermal cells become enlarged and curved downwards (Fig. 27) as a result of which a cavity is formed. Each stoma has two guard cells situated at the base of this cavity surrounded by a pair of subsidiary cells or buffer cells. As the stomata are situated deep at the base of the cavities, they are called as sunken stomata. According to **Pant and Mehra** (1964) these stomata are of **haplocheilic** type in *C. circinalis* and *C. revoluta*.

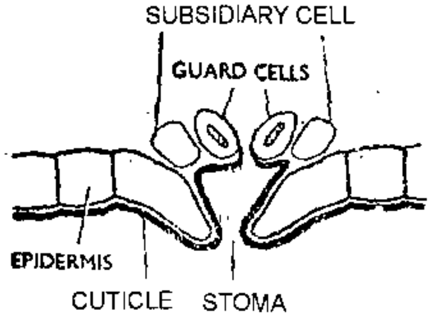


Fig. 27. *Cycas*. Sunken stomata (enlarged)

Hypodermis : Below the upper epidermis is a layer of thick walled sclerenchymatous cells. It is single layered in the region of blade but in the region of mid rib it becomes 2-3 layered thick Two to five layers of sclerenchymatous cells are also present above the lower epidermis only in the region of the mid rib. It helps in checking the rate of transpiration and prevents the tissue from excessive heat.

Mesophyll : There is a *well developed mesophyll tissue differentiated into palisade* parenchyma and spongy parenchyma.

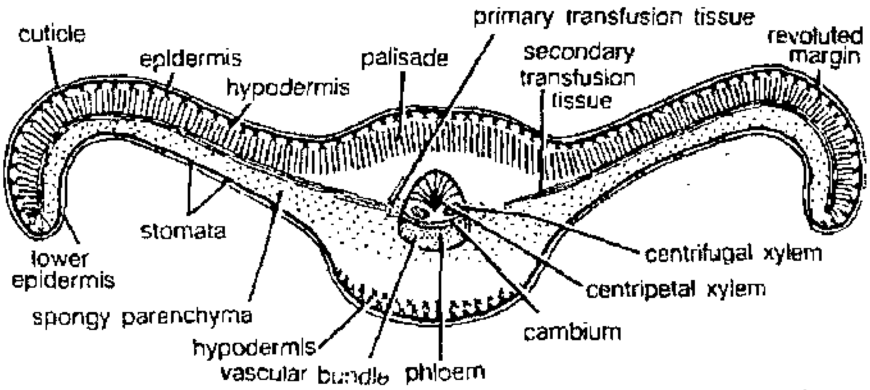


Fig. 28. *Cycas revoluta*. T.S. leaflet diagrammatic.

Palisade parenchyma : On the dorsal side, below the hypodermis is a single layer of radially elongated, tubular parenchymatous cells containing chloroplast. These cells help in carbon assimilation. The palisade tissue may be continuous over the midrib in *C. revoluta* (Fig. 30) or discontinuous as in *C. rumphii* (**Pant, 1973**).

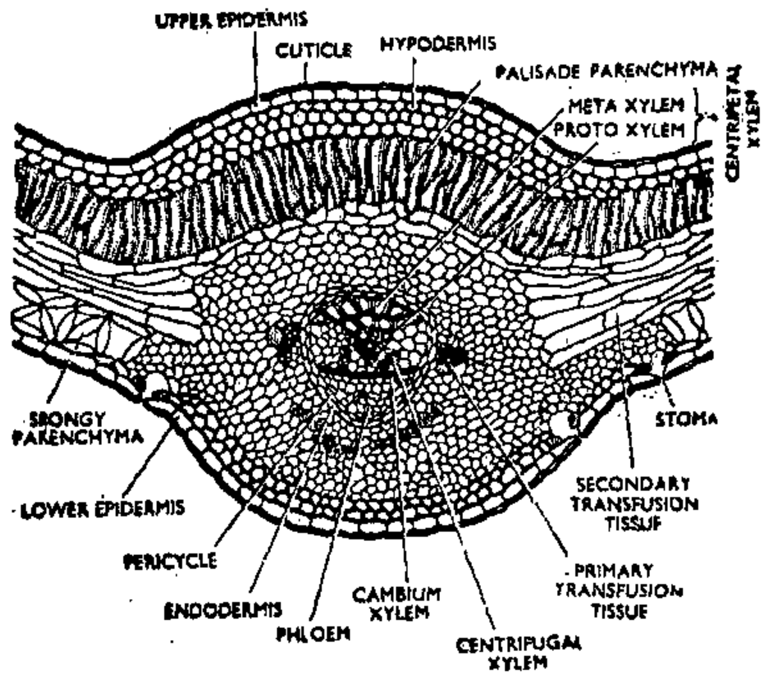


Fig. 29. *Cycas*—T.S. leaflet (midrib portion cellular)

Spongy parenchyma : Directly above the lower epidermis, are thin walled oval or irregular cells containing chloroplasts. These cells are loosely arranged enclosing air spaces. They are present only in the region of blade. They help in gaseous exchange and carbon assimilation.

Stele : It is present in the centre of the mid rib as a single large and prominent vascular bundle surrounded by a single layer of sclerenchymatous cells, known as bundle sheath (endodermis). Pericycle is of few layered parenchymatous cells below the endodermis. The vascular bundle is conjoint consisting of phloem towards the ventral surface and xylem towards the dorsal surface separated by a non-functional strip of cambium, which it not very distinct.

Xylem : It is pseudomesarch and mainly consists of tracheids. It is differentiated into the **centripetal** and **centrifugal xylem (diploxylic condition)**. The centripetal xylem is more or less triangular in shape having metaxylem on the upper side and protoxylem on the lower side. Few tracheids representing centrifugal xylem are also seen on either side of protoxylem (xylem pseudomesarch). Vessels are completely lacking.

Phloem : It is arc shaped and consists of sieve cells and phloem parenchyma only. The companion cells are lacking.

The remaining space of the vascular bundle is filled up with ordinary parenchyma.

Transfusion tissue : It is pressent in the form of transversely elongated cells in both the wings. It helps in conduction of water for the blade region and differentiated into primary and secondary transfusion tissue (Fig. 28).

Primary transfusion tissue : It is represented by few tracheids with bordered pits, on either side of the vascular bundle. (Figs. 28, 29).

Secondary transfusion tissue : (Accessory transfusion tissue) It is also known as **hydrostereon, (Bernard** 1904) or **radial parenchyma (Pilger,** 1926). There are few layers of colourless, transversely elongated cells running parallel to the leaf surface. These cells are present inbetween the palisade parenchyma and spongy parenchyma.

1.4. REPRODUCTION

The plants of *Cycas* are strictly dioecious and reproduce by the following methods :

Vegetative reproduction

It is the simplest method of propagation in *Cycas* and takes place with the help of **bulbils** or vegetative buds or adventitious buds (Fig. 30) which are develoed from the axil of the scaly leaves. A bulbil is a oval structure, which is broader at the base and pointed above. It consists of a dormant stem in the centre covered by numerous brown scaly leaves. The scaly leaves are spirally and compactly arranged and are thick in texture. If the bulbil is detached from the stem and falls on the soil, under suitable conditions it starts germinating and produces roots from the lower side and leaf from the upper side. In this way it gives rise to a new young plant. Some times the bulbil germinates while still attached to the stem apex and later on gives an appearance of dichotomous branching. As the plants are strictly dioecious the bulbil from male plant gives rise to a male plant and that from female to the female plant only.

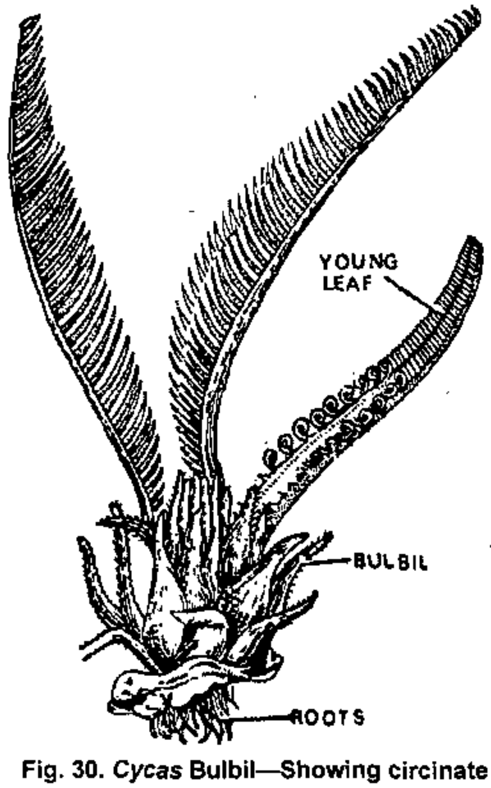


Fig. 30. *Cycas* **Bulbil—Showing circinate vernation of leaf.**

Sexual Reproduction

The plant of *Cycas* is a sporophyte (2X) and the sexual reproduction is of **oogamous** type *i.e.*, takes place by the fusion of distinct male and female gametes. As the plants are strictly dioecious, the male and female sex organs are found on separate plants. The male and female gametes are formed by the germination of micro-and megaspores respectively. The micro and megaspores are borne in microsporangia or megasporangia respectively, which in turn are borne on microsporophylls and megasporophylls respectively. The microsporophylls are grouped together to form a compact, oval or conical structure known as male cone or strobilus whereas the megasporophylls are not aggregated to form a compact structure like a cone. The male cone is terminal while the megasporophylls are produced at the apex of the stem in succession with the leaves. Life history of *C. circinalis* has been worked out in detail by **Rao** (1961).

Male Reproductive Organs

In *Cycas* the male cone is produced every year singly at the apex of the stem (Figs. 31, 32). In the formation of male cone the apical meristem is used up and therefore, the growth of the stem is checked for some time but later on an apical meristem is formed at the base of the cone, which pushes the cone on one side so that the growth of the stem is resumed again. Thus in the male plant of *Cycas* the growth is **sympodial**.

Male cone of *Cycas* is an ovoid or conical structure and at maturity it may be generally 50 cm. or more in length. In *C. circinalis*, it is about 25 cm. long (Fig. 31). Each cone consists of a central axis around which, a large number of leaf like structures called as microsporophylls, are attached at right angle to the central axis of the cone in a compact, spiral and acropetal succession (Fig. 32). The maturation of sporophylls takes place in a basipetal manner *i.e.*, from apex to base. The male cone is surrounded by a crown of young leaves at the base. From the upper surface, the sporophylls appear to be radially arranged. A few of the sporophylls at the base and apex are sterile.

Structure of microsporophylls : Each microsporophyll is a leaf like hard, woody, brown, triangular structure, which is narrow below and broader above (Fig. 34). The upper portion is expended in the form of a sterile disc called as **apophysis**, The dorsal side of microsporophyll is smooth and sterile, where as on the ventral side are present a large number of sporangia (Fig. 35). In *C. media* there are about 160 sporangia (**Chamberlain**, 1935). These are arranged in groups of 3 or 4 to form sori (Fig. 33. and 34). These sori are separated in two groups by a median sterile line. The number of sori on each sporophyll varies with size of microsporophyll. Generally there are about 500-700 sori on each sporophyll.

Microsporophylls are usually unbranched but abnormal branching of microsporophyll have been noticed by **Kashyap** (1930).

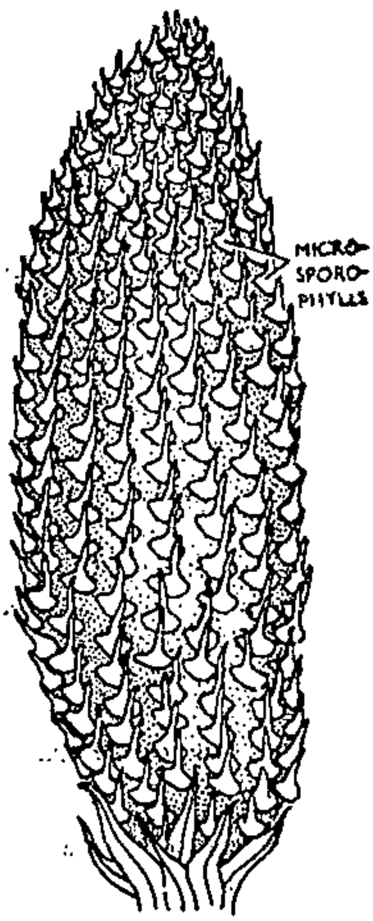


Fig. 31. *Cycas circinalis*—Male cone

Structure of sorus

Each sorus consists of a central growth known a central protuberence or papilla on which are attached four to seven microsporangia but the number may be sometime two or even one. In addition to the sporangia, there are numerous uni or multicellular brown hair arising from the central papilla, which help in dispersal of spores and are known as **inducial hair or soral hair.** (Fig. 33).

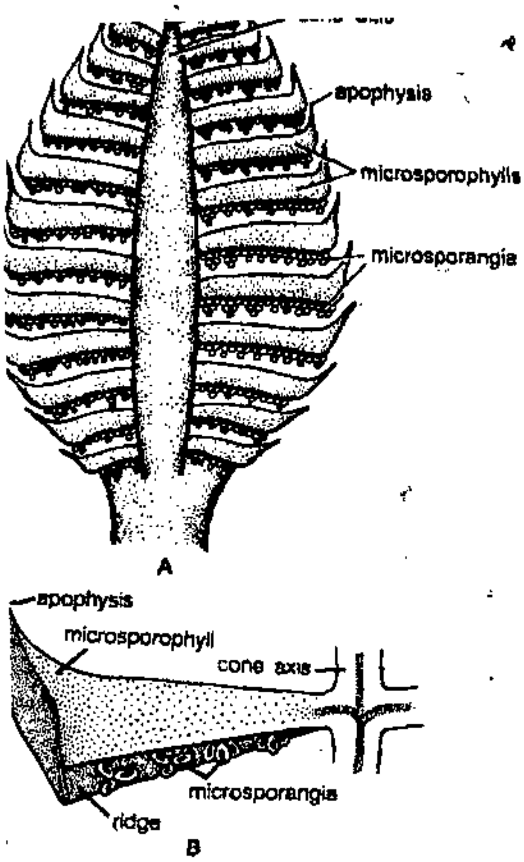


Fig. 32. (A, B). *Cycas*. A. L.S. cone, B. L.S. of a single sporphyll along with one axis.

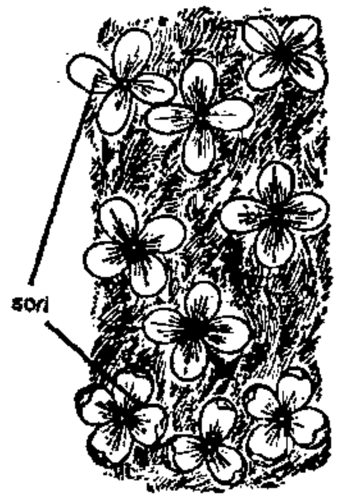


Fig. 33. *Cyas*. Abaxial surface of a microspcrophyll baring groups of microprorangia (sori) enlarged.

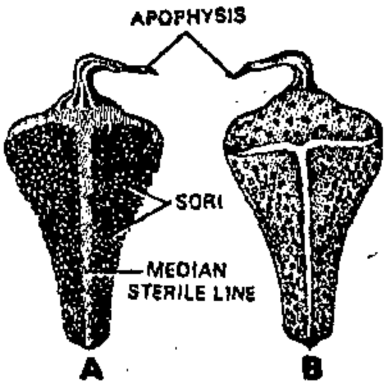


Fig. 34. *Cycas*—Microsporophyll (A) Vential view (B) Dorsal vie

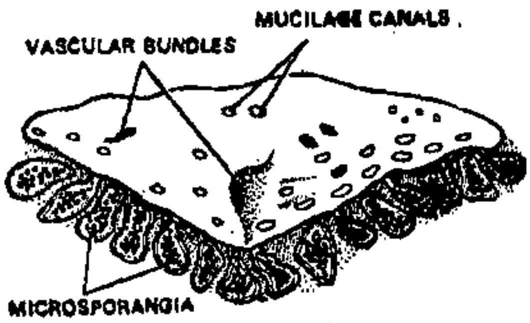


Fig. 35. *Cycas*. T.S. microsporophyll.

Structure of Microsporangia : Each microspsoangium is a small stalked oval structure. The stalk is multicellular and the wall of the sporangium is multilayered. It's outer most layer is epidermis and the inner most is called as tapetum. In the centre there is a spore cavity with a large number of microspores. Each sporangium is provided with a radial line of dehiscence through which dispersal of spores takes place.

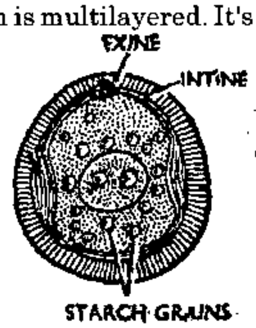


Fig. 36. *Cycas*. Microspore

Structure of Microspores : They are formed in tetrahedral tetrads. Each microspore is a single celled, uninucleate structure. The wall is two layered. The outer one is **exine** which is thick at the base, whereas the inner one is **intine**, which is thick on lateral side (Fig. 36). A single centrally situated nucleus is surrounded by cytoplasm. The haploid chromosome number is 11 but **Nakamure** (1929) reported 12 in *C. revoluta*.

Development of microsporangium and formation of microspores

The development of microsporangiun in *Cycas* is of **eusporangiate type.** The microsporangial initial cell (archesporium) is hypodermal in origin (Fig. 37 A) and is situated on the ventral side of the microsporophyll. There may be a single or a plate of initial cells but in every case the method of development is the same.

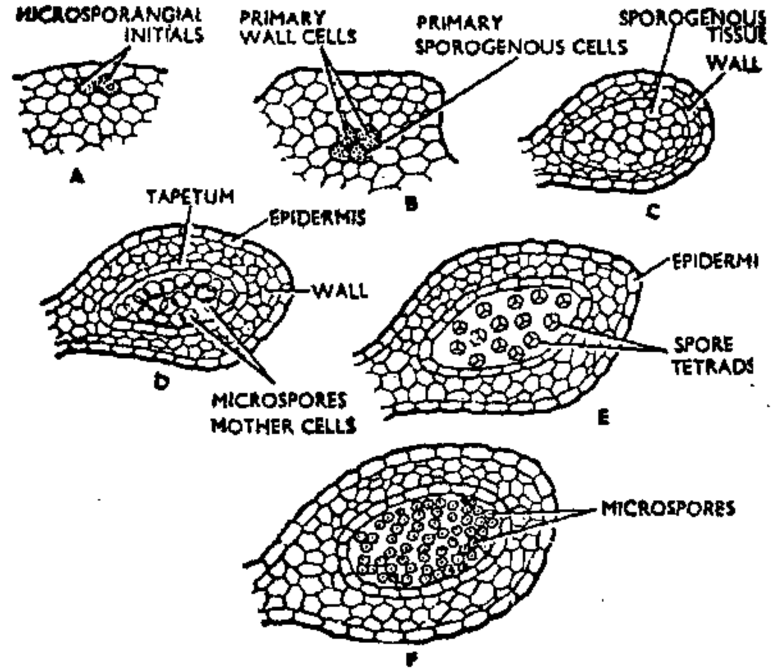


Fig. 37. (A-B) *Cycas*—Development of microsporangium and formation of microspores.

Each sporangial initial cell divides by a periclinal wall into an upper **primary wall cell** and lower **primary sporogenous cell.** (Fig. 37B). Primary wall cell divides and redivides by several periclinal and anticlinal divisions to form three to six layered wall below the epidermis. Primary sporogenous cells also soon divide and redivide irregularly thus forming a mass of cells known as sporogenous tissue. The epidermis also become thickened. At this time from the peripheral cells of the sporogenous tissue, a single celled nourishing layer is differentiated which is known as tapetum. (Fig. 37 C, D). The rest of the cells of sporogenous tissue become separated to function as spore mother cells. Each spore mother cell divides twice. The first division is reductional one followed by a second ordinary division. Thus tetrad of four haploid microspores are formed, which later on separate from each other. (Fig. 37 EF). The microspores or pollen grains soon round off and develop exine and intine. The tapetum is used up during the development of microspores. Only the signs of disintegrated tapetum can be marked at maturity. At this stage

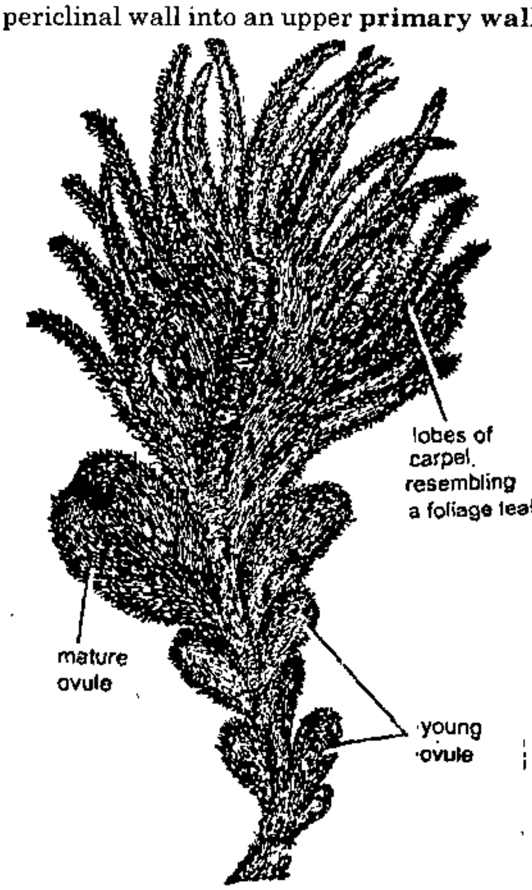


Fig. 38. Megasporophyll of *Cycas revoluta.*

the sporophytic generation comes to an end and further the gametophytic generation starts.

Dehiscence of microsporangium and dispersal of microspores

At the time of maturity of microsporangium, the tapetum disintegrates and the sporangium becomes dry and the cells shrink, as a result of which the sporangial wall ruptures radially along with the line of dehiscence and the numerous microspores or pollen grains are carried away by wind. At the time of the dispersal of microspores the *central axis of male cone* also *elongates* thus the sporophylls are separated and the microspores are easily dispersed away.

Female Reproductive Organs

In *Cycas* the formation of female cones is altogether absent. The **megaspores** are produced inside **megasporangium**, which are borne on leaf like structures, called **megasporophylls.** These megasporophylls are produced at the top of the stem in succession with the leaves but do not form a compact structure like a cone and hence the female cones are altogether absent in *Cycas*. The megasporophylls are produced in a crown at the top of the stem in a mature plant (**Pant** 1973). The number of megasporophylls is much more than the number of foliage leavs on the stem. During the formation of megasporophylls the apical meristem is not used up like that of male cone and therefore, the growth of the stem continues, and thus in female plant growth is **monopodial**.

Structure of Megasporophylls : Each megasporophyll is regarded as a modified foliage leaf and is about 5 to 10 inches long. It is a flattened structure and consists of a central part. The upper portion is pinnate and each pinna is tapering to a point (Fig. 39A, B). On the lower portion, are present, two lateral rows of ovules, which represent the pinnae on the lower side of megasporophyll. In the beginning the ovules are green in colour but at maturity they turn orange in colour. The entire megasporophyll is covered by a thick coating of yellowish brown wooly delicate hair. These hair fall off from the wall of the ovules on maturity.

In the genus *Cycas* there is a great variation regarding the pinnate character of megasporophyll and the number of ovules per sporophyll as a result of which in various species of *Cycas* gradual reduction in megasporophyll may be traced. In *Cycas revoluta* and *C. pectinaia* (Fig. 40), the lamina is large with well developed pinnae and the ovules are 4 to 6 in number. In *C. circinalis, C. rumphii* and *C. thouarsii* the lambina is some what reduced and the pinnae are also greatly reduced. In *C. normanbyana* not only the lamina and pinnae are reduced but the ovules are also two in number.

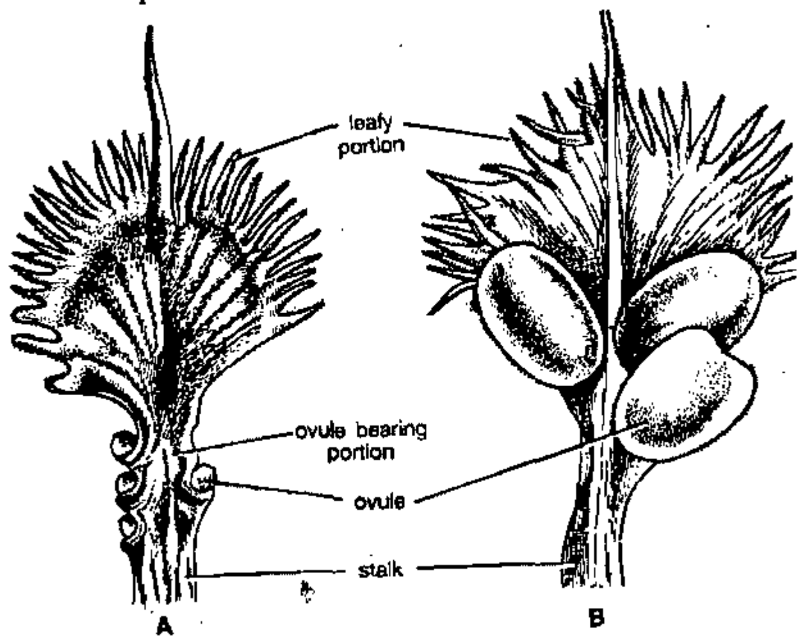


Fig. 39. Megasprophylls of *C. siamensis.*

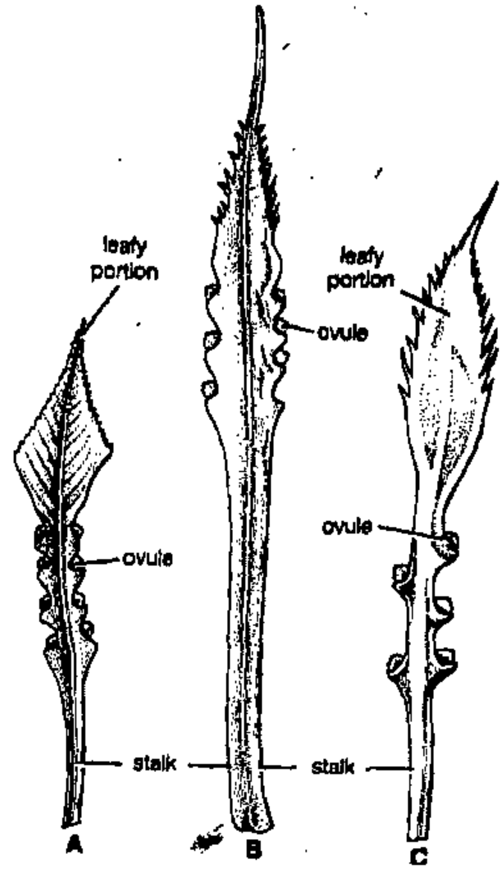


Fig. 40. Megasporphyll of *C. pectinata.*

Structure of ovule

The ovules of *Cycas* are largest in nature and can be seen by naked eye. In *C. circinalis* the ovules are largest in size *i.e.,* about 6 cm in length and 4 cm. in diameter. The ovule is green when young and is covered by hairs. At maturity it's colour changes to orange and the hair also fall off. According to **Pant** (1973) the pigments are present in the outer fleshy layer. Each ovule is oval, sessile structure and is attached to the megasporophyll at its lateral sides. The ovule of *Cycas* is **orthotropus** (Fig. 41) and is chiefly made up of a central mass of parenchymatous cells known as **nucellus**. The nucellus is surrounded on all sides by a single massive covering layer called as **integument.** The integument surrounds the nucellus on all sides except on the top, where a small opening is left, which is called as **micropyle.** The integument is not a simple structure but is differentiated into three layers :

Outer fleshy layer (outer sarcotesta), **Middle stony layer** (outer sclerotesta) **and Inner fleshy layer** (inner sarcotesta).

In the region of micropyle the nucellus is protruded out in the form of a beak like process known as **nucellar beak,** which forms a flask like cavity at the base due to disintegration of the cells and serves as a receptacle, where the

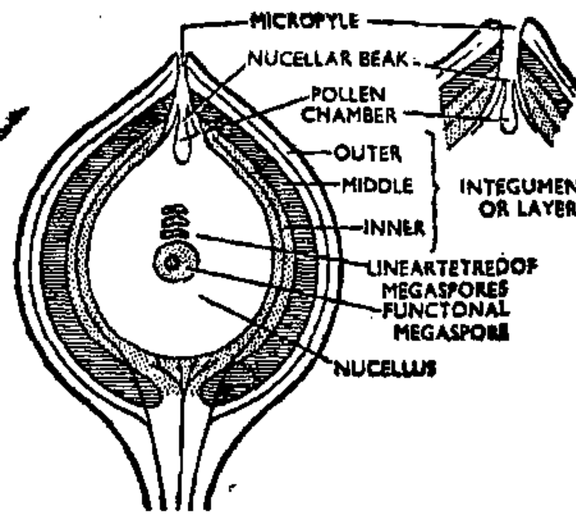


Fig. 41. *Cycas.* L.S. young ovule.

microspores are settled after pollination. Therefore, this cavity is known as **pollen chamber**. In the centre of the nucellus, is present a large single **functional megaspore.** *(Fig. 41).* The main vascular supply of the integument is also peculiar. The main vascular supply divides into two branches, one enters in the outer fleshy layer and goes upto the micropyle while the other branch goes into the inner fleshy layer upto the free end of the nucellus *i.e.,* at the base of the pollen chamber. The xylem of vascular supply is of mesarch nature.

Development of ovule and formation of megaspore (Embryosac)

De silva and Tambiah (1952) described the early stages of the development of the ovule in *C. rumphii.* Four to six ovules arise as a hypodermal mass of meristematic cells on the lateral sides of the lower part of the megasporophyll. The cells divide and redivide forming a mass of parenchymatous cells known as **nucellus.** Soon the neighbouring cells at the base of the nucellus are also activated and they grew upwards forming the **integument,** which surrounds the nucellus on all sides except at the top where a small opening is left which is known as micropyle. In the beginning the nucellus and the integument are free but afterwards due to intercalary growth both of them fuse except in the region of **pollen chamber.**

Deeply situated in the nucellus, only one cells gets differentiated from other cells by its large size, dense cytoplasm and a prominent nucleus. This cell is called as **megaspore mother cell.** (Fig. 42A-C). It divides twice, the first division is transverse and reductional one forming two cells, followed by an ordinary division in each cell in transverse plane, as a rsult of which a **linear tetrad** of 4 haploid cells is formed (Fig. 42D). The three upper cells of the linear tetrad degenerate (Fig. 42E) and the used up in nourishment. The lower cell enlarges in size and acts a **functional megaspore or embryo sac.** (Fig. 42 E).

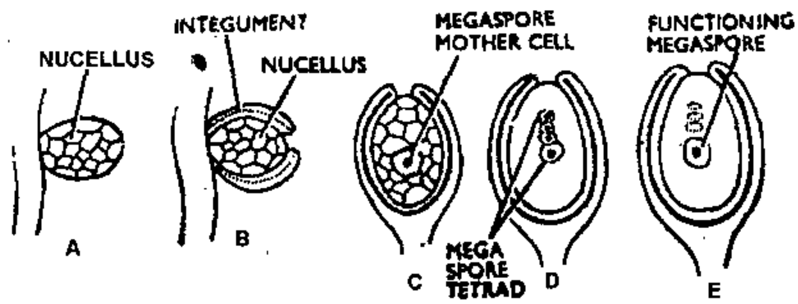


Fig. 42. (A-E) *Cycas* (A-B) showing development of ovule, (C-E) showing formation of functional megaspore.

Gametophytic phase

The spores are the unit of gametophytes. *Cycas* is a heterosporous genus, therefore the development of male and female gametophyte takes place from microspores and megaspores respectively.

Development of Male Gametophyte

The microspore is the initial stage of male gametophyte. Each microspore is a uninucleate, unicelled structure with two layered wall *i.e.,* **exine** and **intine**. The development of male gametophyte can be studied in two stages :

(i) Development of male gametophyte before pollination *i.e.,* inside microsporangium. (Fig. 43 A-C).

(ii) Development of male gametophyte after pollination *i.e.,* inside ovule. (Fig. 43 D-F).

Development of male gametophyte before pollination inside microsporangium

The microspores start germinating *in situ* while they are still inside the microsporangium. First its nucleus divides into two, one of them moves towards the lower side and is separated from the other by a crescent shaped wall resulting in the formation of two unequal cells. The lower smaller cell is called as **prothallial cell** and the upper bigger one as **antheridial cell.** (Fig. 43B). The prothallial cell does not divide further but the antheridial cell divides to from a **generative cell,** which is in close contact with the prothallial cell and a distal **tube cell** with a large nucleus (Fig. 43B,C). The stage is called as three celled stage consisting of a prothallial cell, a generative cell and a tube cell. At this stage shedding of the pollen grains takes place.

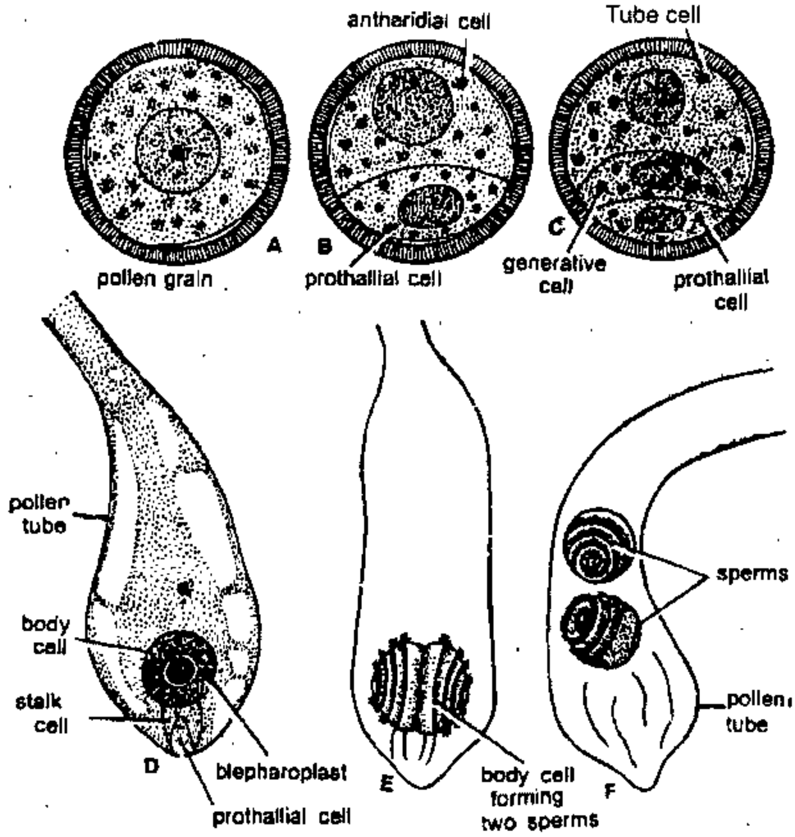


Fig. 43. (A-F). ***Cycas.*** **Development of male gametophyte.**

Pollination

At the three celled stage the microspores are ready for dispersal from the microsporangium. The wall of the microsporangium ruptures along with the line of dehiscence and the microspores are blown away by wind as they are light in weight. At this time the ovules too are ready for pollination. During this process a drop of viscous liquid perhaps formed by the disintegration of few cells of the pollen chamber or from other part of ovule oozes out in the form of a pollination drop from the micropyle. The liquid is adhesive in nature. The pollen grains present in the air current are entangled in it. Gradually the pollintion drop begins to dry up as a result of which the pollen grains too are sucked in through the micropyle into the pollen chamber. Further drying of this drop seales up the micropyle (Fig. 44).

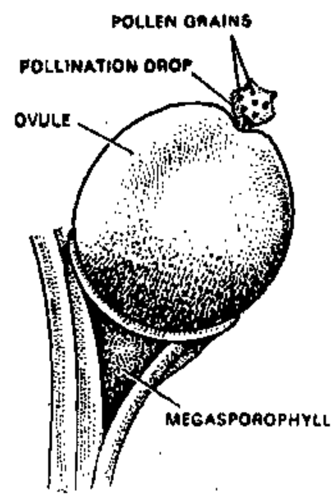


Fig. 44. ***Cycas rumphii*****—An ovule with a pollination drop (Modifield after Pant, 1973)**

Development of male gametophyte after pollination *i.e.*, inside ovule (Post pollination changes in the male gametophyte)

Further development in the formation of male gametophyte is completed with in the pollen chamber. After reaching the pollen chamber, the three celled male gametophyte rests for a week and later on following changes take place :

A pollen tube comes out through the thinner end of the three celled male gametophyte (Fig. 43D). This tube may be branched or unbranched. The nucleus of the tube cell also moves down in the pollen tube. The pollen tube grows down into the nucellus digesting and breaking down the tissue. Thus the pollen tube acts as an absorbing organ or haustorium and not the sperm carrier as in angiosperms. The generative cell divides into a smaller **stalk cell**, which is in contact with the prothallial cell and a large **body cell**. (Fig. 43D).

In *Cycas revoluta* the interval between pollination and fertilization is about 120 days. The prothallial cell and the stalk cell does not divide further. The body cell divides at the time of fertilization (Fig. 42E). In the mean time the pollen tube enlarges and grow through the nucellus and hangs down into the archegonial chamber, which is formed during the development of female gametophyte. The prothallial cell enlarges in size and pushes inside the stalk cell.

In the further development, the body cell enlarges along the long axis of the pollen tube and two special structures known as **blepharoplasts** develop transversely on either side of the nucleus of the body cell. The blepharoplast gives rise to the cilia. Just at the time of fertilization the body cell divides longitudinally into two **sperm mother cells**, each of which having a single nucleus, a blepharoplast and a small amount of cytoplasm. During these changes, the body cell separates from the stalk cell and moves towards the tip of the pollen tube. Each sperm mother cell later on develops into a sperm (Fig. 43F).

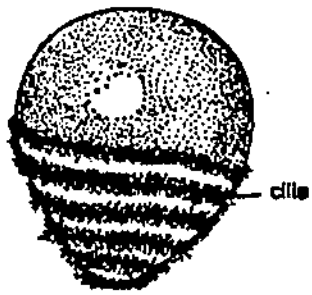


Fig. 45. *Cycas*. A single sperm

The sperms of the *Cycas* are **largest in the plant kingdom** and are easily visible to the naked eyes (Fig. 45). Each sperm is a more or less triangular or top shaped motile structure having four or five spiral bands of cilia with a single nucleus inside. The sperms after breaking the wall of the body cell freely move in rotation inside the pollen tube.

- Microspore
  - Prothallial cell
  - Antheridial cell
    - Tube cell
    - Generative cell
      - Stalk cell
      - Body cell
        - Sperms
        - Sperms

Development of female gametophyte

The megaspore is the initial stage of female gametophytic generation. The development of female gametophyte takes place *in situ. i.e.*, with in the nucellus. The functional megaspore grows at the expense of other degenerating spores and the surrounding nucellus cells. First the functional megaspore increases in size so much

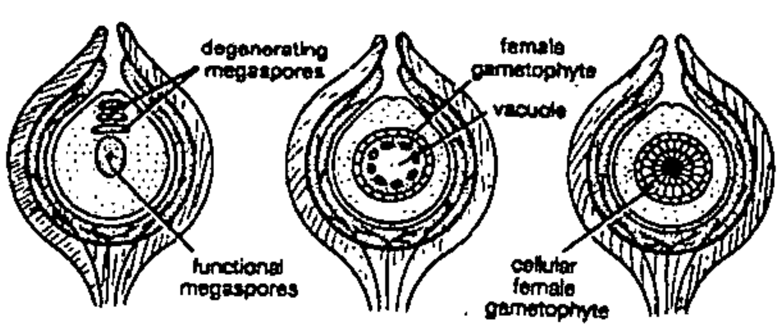


Fig. 46. *Cycas*. Development of female gametophyte.

that the nucellus is reduced (Fig. 46A-C) to a papery layer and its nucleus divides by free nuclear division into a large number of nuclei. A vacuole appears in the centre which pushes the nuclei towards the periphery. Now the wall formation takes place from periphery to the centre (Fig. 46C) *i.e.*, centripetal cell formation takes place to form a cellular tissue called as **endosperm or female prothallus.** Its upper cells are smaller and compactly arranged while the lower cells are large and nutritive in function. Endosperm of *Cycas* differs from that of angiosperms as it is formed after fertilization in angiosperms and before fertilization in gymnosperms. Now 2–8 archegonia develop from the superficial cells of the endosperm (Fig. 47E).

Structure of archegonium : Each mature archegonium is very simple in structure. It consists of a neck consisting of two cells and an egg. The neck canal cells are completely absent in Cycas and there is no proper venter, The surrounding cells of the endosperm act as an archegonial jacket (Fig. 47E).

Development of archegonium : Each archegonium develops from a single superficial cell of the endosperm near the micropyle as an **archegonial initial** (Fig. 47A). It enlarges and gets differentiated from the cells of the endosperm. It divides transversely into an upper **primary neck cell** and a lower **central cell** (Fig. 47B). The primary neck cell divides vertically to form two neck cells. The central cell enlarges in size and its nucleus divides to from a **ventral canal nucleus** and an **egg nucleus** (Fig. 47C). The neck canal cells are not formed at all. Later on the ventral canal nucleus disorganises. **The egg of Cycas is the largest in all living plants.** (Fig. 47D). During the development of archegonium the tissue of endosperm near micropyle grows upward to form a shallow cavity called as **archegonial chamber.**

Fertilization : At the time of fertilization (Fig. 48) the nucellar tissue between the pollen chamber and the archegonial chamber disorganizes and simultaneously the ventral canal nucleus also disintegrates. The tips of the pollen tubes when reach the archegonial chamber, rupture due to there high turgidity as a result of which, its fluid contents along with the sperms are set free and the archegonial chamber becomes moist in which the sperms move freely with the help of their cilia. Only a single sperm enters violently in each archegonium theough neck. Only the male nucleus of the sperm fuses with the egg nucleus to form a **zygote** or **oospore** (2X). This process is called as **Zoidogamy** and was first reported by **Ikano** (1996).

Thus the fertilization brings to an end of the gametophytic generation and the zygote is the initial stage of the sporophytic generation.

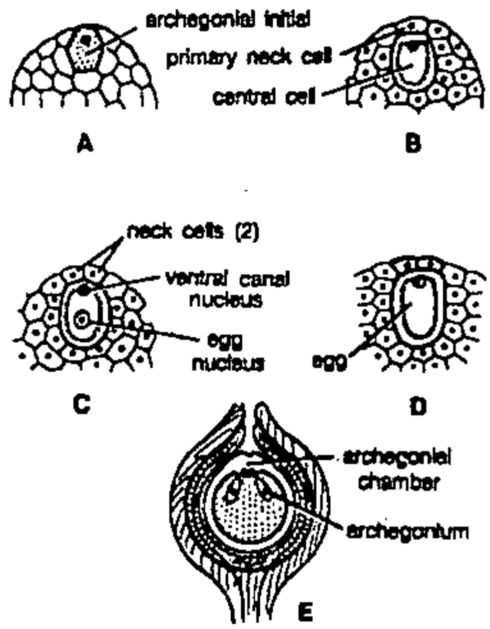


Fig. 47. (A-E). *Cycas*. Development of archegonium.

The function of the pollen tube in *Cycas*

The pollen tube is bifold in function :

(i) Primary function is to absorb food for the developing male gametophyte i.e. it acts as a haustorium.

(ii) Secondly it functions as a sperm carrier.

Therefore, it is established that the fertilization is of **siphonogamous** type, although the sperms move with the help of their cilia.

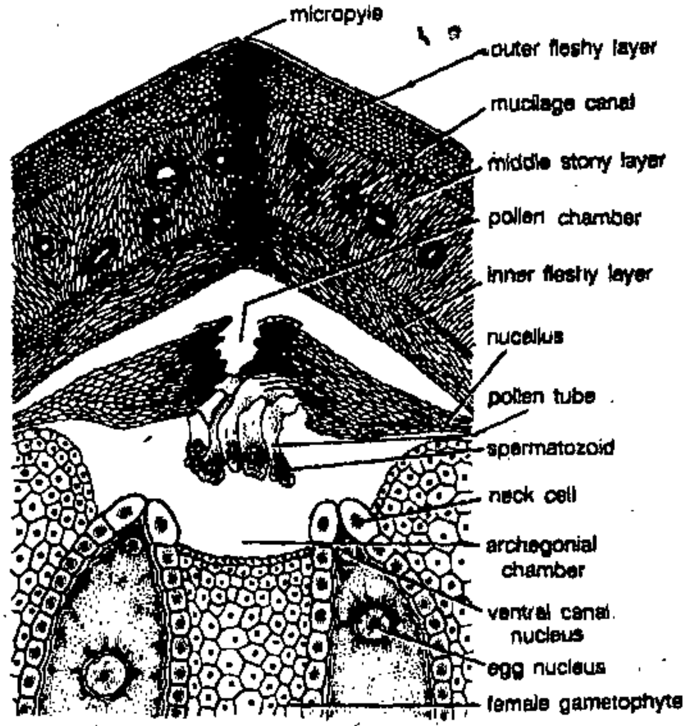


Fig. 48. *Cycas*—A closed top of ovule after pollination, showing course of pollen tubes.

1.5. DEVELOPMENT OF ZYGOTE AND FORMATION OF EMBRYO (EMBRYOLOGY)

Treub (1884) and **Ikeno** (1896) worked out the embryology of *C. circinalis,* and *C. revoluta* respectively. During development, the zygote enlarges in size and finally forms the embryo. In this whole process one year time is utilized. First the zygote divides to form a proembryo and later on from the tip of proembryo, the embryo is differentiated.

In the formation of proembryo, the diploid nucleus of the zygote undergoes a number of free nuclear divisions forming about 256 free uclei (Fig. 49A-C). **Treub** (1884) was of

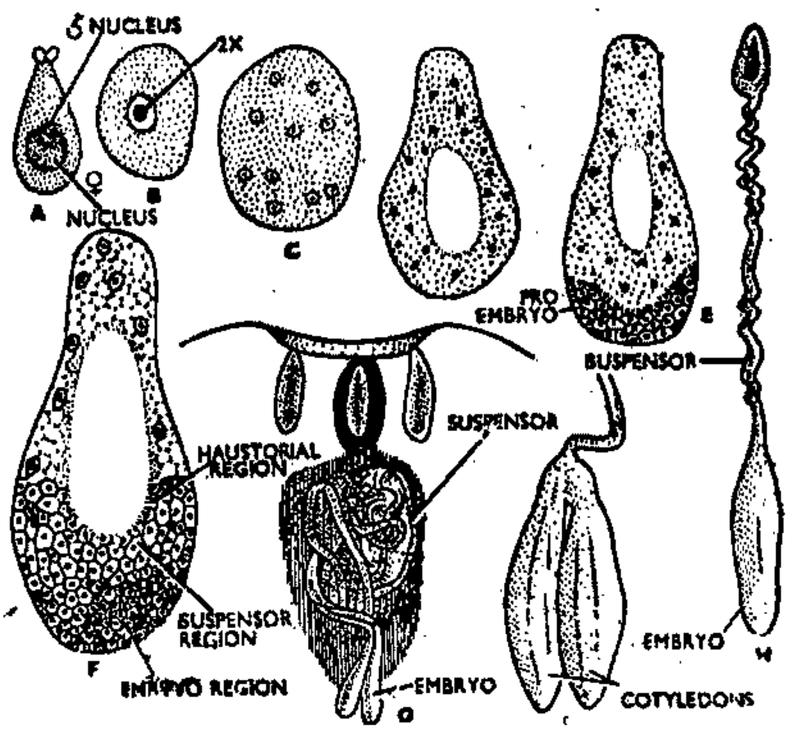


Fig. 49. (A-H) *Cycas*—Development of zygote and formation of embryo.

opinion that a vacuole appears in the centre, which gradually enlarges and pushes the nuclei and cytoplasm towards the periphery, whereas according to **Ikeno** (1896) the nuceli and cytoplasm of the central region disorganize forming a central vacuole (Fig. 49E). Subsequently wall formation takes place from the base and advances towards the upper side forming a small mass of cells. This structure is called as **proembryo**. It is meristematic in nature. Some of the nuclei in the upper region remain in a free state *i.e.*, wall formation is not complete in this region.

The proembryo soon becomes differentiated into the following thre zones (Fig. 49F).

(i) Haustorial zone

(ii) Suspensor zone

(iii) Embryonal zone

Haustorial zone : This is the upper part of the proembryo, which is in contact with the free nuclear tissue of the upper side. It is in direct contact with nutritive material and acts as absorbing organ and absorbs the food material from the endosperm for embryo, via suspensor cells.

Suspensor zone : This is the middle part and the cells of this zone elongate considerably forming a long spirally coiled suspensor, which pushes the embryo into the food containing cells of the endosperm.

Embryonal zone : This is the basal part which gives rise to the embryo. The cells undergo rapid division and enlarges. Soon the growth is checked up at its centre but continues at the margins, as a result of which two cotyledons are formed (fig. 49G, H). In the central depression the plumule is differentiated and the radicle is differentiated below the hypocotyle, which is enclosed in a hard covering called as **coleorrhiza**.

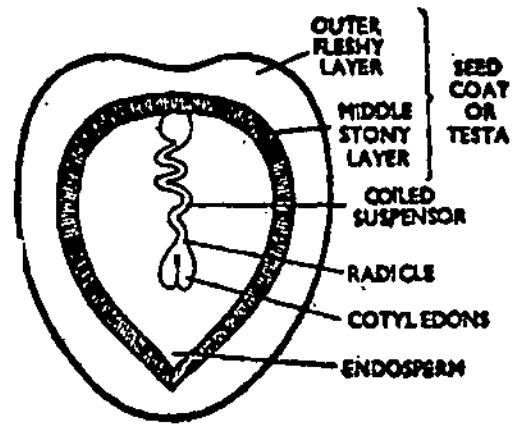


Fig. 50. *Cycas*-L.S. of young seed.

Several archegonia are fertilized in the ovule and several suspensors are formed but finally only one embryo develops at maturity.

1.6. SEED STRUCTURE

After fertilization the ovule behaves as seed (Fig. 50). In the formation of the seed of *Cycas*, the nucellus and the inner fleshy layer of integument are used up as nourishment by developing embryo thus it contains the following parts.

Seed coat or testa : It is formed by the outer brightly coloured fleshy layer and the middle stony layer of the integument.

Micropyle : It is in the form of a small opening at the top of the seed.

Endosperm : Inner to the integument or seed coat, lies the very well developed tissue called as endosperm containing the food material.

Embryo : In the endosperm lies a well developed embryo having the following structures :

(i) Two cotyledons (ii) A plumule and

(iii) A radicle.

The embryo remains suspended in the endosperm by a long spirally coiled suspensor.

Thus a mature seed of *Cycas* is very interesting as it represents three generations.

(1) **Integument**, which forms the seed coat, is the representative of parent sporophytic generation.

(2) **Endosperm** represents the gametophytic generation.

(3) **Embryo** represents the new sporophytic generation.

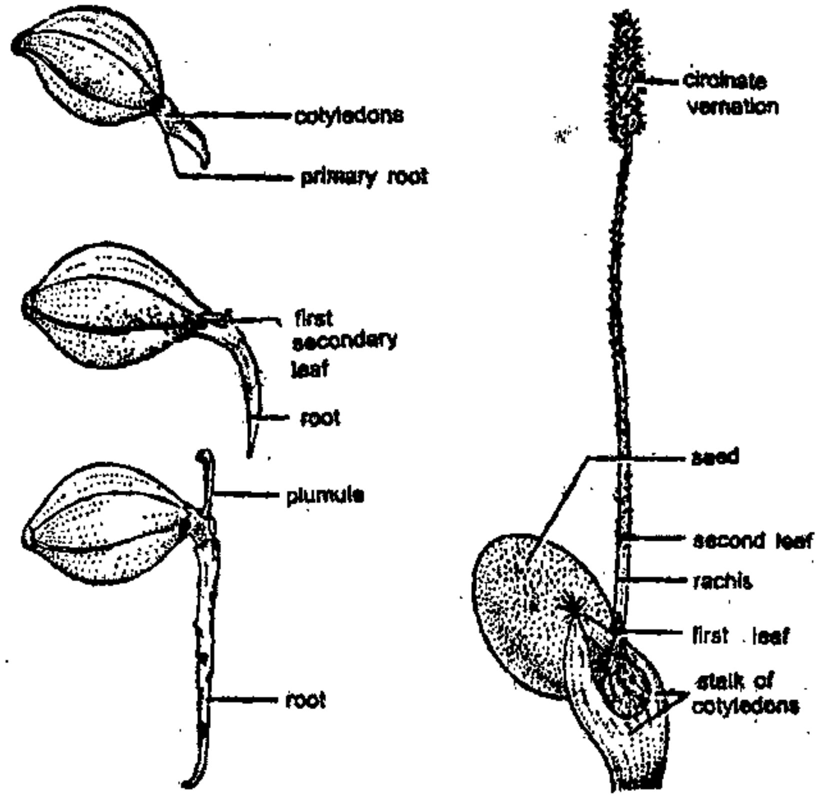


Fig. 51. *Cycas*—Diagrams showing different stages during the germination of seed.

Germination of seed

The seed of *Cycas* germinates in the suitable conditions immediately, (Fig. 51) without undergoing a period of rest, as the seeds are only viable for few months (**Pilger**) 1926 ; **Chamberlain, 1953**) According to **De Silva** and **Tambiah** (1952) "there is further period of physiological immaturity as the seed do not germinate for a long time after embryo is fully formed." Its germination is hypogeal i.e., the cotyledons remain in the soil after germination. By absorbing water through the micropyle, the integument (seed coat) ruptures and the **radicle** comes out in the form of root which grows down piercing the coleorrhiza. The **plumule** grows upwards forming first cotyldonary leaves. The first one or few leaves are generally scaly leaves followed by pinnate foliage leaf with few leaflets. The young leaf shows circinate vernation. After several years the first crown of leaves is formed.

1.7. RELATIONSHIPS OF *CYCAS*

Cycadales is an order of Cycadopsida, comprises of a genera, of which all are living and *Cycas* is one of the them. However, a group of Gymnospermous plants (Cycadofilicales or Pteriodosperms) of Palaeozoic period showed fern like nature and seed habit. It is believed that Cycadales have arisen from this group. It is, therefore natural that *Cycas* shows several fern like character (especially like *Aspidium*) which are discussed below :

Resemblances with Ferns

Morphological Similarities

(1) Both in *Cycas* and Ferns, the plant is a sporophytic (2X) and is differentiated into root, stem and leaves.

(2) When the plant is young, the stem is underground and subterranean in both the cases.

(3) In the old plant the stem becomes aerial and erect. Usually it is columnar and unbranched in *Cycas* like Tree Ferns.

(4) Presence of persistent leaf bases on the stem in *Cycas*, a character similar to that of tree Ferns.

(5) Both in *Cycas* and Ferns the leaves are large, pinnately compound and are present on the stem apex forming a crown (perviously *Stangeria* of Cycadales was placed in the fern family Polypodiaceae because of the the fact that the leaves of both are much similar with each other).

(6) The young leaves of *Cycas* show circinate vernation, a character similar to that of Ferns.

Anatomical Similarities

(8) Presence of foliar gaps in the cortex of both the plants.

(9) In both (*Cycas* and Ferns) anatomical structures are identical. Pith and cortex are large. Xylem consists of tracheids and xylem parenchyma only, while pholem consists of sieve cells and phloem parenchyma. Xylem is devoid of trachea (Vessels) and phloem, of companion cells.

(10) Both in Ferns and *Cycas* mesarch or even concentric vascular bundles are present in the leaf and cone axis.

(11) Sporophylls are leaf like in both the cases.

(12) In case of Ferns, the microsporangia are present on the abaxial (ventrai) side so is the case with *Cycas*. In *Cycas* also the microsporangia are present on the abaxial side.

(13) Microsporangia are present in groups of 3-7 forming several sori. The soral character is definitely Fern like.

(14) Indusial hairs are also present in both the cases.

(15) In *Cycas* the development of microsporangium is of eusporangiate type. In some Ferns (*e.g.*, Ophioglossaceae and Marattiacae) it is also of eusporangiate type.

(16) In both, spores are produced in large number, the stalk is massive, sporangial wall several layered and the manner of dehiscence is also similar.

(17) The megasporophylls of *Cycas* and specially of *C. revoluta* are leafy structures like Ferns, though the marginal ovules are not identical to the sori of Ferns.

(18) Sperms are motile and multiciliate in both the cases *i.e.*, in *Cycas* as well as in Ferns. This is one of the most important character between the two groups.

From the above account it is evident that Cycads might have arisen from Ferns. Evidently Cycads have come from Fern kike *Cycadofilicales* of the Palaeozoic period and have given rise to *Bennettitales* during the Mesozoic period.

Differences with Pteridophytes

(1) Usually the plants of Pteridophytes (except Tree Ferns) are smaller than *Cycas* plant.

(2) There is no secondary growth due to the absence of cambium in Pteridophytes while the secondary growth is prominent in *Cycas* due to the presence of cambium in the stem.

(3) Development of ovule and seed formation is abesent in Pteridophytes while present in Gymnosperms.

(4) In heterosporous members of Pteridophytes both micro—and megaspores are shed from their sporangia, while only mocrospores are shed from microsporangia and megaspores are retained inside the ovule in case of *Cycas*.

(5) In Pteridophytes the archegonia are long and well developed with neck canal cells while the archegonia are very simple in *Cycas* and consist of short neck with two neck cells and the neck canal cells are totally lacking.

Relationship with other Gymnosperms

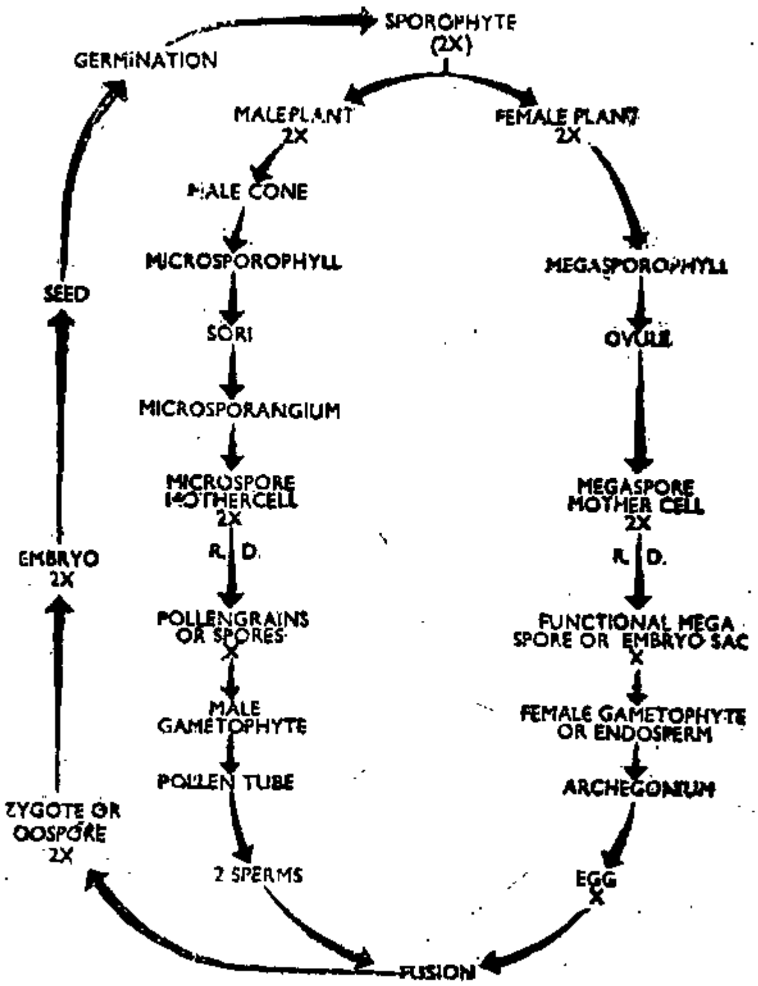
Cycadophyta includes three orders *i.e. Cycadales, Cycadofilicales* and *Bennettitales*. While the 1st order includes living members, the last two include extinct members. *Cycadofilicales* are transitional between ferns and cycads. On one hand they resemble with ferns in their habit, vascular anatomy and presence of sporangia in sori, while on the other hand they resemble with cycads in the structure of ovule having three layered integument and the nucellar beak with a characteristic pollen chamber.

Members of *Bennettitales* had many similarities with *Cycadofilicales, Filicales,* and *Cycadales. Bennettitales* resemble *Cycadales*, so much that they have often been called **fossil cycads.** In both caces the stem has an endarch siphonostele with narrow zone of wood, xylem mesarch in other aerial parts and dicotyledonous embryo.

1.8. *CYCAS* IS LIVING FOSSIL

Cycadales flourished best in Mesozoic era. They resemble ferns in their habit, venation of leaves, vascular anatomy, sporangia grouped in sori, multiciliate sperms and structure of microsporangia. All these characters along with the structure of ovule are common in **Cycadofilicales, Bennettitales** and **Cycadales**. Thus these three oders are closely related and their history traces back to Paleozoic era. **Cycas** being the most primitive member of living cycads as it has fern like megasporophylls and the female cones are not formed as the megasporophylls are loosely arranged. This character bring them close to fossil seed plant line therefore *Cycas* is being called as **living fossil.**

1.9. GRAPHIC LIFE CYCLE OF *CYCAS*



1.10. ECONOMIC IMPORTANCE OF CYCAS

1. *Cycas* sp. are economically important as they are cultivated in gardens. They are beautiful palm like plants and act as ornaments of the gardens *e.g., C. revoluta, C. circinalis, C. rumphii* and *C. bedomei.*

2. Foliage leaves are widely used for decoration of houses and churches as they remain fresh and green for a longer period.

3. *Cycas* is widely cultivated in Japan for "**sago**" a kind of starch, which is used by poor. It is obtained from the stem portion. Hence it is also known as "Sago palm."

4. Seeds of *Cycas* are roasted and are used as food in Assam and certain Islands. The seeds yield a flour called 'indum podi.'

5. The seeds and stem of *C. revoluta* are used in making wine in Japan.

6. Leaves are used in making brooms and baskets etc.

7. Juice of young leaves of *Cycas circinalis* is used as medicine in stomach disorders, blood **vomiting** and other skin diseases.

8. Seeds and crushed bark of Cycas and its megasporophylls when mixed with coconut oil are used as "**Poultice**" for **sores** and wounds in South India.

9. *C. rumphii* yields a gum, which is found effective against malignant tumours.

10. The pollen grains of some species of *Cycas* are narcotic in nature.

1.11. SYSTEMATIC POSITION

Division	– Gymnospermae
Class	– Cycadopsida
Order	– Cycadales
Family	– Cycadaceae
Genus	– *Cycas*

1.12. SUMMARY

Cycas is represented by about 20 species. Only six species of *Cycas* occur in India. *C. revoluta* is cultivated in gardens. The plant body is foliose and sporophytic. Trees are slow growing and show palm habit. The roots are of two types : normal and coralloid. The normal roots conforms to a tap root system. The coralloid roots are coral like, apogeotropic, lacking root cap and root hair. The stem is aerial, erect, woody and usually unbranched. The leaves are dimorphic, scaly and foliage. The scaly leaves are triangular covered by ramenta. The foliage leaves are spirally borne on a terminal crown. They are unipinnate and circinately folded in bud condition. The leaflets are lanceolate with a midrib but no venation.

The normal roots are diarch and exarch. They show dicot type secondary growth. The coralloid root is generally triarch and exarch showing less or no secondary growth. There is an algal zone in the cortex of coralloid roots containing endophytic algae (*Anabaena, Nostoc, Oscillatoria,* diatoms) and bacteria (*Azotobacter, Pseudomonas*). The stem also resembles dicot plants in anatomy. There is a ring of conjoint, collateral and open bundles with endarch xylem. The cortex has leaf trace girdles. Mucilage canals are present throughout. The leaf receives two direct leaf traces and two indirect. The indirect trace arises on the opposite side. It divides and each branch takes a semicircular path before entering the leaf. In secondary growth pattern, *Cycas* resemble some abnormal dicot stems. The wood of *Cycas* is monoxylic and polyxylic. The secondary xylem is made up of tracheids showing multiseriate bordered pits. Bars of sanio have been also observed. Vessels have been also reported from *C. revoluta*. In rachis, the vascular bundles are arranged in a pitcher like manner. They are conjoint, collateral, open and diploxylic (pseudomesarch) due to centrifugal and centripetal xylem groups. The rachis bundle is endarch in the region of stem cortex, pseudomesarch for most of it's length and exarch at the extreme tip. The leaflet in the lamina region is distinguishable into palisade and spongy parenchyma with transfusion tissue in between the two layers. Sunken stomata are present along the lower epidermis. In the midrib region, the leaflet has palisade and a single diploxylic midrib bundle. A well developed hypodermis is present throughout. The plants of *Cycas* reproduce by vegetative and sexual methods. They are heterosporous and dioecious. The male plants produce a terminal male cone comprising an axis bearing microsporophylls spirally. The microsporophyll is a woody wedge shaped structure bearing sori of microsporangia abaxially. In each sorus there may be 2-6 microsporangia. The terminal sterile portion is called apophysis. Each microsporangium has a short stalk, a 5-6 layerd wall enclosing a mass of sporogenous tissue. The outermost wall layer is exothecium and the innermost is tapetum. The sporogenous cells form pollen mother cells (PMC) which undergo meiosis to form tetrahedral tetrad of microspores. The tapetum and inner wall layers of microsporangium degenerate at maturity. The megasporophylls are spirally borne on the female plant. There is no female cone formation. It may be pinnate or ovate-lanceolate or orbicular-rhomboidal. The upper part of rachis bears 1 to 6 pairs of ovules laterally. The ovules of *Cycas* are largest in the plant kingdom. The ovule is orthotropous and unitegmic. It comprises nucellus and an integument which is distinguishable into an outer fleshy layer (outer sarcotesta), middle stony layer (sclerotesta) and inner fleshy layer (inner sarcotesta). The megaspore mother cell undergoes meiosis to form a linear tetrad of megaspores. Of these, upper three megaspores degenerate. The unicelled microspore, after two divisions of gametogenesis forms a three celled (tube cell, generative cell and prothallial cell) and double layered (exine and intine) male gametophyte. It is dispersed at this three celled stage. The megaspore nucleus divides freely. Cell wall formation starts from periphery and reaches the centre forming cellular female gametophyte or `endosperm'.

Archegonial chamber is formed on the upper side between the microspore and nucellus. About 2-8 archegonia are formed in each ovule. An archegonium consists of a two celled neck with no neck canal cell and ventre. The egg and ventral canal nucleus remain surrounded by the cells of prothallus. The pollination is anemophilous. The pollen grains are deposited on the micropylar drop which, when dries sucks the grain into the pollen chamber. The generative cell of the pollen grain divides into stalk and body cells and the body cell forms two pyramidated, multiflagellate antherozoids. The tube cell forms the pollen tube which is also haustorial in nature. The anthrozoids are released in vicinity of neck cells. As a result of fertilization the zygote is formed.

The fertilization is siphonogamous accompanied by zooidogamy. The zygote nucleus divides freely. A central vacuole develops and soon the embryo is differentiated into upper haustorial, middle suspensor and lower embryonal regions.

The suspensor grows quickly and hence becomes coiled. The embryonal region shows differentiation of two cotyledons. A plumule, hypocotyl and radicle are also differentiated. The radicle is enclosed by coleorrhiza. The seed of *Cycas* comprises tissue of three generations namely, parent sporophytic (seed coat, nucellus), gametophytic endosperm and second sporophytic (embryo). Out of several zygotes formed, usually only one embryo reaches maturity in a seed.

The germination of the seed is hypogeal. The plants of *Cycas* reproduce vegetatively by forming bulbils or adventitious buds and rarely by suckers.

Cycas species are economically important as they are cultivated in gardens. The species are also cultivated for `sago' starch in Japan. The fruits of *C. rumphii* and shoots of *C. pectinate* and *C. circinalis* are ceaten. The seeds yield a flour, called `indum podi' is also edible.

1.11. STUDENT ACTIVITY

1. Briefly describe the life cycle of *Cycas*.

2. Describe the internal structure or coralloid root. What are the differnces between normal root and coralloid root ?

1.12. TEST YOUR SELF

1. Name the species of *Cycas* which occurs wildly in Andman and Nicobar Islands.
2. Which species of *Cycas* is popularly known as sago palm?
3. Each leaf of *Cycas* is supplied by how many traces?
4. Name the wood in which during secondary growth large amount of parenchyma is produced.
5. Write the important constituent of xylem which is absent in the wood of *Cycas*.
6. Name the root in which algal zone is present.
7. Name the term which is applied to radial or accessory transfusion tissue in *cycas*.
8. In *Cycas* the pollen grains are shed at which stage?
9. How many integuments occur in the *Cycas* ovule?
10. What is the number of neck canal cells in the archegonium of the *Cycas*?
11. What are the important characters of the male gamete of *Cycas*?
12. What type of polymbryony is seen in *Cycas*?
13. *Cycas* has an embryo with two cotyledons yet it is not classified in dicots. why?
14. What is the important character of *Cycas* in which it resembles with *Pteris*?
15. Why the *Cycas* is called living fossil?

ANSWERS

1. *Cycas rumphii*, **2.** *Cycas revoluta*
3. Four (two direct traces and two girdle traces) **4.** Manoxylic
5. Vessels. **6.** Coralloid root. **7.** Hydrostereom.
8. 3-celled stage **9.** one **10** None
11. Large, multiciliate and top shaped **12.** Potential true polyembryony
13. Its ovules are naked. **14.** Ciliated sperms.
15. The group is better known through fossil records.

UNIT-I

CHAPTER

4

PINUS

STRUCTURE

- Introduction
- Distribution
- External Morphology
- Anatomy
- Reproduction
- Embryogeny
- Seed Structure
- Economic Importance
- Graphic Life Cycle
- Systematic Position
  - Summary
  - Student activity
  - Test yourself
  - Answers

LEARNING OBJECTIVES

After learning this chapter, you will be able to know the morphology, anatomy, reproduction and life cycle of *Pinus*.

1.0. INTRODUCTION

Pinus is a member of order Coniferales. The genus comprises about 105 species. These species are mainly distributed in the Northern Hemisphere, and found commonly in North Europe, Northern and Central America, Subtropics of North Africa, India, Myanmar, Pakistan, Afghanistan, Indonesia etc.

1.1. DISTRIBUTION

Six species of *Pinus* occur in India. They are distributed in Himalayas, north-eastern India and some other parts of the country (Fig. 1).

1. ***Pinus gerardiana*** **:** It is commonly known as *Nioza* or *Chilgoza* Pine. It occurs in Kashmir and Kinnour district of Himachal Pradesh at an altitude of 2,100–3,300 meter's. The tree is 11–20 meter high with trifoliate spur.
2. ***P. wallichiana*** **:** It is commonly known as 'Kail' or 'blue pine' or 'Bhutan pine'. It grows luxuriantly in the hills of Kashmir, Himachal Pradesh and Punjab at an altitude of 1500–3,300 meters. The tree attains height of about 50 meters. There are 5 needles in each foliage spur.
3. ***P. roxburghii*** : It is popularly known as 'Chir pine'. It commonly grows from 460 m to 1500 m in the outer Himalayan regions ranging from Indus to Bhutan. Trees may attain height of about 35 to 53 meters, a girth of about 3 meters adn are pyramid like.

4. ***P. insularis*:** It is commonly known as 'Khasi pine'. The tree grows from 800 to 200 m in Garo, Khasi and Jaintia hills. Branching in whorls, leaves are needle like, tritfoliar and comparatively thick.
5. ***P. armandii* :** Commonly known as **Armond's pine** very common in NEFA and eastern Himalayas. The plants are about 55 ft. tall and range upto the height of 1500 metres. Leaves are pentafoliar 4 – 6" long and cones are 4 – 7" long.

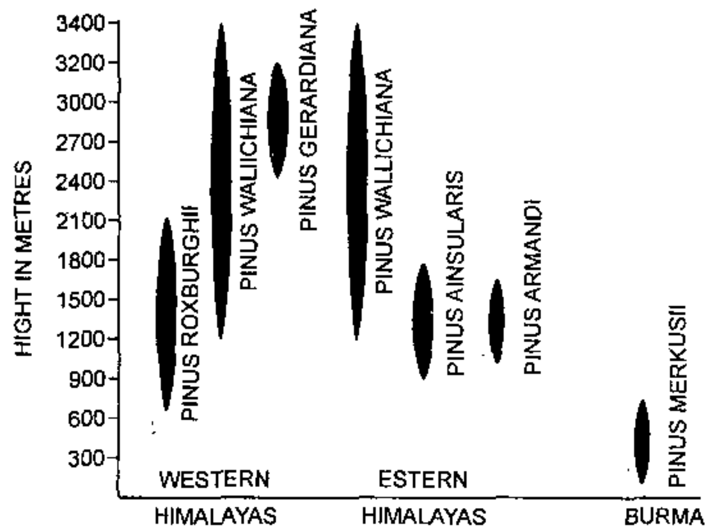


Fig. 1. Altitudinal distribution of *Pinus* Sp. (modified from Konar).

6. ***P. merkusii* :** Commonly known as **Markus pine,** very common in Burma and also found growing in Bengal. The trees are about 50 ft. tall and range at low altitude upto 600 meters height. Leaves are bifoliar.

Other species cultvated in Nurseries and Govt. orchards are *P. montana, P. laricio, P. pinastris, P. sylvestrs* (scotch pine), *P. onophylla,* and *P. strobus* (white pine) etc.

1.2. EXTERNAL MORPHOLOGY

The plant body is sporophytic (2x) and the plants are **monoecious** *i.e.,* male and female sex organs are developed on the same plant. It is a evergreen prennial plant. Mostly the species are tall and straight. The apparent whorled branching gives a typically conical appearance to the plant. The plant body is distinctly differentiated into the following three parts.

(i) Root (ii) Stem (iii) Leaves.

Root : There is a prominent tap root system, which does not penetrate deep into the soil. Later on the lateral roots develop and help in anchoring the plant in the soil. The root hair are poorly developed. Generally the ultimate branches are covered by fungal hyphae forming a covering called as ectotrophic **mycorrhiza.**

According to **Sharma** and **Mishra** (1982) mycorrhizal association in gymnosperms is an essential part of forestation. **Bakshi** (1974) showed that in the absence of mycorrhizal association, the rate of mortality is more in pine nursery. *Boleutus* spp. *Amanita* spp., *Russula, Lacturius, Clavaria* sp. *Scleroderma* sp. and *Lycoperdon* sp. are some of the basidiomycetes, found in pine forests. **(Sharma and Mishra,** 1982).

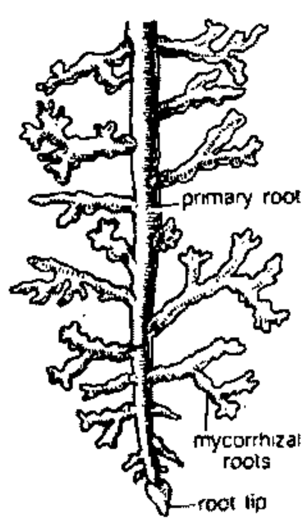


Fig. 2. *Pinus Roots*

Stem : The stem is tall, erect, cylindrical and the branching is of monopodial type. The main stem is rugged and is covered by scaly bark. Branches are developed from the buds present in the axil of the scale leaves and appear to be in whorls. These whorls develop every year as a results of which the plant apppears to be very symmetrical. The whorls form scars on the old stem which help in calculating the age of the plant. Branching in *Pinus* is of two types.

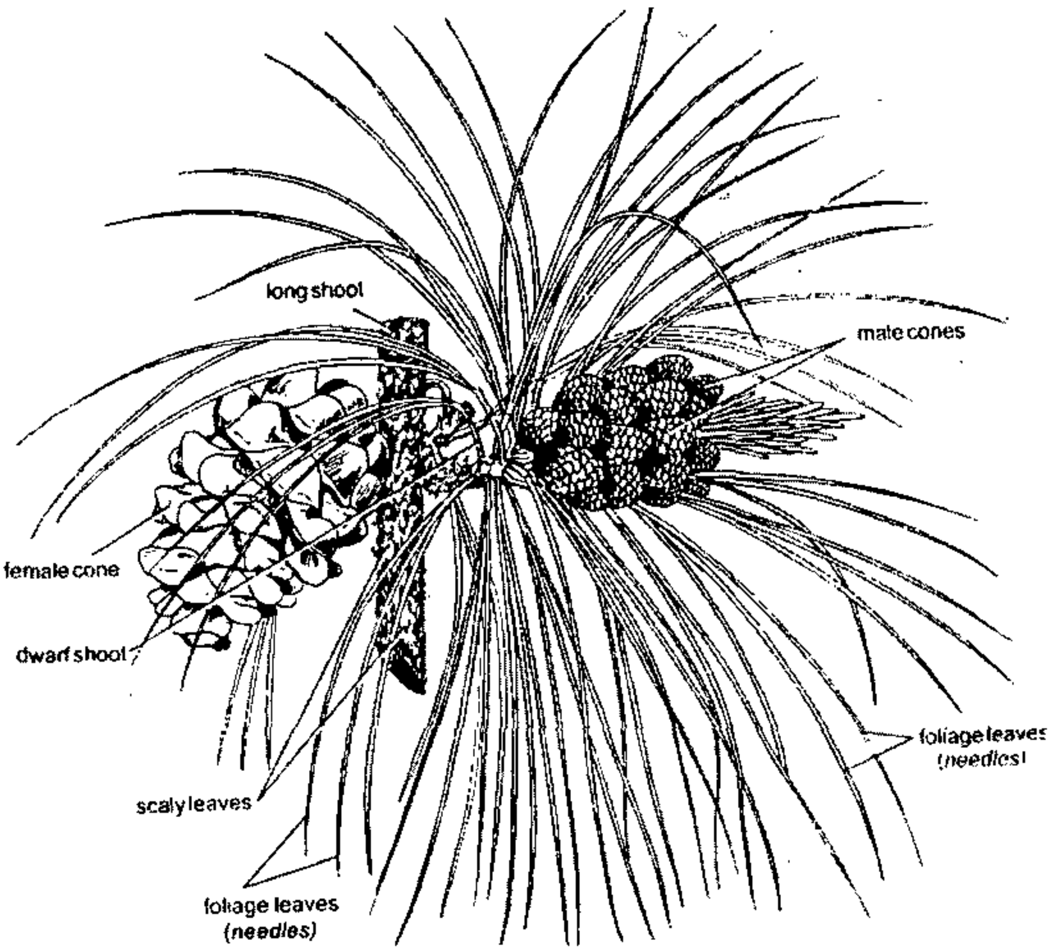


Fig. 3. ***Pinus*** **sp. A twig showing vegetative features.**

(i) Long shoots or branches of unlimited growth : They are provided with apical bud and grows indefinitely in apparent whorls each year from the buds present in the axil of the scale leaves. These branches spread out horizontally and bear scale leaves (Fig. 3).

(ii) Dwarf or short shoots or branches of limited growth : The apical bud is absent and the branch grows for a short period. They arise in the axil of scale leaves on the long shoots. They are also known as **brachyblast (Maheshwari and Konar 1971)** (Fig. 4A).

Leaves : Leaves are dimorphic *i.e.*, of two types but according to **Maheshwari** and **Konar** (1971) the genus *Pinus* shows the presence of five types of foliage *i.e.*, cotyledonary, juvenile, prophyll, Cataphyll and acicular leaves. **Cotyledonary leaves** appear after germination of seeds and are usually 3 – 15 in number, followed by **Juvenile leaves** which may function as leaves during seedling stage *i.e.*,for 1–3 years. **Prophylls** are actually the scale leaves developed in opposite pairs on the dwarf shoots. Otherwise mainly leaves are of two types :

(i) Scale leaves : They are borne on both long as well as dwarf shoots. They are small, thin, flattened and brown structures (Fig. 3).

(ii) Foliage leaves : They occur only on dwarf shoots and are commonly called as "needles." They are long acicular, green and needle like structures. The needles are present for a number of years (3 or more) as a result of which the plant looks like to be ever green (Fig. 4B). The dwarf shoot with foliage leaves is called as **spur.** The number of needles per spur varies in different species. It is only one in *Pinus monophylla* (Fig. 5A), two in *P. sylvestris,* (Fig. 5B), three in *P. longifolia,* (Fig. 5C), *P. gerardiana* or five in *P. wallichiana* (Fig. 5 D). The spur is known as monofolliar, bifoliar, trifoliar or pentafoliar respectively. These foliar leaves are needle like and thus the transpiring surface is reduced. This indicates xerophytic nature of the leaves.

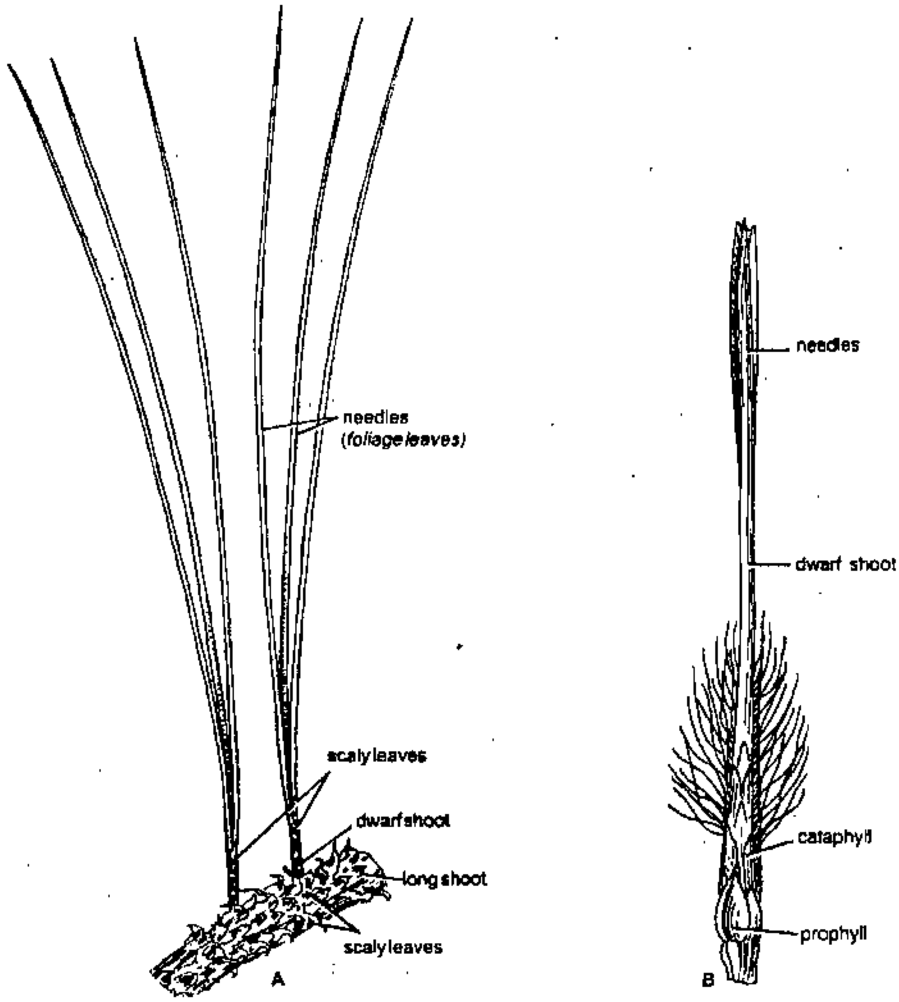


Fig. 4. (A, B). *Pinus*. A part of stem showing two types of branching. B. A dwarf shoot of *Pinus roxburghii*.

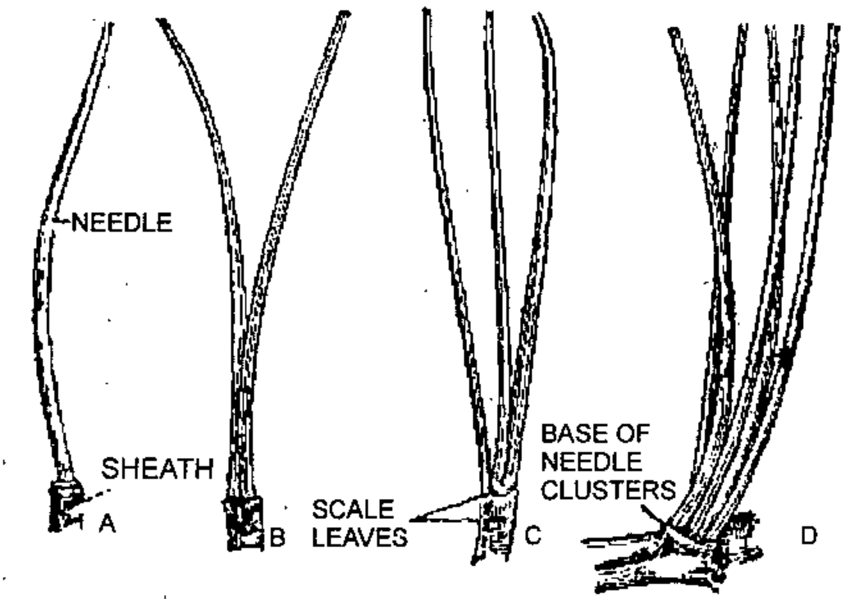


Fig. 5. (A, D). *Pinus*. showing different types of foliar spurs. A Monofoliar spur (*P. monophylla*), B Bifoliar spur (*P. sylvestris*) C Trifoliar spur (*P. longifolia*), D Pentafoliar spur (*P. wallichiana*)

1.3. ANATOMY

Anatomy of Young Root

The internal structure of a young root is identical with that of dicot root. The apical meristem is devoid of dermatogen. Only the peribelum and plerome are present. A transverse section of root is some what circular in out line and reveals the following structures. (Fig. 6) :

Epiblema : It is the outer most limiting layer and is single layered thick. The cells of this layer are peliferous.

Cortex : Epiblema is followed by a wide zone of cortex consisting of 4 or 5 layers of parenchymatous cells provided with intercellular spaces. Some of the cells of the cortex are filled with resinous substances.

Endodermis : The inner most layer of the cortex forms a single layered endodermis of suberized cells.

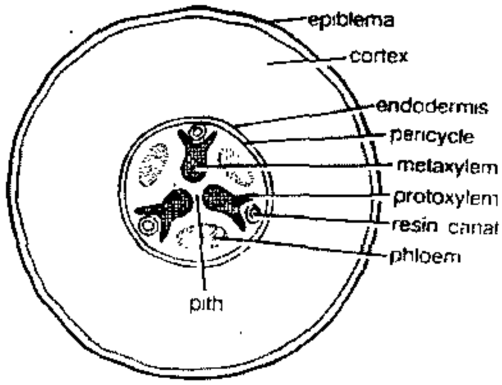


Fig. 6. ***Pinus*** **T. S. young triarch root (diagrammatic).**

Pericycle : Endodermis is followed by a multilayered parenchymatous pericycle.

Vascular tissues : The central portion is occupied by the vascular tissues which consist of xylem and phloem. They are radially arranged *i.e.*, xylem and phloem are arranged on different radii (Fig. 7).

Xylem : It is usually situated in the centre and is provided with 2–6 groups of primary xylem having bifurcated (Y-shaped) protoxylem directed towards periphery (exarch). There is a resin canal in between the two arms of each Y-shaped protoxylem group which is more clear in the older portion of the root. The xylem is devoid of vessels. (Fig. 7).

Phloem : Alternating with the protoxylem groups are present equal number of phloem patches consisting of sieve cells and phloem parenchyma. The companion cells are completely lacking.

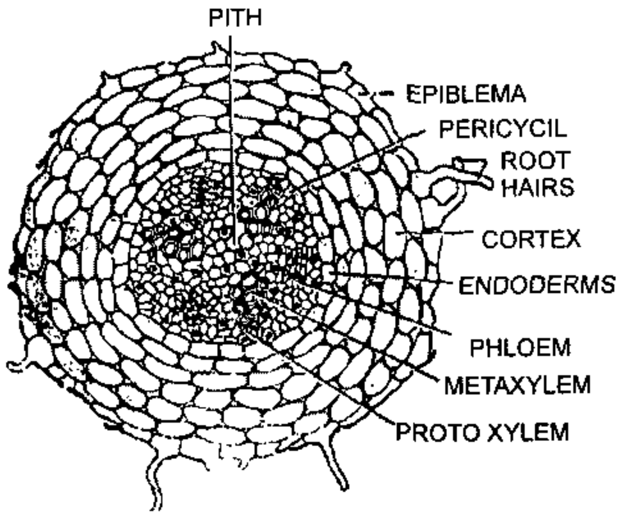


Fig. 7. ***Pinus*** **T.S. young root. (showing normal structure)**

Pith : It is generally absent and if present, it is very small and is made up of parenchymatous cells.

Secondary growth

The secondary growth is usual as in dicots. In the young roots the cambium is absent but at maturity it is differentiated in the form of arches below the phloem patches. The cambium is made up of 2 or 3 celled thick brick shaped cells, which are meristematic in nature. These cambial cells cut off secondary xylem on the inner side and secondary phloem on the outer side as a result of which the root increase in width. In this process the primary phloem is pushed and finally forms a crushed layer. In the very old root the cambium forms a complete ring and cuts off a complete ring of secondary xylem on the inner side and secondary phloem on the outer side (Fig. 8). The secondary xylem consists of radial rows of tracheids separated by parenchymatous cells.

During the courses of secondary growth, the cells of the outer most layer of pericycle also become meristematic forming a ring of cork cambium, which cuts off periderm on the outer side and secondary cortex (phelloderm) on the inner side. Finally the epiblema ruptures and the cork layer is exposed. The walls of the cork cells are suberized.

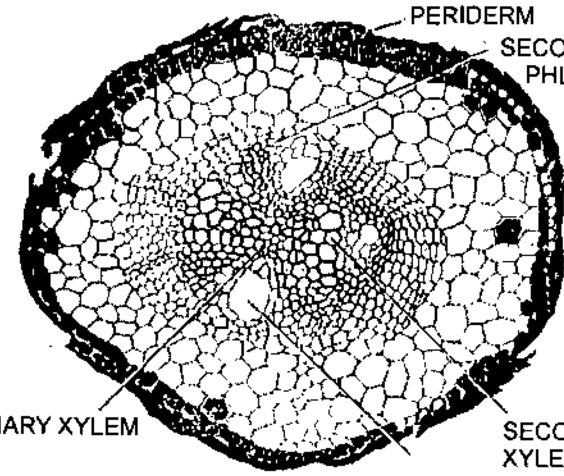


Fig. 8. ***Pinus*—T.S. mature root.**

Anatomy of the stem

The anatomy of the stem of *Pinus* closely resembles with that of a dicotyledonous angiospermic stem (Fig. 9). It shows a wavy or irregular out line due to the presence of the scale leaves and dwarf shoots on the stem. The presence of resin canals in the cortex and xylem is a characteristic feature. The vascular bundles are conjoint, collateral; open and arranged in a ring. Xylem is endarch. In a cross-section the various tissues can be distinguished as follows :

Epidermis : It is the outer most layer, which is single celled thick. The cells are small and compactly arranged. The outer wall of these cells is heavily cuticularised.

Hypodermis : Below the epidermis, there are 4–5 layers of sclerenchymatous cells, which constitute the hypodermis.

Cortex : Inner to the hypodermis is a wide zone of cortex. The cortex is parenchymatous with many intercellular spaces. Some of the cells of cortex are filled with tannin.

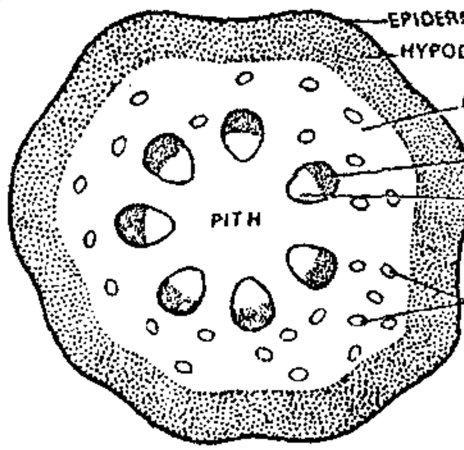


Fig. 9. ***Pinus*—T.S. young stem (Diagrammatic)**

Endodermis : It is the inner most layer of the cortex and is not easily distinguishable as it is made up of parenchymatous cells.

Pericycle : Below the endodermis are few layers of parenchymatous pericycle. Like endodermis it is also indistinguishable from the other parts.

Vascular bundles : They are conjoint, collateral and open. Each vascular bundle consists of the following tissues :

Xylem : It is situated on the inner side of the vascular bundles and is endarch. It consists of only tracheidal cells. The vessels are absent, therefore, the wood is known as non-porous. Protoxylem consists of annular and spiral tracheids, where as metaxylem tracheids have bordered pits on their radial walls.

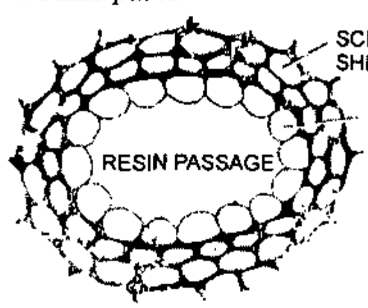


Fig. 10. ***Pinus*—A resin canal**

Phloem : It is situated on the outer side of the vascular bundle and is made up of phloem parenchyma and sieve cells. Sieve plates are present at the ends of sieve cells. The companion cells are completely lacking.

Cambium : In between the xylem and phloem of each vascular bundle, there is a strip of intrafascicular cambium, which consists of two or three layers of brick shaped cells.

Medullary ray : In between the vascular bundles is a zone of parenchymatous cells, connecting the pith and the cortex and is known as medullary ray (Primary).

Pith : In the centre of the stem, is a zone of thin walled parenchymatous cells known as pith. Some of the cells of pith are filled with resinous substances.

Resin canals : There are several resin canals scattered in the cortex as well as in the xylem. Very few may occur in the pith. Each resin canal is having an outer layer of **sclerotic cells** (sclerenchymatous cells) and an inner layer of glandular secretory, **epithelial cells** (Fig. 10) which secrete resinous substances like turpentine.

Secondary Growth

It is the process by which the stem increases in girth. The process of secondary growth in the stem of *Pinus* resembles with that of dicotyledonous stem and takes place in the following way :

Firstly some of the parenchymatous cells inbetween the adjacent vascular bundles and opposite to the intra-fascicular cambium, become metistematic in nature and change into a strip of interfascicular cambium. The inter and intra-fascicular cambium unite to form a complete ring of cambium. The cells of the cambial ring cut tisues on both the sides. The cells cut on the inner side forms the secondary xylem while those on outer side forms the secondary phloem.

Due to the formation of secondary xylem and secondary phloem rings a pressure is created and primary phloem along with pericycle and endodermis is crushed. The activity of the cambium stops in the winter season and again resumes its activity in the following spring.

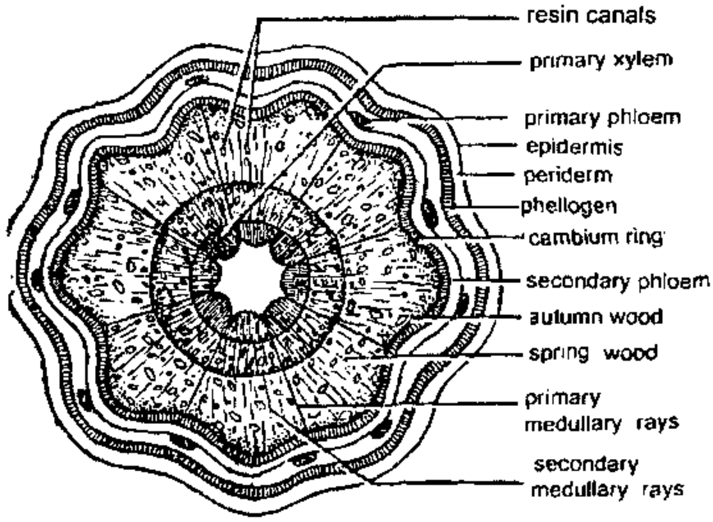


Fig. 11. ***Pinus*—Outline sketec of T.S. old stem showing seconary growth and (Diagrammatic)**

The secondary xylem thus formed clearly shows a number of **annual rings** (Fig. 11, 12). Each annual ring consists of zone of spring wood and a autumn wood. **Spring wood** is formed during spring season when enough water and minerals are easily available to the plant and therefore the cells of spring wood are comparatively thinner, large and polygonal (Fig. 13). **Autumn wood** is formed during autumn season. The cells of this type of wood are smaller, squarish and thick walled. By counting the number of annual rings, the age of the plant can be calculated. The wood is dense and massive and has been termed as **pycnoxylic.**

A number of secondary medullary rays are also formed by the activity of the cambial rings which traverse, only in between the secondary xylem and secondary phloem. Due to the presence of the secondary medullary rays the wood becomes soft. The part of the secondary medullary rays present in the secondary xylem region is called as xylem ray and of the phloem region is called as phloem ray, the structure of secondary medullary rays is complex. They are uniseriate with few cells in height.

Some of the cells in the region of cortex (Not exactly below the epidermis) also become meristematic forming **cork cambium** (Phellogen). The cork cambium also cuts off cells on both sides. The cells cut on the outer side form the cork **(periderm)** while those of the inner side form a secondary cortex **(phelloderm).**

Resin canals are also present in the secondary xylem (Fig. 12). Old stem of *Pinus* shows the following tissues :

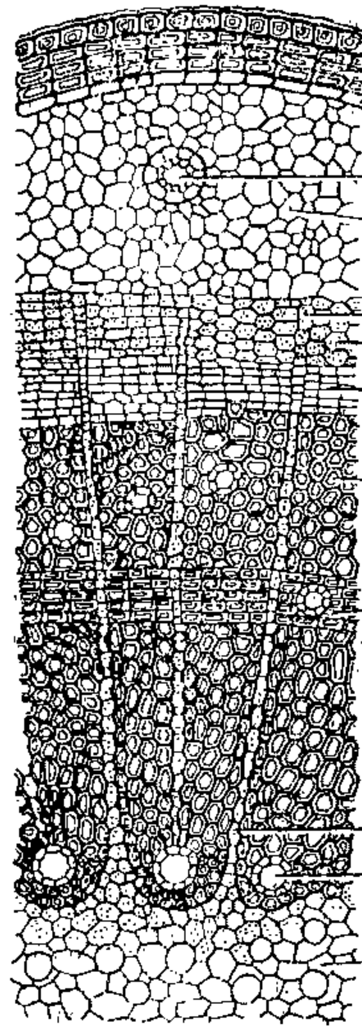


Fig. 12. ***Pinus*—T.S. old stem showing secondary growth (A portion cellular).**

Epidermis : It is the outer most layer and ruptured at places due to secondary growth. It is heavily cuticularised on the outer surface.

Cortex : Below the epidermis, is a thin zone of parenchymatous cells known as cortex.

Cork : Cortex is followed by a zone of cork. The wall of cork cells is suberized due to which it is impermeable to water.

Cork cambium : Next to the cork is 1 or 2 layers of cork cambium made up of brick shaped meristematic cells.

Secondary cortex and primary cortex : These two zones are not distinguishable form each other and is made up of parenchymatous cells.

Endodermis, pericycle and primary phloem : All these tissues form a crushed layer due to the secondary growth.

Secondary phloem : There is a complete ring of secondary phloem, consisting of phloem parenchyma and sieve cells.

Cambium ring : Inner to secondary phloem are few layers of cambium ring consisting of brick shaped meristematic cells.

Secondary xylem : Below the cambium is a wide zone of secondary xylem, which is composed of xylem parenchyma and xylem tracheids.

Primary xylem : A few groups of primary xylem are present at the periphery of the pith. The primary xylem is endarch in condition.

Pith : In the centre, is a small pith made up of parenchymatous cells.

Resin canals : They are found irregularly scattered in the cortex, secondary xylem, primary xylem and some times even in the pith region.

Medullary rays : They are of two types *i.e.*, primary medullary rays and secondary medullary rays. Primary medullary rays connect the pith with the cortex where as the secondary medullary rays traverse in between secondary phloem and secondary xylem only.

Radial Longitudinal Section of the Stem (R.L.S.)

A longitudinal section of the stem passing through the pith is known as R.L.S. (Fig. 14). In this section the following structures are seen. In R.L.S. height and length of medullary rays can be measured.

Cork : It is the outer most layer present on both the sides. The cells are thick walled due to suberization. Pieces of broken epidermis are also present out side the cork.

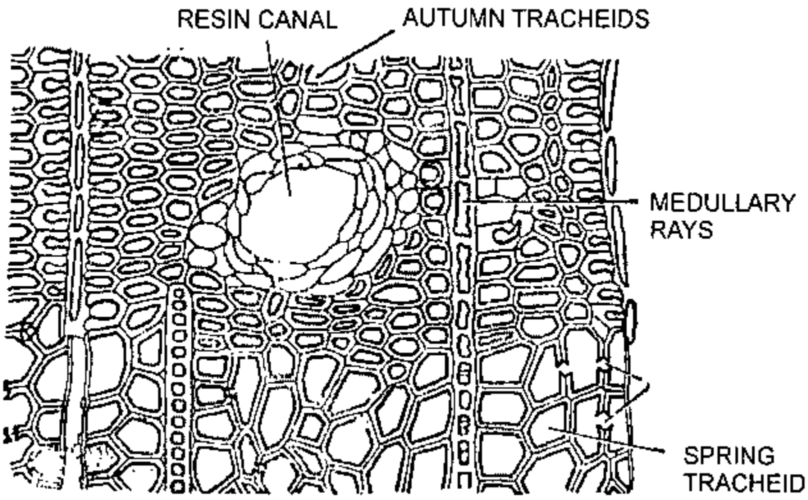


Fig. 13. ***Pinus.*** **T.S. old stem showing only the enlarged portion of spring wood and autumn wood.**

Cork cambium : Inner to the cork is a narrow zone of cork cambium on both sides. The cells are elongated and parenchymatous.

Cortex : Few layers of secondary cortical cells mixed with primary cortical cells are seen inner to the cork cambium. Most of the cells are filled with resinous substances.

Endodermis and pericycle : Not conspicuous.

Phloem : Inner to the cortex is a narrow zone of primary and secondary phloem which consists of elongated cells of sieve cells and phloem parenchyma. The ends of the sieve cells are provided with sieve plates (Fig. 14).

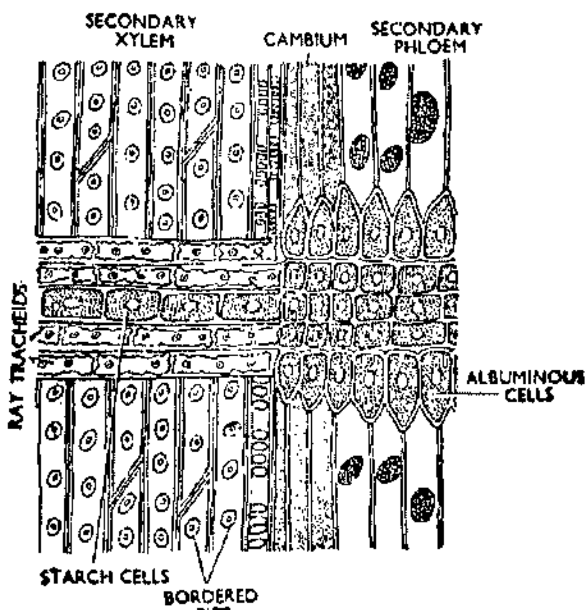


Fig. 14. ***Pinus.*** **A Part of R.L.S. of wood region.**

Vascular cambium : Inbetween the secondary xylem and secondary phloem, is present two or three cells thick vascular cambium.

Secondary xylem : It consists of tracheids only, which are cut longitudinally. The tracheidial walls are highly thickened with a conspicuous middle lamella.

Bordered pits : On the radial walls of each xylem tracheid, are several bordered pits arranged in uniseriate row (Fig. 14). Each bordered pit has two concentic rings. The outer ring represents the outer limit and the inner represents the opening of the bordered pit.

Primary xylem : Inner to the secondary xylem are present few tracheids primary xylem having annular and spiral thickenings.

Pith : The central portion of the stem is occupied by pith, which consists of parenchymatous cells filled with resinous substances.

Resin canals : In the region of cortex and xylem are also visible few resin canals.

Medullary rays : Scattered in the vascular tissue, medullary rays are very prominent. They are very complex structures and their construction is different in the region of xylem and phloem.

Medullary rays in the region of xylem : In this region each medullary ray consists of a central row of starch cells or ray cells having one or two rows of tracheidal cells or ray tracheids (Fig. 14). The tracheidal cells are transversely elongated, empty, thick walled, dead cells having several brodered pits known as pits in the field.

Medullary rays in the region of phloem and cambiumm : In this region the layer of starch cells have vertically elongated cells on either side (Fig. 14). These are rich in protein matter and are called as albuminous cells.

Tangential Longitudinal Section of Stem (T.L.S.)

In T.L.S. of the stem, the pith is absent (Fig. 15). Most of the tissues *e.g.*, cork, cork cambium, cortex, endodermis, pericycle, phloem and vascular cambium are essentially similar to R.L.S. of stem. Only the structure of bordered pits in xylem tracheids and medullary rays is different. In T.L.S. height and breadth of medullary rays can be measured.

Secondary xylem : The tracheids of secondary xylem appear to be elongated tubes. The tracheidal walls are highly thickened with a conspicuous middle lamella.

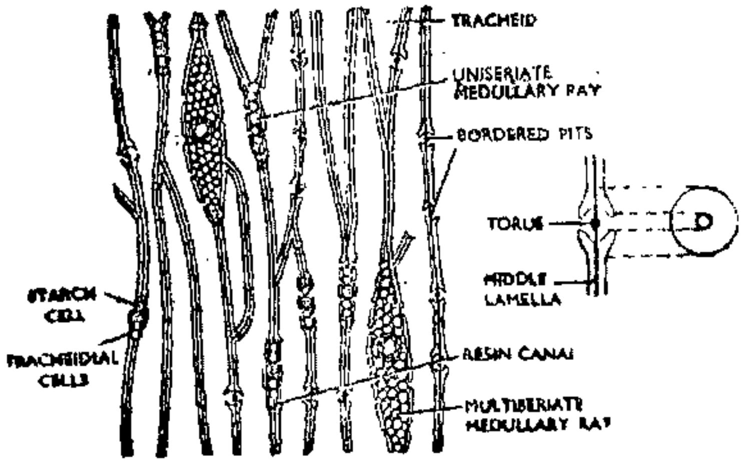


Fig. 15. (A-B) *Pinus*. [A] Part of the T.L.S. of secondary wood. [B] A bordered pit with torus.

Bordered pits : On the tracheidial walls are several bordered pits. Each bordered pit is over arched on either by a dome like appearance (Fig. 15 A,B) and have an opening on lateral sides. On the middle lamella in between the two openings of a bordered pit is a small disc of lignin called as torus (Fig. 15 B) and acts as stopper.

Medullary rays : In T.L.S. the medullary rays are very prominent. Their structure is different in the region of xylem and phloem.

(A) Medullary rays in the region of secondary xylem : In this region the medullary rays are of two types :

(i) Linear medullary rays : These are uniseriate (Fig. 15A) narrow and elongated structures. In the centre is a starch cell having few tracheidial cells on upper and lower sides in each medullary rays.

(ii) Fusiform medullary rays : These are few cells wide, short and oval structures. They are swollen structures due to the presence of resin canal in the centre (Fig. 15A).

(B) Medullary rays in the region of phloem : Here also the medullary rays are linear structures with a starch cell in the centre and few albuminous cell on both the sides.

Anatomy of Dwarf Shoot

Dwarf shoot resembles young long shoot except some minor differences as far its internal structure is concerned. It is narrow in diameter than the long shoot. It is covered by an outer covering of scale leaves. Cortex is comparatively very small with less number of resin canals distributed in it. In the centre six vascular bundles (Fig. 16) are present which constitute the vascular cylinder of the dwarf shoot. They are conjoint, collateral,

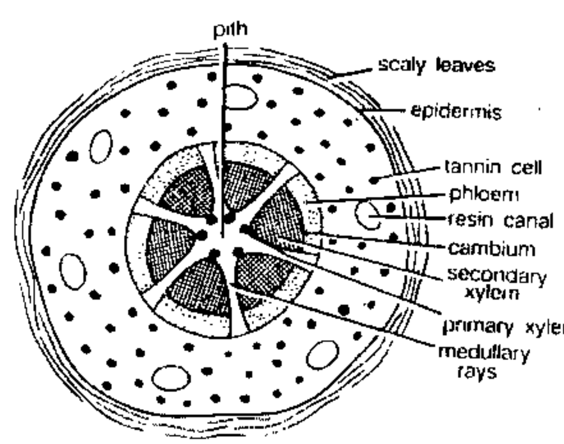


Fig. 16. Pinus—T.S. dwarf shoot (diagrammatic)

open and endarch. Broad and parenchymatous medullary rays separate the vascular bundles, which ultimately enter into three needles (foliage leaves). Pith is very small and composed of parenchymatous cells. Secondary growth has also been reported in dwarf shoots (Fig. 17).

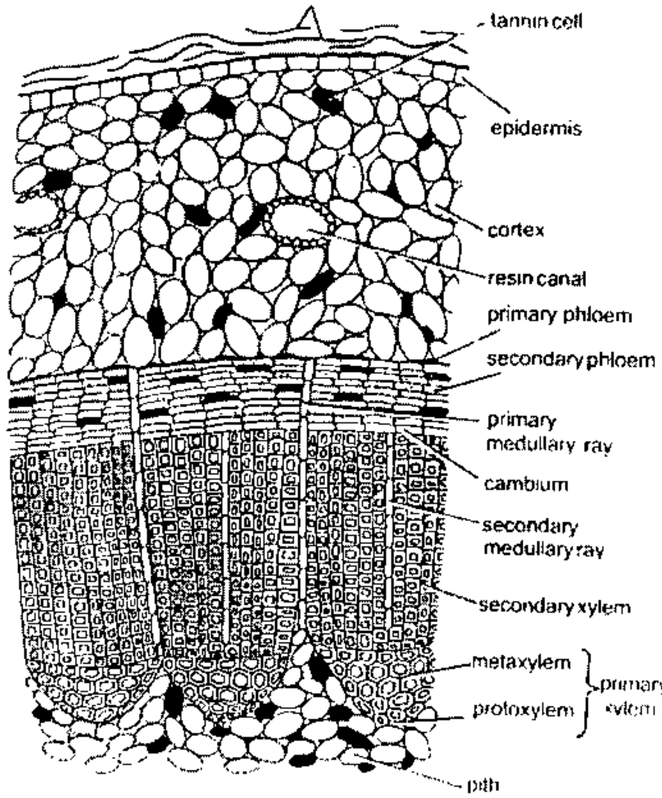


Fig. 17. ***Pinus*—T.S. dwarf shoot (a part cellular)**

Anatomy of the Needle

In a dwarf shoot the number of foliar leaves or needle are variable from species to species, so also they differ in their out line. In a cross-section the out line of the needle of *P. monophylla* is circular, *P. sylvestris* is semicircular and *P. longifolia* is triangular.

Irrespective of the difference in out line structure, the internal structure is essentially the same in all the species of *Pinus*. In case of *P. longifolia* it is triangular in outline (Fig. 18) with a outer convex surface and inner pointed structure in which the differentiation of tissues can be seen :

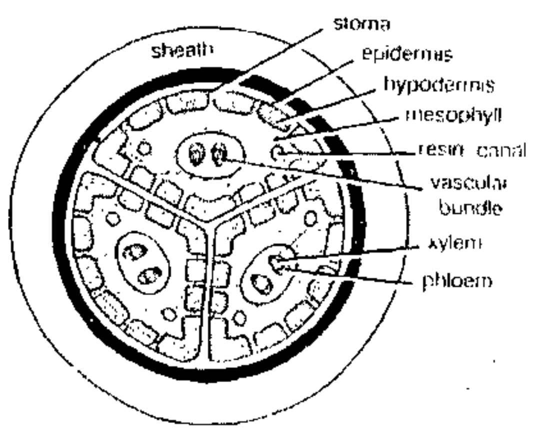


Fig. 18. ***Pinus*—T.S. dwarf shoot (upper part) showing the formation of three needles in a trifoliar species.**

Epidermis : It is the outer most covering layer consisting of single layer of compactly arranged thick walled cells. It is heavily cuticularised on the outer surface.

Stomata : The epidermis is interrupted due to the presence of a number of stomata on all the side **(amphistomatic)**. The stomata are situated in pits (Fig. 19) *i.e.*, they are sunken. Each stomata consists of two guard cells and two subsidiary cells and open internally into a substomatal cavity.

Hypodermis : The epidermis is followed by two or three layers of sclerenchymatous cells forming hypodermis. On the corners the hypodermis is many layered thick. It is broken up into small patches due to the presence of substomatal cavity.

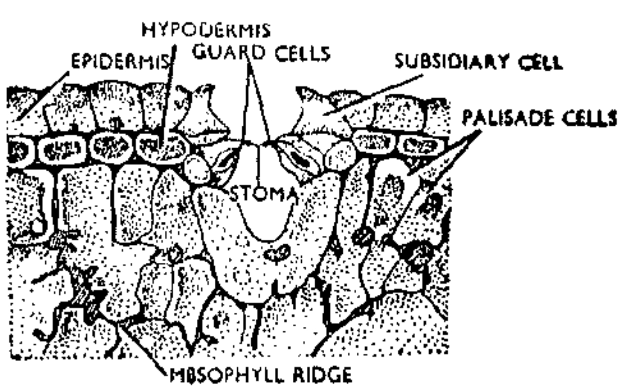


Fig. 19. ***Pinus*—T.S. portion of needle showing stomatal apparatus.**

Mesophyll tissue : Below the hypodermis and above the endodermis are several layers of well developed mesophyll tissue having no differentiation of palisade parenchyma and spongy parenchyma. The cells of the mesophyll are thin walled parenchymatous, polygonal compactly arranged, containing abundant chloroplasts and starch grains. From the iner walls of these cells arise peg like infolding in their cavities (Fig. 19) which help in increasing the photosynthetic and respiratory surface of these cells.

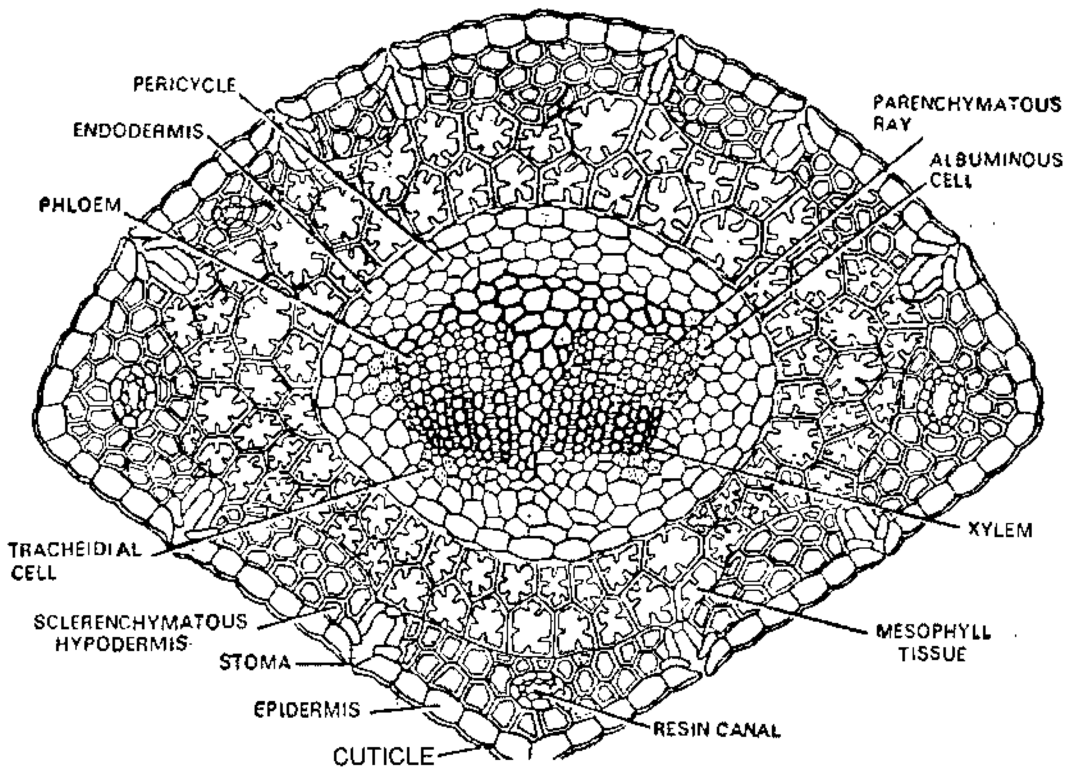


Fig. 20. ***Pinus longifolia*****—T.S. needle**

Resin canals : Few resin canals are also present in the mesophyll region towards the hypodermis. Each resin canal has a inner layer of **epithelial cells** which secretes resin and a outer **sclerotic layer** (sclerencnymatous sheath).

Endodermis : In the centre of the needle is a single stele surrounded by a layer of endodermis. The endodermis is a very conspicuous layer of barrel shaped cells with prominent casparian strips. Their cells also contain startch.

Pericycle : Just below the endodermis is a multilayered pericycle which consists of following type of cells :

(i) A large numebr of ordinary parenchymatous cells.

(ii) Sclerenchyma (sclerotic cells) forming **T-shaped** cap above the vascular bundles.

(iii) The remaining tissue within the endodermis except the vascular bundles is called as transfusion tissue which consists of two types of parenchymatous cells:

(a) Tracheidial cells : They are present near the xylem of the vascular bundles and are pitted and without protoplasm. They serve to conduct water and minerals from the xylem to the mesophyll and are thought to represent in function, as an extension of the tracheidial system.

(b) Albuminous cells : These are situated near the phloem and are living cells without pits. These cells are rich in protein and starch and help in conduction of food from mesophyll cells to the phloem.

Vascular bundles : Embedded in the multilayered pericycle are two slightly obliquely placed vascular bundles which are **conjoint, collateral** and **open.** Each vascular bundle consists of xylem facing towards the pointed end and phloem towards the upper convex surface.

Xylem : It consists of radial rows of tracheids. The protoxylem is directed towards the pointed end. Vessels are absent.

Phloem : It consists of sieve cellls and phloem parenchyma. The companion cells are lacking.

Medullary Rays : In the xylem and phloem dark brown coloured rays are clearly visible.

1.4. REPRODUCTION

Vegetative reproduction is lacking in *Pinus*. It reproduces only by means of spores which produce gametophytes.

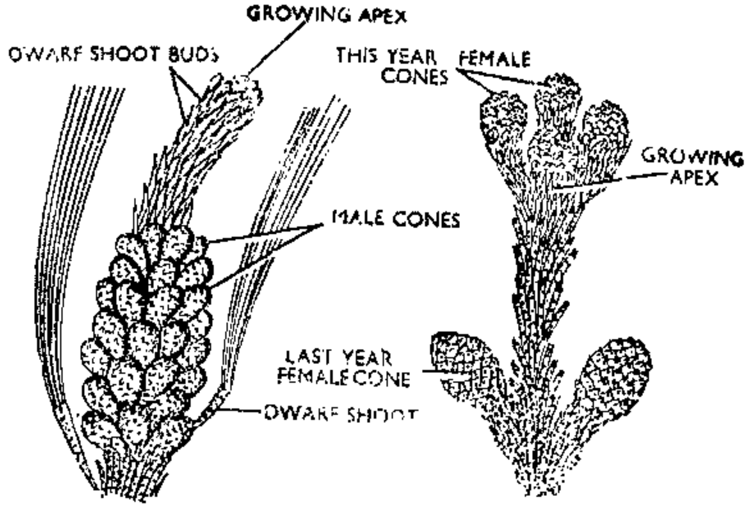


Fig. 21. *Pinus insularis*—Branches with male and female cones.

Pinus plant is a **sporophytic (2X)** and **heterosporous** *i.e.*, produces two types of spores, **micro** and **megaspores.** The microspores are produced inside the **microsporangium** and megaspores inside the **megasporangium.** The micro—and megasporangia are produced on special leaf like structures known as **microsporophylls** and **megasporophylls** respectively. The micro and megasporophylls aggregate around the central axis forming a compact structure known as **cone** or **strobilus.** The cones are of two types *i.e.*, **male cones** and **female cones** formed by the aggregation of micro—and megasporophylls respectively.

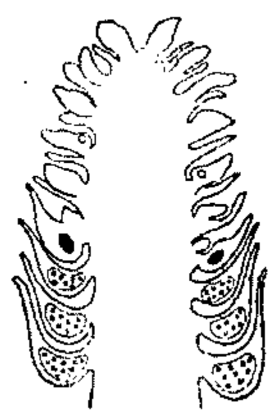


Fig. 22. *Pinus maritima*—L.S. bisporongiate cone.

Both male and female cones are produced on the same plant but it is interesting to note that they are produced on different branches *i.e.*, the plant of *Pinus* is monoecious but the branches are dioecious (Fig. 21). These cones are produced every year on the shoot of the current year. Though the cones are monosporangiate, yet bisporangiate cones (Fig. 22) are also produced in some species, as anamolous structures *e.g., P. maritima* **(Goebel,** 1900), and *P. montana* **(Stell,** 1918).

Male Reproductive Organs (Male Cone)

Male cones are produced earlier than the female cones, in January in plains and in March on hills. They are produced in clusters in the axil of scale leaves on the branches of unlimited growth just after the apical bud (Fig. 23). Therefore each male cone represents a modified dwarf shoot. The apical bud remains uneffected and the growth continues after producing clusters of male cones. Each cluster has a number of male cones, 15 in *P. wallichiana* where as in *P. roxburghii* the number may reach upto 140.

Each male cone (Fig. 24) is a small ovoid structure about an inch long with a scale leaf at the base. It consists of a central axis around which large number of scaly microsporophylls (60–100) are arranged in a spiral manner (Fig. 25).

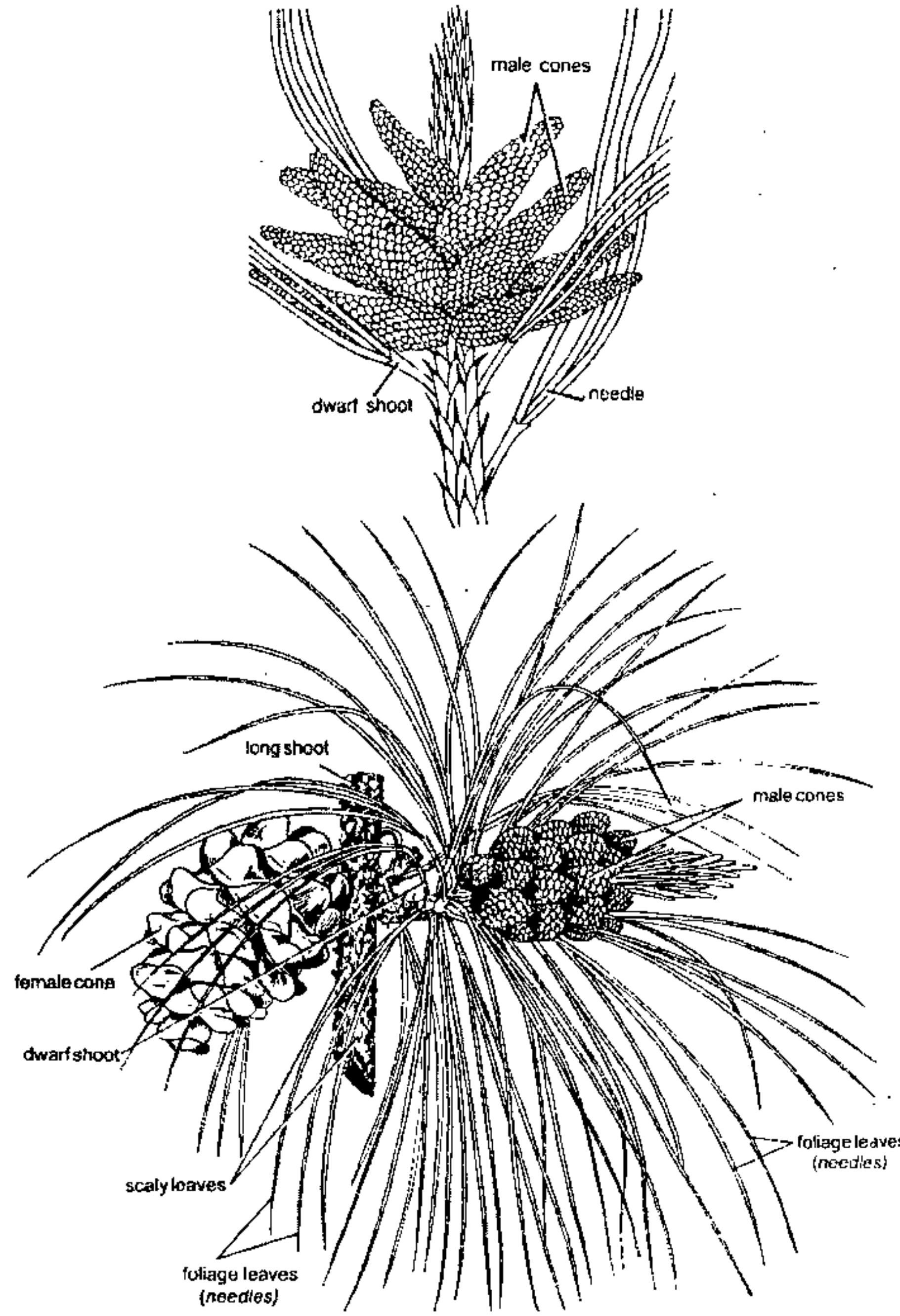


Fig. 23. *Pinus*—Long shoots bearing cones.

Structure of microsporophyll : Each microsporophyll is a small brown, membranous and scaly structure attached at right angle to the central axis of the male cone. It is flat triangular structure with a lower narrow stalk (Fig. 25) and upper flatened portion extended upwards over-lapping the micro-sporophyll of the upper side and also extends downwards covering the microsporangia on the lower side and is known as **apophysis.** Dorsal surface of the microsporophyll is sterile where as on the ventral surface are present two elongated sac like structures placed side-by-side and are known as **microsporangia.** A few of the basal microsporophylls of the male cone are sterile.

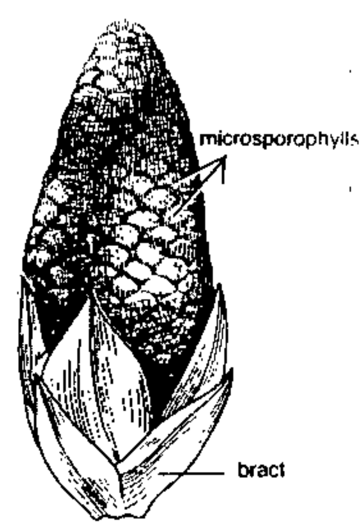


Fig. 24. *Pinus Wallichiana*.—A. male cone.

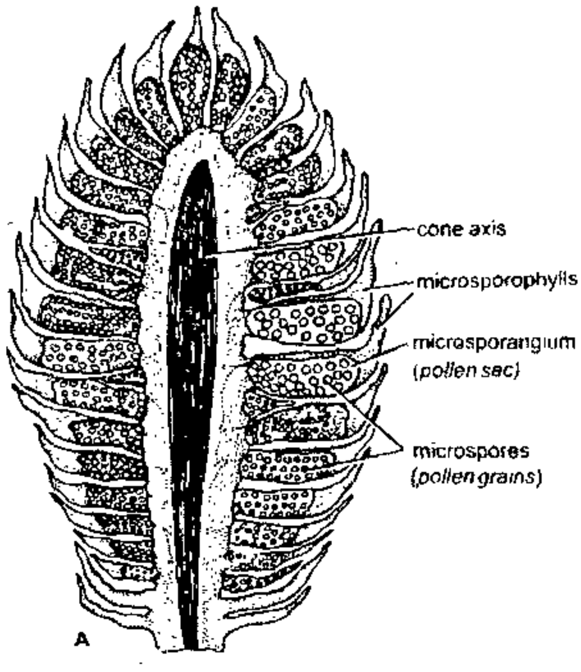


Fig. 25. *Pinus* —L.S. male cone.

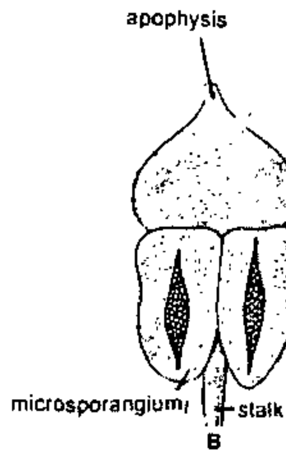


Fig. 26. *Pinus* —A single microsposophyll bearing microspoangia.

Structure of microsporangia : Each microsporangium is a *small, sessile and* elongated sac like structure having two layered wall surrounded by epidermis. Inner to the wall is a nourishing layer known as **tapetum.** In the cavity of sporangium, large number of dusty **pollen grains** or **microspores** are present. These microsporangia have longitudinal line of dehiscence on the dorsal side (Fig. 26, 27).

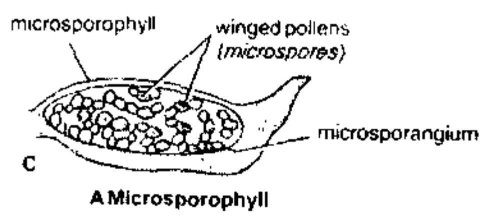


Fig. 27. *Pinus* —A microsporophyll bearing microsporangia.

Structure of microspores (Pollen grains) : The microspores of *Pinus* are yellow in colour, light in weight and are full of starch grains. Each microspore is a rounded, uninucleate structure surrounded by a two layered wall (Fig. 28). The outer wall, which is known as **exine** is thick and heavily cuticularised where as the inner wall **intine** is thin and delicate. **Maheshwari** and **Konar** (1971) referred **Capa** and **Capulla** for exine and intine respectively. The exine on the two sides is protruded in the form of two balloon shaped **wings** filled with air. These wings help the pollen grains to float in the air and also in their disperal (Fig. 28).

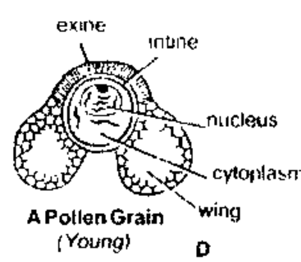


Fig. 28. *Pinus* —Structure of microspore.

Development of microsporangium and formation of microspores : The development of microsporangium (Fig. 29) in *Pinus* is similar to that of *Cycas* and is of **eusporangiate** type *i.e.,* the microsporangial initial is hypodermal in position and is situated on the ventral side of the microsporophyll. There may be a single initial cell or a group of initial cells. What ever the number of initials may be, the method of development is the same.

Each sporangial initial divides by a periclinal wall into an uppper **primary wall cell** and a lower **primary sporogenous cell** (Fig. 29A). The primary wall cell divides and redivides by periclinal and anticlinal divisions forming 2 to 4 layered wall below epidermis. The primary sporogenous cells also soon divide and redivide in all directions forming a mas of cells known as **sporogenous tissue** (Fig. 29 B, C). At this stage a single celled nourishing layer, which is called as **tapetum** is differentiated either from the inner most layer of multilayered wall or from the peripheral cells of the

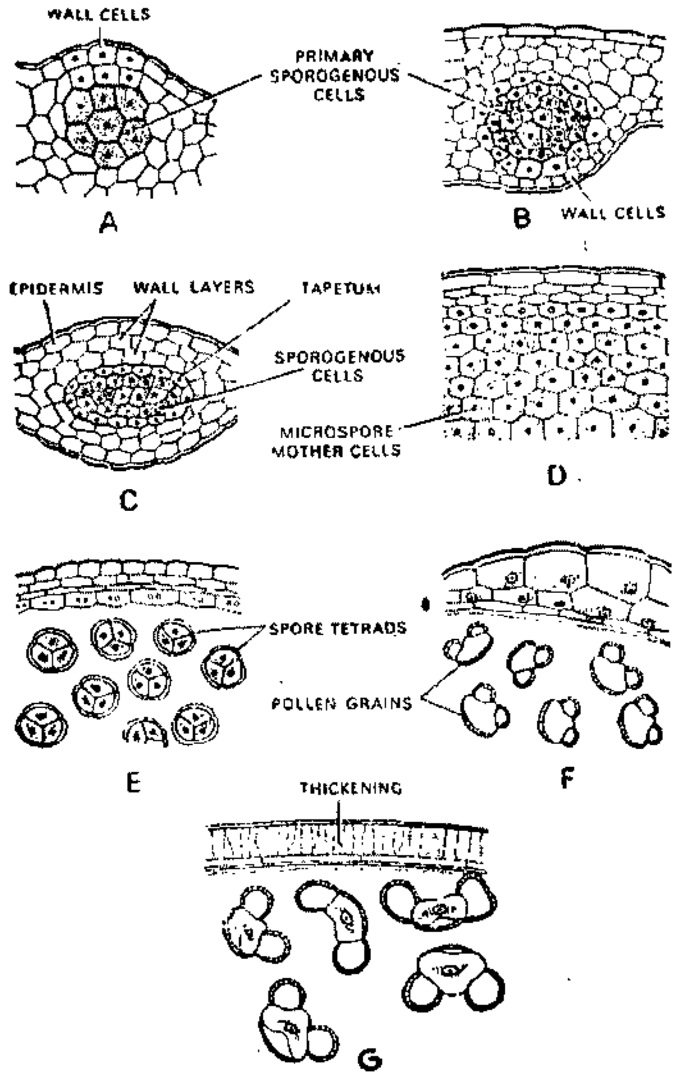


Fig. 29 (A-G). *Pinus* —Development of microsporangium and microspores (Pollen grains).

sporogenous tisue. **Konar** (1960) showed that it develops from the inner most layer of the wall. Later on the cells of the sporogenous tisue separate from one another to function as **microspore mother cells** (Fig. 29D). Each microspore mother cell divides twice. The first division is reductional one and followed by a second ordinary division. Thus **tetrads** of four microspores are formed (Fig. 29E), which later on separate from each other. The microspores or pollen grains soon round off and develop **exine** and **intine.** The tapetum is used up during the development of microspores. At this stage the sporophytic generation ends and the gametophytic generation starts.

Dehiscence of microsporangium and dispersal of microspores : On maturity the bursting of the wall of sporangium takes place from the upper side thus forming a longitudinal slit. Pollen grains are dispersed through this slit in the air in the month of March. When sporangia are empty the male cone rapidly withers and drops off. These microspores are produced in such a large number that at the time of their dispersal yellow clouds of pollen grains are produced in the forest. This is also called as **"shower of sulphur".**

Female Reproductive Organs

The female cone (Figs. 23, 30) is a complicated structure produced laterally in the axil of scale leaves, on the branches which do not bear male cones (Fig. 23). They are usually produced in clusters of 1 to 4 in place of shoots of unlimited growth. These cones begin to develop during winter and are ready for pollination in the following spring.

Each female cone matures in three years. The first year cone is very small and reddish green structure about a cm. long (Fig. 30). In the second year it enlarges in size but the sporophylls remain intact (Figs. 30, 31A). In the third year it becomes fully mature with ovules. The central axis elongates as a result of which the sporophylls get separated from each other so that the pollens may reach the ovules (Fig. 31B).

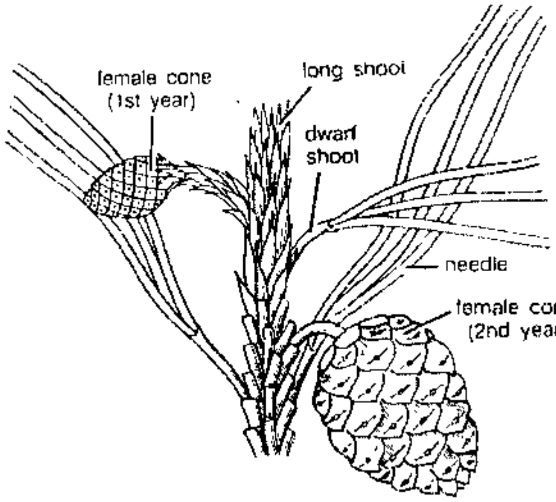


Fig. 30. *Pinus sp.* —A twig showing I year, II year female cones.

Each female cone (Fig. 30) is a oval or some what elongated cylinderical structure with an elongated **central axis** around which large number of **megasporophylls,** are arranged in an acropetal and spiral manner, (Fig. 32). A few of the basal megasporophylls are smaller and sterile. Each megasporophyll is differentiated into two parts (Fig. 34) :

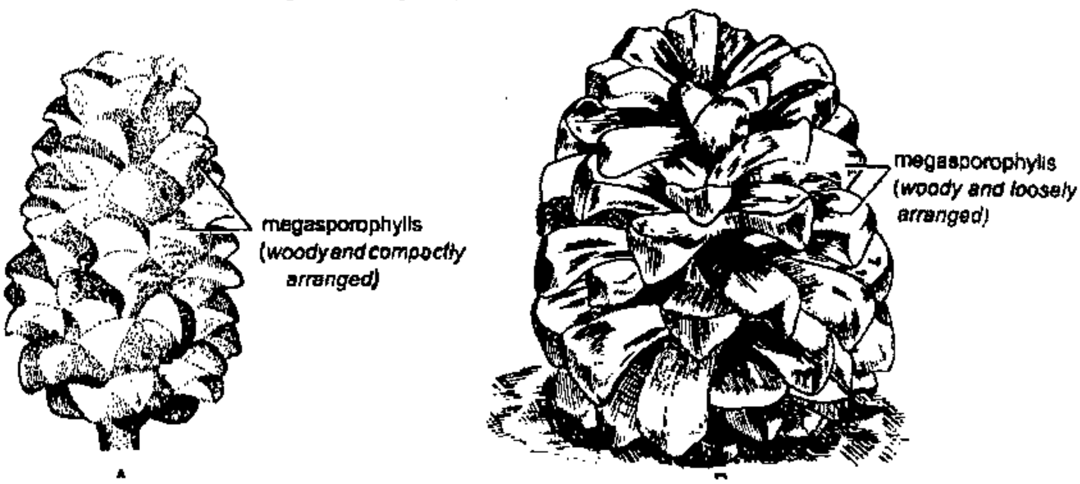


Fig. 31 (A-B). *Pinus* —A II year female cone, B. A III year female cone.

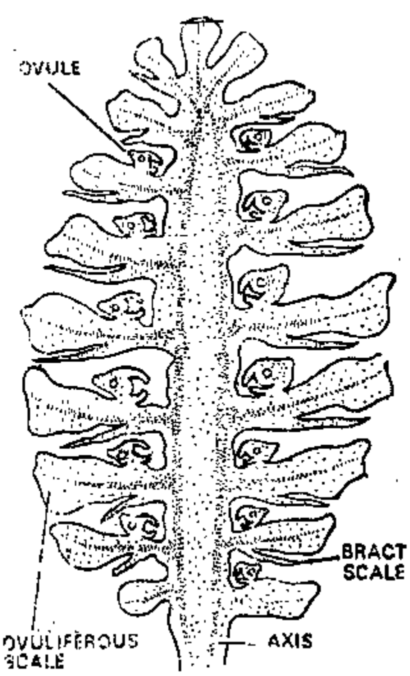


Fig. 32. *Pinus* —L.S. female cone.

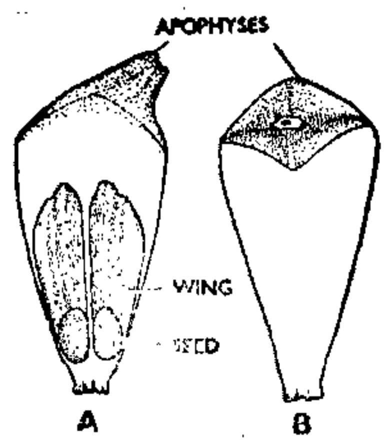


Fig. 33. (A-B)
Pinus—Megasporophyll (A) Darsal view (with two winged seed) (B) Ventral view.

1. **Bract scale** (Lower part)
2. **Ovuliferous scale** (Upper part).

1. Bract scale : These are small dry and membranous structures, attached directly with the cone axis and are present just below the ovuliferous scales (Fig. 35). By some workers it has also been named as **carpellary scale** or **cover scale.** At the time of maturity of cones, these bract scales help in the dispersal of seeds.

2. Ovuliferous scale : As the ovules after fertilization give rise to seeds, it is also called **seminiferous scale.** They are woody, brownish structures, borne on the dorsal side of the bract scale. Each ovuliferous scale is some what triangular in out line (Figs. 33A, B; 34) narrow below and broader above in the form of disc known as **apophysis.** The apophysis appears to be rhomboidal outwardly with a small central point known as umbo. On the dorsal side near the base of each ovuliferous scale, are attached two ovules with their micropyle directed towards the cone axis.

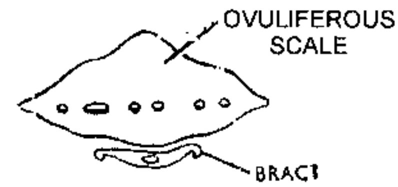


Fig. 34. ***Pinus*** **—T.S. Ovuliferous scale**

Florin (1951) coined the name "**seed scale complex**" to the bract scale along with the associated ovuliferous scale, which was also used by **Maheshwari** and **Konar** (1971).

Morphological Nature of Ovuliferous Scale

The problem of the morphological nature of the ovuliferous scale is even today one of the most controversial topic in Gymnosperms because it is present in the axil of the bract. Even though the following interpretations have been given from time to time by various workers :

1. **Robert Brown** (1827) was of opinion that ovuliferous scale in an **open carpel** arising in the axil of a bract scale but this view got strong opposition.

2. **Schleiden** (1839) discarded the view of **Robert Brown** because the carpel is itself a **leafy structure** and according to him the leaf cannot develop in the axil of another leaf. He therefore considered the ovuliferous scale as a **flattened** axis, a **placental structure.**

3. **Alexander Braun** (1842–1853) was of opinion that the ovuliferous scale is formed by the fusion of first **two leaves of an axillary shoot** by their posterior margins. This view was supported by others also. **Celaskovsy** and **Von Mohl** (1871) also supported **Braun's** conclusion in an indirect manner.

4. **Van tiegham** (1869) considered the bract as a leaf and ovuliferous scale as a **single leaf** on an axillary branch. His views were based on anatomical grounds.

5. **Sachs** (1868) and **Eichler** (1873) gave the simplest explanation, which is altogether different. They considered the bract as a **carpel** (A leafy structure) and ovuliferous scale as **ligular outgrowth** as in *Selaginella* or placenta of **Angiosperms**.

6. **Florin** (1951) worked extensively on fossil conifers and concluded that female cone is equivalent to inflorescence of **Angiosperms** and the cone axis as **peduncle.** Bract scale is really a **bract** and the ovuliferous scale with two ovules is a rudimentary type of **female flower.**

Thus the ovuliferous scale has been considered differently by different workers as (1) a carpel (2) a flattened axis (3) the first two leaves of a axillary shoot (4) a single leaf on axiallary branch (5) a ligule or placenta or even (6) a rudimentary type of female flower with two ovules.

Structure of the ovule (Megasporangium)

Each ovule is an oval anatropus structure and is attached to the ovuliferous scale with the micropylar end directed towards the base on the dorsal side (Fig. 35). It has got the following part :

Nucellus : It is the central part of the ovule and is found in the form of a parenchymatous mass of cells (Fig. 36).

Integument : The nucellus is enclosed by a two lipped protective covering called as integument (Fig. 36). It is differentiated into three layers but the differentiation is not so distinct as in *Cycas*. These three layers are as follows :

1. **Outer fleshy layer**
2. **Middle stony layer**
3. **Inner fleshy layer**

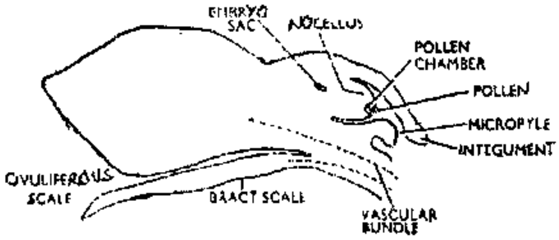


Fig. 35. ***Pinus laricio*** **—Position of ovule and other associated structures.**

Out of these three layers the outer fleshy layer is made up of thin walled cells, which disappear on maturity, middle stony layer is very conspicuous and well developed and the inner fleshy layer is also well developd.

Micropyle : The integument surrounds the nucellus on all sides except at the top , where a small opening (Fig. 36) is left which is called as micropyle.

During the early stages of development of ovule the nucellus and integument remain separated from each other but in the later stages the growth of the nucellus is chiefly in the chalazal region, as a result of which, the nucellus and integument unite with each other in the lower part while in the upper region a small space is left, which is known as pollen chamber.

Vascular supply : The vascular supply of the ovule is poorly developed and represented only by a tracheidal plate at the base of the ovule.

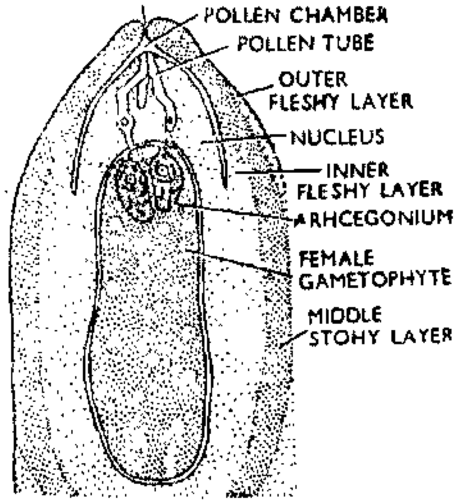


Fig. 36. ***Pinus*** **—L. S. ovule (Old).**

Megaspore : In the centre of the nucellus is a single large functional megaspore, which is also known as embryo sac.

Development of ovule and formation of Megaspore (Embryosac) : Development of the ovule takes place at the base of the dorsal side of ovuliferous scale (Fig. 37 A—H). It arises as a small cellular protuberance, which increases in size and becomes the nucellus. Soon the neighbouring cells at the base of the nucelllus also become meristematic and grow upwards forming the bilipped integument (Fig. 37 C) which surrounds the nucellus on all sides xcept at the top, where a small opening, the **micropyle** is left. In the beginning the nucellus and the integument are separated from each other but later on growth of the nucellus is chiefly in the chalazal region as a result of which the nucellus and the integument unite below and remain free only in the region of micropyle.

After some time a **archesporial cell** which is hypodermal in origin, is differentiated, from the nuclear tissue near the apex. It divides periclinally into an upper **tapetal cell** (parietal cell) and the lower **megaspore mother cell** (sporogenous cell) (Fig. 37 D). The tapetal cell later on forms a nourishing layer.

The megaspore mother cell (sporogenous cell) divides twice forming a linear tetrad of 4 haploid cells (Fig. 37 H) known as **megaspores.** The first division being transverse and reductional one followed by a ordinary division in each cell in a transverse plane. The three micropylar cells of the linear tetrad degenerate. The lower cell enlarges in szie and acts as functional megaspore or **embryo sac.** Further development of embryo sac takes place only after pollination.

In some cases T-shaped tetrad may also be formed **(Maheshwari** and **Konar)** (1971). In species like *P. wallichiana* **Konar** and **Ramchandani** (1958) reported only a triad instead of tetrad. Sometimes more than one megaspore mother cell may become functional in the nucellus (**Maheshwari** and **Konar,** 1971).

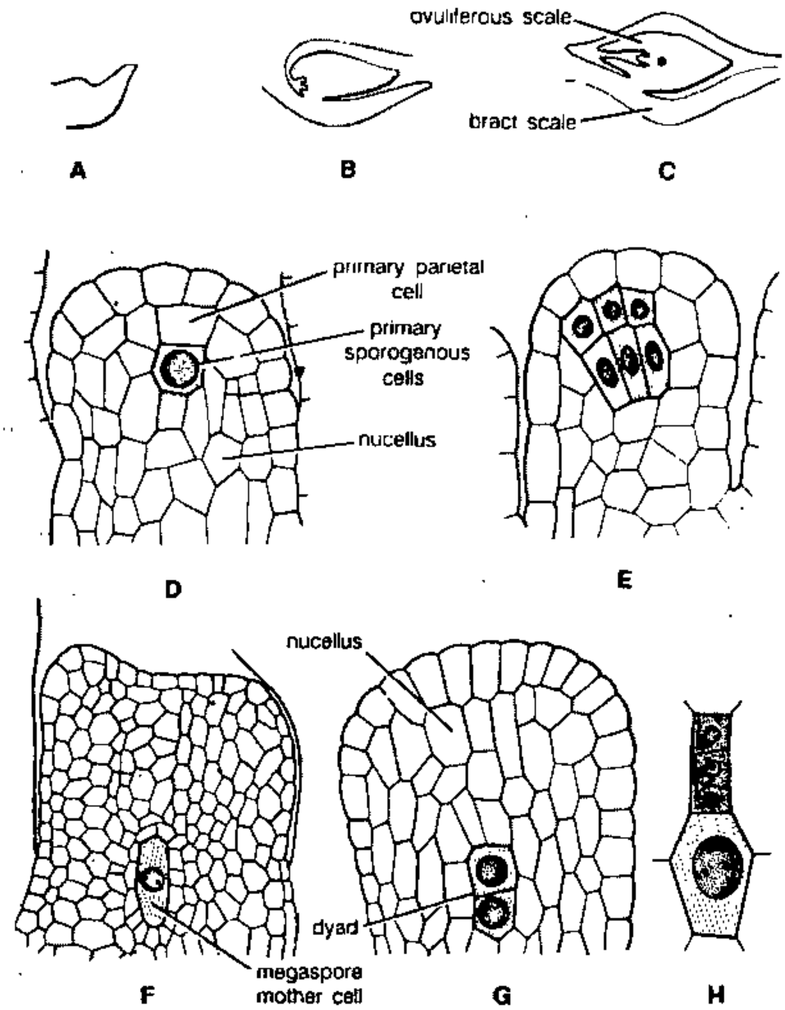


Fig. 37 (A-H). *Pinus* —Development of ovule and formation of megaspores (A-C). Development of ovule. D. Nucellus with primary parietal cell and a sporogenous cell; E. Nucellus with 3 parietal and 3 sporogenous cells; F. Deep separated megaspore mother cell; G. Nucellus with a dyad; H. Formation of a tetrad.

Pollination

Pollination usually takes place by the end of May in hills but earlier in plains *i.e.,* in February and March and is effected by wind **(anemophilous) (Maheshwari** and **Konar 1971).** The pollen grains after liberation from the microsporangium reach the ovule. They are produced in very large number forming yellow clouds of pollen grains. Only a small number of them is used up in fertilization and a vast majority of them go waste.

The phenomenon of pollination has been studied by **Ferguson** (1904) and **Doyle** (1945).

At the time of pollination the female cones become erect and the bract scales inrolled, there by making an easy approach for pollen grains upto the ovule. Prior to the pollination the scales have been tightly closed protecting the developing ovule and after pollination they close again, till the seeds are formed.

As the scales are separated from each other, a mucilaginous drop (Pollination drop) oozes out at the micropyle in which pollen grains are entangled. The mucilaginous drop then gradually dries up, carrying the pollen grains to the top of the nucellus.

At the time of pollination, with the help of the wings the pollen grains are placed in such a position that the weak point of the pollen grains are entangled. The mucilaginous drop then gradually dries up, carrying the pollen grains to the top of the nucellus.

There is a long interval of about a year between pollination and fertilization. During this time of interval many important changes take place inside the ovule and pollen grains. In the third year the female cone matures.

Morphology of the female cone

The problem of the morphology of the female cone of conifers is one of the most sensational controversy known in the history of comparative morphology.

Florin (1954) gave an explanatory account about the whole subject. He faced the problem as follows :

1. ***"Is the female cone of pine, a simple flower i.e., strobilus or assemblege of sporohylls on an unbranched axis."***

2. ***"Is it an inflorscence (compound strobilus) made up of main axis, with secondary fertile short shoots in the axil of bract or do the ovuliferous scales with their ovules constitute flowers in the axil of bract."***

There are four main theories on the nature of ovuliferous scale of conifers.

1. Ligular theory of excresence theory.
2. Foliar theory
3. Brachy blast theory.
4. Modification of Brachyblast theory.

1. Ligular or excrescence theory : This theory was given by **Sachs** and **Eichler.** According to this theory the ovuliferous scale was a single ventral excrescence or **ligule** or placenta on the bract and ovules on ovuliferous scale were considered as *sui generis stuctures.*

2. Foliar theory : It was given by **Delphino** and **Penzig.** They rejected the interpretation of oculiferous scale in an excrescence, or ligule and instead suggested that ovuliferous scale was formed of two lateral lobes of bract. The bract was just considered as tripartite structure, which has a median sterile lobe and two lateral fertile lobes, which bend inwards and fused together at their margins. They considered conifers cone as a flower and *not as inflorescence.*

3. Brachy blast theory : According to this theory the coniferous cone is considered equivalent to an inflorescence rather than a flower. Every ovuliferous scale was considered equivalent to an inflorescence rather than a flower. Every ovuliferous scale was considered as determinate axillary shoot bearing two or three fertile leaves (carpels) which bear one ovule each. According to **Celaskovsky** each ovule has two integuments, the outer of which was represented by **ovuliferous scale** in Pinaceae, **epimatium** in Podocarpacae and **aril** in Taxaceae.

4. Modification of brachy blast theory : Van tiegham's (1869) supported the **braehy blast** (Dwarf branch). He offered a modification of it on the basis of anatomical studies. The vascular bundles in the ovuliferous scale were inverted as compared to those of bract. According to him the ovuliferous scale was an open carpel representing the female flower.

5. Florin's interpretation : Although at the end of 1930 the brachy blast theory was dealing the general situation but it was confusing. This led **Florin** to investigate in details. According to **Florin** (1954), the ovuliferous scale is a highly modified lateral shoot and not a sporophyll.

Gametophytic phase

The spores are the unit of gametophytic generation. In *Pinus,* there is heterospory so the development of male and female gametophytes take place from microspores and megaspores respectively.

Microspore is the first cell of male gametophytic generation. Each microspore is a uninucleate, **haploid** and biwalled structure **(exine** and **intine)** with two laterally expanded **wings.** The germination of microspores takes place *"in situ" i.e.,* it starts when the microspores are still with in the microsporangium. The development of male gametohyte is partly completed in microsporangium and partly in the ovule.

Developemnt of male gametophyte with in the microsporangium (before pollination)

In the course of development (Fig. 38) the nucleus of microspore divides into two and a cell wall is laid down between them in such a way that a small lenticular cell known as **I prothallial cell** is separated from a large **apical cell.** (Fig 38 C). The apical cell again divides into two, a II **prothallial cell** which is just adjacent to the Ist prothallial cell and a large **antheridial cell.** (Fig. 38 E). Now the antheridial cell divides into two, in such a way that a **generative cell** adjacent to the II prothallial cell is separated from a **tube nucleus** in a remaining bigger cell. (Fig. 38 G). The I and II prothallial cells do not take part in the further development and later on disorganise. No further division occurs untill the following spring, a period of about 11 months and in this condition pollination occurs.

At the 4 celled stage (2 prothallial cells, 1 generative cell and 1 tube cell) (Fig. 38 G) the wall of the microsporangium ruptures and developing male gametophyte is liberated out side. After this, pollination takes place and the further development of male gametophyte takes place inside the pollen chamber (ovule).

Development of male gametophyte with in the pollen chamber (ovule) or post pollination changes in the male gametophyte

In the following spring the 4 celled male gametophyte again resumes its activity. The exine ruptures and the intine protrudes out in the form of a **pollen tube,** which gradually grows towards the egg in the archegonium (Fig. 38 H) through nucellus. The pollen tube may be branched or unbranched and is full of starch grains. The branched pollen tube is not only a sperm carrier but also indicates its primitive haustorial function. The **tube nucleus** moves down into the pollen tube and reaches near the tip.

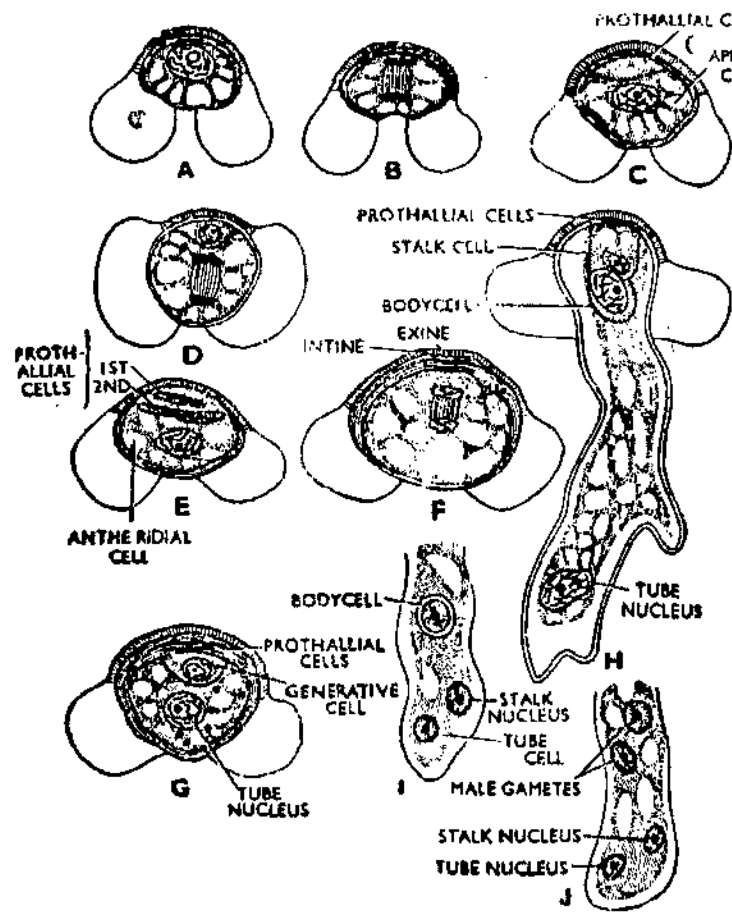


Fig. 38 (A-J) *Pinus* —Development of male gametophyte. (A-G) Development of male gametophyte before pollination. (H-J) Development of male gametophyte after pollination.

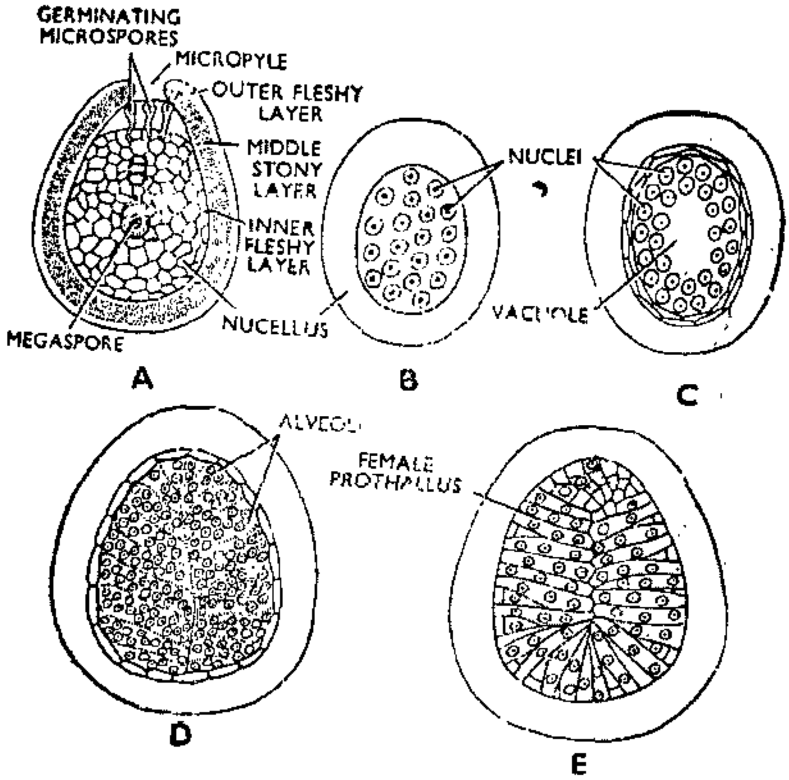


Fig. 39 (A-E) *Pinus* —Development of female gametophyte. (A-C) Stages of free nuclear division. (D-E) Stages of wall formation.

The generative cell divides into two cells, the **stalk cell** and the **body cell** (Fig. 38 H) both adjacent to the degenerating prothallial cells. The stalk cell does not divide further. The body cell soon becomes free from the stalk cell and passes into the pollen tube. The nucleus of the stalk cell also becomes free and moves towards the tip of the pollen tube, (Fig. 38 I).

Just before fertilization the nucleus of the body cell divides into **two male nuclei** but no wall is laid down between them and these two nuclei remain embedded in the cytoplasm of the body cell. According to **Konar** (1960, 62); **Konar** and **Ramchandani** (1958) the two male nuclei are unequal in size. Ultimately the wall of the body cell ruptures and the two male gametes or sperms become free in the cytoplasm of the pollen tube. Thus at maturity there are 4 bodies near the tip of the pollen tube (Fig. 38J). One tube nucleus, one stalk nucleus and two sperms. The sperms of *Pinus* are small, non-ciliated and short lived, therefore formed just before fertilization.

Development of female gametophyte

The functional megaspore is the first stage of female gametophytic generation (Fig. 39A). As the development of female gametophyte starts the axis of female cone and ovuliferous scales also become enlarged.

The development of female gametophyte (n) take place "*in situ*" *i.e.,* inside the nucellus ($2n$) and can be studied under the following three stages :

1. **Stage of free nuclear division.**

2. **Stage of wall formation and formation of female prothallus or endosperm.**

3. **Development of archegonium.**

1. **Stage of free nuclear division :** First of all the functional megaspore increases in size as a result of which the nucellus is greatly reduced. Its nucleus undergoes approximately eleven successive free nuclear divisions producing about two thousand free nuclei (Fig. 39 B). A vacuole appears in the centre (Fig. 39 B) which pushes all the nuclei and the cytoplasm towards the periphery. Later on in the further stages of development the vacuole disappears.

According to Konar and Ramchandani (1958) and Konar (1958) in *P. roxburghii* and *P. wallichiana*, the wall formation starts when the free nuclei become about 2500 in number.

2. **Stage of wall formation** : Now the wall formation takes place centripetally, resulting in the formation of multinucleate radially elongated open tubes known as **alveoli** (Fig. 39 D). Cross-walls are then formed in such a manner that the alveoli become divided into a number of uninucleate cells. Thus, by these divisions a cellular tissue is formed as **female prothallus.** According to **Maheshwari and Konar** (1971) this female prothallus is often named as **endosperm.** At this stage some of the inner cells of the nucellus form a nutritive layer, of two or three cells around the embryo sac known as spongy layer. Endosperm of *Pinus* like that of *Cycas*, also differs from angiosperms as it is a prefertilization structure in *Pinus* and not post fertilization structure as in angiosperms.

3. **Development of archegonium** : It is similar to that of *Cycas*. 1—5 (usually 3) archegonia develop at the micropylar end from the superficial cells of the endosperm. In *P montana* var, *uncinata* as many as nine archegonia have been reported. In the endosperm near the micropylar end. 1—5 suerficial cells become differentiated from other cells and are known as **archegonial initials.** (Fig. 40 A). Each archegonial initial by further divisions gives rise to a single archegonium.

The archegonial initial cell enlarges and gets differentiated from the rest of the cells of the endosperm. Now it divides transversely into an uper small **primary neck cell** or **neck initial** and a lower bigger **central cell** (Fig. 40 B). The primary neck cell divides by two successive vertical divisions at right angles to each other, followed by transverse division, forming a **neck** of eight cells, arranged in two tiers of four cells each (Fig. 40 D). In *P. roxburghii* and *P. wallichiana*, the transverse division does not take place and hence only 4 celled neck is formed (**Konar** and **Ramchandani** 1958; **Konar** 1960) The adjacent cells of the endosperm grow faster than the neck cells so that the neck opens in the bottom of a funnel shaped depression known as the **archegonial chamber.** The central cell enlarges in size and divides to form a upper very small **ventral canal cell** and a lower very large **egg.**

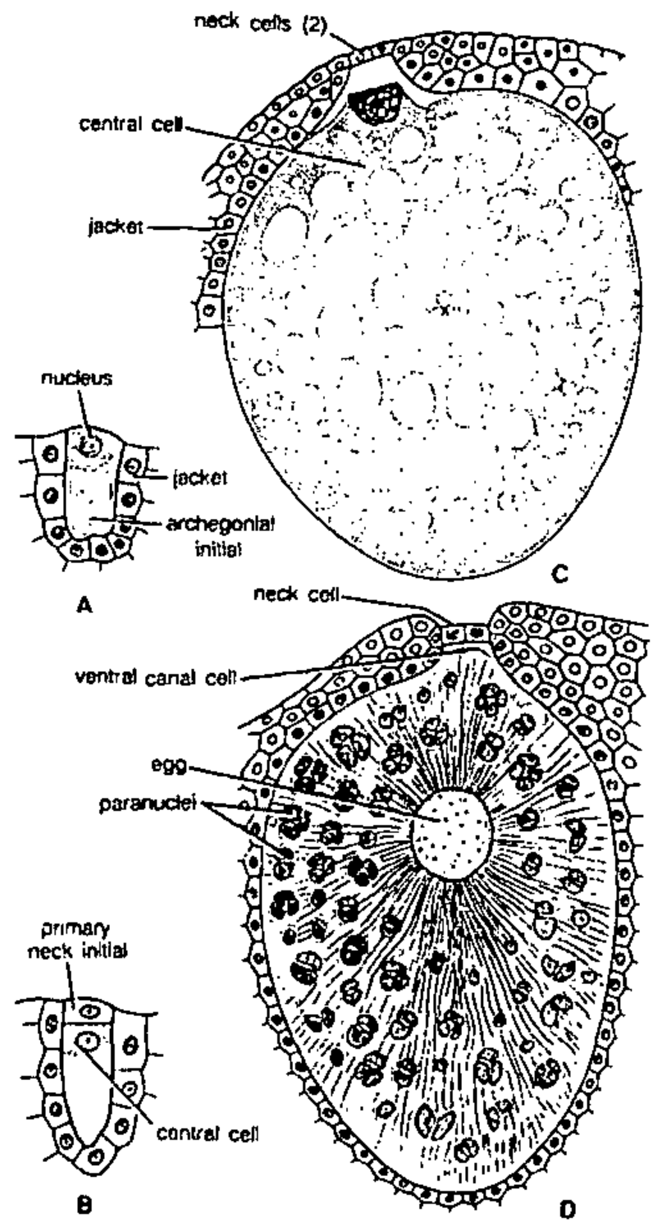


Fig. 40 (A-D) *Pinus* —Development of the archegonium.

During this time, a nutritive layer known as archegonial jacket is developed around each archegonium, which helps in transfusing food material from the endosperm to the egg.

Structure of the Archegonium : Each mature archegonium is very simple in structure and consists of a short neck of 8 cells, arranged in two tiers of four cells each and a venter having a small ventral canal cell and a large egg (Fig. 41). The ventral canal cell disorganises just before fertilization. The neck canal cells are completely absent in *Pinus*. The surrounding cells of the endosperm form the archegonial jacket around each archegonium.

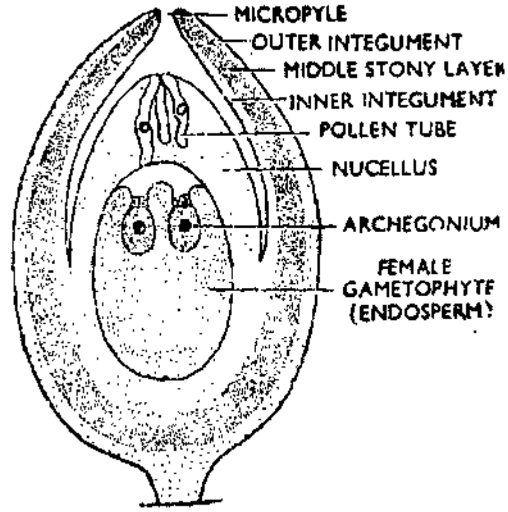


Fig. 41. ***Pinus*** **—L.S. ovule, showing structure and position of archegonium.**

Fertilization

The mode of fertilization was first discovered by **Goroschankin** (1883), who observed the entry of both the sperms into the embryo sac. **Strasburger** (1884) observed the fusion of only one sperm nucleus with the egg nucleus.

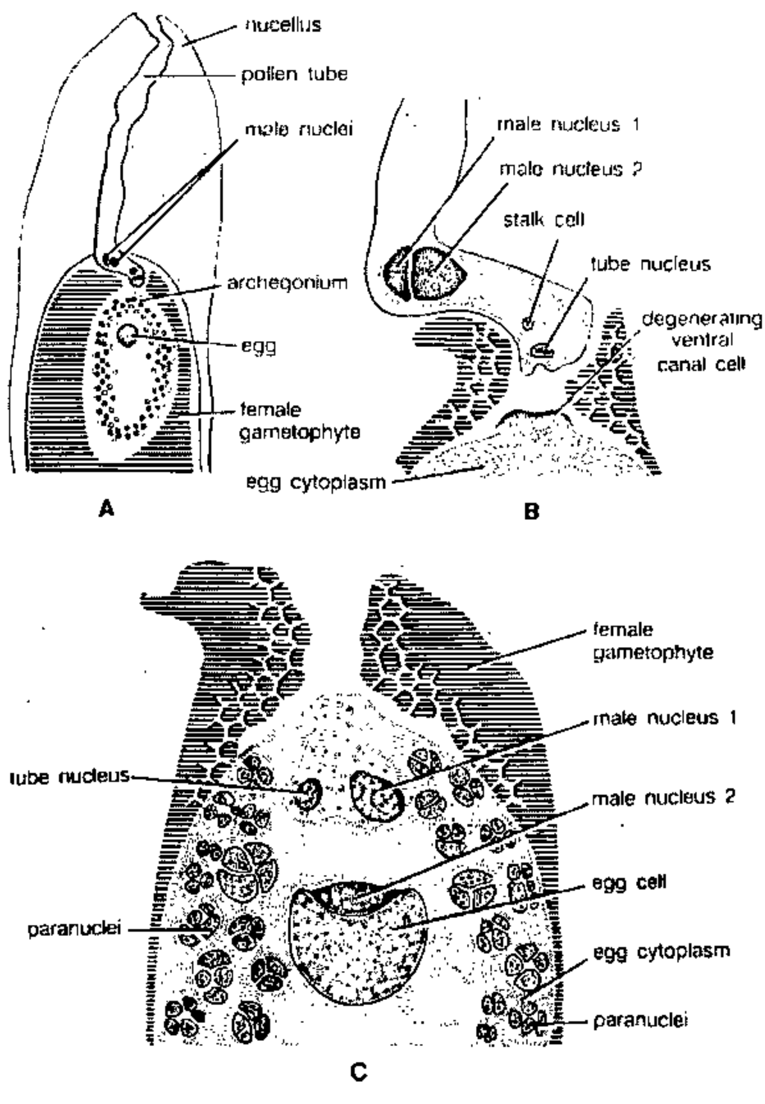


Fig. 42 (A-C). ***Pinus wallichiana*** **—Process of fertilization (A) L.S. ovlule showing enterance of pollen tube through the neck of archegonium. (B) Upper part of ovule enlarged, (C) Showing fusion of male nucleus with the egg cell.**

The pollen tube gradually and gradually makes its way down until it reaches near the tip of archegonium. It forcely penetrates the neck and reaches near the egg. (Fig. 42) (which occurs a year after pollination *i.e.*, two years after the female cone emerges). Here the tip of the pollen tube bursts and all the four bodies *i.e.*, 1 stalk cell, 1 tube cell and 2 male nuclei (gametes) are set free in the cytoplasm of the egg. Out of four bodies only one functional male nucleus or sperm (male gamete) fuses with the egg nucleus (Fig. 43) to form a diploid structure called as **oospore** or **zygote,** while the remaining three bodies disorganise. **(Haput** 1941 & **Konar** and **Ramchandani** 1958). The oospore (2X) is formed in the last week of June and represents the sporophytic generation. As the sperms are nonmotile, the pollen tube acts as a sperm carrier. Fertilization with the help of pollen tube is known as **siphonogamy.**

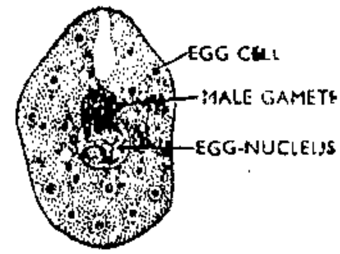


Fig. 43. ***Pinus*** **—Egg cell showing fusion of male gamete and egg nucleus.**

In *Pinus* several branched pollen tubes are formed and more than one archegonia may be fertilized in an ovule but as there is food material sufficient for only one, the others disorganise.

1.5. DEVELOPMENT OF ZYGOTE AND FORMATION OF EMBRYO (EMBRYOGENY)

In *Pinus* the develoment of zygote upto the formation of embryo can be studied in two phases :

1. The development of proembryo in the base of the zygote.
2. The growth of the suspensor into the endosperm and the development of embryo proper at its tip.

The proembryo : The proembryonal development in *Pinus* is reduced as a result of which it may be regarded as more advance than *Cycas*. It has been studied by **Buchholtz** (1918). In the formation of proembryo the zygotic nucleus (2X) divides twice mitotically into four nuclei. All these four nuclei migrate towards the base where they arrange themselves in one plane. Only two nuclei are seen laterally. They divide again forming eight nuclei. These nuclei become arranged in two tiers of four nuclei each (Fig. 44 A—C).

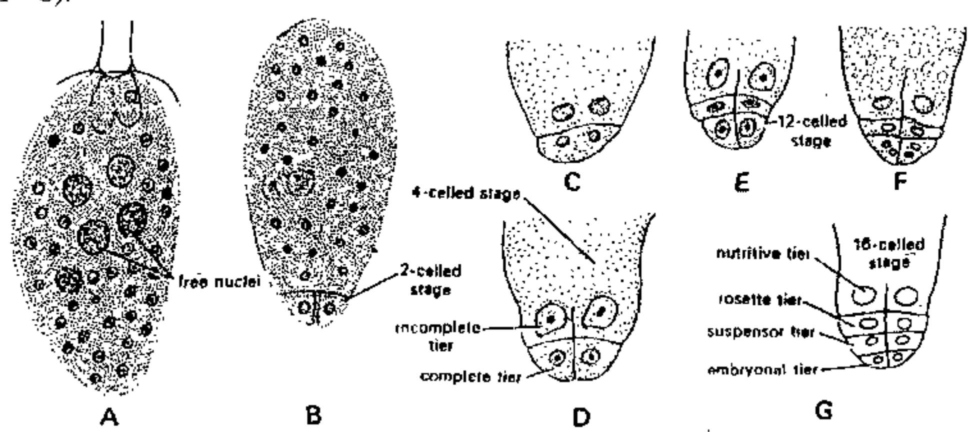


Fig. 44 (A-G). ***Pinus*** **—Stages in the development of proembryo from zygote.**

The wall formation starts around these nuclei in such a way that four complete cells are formed on the lower side and four incomplete cells are formed on the upper side (Fig. 43 D). These four incomplete cells having no walls on the upper side, do not take any part in the further development and are used up in nourishemnt and hence it is called as **nutritive tier.**

The lower four complete cells divide by two transverse divisions, thus a sixteen celled stage is formed having four tiers of four cells each. This sixteen celled stage is celled as **proembryo** : In the proembryo, the function of different tiers is as follows (Fig. 44 E—G) :

(i) The lower most I tier by further divisions gives rise to the embryo proper, therefore, known as **embryonal tier.**

(ii) The next 2nd tier elongates considerably and gives rise to a long spirally coiled suspensor, therefore, this tier is called as **suspensor tier.**

(iii) The cells of the third tier mediate between the food supply of the egg and the suspensor and forms the **rosette tier.**

(iv) The cells of the fourth tier are incomplete and are used up in nourishment, therefore, called as **nutritive tier.**

The suspensor and embryo : All the four cells of the suspensor tier elongate very much and soon become very big and tortuous and the embryonal cells are thrust down into the food containing cells of the endosperm for its nourishment. The suspensors of all the embryos combine, together and form a long spirally coiled common structure (Fig. 45).

The cells of the embryonal tier divide and interpose another tier between them and the primary suspensor cells, thus forming **secondary suspensor cells** (embryonal tubes, Fig. 45 A–C). The process may be repeated once or twice.

All the four cells of the embryonal tier separate from each other and develop independently into four embryos *i.e.*, a single embryo is developed from each cell of the embryonic tier. The formation of more than one embryo from a zygote is called as **polyembryony** or more strictly **cleavage polyembryony.** Origin of cleavage polyembryony in conifers was studied by **Buchholtz** (1926). When more than one archegonia are fertilized and develop into embryos or the embryos develop from the rosette cells, it is termed as **simple polyembryony.** In *Pinus* more than one embryos are formed but as the food supply is enough only for one, the rest degenerate. The surviving embryo reaches maturity in the seed.

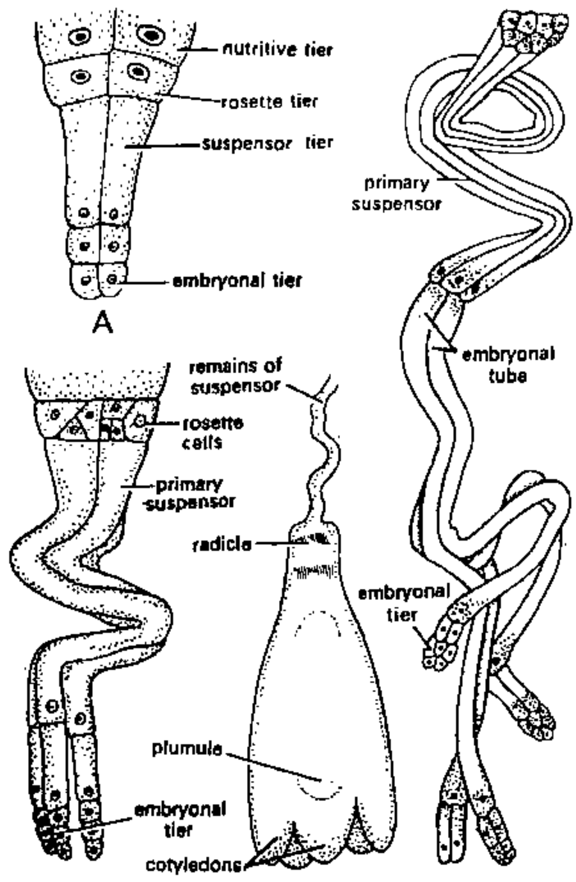


Fig. 45 (A-D). *Pinus* **—Stages in the development of embryo from proembryo.**

During embryo formation each cells of the embryonal tier divides transversely to form two cells, which then further divide forming a quadrant, octant and ultimately a mass of cells is formed, which gives rise to the embryo proper. This embryo is differentiated into the following parts :

(i) **Cotyledons** or primary leaves (Number is variable and usually more than two).

(ii) A **plumule** or stem apex which remains hidden in the cotyledons and away from the micropyle.

(ii) A **radicle,** which lies towards the micropyle.

(iii) A **hypocotyl.**

Seed formation : After fertilization the ovule behaves as seed. In the formation of seed, the integument of the ovule forms the **seed coat or testa.** The outer fleshy layer of the integument disappears, middle stony layer becomes the outer most layer *i.e.*, testa and the inner fleshy layer dries up as a papery **tegmen.** The nucellus is also eaten up during the development of embryo and is represented only near the micropyle in the form of **perisperm.**

The embryo remains embeded in the cells of the endosperm, which occupies most of the space of the seed. The embryo consists of a **plumule,** a **radicle, cotyledons** (polycotyledonous) and a **hypocotyl** (Fig. 46)

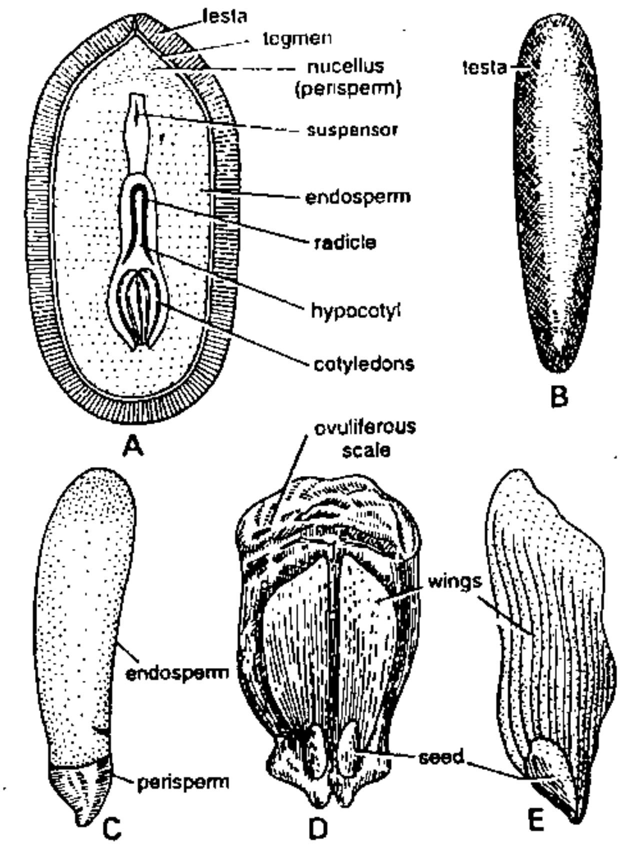


Fig. 46 (A-E). ***Pinus*** **—Seed structure; A. Longitudinal section of seed, B. Seed with testa, C. Seed without testa, D. E. Winged Seeds.**

As the seed matures a thin layer becomes separated from the ovuliferous scale and fuses with the testa of the seed in the form of a wing. This wing helps in the dispersal of seed (Fig. 46 D,E)

As the seeds are fully mature and dry, the whole female cone dries up and forms a whole female cone dries up and forms a hard woody structure. At maturity the cone axis enlarges and the scales are separated apart, which helps in the dissemination of seeds.

1.6. SEED STRUCTURE

The outer most covering layer known as the seed coat or **testa** which is thick and hard and followed by thin papery **tegmen.** Inner to the tegmen, is present **perisperm** only near the top of the micropyle. The micropyle is in the form of a small opening at the top of the seed.

The most of the space inside the seed is occupied by a very well-developed tissue called as female prothallus (endosperm) containing food material. In the so called endosperm lies a well developed embryo having a **plumule, a radicle, cotyledons** and a **hypocotyl** (Fig. 46A).

The mature seed of *Pinus* represents three generation like *Cycas* which are as follows :

(i) Testa, tegmen and perisperm (nucellus) represent the parental sporophytic generation.

(ii) Endosperm or female prothallus represents the gametophytic generation.

(iii) Embryo represents the new sporophytic generation.

Germination of seed : The germination of seed takes place immediately if the suitable conditions are available. It is of **epigeal** type (Fig. 47) *i.e.*, the cotyledons come above the ground by the elongation of hypocotyl. At the time of germination, the seed coat ruptures, the radicle elongates and comes out through the micropyle and goes down in to the soil forming the **primary tap root.** Plumule then comes out and goes upwards carrying the cotyledons. The cotyledons **(cotyledonary leaves)** are green while still in the seed. First of all the primary leaves **(juvenile leaves)** are formed. Higher up in axil of some of these foliage leaves, arise dwarf shoots and still higher up scale leaves are developed, in the axil of which arise long shoots.

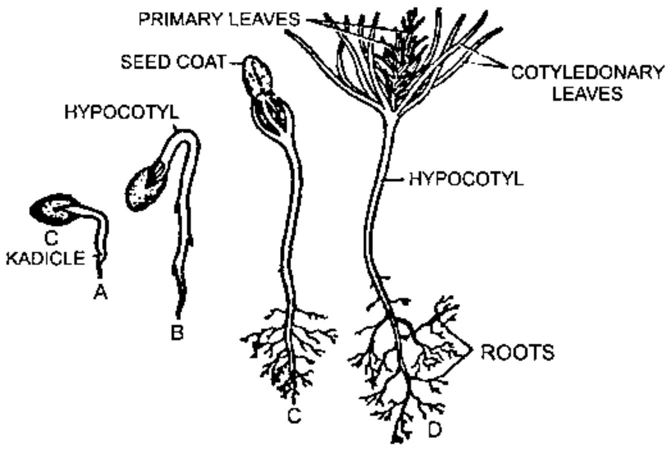


Fig. 47 (A-D). *Pinus*—Showing different stages during the germination of seed.

Economic Importance

Various species of *Pinus* are of great economic value, which has been discussed below :

1. The plants are of great ornamental values as they give a beautiful and attractive look to the gardens and land scape.

2. Seeds of some species of *Pinus* are edible *e.g., P. gerardiana* (chilzoza), *P. edulis,* and *P. pinea* etc.

3. *P. succinifera* is a fossil and its fossalised resin **(amber)** is of great commercial value and is used in jewellery and carved into art objects.

4. Some species of *Pinus* are the chief and cheap source of cellulose.

5. Commercial resin is obtained from *P. insularis, P. roxburghii* and *P palustris.* Turpentine oill is also prepared from these members.

6. *P. markussii* is a valuable source of raw material in the manufacture of craft paper.

7. *P. maritima* is a good source of **Bordeaux turpentine.**

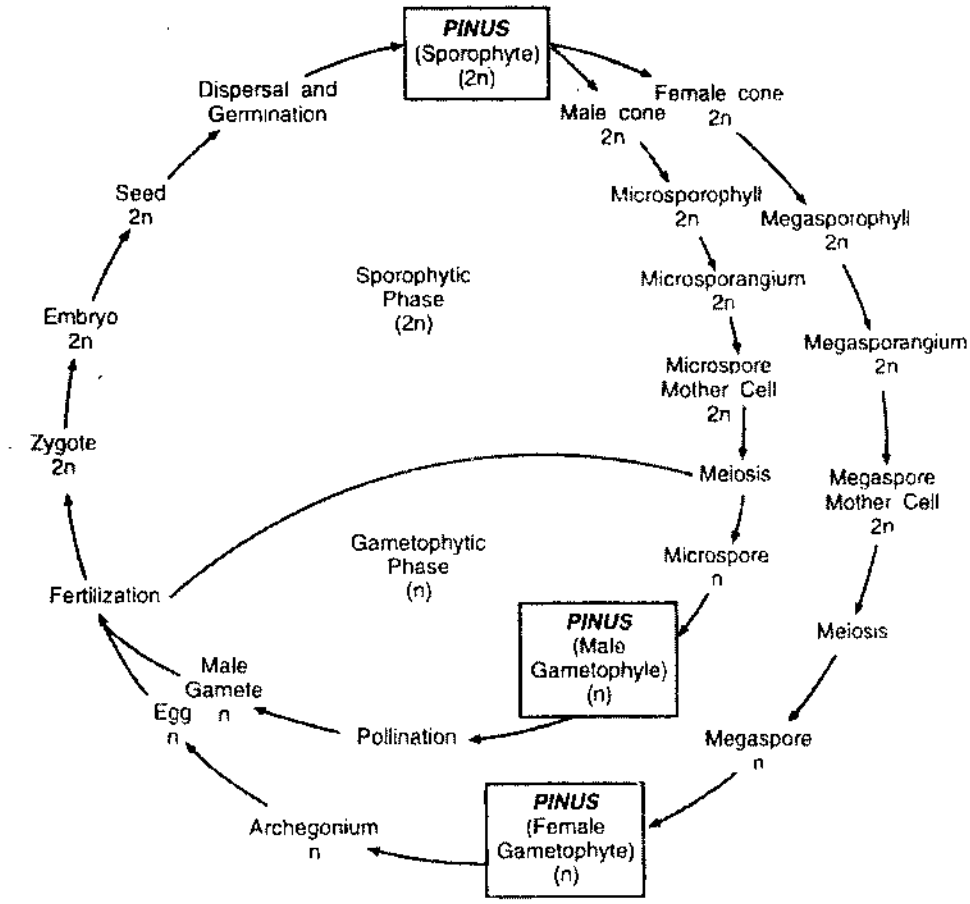
8. Wood gas, wood tar, and wood alcohol are obtained from various species of *Pinus e.g., P. sylvestris.*

9. Wood and dry female cones of *Pinus* are used as fuel specially by hilly people because they contain resins.

10. The wood of *Pinus* is variously used in making of furniture, flooring houses and electric poles (Specially in the hilly regions) and match sticks etc. *P. longifolia* (chir), *P. excelsa* (kail) are good source of wood and timber.

11. *P. roxburghii* is of great medicinal value, its wood is aromatic and antiseptic. The oleoresin is stimulant, diuretic and is given in disorders of urinogenital organs.

1.8. DIAGRAMMATIC LIFE CYCLE



1.9. SYSTEMATIC POSITION

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

1.10. SUMMARY

Out of 105 species only six species of *Pinus* occur wildly in the indian sub-continent namely *P. gerardiana, P. roxburghii, P. wallichiana, P. insularis, P. merkusii* and *P. armandi*. The seeds of *P. gerardiana* (chilgoza) are edible. *P. roxburghii* and *P. wallichiana* produce useful timber. The resin from *Pinus* has numerous uses whereas most of the species are grown for their ornamental value. The sporophytes are tall trees, differentiated into root, stem and leaves. The roots constitute a tap root system with ectotrophic mycorrhiza. The stems are excurrent forming an apical dome of branches. The stems are aerial, erect and woody. The branches are dimorphic, long shots and dwarf shoots. The leaves are also dimorphic, scaly and foliage. The scaly leaves are spirally arranged on the long shoots and dwarf shoots. The dwarf shoots arise on the long shoot in the axil of a scaly leaf and terminate in foliage leaves. The foliage leaves are needle–like. A dwarf shoot may be unifoliar, bifoliar, trifoliar or pentafoliar. Accordingly, a needle may be circular or semi-circular or triangular in outline.

The roots are characterised by radial bundles. The xylem may be dito hexarch, forked at protoxylem end. There is a resin canal in the fork of xylem. It shows dicot type secondary growth. The stems are characterised by a ring of bundles which are conjoint, collateral and open with endarch xylem. Resin canals are present in cortex, xylem, medullary rays and pith. The xylem is made up of tracheids with uniseriate bordered pits. The phloem is composed of sieve cells and albuminous cells. It also shows dicot type of secondary growth. The wood is monoxylic and pycnoxylic. The medullary rays may be linear or fusiform. The dwarf shoot has conjoint, collateral bundles with endarch xylem. It shows limited amount of secondary growth. There is no formation of annual rings.

The needle is characterised by thick cuticle, sunken haplochelic stomata and special arm pallisade. The pericycle is made up of parenchymatous, sclerenchymatous, albuminous and tracheidal cells. The needle generally contains two or rarely one vascular bundle. The needle bundle is conjoint and collateral with endarch xylem. It has a meristem at the base.

The sporophyte of *Pinus* reproduce sexually. The plants are heterosporous and monoecious. The male cones are formed in a cluster. They comprise a cone axis bearing microsporophylls spirally. Each microsporophyll is a triangular structure bearing two sporangia abaxially. The terminal sterile part is called as apophysis. The microsporangia are elongated, sessile structures. It has 2-3 layered wall. The inner most layer is called as tapetum which encloses the sporogenous tissue. The sporogenous cells ultimately form pollen mother cells which undergo meiosis to form tetrahedral tetrads of microspores. The female cone takes three years time to ripe. It consists of a cone axis bearing ovuliferous scales and bracts acropetally in spiral manner. The bract lies abaxial to ovuliferous scale. The scale bears two ovules adaxially. Its terminal sterile portion is called as apophysis. The ovuliferous scale has been interpreted as an open foliar carpel with two naked ovules or an axillary placenta in the axial of a bract or as a fusion product of branch and two leaves or as an out growth in axil of bract like the ligule of *Selaginella*. According to Florin the ovuliferous scale comprises a redimentary axis (in the axil of a bract) with two ovule bearing megasporophylls and two to three distal sterile scales. Thus, the female cone is comparable to an inflorescence of angiosperms. The ovules of *Pinus* are orthotropous and unitegmic consisting of nucellus covered by integument. The integument is distinguishable into an outer fleshy layer, a middle stony layer and inner fleshy layer. The micropyle faces towards the cone axis. The micropyler canal leads into a pollen chamber just above the nucellus. A hypodermal archesporial cell, by a periclinal division forms an outer perietal cell and inner sporogenous cell, the latter behaving as megaspore mother cell. The megaspore mother cell undergoes meiosis to form a linear tetrad of megaspores. While three upper megaspores degenerate, the lower most is functional. A tapetum surrounds the functional megaspore. Unicelled microsppore, by three divisions of gametogenesis forms a four called pollen train. There are two prothallial cells, a generative and a tube cell. The mature pollen grains are three layered and winged. The three layers are cappa, capulla and tenuitas. The capulla form the saccus or wing. The functional megaspore, by free nuclear division followed by wall formation forms the female gametophyte or 'endosperm'. About 3–6 archegonia are differentiated form the superficial cells of 'endosperm'. An archegonium consists of a 4 + 4 celled neck, a ventral canal cell and an egg. There is neither venter nor any neck canal cell.

The pollination is anemophilous. The discharge of pollen is often called as 'shower of sulphur'. The grains are deposited on the micropylar secretion drop. When it dries up, the grains are sucked in. The pollen grains form the pollen tube. The generative cells divides into a stalk and a body cell and the latter forms two non-flagellate male gametes. The fertilization takes place some 12–13 months after pollination. The ventral canal cell degenerates and the neck cells separate. The tip of the pollen tube ruptures releasing the male gametes near the neck of archegonium. As a result of fusion of one male gamete with egg (fertilization), the zygote is formed. The zygotic nucleus moves downward. As a result of early division four tiers of four cells each are formed. These tiers are designated as open tier, suspensor tier, suspensor tier and embryonal tier.

The embryo development is meroblastic. The cells of open tier do not divide but those of rosette tier show some division. The cells of suspensor tier elongate pushing the embryo deep in the 'endosperm' and may divide once or twice. The cells of embryonal tier form the embryo proper. Cleavage polyembryony is seen in *Pinus*. Besides, some rosette embryos are also formed but they do not reach maturity. The embryo shows differentiation of radicle, plumule, hypocotyl and more than two cotyledons. Out of several proembryos formed only one reaches maturity in a seed. The seed comprises a testa and a thin tegmen, if formed. The nucellus persists as perisperm and the embryo remains embedded with in 'endosperm'. A wing is formed by peeling of an upper layer from the ovuliferous scales. The seeds are anemochorous. They are dispered in the third year. The germination is epigeal. Initially several cotyledonary leaves are formed. Later juvenile leaves arise in whose axils longs shoots are formed.

1.11. STUDENTS ACTIVITY

1 Describe the distribution of *Pinus* in India.

2. Describe in brief the reproduction in *Pinus*..

1.12. TEST YOURSELF

1. How many species of *Pinus* occur wildly in the Indian sub-continent.
2. 'Chilgoza' is the seed of which species of *Pinus ?*
3. Which species of *Pinus* is called 'blue-pine' ?
4. What are the important characters of the vascular bundles of *Pinus's* stem ?
5. What is present in the fork of xylem of *Pinus* root ?
6. Name the medullary ray of *Pinus* having a resin canal.
7. What are the important characters of wood of *Pinus ?*
8. In which species of *Pinus* the needles are semi-circular in outline ?
9. What is the most characterstic feature of the needle of *Pinus ?*
10. Name the structure in *Pinus* which is comparable to the stamens in angiosperms.
11. What is the time taken by the female cones of *Pinus* to reach complete maturity ?
12. According to **Florin** the female cone of the *Pinus* is comparable to which structure is of angiosperms ?
13. The term saccus is applied to the which part of the *Pinus* pollen grain ?
14. What is the time lag between the events of pollination and fertilization in *Pinus* ?
15. What is the important character of male gametes of *Pinus* ?
16. Name the tier of pro-embryo of *Pinus* showing extensive elongation.
17. During cleavage polyembrony in *Pinus* the cells of which tiers of the embryo show splitting ?
18. What are the important characters of the seeding of *Pinus ?*
19. What type of seed germination is found in *Pinus* ?
20. Name the part of the ovule of *Pinus* which is attached to the seed and thus the seed becomes winged.

ANSWERS

1. Six species
2. *Pinus gerardiana*
3. *Pinus wallichiana.*
4. Conjoint, collateral and open.
5. Resin canal
6. Fusiform
7. Monoxylic and pycnoxylic.
8. *Pinus sylvestris*
9. Presence of arm palisade
10. Microsporophyll
11. 36 months
12. Inflorescence
13. Wings
14. 12 months
15. Non-flagellate
16. Suspensor tier
17. Embryonal and suspensor tier.
18. Presence of juvenile leaves and several cotyledonary leaves.
19. Epigeal
20. Ovuliferous scale.

UNIT–I

CHAPTER

5

EPHEDRA

STRUCTURE

LEARNING OBJECTIVES

After learning this chapter, you will be able to know the morphology, anatomy, reproduction and life cycle of *Ephedra*.

1.0. INTRODUCTION

Ephedra is a profusely branched shrub of xerophytic habit and grows in exposed situations, dry rocks and even sandy deserts (Including saline tracts). It is a monotypic genus with about 40 species (**Sporne,** 1965) distributed equally in the old and new world and mostly confined to tropical and humid regions (**Maheshwari** and **Vasil,** 1961).

In old world they spread from Cannary Island and Medeira along the Mediterranean coasts upto Black sea. From Mediterranean region it crosses into Asia over Arabia and Iran to the north west to the Indian subcontinent (Sind, Rajasthan, Punjab, Kashmir and Western Himalayas) and upto Sikkim. From Himalayas it reaches upto Siberian Amur basin (Fig. 1). In new world it is found along the drier western coast. From California it spreads to Arizona, New Mexico, Mexico, South American Andes to Bolivia, Paraguay, Argentina, Chile and Patagonia.

Being world wide in distribution, its fossil records are still not well known. Only some pollen fossils of *Ephedra* are known from Cretaceous and Tertiary periods. In 1959, **Wilson** reported fossil pollens of *Ephedra* from Permian in Oklahoma and called them as **Ephedripites.**

1.1. DISTRIBUTION

Hooker reported only three species from India :

(i) *Ephedra vulgaris* from alpine Himalayas spreading from western Tibet (7000–12000 ft.) to Sikkim (12000 – 16000 ft.).

(ii) *E. pachyclada* from central and western Tibet in alpine regions upto 15000 ft.

(iii) *E. peduncularis* from Sind, Rajasthan and Punjab. It is a climber often developing filiform leaves.

From the present accounts the following six species of *Ephedra* have been reported from India :

(i) *E. foliata* Boiss et kotsehy from Sindh, Punjab and Rajasthan.

(ii) *E. intermedia* Schrenk et May, var. *tibetica* stapf. from Kashmir, Punjab, Himachal and Jaunsar.

(iii) *E. saxatilis* Royle ex Florin var. *sikkimensis* (stapf). Florin from Sikkim.

(iv) *E. gerardiana* Wall., from dry alpine and temperate Himalayas spreading from Kashmir to Sikkim.

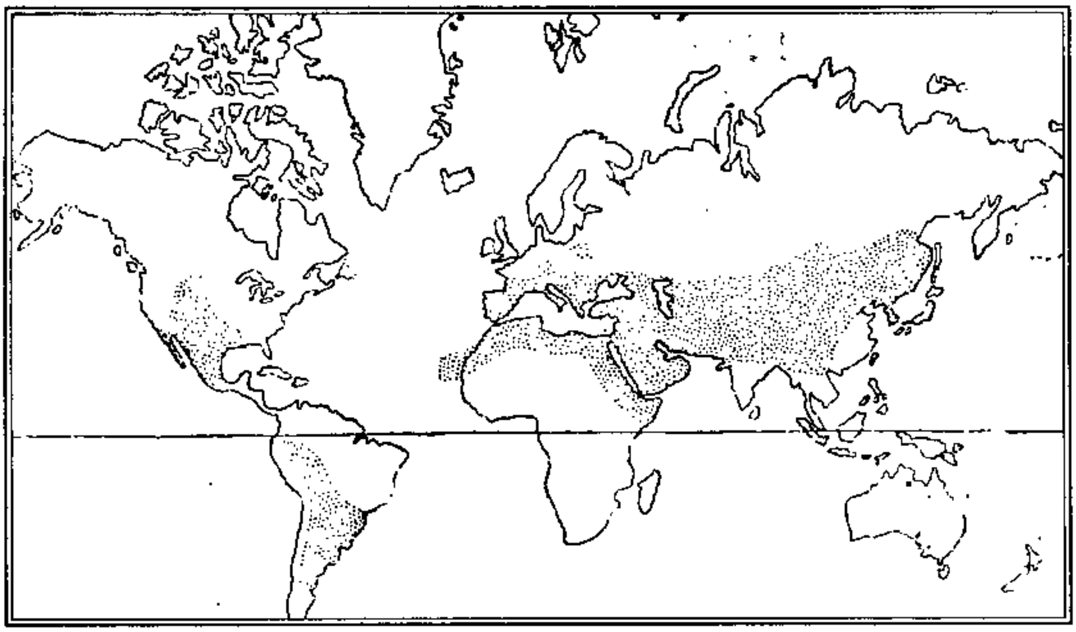


Fig. 1. Geographic distribution of *Ephedra* [Modified from Mclean and Cook]

(v) *E. nebrodensis* Tineo var. *procera* stapf from Kashmir.

(vi) *E. regeliana* Florin (*E. major*) from Ladakh and Lahul.

1.2. MORPHOLOGY

Ephedra resembles *Equisetum* in habit. The plant body is sporophyte (2X) and shows xerophytic characters. Mostly the plants are struggling woody shrubs "(Fig. 20)". A very few species are lianas and some species may grow into a small trees. *E. campacta* reaches 30 cm in height. *E. triandra* is a tree reaching several meters. According to **Chamberlain** (1935) it is a short lived plant. The underground axillary buds grow and give rise to the rhizome which spreads and grow into a new plant, if the soil conditions are favourable. The plant body is distinctly differentiated into three parts (1) Root, (2) Stem and (3) Leaves.

1. Root : There is a prominent underground tap root system. Later on the lateral adventitious roots develop which help in anchoring the plant in the soil.

2. Stem : Like *Equisetum* it is also green, ribbed, fluted and differentiated into nodes and long internodes (Fig. 2 B). It acts as a photosynthetic organ and may be called as phylloclade. The branches arise from the axillary buds and are therefore, in pairs or threes or fours according to the number of scaly leaves at the nodes in different species. The branches are also green and differentiated into nodes and internodes. The branching starts early at the cotyledonary stage. The apical meristem is having a well marked tunica layer but the growth of the internode is independent due to the presence of pale meristematic zone at the base of each node. The meristematic zone at the end of growing season may harden to form an abscission layer due to which the branches fall off and are again replaced in next season by axillary shoot.

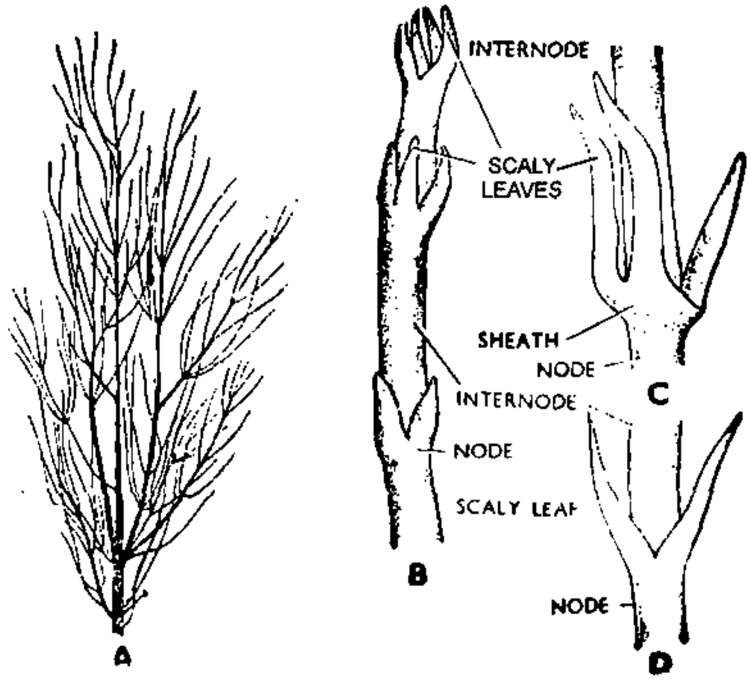


Fig. 2. (A-D) *Ephedra*—showing (A) Shruby habit (B) nodes and internodes (C & D) nodes showing different number of scaly leaves.

3. **Leaves** : They are very small scaly, present in pairs at the nodes and are arranged in opposite, decussate manner (Fig. 2 B, C). The scaly leaves are so minute that they are of no use. The paired leaves present at each node connate at the base to form a small sheath at each node (Fig. 2 C) scaly leaves may be in whorls of three or rarely four at each node. Each scale leaf shows a thick mid rib with a thin blade. The mid rib is traversed by two parallel unbranched veins. The stomata are very rarely present. Each leaf is supplied at the base by a double leaf trace. The abscission layer is formed at the base of leaves which causes shedding of the leaves leaving broad scars. The foliage leaves are generally lacking.

1.3. ANATOMY

Anatomy of the stem

The stem is ribbed so the out line shows distinct ridges and furrows. The resin canals are totally lacking but the cells with large stellate crystals of calcium oxalate are abundant. A cross-section of the internode (stem) shows the following structures (Figs. 3 and 4) :

Epidermis : It is the outer most single celled thick covering layer made up of thick walled cells and punctured by sunken stomata, which are present on the slopes of the ridges in circular pits. The epidermis is heavily cuticularised on the outer side.

Hypodermis : It occurs in the form of sclerenchymatous patches below the ridges and is absent from the grooves.

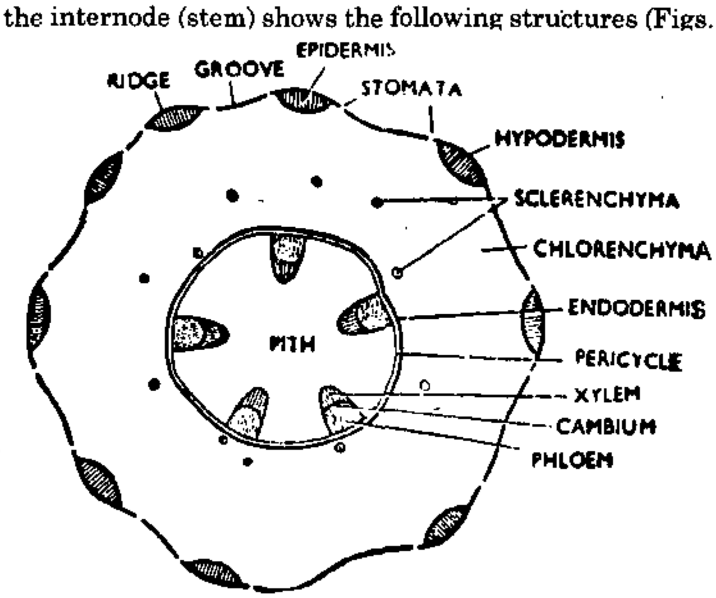


Fig. 3. Ephedra—T.S. young stem. (diagrammatic)

Cortex : There is a wide zone of parenchymatous cortex, which is differentiated into a outer palisade tissue and inner spongy tissue. The cells of both are loosely arranged with large intercellular spaces and are provided with chlorophyll to perform the function of photosynthesis. A few patches of sclerenchymatous cells may also occur, in the cortex to provide resistant and hardness to the young axis.

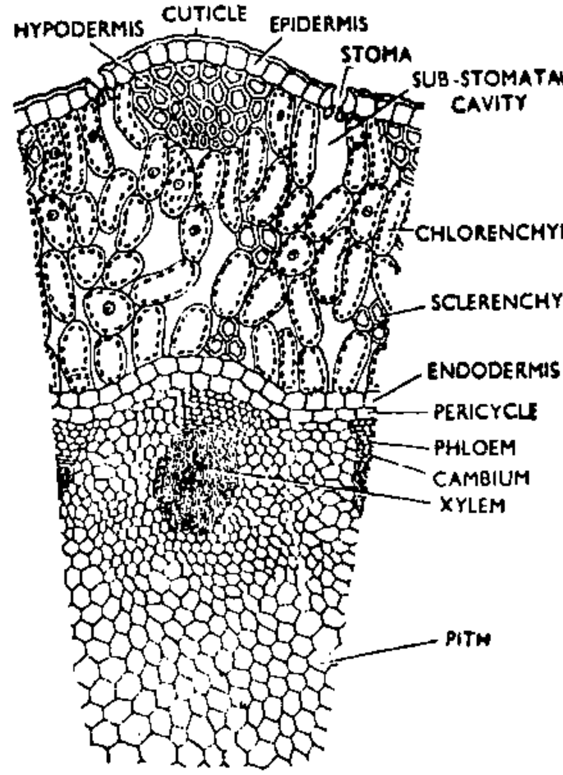


Fig. 4. *Ephedra*—T. S. young stem [A part cellular]

Endodermis : It is the inner most layer of the cortex. Some times it is not easily distinguishable from the cortical cells.

Pericycle : Below the endodermis is a single layered pericyle of parenchymatous cells.

Vascular cylinder (Stele) : It is of ectophloic siphonostelic type and consists of many vascular bundles arranged in a ring. number of vascular bundles is variable in different species.

Vascular bundles : They are conjoint, collateral, open and endarch. Phloem and xylem elements are separated by a narrow strip of cambium, which is persent throughout the plant body. This primary cambium is persistant and gives rise to secondary wood but not in much amount so that the vascular cylinder does not become thick. The phloem is present above the cambium and xylem below the cambium. The xylem tracheids are provided with single row of scattered bordered pits both on radial and tangential walls.

Medullary rays : In between the vascular bundles, is a zone of parenchymatous cells, connecting the pith with the cortex and are known as medullary rays (Primary). The medullary rays are uniseriate.

Pith : In the centre of the stem is a zone of thin walled parenchymatous cells known as pith but at or near the node, the cells become strongly lignified forming a peridermal diaphragm which accounts for the rapid separation fo the branches in this region (Fig. 5).

Secondary growth : It is a process by which the stem increases in girth. The process of secondary growth in the stem of *Ephedra* takes place due to the meristematic activity of primary cambium, which is persistant. The cambial cells cut of secondary phloem on the outer side and secondary xylem on the inner side as a result of which the stem becomes thick (Fig. 6). Due to the formation of secondary

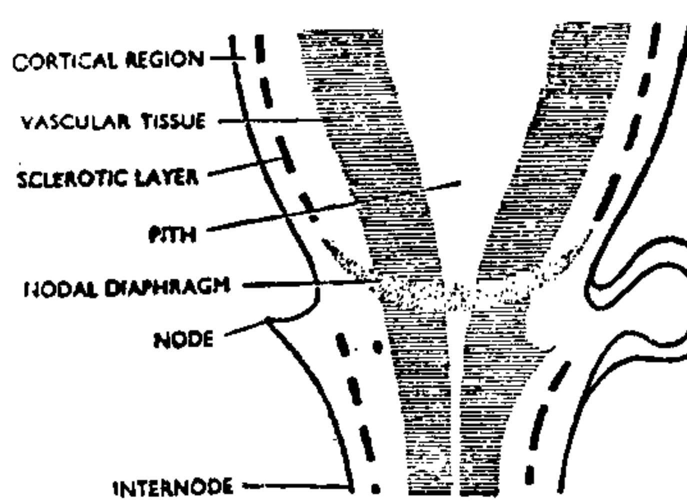


Fig. 5. *Ephedra*—L.S. node [Diagrammatic]

tissues the primary phloem is crushed and the primary xylem is pushed towards the inner side, at the base of scondary xylem. A layer of sclerotic cells (Stone cells) develop just out side the zone of secondary tissues.

In secondary phloem the sieve cells and companion cells are formed in rows, each from different cambial initials (Not from the sub-division of sievė mother cell as in angiosperms). The secondary wood is composed of coniferous tracheids mixed with broad vessels. The presence of vessels is characteristic feature of *Ephedra*, similar to that of Angiosperms but the origin of vessels in *Ephedra* is different from that of

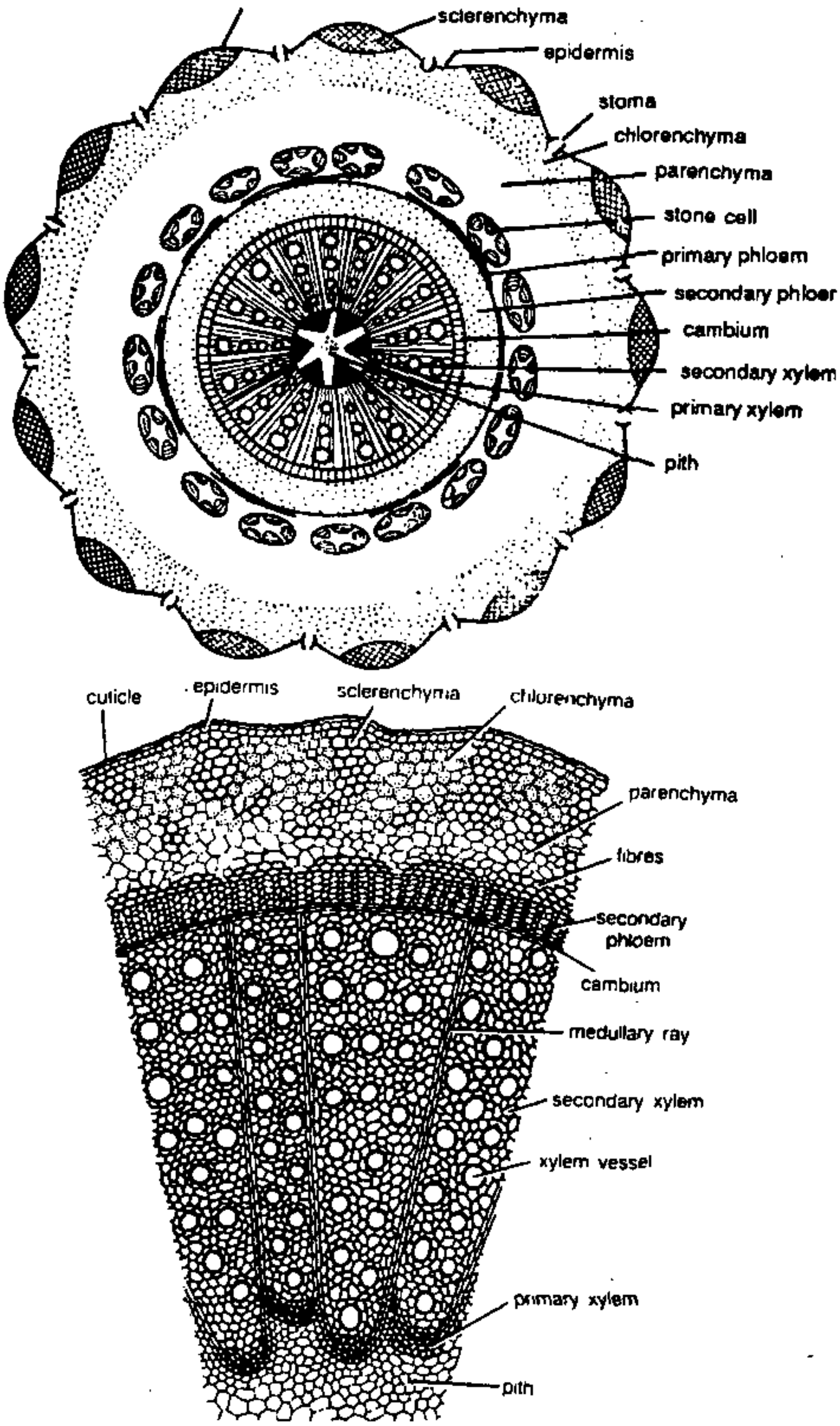


Fig. 6. Ephedra. T. S. old stem (upper diagrammatic; Lower, a part cellular)

Angiosperms. In *Ephedra* the pitted tracheids give rise to the vessels where as ir Angiosperms tracheids with scalariform thickenings give rise to vessels.

In the beginning the vessels have ordinary bordered pits on their end walls but later on septa-less tracheids similar to vessels are formed by gradual absorption of the border and closing membrane as in some lower Angiosperms like Magnoliaceae. During secondary growth the vessels are formed most abundantly in spring and are larger ir size and later on the size and their number decreases and in autumn the number is reduced to nil. The cells of the spring wood are larger and thin walled than the autumr wood where the cells are smaller and thick walled. A ring of spring and autumn wood together forms an annual ring every year. The vessels are marked only in narrow band of each annual ring.

In the older stem (After 3 or 4 years) a **phallogen** (cork cambium) arises just ou side the phloem and the **periderm** (cork) is formed from it, which displaces all the outer tissue.

The secondary medullary rays which traverse between secondary xylem and secondary phloem are very broad (**multiseriate**) and long. They are developed partly by their own growth and partly by the fusion of neighbouring rays. All the cells of the secondary medullary rays are lignified to provide hardness to the wood.

Radial longitudinal section of the wood (R.L.S.)

Xylem tracheids, vessels and medullary rays are only well defined structures in i (Fig. 7). Tracheids constitute the major part of the wood and possess bordered pits on their radial walls. The bordered pits are circular or some what ellipticle in structure and are generally scattered or arranged in compact rows of 2 or 3. Ephedroid perforations are also present, which are formed by the dissolution of the wall of cavities of the pits. The cellulose thickenings are also present n the form of **bars of sanio** below the pits.

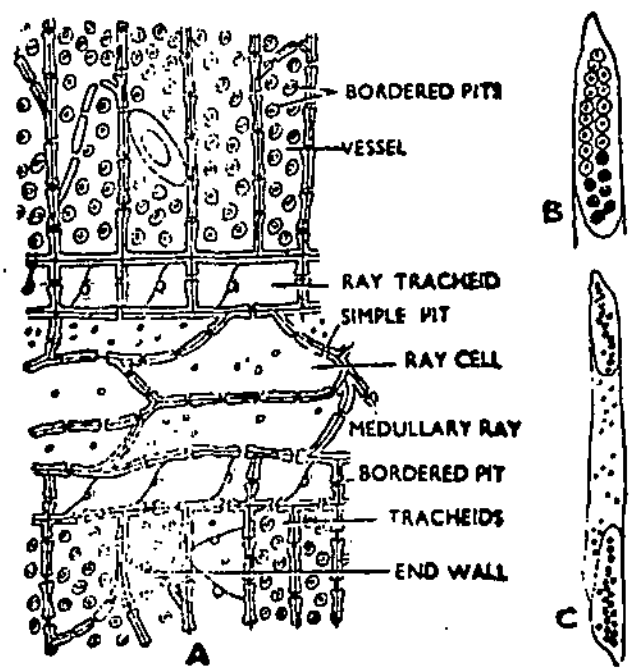
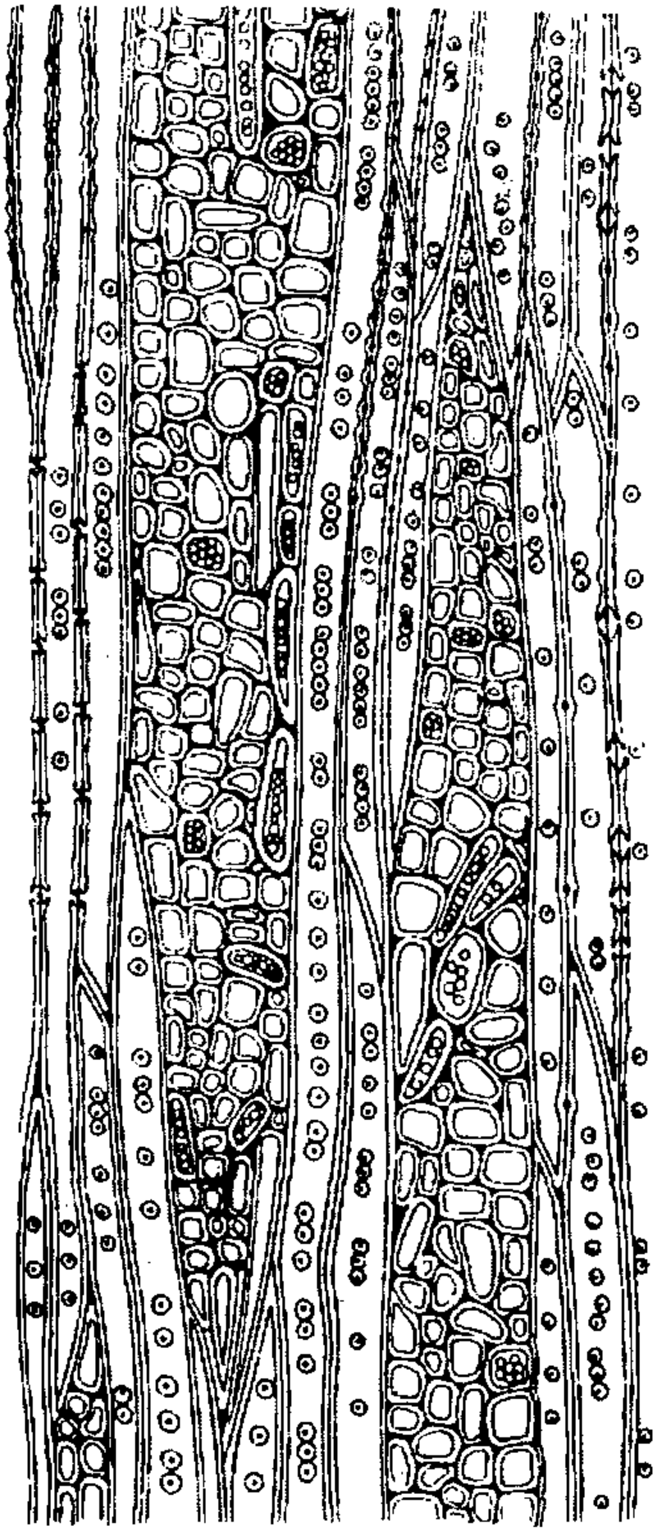


Fig. 7. (A–C) *Ephedra showing* [A] R.L.S. of the wood [B] vessel of *E. major* [C] vessel of *E. californica*.

In case of vessels also, the bordered pits are arranged *in the same way as ir* tracheids *i.e.*, they are scattered or may be arranged in rows of 2 or 3 but the aperture o the bordered pits are generally horizontally oriented. Their end walls are also perforated (Fig. 7C).

As the medullary rays are cut length-wise, they run horizontally. They are uniseriate or multiseriate. Each medullary ray is composed of irregularly dispersed ray cells and ray tracheids (Fig. 7A). The ray cells are both thick as well as thin walled a



A

Fig. 8. *Ephedra*. T.L.S. stem.

the ray tracheids are only thick walled. The former possesses bordered pits or simple pits or slit like openings on their tangential walls, where as the latter possesses bordered pits on the radial as well as on tangential wall (Fig. 7A).

Tangential longitudnal section of the wood (T.L.S.)

Like R.L.S., in T.L.S. also the xylem tracheids, vessels and medullary rays are well defined structures but they are cut transversely here. The bordered pit shows usual *structure i.e., two dome shaped* over arches and a small dics called as **torus** in the centre. Simple pits are also seen on the radial and tangental walls (Fig. 8). The bordered pits are also visible in the surface view. The aperture of the bordered pit seen in the surface view is circular in case of tracheids and slightly horizontally oriented in case of vessels.

The medullary rays are cut transversely. They are elongated and on their tangential walls are present simple pits.

Leaf : In T.S. (Fig. 9) the reduced and membranous scaly leaves are somewhat oval in outline. The epidermis consists of elongated or oval cells. Cuticle is also present.

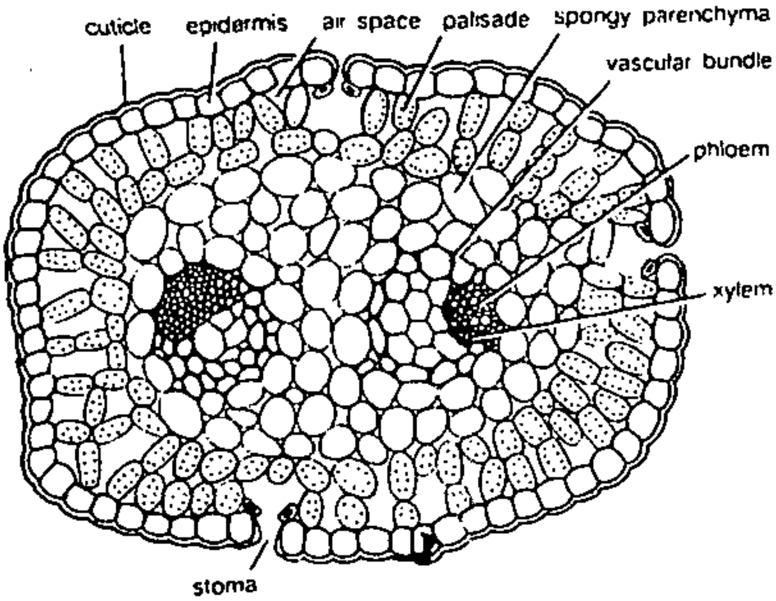


Fig. 9. *Ephedra*. T.L.S. leaf.

Stomata, when present, are sunken. Two to three or more layers of chlorophyll containing cells of palisade tissue are present. Major remaining part of the scaly leaf remains filled with cells of spongy parenchyma. Many air spaces are present in the parenchymatous and palisade regions. The vascular bundles are two in number. They are small and remain embedded in the parenchyatous tissues.

1.4. REPRODUCTION

Ephedra reproduces only by means of spores which produce gametophytes and later on male and female sex organs. It is a **heterosporus** plant *i.e.*, produces two type of spores, micro—and megaspores, which are produced by male and female flowers respectively. The male and female flowers behave as independent strobili and in turn form compound male and female strobili respectively. These strobili are produced in the axil of scale leaves on nodes, thus resembling inflorescance (spike) of angiosperms.

The plants are typically **dioecious** but there are occasional reports of **monoecious** plants and even **bisporangiate strobilus** has been reported *e.g., E. foliata, E. intermedia* etc. **Wettstein** (1960) reported bisporangiate strobili in *E. campylopoda*. In bisporangiate strobilus, the male flowers are situated on the lower side and the female on the upper side.

Each compound strobilus is a cone like clusture of simple axillary strobili. Each axillary strobilus resembles with the flowers, because their bracts are arranged like perianth. Each strobilus consists of a axis bearing decussately arranged sterile scales and stamens or ovules.

Male Strobilus (Staminate strobilus)

Male strobilus (Fig. 10 A, B) or spike is generally rounded or ovoid to spherical in shape and arises in the axil of scale leaf. It has a short axis, (strobilus axis) with about 2–12 pairs of decussately arranged **bracts**. Lower most 1 or 2 pairs of bracts are sterile and the rest are fertile. In the axil of each fertile bract arises a single male flower or staminate flower consisting of a two lipped **perianth** (Bractioles) which enclose a

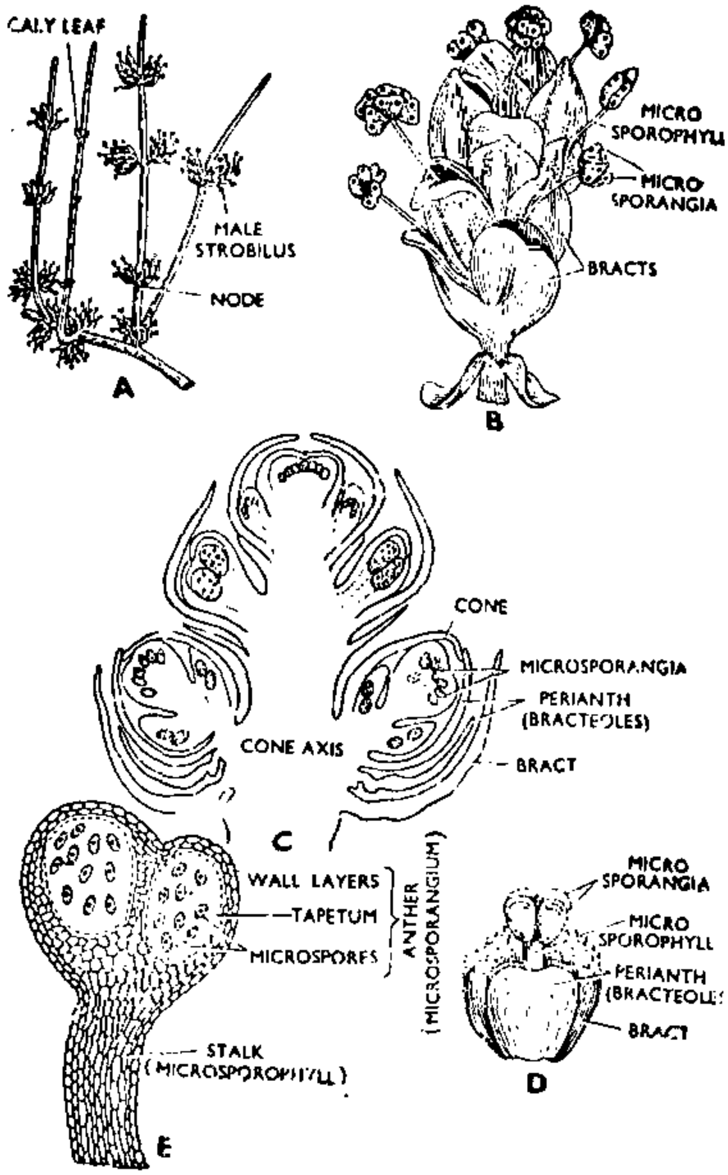


Fig. 10. (A-E). *Ephedra sps.*
[A] Staminate shoot; [B] Male strobilus (compound); [C] L.S. male strobilus; [D] A single male flower; [E] L.S. microsporangium.

'stamen'. Each **'stamen'** comprises of a stalk (bntherophore or sporangiophore or microsporophyll) which is forked in *E. distachya* (**Thoday** and **Berridge,** 1912) and bears 2 to 5 **microsporangia** (anthers or synangia) at its tip (Fig. 10B D).

Each microsporangium is bi- or trilocular structure (Fig. 10 E). Its wall is two layered followed by prominent tapetal layer enclosing a sporangial sac having many pollens or microspores. The microsporangium opens by a terminal slit to release the **pollen grains.** Each pollen grain is ellipticle and uninucleate structure with outer thick exine and inner thin intine. The development of microsporangium is of **eusporangiate type.**

Female strobilus (Ovulate strobilus) : The general structure of the female strobilus is similar to that of male strobilus and it also arises in the axil of scale leaf (Fig. 11A). It is a small and less richly branched structure than the male strobilus and the spike is sessile.

It is an elongated structure with acute apex and consists of a short axis (Fig. 11B) with about 2–4 pairs of decussately arranged bracts which in some species becomes swollen and juicy *e.g., E. americana.* All the pairs of bracts are sterile except the upper most one which bears a pair of **ovules** in their axil and may be variously coloured. Out of the pair of ovules only one survives and it takes up a false terminal position.

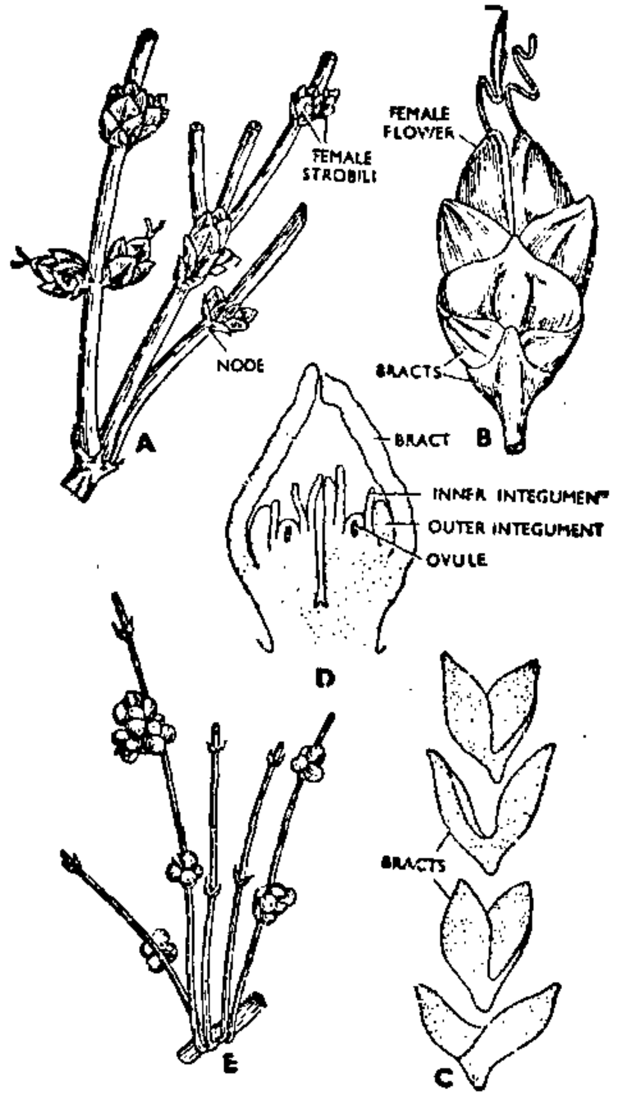


Fig. 11 (A-E). *Ephedra* sps. (A) Ovulate shoots, (B) Female strobilus, (C) Decussately arranged bracts, (D) L.S. of the top of the ovulate strobilus, (E) *E. americana* bracts swollen and juicy.

Each ovule consists of **nucellus** enclosed by two envelopes (Fig. 12) which are separated from each other upto the base. These two envelopes are interpreted either as two **integuments** or outer envelop as **perianth** or anterio-posterior pair of fused **bractioles** and the inner one as integument. The outer envelope is formed by four segments and receives four bundles, while the inner one is formed of two segments and receives two bundles. The lower half of the inner envelope is fused to the nucellus but the uper half is free and is prolonged into a long **micropylar tube** (Fig. 12) by the time of pollination. The pollination drop is exuded at the opening of the micropylar tube by means of which the pollens are drawn down the micropylar tube.

The pollen chamber (Fig. 12) is funnel shaped and **deepest** known among **Gymnosperms.** It is present just below the micropyle. The floor of the pollen chamber is formed by female gametophytic tissue and not by the nucellus as in other **Gymnosperms.**

The development of ovule is much more like that of a typical **Gymnosperms.** A single hypodermal **archesporial cell** of the nucellus gives rise to a single megaspore mother cell, which divides reductionally to give rise to a linear tetrad of four megaspores. Lower most one is functional, which enlarges and gives rise to the female gametophyte and upper three megaspores degenerate. **Singh**

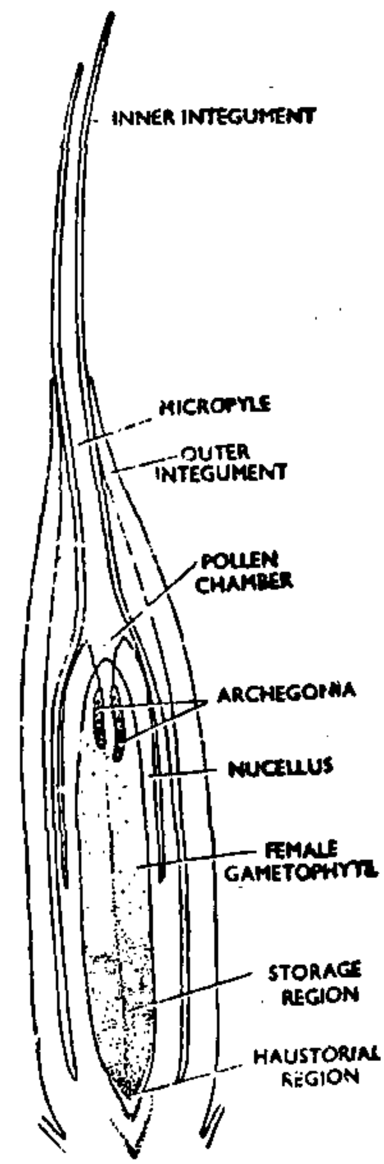


Fig. 12. *Ephedra trifurea.* L. S. ovule. (after Land, 1904)

and **Maheshwari** (1962) has worked out the vascular anatomy of female strobilus of *E. gerardiana.*

Gametophytic Phase

The micro—and megaspores are the unit of male and female gametophytic generations respectively.

Develoment of male gametophyte : It is some what similar to that of *Pinus* thus showing linkage with conifers. It was described in detail by **W. J. G. Land** (1904) in *E. trifurca* and by **Maheshwari** (1935) in *E. foliata*. The uninucleate microspore is the first stage of male gametophytic generation. The development of male gametophyte can be studied better, under the following two heads :

(i) Pre-pollination changes in the male gametophyte.

(ii) Post-pollination changes in the male gametophyte.

(i) Pre-pollination changes in the male gametophyte : In this development, the nucleus of microspore divides into two and a wall is laid down in is such a way that a first **prothallial cell** (vegetative) is cut off and is pressed closely against the wall. A second division cuts off second prothallial nucleus and an **antheridial initial** but no wall is laid down between the two (Fig. 13B). The antheridial initial divides to form a

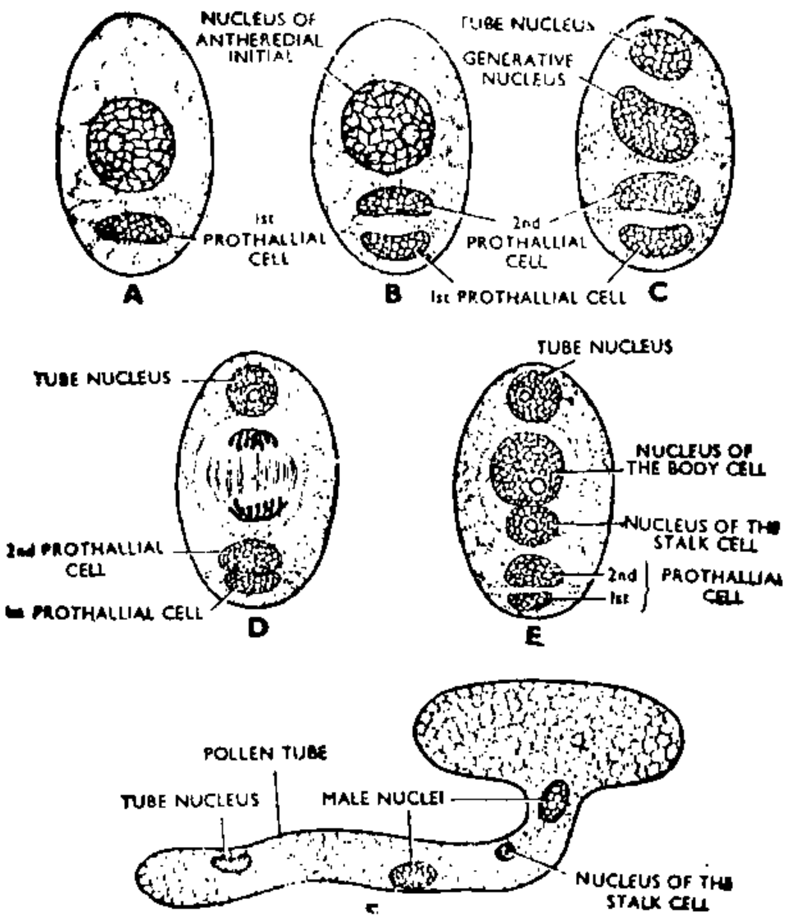


Fig. 13. (A-F). ***Ephedra*—Showing development of male gametophyte [A-E] Pre-pollination changes in teh male gametophyte. [F] Post pollination changes in the male gametophyte.**

tube nucleus and a **generative nucleus** (Fig. 13C). The generative nucleus becomes surrounded by a zone of cytoplasm differentiated from the general cytoplasm which in turn divides to form a **stalk nucleus** and a **body nucleus** (Fig. 13E). The body nucleus soon enlarges in size. At this stage the pollen is shed and it is five nucleate structure two prothallial, a stalk, a body and a tube nucleus, (Fig. 14F). Rest of the development of male gametophyte is completed after pollination *i.e.,* inside pollen chamber.

(ii) Post-pollination changes in the male gametophyte : After pollination, the five nucleate pollen reaches the pollen chamber. The exine of the pollen ruptures and the intine comes out in the form of a pollen tube. By this time the body nucleus divides to from two unequal **male nuclei,** which along with stalk nucleus and tube nucleus pass in the pollen tube. The prothallial nuclei are disorganised by this time. The polllen tube grows down penetrating the neck cells of the archegonium and the two male nuclei pass into the oosphere (egg).

Development of female gametophyte : It was first outlined by **Strasburger (1872)** and later on by **W. J. G. Land (1904)** in detail in *E. trifurca* and by **Maheswhari (1935)** in *E. foliata.* The functional megaspore of a linear tetrad (Fig. 14A), enlarges in size resulting in the formation of a central vacuole. Its nucleus divides repeatedly by free nuclear divisions to give rise to 256 or more nuclei within 20 days. Now the centripetal wall formation starts *i.e.,* from periphery towards the centre. The tissue of the female gametophyte is gradually differentiated into two regions :

1. Micropylar region.

2. Antipodal region.

1. Micropylar region or upper reproductive zone : It consists of loosely arranged thin walled cells, which later on give rise to the archegonia.

2. Antipodal region : It is further differentiated into :

(i) Lower storage zone,

(ii) Basal haustorial zone.

(i) Lower storage zone : It comprises the greater bulk of the endosperm and consists of compactly arranged cells which are full of starch and other food.

(ii) Basal haustorial zone : It consists of two or more outer most layers of endosperm cells at the antiodal end. Its cells are compactly arranged and act as absorbers of food material from the nucellus.

Development of archegonia : They arise in the upper reproductive zone and are usually two in number but occasionally may be one or three. Any superficial cell of the

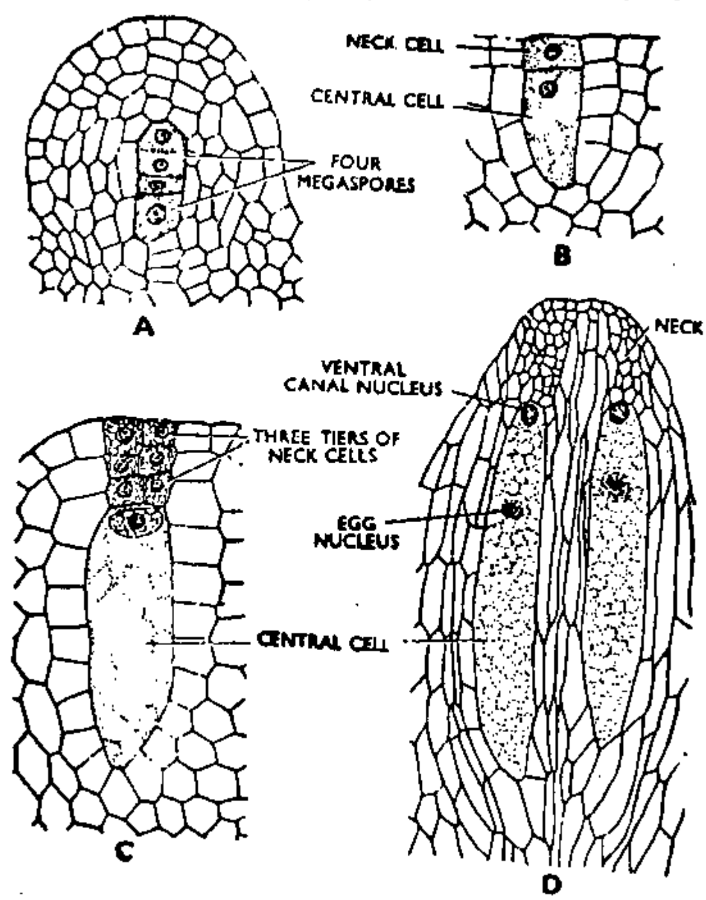


Fig. 14. (A-D). *Ephedra sp.* Showing development of archegonium.

reproductive zone becomes the **archegonial initial,** which divides periclinally to form a upper **primary neck cell** and a **lower central cell.** The primary neck cell divides to form a **neck** of eight or more tiers (With minimum of 32 cells in total). In the beginning the divisions in the formation of neck are regular (upto 8 tiers) but later on become irregular so that the neck cells can no longer be distinguished from the surrounding gametophytic cells. The neck of archegonium in *Ephedra* is longest among the *Gymnosperms.* The nucleus of the central cells divides to form a **ventral canal nucleus** and an **egg nucleus** but no wall is laid down between the two. Around the ventral region a jacket of tapetal cell is formed.

Pollination and fertilization

During pollination, the pollen grains after liberation from microsporangium (anther of synangium) are carried on by wind to the micropyle of the ovule. A pollination drop is exuded at the opening of the micropylar tube in which pollens are entangled and are drawn down through the micropylar tube to the pollen chamber.

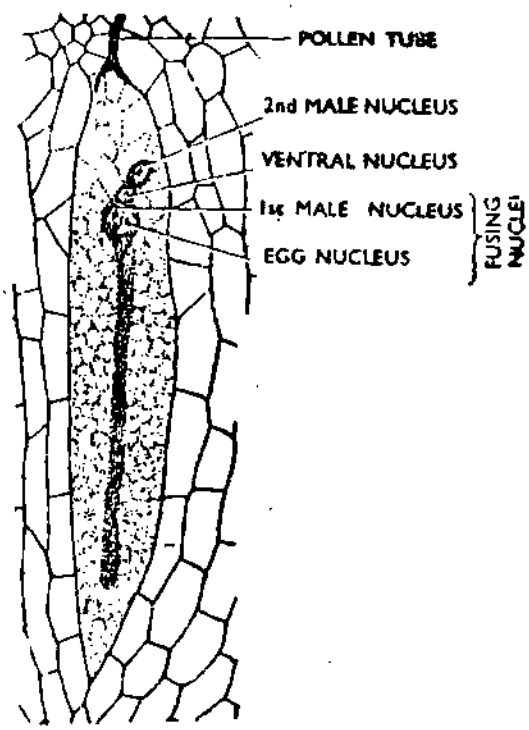


Fig. 15. ***Ephedra sp.*** **Showing fertilization (after Land, 1907)**

Fertilization occurs within ten hours after pollination. During this time of interval many important changes take place inside the male gametophyte. The pollen tube gradually and gradually penetrates the neck cells of the archegonium and discharges all the four nuclei (one stalk, one tube and two male nuclei) into the egg. One male nucleus fuses with the egg nucleus forming the **zygote (2X)** (Fig. 15). In some cases an interesting feature has been observed by **Khan (1943)** *e.g., E. foliata,* where the second male nucleus fuses with the ventral canal nucleus (double fertilization) but no embryo is formed from this fusion. The zygote represents the sporophytic generation.

1.5. DEVELOPMENT OF ZYGOTE AND FORMATION OF EMBRYO (EMBRYOLOGY)

Land (1907) worked out the embryology of *E. trifurca* in detail. According to him the jacket cells disappear after fertilization and the contents of these cells become mingled with those of the egg. In some cases it is suggested that the nuclei of the jacket cells help in apogamy but the evidences are against it. **Berridge** and **Thoday (1912)** in *E. distachya* interpreted that the free nuclei of jacket cells appear to fuse in pairs and to form the functioning proembryonal cells, in others the jacket cells were thought to function directly as proembryonal cells.

The zygote nucleus undergoes three free nuclear divisions to produce 8 free nuclei, more or less unequal in size and which are irregularly distributed through the egg. Usually 3–5 largest nuclei form the walled cells known as proembryonal cells (Fig. 16A, B), each of which produces an independent embryo. This is a type of **polyembryony.** Such precocious polyembryony is remarkable which is different from cleavage polyembryony.

By cleavage, the proembryonal cells are separated. Each functional proembryonal cell round off and its nucleus divides into two nuclei. Two papilla are given out by the wall adjacent to the two nuclei but only one elongates rapidly to form the suspensor and the other disappears. A cleavage plate cuts off a cell at the tip of suspensor tube which is known as embryo initial cell (Fig. 16C-E). Suspensor elongates rapidly from egg and penetrates the endosperm thus thrusting the embryo initial cell deep into the endosperm.

The embryo initial cell divides transversely, followed by successive divisions in various planes forming a ovoid mass of cells (Fig. 16, F, G). The basal cells of this group elongate successively forming a multicellular secondary suspensor, which merges insensibly into the root cap and further thrusting the embryo deep into the endosperm.

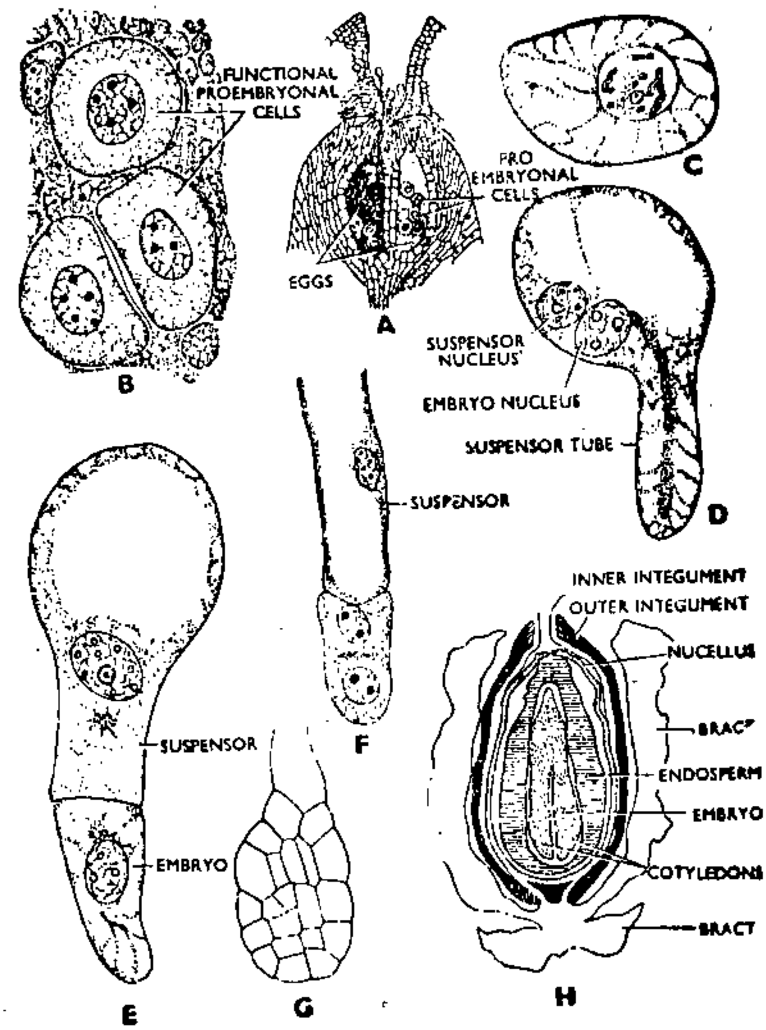


Fig. 16. (A-H) ***Ephedra*** **sp. (A-G) Developments of embyro, (G) L.S. Seed (afer Khan 1943).**

Although several embryos may begin to develop. **Khan (1943)** observed the formation of 18 or 19 embryos in a single ovule but only one survives and reaches at maturity in seed.

Formation of seed : After fertilization the ovule behaves as seed. During seed formation the outer envelop becomes thick walled forming a covering round the seed and the inner envelop disorganises but a little of it persists at the micropylar end. The nucellus is eaten up during the development of embryo and is represented in the form of shrivelled layer of disorganised cells. The embryo is quite prominent structure which remains embeded in the tissue of the endosperm (Fig. 16-H). The embryo has two large cotyledons.

Along with the maturity of the seed the adjacent bracts of the female strobilus also become fleshy and thick to form an additional integument around the seed.

Germination of seed : These seeds germinate without undergoing a period of rest if the atmospheric conditions are favourable. It is of epigeal type. The cotyledons persist as green photosynthetic organs for some time.

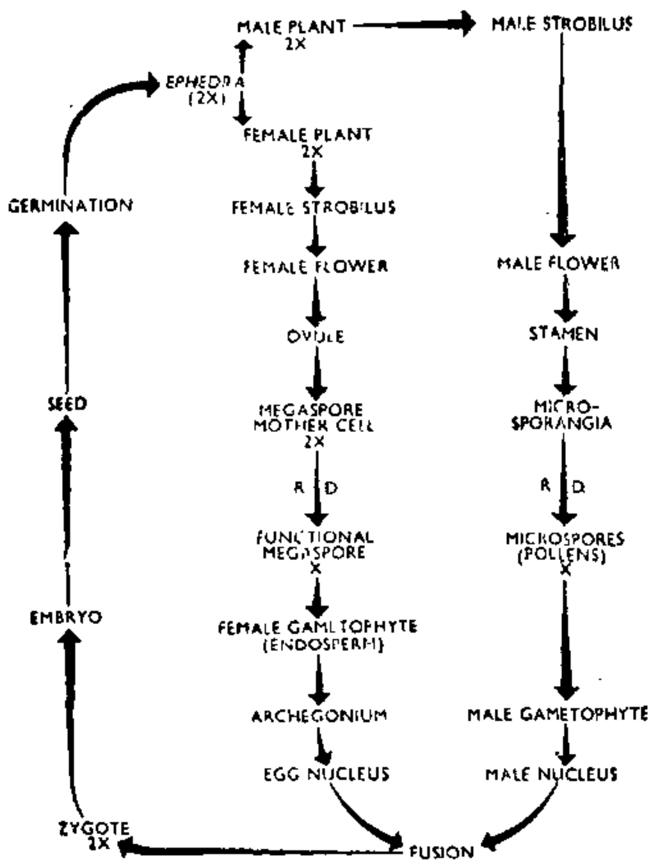
In *E. trifurca* **vivipary** is evident. It is a phenomenon in which the seeds start germinating while they are still attached to the mother plant.

This genera approaches more nearly to the Angiosperms rather than any other Gymnosperms. Some even now believe there is a close affinity between *Ephedra* and *Casuarina (augiorperm)* and (bresume) that there is tales to be the ancestors of flowering plants.

1.6. ECONOMIC IMPORTANCE

Several species of *Ephedra* are of great medicinal value and have been in use in China for over 5000 years. It yields an important alkaloid **ephedrine** which is used as a medicine in cold, hay fever and other respiratory diseases *e.g., E. intermedia, E. gerardiana* etc.

1.7. GRAPHIC LIFE CYCLE



Graphic representation of the life cycle of *Ephedra* plant.

1.8. SYSTEMATIC POSITION

Division	–	Gymnospermae
Class	–	Gnetopsida
Order	–	Gnetales
Family	–	Ephederaceae
Genus	–	*Ephedra*

1.9. SUMMARY

Ephedra, the lone genus of family Ephederaceae of order Gnetales, is represented by six species in India. Most of the species are shrubs. The plant body is sporophytic and shows xerophytic characters. It is distinctly differentiated into root, stem and leaves. A prominent underground tap root system with many adventitious roots is present in *Ephedra*. The stem is green, ribbed, profusely branched, hard glabrous and bears nodes and internodes. Leaves are small, scaly, present in pairs at the nodes and are arranged in opposite decussate manner.

A transverse section of the stem shows many ridges and grooves. Epidermis is single celled thick. Its continuity is broken by many sunken stomata. Patches of sclerenchyma are present particularly below the ridges. Chlorophyll containing green cells are present in between the thick-walled sclerenchyma and vascular cylinder. Stele is ectophloic siphonostele. It is formed by an interrupted ring of 8–12 conjoint, collateral, open and endarch vascular bundles. Foliar traces run upto the node. Secondary growth takes place by the vascular cambium. The distinct annual rings are formed because of the varied activity of the cambium in varied seasons. A transverse section of leaf can be differentiated into epidermis, mesophyll tissue and vascular bundles. The vascular bundles are small, two in number and remain embedded in the mesophyll tissue.

Ephedra is dioecious and heterosporous. The male and female flowers are present in the form of cone like, compound male and female strobili. Male strobilus is rounded or ovoid and arises in the axil of the scale leaf. Two to 12 pairs of bracts remain arranged in opposite decussate manner on the strobilus axis. A single male flower arises in the axil of each bract. Each stamen bears a stalk and 2–5 microsporangia. The development of microsporangium is eusporangiate type. The wall of the microsporangium is two layered, followed by tapetal layer enclosing a sporangial sac having many microspores. Female strobilus also develops in the axil of scaly leaf. It.consists of a short axis with about 2–4 pairs of deccusately arranged bracts. All bracts, except the uppermost pair are sterile. Two ovules are present in the axil of uppermost pair of bracts, out of which generally only one survives. Each ovule consists of a nucellus enclosed by two integuments. The inner integument protrudes out in the form of a long tubular micropyle. Pollen chamber in *Ephedra* is deepest known among the gymnosperms.

Microspore is the first cell of the male gametophyte. The germination of the microspore starts within the microsporangium. Unicelled microspore by four divisions of gametogenesis forms a five celled pollen grain. Pollens are shed at this five celled stage. The functional megaspore is the first cell of the female gametophyte. It enlarges and its nucleus divides several times by many free nuclear divisions to form as many as 256 nuclei. It is followed by wall formation and it results in the formation of endosperm or female gametophyte. Archegonia arise in the upper region at endosperm and are usually two in number. The mature archegonium consists of minimum 32 celled neck, a venter canal nucleus and an egg nucleus.

The pollination is anemophilous. At the time of fertilization, the pollen tube penetrates the archegonium and discharges its contents into the egg cytoplasm. One of the two male nuclei fuses with the egg nucleus and forms zygote. The other male nucleus fuses with the venter canal nucleus exhibiting the phenomenon of double fertilization.

Zygotic nucleus undergoes free nuclear divisions resulting into eight free nuclei. Three to five, out of these eight nuclei functions as potential embryos. It is a polyembryony without any cleavage, and *Ephedra* is unique among gymnosperms to show such type of polyembryony. The embryo show differentiation of radicle, plumule, hypocotyl and two cotyledons and it is embedded in the endosperm. At maturity, the seed is covered by three layers. Two layers are formed from the outer and inner integument while the third layer is formed by adjacent bracts. Seeds germinate without undergoing a period of rest. Seed germination is of epigeal type. Ephedrine, a well known drug is used as a medicine in respiratory diseases is obtained from *Ephedra*.

1.10. STUDENT ACTIVITY

1. Describe the internal structure of the stem of *Ephedra*.

2. Describe the structure of the ovule of the *Ephedra*.

1.11. TEST YOURSELF

1. Why *Ephedra* is a gymnosperm ?
2. What is the characteristic of nodal anatomy of *Ephedra* ?
3. The ovules of *Ephedra* are unitegmic or bitegmic.
4. Name the first cell during the development of male gametophyte in *Ephedra*.
5. What is the nature of endosperm in *Ephedra* ?
6. What is the number of prothellial cells in the male gametophyte of *Ephedra* ?
7. What is the number of cotyledons present in the seed of *Ephedra* ?
8. What type of pollination is present in *Ephedra* ?
9. Name the gymnosperm in which deepest pollen chamber is present.
10. Name the gymnosperm in which largest archegonial neck is present.

ANSWERS

1. It has exposed ovules
2. Presence of nodal diaphragm.
3. Bitegmic
4. Microspore.
5. Haploid
6. Two
7. Two
8. Anemophilous.
9. *Ephedra*
10. *Ephedra.*

UNIT-I

CHAPTER

6

GEOLOGICAL TIME SCALE

STRUCTURE

- Introduction
- Precambrian era
- Palaeozoic era
- Mesozoic era
- Coenozoic era
- Table-Geological Time Scale
  - Summary
  - Student activity
  - Test Yourself
  - Answers

LEARNING OBJECTIVES

By learning this chapter you will be able to know the geological time scale.

1.0 INTRODUCTION

About 350 million years old is the history of earth. Geologists have used two major units *i.e.,* **time** and **strata** for sub-dividing the geological history of the earth.

The geological history of earth has been divided into five **Era** on the basis of **time.** These eras are – Archaeozoic, Proterozoic, Palaeozoic, Merozoic and **Coenozoic**. In each era, several **Periods** are present. Each period is further divided into **Epoch.**

The geological history of the earth is divided into system, series, stage and zone on the basis of **strata.** A brief description is as :

1.1. PRECAMBRIAN ERA

In this era, life originated in the earth. During this era few fossils were present because the environment was not suitable for the making of fossils. Because no fossils were present so it is difficult to assess the environment of that period.

1.2. PALAEOZOIC ERA

Aquatic and land plant both were present. *e.g., Nematothallus,* **Prototaxites** (aquatic) resembled with thallophyte. The first fossils of land plants were found in Silurian and Devonian period of that era *i.e.,* 225-350 million years ago *e.g., Marograptus, Sporogonites, Zosterophyllum, Cooksonia, Pseudosporochnus, Rhynia, Horneophton* and *Psilophyton.*

Lycopsida, sphenopsida and pteropsida formed dense forest in **Carboniferous** and **Persian period** seed ferns were abundant so this periods is called **age of seed ferns.** During this period seasonal change in environment takes place because **annual rings** were observed in some *fossils e.g. Callixylon erianum* and *C. newbarryi.*

Significant change in the environment takes place in late carboniferous period. Due to which development of swampy region takes place. It was unsuitable for woody vegetation. In the late Devonian period, due to geological events, the vegetation present on earth was converted into **coal.** So the coal beds of Pennsylvania and West Virginia were formed due to coalification of Lycopsides. Spenopsides, seed ferns and gymnosperms of that period. Some psilopsides, lycopsids and sphenopsides escaped devastation and eventually gave rise at the present forms.

1.3. MESOZOIC ERA

Arid environment were present in Triassic period of this era. This environment was unsuitable for the growth of plant which require humid climate. But fossil records indicate the presence of many ferns, Cycadophytes and Conifers in the Triassic period. This period is also known as **"age of cycads"**.

In this period flowering plants also originated but their number was negligible. In the vegetation of the cretaceous period significant change takes place.

1.4. COENOZOIC ERA

The era is known as **'age of angiosperms'.** High mountain ranges like the Himalayas in Asia and the Alps in Europe formed during this period Consequently, the effect of hot wind was minimised and the ice age commenced. Gradually the ice shifted towards poles. This ice was accompanied with the development of temperate and tropical regions. These alternations in climate had significant effect on vegetation. The seed plants gradually migrated towards tropical regions and those which could not migrate become extinct. As most plants of the late coenozoic era were deciduous, it shows that there wese seasonal variations too. The vegetation of the temperate and polar regions mostly consisted of annual or biennial herbs which could with stand low temperature.

1.5. TABLE-GEOLOGICAL TIME-TABLE

Era	Period (System)	Epoch (Series)	Climatic variations	Important events in plant-life	Dominant plants
	Recent (30,000 years)	**Recent**			
	Quaternary	**Pleistocene** (1 milion years)	Development of modern climatic regions; cold climate in polar regions.	Dominance of herbaceous plants	Herbaceous plants
	Tertiary	**Pliocene** (17 million years)	Development of alpine mountain ranges.	Spread of herbaceous dicotyledonous plants	
	COENOZOIC	**Miocene** (30 million years)		Decrease in number and area of forests.	
		Oligocene (40 million years)		Rise in the number of woody angiosperms	Angiosperms
		Eocene (60 million years)	Development of Himalayan mountain ranges.	Spread of angiospermic forests.	

		Paleocene (80 million years)			
	Cretaceous (110 million years)	**Upper Cretaceous Middle Cretaceous**	Laramide revolution	Dominance of angiosperms and decrease in the number of gymnosperms. Rapid increase in the number of angiosperms.	
	MESOZOIC	**Lower Cretaceous**		Dominance of cycads, conifers and angiosperms	
	Jurassic (170 million years)		Temperate climate	Rise in the number of leptosporangiate ferns; origin of angiosperms.	Gymnosperms.
	Triassic (200 million years)		Warm temperate climate	increase in number of cycads, conifers and Ginkgoales.	
	Permian (240 million years)		Glaciation	Extinction of primitive gymnosperms and arborescent pteridophytes	
	Carboniferous (280 million years)		Appalachian revolution.	Dominnce of lycopods, Calamitiales, Lepidodendrales and Cordaitales; Origin of bryophytes	Pteridosperms
	Devonian (3600 million years)		Warm and humid climate	Origin of land vascular plants (Lycopsida and Psilopsida); algal members in plenty.	Primitivel and plants
	PALAEOZOIC				(Nema–tophytales then Psilophytales)
	Silurian (375 million years)		Warm climate.	Origin of land plants; dominance of algae.	Algae, mostly calcareous.
	Ordovician (420 million years)		Development of Caledonian ranges.	Dominance of marine and green algae.	
	Cambrian (550 million years)		Development of Acadian rocky ranges.	Origin of algae.	

	PROTEROZOIC (1500 million years)		Blue-green algae and bacteria.	Organisms were probably very simple and unicellular	Probably unicellular or ganisms
	Precambrian ARCHAEOZOIC (3800 million years)		Warm and aquatic conditions, unicellular organisms.		

1.6. SUMMARY

The history of the earth is approximated 350 million years old. Geologists have used two major units-time and strata for sub-dividing the geological history of earth. On the basis of time it has been divided into five eras—Archaezoic, Proterozoic, Palaeozoic, Mesozoic and Coenozoic. Each era includes many periods and each period is further divided into epoch. Life originated on the earth in precambrian era. Palaeozoic era is known as 'age of seed ferns'. The mesozoic era is known as 'age of cycads' and the coenozoic era is popularly called as `age of angiosperms.'

1.7. STUDENT ACTIVITY

1. Describe in brief in geological time scale.

1.8. TEST YOUR SELF

1. In which period origin of land vascular plant takes place?
2. Which period of the geological time scale is known as the 'age of Cycads'?
3. Name the two major units used by two geologists for sub-dividing the geological history of the earth.
4. On the basis of time the geological history of the earth is divided into how many Eras?
5. Name the era which is called the age of angiosperms.

ANSWERS

1. Devonian (360 million years)
2. Triassic period of the mesozoic era
3. Time and strata
4. Five
5. Coenozoic era

UNIT-II

CHAPTER

1

CLASSIFICATION OF ANGIOSPERMS

STRUCTURE

- Introduction
- Aims of Classification
- Basis of Classification
- Ranks of Classification
- Systems of Classification
- Artificial Systems
- Natural Systems
- Phylogenetic Systems
- Recent Systems of Classification
- Plant Nomenclature
- Summary
- Student activity
  - Test yourself
  - Answers

LEARNING OBJECTIVES

By learning this chapter you will be able to know the various systems of classifications and binomial system of plant nomenclature.

1.0 INTRODUCTION

The **Anthophyta** (Gr. *anthos,* flower; *phyta,* plants) commonly called the **angiosperms** (Gr. *angeion,* vessel or receptacle; sperma, seed) form one of the two most highly evolved sub-classes of **Spermatophyta** (seed plants), the other being **Gymnosperms** (Gr. *gymno,* naked; *sperma,* seed). The spermatophyta have been recently estimated to include roughly about 300 families, 12,500 genera and 400,000 already known species. Of these, angiosperms alone include about 200,000 known species.

Man has been absolutely dependent on plants even in the early stage of civilization. The plants furnish most of our food, shelter, clothing fuel, medicine, etc, and furthermore the green plants are the greatest means of utilizing energy from the sun. The primitive man thus tried to group the plants according to ther economic uses. In the simplest form, classification is **the placement of plants, animals and objects into groups and categories for a clear understanding proper study and organization. Andrew Sugden** (1984) defined the word 'Classification' in Longman illustrated **Dictionary of Botany** as "the naming of species and their groups into families, divisions, etc. **Radford** (1986) stated that" Classification is the arrangement of groups of plants with particular circumscriptions by rank and position according to artificial criteria, similarities or phylogenetic relationships.[1, 2]

1. Taxonomy, one of the oldest field of biological science, is "the theory and practise of classification".

2. Systematic botany is the fact finding field of taxonomy which includes genetical and cytological studies as well as other techniques applicable to the problem. The branch of botany in which taxonomy is of principal interest is called *systematic botany.*

1.1. AIMS OF CLASSIFICATION

The aims of the classification are naming, describing and arranging the plants in such a manner that their relationship with regard to their descent from a common ancestory is clearly indicated. The ultimate object of classification is to arrange plants in such a way as to give an idea about the sequence of their evolution from simpler, earlier and more primitive types to more complex, more recent and more advanced types in different periods of the earth.

1.2. BASIS OF CLASSIFICATION

The classification of flowering plants may be based upon a great variety of characteristics possessed by them. We may use such features as environmental conditions, methods of obtaining food, anatomy, life-history, size of body, colour of flowers, uses in daily life, geographic distribution, etc. as the basis of classification. Thus, we may distinguish such groups as **saprophytic** plants, **simple** plants, **complex** plants, **alpine** plants and **land** plants and **water** plants, **shade** plants, and **sun** plants, **parasitic** plants and **lacustrine** (*L. lacus, a* lake) plants, etc. All of the above and many other types of classifications may be found in the books dealing with the varied interests that man takes in plants. As a rule, the **reproductive** or **generic** characters of a plant relating to the flower, are of a more permanent nature and are least affected by the changing environment than the **vegetative** characters relating to the form, shape, surface, division, colour, duration and dimensions, etc. of vegetative parts. Union of sepals, petals, stamens and carpels, epipetalous condition, placentation, hypogyny, perigyny and epigyny, number of floral parts, symmetry, number of cotyledons, presence or absence and nature of endosperm, structure of fruit and seed are the common reproductive characters used in classification. Out of the vegetative characters with the exception of a few, such as phyllotaxis, venation and the presence or absence of stipules, all the rest are discarded and seldom used because of their being very easily influenced by the changing environments when they show various sorts of modifications and metamorphoses.

1.3. RANKS OF PLANT CLASSIFICATION

Species, genus, family, order, class, and division are the six main ranks of plant classification in an ascending order. Each rank has its subcategories, *i.e.* towards the higher ranks, subform, form, subvarieties, varieties, and subspecies are the subcategories of **spectes**; subsection, section, and subgenus are the subcategories of **genus**; subtribe, tribe, and subfamily are the subcategories of **family**; suborder is the subcategory of **order**; subclass is the subcategory of **class**; and subdivision is the subcategory of **division**.

Several species are included within a genus, several genera within a family, several families within an order, several orders within a class, and several classes are included within a division. The classification broadly may, thus, be tabulated as under :

1. Plant kingdom.
2. Sub-kingdom or Sub-division.
3. Classes.
4. Sub-classes.
5. Series.
6. Cohorts.
7. Sub-cohorts.
8. Orders or Families.
9. Sub-orders or Sub-families.
10. Tribes.
11. Sub-tribes.
12. Genera.
13. Sub-genera.

14. Species.
15. Varieties.

1.4. SYSTEMS OF CLASSIFICATION

The past literature described three basic catogries of systems of classification :

1. Artificial systems
2. Natural systems
3. Phylogenetic systems.

1.5. ARTIFICIAL SYSTEMS

The earliest systems of classification were artificial and the systems of this nature remained dominant from 300 B.C. up to about 1830. Since very little information was available about the plants, these systems were based on a very few characters. The artificial systems propounded by early herbalists were based on habits (trees, herbs, shrubs, etc.), and the **Linnaeus'** sexual system on floral characters (particularly the number of stamens and carpels).

Theophrastus (370-285 B.C.)

Theophrastus (370-285 B.C.) the "grandfather of the modern botany", classified the plants into four groups; herbs, subshrubs, shrubs, and trees. He also distinguished between the nonflowering plants (cryptogams) and flowering plants (Phanerogams). He suggested that calyx and corolla are the modified leaves. He described nearly 500 plants in details, and certain names (*e.g. Asparagus, Daucas, and Narcissus*) are used even today in the same sense. The details of his works are available to the world in the form of books entitled "*Enquiry into plants*" and "*The causes of plants*".

Fig. 1. Theophrastus (370-285 B.C.)

Caius Plinius Secundus (23-79 AD)

Caius Plinius Secundus' (23-79 A.D.) voluminous and important works is available in the form of 37 volumes of *Natural History*. He described the biological, medicinal and agricultural aspects of the plants known to the world up to his time in these volumes, and Pliny's *Natural History* was among the first books to be printed by the movable type in the late 15th century. The word 'stamen' in its modern sense was first used by pliny.

Pedanion Dioscorides (62-128 A.D.)

Pedanion Dioscorides (62-128 A.D.), a physician of Asia Minor, described about 600 medicinal plants mainly from the Mediterranean in his book ***Materia Medica,*** written in Greek. Though this work has no taxonomic significance as compared with modern systems, there are certain series of related plants indicating that Dioscorides had some sense of relationship.

Carlous Linnaeus (1707-1778)

Carolus Linnaeus (1707-1778), a great Swedish naturalist, is rightly known as the **'father of modern botany'**. In 1730 he published ***Hortus Uplandicus*** wherein he enumerated the plants of the Uppsala Botanical Garden growing at that time. Later, in 1737, he published his famous ***Hortus Cliffortianus,*** based on the collection of plants in the garden of George Clifford at Hartecamp. His ***Genera Plantarum*** and ***Classes Platarum*** appeared in 1737 and 1738 respectively. Linnaeus ***Philosophia Botanica*** appeared in 1751 which contained a revised version of his system published previously in his ***Classes Plantarum***

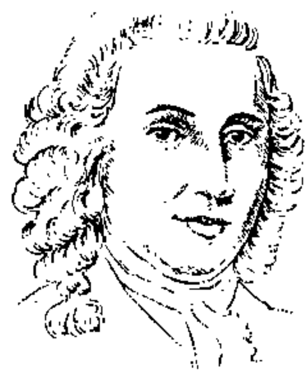


Fig. 2. Carolus Linnaeus (1707-1778)

* Known to botanical world as 'Pliny the elder'.

(1738) and ***Systema Naturae*** (1735). His ***Species Plantarum*** was published in 1753, a work where some 7,300 species are described and arranged according to his sexual system of classification. In this book **Linnaeus** introduced the consistent use of the binomial system of plant names.

Linnaeus recognised 24 classes determined on the basis of the number, size and union of stamens. The classes were subdivided into orders based, not on character, but on his idea of their relationships. Twenty four classes of **Linnaeus** are as follows :

(1) Monandria (stamen one)
(2) Diandria (stamens two)
(3) Triandria (stamens three)
(4) Tetrandria (stamens four)
(5) Pentandria (stamens five)
(6) Hexandria (stamens six)
(7) Heptandria (stamens seven)
(8) Octandria (stamens eight)
(9) Enneandria (stamens nine)
(10) Decandria (stamens ten)
(11) Dodecandria (stamens eleven to nineteen)
(12) Icosandria (stamens twenty or more, attached to the calyx)
(13) Polyandria (stamens twenty or more, attached to the receptacle)
(14) Didynamia (stamens didynamous)
(15) Tetradynamia (stamens tetradynamous)
(16) Monadelphia (stamens monadelphous)
(17) Diadelphia (stamens diadelphous)
(18) Polyadelphia (stamens polyadelphous)
(19) Syngenesia (stamens syngenesious)
(20) Gynandria (stamens adnate to the gynoecium)
(21) Monoecia (plants monoecious)
(22) Dioecia (plants dioecious)
(23) Polygamia (plants polygamous)
(14) Cryptogamia (flowers concealed, *i.e.*, algae, fungi, mosses, ferns)

Linnaeus' classification remained dominant for over 75 years. The "Species Plantarum" has been choosen by modern taxonomists as a starting point of present day nomenclature.

1.6. NATURAL SYSTEMS

These systems of classifications used as many taxonomic characters as possible to group taxa. Some of the natural systems of classification were given by **Adanson** (1727-1806), **A.L. de Jussieu** (1748-1836), **A.P. de Candolle** (1778–1841), **Bentham** (1800-1884) and Hooker (1817-1917).

Antoine Laurent de Jussieu (1748-1836)

De Jussieu, a French contemporary of **Linnaeus**, did not publish his results, but his nephew, **Antoine Laurent de Jussieu** (1748-1836) published his uncle's plan along with his own in "**Genera Plantarum Secundum Ordines Naturals Disposita**" (1789). His natural classification included a hundred orders (now mostly recognised as families) classified in fifteen classes as follows :

1. Acotyledones-cotyledones absent, cryptogams and some aquatic flowering plants.
2. Monocotyledones, stamens hypogynous.
3. Monocotyledones, stamens perigynous.
4. Monocotyledones, stamens epigynous.

5. Dicotyledones, Apetalae-stamens epigynous.
6. Dicotyledones, Apetalae stamens perigynous.
7. Dicotyledones, Monopetalae-stamens hypogynous.
8. Dicotyledones, Monopetalae-corolla hypogynous.
9. Dicotyledones, Monopetalae-corolla perigynous.
10. Dicotyledones, Monopetalae-corolla epigynous, anthers united.
11. Dicotyledones, Monopetalae-corolla epigynous, anthers distinct.
12. Dicotyledones, Polypetalae-stamens epigynous.
13. Dicotyledones, Polypetalae-stamens hypogynous.
14. Dicotyledones, Polypetalae-stamens perigynous.
15. Diclines, irregulares-Gymnosperms, Urticaceae, Euphorbias.

Jussieu's conception of perigyny is different from that of the present day.

Augustin Pyrame de Candolle (1778-1841)

Augustin Pyrame de Candolle (1778-1841), a French botanist, published his views on classification in his classic work, ***Theorie elementaire de la botanique***, published in 1813 in Paris. In this work he set forth the principles of a natural system of classification and further developed morphological approach to classification.

The system of **de Candolle** was similar to that of **de Jussieu** in many respects but it was certainly an improvement over that of the latter particularly in the treatment of the Dicotyledons. He divided the **Dicotyledons** into two groups on the basis of presence or absence of petals, the one with petals was subdivided on the basis of free or *fused petals and the former was further divided on the basis of the position of ovary.*

·Synopsis of A.P. **de Candolle's** system of classification is as follows :

I. Vascular Plants with Cotyledon

(I) Exogens or Dicotyledons; vessel arranged in a ring and embryo with two cotyledons.

(A) Flowers with perianth differentiated into calyx and corolla, *i.e.* perianth leaves in two series.

(a) Thalamiflorae-Petals free on the receptacle.

Cohort 1– Carpels many and stamens opposite to the petals.

Natural orders 1–8, Ranunculaceae, etc.

Cohort 2–parietal placentation, carpels solitary or many, connate.

Natural orders–Cruciferae, Violaceae etc.

Cohort 3–Ovary single.

Natural orders – Caryophyllaceae, Rutaceae etc.

Cohort 4–Fruit gynobasic.

Natural orders–Simarubeae etc.

Fig. 3. A.P. de Candolle (1778-1841)

(b) Calyciflorae –Flowers perigynous, petals free or fused, ovary inferior or superior.

Natural orders–epigynous flowers with gamopetalous corolla *e.g.* Rubiaceae, Compositae.

(c) Corolliflorae –Petals united, ovary superior.

Natural orders –Acanthaceae, Asclepiadaceae etc.

(B) Monochlamydeae –Perianth in one whorl.

(II) Plants with scattered vascular bundles, cotyledon one. It includes Monocotyledons and Cycadaceae with 27 orders.

II. Plants without cotyledons

(a) Foliaceous – Mosses and Liverworts.

(b) Non–foliaceous of unknown sexuality. Fungi, Lichens, etc.

Robert Brown (1773-1858), a Scottish botanist, published no system of his own but proved that the Gymnosperms were a discrete group with naked ovules and seeds.

Adolphe Theodore Brongniart (1801-1876), a French botanist treated Apetalae as a reduced members of a polypetalae.

Betham and Hooker's Systems of Classification (1817-1911)

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

The following table gives a summary of the number of families, genera and species of flowering plants known at the time of the publication of ***Genera Plantarum.*** Their system was widely accepted in Britain and Commonwealth countries but in Europe and North America it did not held much ground where Englerian system has been preferred.

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

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

Fig. 4, George Bentham (1800-1884)

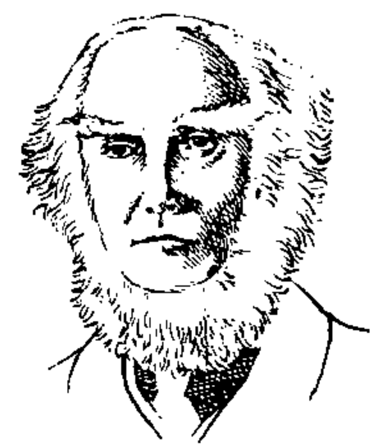


Fig. 5. Hooker (1817-1911)

Bentham and **Hooker** divided the seed plants into Dicotyledons, Gymnosperms and Monocotyledons. They placed Ranales in the beginning and grasses at the end. Their treatment is inconsistent with our present day understanding of these groups. The gymnosperms are a distinct group from the angiosperms and their placement between the Dicotyledons and Monocotyledons is inconsistent with our current understanding of this group. The position of Apocarpeae among Monocotyledons is incorrect and they should have been placed at the first place in the Monocotyledons.

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

I. Dicotyledones

Embryo with two cotyledons; stem with open bundles; usually reticulate venation; flowers usually tetra-or pentamerous :

Group I. **Polypetalae.** Flowers usually with two whorls of perianth, inner whorl or corolla free.

Series 1. Thalamiflorae. Sepals usually distinct and separate, free from ovary, petals 1, 2 or indefinite, stamens hypogynous; ovary superior.

It includes six orders from Ranales to Malvales.

Series 2. Disciflorae. Sepals distinct or united, free, from ovary; disk usually conspicuous as a ring cushion, or spread over the base of the calyx tube, or confluent with the base of the ovary; stamens definite; ovary superior. It includes 4 orders from Geraniales to Sapindales.

Series 3. Calyciflorae. Sepals united, rarely free' often adnate to ovary; petals uniseriate, peri-or epigynous; disk adnate to base of calyx, rarely raised into a torus or gynophore; stamens perigynous, ovary often inferior. It includes 5 orders from Rosales to Umbellales.

Group II. **Gamopetalae.** Petals are united.

Series 1. Inferae. Ovary inferior, stamens usually many or as many as corolla lobes. It includes three orders *i.e.,* Rubiales, Asterales, Campanulales.

Series 2. Heteromerae. Ovary usually superior, stamens epipetalous or free from corolla, opposite or alternate to its segments or twice as many; carpels more than two. It includes three orders from Ericales to Ebenales.

Series 3. Bicarpellatae. Ovary usually superior, stamens as many as or less than corolla lobes, alternate to them, carpels two rarely one or three. It includes four order from Gentianales to Lamiales.

Group III. **Monochlamydeae or Incompletae.** Flowers usually with one whorl of perianth, commonly sepaloid or none.

Series 1. Curvembryae. Terrestrial plants with usually hermaphrodite flowers; stamens generally equal to perianth segments; ovule usually solitary, embryo curved. It includes seven families.

Series 2. Multiovulatae Aquaticae. Aquatic plants with syncarpous ovary and indefinite ovules.

Series 3. Multiovulatae. Terrestres. Terrestrial plants with syncarpous ovary and indefinite ovules.

Series 4. Microembryae. Ovary syncarpous or apocarpous; ovules solitary or few; embryo very small surrounded by endosperm.

Series 5. Daphnales. Ovary usually of one carpel, ovules solitary or few; perianth perfect, sepaloid; stamens perigynous.

Series 6. Achlamydosporeae. Ovary unilocular, one to three ovules; seed without testa.

Series 7. Unisexuales. Flowers unisexual; ovary syncarpous or of one carpel; perianth much reduced or absent.

Series 8. Anomalous Families. Unisexual families of doubtful or unknown affinities.

II. Monocotyledones

Embryo with one cotyledon; stem with closed vascular bundles; leaves with parallel venation; flowers usually trimerous.

Series 1. Microspermae. Inner perianth petaloid; ovary inferior with parietal placentation; seed minute, exalbuminous.

Series 2. Epigynae. Perianth partly petaloid; ovary inferior, endosperm abundant.

Series 3. Coronarieae. Inner perianth petaloid; ovary usually free, superior, endosperm abundant.

Series 4. Calycinae. Perianth sepaloid, hebaceous, condition of ovary as in series 3.

Series 5. Nudiflorae. Perianth none or represented by hairs or scales; carpels one or several, syncarpous; ovary superior, ovules indefinite.

Series 6. Apocarpae. Perianth in one or two whorls, or none, ovary superior, apocarpous; endosperm absent.

Series 7. Glumaceae. Flowers solitary, sessile in the axils of bracts and arranged in heads or spikelets with bracts; perianth of scales or none; ovary unilocular, one ovule; endosperm present *e.g.* Gramineae, Cyperaceae.

Critical assessment of Bentham and Hooker's System :

This system though proposed after Darwin's work was not phylogenetic in approach. It was a natural system based upon Jussieu and de Candollean scheme. The families and groups are more natural and depended upon fusion and reduction of floral parts. The **Polypetalae** were subdivided into **Thalamiflorae, Disciflorae** and **Calyciflorae**. The gamopetalous families were grouped together under **Gamopetalae** and the apetalous families under **Monochlamydeae**.

Merits and demerits of Bentham and Hooker's System

Merits.

1. The description of families and genera is very accurate.
2. The system is very handy for identification purposes.
3. The system is of great practical convenience.

The British and Commonwealth herbaria therefore still adopt this system in arrangement of families.

4. Each family had a synopsis at the beginning which is very useful in identification.
5. The system starts from Ranales, which are now universally considered to be most primitive living angiosperms.
6. Larger genera subdivided into subgenera and sections.
7. They believed in evolution through reduction and hence placed monocots after dicots; even in dicots, the dichlamydeous polypetalae and gamopetalae were placed before the uniseriate monochlamydeae.
8. The gamopetalae placed after polypetalae is justified since union of petals is considered to be an advanced feature.
9. The polypetalae includes Thalamiflorae and Calyciflorae of de Candolle. But Bentham and Hooker distinguished a new series Disciflorae which includes orders which cannot be assigned to Thalamiflorae of Calyciflorae.
10. The 3 series–Thalamiflorae, Disciflorae and Calyciflorae show gradual evolutionary advance from marked hypogyny to epigyny.
11. Treating cucurbitaceae and Umballiferae (Apiaceae) at the end of Polypetalae as connecting links between poly-and gamopetalous families.
12. Creation of Monochlamydeae at the end of Dicots.
13. Disputed families included in Ordines anomali.
14. Placing of unisexual monocot families after bisexual families *e.g.* Palmae and Areaceae after Liliaceae.
15. The series Glumaceae with extremely reduced flowers and inflorescences, placed at the end of the flowering plants.
16. The system was never conceived by its authors on the basis of phylogeny. The theory of organic evolution (theory of descent) was announced independently by Darwin and Wallace in 1859. So, any criticism of the system on the basis of phylogeny is not too justified.

Demerits

1. The system does not give any idea as to the evolutionary history of any genus, family or order.
2. In this system grouping of plants is mainly based on single and artificial characters; with the result, that closely allied families are placed widely apart.
3. The group ``Monochlamydeae" is entirely artificial.

4. Gymnospermae is placed between the Dicotyledones and Monocotyledones, which is extremely anomalous.

5. The system does not show any phylogenetic relationship. The main demerit is that this system does not give us any idea as to the evolutionary history of any genus, family or order nor does it give any idea of phylogenetic relationship between them.

6. Compositae (Asteraceae) is a highly advanced family and placed in Inferae at the beginning of Gamopetalae.

7. Advanced families like Orchidaceae and Scitamineae are treated in the beginning of monocots.

8. Liliaceae and Amaryllidaceae were kept apart though they are very closely related.

9. The Amaryllidaceae is more allied to Liliaceae but is clubbed with Scitamineae in series Epigynae, on account of inferior gynoecium.

10. The position of series Apocarpae is unsatisfactory due to its free and superior carpels.

OUTLINES OF THE SYSTEM OF CLASSIFICATION PROPOSED BY BENTHAM AND HOOKER
SEED PLANTS OR PHANEROGAMS

Class I DICOTYLEDONAE — Class II GYMNOSPERMAE — Class III MONOCOTYLEDONAE

Sub-class 1. Polypetalae — Sub-class 2. Gamopetalae — Sub-class 3. Monochlamydeae

Seties I
Thalamiflorae
Order I.
Ranales
Families
Ranunculaceae
magnoliaceae
Anonaceae
(5 other families)
Order 2.
Parietales
Families
Papaveraceae
Cruciferae
Capparidaceae
(6 other families)
Order 3.
Polygalineae
(4 families)
Order 4.
Caryophyllineae
Family
Caryophyllaceae
(3 other familites)
Order 5.
Guttiferales
(6 families)
Order 6.
Malvales
Families
Malvaceae
Tiliaceae
(1 more family)

Seties II
Disciflorae
Order 1.
Geraniales
Families
Rutaceae
meliaceae
(9 other families)
Order 2
Olacales
(3 families)
Order 3
Celastrales
(4 families)
Order 4
Sapindales
(5 families)

Seties III
Calyciflorae
Order I.
Rosales
Families
Leguminosae
Rosaceae
(7 other families
Order 2.
Myrtales
Family
Myrfaceae
(5 other families)
Order 3.
Passiflorales
Family
Cucurbitaceae
(6 other families)
Order 4.
Ficoidales
(2 families)
Order 5.
Umbellales
Family
Umbelliferae
(2 other families))

Seties I
Inferae
Order 1.
Rubiales
Family
Rublaceae
(1 more family)
Order 2.
Asterales
Family
Compositae
(3 other families)
Order 3.
Campanales
(3 families)

Seties II
Heteromerae
Order 1.
Ericales
(6 families)
Order 2.
Primulales
(3 families)
Order 3
Ebenales
(3 families)

Seties III
Bicarpellatae
Order I.
Gentianales
Families
Apocynaceae
Asclepladaceae
(4 other families)
Order 2.
Polemoniales
Families
Convolvulaceae
Solanaceae
(3 other families)
Order 3.
Personales
Families
Scrohulariaceae
Acanthaceae
(6 other families)
Order 4.
Lamiales
Families
Verbenaceae
Lablatae
(3 other families)

Seties I
Curvembryeae
Family
Amaranthaceae
Chenopodiaceae
polygonaceae
(4 other families)
Series 2.
Multiovulatae aquaticae
(1 family)
Series 3.
Multiovulatae terrestres
(3 families)
Series 4.
Microembryeae
(4 families)
Series 5.
Daphnales
(5 families)
Series 6.
Achlamydosporeae
(3 families)
Series 7.
Unisexuales
Families
Euphlorbiaceae
Urticaceae
(7 other families)
Series 8.
Ordines anomali
(4 families)

Seties I
Microspermae
(3 families)
Family
Orchidaceae
Series 2.
Epigynae
Family
Siltamineae
(6 other families)
Series 3.
Coronarieae
Family
Lillaceae
(7 other families)
Series 4
Calycineae
Family
Palmae
(2 other families)
Series 5.
Nudiflorae
(5 families)
Series 6.
Apocarpae
(3 families)
Series 7.
Glumaceae
Families
Cyperaceae
Gramineae
(4 other families)

Phylogenetic systems

These systems of classification used as many taxonomic characters as possible in addition to the phylogenetic (evolutionary) interpretations. Some of the phylogenetic systems of classification were proposed by **Eichler** (1839-1899), **Engler** (1844-1930) and **Prantl** (1849-1893), **Bessey** (1845-1915), **Wettstein** (1862-1931), **Hallier** (1868-1938), **Hutchinson** (1884-1972), **Takhtajan** (1980), **Cronquist** (1981), **Dahlgren** (1981) and **Thorne** (1981).

August Wihelm Eichler (1839-1889)

Eichler (1883), a German botanist, put forth a widely accepted system of classificati on of plants. This system may be considered as a transitional phylogenetic system. The schematic representation of Eichler's classification is as follows :

Plant kingdom

1. Cryptogamae (Non seed plants)
   Divisions
   1. Thallophyta : Algae, Fungi, Lichens
   2. Bryophyta : Liverworts and Mosses
   3. Pteridophyta : Equisetineae, Lycopodineae and Filicineae
2. Phanerogamae (Seed plants)
   Divisions
   1. Grymnospermae
   2. Angiospermae
      Class
      1. Monocotyledons (7 orders)
      2. Dicotyledons
         Class.
         1. Choripetalae (20 orders)
         2. Sympetalae (9 orders)

Adolph Engler (1844-1930) and **Karl A.E. Prantl** (1849-1893), the two German botanists published a twenty-volume work, ***Die natiirlichen Pflanzenfamilien*** (1887-1899) wherein they classified the plants of the world. from algae to angiosperms, according to their system of classification. This system has gone under some changes in ***Syllabus der Pflanzenfamilien***, a one volume work which was published in several editions, the latest (12th edition) appeared in 1964.

The significant feature of their system is that they placed Monocotyledons before Dicotyledons, considered the orchids to be more highly evolved than the grasses, the apetalous and catkin bearing Dicotyledons (Amentiferae) as primitive to the flowers which bear petals and simple unisexual flowers. These views are, however, not acceptable to most of the recent phylogenetists. The amalgamation of the Polypetalae and Apetalae (of Bentham and Hooker) was certainly a forward step.

Fig. 6, Adolf Engler (1844-1930)

Fig. 7. Karl Prantl (1849-1893)

The following is the outline of the Engler and Prantl's system of classification :

Class 1. Monocotyledoneae

1. Order : Pandanales
2. Order : Helobiae
3. Order : Triuridales
4. Order : Glumiflorae
5. Order : Principes
6. Order : Synanthae

7. Order : Spathiflorae
8. Order : Farinosae
9. Order : Liliiflorae
10. Order : Scitamineae
11. Order : Microspermae

Class 2. Dicotyledoneae

Subclass Archichlamydeae

12. Order : Verticillatae
13. Order : Piperales
14. Order : Salicales
15. Order : Garryales
16. Order : Myricales
17. Order : Balanopsidales
18. Order : Leitneriales
19. Order : Juglandales
20. Order : Batidales
21. Order : Julianales
22. Order : Fagales
23. Order : Urticales
24. Order : Proteales
25. Order : Santalales
26. Order : Aristolochiales
27. Order : Polygonales
28. Order : Centrospermae
29. Order : Ranales
30. Order : Rhoeadales
31. Order : Sarraceniales
32. Order : Rosales
33. Order : Geraniales
34. Order : Sapindales
35. Order : Rhamnales
36. Order : Malvales
37. Order : Parietales
38. Order : Opuntiales
39. Order : Myrtiflorae
40. Order : Umbelliflorae

Subclass Metachlamydeae (Sympetalae)

41. Order : Ericales
42. Order : Primulales
43. Order : Plumbaginales
44. Order : Ebenales
45. Order : Contortae
46. Order : Tubiflorae
47. Order : Plantaginales
48. Order : Rubiales
39. Order : Cucurbitales
40. Order : Campanulatae

Critical assessment of Engler's System

Engler's system is based upon his theoretical concept of a primitive flower. It supposed that the angiosperm flower was derived from a gymnosperm strobilus. The ancestral strobilus was unisexual either megasporangiate or microsporangiate along with their sporophylls. It produced the catkin type of inflorescence, in angiosperms which are either staminate or pistillate. The bisexual flower was derived from this unisexual type. Hence Engler placed the Amentiferae in the beginning of Archichlamydeae. Here the flowers were either naked or having a monochlamydous bract like perianth. The dichlamydous and sympetalous (gamopetalous) families were considered more evolved. Engler considered that the gymnosperms gave rise to the Amentiferae on the one hand and the monocots on the other. Angiosperms were therefore polyphyletic in origin. In fact Engler never believed in a linear system of evolution and therefore never tried to draw an evolutionary tree.

The primitive position of Amentiferae has been criticized by a number of botanists who have laid evidences that the anatomy and other featurs of this group can be best interpreted as a consequence of reduction rather than as a primitive condition. Amentiferae would thus be a highly specialized group derived from dichlamydous and bisexual flowers. But as recently as 1957 **Helsop-Harrison** has mentioned that all unisexual angiosperms need not have arisen from bisexual type and it could even be a primitive condition. Thus this point remains unsolved.

Richard von Wettstein (1862-1931), was an Austrian systematist. His classification was similar to that of Engler's in most respects. He considered the dicotyledons to be primitive and the monocotyledons to be derived from them through Ranales. In general his system of classification was a much better phylogenetic classification than that of the Engler's.

Phylogenetic System of Bessey

Charles Edwin Bessey (1845-1915), was the first American to make a major contribution to the knowledge of plant relationship and classification. His system now known as **Besseyan system**, was evolved in **"The Phylogenetic Taxonomy of Fowering Plants".** The system was based upon a series of 'dicta' or statements of guiding principles used to determine the degree of primitiveness or advancement, of the plant groups. **Bessey** took Ranales as the basal group from which both monocotyledons and other groups of dicotyledons have evolved, but also believed that all flowering plants originated from strobiliferous, cycad ancestors.

Hans Hallier (1868-1938), was a German botanist. His system closely resembled that of **Bessey**. He made much use of ovule structure and position than other workers.

Alfred Barton Rendle (1865-1938), Director of British Museum London, in his two volumes **"Classification of Flowering Plants"** classified plants chiefly according to the Engler and Prantl's system of classification.

Phylogenetic System of Hutchinson

John Hutchinson of Royal Botanic Gardens, Kew has proposed a system which first appeard in Kew bulletins and later in his **"Families of Flowering Plants** (1926, 34) and (1959) Vol. I Dicotyledons and Vol. II Monocotyledons". His system is somewhat like that of Bessey. Hutchinson's revised classification has been based on 24 principles which are similar to Bessey's dicta and are as follows :

Fig. 8. John Hutchinson (1884-1972).

1. Evolution is both upwards and downwards.
2. Evolution does not necessarily involve all organs of plant at a time.
3. Evolution has generally been consistent.

4. The trees and shrubs are more primitive than herbs in certain groups.
5. In one family or genus, the trees and shrubs are older than climbers.
6. Perennials are older than biennials and from biennials the annuals are derived.
7. Aquatic flowering plants are derived from terrestrial ones.
8. Collateral vascular bundles arranged in a ring is a primitive condition *e.g.* dicots..
9. Spiral arrangement of leaves is a primitive character.
10. Simple leaves are primitive than compound leaves.
11. Bisexual flowers are primitive than unisexual.
12. Solitary flowers are more primitive than being arranged in an inflorescence.
13. Spiral arrangement of floral parts is a primitive condition.
14. Polymerous condition is primitive than definite numbers.
15. Apetalous flowers are derived from petaliferous flowers.
16. Polypetaly is primitive than gamopetaly.
17. Actinomorphic condition is primitive than zygomorphic.
18. Hypogyny is primitive than epigyny and perigyny.
19. Apocarpous condition is primitive than syncarpous.
20. Many carpelled condition is primitive than few or one carpel.
21. Endospermic seeds are primitive.
22. Indefinite number of stamens are in primitive flowers.
23. Separate stamens precede connate stamens.
24. Simple fruits are more primitive than aggregate fruits.

Critical assessment of Hutchinson's System

Hutchinson imagined the angiosperms to have originated from a Bennettitaliean stock like **Cycadoidea** along two lines. On one side the woody arborescent types arose and side by side the non-woody herbaceous types also arose. They were termed Lignosae and Herbaceae respectively. The monochlamydeae was considered polyphyletic from these groups and hence this group was altogether omitted. The Magnoliales represented the most primitive of Ligonsae and Ranales and most primitive of Herbaceae.

This system separated families which were otherwise closely similar because they were either woody or herbaceous. Thus herbaceous Umbelliferae and woody Araliaceae or Cornaceae were separated even though their floral characters were very similar. Similarly the Labiatae, from the woody Verbenacae or the Bignoniaceae from the Scrophulariaceae and Genseriaceae.

The main weakness of the system seems to be that all the emphasis has been placed only on the herbaceous and woody habit and neglecting other equally important floral characters. But it must be said to the credit of **Hutchinson** that his description of families is very correct and that he provided a key which is extremely useful in identification of a family. Hutchinson's system is not useful for herbarium keeping and therefore it has not been adopted in any herbaria.

Karl Christian Mez (1866-1944), a German professor of botany, evolved the theory that the relationships between the larger groups of genetically related plants could be determined by study and analysis of their protein reactions. This immunological approach is known as **serum diagonosis**.

7.8. RECENT SYSTEMS OF CLASSIFICATION

Takhtajan's system (1980) :

The latest classification of **Takhtajan** was published in 1980 with the heading "**Outline of the classification of flowering plants (Magnoliophyta)**" in the Botanical Review*. His first paper regarding classification was published on the structural types of gynoecium and placentation (1942) in which he gave a very preliminary phyletic diagram of angiosperms orders. His actual system of classification was published in 1954 as a appendix in his book on the origin of angiosperms (English translation published in 1958). In 1959 his general system of the angiosperms classification was published with some important modifications. In 1966 he gave a more detailed rationale for the delimitation and arrangement of families and orders than was in 1959. After 1966 the system of classification has been gradually undergoing some modification (*e.g.* Takhtajan, 1959, 1973).

The main criteria used by **Takhtajan** in evaluating the relative degree of advancement of flowering plants were growth habit, leaves and leaf arrangement stomatal apparatus, nodal structure, wood anatomy, inflorescences; general floral structure – androecium, pollen grains, carpels, gynoecium and placentation, ovules, pollination, gametophytes and fertilization, seeds and fruits.

Takhtajan (1980) divided Division Magnoliophyta or angiospermae in two classes – Magnoliopsida or dicotyledones and Liliopsida or monocotyledones. He further divided magnoliopsida into 7 sub-classes, 20 super orders and 71 orders and Liliopsida or monocotyledones into 3 sub-classes, 8 superorders and 21 orders. In all he recognizes 92 orders and 310 families of angiosperms.

Outline of Armen L. Takhtajan's (1980) Classification

Division	:	MAGNOLIOPHYTA (Angiospermae)
Class	:	Magnoliopsida or Dicotyledones
Sub-class	:	A Magnoliodae

Super order I. Magnolianae : Orders 1-Magnoliales (8) † . 2-Illiciales (2), 3-Laurales (10), 4-Piperales (2), 5-Aristolochiales (1).

Super order II. Rafflesinae : Orders : 6-Rafflesiales (2).

Super order III. Nymphaeanae : Orders 7. Nymphaeales (3), 8-Nelumbonales (1).

Sub-class B. Ranunculidae.

Super order IV. Ranunculanae : Orders 9-Ranunculales (7), 10-Papaverales (1), 11-Sarraceniales (1).

Sub-class C. Hamamelididae

Super order V. Hamamelidanae : Orders 12-Trochodendrales (2), 13-Circidiphyllales (1), 14-Eupteleales (1), 15-Didymelales (1), 16-Hamamelidales (6), 17-Eucommiales (1), 18-Urticales (5), 19-Barbeyales (1), 20-Casuarinales (1), 21-Fagales (2), 22-Balanopales (1), 23-Leitneriales (1),

Super order VI. Juglandanae : Orders : 24-Myricules (1), 25-Juglandales (2).

Sub-class : D. Caryophyllidae.

Super order VII. Caryophyllanae. Orders : 26-Caryophyllales (14), 27-Polygonales (1).

Super order VIII. Plumbaginanae. Order : 28-Plumbaginales (1).

Sub-class : E. Dilleniandae

Super order IX : Dillenianae : order 29-Dilleniales (2), 30-Paeoniales (1), 31-Theales (19), 32-Violates (14), 33-Begoniales (2), 34-Capparales (5), 35-Tamaricales (3), 36-Salicales (1).

Super order X : Ericanae : Orders : 37-Ericales (8), 38-Ebenales (5), 39-Primulales (3).

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* Takhtajan. Armen L. 1980 outline of the classification of flowering plants. The Botanical review Vol. 46, No. 3, 225-359.

† Number in parenthes is infront order indicates number of families in that particular order.

Super order XI : Malvanae - Orders : 40-Malvales (10), 41-Euphorbiales (4), 42-Thymeleales (1).

Sub-class : F. Rosidae.

Super order XII. Rosanae -Orders : 43-Saxifragales (25), 44-Rosales (3), 45-Fabales (1), 46-Connariales (1), 47-Podostemales (1), 48-Nepenthales (1).

Super order XIII : Myrtanae Orders : 49-Myrtales (14).

Super order XIV : Rutanae. Order : 50-Rutales (15), 51-Sapindales (13), 52-Geraniales (8), 53-Polygalades (6).

Super order XV : Aralianae. Orders : 54-Cornales (10), 55-Araliales (Apiales) (2).

Super order XVI : Celastranae. Orders : 56-Celastrales (15), 57-Santalales (6), 58-Rhamnales (3), 60-Elaeagnales (1).

Super order XVII : Proteanae. Order : 61-Proteales (1).

Sub-class : G Asteridae.

Super order XVIII : Gentiananae. Order : 62-Gentianales (8), 63-Oleales (1), 64-Dipsacales (5), 65-Loasales (1).

Super order XIX : Lamianae. Orders : 66-Polemoniales (7), 67-Lamiales (3), 68-Scrophulariales (16).

Super order XX : Asternae. Orders : 69-Companuales (4), 70-Calycerales (1), 71-Asterales (1).

Class : Liliopsida (Monocotyledones).

Sub-class : A–Alismalidae

Super order - I. Alismatanae. Orders : 1-Alismatales (4), 2-Najadales (10).

Sub-class : B. Liliidae.

Super order II. Triuridanae. Order 3-Triuridales (1).

Super order III. Lilianae. Orders 4-Liliales (23), 5-Smilacales (6), 6-Burmanniales (2), 7-Orchidales (1), 8-Bromeliales (1).

Super order IV. Juncanae. Orders 9-Juncales (2), 10-Cyperales (1).

Super order V. Commelinales (4), 12-Eriocaulales (1), 13-Restionales (5), 14-Hydatellales (1), 15-Poales (1).

Super order VI. Zingiberanae. Orders 16-Zigiberales (8).

Sub-class : C. Arecidae.

Super order VII. Arecanae. Orders 17-Arecules (1), 18-Cyclanthales (1), 19-Pandanales (1), 20-typhales (1).

Super order VIII. Aranae. Orders : 21-Arales (2).

Merits of Takhtajan's Classification

1. Dicots (Magnoliopsida) are discussed before monocots (Liliophsida).
2. Dicots begin with the Magnoliales, which are most primitive living angiosperms.
3. The order Alismatales is the starting point of monocots, being most primitive living monocots.

Cronquist's System (1981)

Cronquist (1981) on the basis of a wide range of taxonomic characters of phylogenetic importance presented a phylogenetic classification. With the help of synoptic keys and detailed charts, he grouped the angiospermic families into orders and subclasses on a worldwide basis. He considereed pteridosperms (seed ferns) as the probable ancestors of angiosperms.

In this system class Magnoliopsida (Dicots) has been divided into six subclasses *i.e.* Magnoliidae, Hamamelidae, Caryophyllidae, Dilleniidae, Rosidae and Asteridae. Of them, the Magnolidae were thought to be the basal complex and all the remaining five subclasses were derived from it separately. Asteridae formed the most advanced group of dicots.

In this system Class Liliopsida (Monocots) has been divided into five subclasses, *i.e.* Alismatidae, Arecidae, Commelinidae, Zingiberidae, and Lillidae. **Cronquist** (1981) proposed that Liliopsida have been arised from aquatic ancestors.

Cronquist (1981) recognized 2 classes, 11 subclasses, 83 orders and 383 families and about 2,19,300 species among the angiosperms. A brief outline of **Cronquist's** system of classification is mentioned below :

Outline of Arthur Cronquist's (1981) Classification

Division -MAGNOLIOPHYTA

Class-1 : *Magnotioprida* (Dicots)

Sub-class-1. *Magnoliidae*

Orders : 1. Magnoliales (10), 2. Laurales (8), 3. Piperales (3), 4. Aristolochiales (1), 5. Illiciales (2), 6. Nymphaeales (5), 7. Ranunculales (8), & papaverales (2).

Sub-class 2. *Hamamelidae*

Orders : 1. Trochodendrales (2), 2-Hamamelidales (5), 3. Daphniphyllales (1), 4. Didymelales (1), 5. Eucommiales (1), 6. Urticales (6), 7. Leitneriales (1), 8. Juglandales (2), 9. Myricales (1), 10. Fagales (3), 11. Casuarinales (1).

Sub-class 3. *Caryophyllidae*

Orders : 1. Caryophyllales (12), 2. Polygonales (1), 3. Plumbaginales (1).

Sub-class 4. *Dilleniidae*

Orders : 1. Dilleniales (2), 2. Theales (18), 3. Malvales (5), 4. Lecythiadales (1), 5. Nepenthales (3), 6. Violales (24), 7. Salicales (1), 8. Capparales (5), 9. Batales (2), 10. Ericales (8), 11. Diapensiales (1), 12. Ebenales (5), 13. Primulales (3).

Sub-class 5. *Rosidae*

Orders : 1. Rosales (24), 2. Fabales (3), 3. Proteales (2), 4. Podostemales (1), 5. Haloragales (2), 6. Myrtales (12), 7. Rhizophorales (1), 8. Cornales (4), 9. Santalales (10), 10. Rafflesiales (3), 11. Celastrales (11), 12. Euphorbiales (4), 13. Rhamnales (3), 14. Linales (5), 15. Polygalales (7), 16. Sapindales (15), 17. Geraniales (5), 18. Apiales (2).

Sub-class 6. *Asteridae*

Orders : 1. Gentianales (6), 2. Solanales (8), 3. Lamiales (4), 4. Callitrichales, 5. Plantaginales (1), 6. Scrophulariales (12), 7. Campanulales (7), 8. Rubiales (2), 9. Dipsacales (4), 10. Calycerales (1), 11. Asterales (1).

Class 2. *Liliopsida* (Monocots)

Sub-class 1. *Alismatidae*

Orders : 1. Alismatales (3), 2. Hydrocharitales (1), 3. Najadales (10), 4. Triuridales (2).

Sub-class 2. *Arecidae*

Orders : 1. Arecales (1), 2. Cyclanthales (1), 3. Pandanales (1), 4. Arales (2).

Sub-class 3. *Commelinidae*

Orders : 1. Commelinales (4), 2. Eriocaulales (1), 3. Restionales (4), 4. Juncales (2), 5. Cyperales (2), 6. Hydatellales (1), 7. Typhales (2).

Sub-class 4. *Zingiberidae*

Orders : 1. Bromeliales (1), 2. Zingibreales (8).

Sub-class 5. *Liliidae*

Orders : 1. Liliales (15), 2. Orchidales (4).

Cronquist (1957) recognised 6 sub-classes and 56 orders in Magnoliatae or dicotyledons and 4 sub-classes and 18 orders in Liliatae or monocotyledons and omitted super-orders and some orders in the system of **Takhtajan**.

Rolf Dahlgren (1983)

Rolf Dahlgren, Professor at the Botanical Museum, University of Copenhagen, Gothersgrado 130. D.K. -1123 Copenhagen, K, Denmark, proposed a new classification-of angiosperms on the basis of characters from developing fields of micro-and macro molecular chemistry, ultrastructure and micromorphology in combination with macromorphology, anatomy, embryology, palaeontology, cytology, biological interaction, and distribution. *Methods used in its construction differ from most* previous attempts at classification, in two ways–

1. That many modern groups of angiosperms are ancestors of other living groups. Thus the Magnoliales are not seen as an ancestral group, but as a group which has retained a high proportion of ancestral characters.

2. The characters used in the classification have been drawn consistently from a wide fields of biology.

Outline of Dahlgren's (1983) Classification

Class : MAGNOLIOPSIDA (= Angiospermae)

Sub-class (1) : Magnoliidae (= Dicotyledoneae)

Super order I. Magnoliiflorae : Orders : 1. Annonales (5)*, 2. Aristolochiales (1), 3. Rafflesiales (2), 4. Magnoliales (4), 5. Latoriades (1), 6. Chloranthales (1), 7. Illiciales (2), 8. Laurales (6), 9. Nelumbonales (1).

Super order II. Nymphaeiflorae : Order : 10. Piperales (2), 11. Nymphales (3).

Super order III. Ranunculiflorae : Order : 12. Ranunculales (8), 13-Papaverales (2).

Super order IV. Caryophylliflorae : Order : 14. Caryophyllales (4).

Super order V. Polygoniflorae : Order : 15. Polygonales (1).

Super order VI. Plumbaginiflorae : Order 16. Plumbaginales (2).

Super order VII. Malviflorae : Orders : 17. Malvales (13), 18. Urticales (6), 19. Euphorbiales (5), 20. Thymeleales (2), 21. Rhamnales (1), 22. Elaeagnales (1).

Super order VIII. Violiflorae : Orders : 23. Violales (10), 24. Cucurbitales (3), 25. Salicales (1), 26. Tamaricales (2), 27. Cappariales (7), 28. Salvadorales (1).

Super order IX. Theiflorae : Orders : 29. Dilleniales (1), 30. Paceoniales (1), 31. Theales (18).

Super order X. Primuliflorae : Orders : 32. Primulales (5), 33. Ebenales (4).

Super order XI. Rosflorae : Orders : 34. Trochodendrales (2), 35. Cercidiphyllales (2), 36. Hamamelidales (3), 37. Geissolomomales (1), 38. Balanopales (1), 39. Fugales (3), 40. Juglandales (2), 41. Myricales (1), 42. Casuarinales (1), 43. Buxales (3), 44. Cunoniales (7), 45. Saxifragales (7), 46. Droserales (3), 47. Gunnerales (1), 48. Rosales (6).

Super order XII. Podostemiflorae : Orders : 49. Podostemales (1).

Super order XIII. Myrtiflorae : Orders : 51. Haloragales (1), 52. Rhizophorales (1), 53. Myrtales (14), 54. Chrysobalanales (1).

Super order XIV. Myrtiflorae. Orders : 51. haloragales (1), 52. Rhizophorales (1), 53. Myrtales (14), 54. Chrysobalanales (1).

Super order XV. Fabiflorae : Order : 55. Fabales (3).

Super order XVI. Rutiflorae : Orders : 56. Sapindalales (15), 57. Rutales (7), 58. Polygonales (5), 59. Geraniales (16), 60. Balsaminales (1), 61. Tropaeolales (2).

Super order XVII. Santaliflorae : Orders : 62. Celastrales (5), 63. Vitales (1), 64. Santalales (7).

Super order XVIII. Balanophoriflorae : Orders : 65. Balanophorales (2).

Super order XIX. Araliflorae : Orders : 66. Pittosporales (3), 67. Araliales (2).

Super order XX. Asteriflorae : Orders : 68. Campanulales (3), 69. Asterales (1).

Super order XXI. Solaniflorae : Orders : 70. Solanales (7), 71. Boraginales (5).

Super order XXII. Corniflorae : Orders : 72. Fouquieriales (1), 73. Ericales (10), 74. Eucommiales (1), 75. Sarraceniales (1), 76. Cornales (27), 77. Dipsacales (5).

Super order XXIII. Loasaliflorae : Order : 78. Loasales (1).

* *Number in parenthesis infront order indicates number of families in that particular order.*

Super order XXIV. Gentianiflorae : Orders : 79. Goodeniales (1), 80. Oleales (1); 81. Gentianales (10).

Super order XXV. Lamiiflorae : Orders : 82. Scrophulariales (15), 83. Hippuridales, (1), 84. Lamiales (3), 85. Hydrostachyales (1).

Sub-class (2) : Liliidae (Monocotyledoneae).

Super order I. Alismataflorae : Orders : 1. Hydrocharitales (3), 2. Alismatales (2). 3-Zosterales (8).

Super order II. Triuridiflorae : Order : 4. Triuridales (1).

Super order III. Ariflorae : Order : 5. Arales (2).

Super order IV. Liliiflorae : Orders : 6. Dioscorales (5), 7. Asparagales (28); 8. Liliales (8), 9. Burmanniales (12), 10. Orchidales (3).

Super order V. Bromelliflorae : Orders : 11. Velloziales (1), 12. Bromeliales (1), 13. Haemodorales (1), 14. Philydrales (1), 15. Pontederiales (1), 16. Typhales (2).

Super order VI. Zingiberiflorae : Orders : 17. Zingiberales (6).

Super order VII. Commeliniflorae : Orders : 18. Commelinales (5). 19. Hydratellales (1), 20. Juncales (1), 21. Cyperales (1), 22. Poales (6).

Super order VIII. Areciflorae : Orders : 23. Arecales (1), 24. Cyclanthales (1), 25. Pandanales (1).

Robert F. Thorne (1983)

Thorne (1983), published a phylogenetic system of angiosperm's classification on the basis of comparative morphology, embryology, cytology, palaeobotany, pollen and seed morphology, plant geography and host-parasite relationships. He believed in theory of monophyletic origin of angiosperms.

He divided class Annonopsida (Angiospermae) into two subclasses, 28 super orders, 54 orders, 75 sub-orders and 350 families.

Outline of Robert F. Thorne's (1983) Classification*

Class : ANGIOSPERMAE (Annonopsida)

Sub-class : Dicotyledoneae (Annonidae)

Super order I. Annoniflorae : Order : 1 Annonales (23)**, 2. Nelumbonales (2), 3. Paeoniales (2), 4. Berberidales (8).

Super order II. Nymphaeiflorae : Order : 5. Nymphaeales (2).

Super order III. Rafflesiflorae : Order : 6. Rafflesiales (2).

Super order IV. Theiflorae : Orders : 7. Theales (30), 8. Ericales (3), 9. Ebenales (4), 10. Primulales (3), 11. Polygonales (1).

Super order V. Chenopodiiflorae : Order 12. Chenopodiales (14).

Super order VI. Geraniiflorae : Order : 13. Geraniales (17).

Super order VII. Santaliflorae : Order : 14. Celastrales (3), 15. Santalales (7), 16. Balanphorales (2).

Super order VIII. Violiflorae : Orders : 17. Violales (16), 18. Capparales (4).

Super order IX. Malviflorae : Orders : 19. Malvales (12), 20. Urticales (3), 21. Rhamnales (2), 22. Euphorbiales (6).

Super order X. Rutiflorae : Order : 23. Rutales (25).

Super order XI. Proteiflorae : Order : 24. Proteales (1).

Super order XII. Hamamelidiflorae : Order : 25. Hamamelidales (7), 26. Casuarinales (1), 27. Fugales (2).

Super order XIII. Rosiflorae : Orders : 28. Rosales (19, 29. Pittosporales (13).)

Super order XIV. Loasiflorae : Order : 30. Loasales (1).

Super order XV. Myrtiflorae : Order : 31. Myrtales (1).

Super order XVI. Gentianiflorae : Orders : 32. Oleales (2), 33. Gentianales (7), 34. Bignoniales (9), 35. Lamiales (3).

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* Thorne, R.F. 1983. Proposed new realignments in the angiosperms–Nord.Jj.B. 3 : 85-117.

** Number in parenthesis, infront each order indicates number of families in that particular order.

Super order XVII. Solaniflorae : Orders : 36. Solanales (7), 37. Campanulales (3).

Super order XVIII. Corniflorae : Orders : 38. Cornales (10), 39. Araliales (3), 40. Dipsacales (5).

Super order XIX. Asteriflorae : Orders : 41. Asterales (1).

Sub-class : Monocotyledoneae (Lilidae).

Super order I. Liliflorae : Order 1. Liliales (10).

Super order II. Triuridiflorae : Orders : 2. Triuridales (1).

Super order III. Alismatiflorae : Orders : 3. Alismatales (3), 4. Zosterales (7), 5. Najadales (1).

Super order IV. Ariflorae : Order : 6. Arales (2).

Super order V. Cyclanthiflorae : Order : 7. Cyclanthales (1)

Super order VI. Pandaniflorae : Order : 8. Pandanales (1).

Super order VII. Areciflorae : Order : 8. Arecales (1).

Super order VIII. Typhiflorae : Order : 10. Typhales (1).

Super order IX. Commeliniflorae : Orders : 11. Commelinales (4), 12. Zingiberales (8).

Statistical Summary of Robert F. Thome's (1998) Classification

	Dicotyledoneae	Monocotyledoneae	Total Angiospermae
Species	173370	52120	225490
Genera	9640	2615	12255
Sub-families	350	102	452
Families	297	53	350
Sub-families and undivided families	561	120	681
Sub-orders	56	17	73
Orders	4	12	53
Sub-orders and undivided orders	82	25	107
Super orders	19	9	28

Thorne's principles on evolutionary trends in angiosperms

1. Existing species have descended with change from pre-existing species.

2. Ancestral conditions and trends of specialization are often recognizable in the organs, tissues, and cells of living and fossil angiosperms.

3. The presence of vestigial rudiments of organs, or sometimes the presence of vestigial vascular supply to greatly modified or missing organs, often furnishes evidence of evolutionary reduction, loss, fusion, or other major modification of structures.

4. The prevalence of parallel and convergent evolution in habit, function, and structure is predictable consequence of the relatively limited means, angiosperms have for effective reporduction and for adaptation to available environment.

5. All parts of plants at all stages of their development may produce evidence that is valuable in establishing relationships.

6. Evolution may tend toward elaboration and diversity or toward reduction and simplicity.

7. The rate and direction of evolution may vary in the different organs and tissues of plants.

8. Most of the existing angiosperms are highly specialized and greatly modified from their primitive, generalized ancestors.

9. Evolutionary trends are sometimes reversible under the influence of changes in environmental factors.

10. Once lost, organs usually are not regained.

11. New angiospermous structures have evolved as modifications of or as outgrowths from pre-existing structures.

Merits of Thorne's system

1. The woody Annonales which are now universally accepted as the most primitive living Angiosperms are the starting point of his system and constitute the base of the phylogenetic shrub of Angiosperms. The Berberidaceae and the Nymphaeales, though more advanced than the Annonales are all considered to be closely related.

2. The arrangement of Dicotyledoneae is much more phylogenetic because it has brought the closely related taxa nearer to each other in their placement. The orders Ericales, Ebenales, and the Primulales, though more advanced are considered to be related to the Theales and all kept under superorder Theiflorae. The order Theales contains the closely related families Dilleniaceae and Sarraceniaceae.

3. The Amentiferae which has long been considered as an assemblage of unrelated families has been abolished and its families distributed in different orders near their relatives.

4. Inclusion of the orders Malvales, Urticales, Rhamnales, Euphorbiales, Solanales and the Campanulales under the superorder Malviflorae. Cornales and Dipsacales are placed in one superorder Corniflorae.

5. The orders Pittosporales and Proteales though more advanced than the Rosales are all considered to be related and kept under the superorder Rosiflorae.

6. The family Stylidiaceae is kept under the suborder Saxifragineae under the order Rosales.

7. The order Dipsacales are considered as related to the Cornales and both these orders are kept under the superorder Corniflorae.

8. Among the subclass Monocotyledonae, the order Liliales are considered to be the starting point, the highest evolved family of this order being the Orchidaceae. The Alismatales are considered to be more specialized than the Liliales.

9. The Typhales are considered as related to but more advanced than the Araceae. On the contrary, the traditional relatives of Typhaceae, the Pandanales are included under the superorder Areciflorae along with the orders Arecales and Cyclanthales.

10. Among the Commelinales, the Bromeliaceae forms the starting point while the Poaceae is the most highly evolved family of the order.

Demerits of Thorne's System

1. It is not of much practical value in identification.

2. Thorne's of the view that angiosperms have originated from some Pteridospermous members is also not accepted by several taxonomists.

In the history of plant classification there is no final word. The systems which seem adequate today may become out moded in light of further researches.

1.9. PLANT NOMENCLATURE

The system of naming objects of biological origin is called as **nomenclature.** Earlier botanical names were **Polynomials** *i.e.*, comprising many parts. What Pulkonat named as *Chrysophyllum, foliis ovalis, superme glabris, parallele striatis, substus tomentosinitidis* in now called as *Sida acuta* Burm.f.

BINOMIAL NOMENCLATURE :

Bauhin, 1623 proposed a binary system of naming plants in his book **'Pinax theatre Botanica'**. This concept was properly enlarged by **Linnaeus**, 1753 while publishing **'Species Plantarum'**. According to binomial system of nomenclature, a plant name consists of two parts :'

(a) The **generic epithet** *i.e.*, the name of the genus.

(b) The **specific epithet** *i.e.*, the name of the species.

For example the botanical name of graden pea is *Pisum sativum* Linn. The generic epithet here is *Pisum* and the specific epithet is *sativum*. The generic name of graden pea is *Pisum* but the specific name is *Pisum sativum*. L. The name of the scientist who named the plant for the first time is also appended in short form. Here the name of

Linnaeus is abbreviated as Linn. or simply as L. All botanical names are printed in italics or underlined when hand written.

Advantages of Binomial Nomenclature

1. These names are more definite and precise than ordinary names.
2. Being generally in Latin, they have a universal acceptance by people of all languages.
3. They are more comprehensible and easier to study.
4. They indicate the genetic relationship and descent of individual plant.
5. They are more independent.
6. They are usually descriptive.

International Code of Botanical Nomenclature

Prior to 1930 there was no single code for plant nomenclature. Various countries followed different codes such as **Paris code, Kew rule, Rochester code, Vienna code.** Due to efforts of **Sprague, Hitchcock** and **Green** in 1930, an International Code of Botanical Nomenclature came into being at Cambridge. The code is divided into three parts, **Principles, Rules** and **Recommendations.**

(A) PRINCIPLES : The contitute the basis of botanical nomenclature which are as under :

1. The botanical nomenclature is independent of Zoological nomenclature.
2. The application of names of taxonomic groups, (taxa) are determined by means of nomenclatural types.
3. The nomenclature of taxonomic groups is basd upon the priority of publication.
4. Each taxonomic group can bear only one correct name; the earliest that is in accordance with the rules, except in specific cases.
5. Scientific names of taxonomic groups are treated as latin regardless of their derivation.
6. The rules of nomenclature are retroactive unless expressly limited.

(B) RULES : The rules describe in detail, all the relevant points concerned with naming of plants. Some of the important rules are as under :

I. **Ranks of Taxa :** The term **taxa** (singular taxon) means `taxonomic group of any rank'. Here the rank of a species is taken as basis. The supraspecific taxonomic hierarchy comprises **genus, tribe, family, orders, class, division** and **kingdom.** A species is divided into sub-species, sub-species into **varieties,** variety into **sub-varieties,** sub-variety into **forma** and forma into **clone.** The synthesis of rose plant shall be as under :

Kingdom	:	Vegetable
Division	:	Spermatophyta
Sub-division	:	Angiospermae
Class	:	Dicotyledonae
Sub-class	:	Archichlamydeae
Order	:	Rosales (-ales)
Sub-order	:	Rosineae (-ineae)
Family	:	Rosoideae (-aceae)
Sub-family	:	Rosoideae (-oideae)
Tribe	:	Roseae (-eae)
Sub-tribe	:	Rosinae (-inae)
Genus	:	*Rosa*
Sub-genus	:	*Eurosa*
Species	:	*Rosa gallica*

(The authorised suffixes are given in brackets)

II. **Typification :** According to this rule 'The application of names of taxa of the rank of family or below is determined by means of nomenclatural type.' The '**type**' specimen is a herbarium sheet of the specimen used by the author who described the plant for the first time. The type of a genus is a species and that of family is a genus. Unless we have a species, we can not constitute a genus. Similarly, if there is no genus, we can not establish a family. Several terms are used in the nomenclature of types such as **Holotype, Isotype, Lectotype, Syntype, Neotype, Paratype, Cotype, Topotype** etc. The holotype is the specimen used by the original author or designated by him as the nomenclature type. It is usually designated as the 'Type Specimen'. The name of the plant is permanently attached to it.

III. **Principle of Priority :** Out of all, this is the most important rule. According to the principle of priority each taxon can bear only one correct name. The correct name is the earliest legitimate name except if it is retained by conservation. If the same plant is named differently by two or more authors, it's earliest correct name is considered as valid.

IV. **Names of Families :** A family name is formed by adding the suffix-aceae to the stem of a legitimate included genus *e.g.*, Rosaceae from Rosa. Some family names which do not follow this rule were, therefore, changed. However, the old names are also conserved due to their long use.

Compsitae	⟶	Asteraceae
Cruciferae	⟶	Brassicaceae
Gramineae	⟶	Poaceae
Guttiferae	⟶	Clusiaceae
Labiatae	⟶	Lamiaceae
Leguminosae	⟶	Fabaceae
Palmae	⟶	Arecaceae
Umbelliferae	⟶	Apiaceae

There are separate rules for naming the species. Tautonyms are invalid in botany and hence *Linaria linaria* became *Linaria vulgaris*. There are rules for naming intraspecific taxa, cultivated plants, for valid publication, citation of authors names etc.

(C) **RECOMMENDATIONS :** They are concerned with practical application of rules *i.e.*, for providing guidance for naming the plants according to the rules.

The code has three appendices *i.e.*, **Apendix I, Appendix II** and **Appendix III.**

1.10. SUMMARY

Taxonomy is defined as the branch of botany which treats of classification *i.e.*, the methodical distribution of plants in groups named classes, families (or orders), genera and species. Various classification proposed so far fall into three categories : artificial systems, natural systems and phylogenetic systems. In artificial systems only one or a few external characters are taken into consideration for plant classification. The first artificial system was proposed by Theophrastus (300 BC) and the best by Linnaeus (1937). The former divided the plants on the basis of habit and the latter on the basis of stamens. Natural systems evaluate a taxon as it is believed to exist in nature. In these systems maximum characters have been taken into consideration. The first natural system was proposed by de Jussieu (1789), and the best came from Bentham and Hooker, (1862-83). The latter system is followed by many herbaria of the world. In phylogenetic systems, the concept of evolution has been amalgamated with the particular taxon. Therefore, it enables to identify the precursor, ancestor as also the derivatives of a particular taxon, by constructing an imaginary evolutionary tree. The first phylogenetic system was proposed by Eichler (1875-78). The systems proposed by Engler and Prantl (1887-99), Hutchinson (1926, 59), Fullar and Tippo (1961) are also phylogenetic. No phylogenetic system is truely phylogenetic. It is partly natural and partly phylogenetic because the grouping is natural and only placing is phylogenetic.

The system of naming objects of biological origin is called nomenclature. Bauhin (1623) proposed a binary system of naming the plants and this concept was properly enlarged by Linnaeus (1753). While publishing 'Species Plantarum'. According to binomial system of nomenclature, a plant name consists of two parts : the generic epithet *i.e.*, the name of the genus and the specific epithet *i.e.;* the name of the species. An International Code of Botanical Nomenclature came into existence in 1930, It comprises three parts principles, rules and recommendations with three appendices. The principles form the basis of botanical nomenclature. The rules describe the relevant points for describing the plants in details. The recommendations are directly towards the practical application of the rules.

STUDENT ACTIVITY

1. Describe the merits and demerits of Bentham and Hooker's system of classification.

2. Describe international code of botanical nomenclature.

TEST YOURSELF

1. Who is called as 'the father of botany'?
2. Who is known as the 'father of modern botany'?
3. Name the book published by **Linnaeus** in 1730.
4. Who proposed the natural system of classification?
5. Why the system proposed by **Linnaeus** is artificial?
6. On which part of the flower, the classification of **Linnaeus** was based?
7. Name the linnaean class having twenty or more number of stamens on the receptacle.
8. How manys families are included in the Bentham and Hooker's system of classification?
9. A monochlamydous flower with endospermic seeds and small embryo be kept in which series of the Bentham and Hooker's system of classifciation?
10. A polypetalous plant with inferior ovary will be kept in which series of the **Bentham** and **Hooker** System of classification?
11. According to the **Hutchinson** which is the most highly evolved order in monocots?
12. What do you mean by binomial system of nomenclature?
13. Write the correct sequence of taxonomic categories.
14. In which treatise binomial system of nomenclature was proposed?
15. In which year international code of botanical nomenclature came into existence?

ANSWERS

1. **Theophrastus** 2. **Linnaeus** 3. **Hortus Uplandicus**

4. **Bentham and Hooker** 5. Because it is based on similarities and differences in floral and other morphological characters only. 6. Stamens

7. Polyandria 8. 200 9. Microembryae

10. Calyciflorae 11. Graminales

12. Every organism has one scientific name consisting of a generic and a specific epithet

13. Division-class-order-family-tribe-genus-species.

14. Species Plantarum 15. 1930.

UNIT-III

DESCRIPTION OF FLOWRING PLANTS

1

METHOD OF STUDYING ANGIOSPERMIC PLANTS

STRUCTURE

- Introduction
- Salient features of characters used to describe plants
- Alternative terms and illustrated terminology
- Floral formula
- Classification and identification
- The diagrams
- Summary
- Student Activity
  - Test Yourself
  - Answers

LEARNING OBJECTIVES

By learning this chapter you will be able to describe an angiospermic plant.

1.0 INTRODUCTION

There are two parts to describe any angiospermic plant. First part is the list of characters of the plants, its classification, identification and second part is drawing the diagrams of the plant, flower, and specific parts of the flower.

1.1. SERIAL LIST OF CHARACTERS USED TO DESCRIBE PLANTS

(1) Habitat

The natural abode or locality of the plant i.e., whether cultivated as an ornamental plant or a food crop or occurs wild.

(2) Habit

(a) Annual, biennial or perennial.

(b) Herb, undershrub, shrub or tree.

(c) Any other peculiarity such as parasite, epiphyte, xerophyte or hydrophyte.

(3) Root

(a) Tap or adventitious.

(b) Branched or unbranched.

(c) Any speciality such as tuberous, fleshy, fibrous, nodulated, aerial, climbing, parasitic, conical, fusiform, napiform etc.

(4) Stem

(a) Erect, prostrate, twining or climbing. If climbing write the mode of climbing *i.e.*, whether by tendrils or spines or hooks or by any other means.

(b) *Any special modification i.e.,* rhizome, bulb, tuber, corm, phylloclade runner, sucker etc.
(c) Branched or unbranched. If branched, write the mode of branching *i.e.,* whether racemose or cymose. If cymose, whether uniparous, biparous or multiparous.
(d) Herbaceous or woody.
(e) Cylindrical, angular, compressed or reduced.
(f) Hairy, glabrous, waxy or spiny.
(g) Solid or fistular.

(5) Leaf

(a) Deciduous or evergreen.
(b) Radical, cauline or ramal.
(c) Alternate, opposite or verticillate (whorled). If opposite, whether superposed or decussate.
(d) Petiolate or sessile.
(e) Stipulate or exstipulate. If stipulate, write the nature of the stipules.
(f) Nature of the leaf base, whether sheathing, connate, perfoliate or ligulate.
(g) Simple or compound. If simple, write about the outline of the lamina, its incisions, nature of the margins, apex, surface and venation (unicostate or multicostate; reticulate or parallel). If compound, whether pinnate or palmate, if pinnate whether paripinnate or imparipinnate, number and arrangement of leaflets. If palmate whether uni-, bi-, tri-, tetra-, penta-, or multifoliate. If the leaf is compound, the leaflets should be described in the same way as a simple leaf.

(6) Inflorescence

Racemose, cymose, mixed, compound or of any special form. In all cases write about the details of the inflorescence.

(7) Flower

(a) Pedicellate or sessile.
(b) Bracteate or ebracteate. If bracteate, the bracts should be described.
(c) Complete or incomplete.
(d) Hermaphrodite or unisexual.
(e) Actinomorphic or zygomorphic.
(f) Colour of the flowers.
(g) Hypogynous, perigynous or epigynous.

(8) Calyx

(a) Number of sepals.
(b) Poly-or gamosepalous. If polysepalous, the shape, outline and the apex of the sepals should be described. If gamosepalous, give special forms such as tubular, campanulate, bilabiate, spurred etc.
(c) Green or petaloid.
(d) Inferior or superior.
(e) Aestivation of the calyx.

(9) Corolla

(a) Number of petals.
(b) Poly-or gamopetalous. If polypetalous, the shape, outline and the apex of the petals should be described. Give special forms if any, such as caryophyllaceous, rosaceous, papilionaceous etc. If gamopetalous, give special forms such as tubular, campanulate, bilabiate, spurred etc. If corona is present, describe it giving its nature.

(c) Colour of the petals.
(d) Inferior or superior.
(e) Aestivation of the corolla.

(10) Perianth

If perianth is present, describe it in a similar way except that the terms poly and gamophyllous should be used.

(11) Androecium

(a) Number of stamens. If more than ten, write indefinite.
(b) Polyandrous, syngenesious or adelphous. If polyandrous, write special arrangements if any, such as didynamous, tetradynamous etc. If adelphous, whether mono, di or polyadelphous.
(c) Whether epipetalous or free from the petals.
(d) Nature of the filaments, whether long, short or flattened.
(e) Anthers introrse or extrorse.
(f) Colour, fixation and dehiscence of the anthers.

(12) Gynoecium

(a) Number of carpels, whether mono-, bi-, tri-, tetra-, penta-, or poly-carpellary.
(b) Syncarpous or apocarpous.
(c) Ovary superior or inferior.
(d) Number of loculi.
(e) Number of ovules in each loculus or on each placenta.
(f) Shape of the ovules.
(g) Placentation.
(h) Nature and form of the style and the stigma.
(i) Nectar secreting disk should be described if present.

(13) Seeds

(a) Endospermic or non-endospermic.
(b) Position, shape and the size of the embryo.
(c) Cotyledons, straight or folded.
(d) Number of the cotyledons.

(14) Fruit

Kind of fruit.

(15) Floral formula

A detailed floral formula be given *e.g.*, *Family* Fabaceae—

$$\mathrm{Br},\ \mathrm{Brl},\ \oplus,\ ⚥,\ K_{(5)}\ C_{1+2+(2)},\ A_{(a)+1},\ \underline{G}_1$$

(16) Floral diagram—

(17) Classification

(a) Dicot or Monocot.
(b) Lignosae or Herbaceae.
(c) Order
(d) Family.
(e) Genus.
(f) Species.

(18) Reasons for the identification of the family should be given.

Note : When the flowers are unisexual, the male and the female flowers should be described separately.

1.2. ALTERNATIVE TERMS AND ILLUSTRATED TERMINOLOGY

Habitat

Natural living place of the plant should be described (This can be described only in the natural surroundings of the plant and not in the laboratory).

Habit

The duration and mode of their life, nature of the stem and the height the plants attain determine their habit.

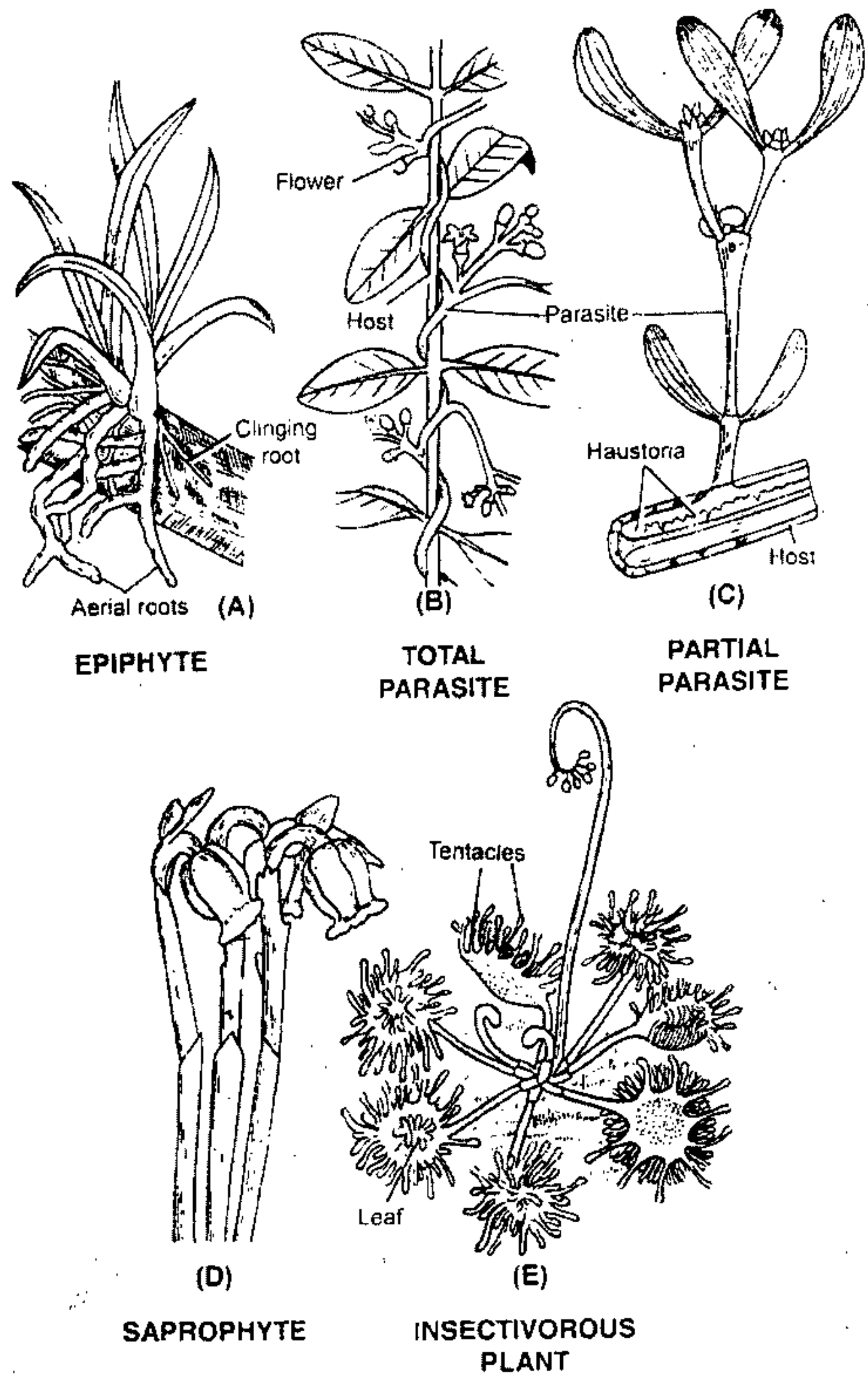


Fig. 1.1. (A-E) Peculiar habit of plants : (A) Epiphyte, (B) Total parasite, (C) partial parasite, (D) Saprophyte, (E) Insectivorous plant.

Alternative terms : Form : Herb/Shrub/Tree/Any other pecularity such as epiphyte, parasite, saprophyte, insectivore, etc.

Herb (L. *Herba*, grass, green blades) : A seed plant that does not develop woody tissues. According to their duration of life, herbs may be classified as :

(1) Annuals (L. *Annualis*, within a year) : A plant that completes its life cycle within one year and then dies *i.e.*, a seed germinates and the mature plant so produced dies, having produced seeds within the season.

(2) Biennials (L. *Biennium*, a period of two years) : A plant that requires two years to complete its life cycle and then dies. Plant develops vegetatively and produces a food-storage organ in the first year. It flowers in the second year only, and then dies.

(3) Perennial (L. *Perennis*, lasting the whole year through) : A plant living for three or more seasons, and normally flowering and fruiting at least in the second and subsequent seasons.

Shrub : A woody plant in which the side shoots are well-developed, so that there is no trunk. These plants are usually less than thirty feet tall.

Tree : A tall woody, perennial plant, having a well-marked trunk with few or no branches persisting from the base.

Epiphyte : A plant growing on another plant, but not deriving food from it *e.g., Vanda, Vanilla* (orchid) (Fig. 1.1. A).

Parasite : A plant living on, or in another organism, called the host. The parasite extracts the food from the host and lives at the latter's detriment. On the basis of their complete or incomplete independence, the parasite may be called **total parasite** for *e.g., Cuscuta reflexa, Orobanche, Balanophora, etc.,* (Fig. 1.1 B) or **partial parasite** for *e.g., Viscum album, Loranthus, Santalum,* etc. (Fig. 1.1C).

Saprophyte : A plant living on, and deriving its food from dead organic matter for *e.g.,* Monotropa (Fig. 1.1. D).

Insectivore : Plants which trap small insects and digest their body protein for *e.g. Drosera, Utricularia, Nepenthes,* etc. (Fig. 1.1. E)

Root

The plant structure that anchors the plant to the ground and that is responsible for the uptake of water and mineral nutrients from the soil is called **root**. It constitutes the lower part of the plant axis and grows towards gravity. It is usually subcylindrical and tapering towards the tip. Roots can be divided into two categories : **Tap and Adventitious Roots**

Alternative terms : Tap/ Adventitious; If adventitious then type of adventitious root.

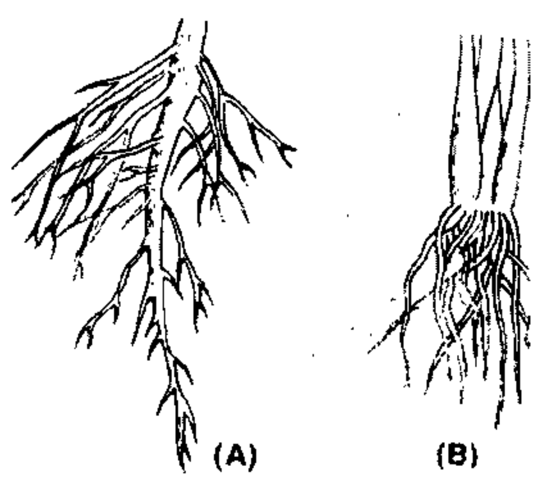


Fig. 1.2 (A, B) Types of roots : (A) Tap root, (B) Adventitious root.

Tap root : The embryo enclosed within the seed consists of two parts- The radicle which gives rise to the root and the plumule which is the progenitor of the shoot. The part of the plant that develops from direct elongation of the radicle is called **tap root** or **primary root.** The primary root along with the branches is termed as the **tap root system.** These roots are usually found in **dicotyledons** (Fig. 1.2. A).

Adventitious root : It includes those roots which develop from any part of the plant other than the radicle. These roots are usually found in monocotyledons (Fig. 1.2.B).

Stem

Alternative terms :

(a) Habit : Herbaceous/Woody

(b) Types of stem : Aerial/Underground/Specialized

(c) External shape : Cylindrical/Angular

(d) Branching : Branched/Unbranched

(e) Interior : Solid/Fistular

(f) Surface : Glabrous/Hairy

Herbaceous (L. *Herbaceus,* grass) : Referring to the plants having the characteristic of herbs *i.e.*, lacking the woody tissues.

Woody : Stem is hard and there is increase in the diameter of the stem every year due to formation of secondary xylem *e.g., Ficus, Cassia, Acacia,* etc.

Aerial : The stem remains in the air above the soil *e.g., Solanum.* If the stem is aerial it may be erect or weak.

Erect : A rigid and strong stem holding itself in an upright position *e.g., Acacia* Erect stem may be :

(i) Caudex : Cylindrical, unbranched, stout, marked with scars of fallen leaves *e.g.,* Palms.

(ii) Culm : The jointed stem with hollow internodes and solid nodes *e.g.,* Wheat, Bamboo.

(iii) Scape : A leafless, usually unbranched flowering shoot produced by underground stem *e.g.,* onion, canna.

(iv) Excurrent : When the main axis continues growth and the lateral branches develop regularly giving a conical appearance to the tree *e.g., Polyalthia, Casuarina.*

(v) Deliquescent : When the growth of the main axis is subordinated by more vigorously growing lateral branches giving a rounded or spreading appearance to the tree *e.g.,* mango, teak, gold mohur, etc.

Weak : A stem which is not strong enough to keep itself in an upright position *e.g., Cuscuta.*

Weak stem may be three types :

(i) Trailing, (ii) Creeping, (iii) Climbing

(i) Trailing : A weak stem spreading at the ground without rooting at the nodes.

These are of following three types :

(a) Prostrate (Procombent) : The trailing stem lying flat on the soil *e.g., Portulaca* (Fig. 1.3.A).

(b) Decumbent : Stem that lies along the ground and often has upturned tip e.g., *Tridax* (Fig. 1.3B).

(c) Diffuse : A trailing stem with many spreading branches in all the directions *e.g., Boerhaavia* (Fig. 1.3C).

(ii) Creeping : Stem growing along the surface of the ground and rooting at the nodes. These are of following four types :

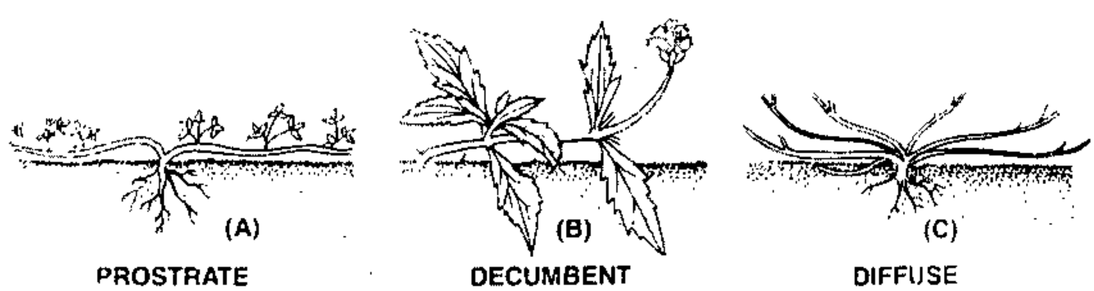


Fig. 1.3. (A-C) Trailing Stem : (A) Prostrate, (B) Decumbent, (C) Diffuse

(a) Runner : A creeping stem with long internodes, running horizontally on the surface of the soil is called a runner. Roots are given out at nodes. Axillary buds form new aerial shoots *e.g., Oxalis*, mint, etc.

(b) Stolon : A slender lateral branch that arises from the base of the main axis. After growing aerially for sometime the branch arches downwards to touch the ground, where its terminal bud gives rise to a new shoot and roots *e.g., Jasminum.*

(c) Offset : The stem is like a runner but the internodes are thicker and shorter. Branches arise all around the main stem. Apex of the each branch curved upwards bearing a group of leaves at the apex and a bundle of adventitious roots below. The branches break off from the parent and become independent plant *e.g., Eichhornia* (WAter hyacinth), *Pistia.*

(d) Sucker : It is like a runner but originates from the basal and underground portion of the main stem. It is shorter and stouter than a runner. It grows horizontally for a distance beneath the soil and then emerges obliquely bearing a leafy shoot *e.g., Chrysanthemum.*

(iii) Climbing : Weak stem attaching itself by means of some special structures to a neighbouring object and then climbing over it. These are of follwoing types :

(a) Rootlet climber : Climbing with the help of small adventitious roots which arise from the nodes; *e.g., Pothos*, ivy (Fig. 1.4A).

(b) Hook climber : A weak stem climbing with the help of pointed curved hooks; *e.g., Bougainvillea* (Fig. 1.4. B).

(c) Tendril climber : Climbs with the help of slender, leafless, spirally coiled structures known as tendrils; *e.g., Lathyrus* (Fig. 1.4. C).

(d) Leaf climber : Climbing with the help of sensitive petiole or leaf apex *e.g., Clematis Gloriosa*, etc. (Fig. 1.4 D).

(e) Twiner : A long, slender and branched stem which climb by twining bodily round trees, shrubs and hedges. Twiners have no special organs of attachment *e.g.;* Railway creeper, *Cuscuta* (Fig. 1.4 E).

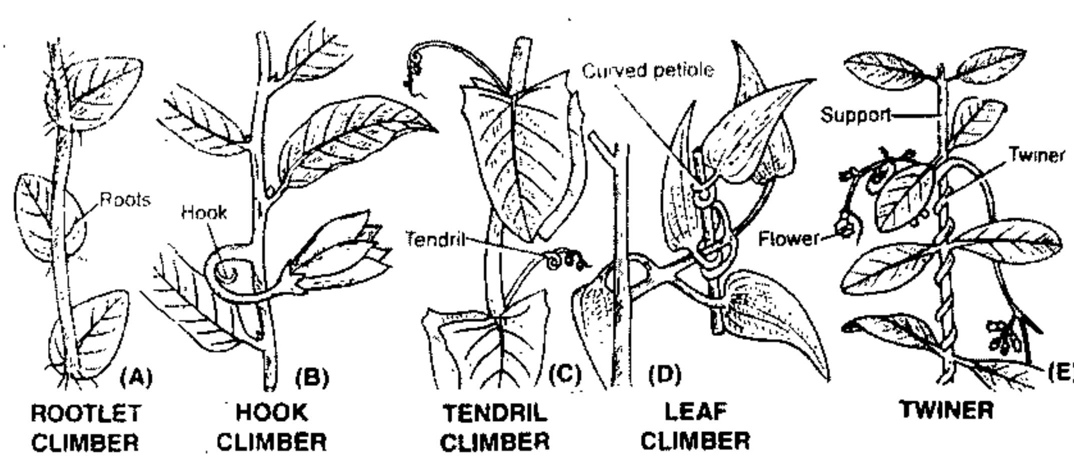


Fig. 1.4. (A-E) Climbing stems, (A) Rootlet climber, (B) Hook climber, (C) Tendril climber, (D) Leaf climber, (E) Twiner

(f) Lianas : Thick and woody perennial climbers commonly found in forests. They twine themselves round tall trees in search of sunlight and ultimately reach their top *e.g., Bauhinia vahlii* (Climbing mountain ebony) and some species of Fig (*Ficus*).

Underground : Stems remain in the ground and serve the function of perennation and storage of food. These stem produce aerial shoots annually. These resemble roots superficially but are distinguishable by the presence of scale leaves and buds at nodes. These stems also act as a means of vegetative propagation. These are of four types :

(a) Rhizome : These are prostrate and thickened stems that grow horizontally under the soil. Nodes are marked as dry scars. They bear scale leaves, with buds on branches in their axil. *e.g.*, ginger, banana, ferns, etc. Sometimes, it grows vertically and called **root-stock.**

(b) Tuber : It develops underground by the swelling of the tips of a stem. The 'eyes' present on its surface present nodes; each consisting one or more buds subtended by a leaf scar, *e.g.*, potato, Jerusalem artichoke.

(c) Bulb : It is characterized by the presence of a highly condensed and discoidal stem and a large number of fleshy scale leaves. A cluster of adventitious roots is noticed at the base of the bulb, *e.g.*, onion, garlic, lilies, etc.

(d) Corm : It is a condensed form of rhizome and consists of a stout, solid, underground, stem growing in the vertical direction. Adventitious roots normally develop from the base but sometimes from the sides. *e.g., Gladiolus, Amorphophallus, Colocasia, Colchicum, Crocus,* etc.

Specialized stem : Some stems perform unusual functions. These are called specialized stems. These are of following types :

(a) Phylloclade : It is a green, flattened or rounded stem. Being green it carries on the function of the leaves which are seen to be either feebly developed or modified into spines. *e.g., Opuntia* (Fig. 1.5A), Cocoloba (Fig. 1.5 B), *Epiphyllum* (Fig. 1.5 C).

(b) Cladode : The phylloclade of one or two internodes is known as the cladode *e.g., Asparagus* (Fig. 1.5. D), *Ruscus.* In *Asparagus* each cladode consists of a single internode and in *Ruscus* it is made of two internodes.

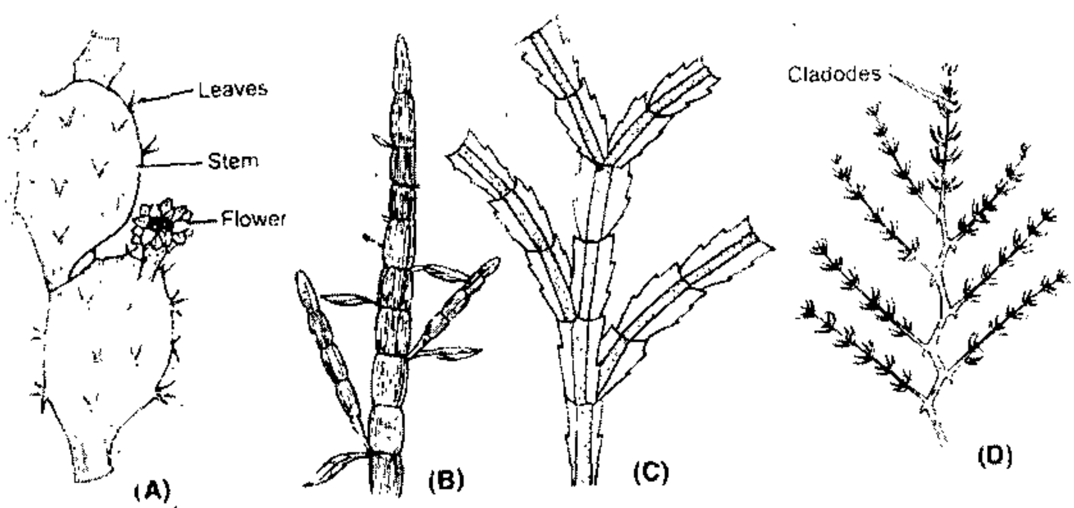


Fig. 1.5. (A-D) Phylloclades,
(A) *Opuntia*, (B) Cocoloba, (C) *Epiphyllum*, (D) Cladodes of *Asparagus*

Cylindrical : In transverse section stem appears circular *e.g., Solanum* (Fig. 1.6A).

Angular : Stem shows many lateral angles in transverse section *e.g., Coriandrum* (Fig. 1.16.B).

Branched : A stem with many lateral shoots, *e.g., Solanum.*

Unbranched : A stem without lateral shoots *e.g., Palms.*

Solid : A stem having filled interior *e.g., Solanum* (Fig. 1.7. A).

Fistular : A stem having a hollow interior *e.g.,* Wheat (Fig. 1.7 B).

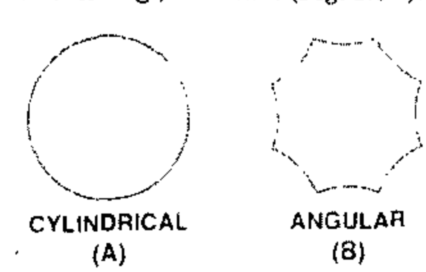


Fig. 8.6. (A, B) Shapes of stem : (A) Cylindrical, (B) Angular

Glabrous : Not hairy *e.g., Solanum*.

Hairy : Covered with hairs, *e.g., Calotropis*.

LEAF

Leaf is a flattened lateral outgrowth of the stem or the branch, developing from a node and having bud in the axil (Fig. 1.8). It is normally green in colour and is regarded as the most important organ of the plant since food material is prepared in it.

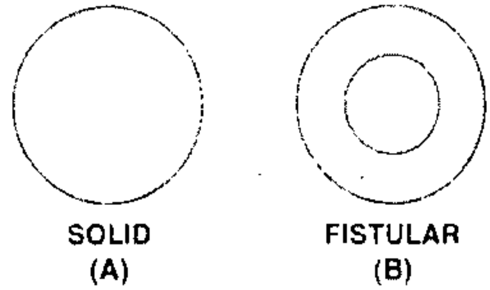


Fig. 1.7. (A, B) Interiors of stem : (A) Solid, (B) Fistular

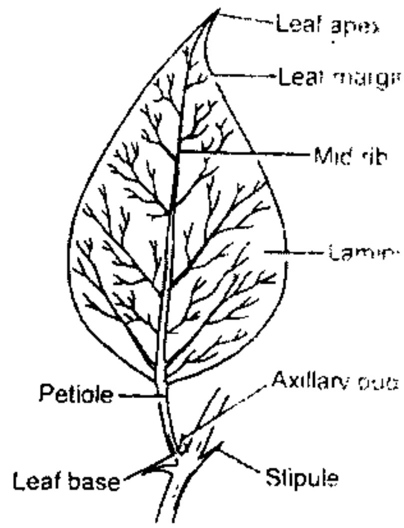


Fig. 1.8. Leaf and its parts

Alternative terms : (i) Bearing of leaf: Cauline/Cauline and Ramal/Radical.

(ii) Phyllotaxy[1] : Alternate/Opposite/ Whorl.

(iii) Stipules[2] **:** Exstipulate/Stipulate.

(iv) Types of leaves : Simple/Compounds.

(v) Leaf attachment : Sessile/Petiolate.

(vi) Leaf shape : Linear/ Lanceolate / Rotund/Elliptical/Ovate/Spathulate/ Oblique / Oblong/ Reniform/ Cordate/ Sagittate/Hastate/ Lyrate/Acicular/ Cuneate / Falcate/Lorate.

(vii) Leaf margins : Entire/Repand/ Serrate/Serrulate/Biserrate/Dentate/ Runcinate/Crenate/Spinous/Ciliate/Lobed.

(viii) Leaf apices : Obtuse/Acute/ Acuminate or Caudate/Cuspidate/ Truncate/ Retuse/ Emarginate/Mucronate/Cirrhose.

(ix) Surface of the leaf : Glabrous/ Glutinous/Glaucous/Rough/Spiny/Hairy.

Venation: Reticulate/Parallel.

Cauline: The leaves arising only on the main stem are called cauline; *e.g.,* Palms and Cycads. (Fig. 1.9 A).

Cauline and Ramal : The leaves arising on main stem, as well as on the lateral branches are called Cauline and Ramal; *e.g., Solanum* (Fig. 1.9B).

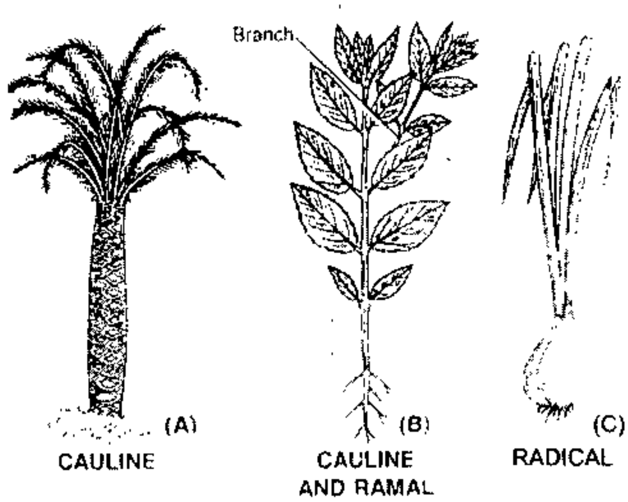


Fig. 1.9. (A-C) Bearing of leaves : (A) Cauline (B) Cauline and ramal, (C) Radical

1. The arrangement of the leaves on the stem is called phyllotaxy.

2. Basal appandages of a leaf or petiole. They may photosynthesize, or be scales, and may protect the axillary buds.

Radical : The leaves arising from the modified underground stem are called radical; *e.g.*, Onion (Fig. 1.9C).

Alternate : Leaves are arranged singly at each node. (Fig. 1.10A); *e.g.*, *Solanum*. These are of following types :

(a) Distichous, 1/2 or 2 ranked : Third leaf comes over the first one and there is one spiral between the two leaves *e.g.*, Family Poaceae, ginger (Fig. 1.10B).

(b) Tristichous, 1/3 or 3 ranked : Fourth leaf comes over the first and there is one spiral between the two leaves. *e.g.*, *Cyperus* (Fig. 1.10 C).

(c) Pentastichous, 2/5 or 5 ranked : Sixth leaf comes over the first one after completing two revolutions on the spiral *e.g.*, China rose (most common type of alternate phyllotaxy Fig. 1.10D).

(d) Octostichous, 2/8 or 8 ranked : Ninth leaf comes over the first one after completing three revolutions of the spiral *e.g.* Papaya.

Opposite : Leaves inserted in pairs at each node, with one on each side of the stem *e.g. Calotropis*.

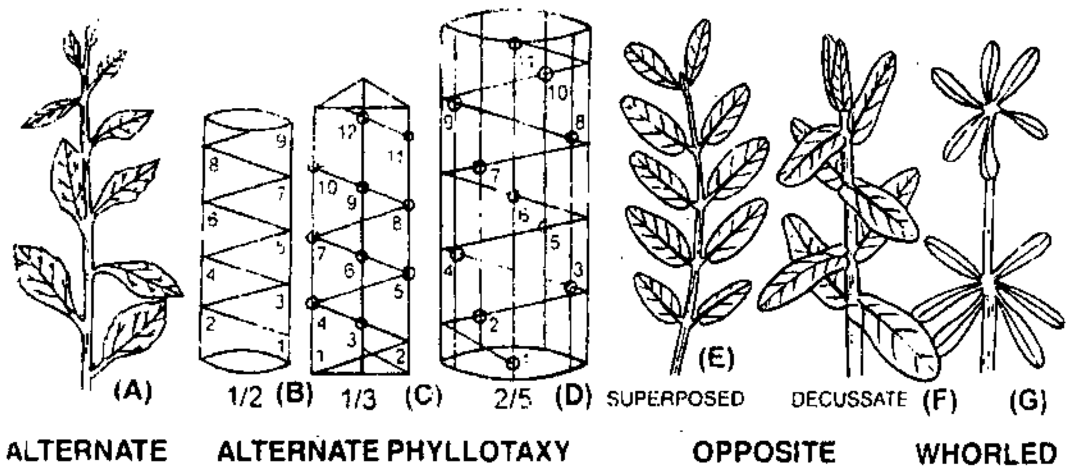


Fig. 1.10. (A-G) Different types of Phyllotaxy : (A) Alternate, (B) Distichous, (C) Tristichous, (D) Pentastichous, (E) Opposite superposed, (F) Opposite decussate, (G) Whorled

If a pair of leaves that stands directly over a pair in the same plane, it is called **opposite superposed;** *e.g.*, *Quisqualis, Carrisa* (Fig. 1.10E) and if a pair of leaf stands at right angle to the next upper or lower pair, it is called **opposite decussate** *e.g.*, *Calotropis, Mussaenda* (Fig. 1.10F).

Whorled : More than two leaves are arranged in the form of a whorl at each node, *e.g.*, *Neriun* (Fig. 1.10G)

Exstipulate : Lacking stipules *e.g.*, *Ipomoea*.

Stipulate : Stipules present *e.g.*, Rose.

Simple leaf : A leaf with the lamina in one piece is called simple leaf *e.g.*, Mango (Fig. 1.11 A). It may be lobed but the lobes never reach the midrib (incisions, do not touch the midrib, Fig. 1.11B, C). Note the position of axillary bud in a simple leaf (Fig. 8.8) and compound leaf (Fig. 1.12 A, B).

Compound leaf : When the incision of the lamina goes down to the midrib or petiole, the leaf becomes compound (Fig. 1.12 A, B). These leaf segments are known as leaflets. A leaflet is like a simple leaf but it lacks a bud in its axil. e.g., sweet pea, gold mohur. Compound leaves may be of two types. **Pinnately compound** and **palmately compound**.

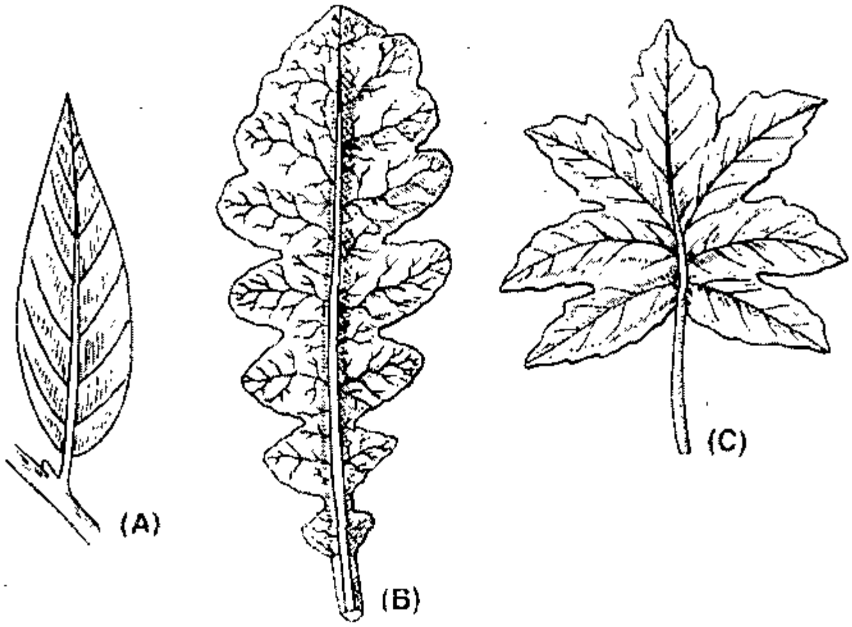


Fig. 1.11. (A-C) Simple leaves

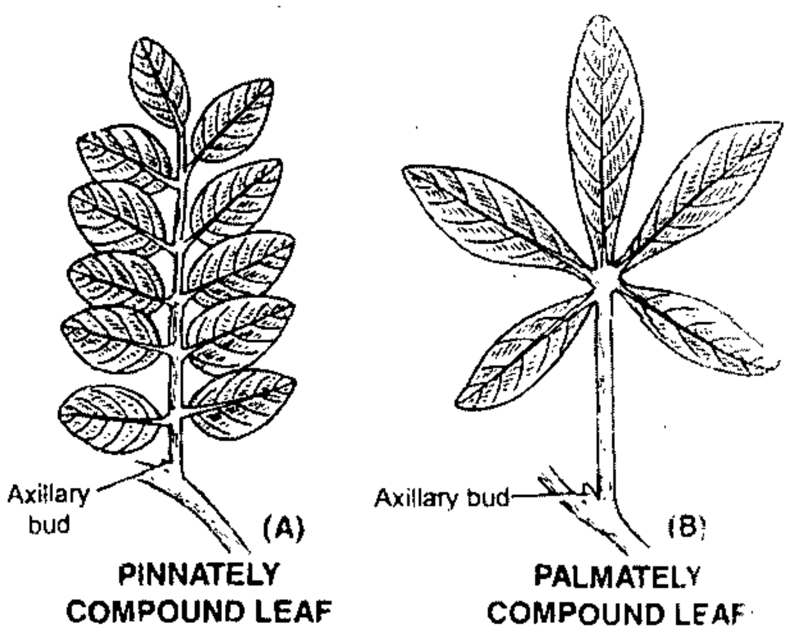


Fig. 1.12. (A, B) Compound leaves

Pinnately compound : A compound leaf is said to be pinnate when the leaflets are lateral to the midrib (or along the sides of the common axis called **rachis**). *e.g.,* tamarind (Fig. 1.12 A). These are of following types :

(a) Unipinnate : Leaflets are directly attached to the rachis *e.g.,* rose. When the leaflets are even in number the leaf is said to be **paripinnate;** *e.g.,* tamarind, gold mohur (Fig. 1.13A) and when the leaflets are odd in number of leaf is said to be **imparipinnate;** e.g., rose, neem, etc. (Fig. 1.13B).

(b) Bipinnate : The compound leaf is twice pinnate, *i.e.,* midrib produces secondary axes which bear the leaflets; *e.g.,* sirish (*Albizzia*) (Fig. 1.13C).

(c) ***Tripinnate*** *: The leaf is thrice pinnate i.e.* the secondary axes produces the tetriary axes which lyear the leaflets; *e.g., Oroxylum* (Fig. 1.13D).

(d) Decompound : The compound leaf is more than thrice pinnate; *e.g., Coriandrum* (Fig. 1.13 E).

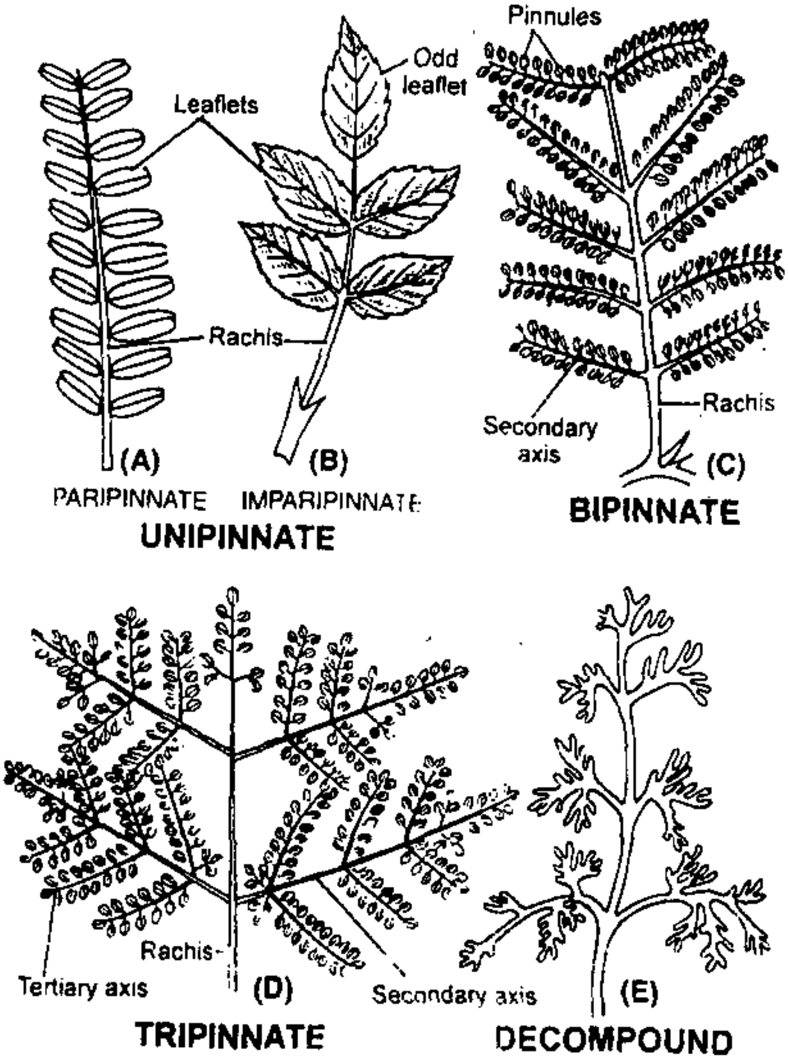


Fig. 1.13. (A-E) Pinnately compound leaves : (A) Paripinnate, (B) Imparipinnate (C) Bipinnate, (D) Tripinnate, (E) Compound.

Palmately compound : A compound leaf with the leaflets attached at the tip of petiole and thus seem to be radiating from a common point like fingers from the palm; *e.g.*, hemp (*Cannabis*), hulhul (Cleome) (Fig. 1.12 B). These are of following five types :

(a) Unifoliate : Only one leaflet is attached on the apex of lamina; *e.g.*, lemon, orange, etc. (Fig. 1.14A).

(b) Bifoliate : Two leaflets are present on the apex of the petiole; *e.g., Hardwickia binnata* (Fig. 1.14B).

(c) Trifoliate or Ternate : Three leaflets are arranged at the apex of petiole; *e.g., Aegle, Trifolium, Oxalis*, etc. (Fig. 1.14C).

(d) Quadrifoliate : Four leaflets are present on the apex of the petiole; *e.g., Marsilea, Paris quadrifolia* (Fig. 1.14D).

(e) Multifoliate : More than four leaflets are present on the apex of petiole; *e.g., Bombax* (Fig. 1.14 E).

Sessile : Leaf lacking a stalk *e.g., Dianthus.*

Petiolate : Leaf having a stalk *e.g.*, China rose.

Leaf shape : The shape of the lamina varies from plant to plant. The various shapes of the lamina are :

(a) Linear : Leaf is long and narrow e.g., grasses (Fig. 1.15 A).

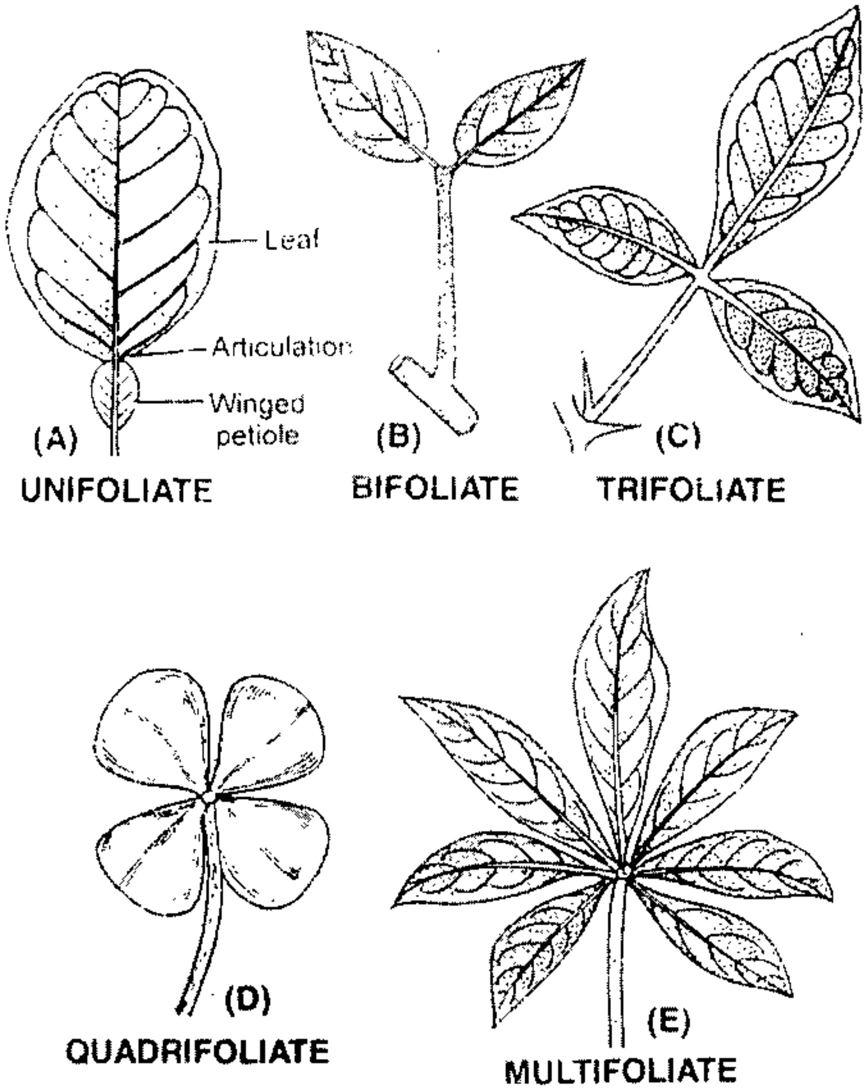


Fig. 1.14. (A-E) Palmately compound leaves : (A) Unifoliate, (B) Bifoliate, (C) Trifoliate, (D) Quadrifoliate, (E) Multifoliate

(b) Lanceolate : Lens shaped, much longer than broad, widening above the base and tapering to the apex *e.g., Nerium* (Fig. 1.15 B).

(c) Rotund or Orbicular : Leaf blade is circular in outline *e.g.,* lotus, garden nasturtium, etc (Fig 1.15C).

(d) Elliptical or Oval : Leaf has shape of an ellipse *e.g.,* rose-apple, guava, jack, etc. (Fig. 1.15 D).

(e) Ovate : Leaf blade is egg-shaped, slightly broader at the base than at the apex e.g., banyan (Fig. 1.15E). If the leaf is inversely egg-shaped, it is said to be obovate *e.g.,* country almond.

(f) Spathulate : Leaf blade is like that of a spatula *i.e.,* broad and round at the top and narrower towards the base *e.g., Drosera, Calendula* (Fig. 1.15 F).

(g) Oblique : Two halves of the leaf are unequal *e.g., Begonia* (Fig. 1.15 G).

(h) Oblong : Leaf blade is wide and long with rounded ends *e.g.,* bannana (Fig. 1.15 H).

(i) Reniform : Leaf blade is kidney shaped *e.g.,* Indian Pennywort (Fig. 1.15 I).

(J) Cordate : Leaf blade is heart shaped *e.g.,* betel (Fig. 1.15J). When the leaf blade is inversely eart shaped it is said to be obcordate *e.g.,* wood-sorrel.

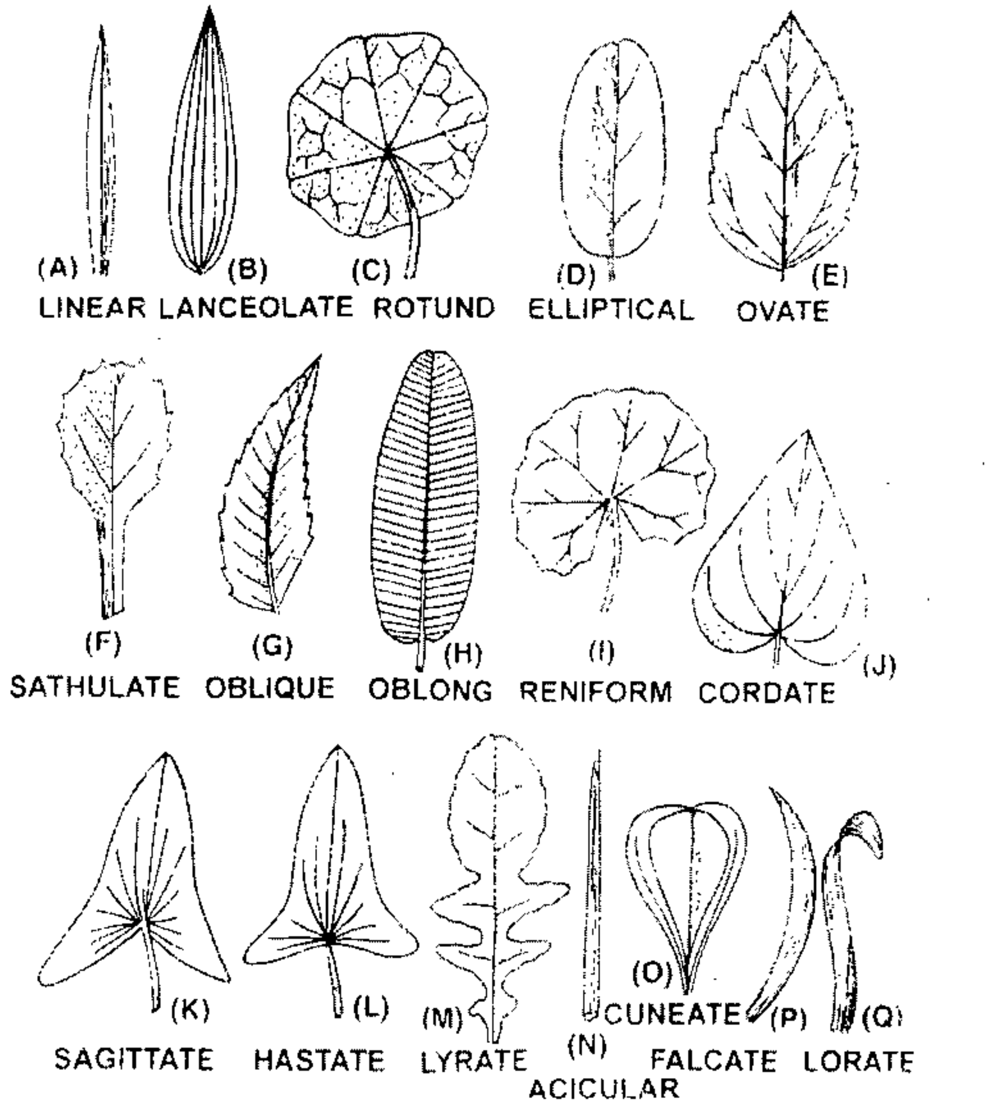


Fig. 1.15. (A-Q) Leaf shapes : (A) Linear, (B) Lanceolate, (C) Rotund, (D) Elliptical, (E) Ovate. (F) Spathulate, (G) Oblique, (H) Oblong, (I) Reniform, (J) Cordate, (K) Sagittate, (L) Hastate, (M) Lyrate, (N) Acicular, (O) Cuneate, (P) Falcate, (Q) Lorate

(k) Sagittate : Leaf blade is like an arrowhead *e.g., Sagittaria sagittifolia,* Arum (Fig. 1.15 K).

(l) Hastate : Two lobes of a sagittate leaf become pointed and directed outward *e.g., Ipomoea, lyphonium* (Fig. 1.15 L).

(m) Lyrate : The shape of the leaf blade is like a lyre, *i.e.,* with a large terminal lobe and some smaller lateral lobes *e.g.,* radish, mustard, etc. (Fig. 1.15 M).

(n) Acicular : Leaf is long, narrow and cylindrical, *i.e.,* needle shaped *e.g.,* pine (Fig. 1.15 N).

(o) Cuneate : Leaf blade is wedge-shaped with lower narrow end *e.g.,* water lettuce. (Fig. 1.15 O).

(p) Falcate : Leaf blade is sickle shaped *e.g., Eucalyptus* (Fig. 1.15 P).

(q) Lorate : Leaf blade is like a narrow strip of leather *e.g., Vallisneria* (Fig. 1.15Q).

Leaf marigns : A few common type of leaf margins are :

(a) Entire : Even and smooth margin *e.g.,* banyan (Fig. 1.16 A).

(b) Repand : Shallowly wavy or undulating *e.g.,* mango (Fig. 1.16 B).

(c) Serrate : Cut like the teeth of a saw and the teeth directed upwards *e.g.,* china rose, rose, etc. (Fig. 1.16 C).

(d) Biserrate : Double serrate (each tooth serrated again) *i.e.,* double serrate e.g., *Elm* (Fig. 1.16D)

(e) Serrulate : Teeth in serrate margins are very minute *e.g., Croton* (Fig. 1.16E).

(f) Dentate : The teeth directed outwards at right angles to the margin of the leaf *e.g.*, melon, water lily (Fig. 1.16 F).

(g) Runcinate : Serrated with the teeth pointed backwards (Fig. 1.16 G).

(h) Crenate : Teeth are rounded *e.g., Bryophyllum* (Fig. 1.16 H).

(i) Spinous : Provided with spines *e.g., Argemone* (Fig. 1.16 I).

(j) Cuiliate : Fringed with hairs *e.g., Cleome viscosa* (Fig. 1.16 J).

(k) Lobed : Provided with many lobes *e.g., Ranunculus* (Fig. 1.16 K).

Apex of the leaf : The apex of the leaf said to be :

(a) Obtuse : Apex is rounded *e.g.*, banyan (*Ficus benghalensis*) (Fig. 1.17 A).

(b) Acute : Pointed in the form of acute angle *e.g.*, china rose (Fig. 1.17B).

(c) Acuminate or Caudate : Drawn out into long cylindrical tale *e.g.*, pipal (*Ficus religiosa*) (Fig. 1.17C).

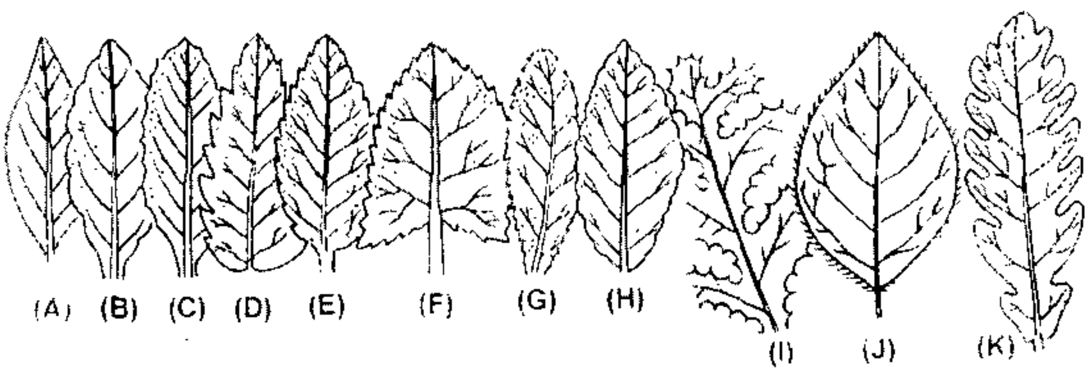


Fig. 1.16. (A-K) Leaf margins : (A) Entire, (B) Repand, (C) Serrate, (D) Biserrate, (E) Serrulate, (F) Dentate, (G) Runcinate, (H) Crenate, (I) Spinous, (J) Ciliate, (K) Lobed

(d) Cuspidate : Apex ends in a long rigid sharp (spiny) point, *e.g.*, date palm, pineapple, etc. (Fig. 1.17 D).

(e) Truncate : Apex ends abruptly as it cut off in a straight line *e.g.*, Indian sago palm (*Caryota urens*).

(f) Retuse : Obtuse or truncate apex is furnished with a shallow notch *e.g.*, Water lettuce (*Pistia*) (Fig. 1.17 E).

(g) Emarginate : Apex is provided with a deep notch *e.g.*, Kachnar (*Bauhinia*) or wood-sorrel (*Oxalis*) (Fig. 1.17F).

(h) Mucronate : Rounded apex abruptly ends in a short point *e.g., Ixora* (Fig. 1.17 G).

(i) Cirrhose : Apex ends in a tendril or thread like appendage *e.g.*, glory lily (*Gloriosa*) (Fig. 1.17 H).

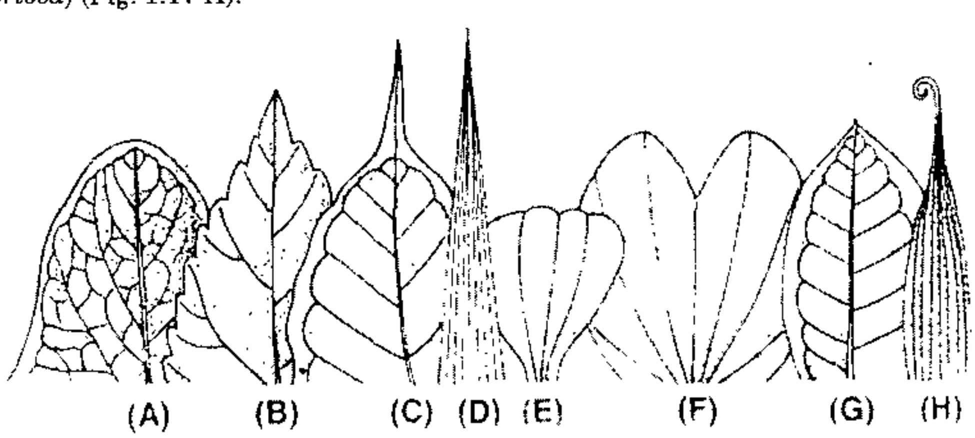


Fig. 1.17. (A-H) Apex of the leaf : (A) Obtuse, (B) Acute, (C) Acuminate, (D) Cuspidate, (E) Retuse, (F) Emarginate, (G) Mucronate, (H) Cirrhose

Surface of the leaf

(a) Glabrous : Surface of the leaf is smooth and free from hairs or outgrowths of any kind *e.g.,* china rose.

(b) Glutinous : Surface is covered with sticky exudation *e.g.,* tobacco.

(c) Glaucous : Surface is green and shining.

(d) Rough : Surface is somewhat harsh to touch *e.g., Petrea.*

(e) Spiny : Surface is covered with spines *e.g., Argemone.*

(f) Hairy : Surface is covered with densely or sparsely hairs.

Venation : The arrangement of the veins and the veinlets in the leaf-blade is known as venation. There are two principal type of venation : **reticulate** (Fig. 1.18 A) and **parallel** (Fig. 1.18B).

Reticulate : The veinlets are irregularly distributed, forming a network (Fig. 1.18A). It is found most of the dicot leaves. Exceptionally it is also present in monocot leaves *e.g., Smilax and Dioscorea.* It is of two types :

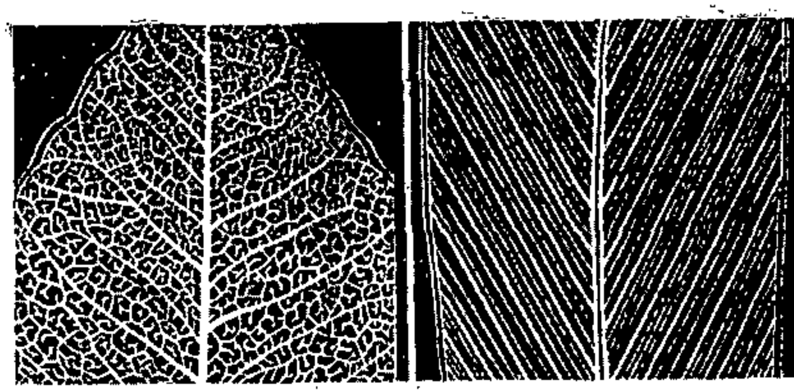


Fig. 1.18. (A, B) Types of venation (A) Reticulate venation, (B) Parallel venation

(a) Pinnate or Unicostate type (*Unus, one; costa, a rib*) **:** In this type of venation there is a strong midrib or costa; this gives off branches on lateral sides like the wings of a bird. Small branches or veinlets again come out from these in every direction and make a network *e.g.,* mango, peepal, etc. (Fig. 1.19 A).

(b) Palmate or Multicostate type (*Multi,* many) : In this type there is more or less equally strong ribs which arise from the tip of the petiole and proceed outwards or upwards. It has two kinds : **divergent type** and **convergent type.**

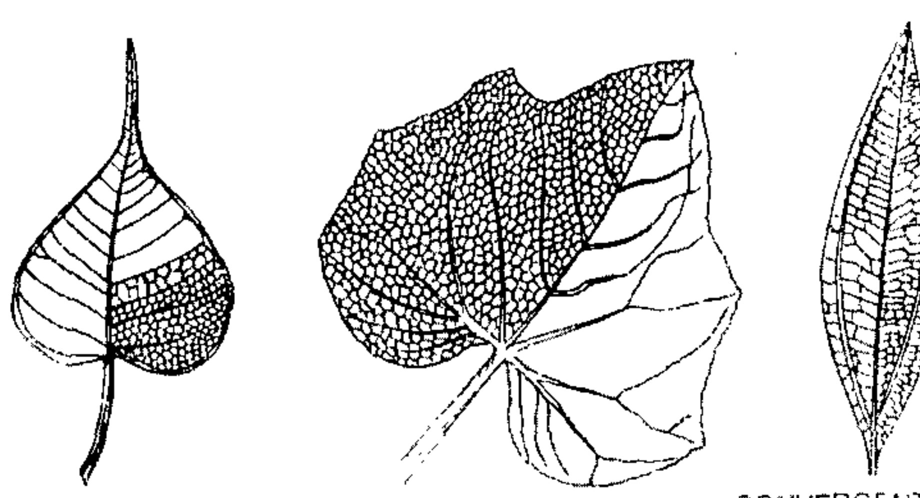


Fig. 1.19. (A-C) Types of reticulate venation : (A) Pinnate type, (B) Palmate (divergent type), (C) Palmate (convergent type)

(I) Divergent type : Leaf possesses a number of strong veins or costa that arise at the base of the leaf-blade and then diverge from one another towards the margin of the leaf, like the fingers from the palm (Fig. 1.19B) *e.g.*, Cucumber, Papaya, *Cucurbita*, etc.

(II) Convergent type : Veins instead of diverging from one another run in a curved manner from the base of the blade to its apex. The leaf in this is said to be curved vein (Fig. 1.19C) *e.g.*, Indian plum (*Zizyphus*), tezpata, Cinnamon, etc.

Parallel : All veins run parallel to each other (Fig. 1.18B). Veinlets are absent and no network is formed. Most of the monocot leaves have this type of venation. Rarely it is present in dicot leaves *e.g., Calophyllum, Eryngium*, etc. It is of two types :

(a) Pinnate or Unicostate : Lamina has only one principal vein that gives off many lateral veins which proceed towards its margin or apex *e.g., Canna*, turmeric, ginger, etc. (Fig. 1.20A).

(b) Palmate or Multicostate : Many principal veins arise from the tip of the petiole. It also has two kinds; **divergent** type and **convergent** type.

(i) Divergent type : Veins diverge from one another towards the circumference of the blade *e.g.*, fan palms, palmyra-palm (Fig. 1.20 B).

(ii) Convergent type : A number of more or less equally strong veins proceed in a somewhat parallel direction from the base of the leaf blade and converge at its apex *e.g.*, water hyacinth, grasses, rice, bamboo, etc. (Fig. 1.20 C).

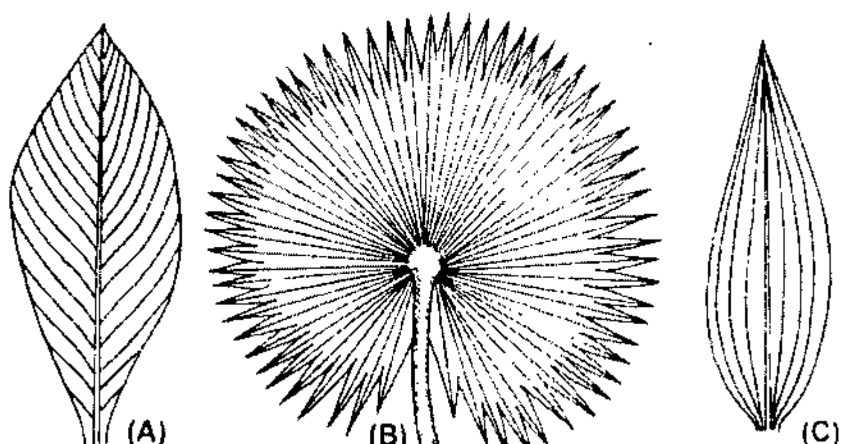


Fig. 1.20. (A-C) Types of parallel venation : (A) Pinnate type, (B) Plamate (divergent type), (C) Palmate (convergent type)

(C) Palmate (convergent type)

1.3. INFLORESCENCE

In many cases the vegetative axis bears a single flower (solitary flower) either at its apex (terminal flower) or in the axil of a leaf (axillary flower). In other cases the floral region consists of a collection of flowers. A flowering shoot bearing more than one flower is called inflorescence.

Alternative terms : Solitary/Racemose/Cymose/Compound/Special type.

1.4. FLOWER

Flower is a highly condensed and modified shoot. It is meant essentially for the reproduction in plants. It plays an important role in identification, classification and naming of plants. A typical or complete flower has four main parts namely, **calyx, corolla** (accessory organ), **androecium** and **gynoecium** (reproductive parts). All the four parts are arranged in a cyclic manner on the **thalamus**—a swollen end of the stalk or pedicel of the flower.

I. Bract and Bracteoles

Alternative terms : Bracteate/Ebracteate/Bracteolate.

(A modified leaf from the axis of which arises a flower or an inflorescence is called bract. A leaf, generally small, on a flower stalk is called bracteole).

(a) Bracteate : With bracts *e.g., Adhatoda.*

(b) Ebracteate : Without bracts *e.g., Solanum.*

(c) Bracteolate : With bracteoles *e.g., Hibiscus rosa-sinensis* (Gurhal).

(d) Epicalyx : Extra whorl of sepal-like floral appendages in some flowers that lies external to the whorl of sepals (*i.e.*, calyx) *e.g., Hibiscus rosa-sinensis.*

II. Attachment of flower

Alternative terms : Sessile/Pedicellate.

(a) Pedicel : Stalk of an individual flower.

(b) Peduncle : The stalk of an inflorescence.

(c) Sessile : Without a stalk *e.g., Adhatoda, Morus.*

(d) Pedicellate : Having a stalk *e.g., Dianthus.*

III. Presence of floral whorls

Alternative terms : Complete/Incomplete.

(a) Complete : A flower having all the four sets of floral organs *i.e.*, sepals, petals, stamens and carpels *e.g., Solanum.*

(b) Incomplete : A flower lacking one or more sets of floral organs *e.g., Euphorbia*

IV. Symmetry

Alternative terms : Actinomorphic/Zygomorphic.

(a) Actinomorphic : With radial symmetry, the parts similar in size and shape : such a flower can be divided into two equal havles along more than one median planes *e.g., Solanum, Hibiscus* (Fig. 1.21A)

(b) Zygomorphic : Can be divided longitudinally into two equal halves in only one vertical plane; floral whorls are unequal *e.g.,* Pea, *Adhatoda* (Fig. 1.21 B).

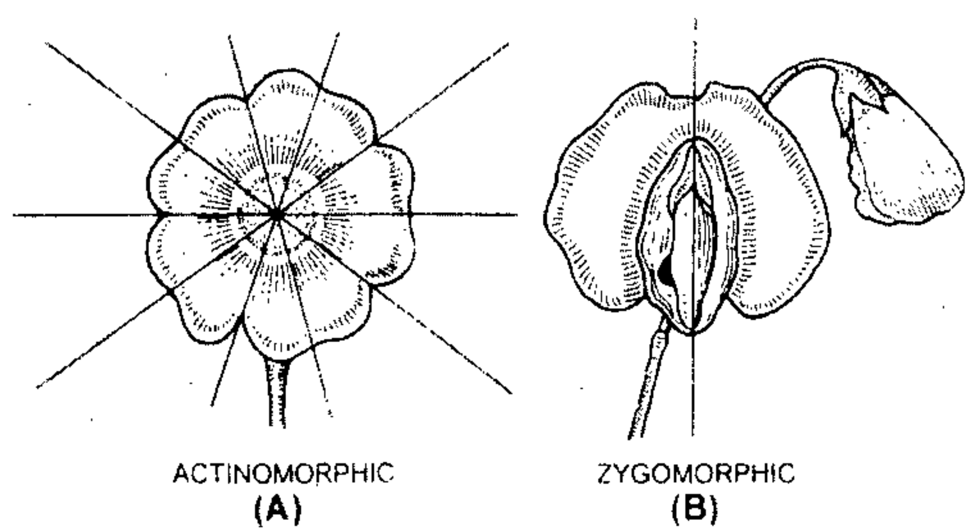


Fig. 1.21. (A, B) Symmetry of the flower : (A) Actinomorphic, (B) Zygomorphic

V. Presence of reproductive whorls

Alternative terms : Hermaphrodite/Unisexual.

(a) Unisexual : A flower having only one sex *e.g., Morus.*

(i) Staminate : A unisexual flower with stamens but not pistil *e.g., Ricinus.*

(ii) Pistillate : A unisexual flower with a pistil but not stamens *e.g., Ricinus.*

(iii) **Monoecious** : Both staminate and pistillate flowers borne on the same individual plant.

(iv) **Dioecious** : Staminate and pistillate flowers borne on different individual plants.

(b) Hermaphrodite (bisexual) : Flowers with both stamens and carpels *e.g., Petunia, Solanum*, etc.

VI. Number of floral parts

Alternative terms : Dimerous/Trimerous/Tetramerous/Pentamerous

(a) -merous : A suffix indicating the number of parts of floral organs.

(b) Dimerous : The parts in 2's or multiple of two *e.g.*, Poppy.

(c) Trimerous : The parts in 3's or multiple of three *e.g., Argemone.*

(d) Tetramerous : The parts in 4's or multiple of four *e.g.*, Mustard.

(e) Pentamerous : The parts in 5's or multiple of five *e.g., Solanum.*

VII. Position of floral organs on thalamus

Alternative terms : Hypogynous/Perigynous/Epigynous.

(a) Hypogynous : A flower in which all other floral organs are situated beneath the ovary *e.g., Citrus* (Fig. 1.22A).

(b) Perigynous : The floral organs, borne and arising from around the ovary and not beneath it *e.g.*, Peach, Plum (Fig. 1.22 B).

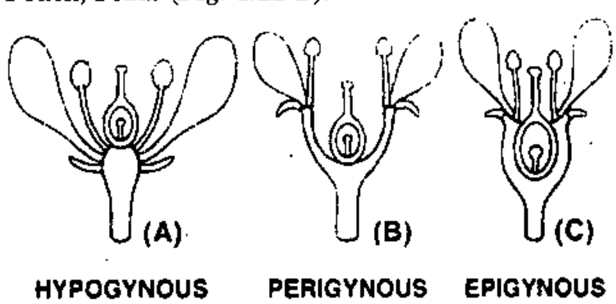


Fig. 1.22. (A-C) Position of floral organs on thalamus : (A) Hypogynous, (B) Perigynous,

(c) Epigynous : The other floral organs are attached to the upper part of the ovary, the ovary then appear inferior in position *e.g., Coriandrum* (Fig. 1.22 C).

VIII. Arrangement of floral organs

Alternative terms : Acyclic/Spirocyclic/Cyclic.

(a) Cyclic : Arranged in definite whorls *e.g., Petunia.*

(b) Spirocyclic : Half cyclic *e.g., Ranunculus.*

(c) Acyclic : Arranged in spirals and not in whorls *e.g., Ranunculus.*

IX. Calyx

(Calyx is the outer or first whorl of flowers. It is made of many separate parts called sepals. It is usually green and foliaceous).

(a) Number of sepals : *e.g.*, 4 sepals

(b) Cohesion :

Alternative terms : Polysepalous/Gamosepalous/Asepalous.

(i) **Polysepalous** : When the sepals are free *e.g., Cassia.*

(ii) **Gamosepalous** : When the sepals are fused *e.g., Dianthus.*

(iii) **Asepalous** : Without sepals.

(c) Aestivation : Arrangement of floral parts in the bud (sepals in this case).

Alternative terms : Valvate/Twisted/Imbricate/Quincuncial.

(i) Valvate : Aestivation in which individual units are arranged in circle, their edges just touching each other but not overlapping *e.g., Solanum* (Fig. 1.23A).

(ii) Twisted (contorted) : One margin overlaps that of the next one and other margin is overlapped by third one (Fig. 1.23 C).

(iii) Imbricate : In aestivation one of the sepal is internal being overlapped on both the margins and one of them is external, and three partly internal and partly external *e.g., Iberis amara, Cleome* (Fig. 1.23 D).

(iv) Quincuncial : In aestivation there are 5 sepals, two external, two internal and one partly internal and partly external *e.g., Stellaria, Dianthus* (Fig. 1.23E).

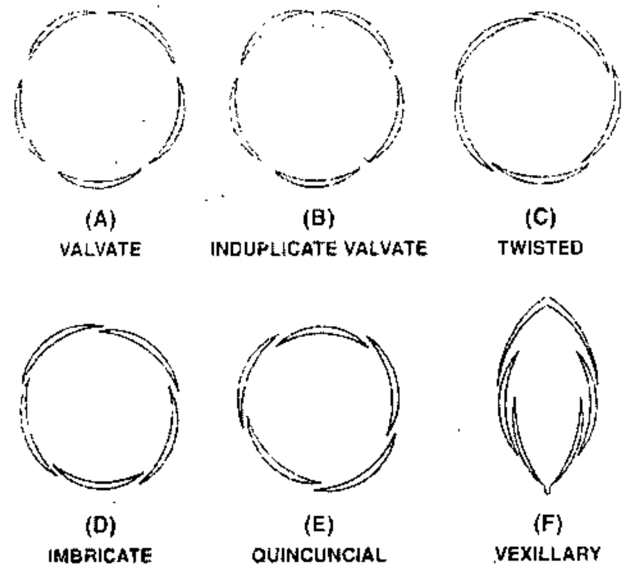


Fig. 1.23 (A-F) Aestivation : (A) Valvate, (B) Induplicate valvate, (C) Twisted, (D) Imbricate, (E) Quincuncial, (F) Vexillary

(d) Duration of calyx

Alternative terms : Caducous/Deciduous/Persistent.

(i) Caducous (Fugacious) : Falling of early or prematurely *e.g.*, Poppy.

(ii) Deciduous : Falling off along with the petals just after fertilization *e.g., Mustard.*

(iii) Persistent : Remaining attached in the fruit also, not falling off *e.g., Solanum.*

X. Corolla

(Corolla is the second whorl of flower. It is made of many separate parts called **petals.** It is usually coloured and more or less showy).

(a) Number of petals : *e.g.,* 4 petals.

(b) Cohesion :

Alternative terms : Polypetalous/Gamopetalous.

(i) Polypetalous : Petals are free *e.g.*, Mustard.

(ii) Gamopetalous : Petals are united *e.g., Ipomoea.*

(c) Aestivation :

Alternative terms : Valvate/Induplicate valvate/Twisted/ Imbricate/Qunicuncial/ Vexillary

(i) Valvate : Having the margins not overlapping *e.g., Solanum.* (Fig. 1.23 A).

(ii) Induplicate valvate : Margins of the petals are folded inwards e.g., *Ipomoea* (Fig. 1.23 B).

(iii) Twisted : Like sepals *e.g., Hibiscus* (Fig. 1.23C).

(iv) Imbricate : Like sepals *e.g., Callistemon* (Fig. 1.23 D).

(v) Quincuncial : Like sepals *e.g., Murraya* (Fig. 1.23 B, E).

(vi) **Vexillary (Papilionaceous) :** An aestivation when there are five petals, of which the posterior one is largest and it almost covers the two lateral petals, and the latter in their turn nearly overlap the two anterior or smallest petals *e.g.*, characteristic of family Fabaceae (Fig. 1.23F).

(d) Shape of corolla :

Alternative terms : Cruciform/ Caryophyllaceous/ Rosaceous/ Urceolate/ Campanulate/ Tubular/ Infundibuliform/ Hypocrateriform/ Rotate/ Papilionaceous/ Bilabiate/ Personate/Ligulate.

(i) **Cruciform :** Cross shaped. each petal differentiated into claw and a limb *e.g.*, Mustard (Fig. 1.24 A).

(ii) **Caryophyllaceous** : Five petals with comparatively long claws and with limbs placed at right angles to the claws *e.g., Dianthus* (Fig. 1.24 B).

(iii) **Rosaceous** : Petals spreading regularly outwards, not distinguishable into limbs and claws, *e.g.*, Rose (Fig. 1.24 C).

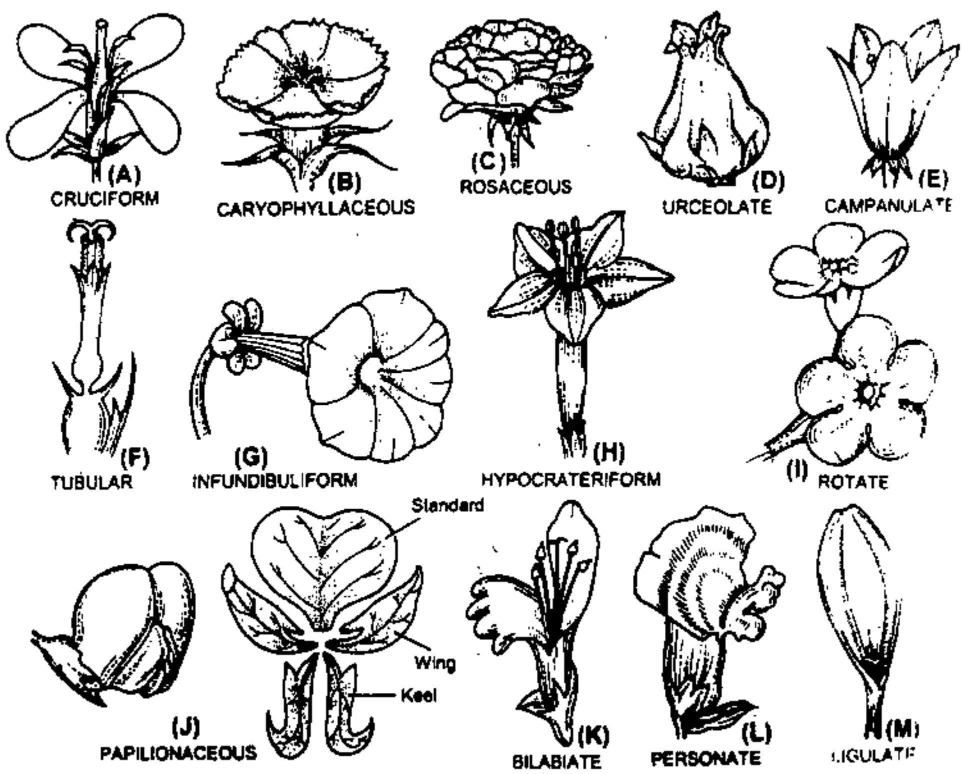


Fig. 1.24 (A-M) Shapes of corolla

(iv) **Urceolate :** Pitcher like or urn shaped *e.g., Urceola, Bryophyllum* (Fig. 1.24D).

(v) **Campanulate :** Bell shaped *e.g., Cucurbita, Withania* (Fig. 1.24 E).

(vi) **Tubular :** Cylindrical or tube like, gamopetalous *e.g.*, Sunflower (Fig. 1.24 F).

(vii) Infundibuliform : Funnel shaped, gamopetalous corolla like the mouth of a gramophone *e.g., Ipomoea* (Fig. 1.24G).

(viii) Hypocrateriform : Salver-form, long slender tube and an abruptly expanded flat limb *e.g., Mussaenda* (Fig. 1.24H).

(ix) Rotate : Wheel shaped, gamopetalous *e.g., Nerium, Solanum*, Brinjal (Fig. 1.24 I).

(x) Papilionaceous : Butterfly like, zygomorphic corolla with one large posterior **standard,** two lateral **wings** and two innermost fused petals, the **keel** *e.g.*, Pea (Fig. 1.24J).

(xi) Bilabiate : Two lipped gamopetalous corolla, mouth gap wide open *e.g., Ocimum* (Fig. 1.24 K).

(xii) Personate : Masked, zygomorphic gamopetalous corolla, mouth gap is closed *e.g., Antirrhinum* (Fig. 1.24 L).

(xiii) Ligulate : Strap shaped, zygomorphic, gamopetalous corolla *e.g., Sonchus* (Fig. 1.24 M).

(e) Colour of corolla : *e.g.,* 6 yellow, pink, red etc.

XI. Perianth

In some cases calyx and corolla are not distinguishable from one another and the outer whorl is thus called **perianth.**

(a) Number of tepals : *e.g.,* 6 tepals.

(b) Number of whorls : *e.g.,* 6 tepals in two whorls of three each.

(c) Cohesion :

Alternative terms : Polytpalous/Gamotpalous.

- **(i) Polytepalous :** Tepals free.
- **(ii) Gamotepalous :** Tepals are fused.

(d) Types of tepals :

Alternative terms : Sepaloid/Petaloid.

- **(i) Sepaloid :** Like sepal *e.g.,* Date palm.
- **(ii) Petaloid :** Like petal *e.g., Asphodelus.*

(e) Aestivation : Like sepals and petals.

XII. Androecium

(It is a male whorl or third whorl of the flower. Stamen is an individual part of androecium. It consists a filament, anther lobes and connective. It produces pollen grains).

(a) Number of stamens : *e.g.,* 4 stamens.

(b) Fertility : Note all the stamens are fertile or some of these are reduced to **staminodes.** Staminode is a sterile stamen.

(c) Cohesion of stamens :

Alternative terms : Polyandrous/adelphous.

- **(i) Monoadelphous :** Stamens united in one group by connation of their filaments *e.g., Hibiscus* (Fig. 1.25A).
- **(ii) Diadelphous :** The filaments of nine stamens are united into one bundle and the tenth posterior stamen stands apart *e.g.,* Pea (Fig. 1.25B).
- **(iii) Polyadelphous :** Stamens disposed into several groups by connation of their filaments *e.g., Citrus, Bombax* (Fig. 1.25 C).
- **(iv) Syngenesious :** Stamens are united by their anthers to form a tube around the style *e.g., Sonchus* (Fig. 1.25D).
- **(v) Synandrous :** All stamens united throughout their whole length by both the filaments and the anthers *e.g., Cucurbita* (Fig. 1.25 E).
- **(vi) Polyandrous :** Stamens are free (anthers as well as filament) *e.g., Papaver.*

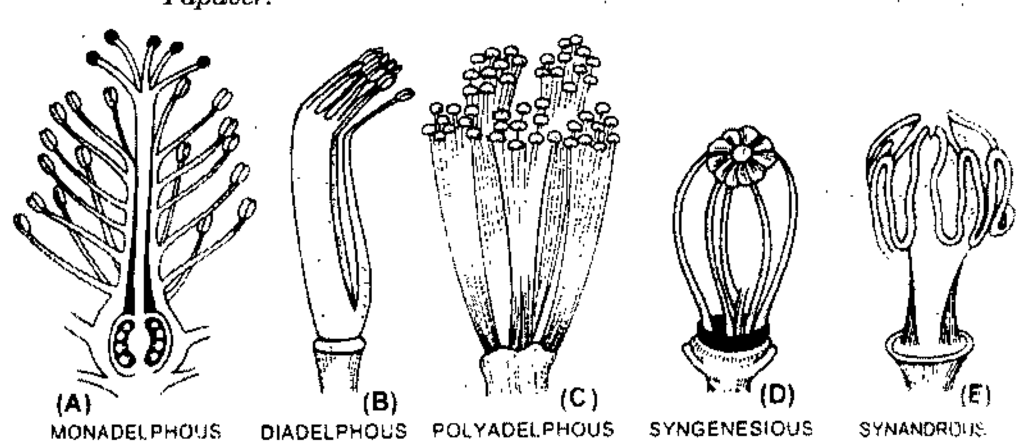


Fig. 1.25 (A-E) Cohesion of stamens

(d) Adhesion of stamens :

Alternative terms : Epipetalous/Gynandrous.

(i) **Epipetalous :** Stamens that are attached to and arise from petals *e.g., Ocimum.*

(ii) Episepalous : Stamens that are inserted on sepals or borne on sepals.

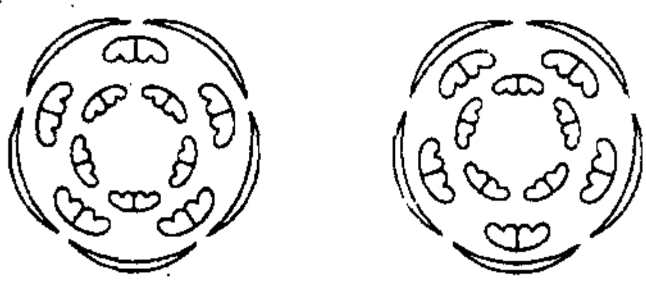
(iii) Epitepalous : Stamens that are inserted on tepals *e.g., Asphodelus.*

(iv) **Gynandrous :** Stamens adhering to the carpels either throughout their length or by their anthers only *e.g., Calotropis.*

(e) Sequence of staminal whorls :

Alternative terms : Diplostemonous/Obdiplostemonous.

(i) **Diplostemonous :** Stamens are arranged in two alternating whorls and those of the outer whorl alternate with the petals *e.g., Murraya* (Fig. 1.26 A).



(A) DIPLOSTEMONOUS (B) OBDIPLOSTEMONOUS

Fig. 1.26 (A, B) Position of staminal whorls with reference to petals

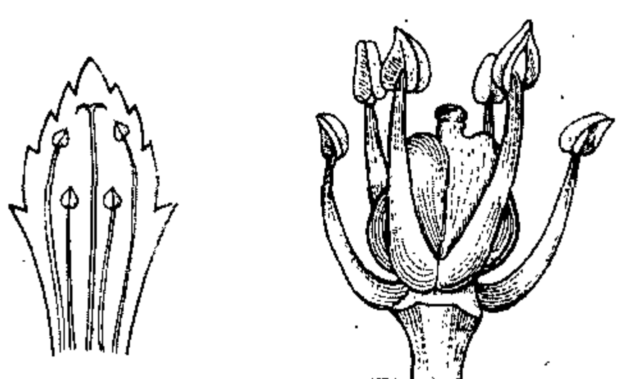
(ii) **Obdiplostemonous :** Stamens are arranged in two alternating whorls and those of the outer whorl lying opposite the petals *e.g., Stellaria* (Fig. 1.26 B).

(f) Length of filaments :

Alternative terms : Didynamous/Tetradynamous.

(i) **Didynamous :** Out of four stamens two are long and two are short *e.g., Ocimum* (Fig. 1.27 A).

(ii) **Tetradynamous :** An androecium of six stamens, four longer than the outer two *e.g.,* Mustard (Fig. 1.27 B).



(A) DIDYNAMOUS (B) TETRADYNAMOUS

Fig. 1.27 (A, B) Length of filaments.

(g) Position of stamens :

Alternative terms : Exerted/Inserted.

(i) **Exerted :** Stamens are protruding out of corolla tube *e.g.,* Passion flower.

(ii) **Inserted :** Stamens are included within the corolla tube *e.g., Catharanthus, Mussaenda.*

(h) Number of locules :

Alternative terms : Monothecous /Dithecous.

(i) **Monothecous** : One celled anther *e.g., Malva* (Fig. 1.28 A).

(ii) **Dithecous** : Two celled anther *e.g., Solanum* (Fig. 1.28 B).

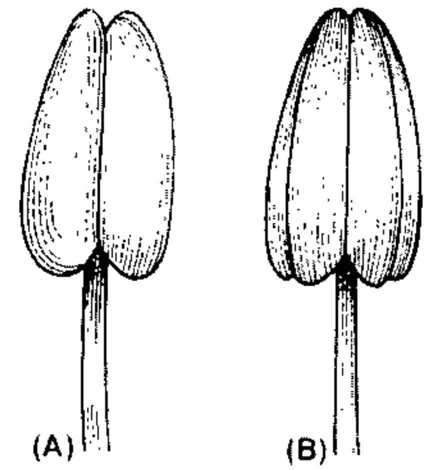


Fig. 1.28 Monothecous and dithecous stamens

(i) Attachement of filament of anther :

Alternative terms : Basifixed/Adnate/Dorsifixed/Versatile.

- **(i) Basifixed** : Filaments are usually attached to the base of the anther lobes *e.g., Brassica* (Fig. 1.29 A).
- **(ii) Adnate** : Filament runs up from base to the apex *e.g., Michelia* (Fig. 1.29 B).
- **(iii) Dorsifixed** : Filaments are attached to the dorsal side of anther *i.e.,* to the back of anther *e.g., Bauhinia* (Fig. 1.29 C).
- **(iv) Versatile** : Filament attached to the back of the anther at a single point only, so that the latter can swing freely *e.g.,* Grasses, Bottle brush (Fig. 1.29 D).

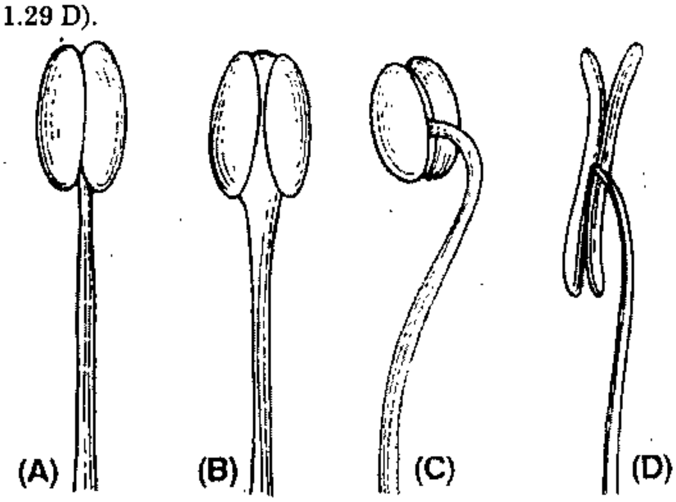


Fig. 1.29 (A-D) Attachment of filament to anther

XIII. Gynoecium

(It is collective term for the female whorl or fourth whorl of the flower. It is composed of one or more carpels. Carpel is a leaf like organ bearing ovules along the margins. In staminate flowers, sterile gynoecium or pistil is called **pistillode**).

(a) Number of carpels :

Alternative terms : Alternative terms : Monocarpellary/Bicarpellary/ Tricarpellary/ Tetracarpellary/Pentacarpellary/Multicarpellary.

- **(i) Monocarpellary** : Gynoecium is made up of only one carpel *e.g.,* Pea.
- **(ii) Bicarpellary** : With two carpels *e.g., Petunia.*
- **(iii) Tricarpellary** : With three carpels *e.g., Stellaria.*
- **(iv) Tetracarpellary** : With four carpels *e.g., Datura.*
- **(v) Pentacarpellary** : With five carpels *e.g., Hibiscus.*
- **(vi) Multicarpellary** : With many carpels *e.g., Papaver.*

(b) Cohesion of carpels :

(i) **Apocarpous :** A pistil with two or more separate carpels *e.g., Clematis.*

(ii) **Syncarpous :** A pistil with two or more united carpels *e.g., Hibiscus.*

(c) Position of ovary :

Alternative terms : Superior/Semi-inferior/Inferior.

(i) **Superior :** Ovary is borne at the top or occupies the highest position on thalamus *i.e.,* flower is hypogynous, above sepals, petals and stamens, *e.g., Dianthus, Stellaria, Citrus* (Fig. 1.30 A).

(ii) **Semi-inferior :** When the ovary is neither completely superior or completely inferior, thalamus grows around the ovary to form a cup, and bears sepals, petals and stamens on the rim of the cup, flower is perigynous *e.g.,* Peach, Plum, Rose (Fig. 1.30 B).

(iii) **Inferior :** When ovary borne below the level of sepals, petals and stamens, thalamus completely encloses it, flower is epigynous *e.g., Coriandrum, Mussaenda* (Fig. 1.30C).

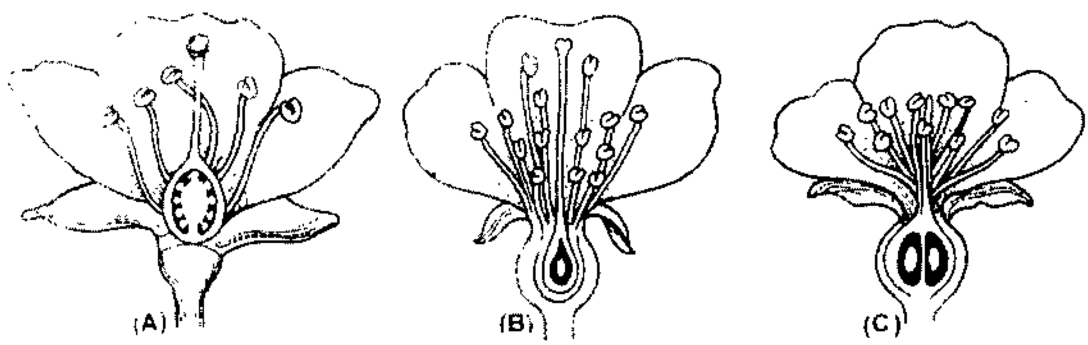


Fig. 1.30 (A-C) Position of ovary on thalamus

(d) Number of locules :

(A locule is a chamber or compartment of ovary)

Alternative terms : Unilocular/Bilocular/Trilocular/ Tetralocular/ Pentalocular/ Multilocular.

(i) **Unilocular :** With one compartment *e.g., Helianthus* (Fig. 1.31 A).

(ii) **Bilocular :** With two compartments *e.g., Solanum* (Fig. 1.30 B).

(iii) **Trilocular :** With three compartments *e.g., Asphodelus* (Fig. 1.31 C).

(iv) **Tetralocular :** With four compartments *e.g. Ocimum, Salvia* (Fig. 1.31. D).

(v) **Pentalocular :** With five compartments *e.g., Hibiscus* (Fig. 1.31 E).

(vi) **Multilocular :** With many compartments *e.g., Citrus.*

Fig. 1.31. (A-E) Number of locules.

(e) Number of ovules :

(An ovule is young seed in the course of development)

Number of ovules in each locule can be seen by cutting a transverse section of the ovary and observing it under microscope.

(f) Placentation :

Alternative terms : Marginal/Axile/Parietal/Free-central/Basal/Superficial.

(The arrangement of ovules within the ovary is called **placentation**. A place or part in the ovary where ovules are attached is called **placenta**).

- **(i) Marginal :** Placenta developing along the junction of the two margins of the carpel in one chambered ovary e.g., Pea (Fig. 1.32 A).
- **(ii) Axile :** The ovules are borne at or near the centre of a compound ovary (more than one carpels) on the axis formed by the union and fusion of the septa *e.g., Solanum* (Fig. 1.32 B).
- **(iii) Parietal :** Ovary unilocular and placenta bearing the ovules develop on the inner wall of the ovary *e.g., Argemone* (Fig. 1.32 D).
- **(iv) Free-central :** Ovary multilocular, the ovules are borne on a central column without any septa, *e.g., Stellaria* (Fig. 1.32 D).
- **(v) Basal :** Ovary unilocular and ovules are borne at the base of the ovary *e.g., Helianthus* (Fig. 1.32 E).
- **(vi) Superficial :** Ovary multilocular, placentae bearing ovules develop all around the inner surface of partition walls *e.g.,* water lily (Fig. 1.32 F).

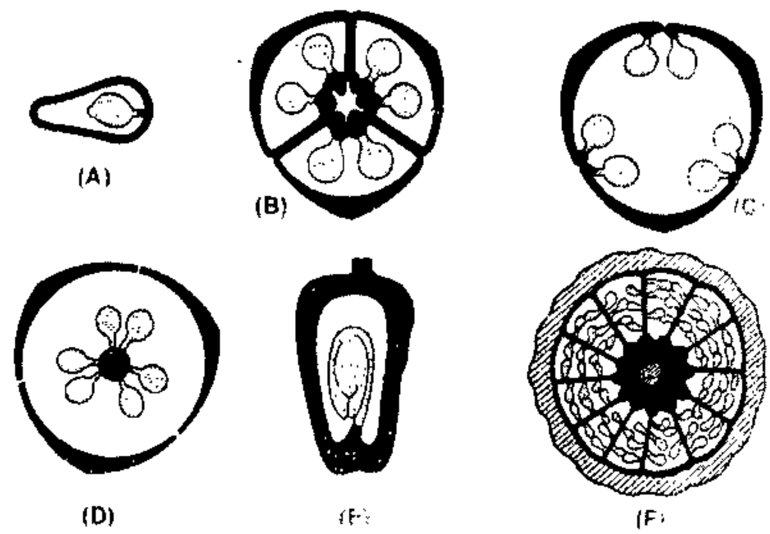


Fig. 1.32 (A-E) Various types of placentation (A) Marginal, (B) Axile, (C) Parietal, (D) Free-central, (E) Basal, (F) Superficial

1.5. FLORAL FORMULA

Once the description of the plant is completed, major characters of the flowers are written in a special way where a few signs and litters are used. It is called **floral formula.** This formula is useful in knowing major characters of a flower at one glance. Some of the commonly used denotations and to use these denotations indefinite order is given below :

(a) Bracts and epicalyx

Bracteate	Br
Ebracteate	Ebr
Bracteolate	Brl
Epicalyx	Epix
0 (zero) Absence of a particular whorl	

(b) Symmetry

Actinomorphic	⊕
Zygomorphic	Φ or %

(c) Sex

Male or staminate flower

Female or pistillate flower	
Hermaphrodite or bisexual flower	

(d) Calyx

Calyx	K
5 sepals free (Polysepalous)	K_5
5 sepals fused (Gamosepalous)	$K_{(5)}$

(e) Corolla

Petals	C
5 petals free (Polypetalous)	C_5
5 petals fused (Gamopetalous)	$C_{(5)}$

(f) Perianth

Tepals	P
Three free tepals (Polytepalous)	P_3
Three fused tepals (Gamotepalous)	$P_{(3)}$
Six tepals in two rows of three each	P_{3+3}

(g) Androecium

Androecium (Stamens)	A
Five free stamens (Polyandrous)	A_5
Five fused stamens	$A_{(5)}$
Ten stamens in two whorls of 5 each	A_{5+5}
Stamens absent	A_0
Stamens indefinite in number	A_∞
Stamens epipetalous	$\overparen{C \quad A}$
Stamens epitepalous (epiphyllous)	$\overparen{P \quad A}$
2 + 4	2 in one set and 4 in another
2 — 4	2 or 4
X	Variable.

(h) Gynoecium

Gynoecium (carpels)	G
Five free carpels (apocarpous)	G_5
Five fused carpels (syncarpous)	$G_{(5)}$
Carpels absent	G_0
Pentacarpellary, syncarpous, superior ovary	$\underline{G}_{(5)}$
Pentacarpellary, syncarpous, inferior ovary	$\overline{G}_{(5)}$
Pentacarpellary, syncarpous, semi-inferior ovary	$G_{(5)-}$
Pistil,	Pistillode
$\overparen{A \quad G}$	Androecium and gynoecium united

1.4. CLASSIFICATION AND IDENTIFICATION

At the end of the study, plant is placed in a known and recognised system of classification. **Benlham** and **Hooker's** system is considered to be most practical and used in this book. It is the most commonly used system in the important herbaria of the world. (For details please see unit II)

1.5. THE DIAGRAMS

A diagram illustrating the relative position and number of parts in each of the sets of organs comprising a flower, is called the **floral diagram.** It is a diagrammatic representation of cross-section of the floral bud in relation to mother axis. In floral diagram structure of a flower with whorls of floral parts is shown in concentric circles. All floral segments arising at the same level are placed in their correct relative positions in the same circle. Diagram is drawn in relation to its mother axis which is represented by a dot at the top of the diagram. Top of the diagram represents the posterior position of flower and base of represents anterior portion of flower. Bracts are shown at the base of the diagram and bracteoles if any, on sides of diagram. In diagram, outermost whorl represents calyx followed by corolla and androecium. Gynoecium is represented in the centre in its cross section. Fusion of units of a whorl is represented by joining them in a diagram. The symbols used in drawing a floral diagrams are as follows:

Mother axis
Actinomorphic flower
Zygomorphic flower
Bract
Epicalyx
Calyx or sepals
Corolla or petals
Stamens (dithecous)
Stamens (monothecous)
Stamens dithecous extrorse
Stamens dithecous introrse
Staminodes
Monoadelphous androecium
Syngenecious androecium
Nectar secreting disc around carpel
Gynoecium monocarpellary
Gynoecium bicarpellary syncarpous
Gynoecium tricarpellary syncarpous
Gynoecium pentacarpellary syncarpous

Floral formula and diagram provide complete characteristics and correct identification of the flower.

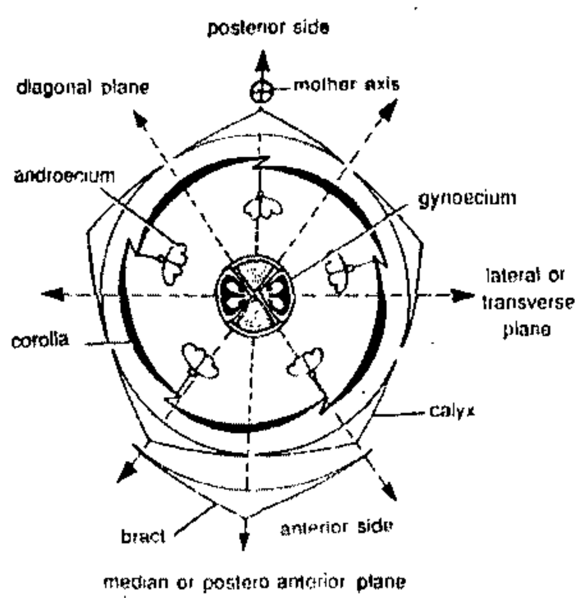


Fig. 1.33. Floral diagram of *Catharanthus roseus* showing different planes of floower.

1.6. SUMMARY

The angiospermic plant can be described in two parts : (a) the list of characters of the plant, its classification, identification, and, (b) drawing the diagrams of the plant, flower and specific parts of the flower. Description of angiospermic plant is done by special method. Only technical terms are used for their description. There are several alternative terms for every character of an organ. Of these, only one appropriate term is chosen and then written in a place meant for it in a particular series of terms. Once the description of the plant is completed, major characters of a flower are written in a special way where a few signs and letters are used. It is the floral formula and useful in knowing the major characters of a flower at a glance. In this method characters of bracts, symmetry, sex, calyx, corolla (or perianth), androecium and gynoecium are denoted in this order. At the end of description, plant is placed in a known and recognised system of classification, and diagrams of a flower twig, longitudinal section of the flower, a stamen, gynoecium, transverse section of the ovary and floral diagram should be drawn. The floral diagram is an ideal ground plan of a flower. It is a method with which many of the characteristics of flower parts and its symmetry can be expressed in graphic form.

STUDENT ACTIVITY

1. How you describe the flower in semitechnical language?.

2. Describe the significance of floral formula and floral diagram.

TEST YOUR SELF

1. Name the term in which major characters of a flower are written in a special way using few signs and letters.
2. Name the method with which many of the characteristic of flower, its parts and symmetry can be expressed in graphic forms.
3. What is the valid suffix for a family?.
4. What is the valid suffix for an order?
5. Name the mode of arrangement of the leaves on the stem and the branch.
6. Name the phyllotaxy when successive pairs of leaves arise at right angles to the preceding pair.
7. Name the term for the arrangement of flowers on the floral axis.
8. What is verticillaster?
9. What those leavs are called which arise from the underground modified stem?
10. What that flower is called in which gynoecium is present at the top most position of the thalamus.

ANSWERS

1. Floral formula 2. Floral diagram 3. –aceae
4. –ales 5. Phyllotaxy 6. Opposite decussate 7. Inflorescence
8. An special types of inflorescence, characteristic of *ocimum* and several members of family Lamiaceae.
9. Radical 10. Hypogynous.

UNIT-III

2

DESCRIPTION OF FAMILIES : DICOTYLEDONES POLYPETALAE

STRUCTURE

- Ranunculacae
- Caryophyllaceae
- Rutaceae
- Fabaceae
- Rosaceae
- Apiaceae
  - Summary
  - Student activity
  - Test yourself
  - Answers

LEARNING OBJECTIVES

By learning this chapter you will know the important characters of some important dicotyledons families belonging to class Polypetalae (Corolla of free petals)

2.0. RANUNCULACEAE (Butter Cup or Crow-Foot Family)

Classification :

Bentham and Hooker	**Engler and Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Herbaceae
Thalamiflorae	Ranales	Ranales
Ranales	Ranunculaceae	Ranunculaceae
Ranunculaceae		

This is a small family containing about 50 genera and over 1,900 species distributed mainly in north temperate zone. In India the family is represented by 20 genera and 154 species mainly confined to mountanious regions. The common examples are *Ranunculus* (butter cup, plains and warm valleys of Himalayas), *Delphinium* (lark spur, Plains and and Himalayas), *Clematis* (Virgins bower, Dehradun and Western Himalayas), *Thallictrum* (meadow-rue, from Simla to Sikkim and on Khasia Hills) etc.

Vegetative characters

Habit. The plants are annual or perennial herbs or a climbing shrubs (*Clematis, Narvelia*), rarely trees. They perennate by means of tuberous roots (*Aconitum*) or rhizomes.

Root. Tap root, adventitious or tuberous (*Ranunculus* spp. and *Aconitum*). The tap root system is in the initial stage but sooner or later replaced by the adventitious roots.

Stem. Herbaceous, in some climbing (*Clematis*) or underground rhizome or erect, branched.

Leaves. Generally simple, alternate, or opposite (*Clematis* Fig. 3), exstipulate rarely stipulate (*Thalictrum*), sheathing leaf base, petiolate rarely sessile

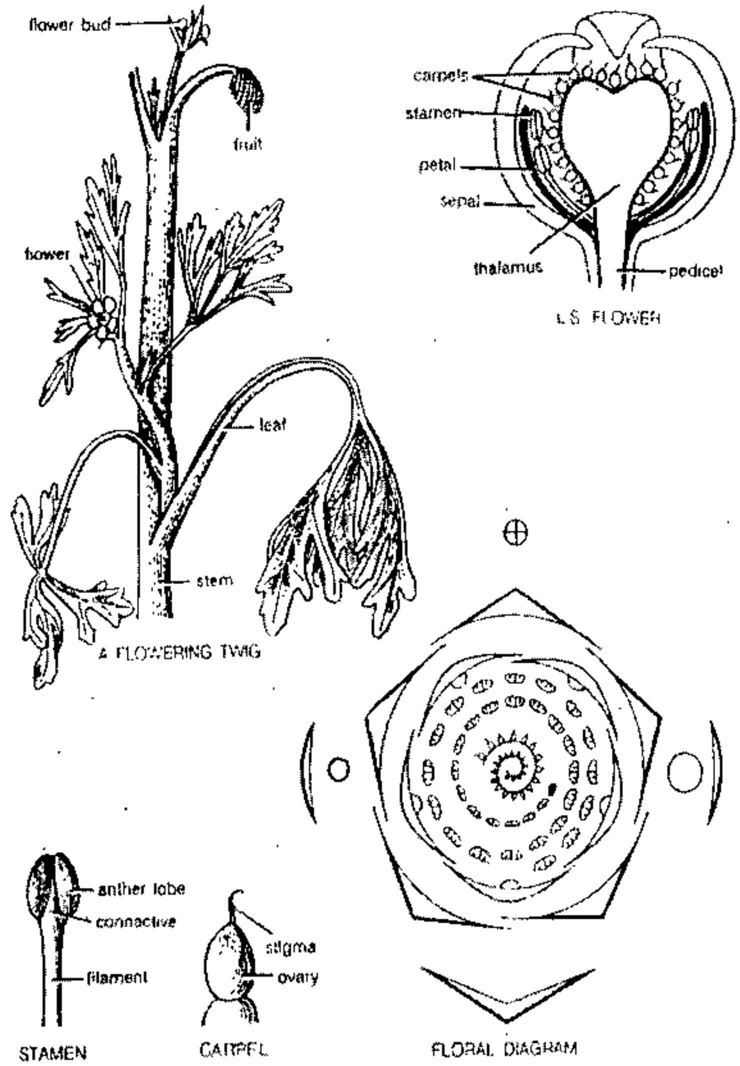


Fig. 1. ***Ranunculus scleratus.***

(*Delphiinium* Fig. 2). In some aquatic species leaves may show dimorphy (*Ranunculus aquatilis,* Fig. 1); unicostate or multicostate reticulate venation.

Floral characters

Inflorescence : Solitary terminal (*Anemone*), axillary (*Clematis,* Fig. 3), raceme (*Aconitum, Delphinium* Fig. 2) and cymose (*Ranunculus* spp.).

Flower : Pedicellate, ebracteate rarely bracteate, hermaphrodite, (unisexual in *Thalictrum*). Mostly actinomorphic (*Ranunculus*) rarely zygomorphic (*Delphinum* and *Aconitum*) hypogynous, complete, pentamerous. The floral parts are arranged spirally on the elongated receptacle.

Calyx : Sepals 5-8 caducous, polysepalous, petaloid, imbricate or valvate aestivation. In *Delphinium* and *Aconitum* the sepals are petaloid and the posterior sepal is spurred.

Corolla : Petals 5, polypetalous, variously coloured, caducous or wanting, nectaries present at the base of petals. Petals are united to form spur (*Delphinium*).

Androceium : Stamens indefinite, polyandrous, spirally arranged on the thalamus, inferior; anthers dithecous, extrorse and adnate.

Gynoecium : Polycarpellary (one carpel in *Delphinium* and 3 to 5 in *Aconitum*), apocarpous rarely syncarous (*Nigella*), ovary superior, marginal placentation (axile in *Nigella*).

Fruit : Aggregate, etario of achenes (*Ranunculus*), etario of follicle (*Aconitum*), follicle (*Delphinium*), septicidal capsule (*Nigella*) or berry (*Actaea*), etario of drupes (*Adonis*), etario of barries (*Hydrastis*) and simple pod (*Xanthrohiza*).

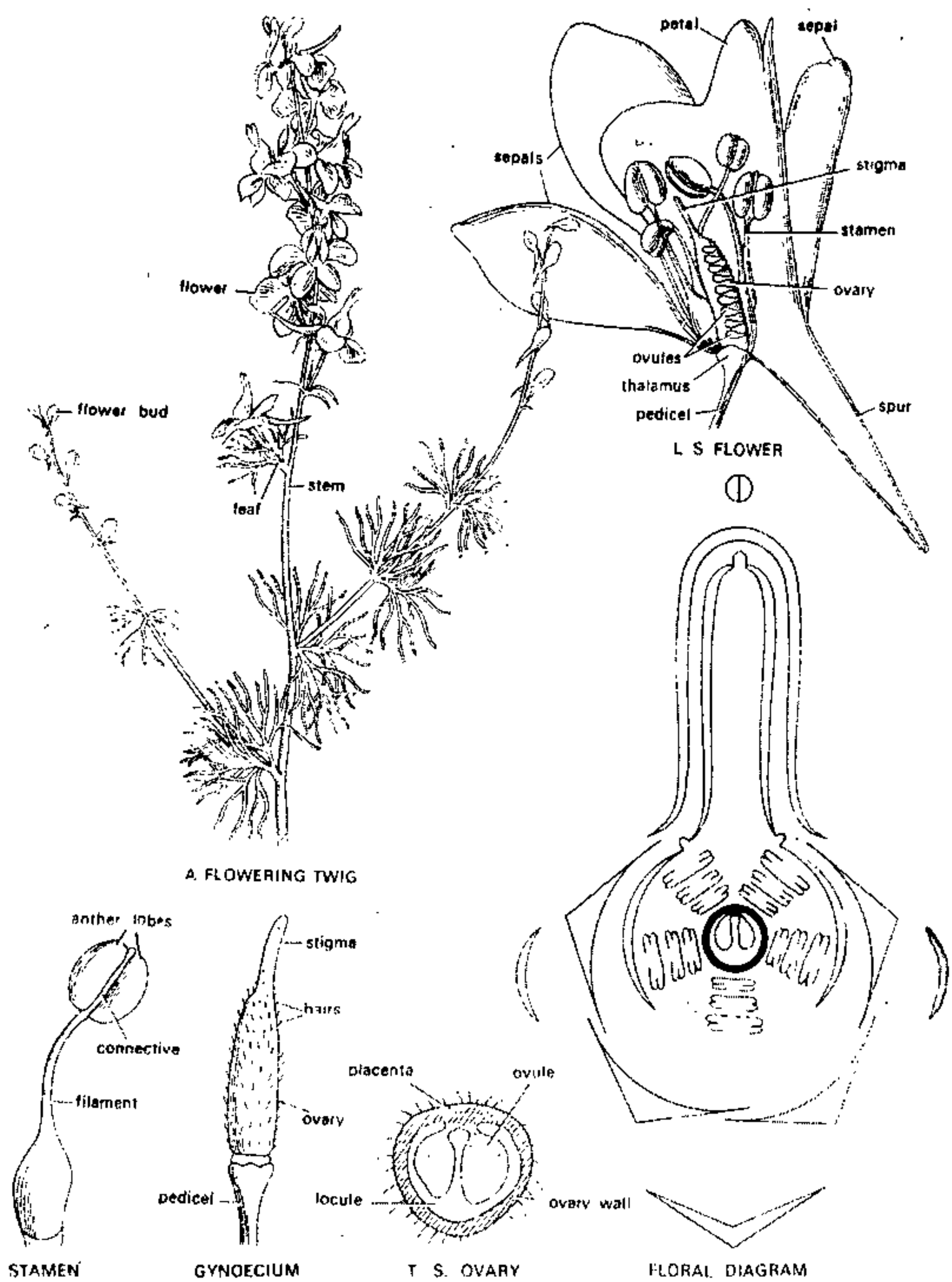


Fig. 2. *Delphinium ajacis.*

Seed : Small, oily and endospermic.

Pollination : Generally entomophilous (*Delphinium, Aconitum, Aquilegia*) and anemophilous in *Thalictrum.*

Floral formula.

Ranunculus : Br, brl, ⊕, ⚥, K_5, C_5, A_α, $\underline{G}\alpha$

Delphinium : Br, brl, ⊕, ⚥, K_5, $G_{(4)}$, A_{15}, $\underline{G}l$

Clematis : Br, brl, ⊕⚥, K_4, C_0, A_α, $\underline{G}4-6$

Economic Importance

A. Ornamentals :

Aconitum bicolor

Anemone purviflora : (Wind flower).

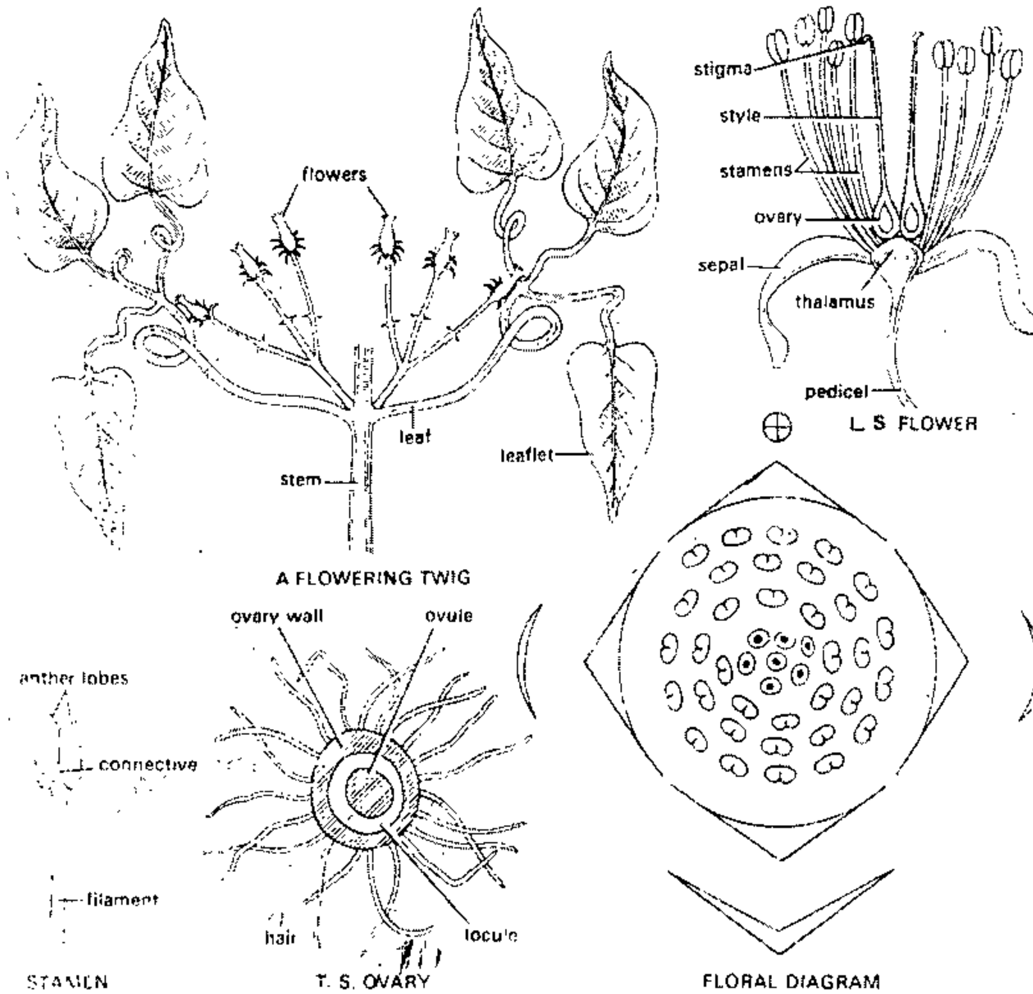


Fig. 3. *Clematis paniculata.*

Aquilegia vulgaris : (Columbine).
Caltha pulustris : (Marsh merigold).
Clematis paniculata : (Virgin Flower)
Delphinium ejacis : (Lark sur).
Nigella damascena : (Love-in-a-mist).
Paeonia emodii
Ranunculus asiaticus : (Butter cup).
Thallictrum alpinum : (Meadow-rue)
Ranunculus ficaria : Roots contain starch

Condiments :

Nigella sativa : (Black fennel, 'Kalaunji') : Seed.

C. Medicinal plants :

Aconitum nepallus

Roots tubers contain alkaloids 'aconite', 'pseudoaconite', used in the treatment of rheumatism.

Adonis aestivalis : Roots as cardiac stimulant.

Actaea spicata : Roots as nerve sedative.

Anemone pulsatilla : The drug 'pulsatilla' is used for treating nervous exhaustion in women.

Delphinium staphysagaria : Seeds contain alkaloid 'delphinin'; used in the treatment of skin diseases. *D. vestitum. D. brunonianum* : Cardiac and respiratory depresent.

Helleborus niger (Hellebore) : Used for chronic skin infections and worms.

Hydrastis canadensis : Contains an alkaloid barbarine which is used as antitode for snake poison.

Nigella saliva : Seeds are used as antidont for snake poison.

2.1. CARYOPHYLLACEAE (Pink or Chick weed family or *Dianthus family*)

Classification :

Bentham and Hooker	**Engler and Prantl**	**Hutchinson**
Dicotyledons	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Herbaceae
Thalamiflorae	Centrospermae	Caryophyllales
Caryophyllinae	Caryophyllaceae	Caryophyllaceae
Caryophyllaceae		

This is a small family containing about 70 genera and 1750 species. The plants are mostly distributed in cold climates of temperate regions, especially North temperate regions. In India, the family is represented by 20 genera and 105 species in temperate regions. The important members of the family are *Silane* (500 species), *Dianthus* (350 species), *Stellaria* (100 sps), *Spergula*, *Vaccaria* etc.

Vegetative characters

Habit : Mostly annual or perennial herbs and a few undershrub (*Acanthophyllum*), *Stellaria aquatica* is an aquatic herb.

Root : Branched tap root.

Stem : Aerial erect or partially decumbent branched with **swollen nodes,** glaucous.

Leaves : Simple, sessile, opposite decussate rarely alternate, exstipulate, if present scarious (thin, dry and membranous) margin entire or serrate, shape linear to lanceolate, leaf base connate, perfoliate or sheathing.

Floral characters

Inflorescence : Typical dichasial cyme characteristic of family and is known as **Cincinous** or **Caryophyllus** type of inflorescence, sometimes it ends in monochasial cyme rarely solitary. (*Githago, Arenaria, Drymaria*).

Flower : Bracteate, pedicellate, actinomorphic, hermaphrodite rarely unisexual, complete, pentamerous rarely tetramerous; **caryophyllaceous** and hypogynous.

Calyx : Sepals 5, polysepalous or gamosepalous, persistent, imbricate aestivation.

Corolla : Petals 5. polypetalous, clawed, notched or bifid, caryophyllaceous, imbricate aestivation.

Androecium : Stamens 8 to 10, polyandrous, obdiplostemonous; anthers dithecous, dehiscing longitudinally sometimes staminodes are present.

Gynoecium : Typically 5 carpels, may be 2 to 5, syncarpous; ovary superior, unilocular; **free central placetation** (Fig. 1–3), ovules one to many on each placentum, style free and corresponds to the number of carpels; so also the stigmas.

Fruit : Capsule rarely berry (*Cucubalus*).

Seed : Small. many and albuminous.

Floral Formula : $\oplus$, ⚥, C_5, A_{5+5}, $\underline{G}_{(2-5)}$

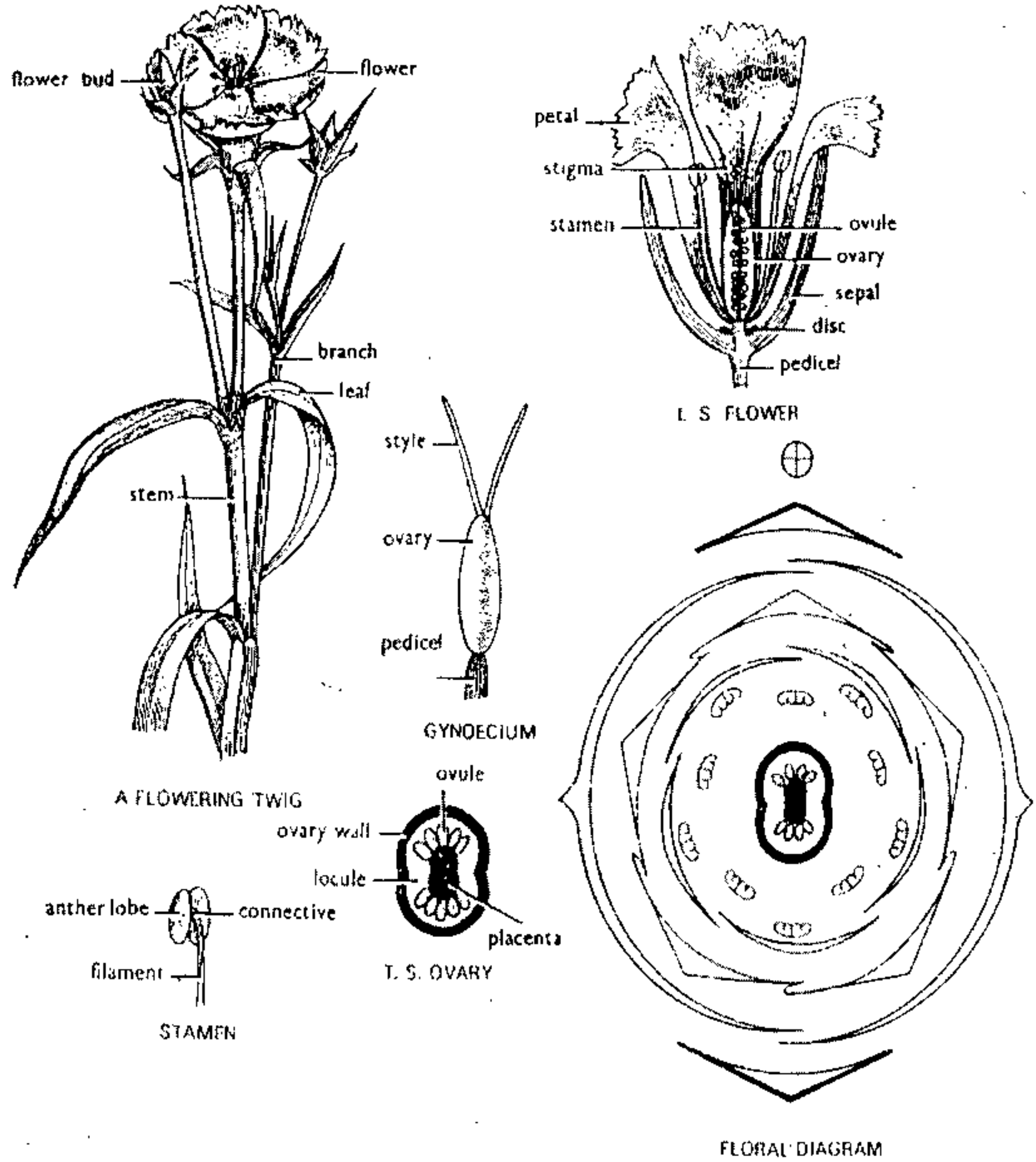


Fig. 1. ***Dianthus caryophyllus.***

Economic Importance

A. Ornamentals :

Arenaria grandiflora

Cerastiumarvense

Dianthus barbatus : (Sweet william).

D. carophyllus : (carnation).

Gypsophila elegans

Lychins flos-cuculi

Silene cucubalus

Vaccaria pyramidata

B. Edible Plants :

Stellaria aquatica : Stems and leaves edible.

C. Medicinal Plants :

Dianthus sinensis : Used as diuretic and anthelmintic in China.

Spergula arvensis : As diuretic in Columbia.

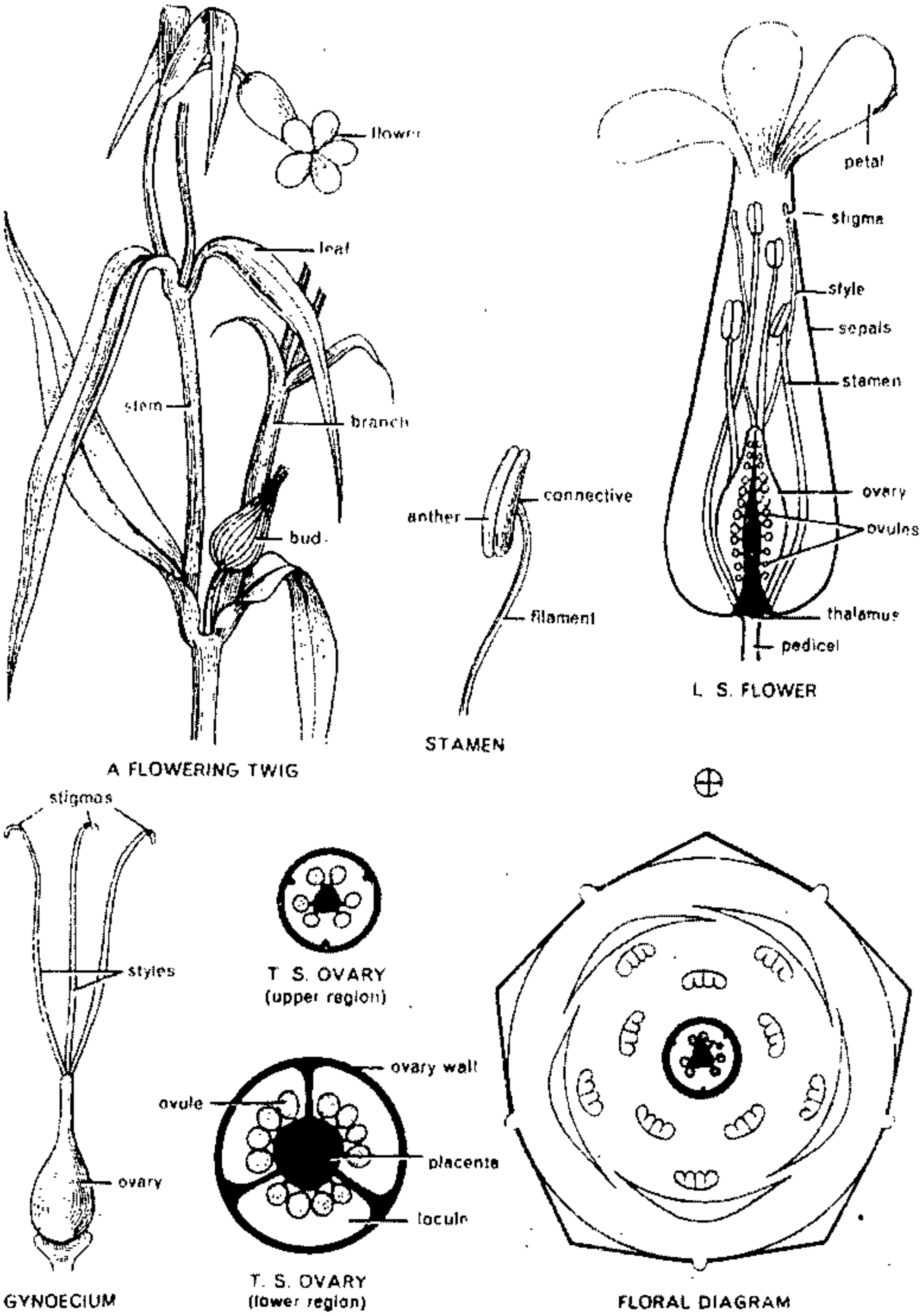


Fig. 2. ***Silene conoidea***

Stellaria media : Against inflamations of digestive, respiratory and renal tract.

D. Miscellaneous Uses :

Saponins are obtained from the roots of *Arenaria, Dianthus, Gypsophila, Lychnis, Vaccaria etc. Spergulad aevensis* and *Stellaria media* : Used as green manure. *Drymeria cordata :* Used to check soil erosion.

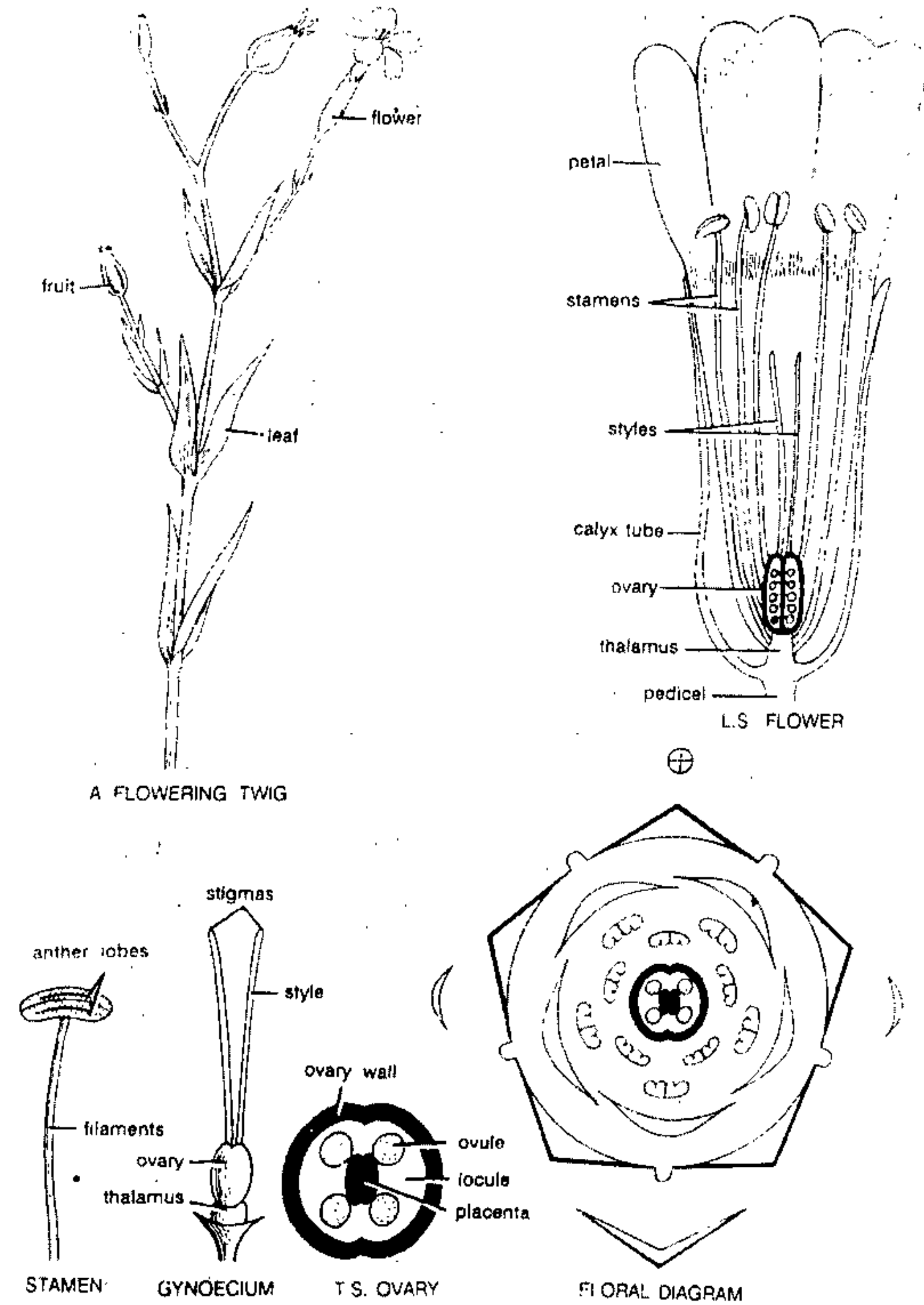


Fig. 3. ***Vaccaria pyramidata (= Saponaria vaccaria).***

9.2. RUTACEAE (Orange Family)

Classification :

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Lignosae
Discoflorae	Geraniales	Rutales
Guraiales	Rutaceae	Rutaceae
Rutaceae		

The family contains about 150 genera and 900 species. The plants are widely distributed both in temperate as well as tropical regions; especially in Australia and South Africa. In India, the family is represented by 23 genera and 80 species occurring mostly in the tropical and sub-tropical Himalayas and the Western Peninsular India : The well known plants are Lemon (*Citrus limon*), Malta or sweet orange (*C. sinensis*), Shaddock (*C. maxima*), Bael fruit (*Aegle marmelos*), Kaith (*Feronia limoni*) Kamina or Jasmine (*Murraya paniculata*) etc.

Vegetative Characters

Habit : The plant are generally shrubs (*Murraya, Limonia, Zanthoxylum*), trees (*Aegle, Citrus, Feronia*), rarely herbs (*Ruta graveolens*) with strong fragrance *Paramignya* is a shrub but climbs by means of axillary thorns.

Root : Tap root, branched often infected with fungus.

Stem : Woody (*Citrus, Feronia*), erect, cylindrical, branched, solid often thorny (*Citrus*), gland dotted.

Leaves : Alternate (*Citrus, Murraya* Figs. 1, 2), or opposite (*Evodia*), petiolate, petiole may be winged (*Citrus aurantium*), siple or compound-pinnate (*Murraya*),

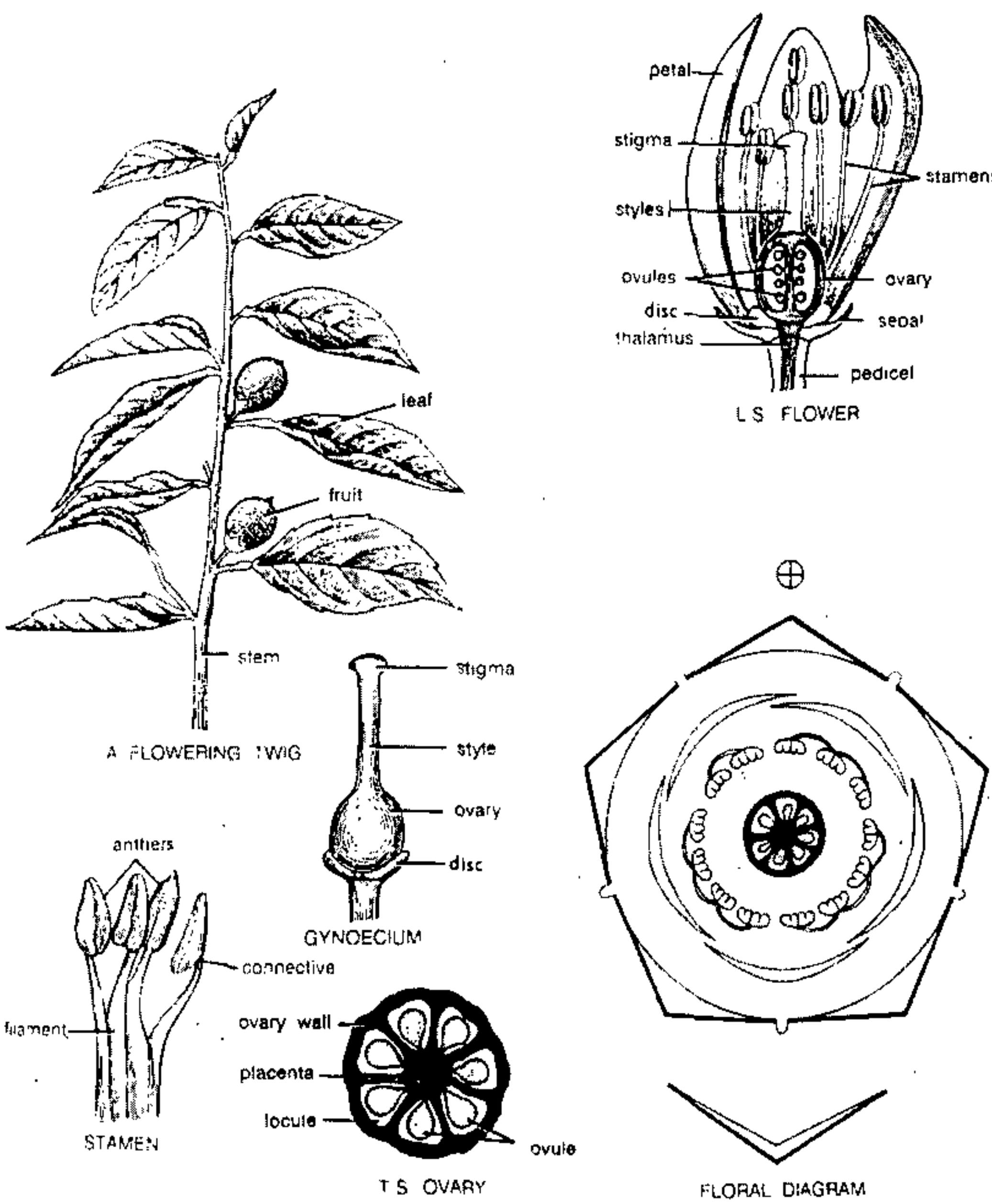


Fig. 1. *Citrus medica.*

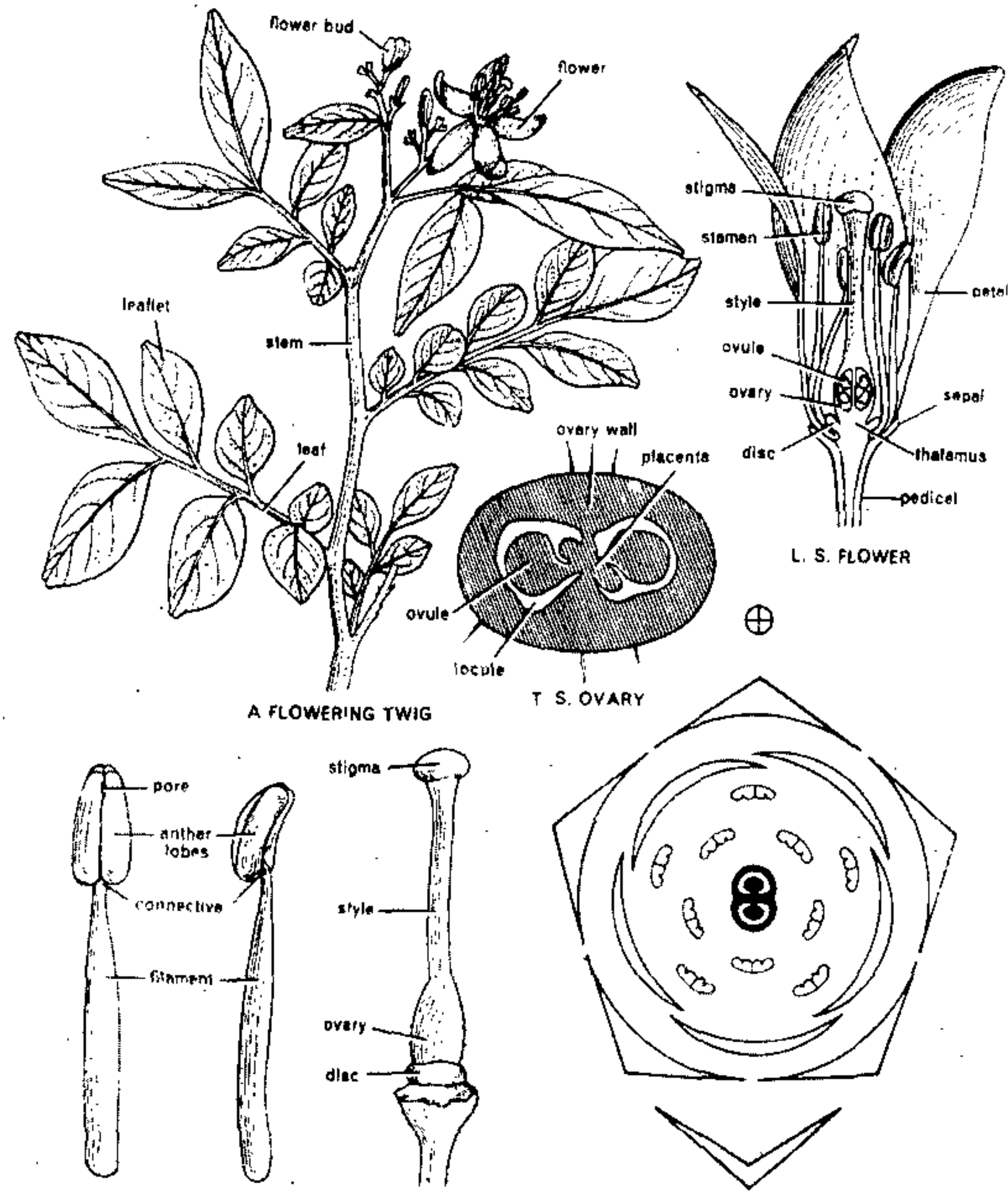


Fig. 2. ***Murraya paniculata.***

palmate (*Aegle* and *Citrus*) smooth, gland dotted, glands with essential oils, exstipulate, margin entire or serrate, unicostate reticulate venation. In *Citrus* petiole is winged.

Floral Characters

Inflorescence : Usually cyme or axillary or terminal corymb (*Murraya paniculata*) sometimes racemose or solitary.

Flower : Pedicellate, bracteate, bracteolate, hermaphrodite, or unisexual (*Zanthoxylum*, *Evodia*, *Feronia*), actinomorphic rarely zygomorphic (*Dictamnus* and *Correa*), hypogynous, complete, pentamerous or tetramerous (*Acronychia* and lateral flowers of *Ruta*). A fleshy nectariferous disc is present between the stamens and the ovary.

Calyx : Sepals 5 or 4, free or fused; in zygomorphic flower it becomes gamosepalous and tubular; imbricate; sometimes deciduous.

Corolla : Petals 5 or 4, polypetalous rarely gamopetalous (*Correa speciosa*) or absent (*Zanthoxylum*), variously coloured, imbricate.

Androecium : In majority of cases the stamens are as many as or twice the petals, obdiplostemonous and 10 in number; in *Citrus* numerous stamens with polyadelphous condition; in *Zanthoxylum* 3 stamens and in *Skimmia* 5 stamens; anthers introrse, dithecous, basifixed or versatile.

Gynoecium : Two to pentacarpellary and only slightly united at the base or the sides forming deeply lobed ovary with fused styles originating from the centre. In *Citrus* and *Taddalia* the carpels are fully united. In *Feronia* the carpel is only one celled with many parietal placentae. In other genera the placentation is of the axile type. Typically the ovary is superior with a prominent nectariferous disc below it. Ovule atropous.

Fruit : In Flindersioideae there is septicidal or loculicidal capsule; in Toddalioideae or drupaceous fruit; hesperidium in *Citrus* and berry in *Murraya*.

Seed : Endospermic or exalbuminous.

Pollination : Entomophilous; insects are attracted by the coloured petals, the nectar secreted by the disc is easily available.

Floral Formula

Citrus : Br, brl, ⊕, ⚥, $K_{(5) \text{ or } (4)}$, $C_{(5) \text{ or } (4)}$, A_{α} (Polyadel), $\underline{G}(\alpha)$

Murraya : Br, brl, ⊕, ⚥, C_5, A_{5+5}, $\underline{G}(2)$

Economic Importance

A. Ornamentals :

Dictamnus albus
Fortunella japonica
Glycomis pentaphylla
Luvunga scandens : ('Luvang lata').
Murraya paniculata : ('Kamini')
Ruta graveolens
Skimmia arborescens

B. Edible Plants :

Aegle marmelos : (Wood apple, 'Bel') : Fruit.
Feronia limoni : (Elephant apple, 'kaith') : Fruit.
Fortunella margaritta : ('Cheenarangi') : Fruits.
F. japonica - Fruits.
Citrus maxima : (Shaddock, 'Chakotra') : Fruit.
C. aurantifolia : (Lime, 'Kagzi Neebu') : Fruit.
C. aurantium : (Butter orange, 'Khatta') : Fruit.
C. limon : (Lemon, 'Pahari Neebu') : Fruit.
C. media : (Citron, 'Bara Neebu') : Fruit.
C. paradisi : (Grape fruit) : Fruit.
C. reticulata : (Loose skin orange, 'Santra') : Fruit
C. sinensis : (Sweet orange, 'Mausmi') : Fruit.

C. Condiments and Flavouring Materials :

Murraya koenigii : ('Kari patta') : Leaves.
Ruta graveolens : Leaves.
Zanthoxylum armatum : ('Tejbal') : Leaves

D. Oil Yielding :

Citrus aurantifolia : Essential oil obtained from flowers and leaves.

C. limettioides : Essential oil from flowers fruit and leaves **(Petitgrain oil)** is used in confectionary, cosmetics and flavouring agent.

C. reticulata : Essential oil from twigs and leaves used in perfumery.

C. aurantium var. *bergania* : Volatile oil from flowers fruits and leaves (**Bergamot oil**) used in confectionary, cosmetics and perfumery.

C. sinensis : Essential oil obtained from flowers (**Neroli oil**) used in perfumery.

E. Timber Yielding :

Fagera budranga : For making shuttles.

Feronia limonia : For agricultural implements.

Glycomis pentaphylla : For making tent pegs and tool handles.

Murraya paniculata : Wood for making tool handles, mathematical instruments, walking sticks and cabinet work.

Zanthoxylum armatum : For making walking sticks.

F. Dye Yielding :

Taddalia asiatica : Root bark yields yellow dye.

G. Gum Yielding :

Aegle marmelos : Gum similar to 'gum arabic' in it's properties.

H. Medicinal Plants :

Acronychia pedunculata : Fish poison, used against ulcers.

Aegle marmelos : Fruit pulp cooling, laxative; unripe fruits in diarrhoea; Root and stem bark in intermittent fever.

Citrus aurantifolia : Appetizer, in bilious vomiting.

C. aurantium : Laxative.

C. limettioides : In fever, jaundice.

C. limon : In scurvy, rheumatism.

C. maxima : Nutritive, cardiotonic, in epilepsy.

C. medica : Laxative, carminative.

C. reticulata : Laxative, tonic, relieves vomitting.

C. sinensis : Fruit blood purifier, rind carminative.

(Rind of *Citrus* fruits contains d-limonene, linalool etc.).

Cusparia febrifuga : 'Cusparian bark' as a substitute for quinine.

Murraya koenigii : Plant as stimulant, antiseptic.

M. paniculata : Leaves in dropsy, root and stem bark in diarrhoea.

I. Miscellaneous Uses :

C. maxima : for making jams and jellies.

C. aurantifolia : For making non-alcoholic drink, jams and jellies.

2.3. FABACEAE* (Cassia or Amaltas Family)

Classification :

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Lignosae
Calcycflorae	Rosales	Leguminales
Rosales		

This family contains about 482 genera and 7,200 species cosmopolitan in distribution but abundant in the tropical and subtropical regions. The family is represented in India by 100 genera and over 700 species occurring chiefly in Pennisular India and the Himalayas. The family includes important food crops for *e.g., Pisum sativum* (garden pea), *Glycine max* (soybean), *Arachis hypogaea* (ground nut), *Phaseolus* spp. (Beans), *Crotolaria juncea* (sun hemp) etc.

*If the three subfamilies of Leguminosae are raised to family level then the alternative name given above (Fabaceae) is used for the Papilionaceae and other are named as Caesalpiniaceae and Mimosaceae.

Vegetative Characters

Habit : The plants are generally herbaceous climbers but there are also herbs. (*Trifolium*) or shrubs (*Cajanus*) or lianas (*Donis*) or trees (*Dalbergia*) or twiner (*Lablab*).

Root : Tap with nodules containing nitrogen fixing bacteria (*Rhizobium*).

Stem : Aerial; erect or weak: herbaceous or woody, winged in *Lathyrus*, presence of stem nodules in *Aeschynemene* having nitrogen fixing bacteria.

Leaf : Alternate; Stipulate, Simple in *Flamingia*, 3-foliate in *Trifolium, Trigonella*, 5-foliate in *Lotus*, pinnate in *Indigofera, Cyamopsis;* Upper leaflets modified into tendril in *Pisum;* Pinnate leaf ending in a bristle or tendril in *Cicer, Vicia;* Leaf modified in a tendril in *Lathyrus aphaca*.

Floral Characters

Inflorescence : Raceme in *Melilotus;* Panicle in *Dalbergia;* Axillary heads in *Trifolium;* Cyme in *Pisum*.

Flower : Usually bracteate; Zygomorphic; Hermaphrodite; Hypogynous; Pentamerous; Pollination generally cross, entomophilous, self also in *Pisum*, the essential organs slip back within the keel in *Trifolium*, piston mechanism in *Lotus, Ononis;* Style hairy to sweep pollen grains from keel in *Lathyrus* and *Pisum* (Fig. 1).

(i) Calyx : 5 sepals; Gamosepalous; Odd sepal anterior, valvate or imbricate aestivation.

(ii) Corolla : 5 petals arranged as 1+2+(2); Polypetalous (Fig. 2–5); Papilionaceous; Posterior petal called **standard** or **vexillum;** Postero-laterals as **wings** or **alae;** two

Fig. 1. A-F. *Pisum sativum* : A. Flowering and fruiting branch, B. Standard petal, C. flower (longitudinal section), D. Pod, E. Pod (longitudinally cut), F. Seed.

Fig. 2. A-E. *Crotaloria juncea* : A. Flowering and fruiting branch. B. Flower, C. Expanded androecium, D. Gynoecium (longitudinal section), E. Pod (longitudinally open).

anterio-laterals fused from the **keel** or **carina** which encloses the stamens and carpels. Corolla showing vexillary or descending imbricate aestivation; Wings and keel absent in *Amorpha*.

(iii) Androecium : Generally (9) + 1; diadelphous; (5) + (5) Stamens, diadelphous in *Smithia* and *Aeschynomene;* Monoadelphous in *Crotalara, Ononis, Cyamopsis, Zornia, Glycine, Pueraria* etc. Polyandrons in *dalhousia, Sophora, Pericopsis;* 10th stamen absent in *Abrus;* Introrse.

(iv) Gynoecium : Monocarpellary; Superior or rarely semi-inferior; narginal placentation. both androecium and gynoecium remain enclosed within the keel.

Fruit : Legume or Pod; Pods moniliform in *Desmodium,* spiral in *Medicago;* 10 seeded in *Butea* and *Psoralia.*

Seed : Non-endospermic with large curved embryo.

Floral Formula : Br, brl. ⚥, $K_{(5)}, C_{1+2+(2)}, A_{(9)}+1, \underline{G}_1$

Economic Importance

A. Ornamentals

Clitoria ternatea : (Butterfly pea, 'Aparajit') : Worshipped particularly in Bengal.

Erythrina indica : (Indian coral tree).

Lathyrus odoratus : (Sweet pea).

Lupinus albus : (Lupine)

Pongamia pinnata : A shade tree, Pongam oil tree.

Sophora japonica : (Japanese pagoda tree).

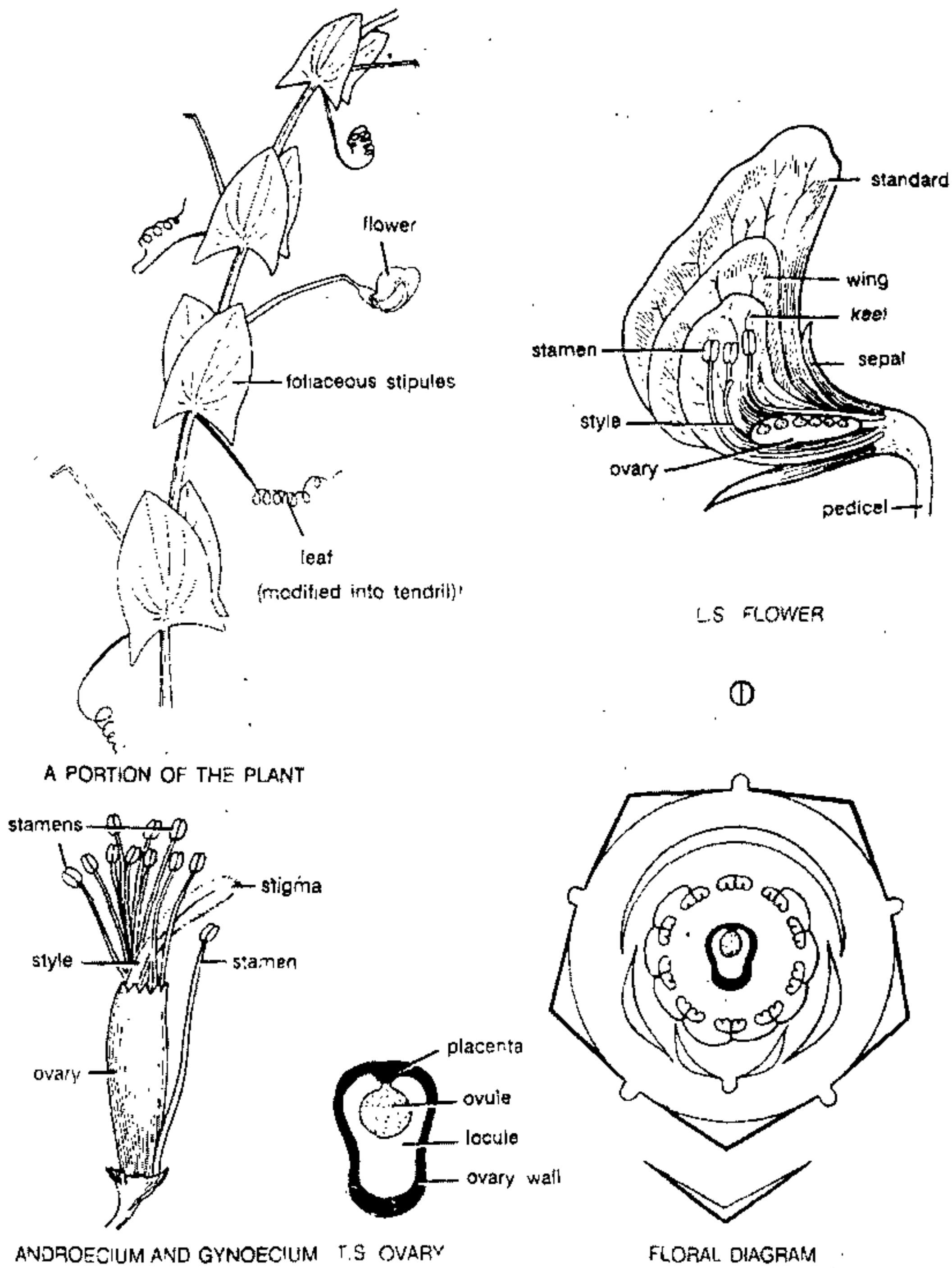


Fig. 3. Lathyrus aphaca

B. Pulses and vegetables

Cajanus cajan : (Pgeon Pea, 'Arthar').
Cicer arietinum : (Chick pea, Gram, 'Chana').
Cyamopsis tetragonoloba : Cluster bean, 'Gwar').
Dolichos biflorus : Horse gram, 'Kulat').
Glycine max : (Soybean, Soya).
Lablab biflorus : (Hyacinth bean, 'Sem')
Lens culinaris : (Lentil, 'Masoor').
Pisum sativum : (Garden Pea. 'Matar').
Phaseolus vulgaris : (French bean).
Vicia faba : (Field bean, 'Bankla').
Vigna mungo : (Black gram, 'Urd').

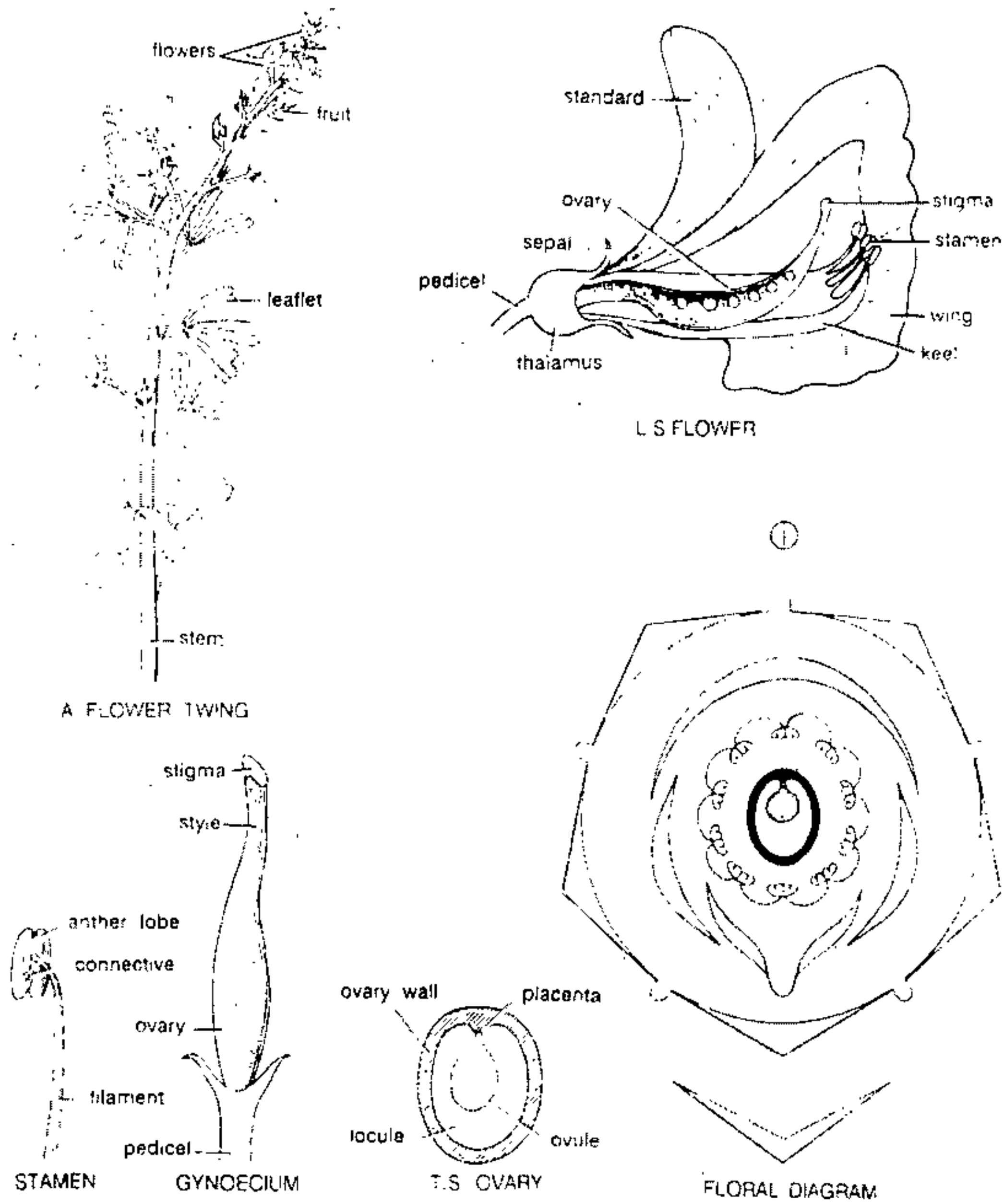


Fig. 4. *Crotolaria medicaginea.*

V. aconitifolia : ('Moth').

V. radiatus : (Green gram, 'Moong').

V. unguiculata : (Cow pea, 'Lobia').

C. Condiments :

Trigonella foenum-graecum : (Fenugreek, 'Maithi') : Seeds used as condiment, shoots as vegetable.

D. Oil Yielding :

Arachis hypogea : (Ground nut, 'Moongphali') : Seed oil for cooking, soap manufacture, also an lubricant, by hydrogenation yields 'Vanaspati ghee'.

Ghycine max : Seed oil used in medicine.

Pongamia pinnata : Seed oil used as illuminant, lubricant and in soap manufacture.

E. Fibre Yielding :

Abrus precatorius : ('Ratti') : Stem fiber for making baskets.

Crotalaria juncea : (Sun hemp, 'Sunn') : Stem fiber used for making ropes.

F. Timber Yielding :

Aeschynomena aspara : (Soft sola, 'Sola') : For making hats, rafts, elephant pads etc.

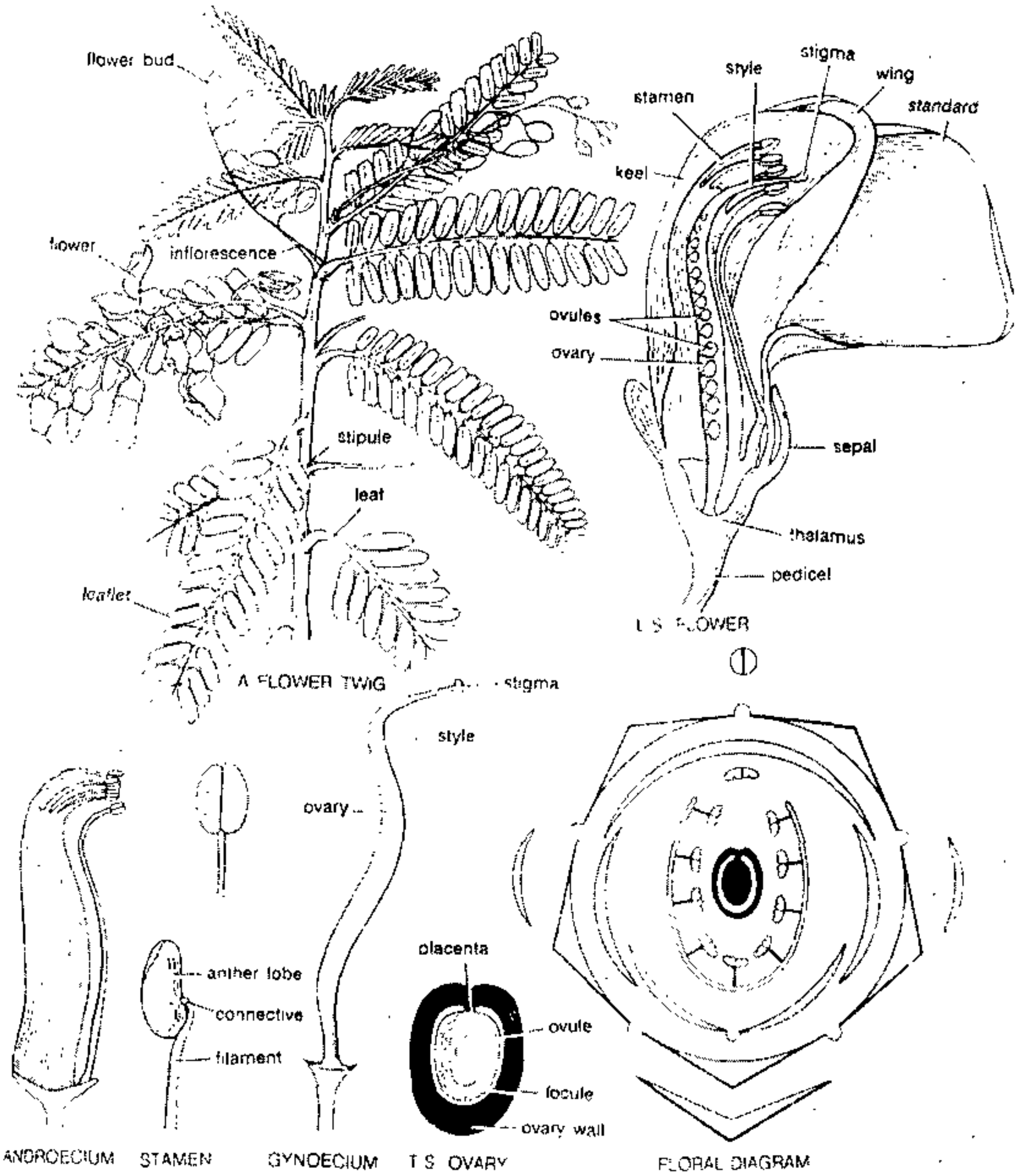


Fig. 5. *Sesbania sesban.*

A. indica : (Hard sola).

Dalbergia sissoo (Sisal, 'Sheesham') : Yields furniture wood.

D. latifolia (Rose wood) : Furniture wood.

Ougenia dalbergioides : Elastic wood.

Pterocarpus santalinus (Red sandal wood, 'Lal chandan') : For agricultural impliments, photoframes.

P. marsupium (Indian kino tree) : For plough and oil mills.

Dye Yielding :

Butea monosperma : ('Taisu', 'Palash') : Orange-red dye from flowers.

Clitoria ternatea : Blue dye from flowers and seeds.

Crotalaria striata : Black dye.

Ertythrina variegata : Red dye from flowers.

Indigofera tinctoria : (Indigo, 'Neel') : Blue dye from plant for dying cotton and rayon, also for making ink.

Pterocarpus santalinus : Red dye from wood for dying cotton, wood and leather.

H. Gum Yielding :

Astragalus gummifera : Source of **Gum tragacanth,** used in cosmetics, confectionery and textile industry.

Cyamopsis tetragonoloba : Yield edible gum.

G. Medicinal Plants :

Abrus precatorius : Leaves and roots in cough and cold, seeds contain 'abrin', poisonous, used for criminally poisoning the cattles.

Arachis hypogea : Seed oil aperient and emollient.

Cyamopsis tetragonolobba : Used to cure night blindness.

Glycerrhiza glabra : (Liuoric, 'Mulehti') : Roots and stems used in cough.

Krameria triandra : Yields drugs 'krameria' for diarrhoea.

Lupinus albus : Anthelminthic and diuretic.

Moghania grahamiana : Resin anthelminthic, also in cough

Mucuna prurita : ('Kaunch') : Pods anthelminthic.

Trigonella foenum-graecum : Seeds carminative.

J. Miscellaneous uses :

Crotolaria serica : Used as fodder and green manure.

Medicago sativa : (Alfalfa, Lucerene, 'Rizka').

Trifolium alexandrianum : (Clover, 'Barseem') used as fodder and green manure.

T. repens, T. lappaceum : Fodder and green manure.

Abrus precatorinus : ('Ratti') : Seeds for weighing, each seed weighing 1.75 grains, once used by jewellers in India

2.4. ROSACEAE (Rose family)

Classification :

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Polypetalae	Archichlamydeae	Lignosae
Calyciflorae	Rosales	Rosales
Rosales	Rosaceae	Rosaceae
Rosaceae		

The family comprises some 2000 species distributed over 100 genera. In India they are represented by over 25 genera and 215 species mainly confined to the temperate Himalayas ascending upto about 6000 meters.

Vegetative Characters

Habit : The plants show great variatiion in habit. The plants may be annual (*Neurada* spp.) or perennial prostrate herb, scandent or climbing or erect (*Rosa* spp.) shrubs or trees. *Cydonia* species are bushes. Trees are common and many of them are our popular fruit trees *e.g., Prunus amygadalus* (H. Badam); *Prunus persica* (H. Aru); *Pyrus communis* (H. Naspati, Fig. 1); *Pyrus malus* (H. Seb) etc.

Root : Tap, branched sometimes adventitious arising from stem cuttings.

Stem : Erect, prostrate or climber, branched, hard and woody, runner or sucker. Vegetative propagation takes place by means of runner or sucker or cuttings, many shrubby species are with spines, in some prickles are present (*Rosa* spp.)

Leaves : Alternate rarely opposite (*Rhodotypos*). simple or compound sometimes pinnately compound, stipulate, stipule may be minute and caducous (*Spiraea, Pyrus*), adnate and persistent (*Rosa, Rubus*), leaf base conspicuous.

Floral Characters

Inflorescence : Solitary (*Potentilla, Rosa servica*) or grouped in racemose (*Agrimonia*), terminal corymbose (*Rosa moschata*), terminal cyme or corymbose cyme (*Potentilla sibbaldi*)..

Flower : Actinomorphic very rarely zogomorphic, bisexual or rarely unisexual (*Spiraea aruncus*), pentamerous or tetramerous, hypogynous or epigynous (*Pyrus*) or perigynous (*Rosa*); stipules may be represented by epicalyx (*Fragaria, Potentilla,* Fig. 2, 3).

Calyx : Sepals 5, gamosephalous, adnate to the receptacle; sometimes epicalyx present; calyx tube remains free or adnate to the ovary, green, imbrcate or valvate aestivation.

Corolla : Petals 5, or multiples of 5, polypetalous, **rosaceous,** inserted on the receptacle cup variously coloured; petals entirely absent (*Poterium, Alchemlla, Pygeum gardneria*), or petals may be indefinite (*Rosa* spp.) sometimes stamens may be transformed into petal like structures; imbrcate aestivation in bud.

Androecium : Stamens 2, 3 or 4 times the number of ppetals, may be indefinite, free, commonly borne on the rim of the torus; anthers small, dithecous, splitting longitudinally, introrse in bud; rarely stamens 1 to 4 (*Alchemilla*).

Gynoecium : Carpel 1 (*Prunus, Prinsepia*) or (*Agrimonia atorium*) or 5 (*Pyrus*) or indefinite (*Fragaria* and *Rosa*), apocarpous rarely syncarpous, ovary superior sometimes inferior (*Pyrus*), axile placentation, nectar secreting disc present between stamens and carpels; when syncarpous the placentation is axile, if apocarpous then basal.

Fruit : Variable, drupe (*Prunus,* Fig. 4), etario of achenes (*Potentilla*) berry (*Eriobotrya japonica*), pome (*Pyrus,* Fig. 4).

Pollination : Entomophilous-insects are attracted by nectar, colour, aroma or protandrous nature.

Fig. 1. A-F. ***Prunus persica :*** **A. Flowering branch, B. Flower, C. Flower (longitudinal section), D, E. Stamens, F. Ovary (transverse section).**

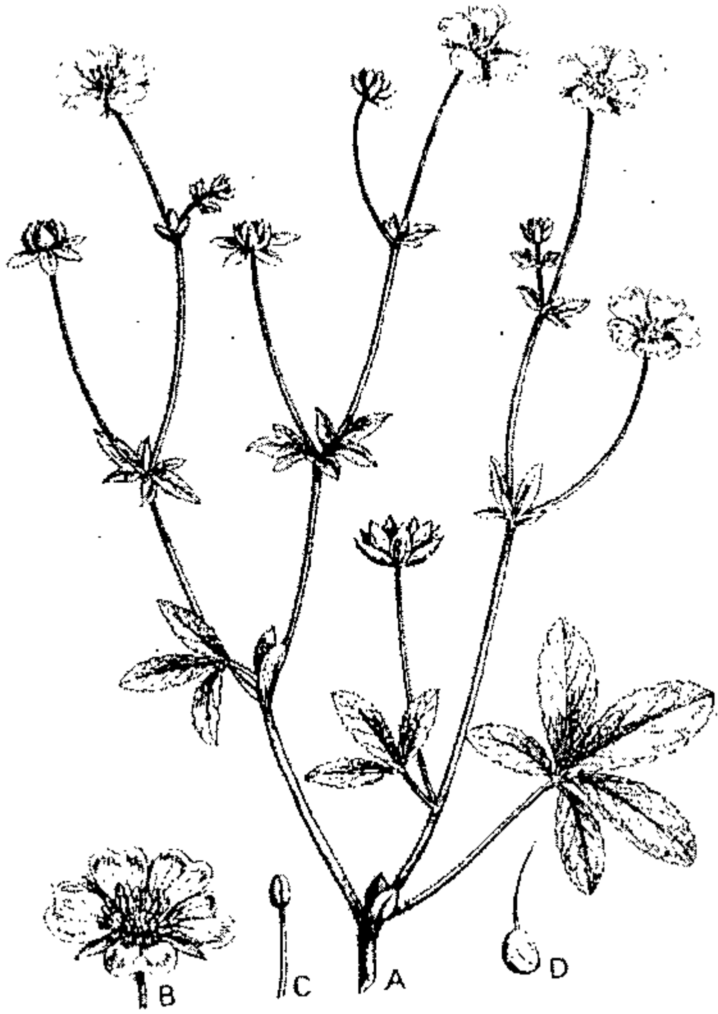


Fig. 2. A-D. *Potentilla nepalensis* : A. Flowering branch, B. Flower, C. Stamen, D. Carpel.

Floral Formula

Prunus : Br, $\oplus$, $\mathrm{⚥}$,$K_{(5)}$ $C_{(5)}$, A_{α} ,$\underline{G}_1$

Eriobotrya : Br, $\oplus$, $\mathrm{⚥}$, $K_{(5)}$, $C_{(5)}$, A_{α} ,$\overline{G}_{(2-5)}$

Potentilla : Br, $\oplus$, $\mathrm{⚥}$,$K_{(5)}$, $C_{(5)}$, A_{α} ,$\underline{G}_{(\alpha)}$

Economic Importance

A. Ornamentals :

L. mollis : (Hawthorn).

Exocorda racemosa : (Pearl bush).

Pyracantha coccinea : (Fire thorn).

Rosa alba : (Rose) : extensively cultivated in gardens

R. banksiae : (Climbing rose).

R. moschata : All garden roses.

Spiraea cantoniensis : Hedge plant.

B. Edible plants :

Eriobotrya japonica : ('Loquat') : Fruit.

Fragaria vesca : (Perpetual strawberry) : Fruit.

F. nilgerensis : (Houtbois strawberry) : Fruit.

F. chiloensis : (Garden strawberry) : Fruit.

Pyrus malus : (Apple) : Fruit

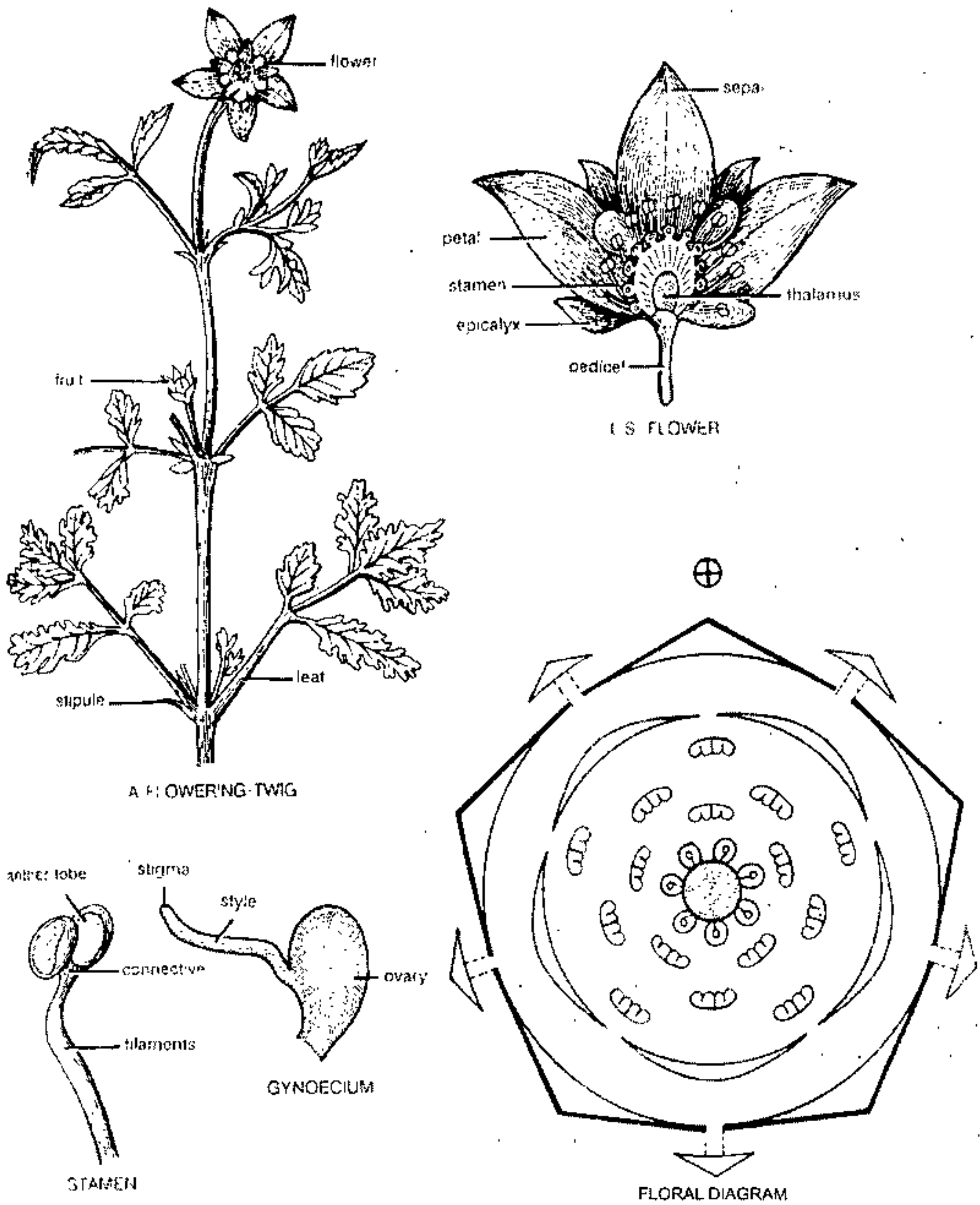
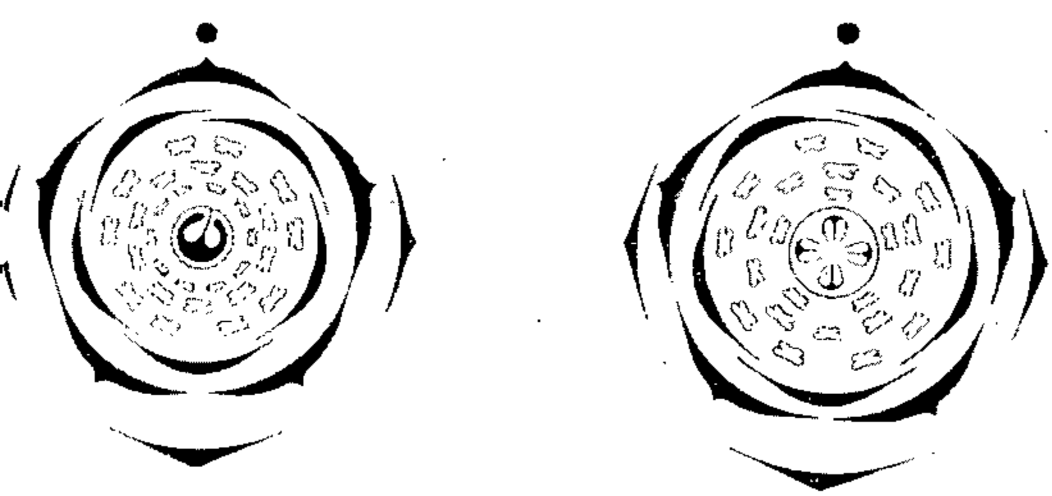


Fig. 3. ***Potentilla supina.***



A. *Prunus persica* B. *Pyrus*

Fig. 4. Floral Diagrams

P. communis : ('Naak') : Fruit, Pear

P. pyrifolia var. *culta* : (Pear, 'Nashpati') : Fruit.

P. vestita ('Mauli') : Fruit.

Prunus amygdalus : (Almond, 'Badam') : Seed.

P. armeniaca : (Apricot, 'Khubani') : Fruit.

P. avium : (Sweet cherry, 'Gilas') : Fruit.

Prunus domestica sub sp. *insititia* : (Plum, 'Aalucha') : Fruit.

P. cerasus : (South cherry, 'Aalu-balu') : Fruit.

P. persica : (Pear, Aru) : Fruit.

Rubus ellipticus : (Yellow raspberry, 'Hisalu') : Fruit.

C. Oil Yielding :

Prunus amygdalus : Seed oil as hair tonic, also used in perfumery.

P. persica : Seed oil for cooking and illumination.

Rosa centifolia : Perfume obtained from petals.

D. Timber Yielding :

Wood from *Crataegus oxycantha, Cotoneaster bacillaris, Prunus cerasoides, Pyrus pashia, P. malus, P. communis* and *P brunonii* used for making walking sticks.

E. Dye Yielding :

Agrimonia eupatoria : Used as asteringent.

F. Medicinal Plants :

Agrimonia eupatoria : Used as asteringent.

Geum arboreum : Used in diarrhoea and dysentry.

Hagenia abyssinica : An anthelminthic drug from flowers.

Potantilla anserina : Used in arthrites.

Rosa centifolia : Petals laxative.

Rubus fruticosus : Roots and leaves in whooping cough and dysentry.

2.5. APIACEAE (UMBELLIFERAE)

(Coriander family)

Classification :

Bentham & Hooker	Engler & Prantl	Hutchinson
Dicotyledones	Dicotyledoneae	Dicotyledones
Polypetalae	Archichlamydeae	Herbaceae
Calyciflorae	Umbelliflorae	Umbellales
Umbellales	Apiaceae	Apiaceae
Apiaceae		

This is a large family containng about 275 genera and 2,850 species widely distributed throughout the world but they are most abundant in north temperate zone In India it is represented by 53 genera and 200 species occurring chiefly in the temperate and Himalayas but some species are also cultivated in warmer parts.

Vegetative Characters

Habit : Plants are mostly herbs which may be annual, biennial or perennial, the herbs may be large (*Bupleurum, Heraceleum, Agelica*) rarely shrubs with aromatic odour due to the presence of oil ducts. *Pseudocarum* climbs by means of its petioles which are very sensitive to contact.

Root : Tap, branched sometimes swollen for the storage of food material *e.g.*, Carrot (*Daucus carota*).

Stem : Erect or prostrate; climbng in *Pseudocarum;* swollen nodes, sometimes ridged, usually fistular, glaucous or glabrous.

Leaf : Cauline and ramal; radical in young plants of *Daucus,* usually exstipulate, stipulate in *Centella;* alternate, opposite in some species or *Apiastrum;* simple or much dissected, often **decompound;** petiolate, petiole usually sheathing at the base, venation reticulate unicostate (*Centella*), multicostate (*Astrantia*), parallel in *Eryngium* and *Aciphylla*. Palmately lobed leaves in *Sanicula*.

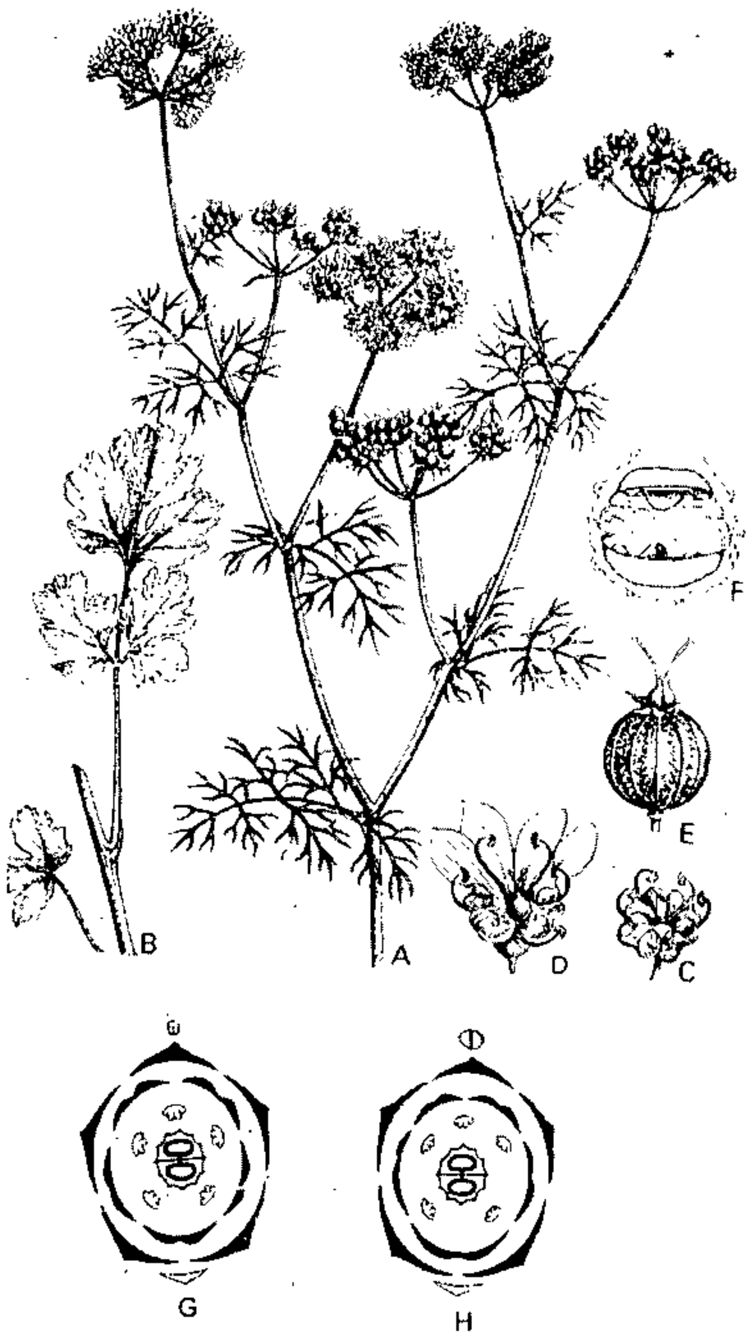


Fig. 1. A-H. *Coriandrum sativum* : A. Flowering branch, B. Basal leaf, C. Central flower, D. Peripheral flower of inflorescence with two enlarged anterior petals, E. Fruit, F. Fruit (transverse section), G. Floral dagram of central flowers, H. Floral diagram of peripheral flowers.

Inflorescence : Simple or compound umbel surrounded by thin leafy bracts called involucre; in some reduced to single flower *e.g.*, in some species of *Centella* and *Azorella;* and to a compact head in *Eryngium.*

Flower : Pedicellate, bracteate (*Centella*) or ebracteate (*Foeniculum*), perfect, complete, actinomorphic and in some zygomorphic due to the enlargement of the outer petals of the peripheral flowers of the umbel (*Coriandrum* Fig. 7, 12); hermaphrodite, pentamerous, epigynous, disc is present. In *Echinophora* each umbel has a central female flower surrounded by male flowers. In *Arctopus and Aciphylla* the flowers are fully dioecious. In *Astrantia* an intermediate condition is found.

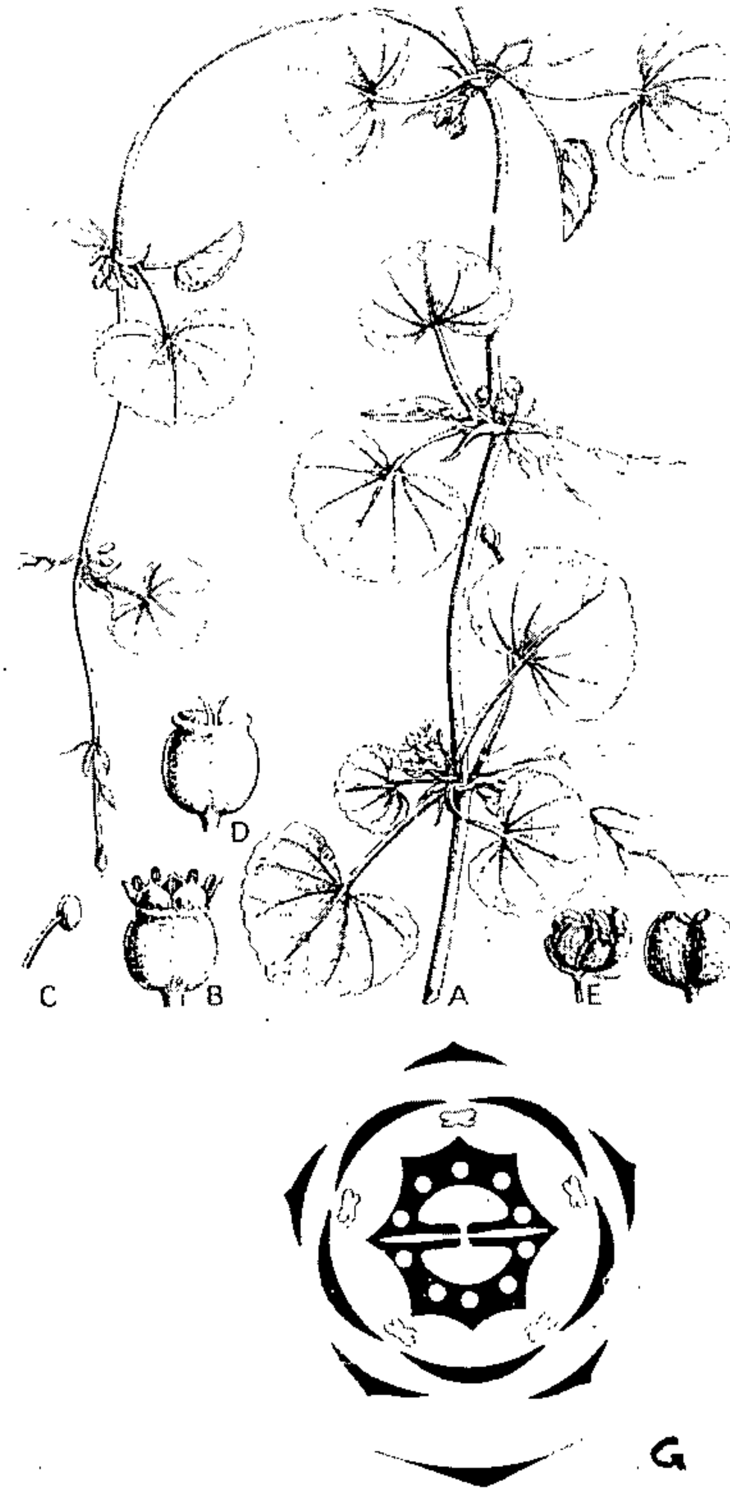


Fig. 2. A-G. *Centella asiatica* : A. Flowering plant, B. Flower, C. Stamen, D. Gynoecium, E, F. Fruits, G. Floral diagram.

Calyx : Sepals 5, gamosepalous, small teeth or scales or absent (*Foeniculum*) adnate to the ovary, valvate, green.

Corolla : Petals 5, polypetalous, epigynous often emarginate or two lobed, tip inflexed, valvate (*Foeniculum*) imbricate, coloured. The peripheral flowers of *Coriandrum* have unequal petals.

Androecium : Stamens 5, alternating with petals, polyandrous, inserted under the disc, anthers dithecous, versatile, introrse, flament long, equal in length, bent in the bud but ultimately spreading out.

Gynoecium : Bicarpellary, syncarpous, inferior, bilocular with a single pendulous ovule in each locule, antero-posteriorly placed, axile placentation, style two; stigmas two; an epigynous **(stylopodium)** is present on the top of the ovary is prolonged into the styles which are thickened at the base; the stigmas are differentiated from the styles.

Fruit : Schizocarpic **cremocarp** which splits into two one seeded mericarps, which remain attached to a slender often forked axis - the carpophore; mericarps are longitudinally ridged, in between the ridges are the furrows having oil ducts or **vittae.**

Seed : Endospermic, embryo small.

Pollination : Entomophilous due to nectar, scent and protandrous nature of flowers.

Floral Formulae :

Central flower: Br, ⊕, ⚥, $K_{(5)}, C_5, A_5, \overline{G}_{(2)}$

Peripheral flower : Br, %, ⚥, $K_{(5)}, C_5, A_5, \overline{G}_{(2)}$

Economic Importance

A. Ornamentals :

Eryngium planum : (Sea holly).

Heracleum maximum : (Cowparsnip).

Pimpinella sp.

B. Edible plants :

Apium graveolens var. *dulce :* (Celery, 'Ajmud').

Daucas carota : (Carrot, 'Gajar') : Roots.

Pastinaca sativa : (Parsnip, 'Gajoor') : Roots.

C. Condiments and Flowering Materials :

Anethum graveolens : ('Soya') : Fruits as spice and condiment.

A. sowa : ('Soya') : Leaves as flavouring material.

Angelica archangelica, A. glauca : Roots as condiment or flavouring material.

(Black cumin, 'Syah zira') : Seeds as spice.

Carum curvi : (Black cumin, 'Syah zira') : Fruit as condiments.

Coriandrum sativum : (Coriander, 'Dhania') : Fruits and leaves as condiment and spice.

Cuminum cyminum : (Cumn, 'Zira') : Fruits aromatic, used as flavouring material.

Ferula asafoetida, F. rubricaulis, F. nartex ('Heeng') : Oleoresin from root stocks and roots used as flavouring material.

Foeniculum vulgare : (Fennel, 'Saunf') : Fruits as spice.

Trachyspermum ammi : ('Ajwain') : Fruits as spice.

T. roxburghianum : ('Raghuni') : Seed for flavouring food.

D. Oil Yielding :

Ferula galbaniflua : (Galbanum, 'Bairoza') : Oleoresin from roots is used in perfumery

F. jaeschkeana : Roots and seeds yield essential oil.

F. asafoetida : Gum resin used in perfumery.

Foeniculum vulgare : Seed oil used as medicine.

Opoponax clironium : ('Javasoor') : Gum-resin from the plant used in perfumes.

Pimpinella anisum : Yields **'Oil of aniseed'** used in perfumery.

E. Medicinal Plants :

Centella asiatica : (Asiatic pennywort, 'Brahmi'). Antidote against cholera, brain tonc, also cures madness.

Coriandrum sativum : Carminative and gastric stimulant.

Ferula asafoetida : For treating indigestion, cough and asthma.

F. galbaniflua : Given in bronchitis.

F. sumble : A medicine called 'sambule' is prepaerd which is given in histeria.

Foeniculum vulgare : Carminative and gastric stimulant.

F. Miscellaenous Uses :

Conium maculatum : (Hemlock) : Poisonous, given to kill the great Greek teacher and philosopher Saucretes.

Cicuta virosa : (Water Hemlock) : A highly poisonous plant.

2.6. SUMMARY

In this chapter the families grouped under Polypetalae (according to Bentham and Hooker's system of classification) are described. The important characters of the different families can be summarised as :

Family Ranunculaceae

Vegetative : Herbs, rarely shrubs or climbers; Tap; Aerial, erect, herbaceous rarely rhizomatous; Alternate, exstipulate, simple or compound.

Floral : Solitary or raceme or cyme; actinomorphic, bisexual, hypogynous, pentamerous, cross-pollinated by insects; **K** : five sepals, polysepalous, rarely spurred; **C** : Five petals, polypetalous, rarely spurred; **A** : numerous stamens, polyandrous, spirocyclic, dithecous, extrorse; **G** : Multicarpellary, rarely 1– 5 carpellary, apocarpous, superior, basal or marginal; Etaerio of achenes; Endospermic, anemochrous.

Economic Importance : The family includes ornamentals (*Aconitum, Anemone, Aquilegia, Caltha Clematis, Delphinium, Nigella, Paeonia Ranunculus, Thallictrum*), condiments (*Nigella*), and medicinal plants (*Aconitum, Actaea, Adonis, Delphinium, Helleborus, Hydrastis, Nigella*).

Family Caryophyllaceae

Vegetative : Generally herbs, rarely shrubs; Tap; Aerial; erect, herbaceous; opposite, exstipulate, simple.

Floral : Cyme or solitary; actinomorphic, bisexual, hypogymous, pentamerous, cross-pollinated by insect; **K** : 5 sepals, poly or gamosepalous; **C** : 5 petals, polypetalous, petals sessile or clawed (caryophyllaceous); **A** : 5+5 stamens, polyanderous, obdiplostamonous, dithecous, introrse; **G** : Bi to pentacarpellary, syncarpous, unilocular, unilocular, free central; capsule; endospermic.

Economic Importance : The family includes ornamentals (*Arenaria, Cerasium, Dianthus, Lychins, Crypsophila, Silene, Vaccaria*), edible plants (*Stelleria*), medicinal plants (*Dianthus, Spergula, Stellaria* and those yielding saponius (*Vaccaria, Lychnis, Dianthus* etc).

Family Rutaceae

Vegetative : Herbs, shrubs or trees; tap; aerial, erect, herbaceous or woody; alternate, exstipulate, simple or compound, presence of oil glands.

Floral : Cyme or raceme; actinomorphic; bisexual, hypogynous, pentamerous; cross-pollinated by insects; **K** : 4 to 5 sepals, polysepalous; **C** : 5 petals, polypetalous; A : 5 to ∞ stamens; polyandrous, dithecous, introrse; **G** : 5 to multicarpellary, syncarpous, superior, 5 to multilocular, axile, presence of a disc below the ovary; Berry or hesperidium or drupe or capsule; With or without endosperm.

Economic Importance : The family includes ornamentals (*Dictamnus, Fortunella, Glycomis, Luvunga, Murraya, Ruta, Skimmia*), flavouring materials (*Murraya, Ruta, Zanthoxylum*), oil yielding (*Citrus*), timber yielding (*Fagera, Feronia, Glycomis, Murraya, Zanthoxylum*), dye yielding (*Taddalia*), gum yielding (*Aegle, Feronia*), medicinal plants (*Acronychia, Aegle, Citrus, Murraya*) mosquito repellant (*Boenninghausenia*) etc.

Family Fabaceae

Vegetative : Herbs, shrubs, trees, twiners or clumbers; Tap with bacterial nodules; Aerial, erect or weak, herbaceous or woody; Alternate, stipulate, simple or compound.

Floral : Raceme, panicle or cyme; bracteate, zygomorphic, bisexually hypogynous, pentamerous; cross-entomophilous or self; **K** : 5 sepals, gamosepalous; **C** : 5 petals, 1 standard, 2 wing and (2) keel, papilionaceous; **A** : (9) + 1 stamens, diadelphous, dithecous, introrse; **G** : Monocarpellary, superior, marginal; Legume; Non-endospermic.

Economic Importance : The family includes ornamentals (*Ctitoria, Erythrina, Lathyrus, Lupinus, Pongamia, Robina, Sophora*), edible plants (*Cajanus, Cicer, Dolichos, Glycine, Lablab, Pisum, Phaseolus, Vicia, Vigna*), condiments (*Trgonella*), oil yielding (*Arachis, Glycine, Pongannia*), fiber yielding (*Abrus, Crotalaria*), Timber yielding (*Aeschnomene, Dalbergia, Ougenia, Pterocarpus*), dye yielding (*Butea, Clitoria, Crotalaria, Erythrina, Indigofera, Psoralia, Pterocarpus*), gum yielding (*Astragalus, Cyamopsis, Myroxylum, Pterocarpus*) and Medicinal plants (*Abrus, Arachis, Cyamopsis, Glycerrhiza, Krameria, Lupinus, Moghania, Mucuna, Trigonella*). Besides, many plants are used as fodder and green manure (*Crotalaria, Medicago, Trfolium*) etc.

Family Rosaceae

Vegetative : Usually herbs, shrubs, trees, rarely lianas or climbers; tap; Aerial, erect, herbaceous or woody; Alternate, stipulate, simple or compound.

Floral : Raceme, corymb, cyme or solitary; actinomorphic rarely zygomorphic, bisexual, hypogynous or perigynous or epigynous, pentamerous; Cross pollinated by insects; **K** : 5 sepals, basally connate; **C** : 5 petals, polypetalous, rosaceous; **A** : 10 to ∞ stamens, polyandrous, dithecous, introrse; **G** : Mono-to multicarpellary, apocarpous, superior to semi-inferior or inferior, basal or rarely axile, style terminal or lateral; Etaerio of achenes or pome or berry or drupe; Non-endospermic.

Economic Importance : The family includes ornamentals (*Crataegus, Exocorda, Pyracantha, Rosa, Spiraea*), edible plants (*Eriobotrya, Fragaria, Pyrus, Prunus, Rubus*), oil yielding (*Prunus, Rosa, Principia*), timber yielding (*Crataegus, Cotoneaster, Prunus, Pyrus, Rosa*), dye yielding (*Agrimonia*), medicinal plants (*Agrimonia, Geum, Hagenia, Potantilla, Rosa, Rubus*).

Family Apiaceae

Vegetative : Herbs, rarely caespitose; Tap; Aerial, erect, herbaceous with swollen nodes; Alternate, exstipulate, pinnate or palmate, presence of oil glands.

Floral : Compound umbel; bracteate, actinomorphic, bisexual, epigynous, pentamerous; cross, entomophilous, protandrous; **K** : 5 sepals, polysepalous; **C** : 5 petals, polypetalous; **A** : 5 stamens, polyandrous, dithecous, introrse; **G** : Bicarpellary, syncarpous, inferior, bnilocular, axile, presence of stylopodium; cremocarp; endospermic.

Economic Importance : The family includes ornamentals (*Eryngium, Heracleum, Pimpinella*), edible plants (*Apium, Daucas, Pastinaca*), condiments (*Anethum, Angelica, Apium, Bunium, Carum, Coriandrum, Cuminum, Ferula, Foeniculum, Oenanthe, Trachyspermum*), oil yielding (*Apium, Ferula, Foeniculum, Opoponax, Pimpinella*), and medicinal plants (*Anethum, Carum, Coridandrum, Dorena, Ferula, Foeniculum, Pimpinella, Sesli, Trachyspermum*). Besides the family has poisonous plants lke *Conium* and *Cicuta*.

2.7. STUDENT ACTIVITY

1. Describe the floral characters of family Ranunculaceae.

2. Write the economic importance of family Fabaceae.

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2.8. TEST YOURSELF

1. Name the family in which apocarpous gynoecium is found.
2. The drug plant *Aconitum nepallus* belongs to which family ?
3. Write two important characters of anthers of Ranunculaceae.
4. What type of placentation is found in family Caryophyllaceae ?
5. Write the floral formula of family Caryophyllaceae.
6. What are the important characters of stamens of family Rutaceae.
7. What in the botanical name of 'santra' ?
8. What type of symmetry of flower is found in Fabaceae ?
9. What type of cohesion of stamens is found in Fabaceae ?
10. What is the number of carpels in Fabaceae ?
11. What shape of corolla is present in family Rosaceae ?
12. Write the botanical names of two plants of family Rosaceae from which important edible fruits are obtained.
13. What is the important characters of family Apiaceae ?
14. Seeds of several plants of family Apiaceae are used as spices. Name any two important plants.
15. Name the type of fruit in family Apiaceae.

ANSWERS

1. Ranunculaceae **2.** Ranunculaceae

3. Dithecous, Extrorse **4.** Free central placentation

5. $\oplus$, ⚥, $K_5, C_5, A_{5+5}, \underline{G}_{(2-5)}$

6. Frequently the stamens are double the number of petals and Obdiplostemonous

7. *Citrus reticulata.* **8.** Zygomorphic

9. Usually diadelphous

10. Monocarpellary **11.** Rosaceous

12. *Pyrus malus* (Apple), *Pyrus amygdalus* (Almond)

13. An umbel inflorscence is the characteristic of the family

14. *Cariandrum sativum* (Coriander, Dhania), *Foeniculum vulgare* (Fennel, Saunf)

15. Cremocarp.

U N I T - III

CHAPER

3

DESCRIPTION OF FAMILIES GAMOPETALAE

STRUCTURE

- Rubiaceae
- Apocyanaceae
- Asclepiadaceae
- Solanaceae
- Acanthaceae
- Lamiaceae
  - Summary
  - Student activity
  - Test yourself
  - Answers

LEARNING OBJECTIVES

By learning this chapter you will know the taxonomic characters of some dicotyledones families belonging to class Gamopetalae (Corolla of fused petals).

1.0 RUBIACEAE (MADDER FAMILY)

Classification :

Bentham & Hooker	Engler & Prantl	Hutchinson
Dicotyledones	Dicotyledoneae	Dicotyledones
Gamopetalae	Sympetalae	Lignosae
Inferae	Rubiales	Rubiales
Rubiales	Rubiaceae	Rubiaceae
Rubiaceae		

This is one of the largest families of the flowering plants containing nearly 500 genera and 6,000 species. The majority of the members of this family are distributed in tropical regions but some grow in the temperate regions. In India the family is represented by about 76 genera and 274 species.

Vegetative Characters

Habit—Mostly shrubs (*Gardenia, Ixora, Mussaenda, Hamelia)* and trees (*Morinda, Adina*) and a few herbs (*Galium, Rubia*), sometimes woody climbers (*Paederia*).

Root—Much branched tap root system.

Stem—Erect, herbaceous or woody or twining (*Manettia*), climbing by hooks (*Uncaria*), branched, cylindrical or angular, hairy or smooth.

Leaves—Cauline, ramal, opposite decussate or sometimes whorled, simple, entire or toothed, stipulate, stipules bristle like (*Pentas*) and leafy (*Galium, Rubia*), mostly **interpetiolar** or sometimes **intrapetiolar**, *unicostate reticulate venation.*

Floral characters

Inflorescence—Solitary (*Gardenia*) usually cymose or globose head (*Adina*), or panicled cyme; may be axillary (*Coffea arabica*) or terminal cyme (*Mussaenda glabra*).

Flower—Actinomorphic, rarely zygomorphic (some what bilabiate as in *Heneriquezia*), mostly hermaphrodite, rarely unisexual, epigynous, pedicellate or sessile (*Greenia*, *Randia*), bracteate or ebracteate, complete, tetra or pentamerous, cyclic, variously coloured.

Calyx—Sepals 4 or 5, gamosepalous, superior, sometimes one sepal modified into coloured bract like structure (*Mussaenda*, Fig. 1), valvate.

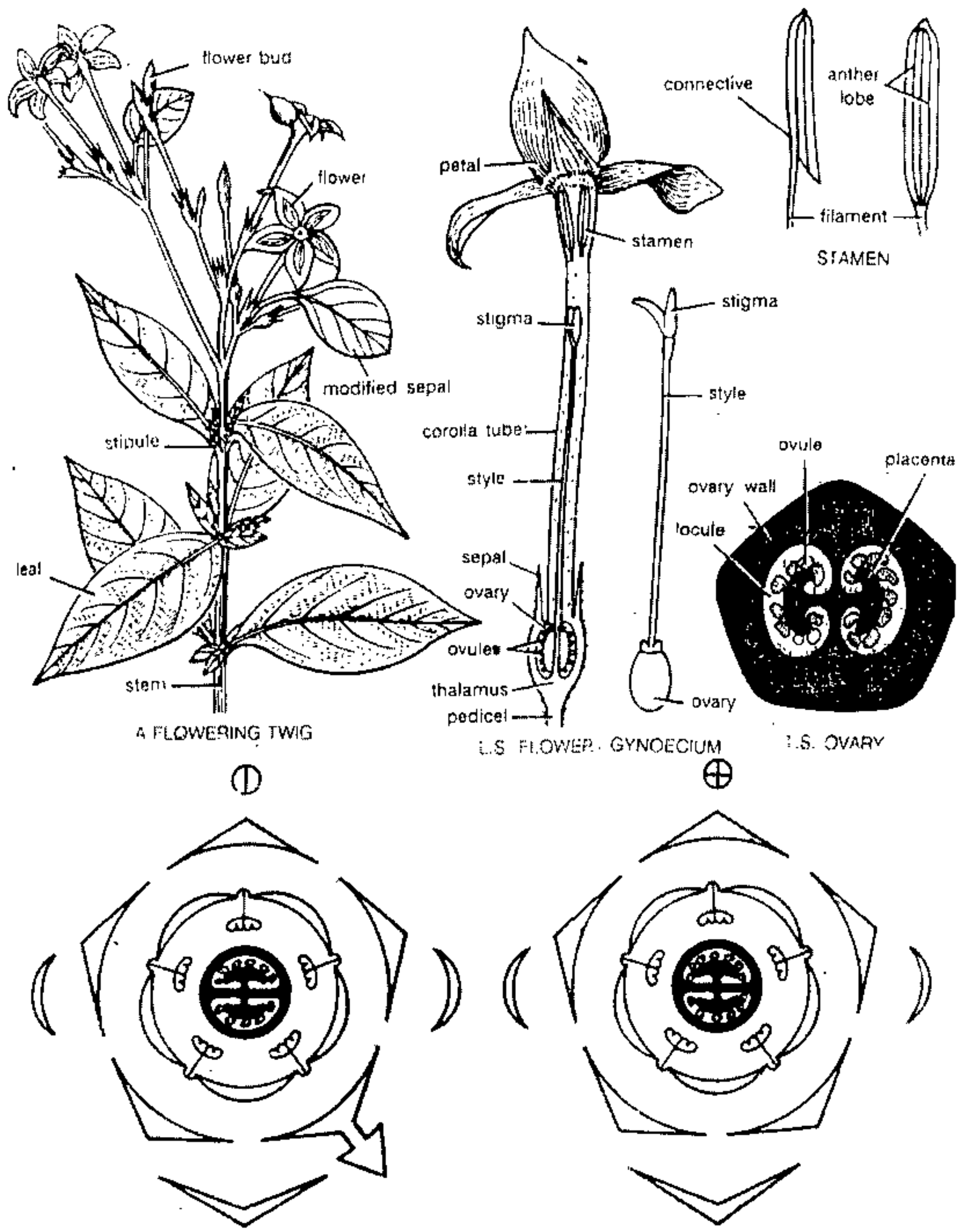

Fig. 1. ***Mussaenda luteola.***

Corolla—Petals 4 or 5, gamopetalous, lobed, generally funnel shaped (*Asperula*), tubular (*Ixora*, Fig. 3), valvate to twisted or imbricate, superior.

Androecium—Stamens 4 or 5, rarely many (*Gardenia*), epipetalous, alternipetalous, inserted near the mouth of corolla tube, stamens dithecous, introrse, dehiscing longitudinally.

Gynoecium—Bicarpellary (Fig. 2), rarely polycarpellary, syncarpous, inferior rarely half inferior (*Synaptanthera*) or superior (*Paganea*), sometimes unilocular (*Gardenia*) with one to many anatropous ovules in each loculus, axile placentation (parietal placentation in *Gardenia*), style one sometimes bifid or multifid, stigma capitate or bilobed.

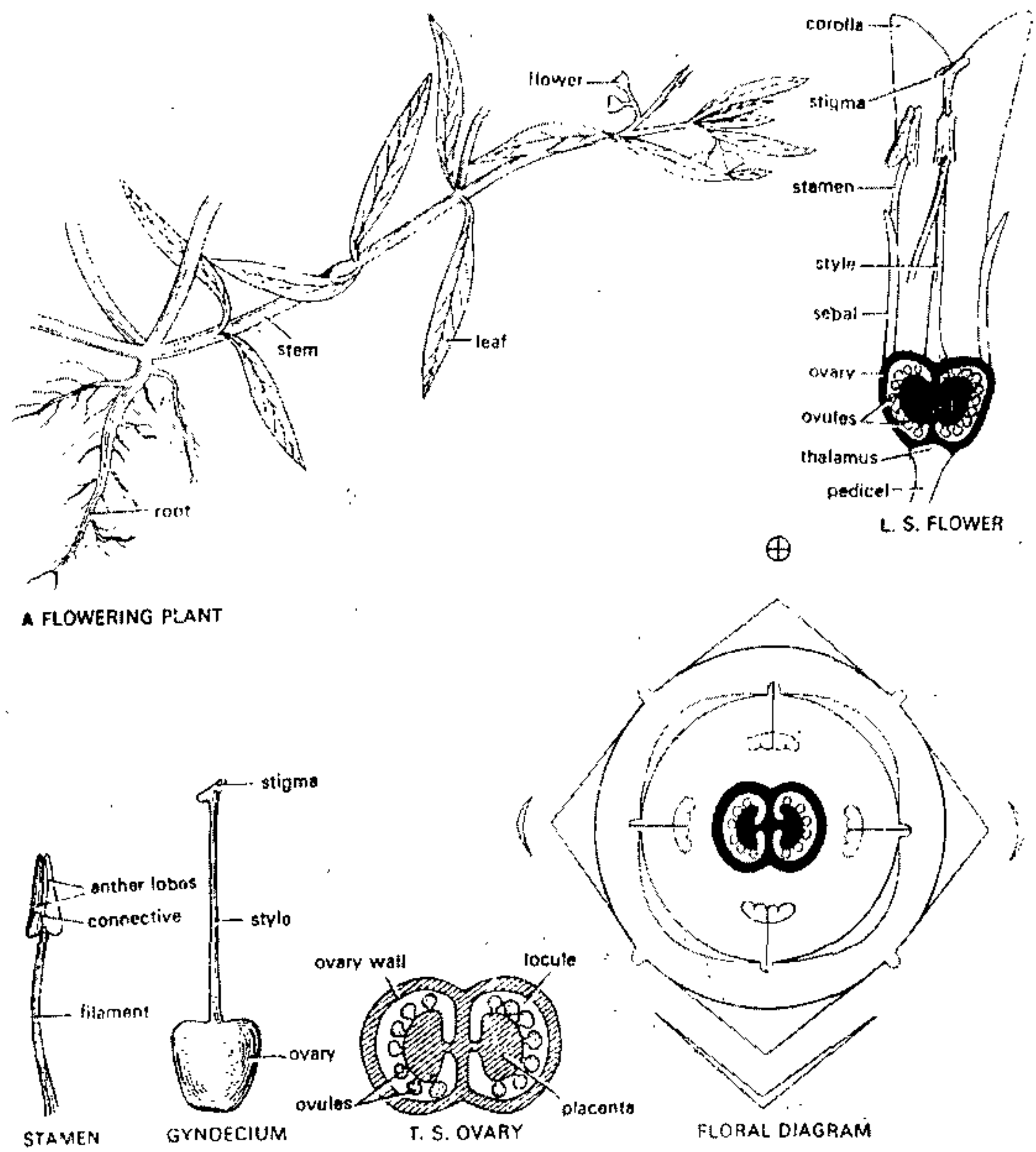

Fig. 2. ***Oldenlandia corymbosa.***

Fruit —Capsular (*Anotis*), berry (*Mussanenda, Hamelia, Ixora*)

Seed—Endospermic, sometimes winged.

Pollination—Entomophilous, ant pollination is weell known.

Floral Formula Br, Brl, ⊕ or ⊕, ⚥, K_5, $\overset{\frown}{C_{(5)},\ A_5}$, $\overline{G}_{(2)}$

ECONOMIC IMPORTANCE

A. Ornamentals :

Anthocephalus cadamba : ('kadam')

Gardenia jasminoides : (Cape Jasmine)

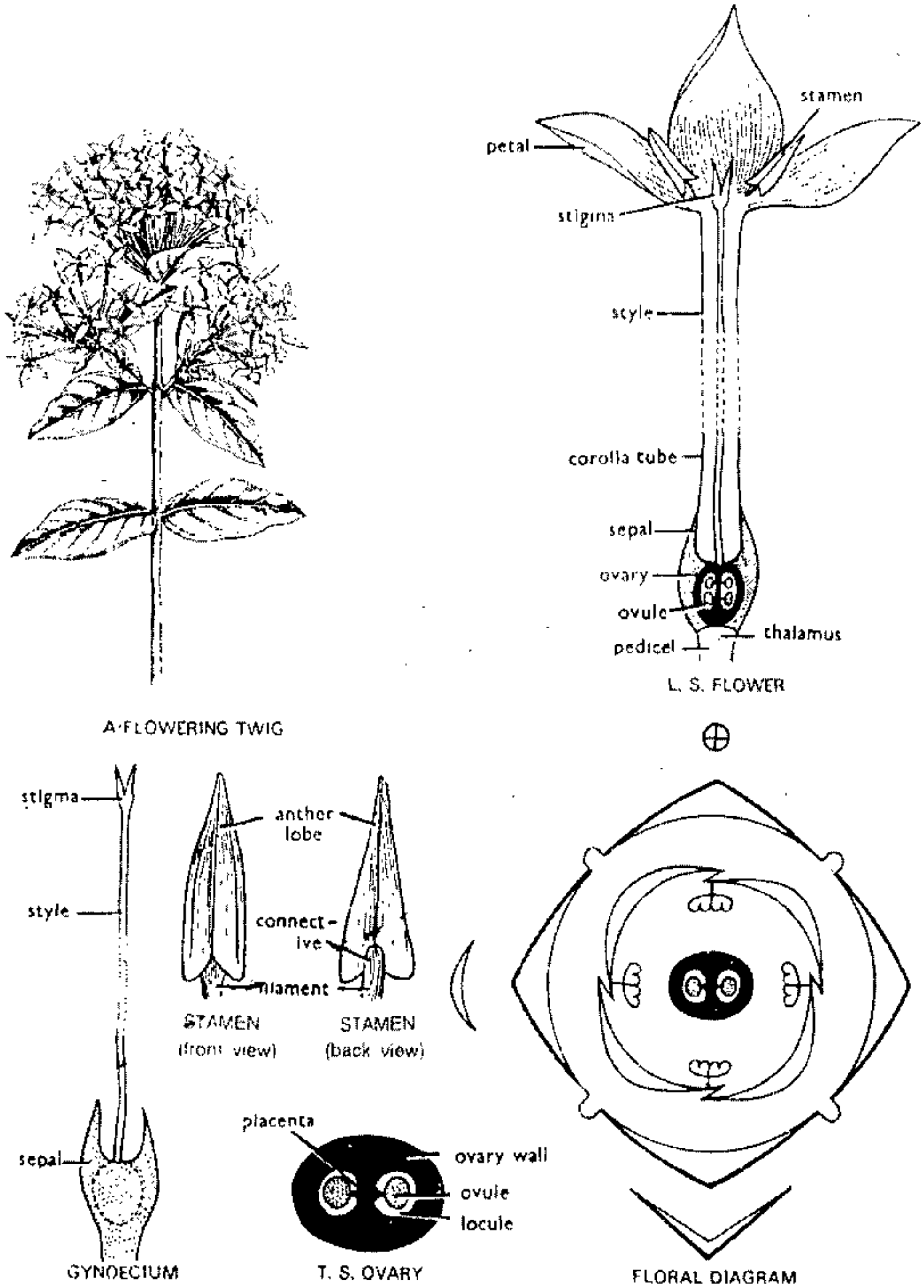

Fig. 3. ***Ixora coccinea.***

Hamelia patens
Ixora arborea : (Torch tree)
Morinda tinctoria : ('Aal')
Mussaenda glabrata

B. Edible Plants :

Coffea arabica : (Aabian offee) : Seeds.
C. liberica : (Liberian coffee) : Seeds.
C. robusta : (Cango coffee) : Seeds.

A non-alcoholic drink prepared from roasted seeds of all the four species; The stimulating effect of coffee is due to the presence of an alkaloid 'caffeine'.

Vangueria madagascariensis : Fruits.

C. Fiber Yielding :

Mitragyna parviflora : Stem fiber used for cordage.

D. Timber Yielding :

Adina cordifolia : ('Haldu') : Wood for making agricultural implements.
Anthocephalus cadamba : Wood for agricultural uses.

E. Dye Yielding :

Morinda angustifolia : ('Daru haridra') : Yellow dye from roots.
M. bracteata : Red dye from roots.
Oldenlandia umbellata : Red dye from roots.
R. tinctorum : Red dye from this roots.

F. Medicinal Plants :

Cinchona calisaya, C. ledgerina, C. succirubra : The bark yields 'quinine' used in the treatment of malaria; It is cultivated in India and Srilanka.

G. Micellaneous used :

Hymenodictyon excelsum, Uncaria gambier : Used in tanning industry.

1.1. APOCYANACEAE (DOGBANE FAMILY, OLEANDER FAMILY)

Classification :

Bentham & Hooker	Engler & Prantl	Hutchinson
Dicotyledones	Dicotyledoneae	Dicotyledones
Gamopetalae	Sympetalae	Lignosae
Bicarpellatae	Contortae	Apocynales
Gentianales	Apocynaceae	Apocynaceae
Apocynaceae		

The family comprises about 180 genera and 1500 species. In India the family is represented by some 30 genera and 600 species occuring chiefly in the Eastern Himalayes and Southern Peninsular India.

Vegetative Characters

Habit—Herbs (*Catharanthus*), shrubs (*Carissa, Nerium*), twinners (*Vallaris*), tree (*Alstonia*) with latex.

Root—A much branched tap root system.

Stem—Usually herbaceous (*Catharanthus*) erect, woody, solid, branched, green or succulent with latex, sometimes armed with sharp spines (*Carissa*).

Leaves—Simple, opposite (Catharanthus) or whorled (*Nerium*), petiolate or sub-sessile, exstipulate, margin entire, unicostate reticulate venation.

Floral characters

Inflorescence—Usually cymose either terminal or axillary, may be cyme (*Carissa*) or umbellate cyme (*Rauwolfia*).

Flower—Bracteate or ebracetate, pedicellate, complete, hermaphrodite, actinomorphic, tetra or pentamerous, often with corona.

Calyx—Sepals 5, rarely 4, gamosepalous, deeply lobed, small, often glandular at the base, quincunical (*Thevetia*) or valvate and in odd sepal is posterior.

Corolla—Petals 5, gamopetalous forming a corolla tube which may be long or short, corona present (hairy scales or outgrowth), usually twisted, sometimes imbricate, rarely valvate.

Androecium—Stamens are as many as corolla lobes and alternating with them, epipetalous, and attached at the mouth or deeper in the corolla tube, filament short, free, dithecous, sagitate shaped, introrse, dehiscing longitudinally.

Gynoecium—Bicarpellary, syncarpous ovaries are free below but united by stule only, superior style short, enclosed in a tube formed by the corolla, stigma thickened distally; when ovaries are free each ovary is unilocular with marginal placentation but when ovaries are fused then axile placentation.

Fruit—A drupe (*Thevetia*), berry (*Carissa*), follicle (*Nerium, Amsonia*).

Seed—Endospermic, hairy or winged.

Pollination—Entomorphilous.

Floral Formulae

Catharanthus roseus (Fig. 1) :

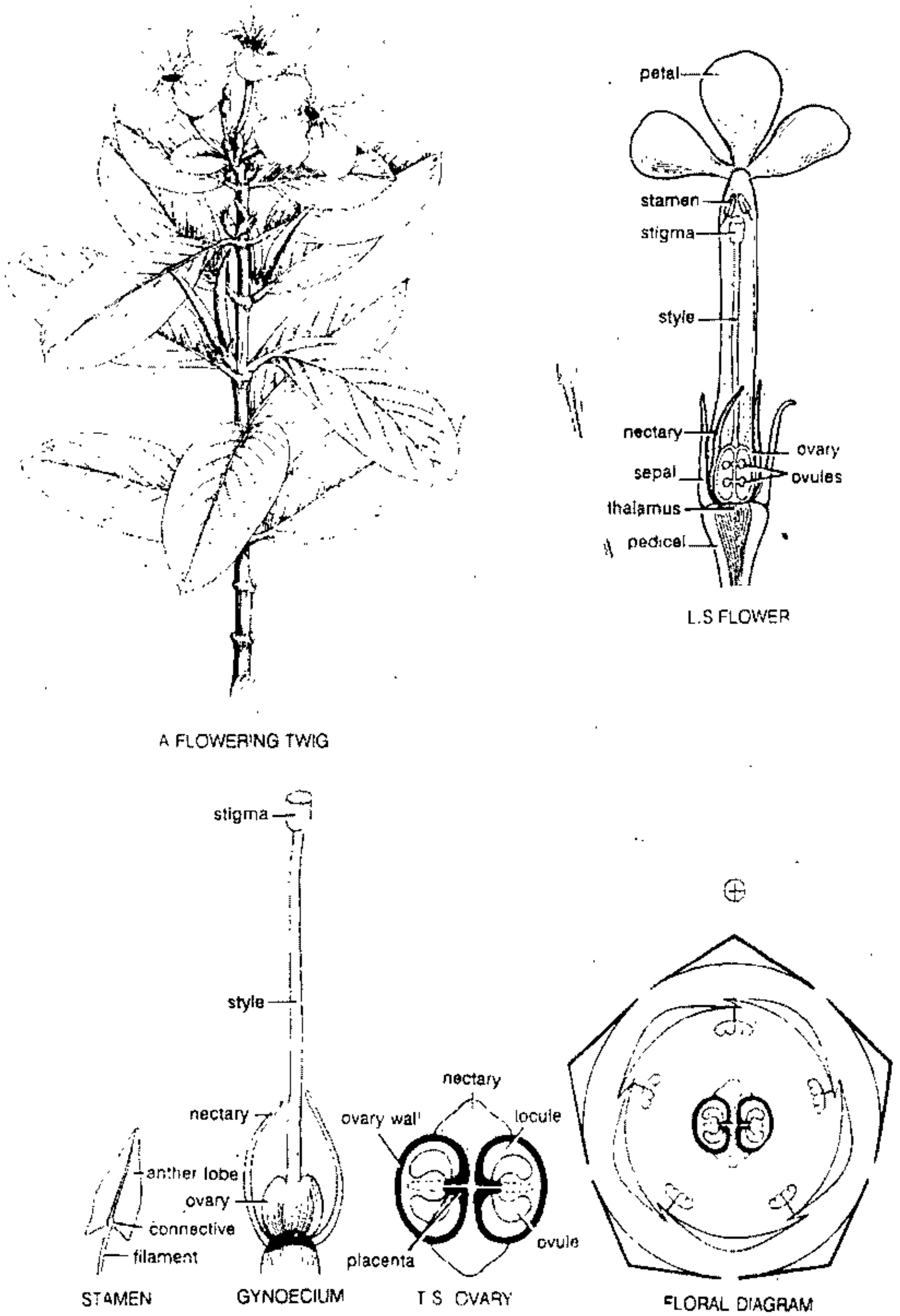

Fig. 1. *Catharanthus roseus*.

Thevetia peruviana (Fig. 2) :

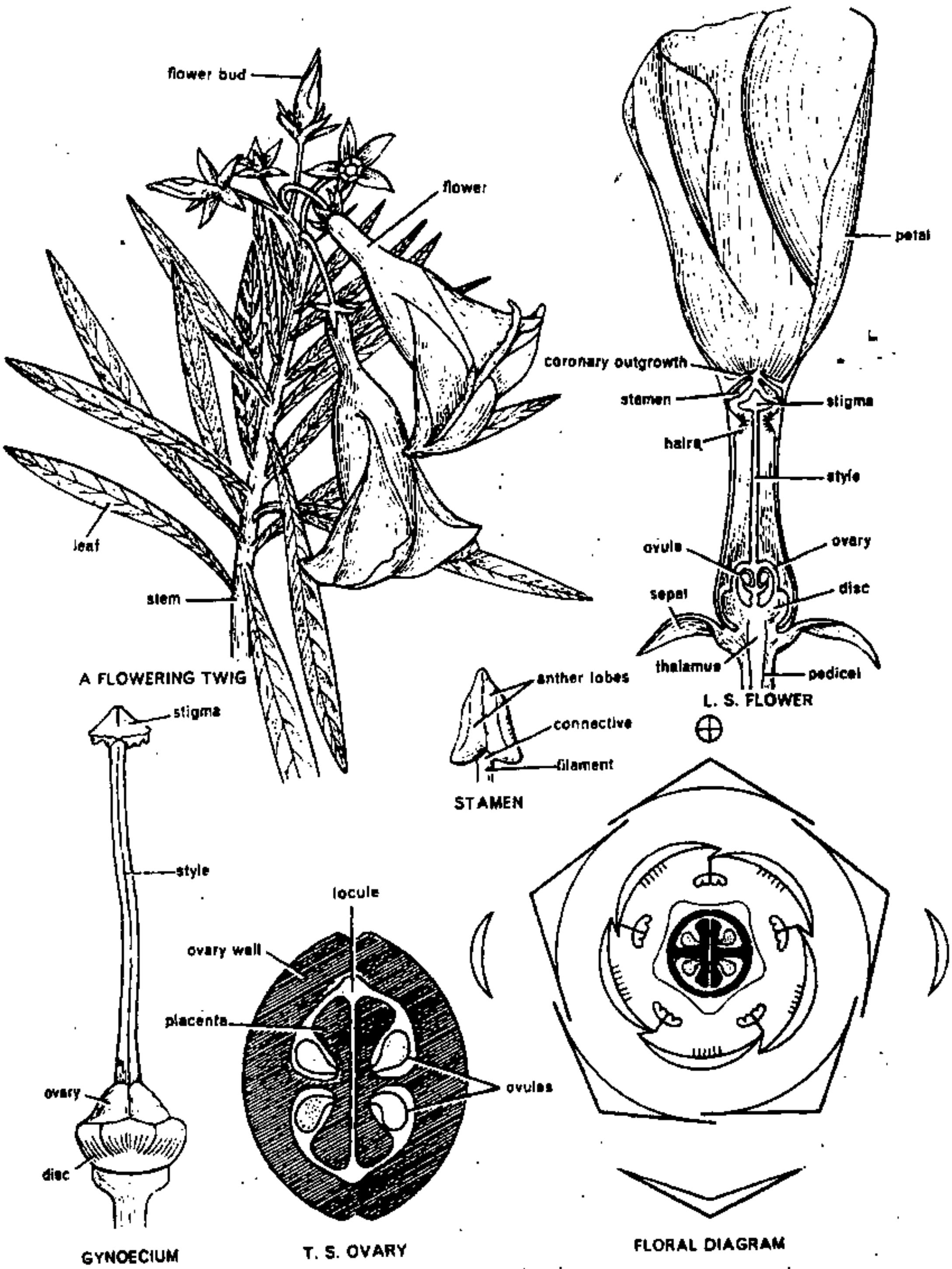

Fig. 2. *Thevetia preuviana.*

Tabernaemontana divaricata (Fig. 3) :

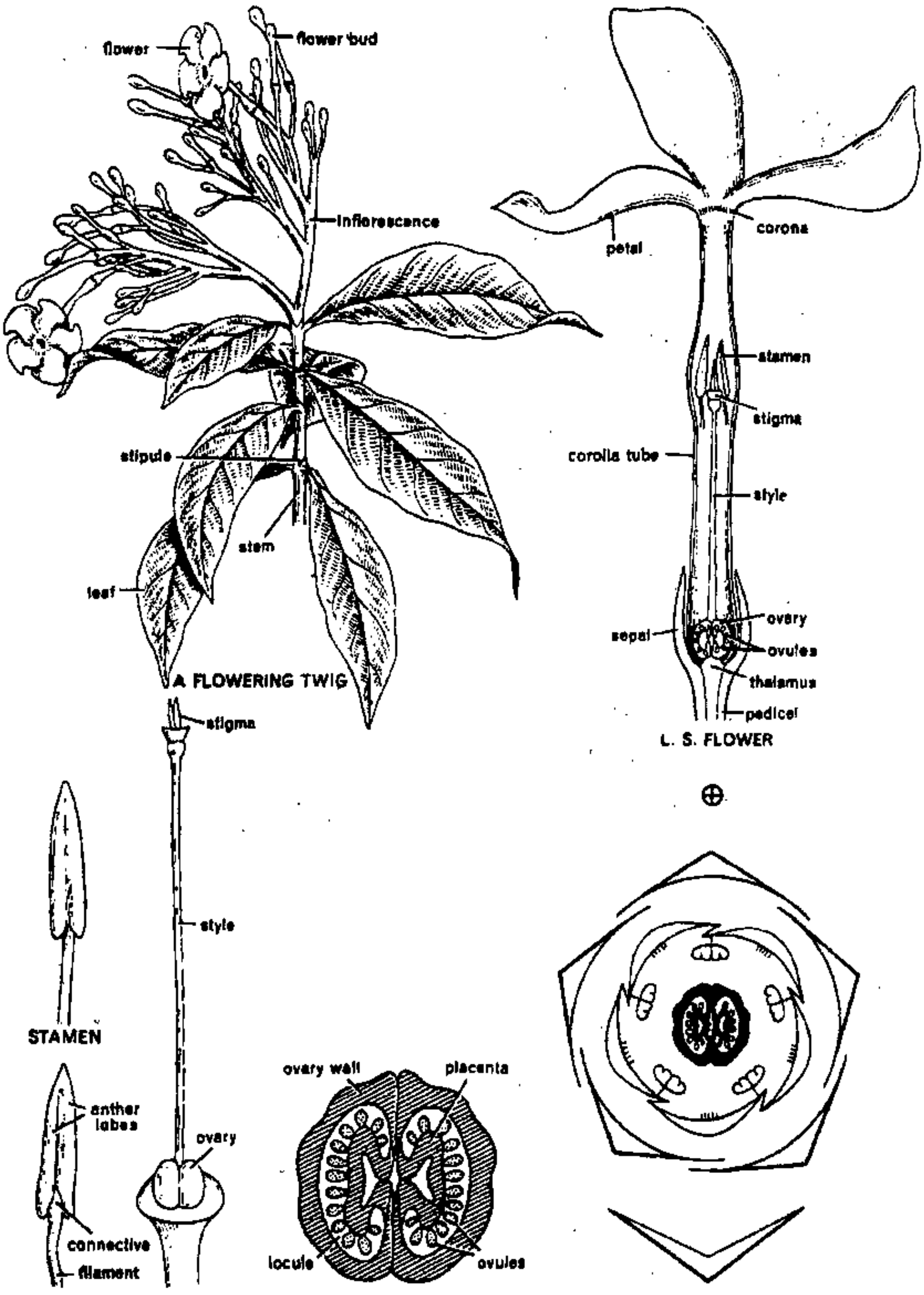

Fig. 3. *Tabernaemontana divaricata.*

Nerium indicum (Fig. 4) :

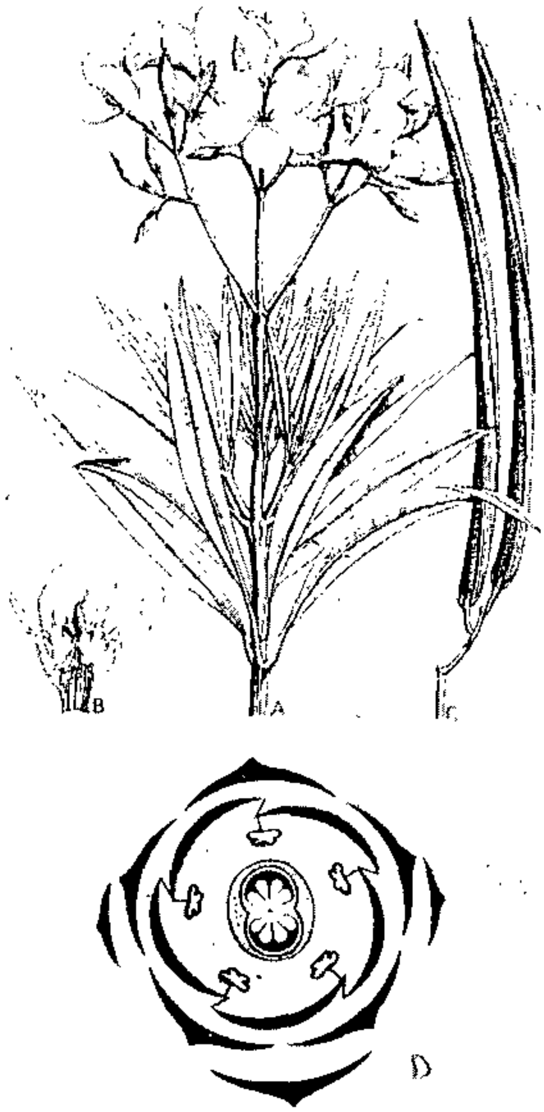

Fig. 4. A-C. *Nerium indicum* : A. Flowering branch, B. Corolla expanded, C. Fruits, D. Floral diagram.

ECONOMIC IMPORTANCE

A. Ornamentals :

Beaumontia grandiflora
Carissa spinarum
Cathernanthus roseus : (Periwinkle, 'Sada bahar')
Nerium indicum : (Indian oleander, 'kaner')
Plumeria alba : ('Gulachin')
Tabernaemontana divaricata : ('Chandni')
Thavetia peruviana : (Yellow oleander, 'Pili kaner')
Trachelospermum jasminoides.
Valleris solanaceae : ('Dudhi bel')
Wrightia tinctoria : ('Meetha indrajou')

B. Edible Plants :

Carrisa carandus : ('Karaunda') : Fruits.
C. grandiflora : Fruits
C. spinarum : ('Karaunda') : Fruits.

C. Fiber Yielding :

Chonemorpha fragrans : Stem fiber for fishing nets.

Ichnocarpus frutiscens : Stem fiber for making ropes.

D. Timber Yielding :

Alstonia scholaris : Wood for making packing cases.

Carissa congesta : Wood for making combs.

Wrightia tinctoria : Match splints from wood.

E. Dye Yielding :

Tabernaemontana divaricata : Red dye from seed.

Wrightia tinctoria : Blue dye from flowers and fruits.

W. tomentosa : Yellow dye from roots.

F. Medicinal Plants :

Alstonia scholaris: Bark in diarrhoea and dysentry.

Catharanthus roseus : Bark in rheumatism and dropsy.

Cerbera manghas : Latex is emetic and purgative.

Holarrhina antidysenterica : Leaves, bark and seeds are used in treatment of dysentry.

Rauvolfia serpentina : ('Sarpagandha') : Roots for treating hypertension, mental disorder and related diseases; Most important alkaloid is 'Reserpine' : Besides it also contains alkaloid like Yohimbine, Ajmanine, Isoajmaline, Ajmalinine etc.

Stropanthus combe : Contains alkaloid 'stropanthin' for heart diseases.

Valleris solanacea : Used in toothache.

1.2. ASCLEPIADACEAE (MILK WEED FAMILY)

Classification :

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledones
Gamopetalae	Sympetalae	Lignosae
Bicarpellatae	Contortae	Apocynales
Gentianales	Asclepiadaceae	Asclepiadaceae
Apocynaceae		

The family is represented by some 175 genera and 2200 species widely distributed in the tropical and subtropical regions of the world. In India 250 species belonging to 53 genera are reported. The plants are mainly distributed in the tropical Himalayas and Western India.

Vegetative Characters

Habit : Perennial herbs (*Asclepias*) or shrubs (*Calotropis, Leptadenia*), climbers (*Cryptostegia, Daemia*), plants succulent (*Hoya*) or xerophytic with cactus - like habit (*stapelia*), latex present.

Root : A deep branched tap root.

Stem : Herbaceous, week and climbing or succulent, woody below (*Calotropis*), erect, twiner or climbers (*Cryptostegia*) cylindrcal, rarely hairy and solid, latex present.

Leaves : Simple, petiolate, exstipulate, entire, opposite decussate, rarely whorled. waxy in *Dischidia rafflesiana* leaves are modified into pitchers.

Floral characters

Inflorescence : Mostly umbellate cymes (*Calotropis)* or dichasal cyme ending in monochasial cyme.

Flower : Bracteate or ebracteate, pedicellate, complete, hermaphrodite, actinomorphic, rarely zygomorphic (*Cerepogia*), pentamerous, hypogynous.

Calyx : Sepals 5, polysepalous or gamosepalours-fused near the base, quincuncial aestivation, sometimes valvate.

Corolla : Petals 5, gamopetalous, 5 lobed,twisted aestivation or valvate. The corolla tube is often with a corona which is in the form of a ring or hairs, scales or process (Coralline corona).

Androecium—Stamens 5, synandrous, **gynostegium** (stamens fused with stigmatic disc to form gynostegium), anthers dithecous, epipetalous, coherent; the pollen grains of each half anther usually agglutinated into granular mass of tetrads or waxy pollen called **pollinium** (*Asclepias*, *Calotropis*, Figs., 1, 2). Thus each stamen has two pollinia. The pollinia of two adjacent anther halves are connected together at the Black, dot-like gland called **corpusculum** by appendages called—**retinacula**. The two pollinia (of adjacent anther halves), two retinacula and corpusculum together from a single translator. So in all there are 5 translators.

Gynoecium—Bicarpellary, syncarpous, ovaries free, superior, enclosed in staminal tube, ovules many on marginal placentation, each carpel is unilocular, style 2,

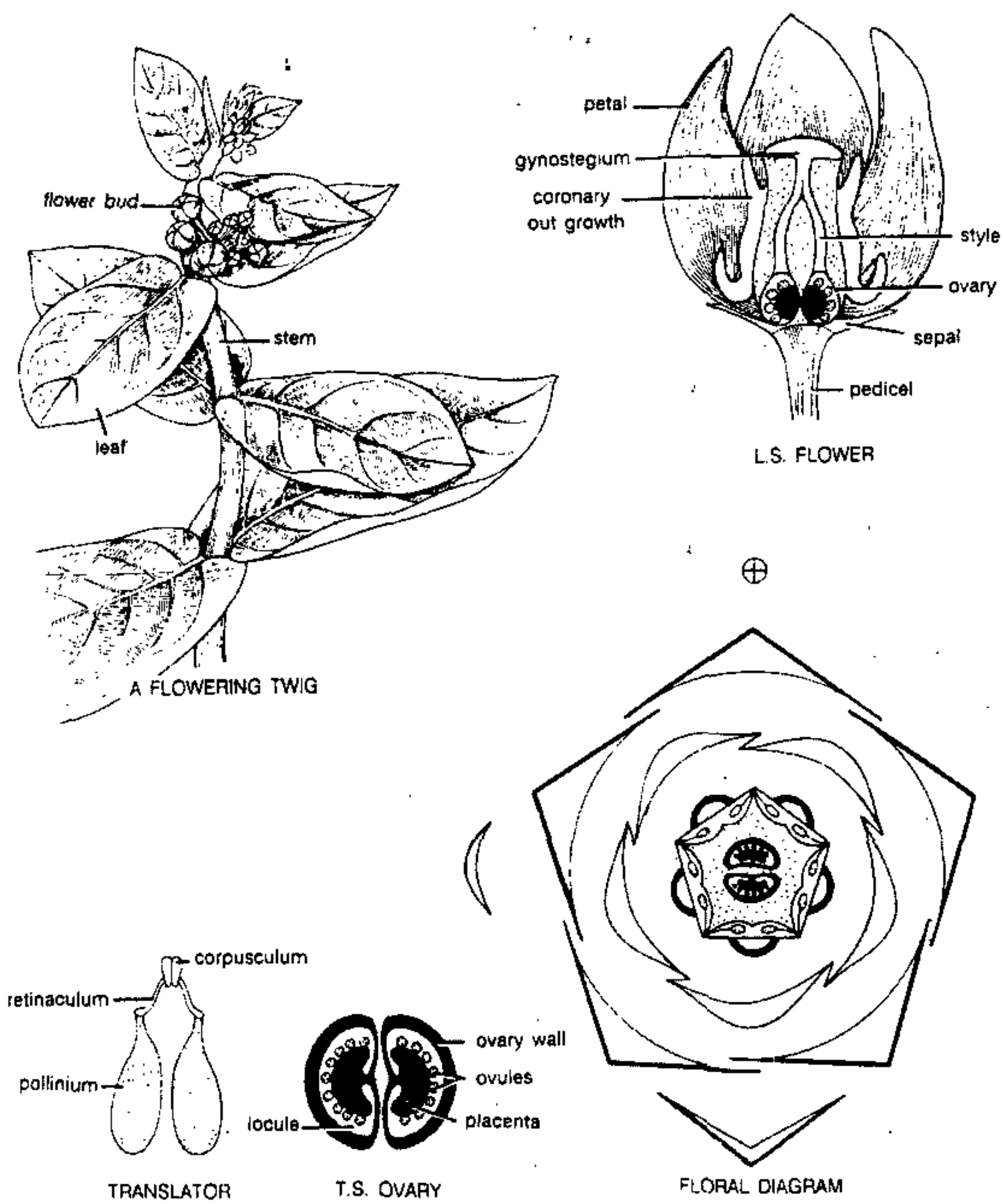

Fig. 1. ***Calotropis procera.***

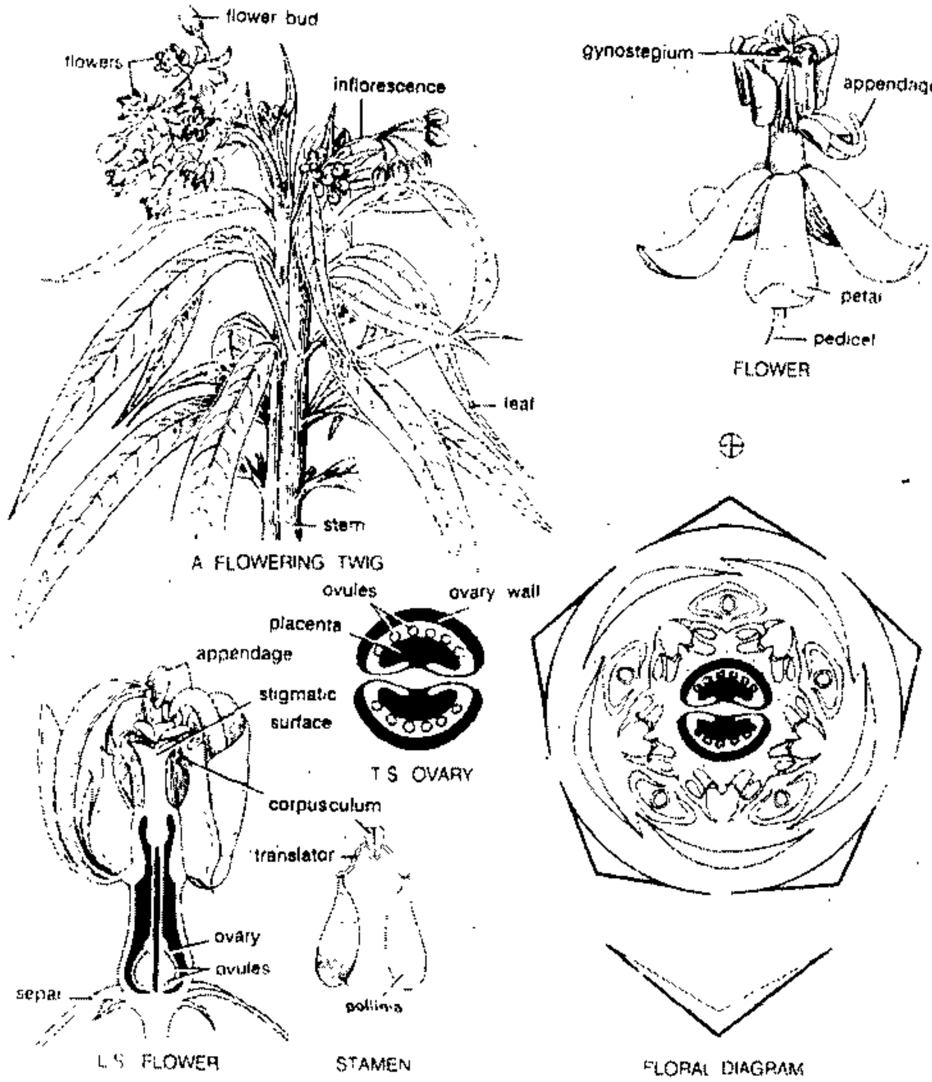

Fig. 2. ***Asclepias curassavica.***

free, distinct; stigmas united to form a pentangular disc with which anthers are fused to for **gynostegium**.

Fruit—An etaerio of two, often widely divergent follicles; in some one follicle is abortive.

Seed—Many small, compressed with long silky hairs.

Pollination—Entomophilous, translator mechanism.

Floral formula— Br, Brl, ⊕, ⚥, K_5, $\widehat{C_{(5)}, A_5}$, $\underline{G}_{(2)}$

ECONOMIC IMPORTANCE

A. Oranamentals :

Asclepias curassavica : (Milkweed).

A. tuberosa : (Butterly weed).

Cropegia bulbosa : (Pelican flower).

Cryptostegia grandiflora

Leptadenia reticulata : (Rubber wine).

B. Edible Plants :

Caralluma fimbriata : Root tubers edible.

C. Spice and Condiment :

Decalepis hamiltonii : Aromatic root as spice and condiment.

D. Fiber yielding :

Marsadenia royalei : Stem fiber for strong ropes and fishing nets.

Calotropis procera : (Madar, 'aak') : Stem fiber in cordage industry. Besides, fiber is also obtained from the stem of *Tylophora tenuis* and *Leptadaenia pyrotechnica*.

E. Dye Yielding :

Marsdenia tinctoria : Leaves yield an indigo dye.

F. Medicinal Plants :

Cynanchum arnottianum : Dried leaves for destroying maggots, also as insecticide.

Gymnema sylvester : For treating cough and eye troubles.

Hemidesmus indicus : (Indian sarsaparilla, 'Anantmool') : Root used as substitute for 'Sarsaparilla', as tonic, diuretic, diaphoretic and demulcent.

Tylophora indica : Leaves and roots as substitute for ipecacuanha: emetic, diphoretic and expectorant, cures asthma.

G. Miscellaneous Uses :

Calotropis gigantea : Floss from seeds for stuffing pillows and lining jackets.

C. procera : Floss from seeds for stuffing and lining; Latex *in tanning industry*, stem and leaves as green manure.

Cryptostegia grandiflora : Source of rubber from latex.

1.3. SOLANACEAE (NIGHTSHADE FAMILY)

Classification :

Bentham & Hooker	Engler & Prantl	Hutchinson
Dicotyledones	Dicotyledonease	Dicotyledones
Gamopetalae	Sympetalae	Herbaceae
Bicarpellatae	Tubiflorae	Solanales
Polemoniales	Solanaceae	Solanaceae
Solanaceae		

It is a large family containing about 90 genera and over 2000 species. the plants are distributed in the tropical and temperate regions of the world. In India it is represented by 15 genera and 88 species.

Vegetative characters

Habit—Mostly annual or perennial herbs (*Petunia, Withania,* Fig. 2), shrubs (*Solanum torvum*) or small trees (*Solanum Verbascifolium*).

Root—A branched tap root system.

Stem—Aerial, erect, climbing (*Solanum jasminoides*), herbaceous, or woody, cylindrical, branched, solid or hollow, hairy, or glabrous, underground stem in *Solanum tuberosum*.

Leaves—Cauline, ramal, exstipulate, petiolate or sessile, alternate sometimes opposite, simple, entire, pinnately compound in *Lycopersicum*, unicostate reticulate venation.

Inflorescence—Solitary axillary, umbellate cyme, or helicoid cyme in *Solanum*.

Flower—Bracteate or ebracteate, pedicellate, complete, hermaphrodite, actinomorphic, pentamerous, hypogynous.

Calxy—Sepals 5, gamosepalous, tubular or companulate, valvate or imbricate, persistent, green or coloured, and much enlarged in fruit.

Corolla—Petals 5, gamopetalous, *tubular or infundibuliform, valvate or imbricate* aestivation, scale or hair-like outgrowth may arise from the throat of the corolla tube, coloured.

Androecium—Stamens 5, epipetalous, polyandrous, alternipetalous, filaments inserted deep in the corolla tube, anthers dithecous, usually basifixed or dorsifixed, introse, dehisce by longitudinal slits or apical pores e.g., *Solanum* (Fig. 1).

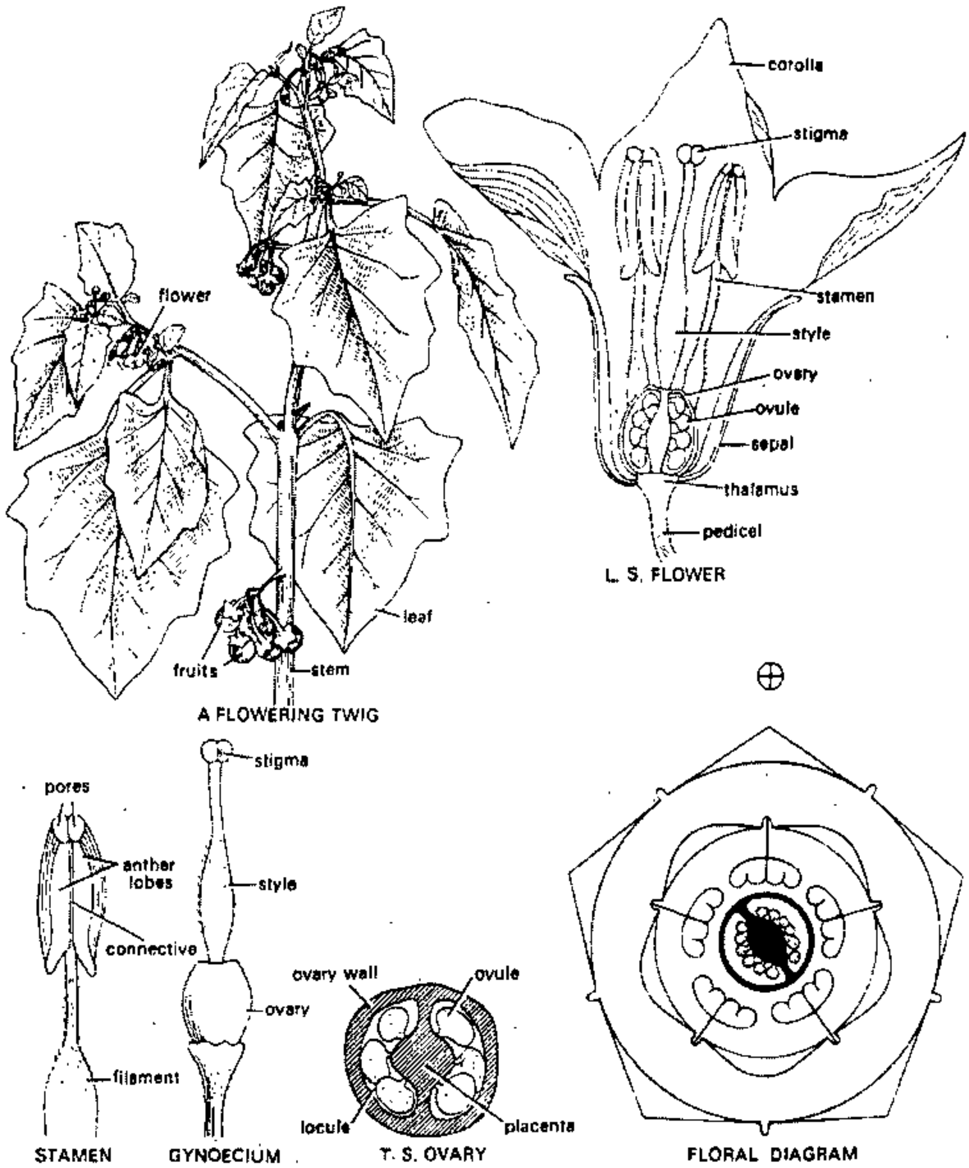

Fig. 1. ***Solanum nigrum.***

Gynoecium—Bicarpellary (Fig. 3) syncarpous, ovary superior, bilocular, unilocular in *Henoonia,* axile placentation, placentae swollen, many ovules in each loculus, ovary obliquely placed, in some cases nectariferous disc is present; style simple; stigma bifid or capitate.

Fruit—A capsule or berry.

Seed—Endospermic.

Pollination—Entomphilous.

Floral formula — Br, ⊕, ⚥, $K_{(5)}$, $\overset{\frown}{C_{(5)}, A_5}$, $\underline{G}_{(2)}$

ECONOMIC IMPORTANCE

A. Ornamentals :

Brunfelisa calycina

Cestrurn diurnum : (Day jasmime, 'Din ka raja')

C. nocturnum : (Night jasmine, 'Raat ki raani')

Datura suaveolens

Petunia axillaris

Solanum dulcamara

Salpiglossis sinuata (Painted tongue)

Schizanthus pinnatus (Butterfly flower)

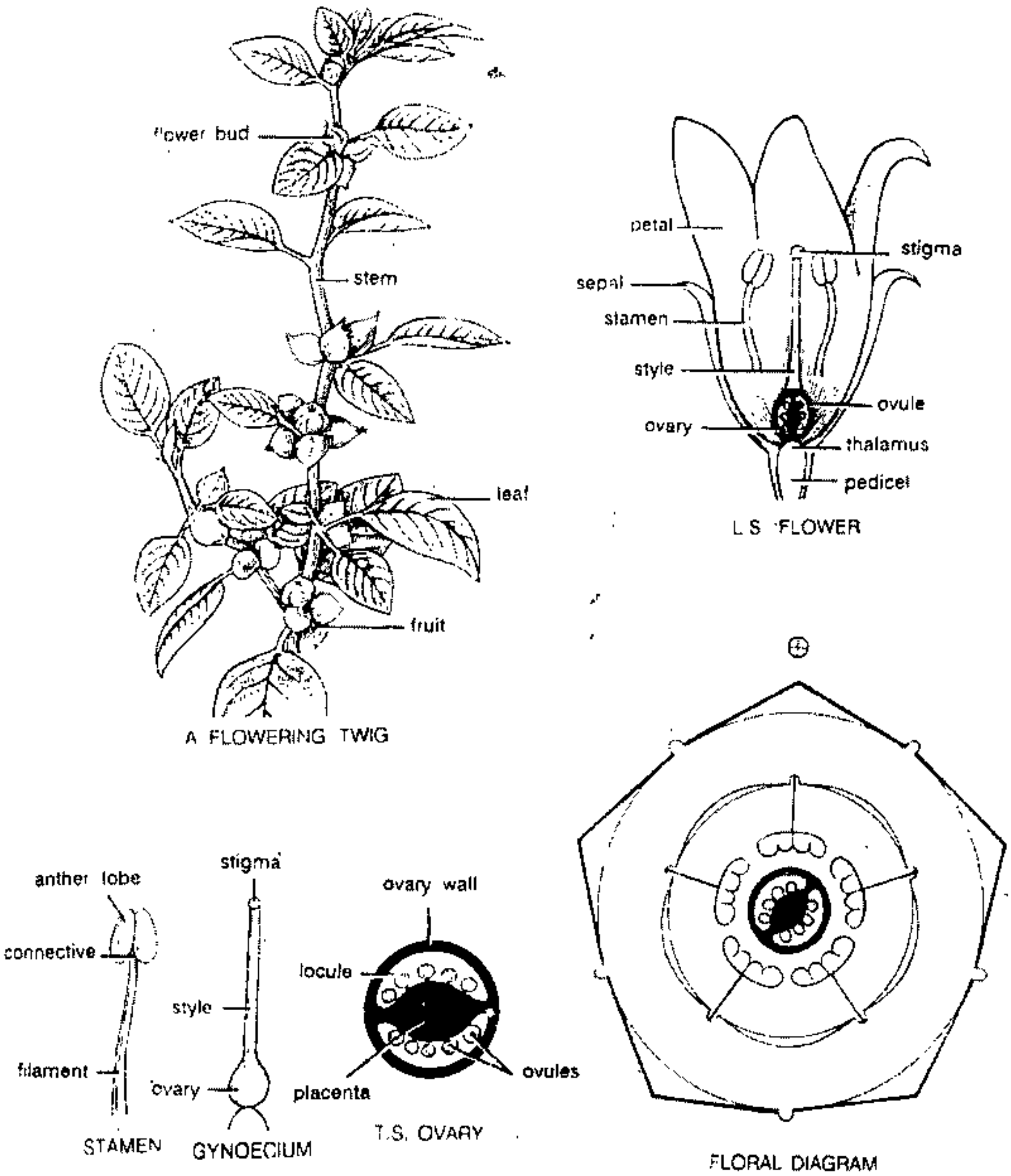

Fig. 2. ***Withania sommnifera***

B. Edible Plants :

Capsicum annuum : (Red Pepper, 'Lal Mirch') : Fruits.

C. frutescens : (Red pepper, 'Lal mirch') : Fruits.

Cyphomandra betacea : (Tree tomato) : Fruits.

Lycopersicon esculentum (Tomato, 'Tamatar') : Fruits.

Physalis minima : Fruits.

P. ixocarpa : For making chilli sauce and also as a dressing for meat.

P. peruvianum : (Raspberry, Wild gooseberry, 'Rasbhari') : Fruits.

Solanum melongena (Bringal, 'Baingan') : Fruits.

S. tuberosum : (Potato, 'Aalu') : Stem tubers, commercial source of starch, dextrin and many alcohols.

C. Condiments :

Capsicum annuum : (Chilli, Red Pepper) : Fruits.

D. Medicinal Plants :

Atropa acuminata : (Roots for manufacturing tinctures and plasters; Source of 'Indian Belladonna'.

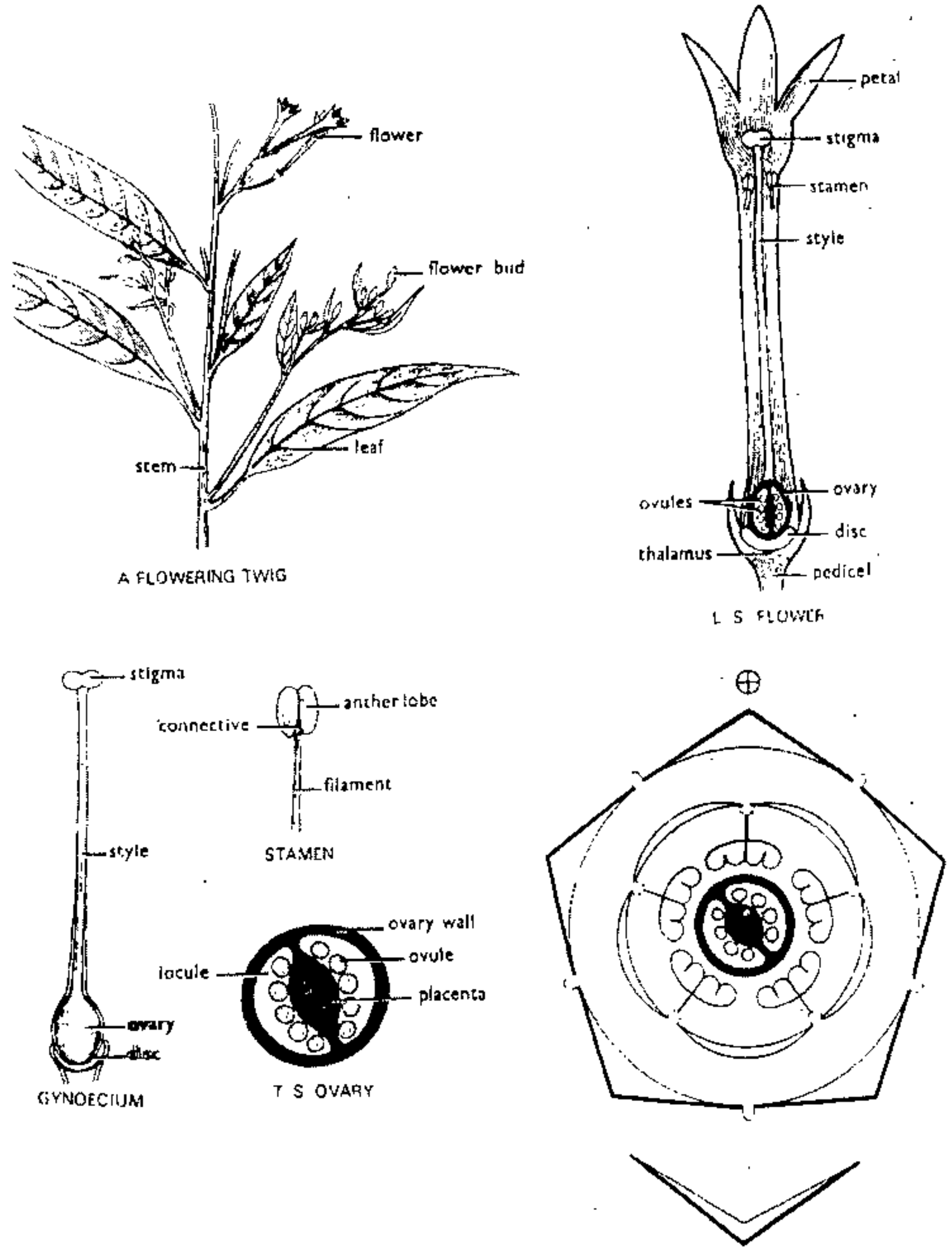

Fig. 3. ***Cestrum nocturnum.***

A. belladonna : Roots sedative and antispasmodic; Source of 'Indian Belladonna'.

A. belladonna : Roots sedative and antispasmodic; Source of alkaloid 'Atropine'; dialates pupils relieves pains; 'Belladonna' prepared for tinctures and plasters; Antiodote for opium poisoning.

Capsicum frutescens : Fruits in rheumatism.

Hyoscyamus niger : (Henbane, 'Khurasni ajwain') : Leaves yield a drug called 'Henbane'; Used as sedative and narcotic, also in asthma and whooping cough; Smoke used for criminal poisoning.

Datura innoxia, D. metel : Leaves used in asthma.

D. stramonium : (Datura, 'Dhatura') : Leaves used in asthma, cutaneous diseases, piles and ache; Seeds narcotic, used for criminal poisoning; Source of alkaloid 'atropine'.

Mandragora autumnalis : Roots sedative.

Solanum nigrum : ('Makoi') : Fruits laxative.

S. xanthocarpum : ('Neeli kateli') : Roots in cough; Leaves as cure for asthma.

Withania coagulans : Fruits for coagulating milk; Also is asthma and liver trouble; Blood purifier.

W. somnifera : Roots narcotic; Fruits diuretic; Applied with ginger on joints in rheumatism.

E. Miscellaneous Uses :

Nicotiana tabacum (Tabacco, "Tambaku") : Leaves used for smoking, chewing and for making snuff': Contain alkaloid 'nicotine'; Sedative, antispasmodic and vermifuge; Seed oil illuminant, used in paints and varnishes; Oil cake as fodder.

N. rustica : Having high nicotine contents; Leaves for smoking and manufacturing insecticide-nicotine contents; Leaves for smoking and manufacturing insecticide-nicotine sulphate.

1.4. ACANTHACEAE (ACANTHUS FAMILY)

Classification :

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledones
Gamopetalae	Sympetalae	Herbaceae
Bicarpellatae	Tubiflorae	Personales
Personales	Acanthaceae	Acanthaceae
Acanthaceae		

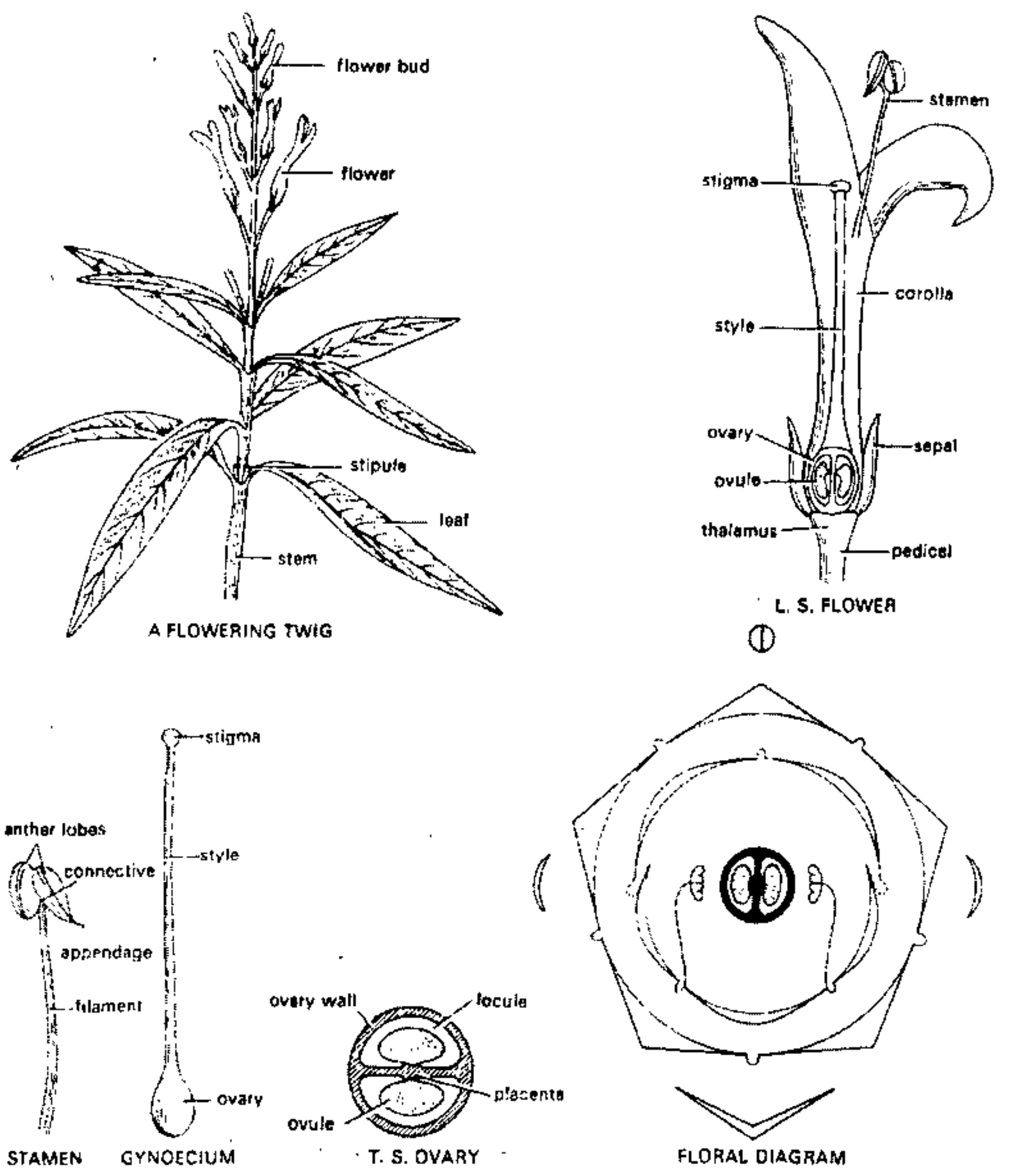

Fig. 1. ***Justicia gendarussa***

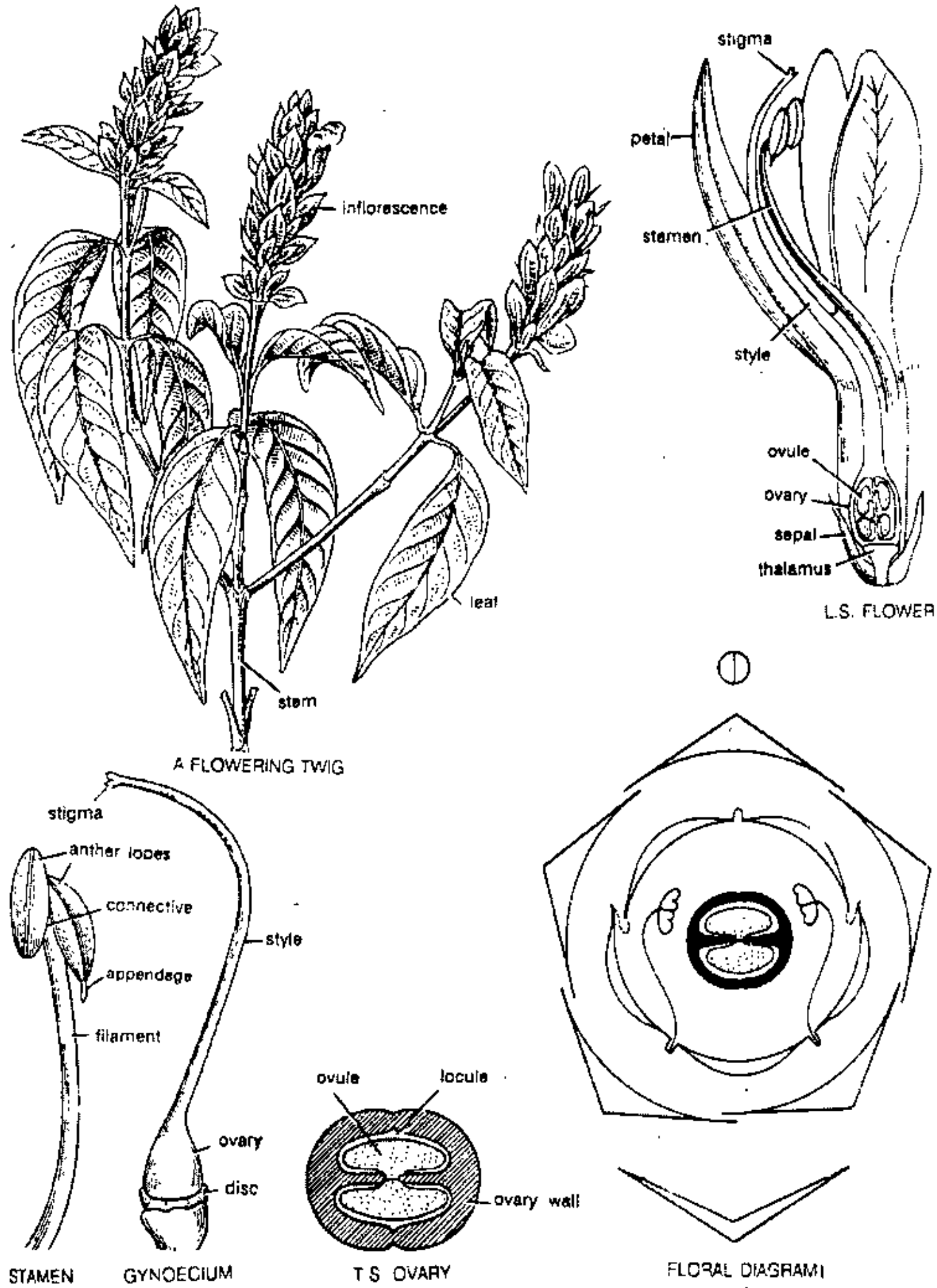

Fig. 2. *Adhatoda vasica*

The family comprised 256 genera and 2,765 species. The plants are mostly distributed in the tropical parts of the world. In India the family is represented by about 68 genera and 337 species.

Vegetative characters

Habit—Plants are mostly herbs, shrubs or a few climbers (*Thunbergia*); some xerophytes (*Barleria, Blepharis, Acanthus*), acquatic (*Asteracantha longifolia*).

Root—Branched tap root system.

Stem—Aerial, erect, underground (*Ruellia tuberosa*), herbaceous or woody, branched cylindrical, node swollen, climbing to twining (*Thunbergia*), spinous (*Barleria*).

Root—Branched tap root system.

Stem—Aerial, erect, underground (*Ruellia tuberosa*), herbaceous or woody, branched cylinderical, node swollen, climbing or twining (*Thunbergia*), spinous (*Barleria*).

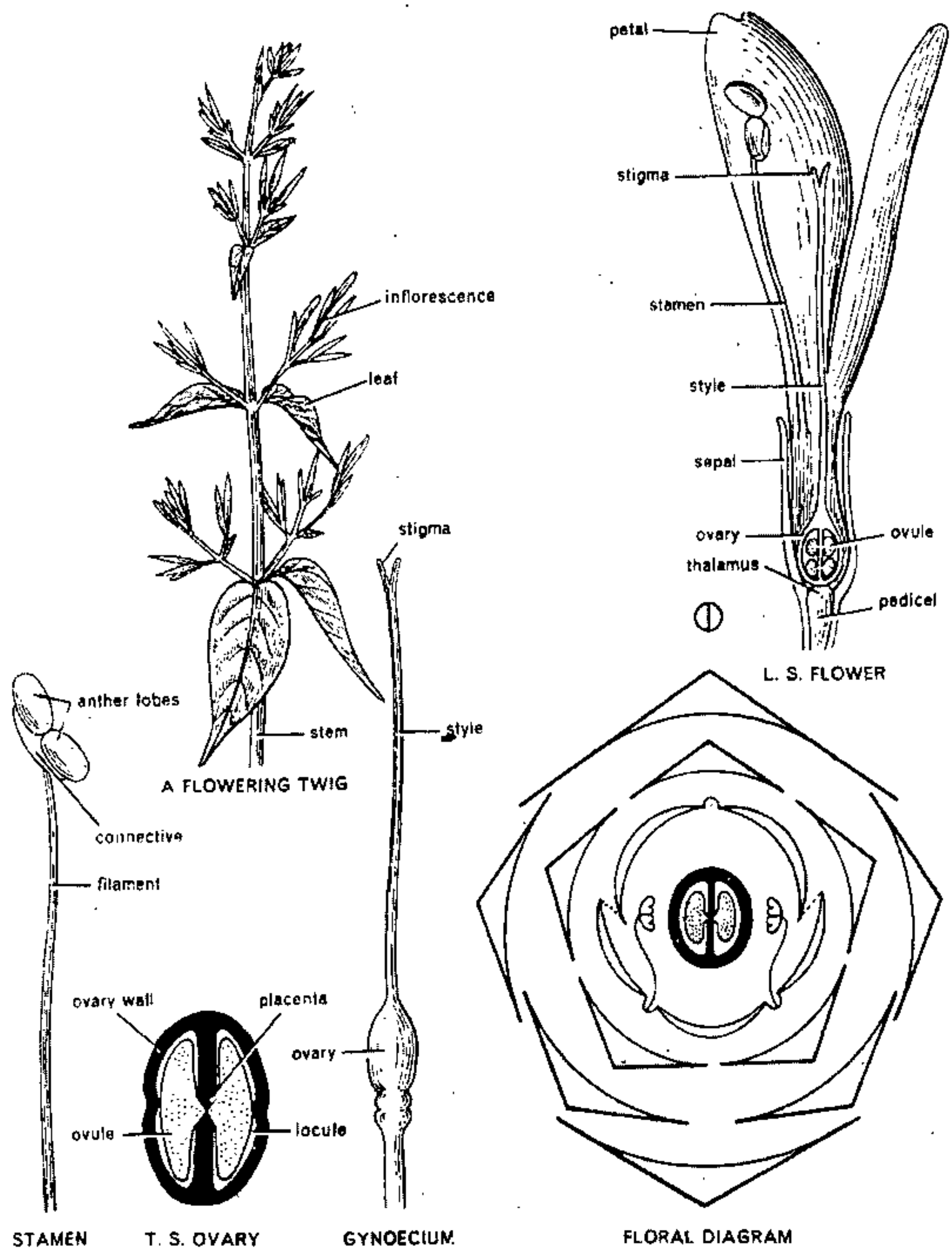

Fig. 3. Peristropha bicalyculata.

Leaves—Opposite decussate, simple, exstipulate, petiolate, usually entire, acute apex, hairy, cystoliths are present in the epidermal cells of stem, leaves and are very characteristics and useful in distiguishing various genera and tribes.

Floral characters

Infloresence—Solitry axillary (*Thunbergia*), spike (*Blepharis*) racemes, dichasial or monochasial cymes.

Flower—Bracteate, bracteolate, bracts and bracteolates conspicuous, pedicellate or sessile, and brightly coloured, hermaphrodite, complete, zygomorphic, pentamerous, or tetramerous, hypogynous, nectariferous disc present below the ovary wall.

Calyx—Sepals 4 or 5 gamosepalous mostly bilabiate, hairy, imbricate, inferior.

Corolla—Petals 2 to 5, bilipped, gamopetalous, variously coloured, imbricate or twisted.

Androecium—Generally 4, rarely 5 (Penstemon), in some 2 fertile stamens and 2 staminodes, epipetalous, filaments free, dithecous, dorsifixed, alternate with the corolla lobes, one anther lobe may be smaller than the other, unequally placed, anthers sometimes spurred.

Gynoecium—Bicarpellary, syncarpous, superior, bilocular, axile placentation (Fig. 1, 3) carpels median, one or more ovules per loculue, style simple, stigma bilobed, disc present below the ovary.

Fruit—Loculicidal capsule or rarely drupe.

Pollination—Entomophilous.

Floral formula— Br, Brl, ⚥, $K_{(4-5)}, \overparen{C_{(5) \text{ or } (2/3)}, A_{2+2 \text{ or } 2 \text{ or } 5}}, \underline{G}_{(2)}$

ECONOMIC IMPORTANCE

A. Ornamentals :

Baleria alba

Beloperone gultata (Shrimp plant)

Eranthemum bicolor

Justicia jeuderussa

Ruellia tuberosa

Strobilanthes isophyllus

Thunbergia alata : (Clock vine)

B. Edible Plants :

Hygrophila angustifolia : Leaves.

C. Dye Yielding :

Peristrophe bivalis : Yellow dye from leaves.

D. Medicinal Plants :

Adhatoda vesica : ('Vasaka') : Leaves yield an ayurvedic drug used as expectorant and relieves cough.

Andrographic paniculata : Yields native drug 'Alvi', used in liver troubles.

Asteracantha longifolia : ('Taal makhana') : Leaves roots and seeds in dropsy, jaundice and rheumatism.

B. prionitis : ('Kala bansa') : Roots and leaves in severe cough and bronchial inflamation.

E. *Miscellaneous Uses :*

Ruellia suffruticosa : Roots in the manufacture of beer.

1.5. LAMIACEAE (LABIATEAE) (MINT FAMILY)

Classification :

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledones
Gamopetalae	*Sympetalae*	Herbaceae
Bicarpellatae	Tubiflorae	Lamiales
Lamiales	Lamiaceae	Labiatae
Lamiaceae		

The family includes about 180 genera and 3500 species of world wide distribution. In India the family is represented by about 64 genera and 380 species.

Vegetative characters

Habit—Plants are mostly aromatic perennial herbs or shrubs (*Leonotis, Pogostemon*) or rarely small trees (*Leucos captrum*).

Root—Tap, branched, rarely adventitious (*Mentha*).

Stem—Aerial, herbaceous, rarely woody, erect or prostrate, quadrangular, hairy, branched, solid or hollow, sometimes underground suckers (*Mentha*).

Leaves—Opposite décussate, rarely whorled, simple, petiolate or sessile, exstipulate, hairy with aromatic smell, entire, pinnatifid (*Perovskia*), unicostate recticulate venation.

Floral characters

Inflorescence—Very commonly ***verticillaster*** consisting of a pair of condensed dichasial cymes at each node; often the verticillasters are grouped together in a thyrsus form; rarely solitary (*Scutelleria*), each flower is usually subtended by a pair of bracts and bracteoles.

Flower—Pedicellate or sessile, bracteate, complete, zygomorphic rarely actinomorphic (*Mentha, Eisholtzia*), hermaphrodite, rarely unisexual (*Nepeta, Thymus*), pentamerous hypogynous.

Calyx—Sepals 5, gamosepalous, bilabiate (*Salvia, Thymus*) campanulate (eucrium) persistent, valvate or imbricate aestivation. When a bilabiate calyx is present the arrangement of the sepals may be (1/4) as in *Ocimum* (fig. 1) or (2/3) as in *Calamintha*.

Corolla—The corolla possesses a tubular base which widens towards the mouth. Petals generally 5, gamopetalous and the five teeth are sub-equal and mostly bilabiate. In *Mentha* a four lobed corolla arises due to the fusion of two upper teeth. When a distinct bilabiate condition is found the arrangment of the petals may be gamopetalous 2/3 *i.e.*, two petals in the posterior upper lip and three in the anterior low lip (*Salvia*, Fig. 2) *Nepeta, Leucas* etc.). In *Ocimum* (Fig. 1). *Coleus, Plectrathus* etc. the petals arrangement is gamopetalous **4/1** *i.e.*, four petals in the posterior upper lip and only one petal in the anterior lower lip. In extreme cases the arrangement may be gamopetalous 0/5 *i.e.*, all the five petals forming the lower lip so that the corolla becomes one lipped. Aestivation in the petals is valvate or imbricate.

Androecium—Typically only 4 stamens, didynamous (2+2) and posterior stamen is reduced or represented by a staminode; in *Calamintha* only two perfect stamens are found, two are imperfect and the fifth reduced. In *Salvia* only two stamens on the anterior side are found; they are characterised by peculiarly long connectives which help in insect pollination stamens generally introrse and dithecous.

Gynoecium—Bicarpellary, syncarpous, superior, situated on hypogynous honey secreting disc; bilocular becomes tetralocular by the formation of false septum; axile placentation, one ovule in each loculus; **style gynobasic** (arising from the base of the ovary), stigma bilobed. The gynoecium character is thus uniform without any variation.

Fruit—Usually schizocarpic carcerulus or achenes or nutlets rarely drupaceous.

Seed—Non-endospermic.

Pollination mechanism in the Lamiaceae

There are five important characters of the flower affecting the pollination mechanism viz.

(a) The horizontal position of the axis of the flower; (b) division of the corolla into an upper and a lower lip; (c) position of stamens and stigma below the upper lip which shelters them; (d) position of the nectary at the base of the flower below the lower lip whose anterior part forms a platform for insects; and (e) well marked dichogamy. **Muller**, who is an authority on the pollination mechanism has remarked in this connection that out of the above the first three are generally true but not universal; the fourth is almost universal but dichogamy is not so complete so as to prevent self pollination. The types of insects visiting these flower have a remarkale correspondence with the length of the corolla tube. Those with short tubes are pollinated by files; slightly longer tubed flowers e.g., *Thymus* or *Origanum* are pollinated by bees; *Salvia, Lamium, Teucrium* with still longer tubes are pollinated by bees as well as other longer tongued insects.

Floral formula— Br, $\oplus$, ⚥, $K_{(3/2)\text{ or }5}$, $\widehat{C_{(2/3)\text{ or }(4/1)\text{ or }(0/5)}, A_{2+2}}$ (std). $\underline{G}_{(2)}$

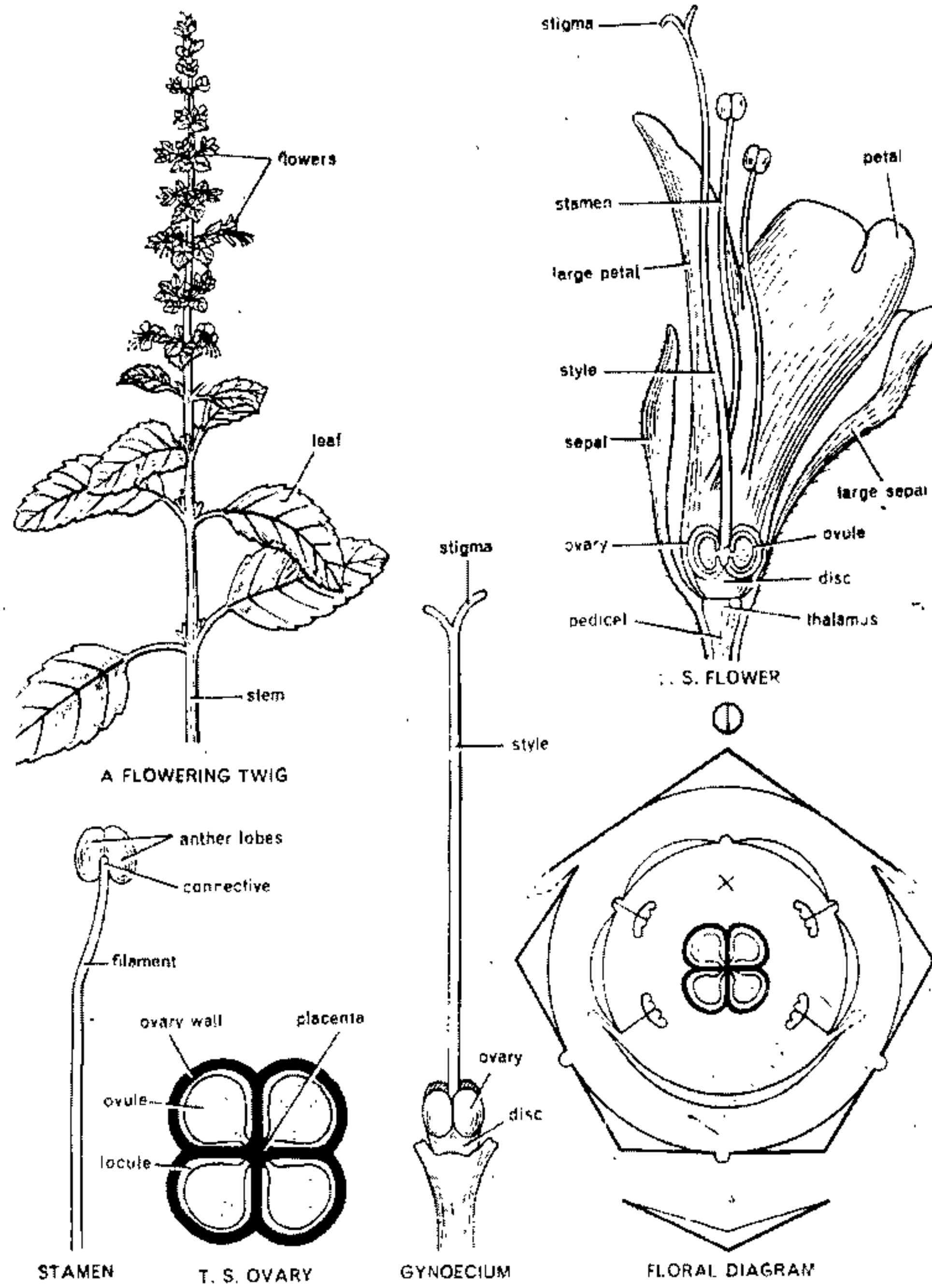

Fig. 1. ***Ocimum sanctum.***

ECONOMIC IMPORTANCE

A. Ornamentals :

Coleus blumei
Ocimum americanum
O. gratissimum : ('Ram tulsi')
O. sanctum : (Basil, 'Tulsi')
Rosarimus officinalis : (Rosmary).
Salvia officinalis : (Garden sage).
S. splendens : (Scarlet sage).

B. Edible Plants

Coleus rotundifolius : Stem tubers.
Lamium album : Stem tops.

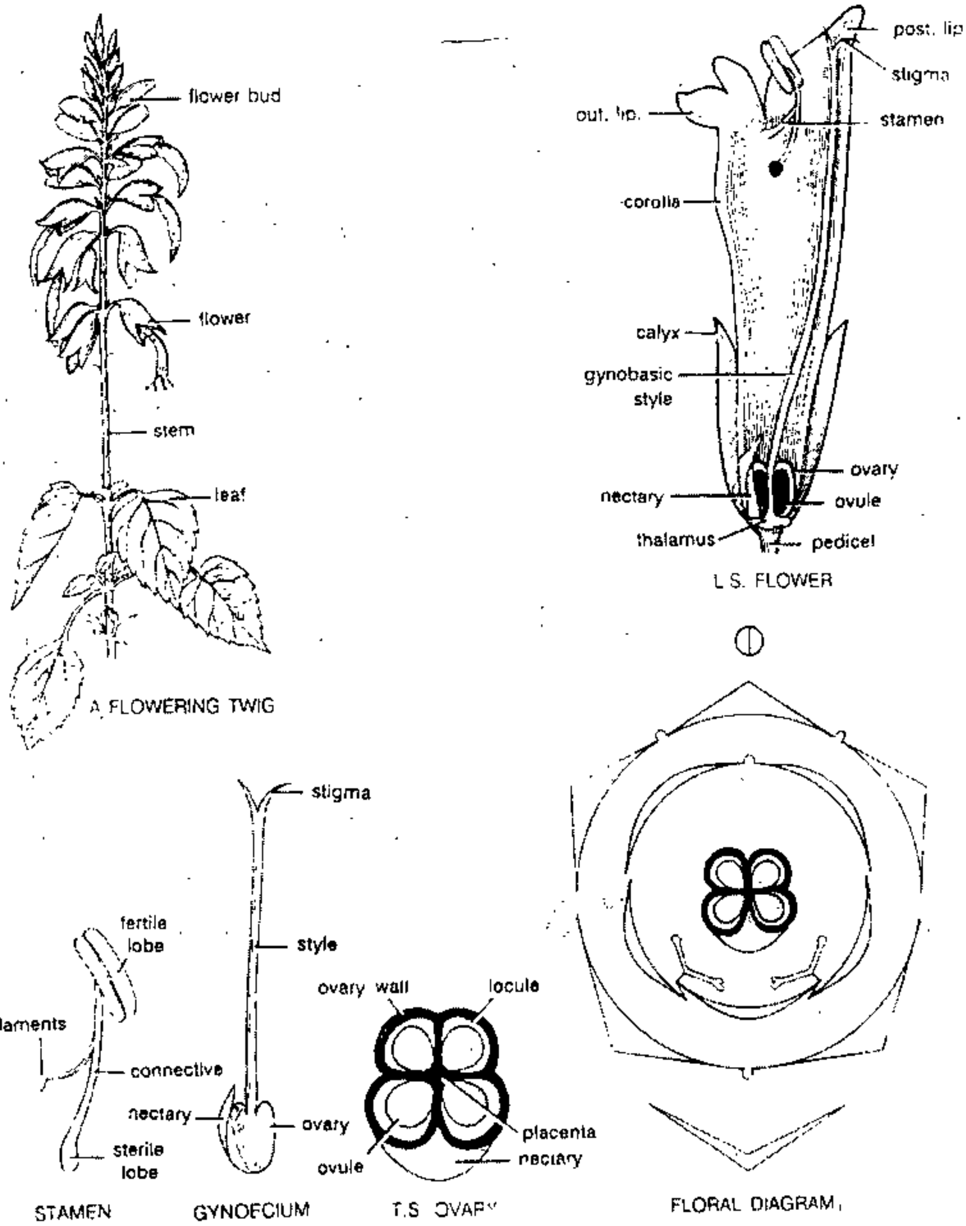

Fig. 2. ***Salvia splendens.***

Mentha arvensis, M. spicata : Leaves.

Thymus serpyllum : Leaves.

C. Condiments and Flowering Materials :

Majorana hortensis : (Majoram).

Mentha arvensis : (Corn mint, 'Podina')

M. longifolia : (Horse mint).

M. piperata : (Peppermint)

M. spicata : (Garden mint, 'Podina')

Ocimum basilicum : (Sweet basil, 'Kali Tulsi')

Thymus vulgaris : (Thyme).

In most of the cases, the leaves and young flowering shoots are used.

D. Oil Yidlding :

Lavendula officinalis : (Lavender), *L. hybrida, L. latifolla*: Essential oil used in performery.

Melissa officinalis : Essential oil in perfumery.

Mentha piperata : Essential oil in confectionary, cosmetics and pharmacy.

M. Pulegium : Essential oil (Pennyroyal oil) in perfumery,

M. spicata : Spearmint oil in cosmetics.

Microtoena insuavis : Essential oil in perfumery.

Oreganum vulgare : Essential oil in cosmetics and perfumery.

Perilla frutiscens : (Perilla oil) : Oil used in paints.

Plectranthus mollis : Oil in medicines.

Pogostemon perilloides : (*Oil of patchouli*), *P. cablin, P. benghalense* : Essential oil in perfumery; also for favouring food.

Rosmarinus officialus : (*Rosmary oil*) : Essential oil in perfumery.

Thymus vulgare : Essential oil in perfumery and medicine.

E. Dye Yielding :

Leonurus cardica : Green dye.

F. Medicinal Plants :

Majorana hortensis : ('Mairua') : Carminative, stimulant, in toothache, also in paralysis.

Mentha arvensis : ('Podina') : Carminative, stimulant and refrigerant, also in rheumatism.

M. arvensis var. *piperascens* : (Japanese peppermint) : Leaves yield **menthol**, used in cold.

M. longifolia : Leaves carminative and stimulant, also in heart ailments.

M. piperata : ('Vilayati peppermint') : Leaves carminative and stimulant, for alleying nausea, sickness and vomitting.

M. spicata : ('Podina') : Stimulant and carminative.

Ocimum basilicum (Sweetbasil, kalibasil) : Seed in diarrhoea and dysentry.

O. gratissium : Seed in neuralgia, rheumatism, leaves in seminal weakness.

O. sanctum (Holybasil, Tulsi) : Leaves in cough and cold, carminative and stimulant, also as insect repellant.

Plectranthus mollis : Leaves applied to stop bleeding.

Saliva officinalis : Used as insecticide.

Thymus serpyllum : ('Ban ajwain') : Used in toothache.

T. vulgaris : Source of **thymol**, a derivative of essential oil, used in tooth paste, mouth wash, also to repel hook worms.

G. Miscellaneous Uses

Ocimum kilimandscharicum : ('Kapoor tusli') : Source of camphor.

Anisomeles indica : Used as fodder.

1.6. SUMMARY

In this chapter the families grouped under camopetalae (according to Bentham and Hooker's system of classification) are described. The important characters of different families can be summarised as :

Family Rubiaceae

Vegetative : Herbs, shrubs or trees, rarely climbers, lianas and epiphytes; Tap; Aerial, erect or weak, herbaceous or woody; opposite, stipulate, simple.

Floral : Cyme, panicle or solitary; Actinomorphic, bisexual, epigynous, pentamerous; Cross entomophilous ; **K** : 4 to 5 sepals, gamosepalous ; **C** : 4 to 5 petals, gamopetalous : **A** : 4 to 5 stamens polyandrous, epipetalous, dithecous, introrse; **G** : Bi-to multicarpellary, syncarpous, inferior, bi-to multilocular, axile or parietal, disc above the ovary; Berry or drupe; Endospermic.

Economic Importance : The family includes ornamentals (*Anthocephalus, Gardenia, Hamelia, Ixora, Morinda, Mussaenda*), edible plants (*Coffea, Vangueria*), fiber yielding (Mitragyna), timber yielding (Adina, Anthocephalus, dye yielding (*Mitragyna*), timber yielding (*Adina, Anthocephalus*), dye yielding (*Morinda, Oldenlandia*), medicinal plant (*Cinchona*). Besides Hymenodictyon used in tanning industry.

Family Apocynaceae

Vegetative : Herbs, shrubs or trees, rarely climbers and lianas : Tap; Aerial, erect, herbaceous or woody; Opposite, exstipulate, simple, latex present in vegetative parts.

Floral : Cymose, solitary or umbellate, Actinomorphic, bisexual, hypogynous, pentamerous: K : 4to 5 sepals, gamosepalous; C : 4 to 5 petals, gamopetalous; A : 5 stamens, polyandrous, epipetalous dithecous, introrse, anthers sagittate : G : Bicarpellary, syncarpous, superior, bilocular, axile, Follicle, Drupe or berry; Endospermic, rarely winged.

Economic Importance *: The family includes ornamentals (Carissa, Catharanthus, Nerium, Plumeria, Tabernaemontana, Thevetia, Trachelospermum,* Vinca) edible plants (*Carissa, Plumeria, fibre*), timber yielding *(Alstonia; Carissa, Wrightia*), dye yielding (*Tabernaemontana, Wrightia*) and medicinal plants (*Acokanthera, Alstonia, Catharanthus, Cerbera, Holarrhina, Rauvolfia, Stropanthus, Valleris, Wrightia).*

Family Asclepiadaceae

Vegetative : Herbs, shrubs or lianas, rarely trees; Tap, Aerial, erect, herbaceous or woody, presence of bicollateral bundles; Opposite, exstipulate, simple.

Floral : Cyme, raceme or umbel : Actinomorphic, bisexual, hypogynous, pentamerous; Cross-pollinated by insects through a specific translator mechanisms; **K:** 5 sepals, polysepalous; **C** : 5 petals, gamopetalous, corona present ; **A** : 5 stamens, polyandrous, dithecous, introrse or anthers fused to stigma to form gynostegium; Pollinia of adjacent anthers fused to corpusculum through retinaculae to form the translator, **G** : Bicarpellary, carpels connate at the base, style free, stigmas fused, superior, axile to marginal, Etaerio of follicles, Endospermic.

Economic Importance : The family includes ornamentals (*Asclepias, Cryptostegia, Leptadenia*), edible plants (*Caralluma, Ceropegia*), spices (*Decalepis*), fiber yielding (*Marsdenia, Calotropis*), dye yielding (*Marsdenia*) and medicinal plants (*Cynanchum, Cosmostigma, Hemidesmus, Pergularia, Tylophora*). Besides the seed floss of *Calotropis* is filled in pillow and *Cryptostegia*, a source of rubber.

Family Solanaceae

Vegetative : Herbs, rarely shrubs, climber, or trees; Tap; Aerial, rect, herbaceous, with bicollateral bundles; Alternate, exstipulate, simple, rarely fused with stem for one internode length.

Floral : Cyme, axillary or extra-axillary; Zygomophic in true sense, bisexual, hypogynous, pentamerous; Cross-pollinated by insects; **K** : 5 sepals, gamosepalous, persistent; **C** : 5 petals, gamopetalous; **A** : 5 stamens, polyandrous, epipetalous, dithecous, introrse or poral ; **G** : Bicarpellary, carpels obliquely placed, syncarpous, superior, bilocular, axile, placenta swollen, disc below the ovary; Berry or capsule; Endospermic.

Economic Importance : The family includes ornamentals (*Brunfelsia, Cestrum Datura, Solanum, Petunia*), edible plants (*Cyphomandra, Lycopersicon, Physalis*), condiments (*Capsicum*) and medicinal plants (*Atropa, Capsicum, Datura, Hyoscyamus, Mandragora, Solanum, Withania*). Besides, *Nicotiana* gives tobacco.

Family Acanthaceae

Vegetative : Herbs or shrubs, rarely twiners, lianas, halophytes or xerophytes; Tap; Aerial, erect, herbaceous or woody; Opposite, exstipulate, simple.

Floral : Cymose or racemose; Bracteate, bracteolate, zygomorphic, bisexual, hypogynous, pentamerous; Cross pollinated by insects; **K** : 5, sepals, Polysepalous; **C** : Five petals, gamopetalous, 2/3 bilabiate; A : 4 stamens, rarely 2 or 5; polyandrous, epipetalous, didynamous, dithecous, introrse, discrete : **G** : Bicarpellary, syncarpous, superior, bilocular, axile, disc below the ovary: Capsule or drupe; Non-endospermic.

Economic Importance : The family includes ornamentals *Barleria, Beloperone, Eranthemum, Justicia, Ruellia, Strobilanthus, Thunbergia),* edible plants (*Hygrophila*), dye yielding (*Peristrophe*) and medicinal plants (*Adhatoda, Andrographis, Asteracantha, Barleria*). Besides *Ruellia* is used for the manufacture of beer.

Family Lamiaceae

Vegetative : Herbs or shrubs, rarely climber or trees : Aromatic odour : Tap; Aerial, erect, herbaceous or woody, quadrangular; Opposite, exstipulate, simple.

Floral : Verticillaster or cyme; Bracteate, zygomorphic, bisexual or gynodioecious, hypogynous, pentamerous; Crosspollinated by insects, rarely by lever mechanism; **K** : 5 sepals, gamosepalous; 1/4-bialbiate, presistent ; **C** : 5 petals, gamopetalous, 4/1, bilabiate; **A** : 4 stamens, polyandrous, epipetalous, dithecous, introrse; **G** : Bicarpellary, syncarpous, superior, tetralocular, axile, style gynobasic; Carcerullus; With little or no endosperm.

Economic Importance : The family includes ornamentals (*Coleus, Ocimum, Rosmarinus, Salvia*), edible plants (*Coleus, Lamium, Mentha, Thymus*), condiments and flavouring materials (*Coleus, Majorana, Mentha, Nepeta, Ocimum, Perilla, Sauteria, Thymus*), oil yielding (*Lavendula, Melissa, Mentha, Microtoena, Oreganum, Perilla, Plectranthus, Pogostemon, Rosmarinus, Thymus*), dye yielding (*Leonurus*) and medicinal plants (*Lallemantia, Leonotis, Lenurus, Leucas, Majorana, Marrubium, Melissa, Mentha, Meriandra, Nepeta, Ocimum, Plectranthus, Salvia, Thymus*). Besides, comphor is also obtained from *Ocimum*.

STUDENT ACTIVITY

1. Write the differences between families Apocyanaceae and Solanaceae.

2. Describe the pollination mechanism in family Lamiaceae.

TEST YOURSELF

1. Why the family Rubiaceae is placed in series inferae ?
2. Family Rubiaceae is characterized by what types of stipules ?
3. Write the type of fruit in *Coffea*.
4. What is the shape of anthers in the family Apocynaceae ?
5. How many pollinia are generally present in a translator of family Asclepiadaceae.
6. Name the family in which gynobasic style is found.
7. Name the family in which oblique septum and swollen placentae are present.
8. Name the family in which verticillaster inflorescence is observed.
9. In family Solanceae, which whorl of the flower is responsible for obliquely zygomorphic nature of the flower ?
10. Name the family in which one anther lobe may be smaller than the another and unequally placed.

ANSWERS

1. Ovary inferior **2.** Inter- and intrapetiolar **3.** Berry **4.** Sagittate
5. Two **6.** Lamiaceae **7.** Solanaceae
8. Lamiaceae **9.** Gynoecium **10.** Acanthaceae

U N I T-III

4

DESCRIPTION OF FAMILIES MONOCHLAMYDEAE

STRUCTURE

- Amaranthaceae
- Euphorbiaceae
- Summary
- Student Activity
  - Test Yourself
  - Answers

LEARNING OBJECTIVES

By learning this chapter you will know the important characters of some dicolyledones families belonging to class Monochlamydeae (petals absent).

• 1.0 AMARANTHACEAE

Classification

Bentham & Hooker	**Engler & Prantl**	**Hutchinson**
Dicotyledones	Dicotyledoneae	Dicotyledones
Monochlamydeae	Archichlamydeae	Herbaceae
Curvembryeae	Centrospermae	Chenopodiales
Amaranthaceae	Amaranthaceae	Amaranthaceae

This is a small family containing about 65 genera and 850 species. The plants are widely distributed in thtemperate and tropical regions of the world. In India the family is represented by 17 genera and over 50 species occurring mostly in warmer parts.

Vegetative characters

Habit : Mostly herbs, rarely shrubs or undershrubs (*Deeringia*), annual or perennial (*Bosia, Ptilotus*)..

Root : A branched tap root.

Stem : Aerial, herbaceous or woody, erect or straggling, cylindrical, or angular, branched, solid, hairy, green or striped green.

Leaves : Simple, alternate or opposite, petiolate, exstipulate, reddish in colour, unicostate reticulate venation.

Floral characters

Inflorescence : Axillary or terminal spikes (*Achyranthes, Digera*). Some times in cymose panicles.

Flower : Bracteate, sessile or sub-sessile, bracteolate, bracteoles two, actinomorphic, hermaphrodite or unisexual (then the plants are polygamo-dioecious or dioecious), hypogynous, pentamerous, small inconspicuous, green or variously coloured.

Perianth : Usually five tepals, free or basally connate, sometimes two or three (*Amaranthus*), dry membranous, imbricate in bud, sometime, hairy, green or coloured, persistent.

Androecium : Stamens 5 or 3 (*Amaranthus*), free or united, staminodes sometimes present, introrse, dithecous or monothecous (*Alternanthera*), open by longitudinal slits.

Gynoecium : Bicarpellary, or tricarpellary, syncarpous, ovary superior, unilocular, usually one campylotropous or pendulous ovule; basal placentation: style short or filiform; stigma 2 or 3.

Fruit : Dry one seeded achene or several seeded capsule or one to several seeded berry.

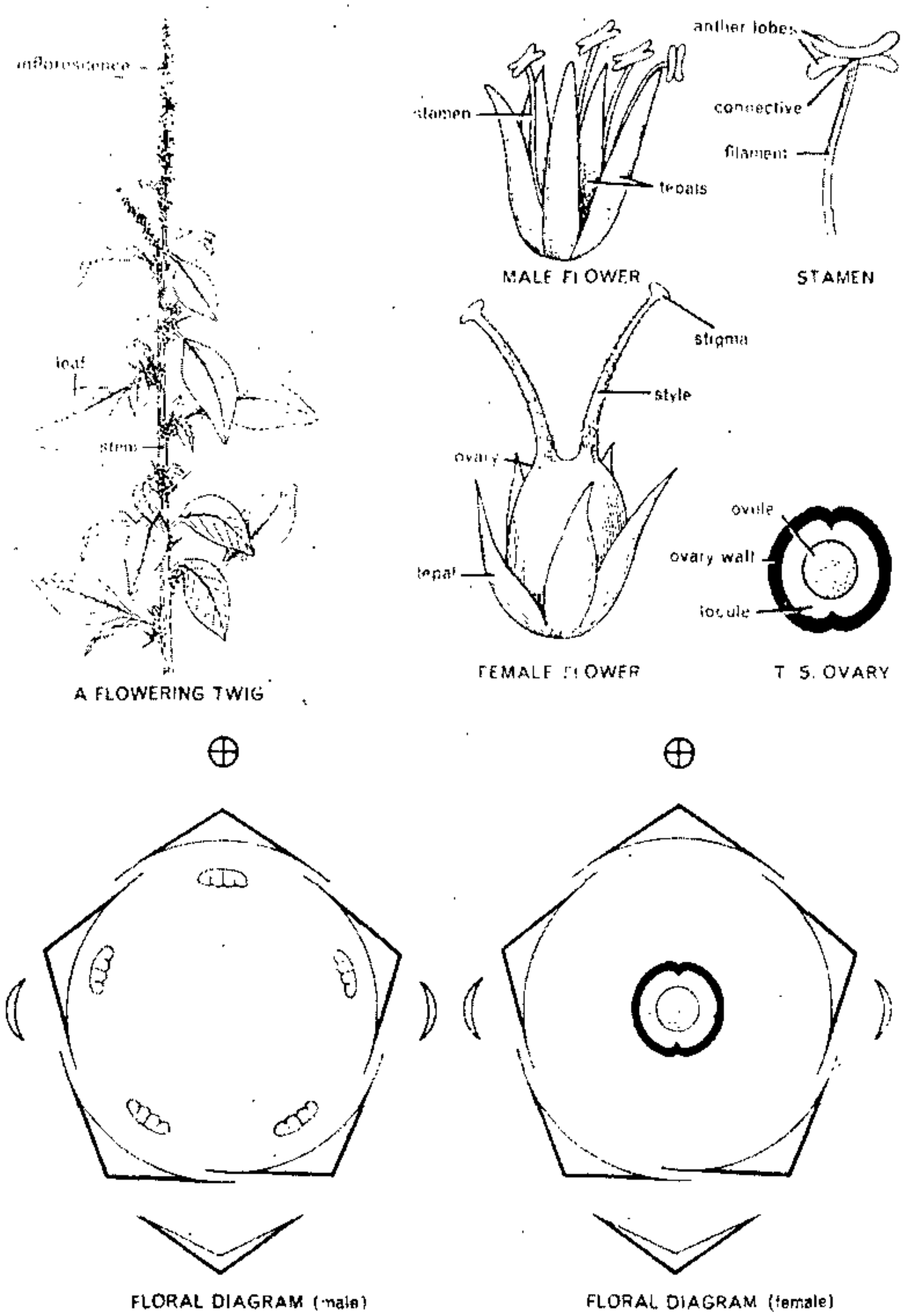

Fig. 1. ***Amaranthus spinosus.***

Seed : Endospermic with polished testa, kidney-shaped embryo curved.

1. English name. *Amaranth.*

2. Vernacular names. *Jangli chaulai, Kantewali chaulai, Goja.*

Vernacular name. *Latjeera, Chirchita, Puthkunda.*

Pollination : Mostly anemophilous and in some plants entomophilous.

Floral formula : *Amaranthus spinosus.*

Male flower : Br, Brl, $\oplus$, ♂ P_5, A_5, G_0

Male flower : Br. Brl. $\oplus$, ♀ $P_5, A_0, \underline{G}_{(2)}$

Achyranthes aspera :

Br, Brl, $\oplus$, ⚥ $P_5, A_5, \underline{G}_{(3)}$

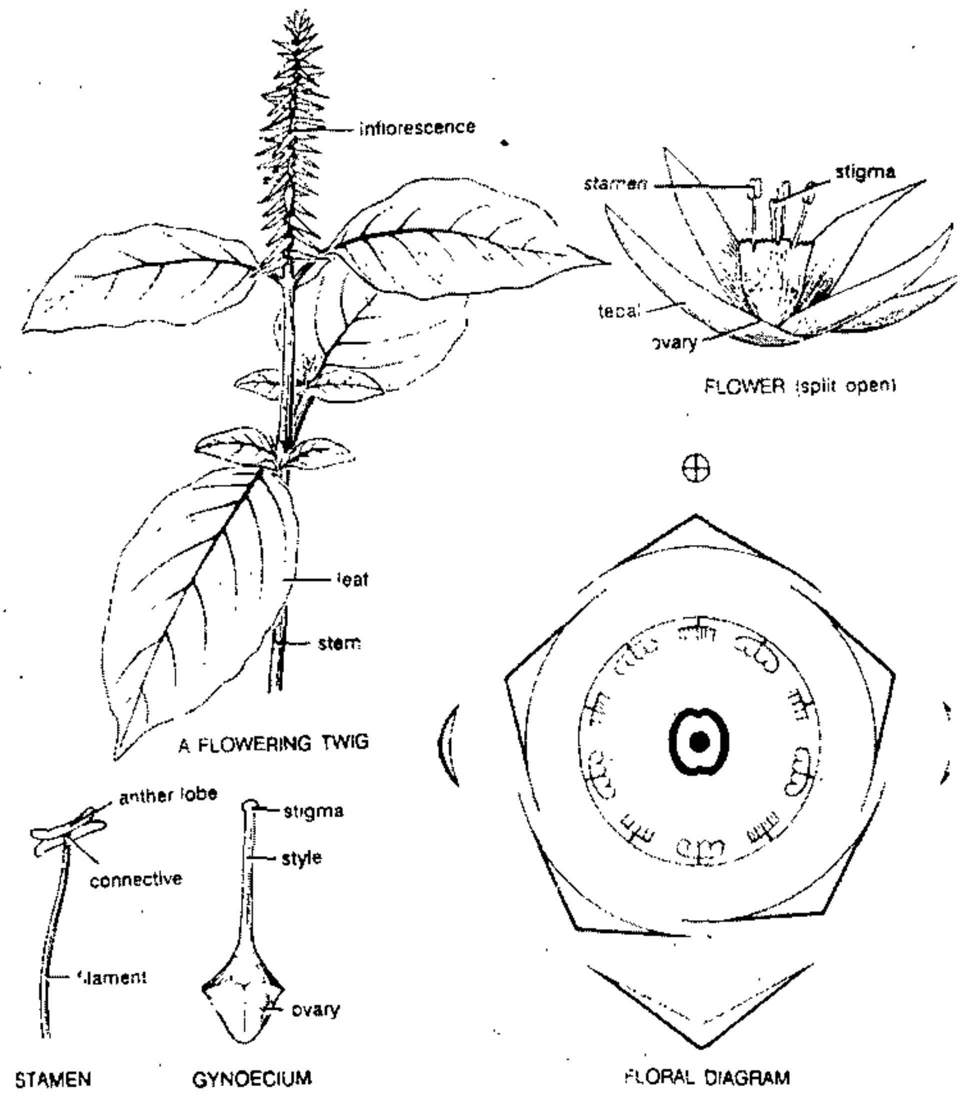

Fig. 2. ***Achyranthus aspera.***

Economic Importance

The family is of little economic importance.

A. Edibles : Species of *Amaranthus* (Amaranth, Chaulai) such as *A. blitum, A, caudatus* and *A. hybridus* are grown as pot herbs for their leaves and branch tops which are used as vegetable.

B. Ornamentals : Several species of *Amaranthus* are grown in gradens for their brightly coloured spikes and variegated foliage, *e.g., A. salicifolius, A. caudatus* var. *alopecurus, A. hypochondriacus* and *A. tricolor.*

Celosia argentea (Cockscomb).

Gompherna globosa (Globe amaranth).

Iresine (Blood-leaf) – *I. herbtsii, I. lindenii.*

C. Medicines : *Achyranthes aspera* (Chirchita) : It is a much valued plant in indigenous medicine. The flowering spikes ground into paste are used as an external application in poisonous insect bites.

The leaves of *Deeringia amaranthoides* are applied to sores.

• 1.1. EUPHORBIACEAE

Classification :

Bentham & Hooker	Engler & Prantl	Hutchinson
Monochlamydeae	Archichlamydeae	Lignosae
Unisexuales	Geraniales	Euphorbiales
Euphorbiaceae	Euphorbiaceae	Euphorbiaceae

It is one of the largest families consisting of 300 genera and 5,000 species. The members are cosmopolitan in distribution except arctic region. In India, the family is represented by about 61 genera and 336 species-mostly in the tropical and subtropical Himalayas and the mountains of south India.

Vegetative characters

Habit : The plants are mostly shrubs (Species of Croton, *Phyllanthus* are herbs; those of *Acalypha* and *Jatrapha* are shrubs) or trees (*Putranjica roxburghii*), *Bischofia* sp. and *Emblica officinalis* (H. *Amla*); *Ricinus communis*). The *genus Euphorbia,* with more than seven hundred species, shows various gradations of habit from small herbs (*E. hirta* and *E. thymifolia*), spiny perennial herbs (*E. mili* syn. *E splendens*) to shrubs (*E. pulcherrima*) and finally to cactus like shape as in Euphorbias of tropical Africa or Indian species of *E. royleana*.

Root : Much branched tap root.

Stem : Aerial, herbaceous or woody, erect or prostrate, cylindrical, or angular, sometimes spiny, branched, in some cladodes (*Euphorbia* sp.), hollow or solid, milky latex present.

Leaves : Alternate, sometimes opposite or whorled, petiolate or sessile, stipulate (*Euphorbia, Croton*) or exstipulate, petiolate or sessile, compound (*Hevea*), entire or serrate, unicostate (*Jatropha*), multicostate (*Ricinus, Manihot*), reticulate venation. In some leaves are variegated (*Codiaeum variegatum*).

Floral characters

Inflorescence : Terminal spike like racemes or spikes (*Croton*); axillary interrupted spikes (*Mercurialis*); axillary (*Phyllanthus*); terminal panicled raceme (*Ricinus*); catkin with pistillate flowers at the base and staminate flowers at the apex of the same inflorescence (*Acalypha*); and cyathium (*Euphorbia* and *Synadenium*). A **cyathium** is a cymose inflorescence of which the terminal flower is female; below it there are four or five bracts which are connate forming a calyx like involucre (fig. 1). In the axil of each bract there is a scorpioid cyme of male flowers; each male flower consists of a single stamen. In between involucral bracts coloured glands are found. These glands are free in *Euphorbia* but always fused in *Synadenium*.

Flowers : Bracteate and pedicellate but incomplete unisexual and apetalous, sometimes both the perianth whorls are absent. Where perianth is present it is regular and hypogynous. In *Weilandia* a pentamerous flower with both sepals and petals are found; carpels epipetalous. In *Croton* sepals and petals are five with numerous stamens in male flowers but only three carpels in female flowers, Apetalous flowers in *Manihot, Acalypha, Phyllanthus*. Both the perianth whorls totally absent in *Euphorbia* where both the male and the female flowers are naked.

Male flower

Perianth : Absent or 3 or 5.

Adroecium : Stamens single in Euphorbia, 3 in *Phyllanthus*, 5 in *Crotonopsis*; highly branched but in 5 groups so as to give a miniature tree like appearance in *Ricinus;* 8-16 in *Acalypha* and slightly monadelphous; 10 in *Jatropha*; 80-100 free stamens in *Croton*; anthers dithecous. In *Phyllanthus cyclanthera* synadrous condition

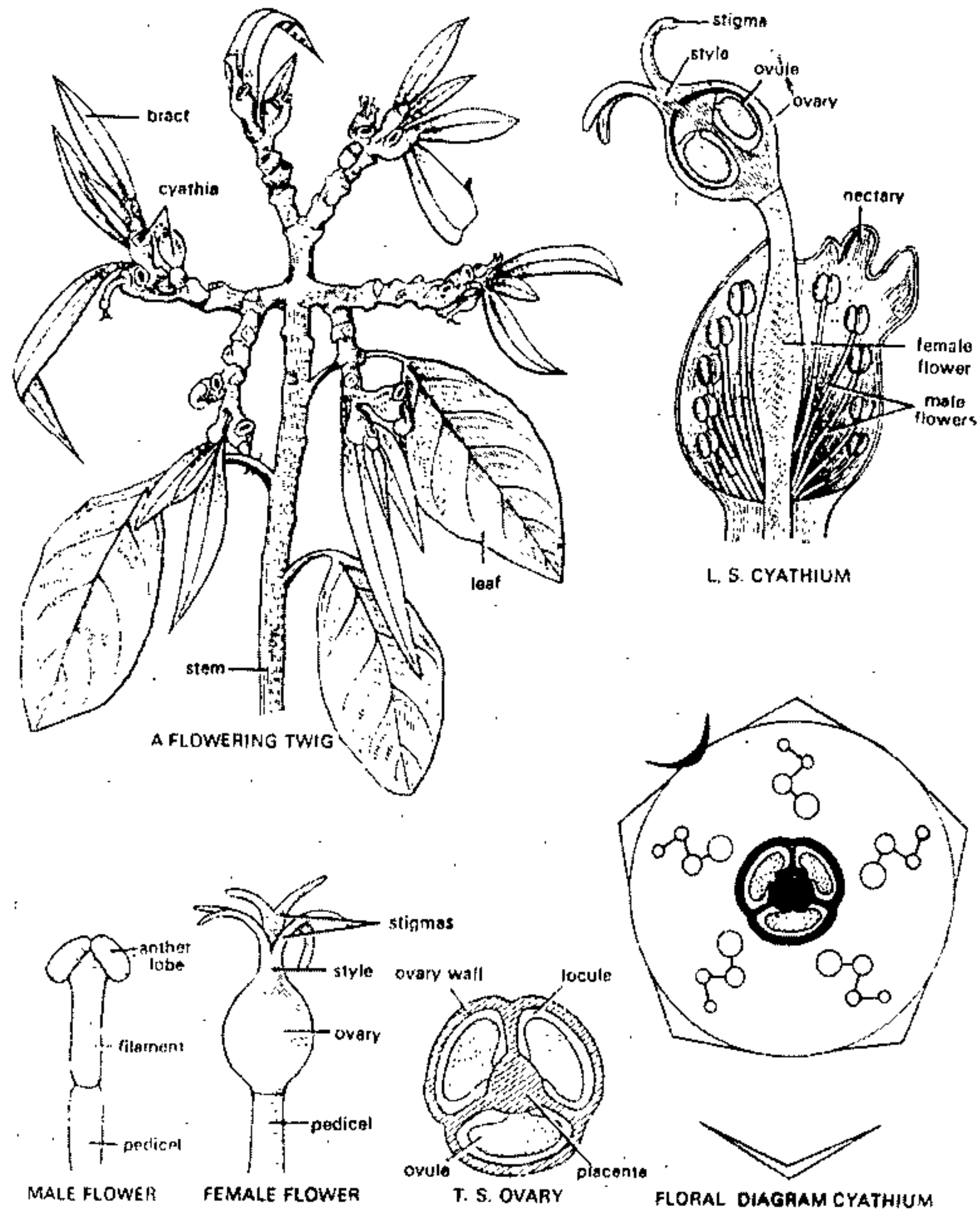

Fig. 1. *Euphorbia pulcherrima*.

is found with both filaments and anthers fused to form a closed ring like structure (compare the genus *Cyclanthera* of the Cucurbitaceae).

Female Flower :

Perianth : As in male flower.

Staminodes may be present or absent.

Gynoecium : Tricarpellary, syncarpous, superior, trilocular, axile placentation, one or two ovules per loculus; styles 3, may be forked; stigma 3 or 6, linear or filiform, plumose and red in *Ricinus*. In *Crotonopsis* there are three carpels but the ovary is unilocular and one ovuled.

Fruit : Schizocarpic capsule or regma (*Ricinus*) rarely drupe (*Hippomane*), or berry (*Bischofia*).

Seed : Endospermic, cotyledons flat or folded; caruncle found in *Ricinus*, *Mercurialis* etc.

Pollination : Entomophilous and in some anemophilous (*Ricinus*).

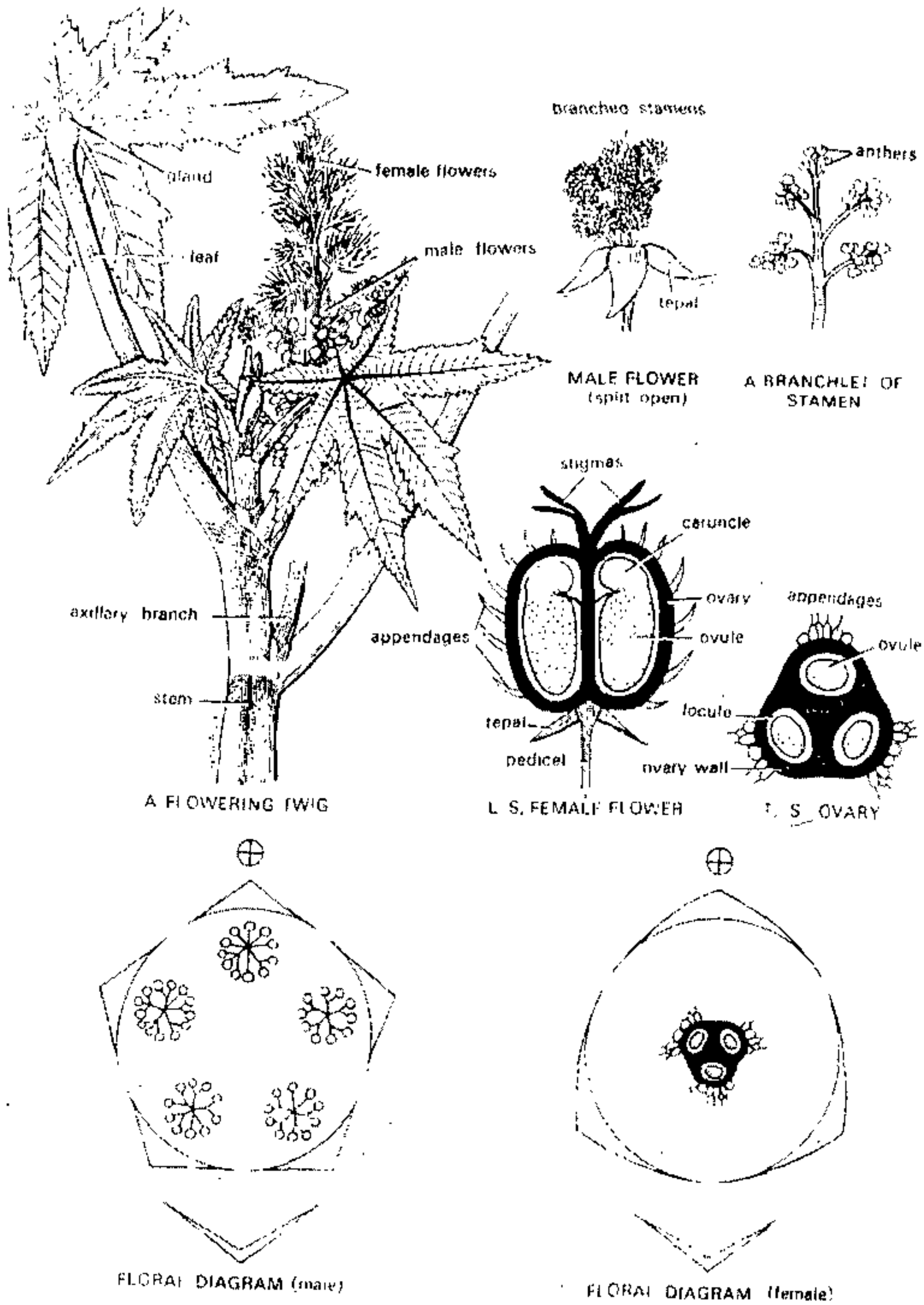

Fig. 2. *Ricinus communis*.

Floral Formulae

Euphorbia	:	male flower : Br, ⊕, ♂ K_0, C_0, A_1, G_0
		female flower Br, ⊕, ♀ $K_0, C_0, A_0, \underline{G}_{(3)}$
Ricinus	:	male flower : Br, ⊕, ♂, P_5, A_5, G_0
		female flower : Br, ⊕, ♀, $P_3, A_0, \underline{G}_{(3)}$
Phyllanthus	:	male flower : Ebr. ⊕, ♂, $P_{3+3}, A_{(3)}, G_0$
		female flower : EBr. ⊕, ♀, $P_{3+3}, A_0, \underline{G}_{(3)}$
Jatropha gossypifolia	:	male flower : Br. Brl ⊕, ♂, K_5, C_5, A_{5+5}, G_0
		female flower : Br. Brl. ⊕, ♀, $K_5, C_5, A_0, \underline{G}_{(3)}$

ECONOMIC IMPORTANCE

A. **Ornamentals :**

Acalypha hispida : (Redhot cat's tail),

Codiaeum variegatum : (Croton).

Euphorbia antiquorum

E. pulcherrima : ('*Lal patta*').

Jatropha curcas : ('Safed arand').

J. gossypifolia : ('Bherenda').

B. **Edible Plants :**

E. officinalis : (Myrobalam, 'Amla') : Fruits.

Manihot esculenta : (Cassava) : Tapioca tubers used commercially for obtaining starch, sago and flour.

C. **Oil Yielding :**

Croton oblongifolius : Seed oil as insecticide.

C. tiglium : (Croton oil) Seed oil medicinal.

Jatropha curcas : Seed oil as lubricant, illuminant, also in soap and candle industry.

Ricinus communis : (Castor, 'Arand') : Seed oil as lubricant, for manufacturing transparent textile soap, type ink, perfumes, paints and varnishes; Oil cake as fodder.

D. **Timber Yielding :**

Excoecaria agallocha : ('Gangwa') : Wood for making match splints.

Gelonium multiflorum : Wood for making posts and rafters.

Hura crepitans : (Sand box tree) : Timber used for making vaneers, plywood.

Trewia nudiflora : Timber for making match box, tea box etc.

E. **Dye Yielding :**

Kirganelia reticulata : Red dye from roots.

Mallotus philippinensis : Red dye from fruit sürface for dying silk.

F. **Gum, Mucilage and Resin Yielding :**

Croton aromaticus : Yields gum-resin used in varnishes.

G. **Medicinal Plants :**

Croton oblongifolius : Seed oil purgative.

C. tiglium : ('Jamalghota') : Sed oil is a very strong purgative.

Emblica oticinalis : Fruits in diarrhoea and dysentry.

Jatropha curcas : Seed oil purgative.

Mallotus philippinensis : Anthelmintic.

Ricinus communis : Seed oil laxative and cathartic.

H. **Miscellaneous Uses :**

Emblica officinalis : Bark, leaves and fruits in tanning industry.

Ricinus communis : Wood pulp used in the manufacture of paper and card board.

Hevea brasiliensis : (Rubber tree) : Latex from the bark is main source of rubber, used for making tyres, tubes and water proof coatings etc.

Manihot glaziovii : Latex gives rubber.

• SUMMARY

In this chapter the families grouped under Monochlamydeae (according to Bentham and Hooker's system of classification) are described. The important characters of different families can be summarised as :

Family Amaranthaceae

A. Vegetative : Annual or perennial herb or undershrubs, aerial, tap, herbaceous or woody, simple, alternate or opposite, petiolate, exstipulate,

B. Floral : Axillary or terminal spikes, bracteate, actinomorphic bisexual or unisexual, hypogynous, small inconspicuous anemophilous or entomophilous : **P** : 5 tepals, free or basally connate, persistent, imbricate; **A** : 5 and lie opposite the sepals, dithecous and introrse and open by longitudinal slits; **G** : bi- or tricarpellary, syncarpous, superior, unilocular, pendulous or erect. campylotropous ovule, urticle.

Economic Importance : The family includes ornamentals (*Celosia, Gomphrena, Iresine, Derringia*), edible (*Amaranthus*) and medicinal plants (*Achyranthes aspera, Deeringia amaranthoides*).

Family Euphorbiaceae

A. Vegetative : Herbs, rarely shrubs, trees or cactoid; Tap; Aerial, erect, herbaceous, latex present; Alternate, stipulate, simple, latex present.

B. Floral : Cyme, spikate cyme or cyathium; Bracteate, actinomorphic, unisexual hypogynous, pentamerous : cross pollinated by in sects; **P** : 3 + 3 tepals or absent, polyphyllous; **A** : 5 or 5 + 5 or tree like branched or numerous stamens, polyandrous, dithecous, introrse; **G** : tricarpellary, syncarpous, superior, trilocular, axile, obturator present; Regma, rarely berry or capsule; endospermic and carunuculate.

Economic Importance : The family includes ornamentals (*Acalypha, Codiaeum, Euphorbia, Jatropha,* edible plants (*Emblica, Jatropha, Manihot*), oil yielding (*Croton, Jatropha, Ricinus*), timber yielding (*Excoecaria, Gelonium, Hura, Trewia*), dye yielding (*Kirganelia, Mallotus*), gum/mucilage yielding (*Croton, Macranga, Ostodes, Sauropus*) and medicinal plants (*Croton, Emblica*). Besides some plants are used as tan (*Aleurites, Bischoffia, Cicca*) and a few yield rubber (*Hevea, Manihot*).

• STUDENT ACTIVITY

1. Describe the floral characters of family Euphorbiaceae.

2. Write the floral formulae of family and draw floral diagram of family Amaranthaceae.

• TEST YOUR SELF

1. What type of placentation is present in family Euphorbiaceae?
2. What is the position of the floral organs on thalamus in family Euphorbiaceae?
3. Which special type of inflorescence is present in *Euphorbia*?
4. Write the important character of family Euphorbiaceae, due to which it is placed in sub-class monochlamydeae
5. Write the important characters of gynoecium of family Amaranthaceae.

ANSWERS

1. Axile placentation
2. Epigynous
3. Cyathium
4. Flowers usually with one whorl of perianth
5. Gynoecium 2-3 carpellary, syncarpous, superior, unilocular with indefinite to 1 ovule.

UNIT-III

5

DESCRIPTION OF FAMILIES MONOCOTYLEDONES

STRUCTURE

- Poaceae
- Summary
- Student activity
- Test yourself
- Answers

LEARNING OBJECTIVES

By studying this chapter you will know the important characters of one of the largest monocotyledones family.

• 5.0. POACEAE (GRAMINEAE)

Butter Cup or Crow-foot family (Grass Family)

Classification

Bentham & Hooker	Engler & Prantl	Hutchinson
Monocotyledones	Monocotyldoneae	Monocotyledons
Glumaceae	Glumiflorae	Graminales
Poaceae (Gramineae)	Poaceae (Gramineae)	Poaceae (Gramineae)

It is one of largest and most important family of plant kingdom. The family includes some 600 genera and 10,000 species, widely distributed all over the world. In India the family is represented by 239 genera and 1180 species occurring throughout the country.

Vegetative Characters

Habit : Herbs, annuals or perennials or shrubs, sometimes tree like (*Bombusa, Dendrocalamus*).

Root : Adventitious, fibrous, branched, fascicled or stilt (*Zea mays*).

Stem : Underground rhizome in all perennial grasses, cylindrical, culm with conspicuous nodes and internodes, internodes hollow, herbaceous or woody, glabrous or glaucous, vegetative shoots are arising from the base of aerial stem or from underground stems are called **tillers.**

Leaves : Alternate, simple, distichous, exstipulate, sessile, ligulate (absent in *Echinochloa*), leaf base forming tubular sheath, sheath open, surrounding internode inncompletely, ligule is present at the junction of the lamina and sheath, entire, hairy or rough, linear, parallel venation.

Floral Characters

Inflorescence : Compound spike which may be sessile or stalked. Each unit of inflorescence is spikelet. The spikelets are arranged in various ways on the main axis called **rachilla.** A compound inflorescence may be spike of spikelets (*Triticum*), panicle of spikelets (*Avena*).

The spikelet consists of a short axis called rachilla on which 1 to many sessile or short stalked flowers are borne. The florets may be arranged in alternate or opposite manner on the central axis.

At the base of rachilla two sterile scales, called **glumes,** are present. The glumes are placed one above the other on opposite sides. The lower one is called first glume and the upper is called second glume. Both the glumes are boat shaped and sterile. Above the glumes a series of florets are present. Each floret has an inferior palea or lemma and above it a superior palea. The lemma frequently bears a long, stiff hair called **awn.**

Flower : Bracteate and bracteolate, sessile, incomplete, hermaphrodite, or unisexual (*Zea mays*), irregular, zygomorphic, hypogynous, cyclic.

Perianth : Represented by membranous scales called the **lodicules.** The lodicules are situated above and opposite the superior palea or may be absent, or many (*Ochlandra*), or 2 or 3.

Androecium : Usually stamens 3, rarely 6 (*Bombusa, Oryza*) and one in various species of *Anrostis, Lepturus;* polyandrous, filaments long, anthers dithecous, versatile, linear, extrorse; pollen grains dry.

Gynoecium : Monocarpellary, according to some authors carpels 3, of which 2 are abortive, ovary superior, unilocular with single ovule, basal placentation, style short or absent; stigmas two feathery or papillate and branched.

Fruit : Caryopsis (achene with pericarp completely united or adherent with the seed coat) or rarely nut (*Dendrocalamus*) or berry (*Bambusa*).

Seed : Endospermic and containing a single cotyledon called **scutellum,** which is shield shaped and pressed against the endosperm.

Floral Formula : %, , $P_{0 \text{ or } 2 \text{ (Lodicules)}}$ $A_{3 \text{ or } 6}$ $\underline{G}_1$.

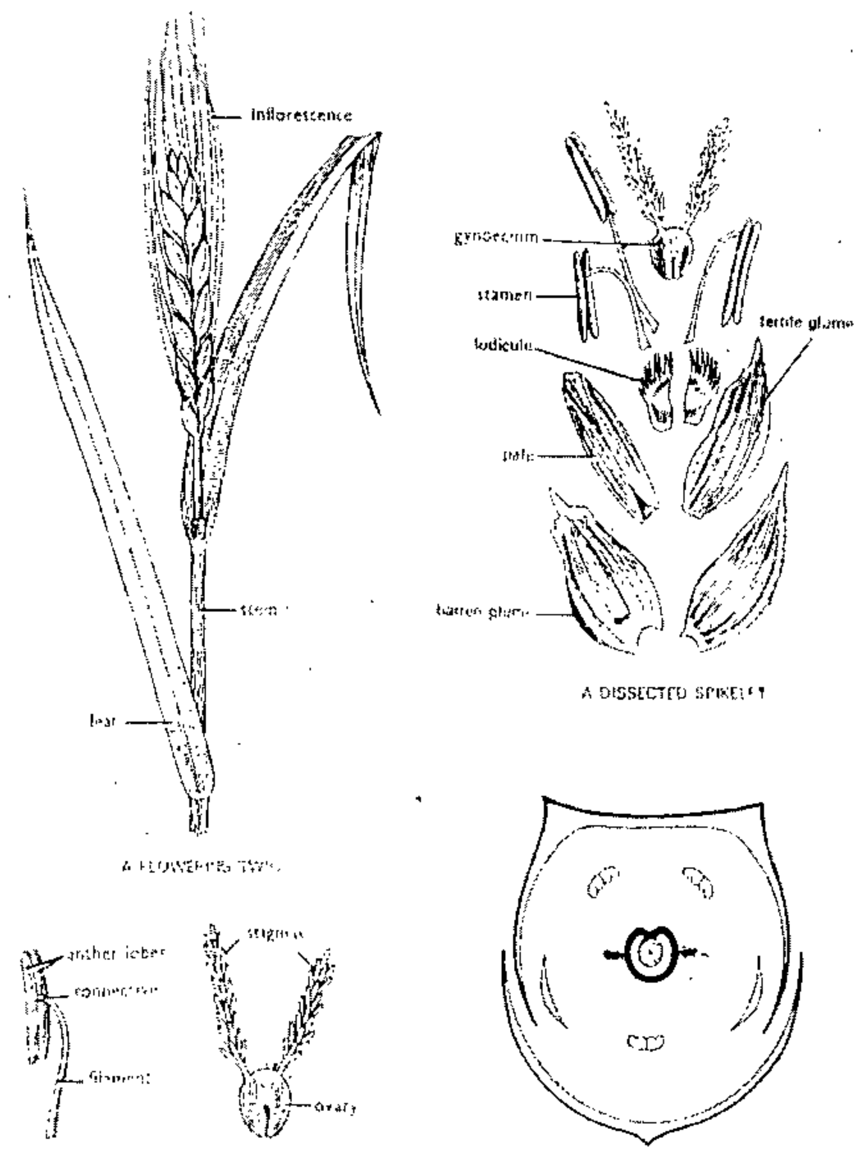

Fig. 1. *Triticum aestivum.*

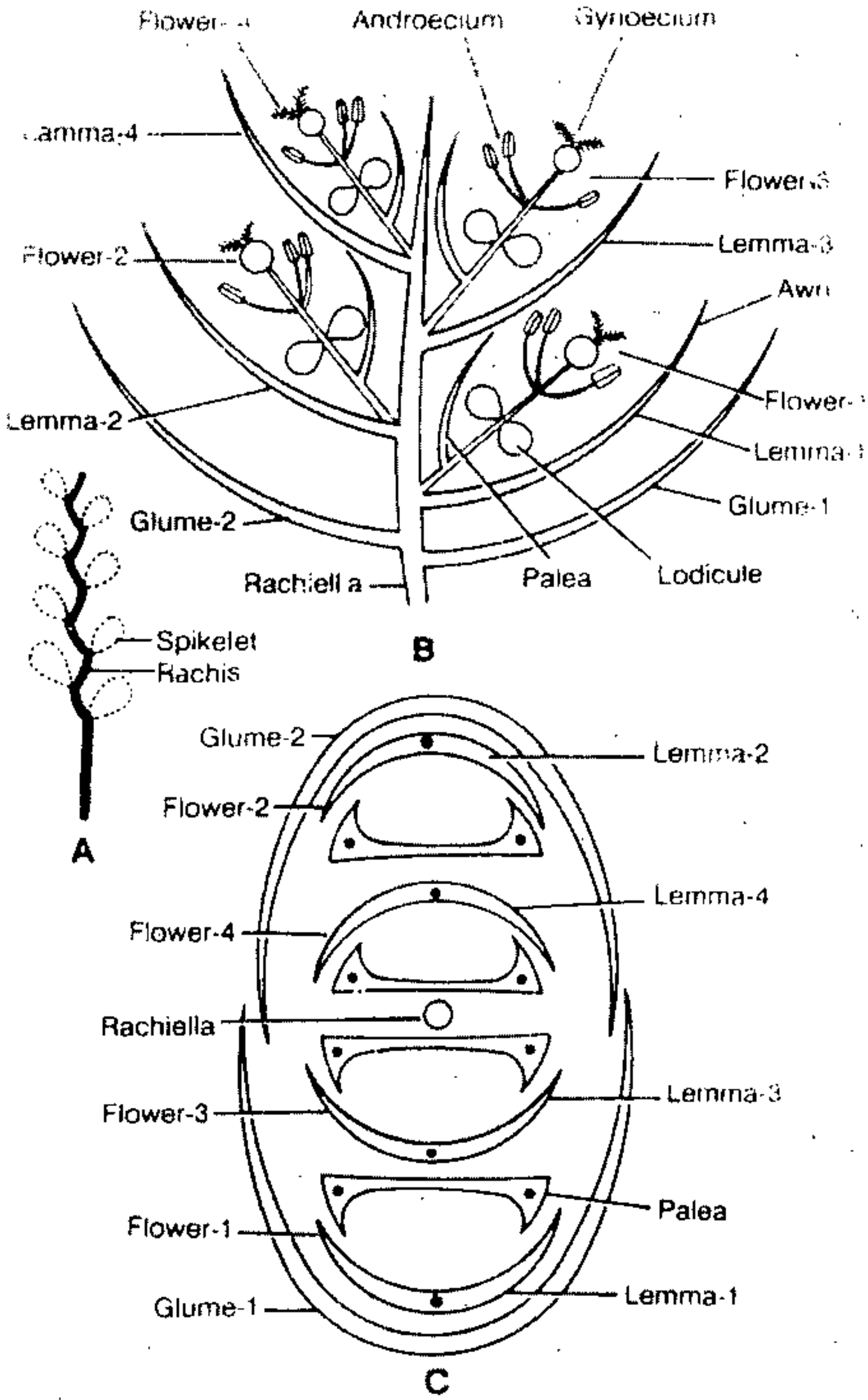

Fig. 2. Diagrammatic representation of the floral plan of Gramineae : A. Spike, B. Spikelet, C. Floral diagram of the spikelet.

Economic Importance

A. Ornamentals Plants :

Cynodon dactylon : ('Doob')
Dendrocalamus strictus
Oplismenus burmannii
Phalaris minor
Sasa tassellata
Stipa pinnata

B. Cereals-Major and Minor :

Avena sativa : (Oat, 'Jai')

Eleusine coracana : ('Ragi').

Hordeum vulgare : (Barley, 'Jau').

Oryza sativa : (Rice, 'Chawal')

Panicum miliaceum : (Sommon millet).

Pennisetum typhoides : (Pearl millet, 'Bajra').

Secale cereale : (Rye).

Setaria italica : (Italian millet).

Sorghum vulgare : ('Jawar').

Triticum aestivum : (Wheat, 'Gehun')

Zea mays : (Maize, 'Makka').

C. Sugar :

Saccharum officinarum : (Sugarcane, 'Ganna')

D. Oil Yielding :

Cymbopogon caesius : (Giner grass) : Leaves yield essential oil used in soap industry.

C. citratus, C. flexuosus : (Lemon grass) : Leaf oil called **'Lemon-grass oil',** used in perfumery and cosmetics.

C. jawarancusa : Oil smells like peppermint.

C. martinii : (Ginger grass) : Leaf oil used in perfumery and cosmetics, two distinct varieties : 'Motia' and 'Sofia'; 'Motia oil' called **'Palmorosa oil;** 'Sofia oil' as **'Ginger grass oil'.**

Vetiveria zizanioides : ('Khas') : Essential oil from roots used in perfumery and cosmetics.

E. Fiber Yielding :

Erianthus arundinaceus : ('Sarkanda') : Leaf sheath fiber used for making ropes.

E. munja ('Moonj') : Stem fiber for making baskets, mats and ropes.

F. Timber Yielding :

Bambusa balcooa, B. polymorpha, B. tulda : (Mamboo, 'Baans').

Dendrocalamus giganteus.

G. Paper Industry :

Bambusa arundinacea, B. polymorpha, B. tulda : (Bamboo, 'Bans')

Dendrocalamus hamiltoni : ('Kagzi baans').

Erianthus arundinaceus : ('Sarkanda').

E. munja : ('Moonj').

Ochlandra travancorica : ('Iraal')

Phragmites karka : ('Narkul', 'Pora').

H. Fodder : Species of *Alopecurus, Cynodon, Pennisetum, Phalaris, Setaria, Sorghum, Themeda, Triticum* and *Zea* are used as fodder.

I. Soil Binders :

Bothriochloa insculpta

Eragrostis curvula

J Raclamations of Sand Dunes :

Panicum antidotale

Rottbellia hirsuta

Saccharum spontaeum

K. Mats, Baskets and Curtains :

Desmostachya bipinnata ('Kusha'), *Thysanolaena mexima* ('Seenk'), *Vetiveria zizanioides.*

L. Medicinal Plants :

Agropyron repens : Demulcent and diuretic.

Arundo donax : Stimulates menstural discharge.

Bambusa vulgaris : Bark astringent.

Cenchrus barbatus : Diuretic.

Cymbopogon nardus : Carminative.

Desmostachya bipinnata : Used in dysentry.

Setaria italica : Diuretic and Astringent.

Vetiveria zizanioides : Roots applied on swellings.

M. Miscellaneous Uses :

Hordeum vulgare : Source of beer.

Saccharum officinarum : For making industrial alcohol.

Thysanolaena mexima : For making brooms.

Vetiveria zizanoides : Source of non-alcoholic cold drink.

Zea mays : For making industrial alcohol.

• 1.1. SUMMARY

In this chapter one of the largest and most important family of monocotyledones is described. The important characters of the family are :

A. Vegetative : Generally herbs, rarely woody plants; Adventitious fibrous; Aerial terminating in culms, erect, herbaceous, fistular; Alternate, exstipulate, sheathing, ligule present between sheath and lamina.

B. Floral : Spike of spikelets, rarely panicle or spadix of spikelets, axis called rachis, spikelet axis called rachiella; Presence of two empty bracts called glume I and II, fertile bract called lemma terminating into a spiny or hairy awn, bracteolate, bracteole called palea, sessile, zygomorphic, bisexual or andromonoecious, hypogynous, trimerous; Cross pollinated by wind or self; **P** : 2 membranous lodicules, rarely three, polyphyllous; **A** : 3 stamens, rarely 3+3 or 2, polyandrous, dithecous, introrse, versatile; **G** : Tricarpellary, syncarpous, superior, unilocular, basal; Caryopsis, rarely utricle; Endospermic.

Economic Importance : The family includes ornamentals (*Cynodon, Dendrocalamus, Olismenus, Phalaris, Sasa, Stipa*), cereals (*Avena, Eleusine, Hordeum, Oryza, Panicum, Pennisetum, Secale, Setaria, Sorghum, Triticum, Zea*), sugar yielding (*Saccharum*), oil yielding (*Cymbopogon, Vetiveria*), fiber yielding (*Erianthus), timber yielding (*Bambusa, Dendrocalamus), paper industry (*Bambusa, Pharagmites, Saccharum*), Soil binders (*Bothriochloa, Eragrostis*) for reclaming sandy dunes (*Panicum, Rottboellia, Saccharum*), for making mats and baskets (*Bambusa, Vetiveria*) and medicinal plants (*Agropyron, Arundo, Bambusa, Cenchrus, Cymbopogon, Desmostachya, Setria, Vetiveria*). Besides, a few plants are used for making drinks (*Saccharum, Zea, Hordeum, Vetiveria*) brooms (*Thysanolaena, Eragrostis*), writing pen (*Phragmites*), walking sticks (*Phyllostachya*, Pseudostachyum), fishing rods (*Arundinaria*) etc.

• 1.2. STUDENT ACTIVITY.

1. Write the floral characters of family Poaceae.

Q. 2. Write the economic importance of family Poaceae.

• 1.3. TEST YOURSELF

1. What type of placentation is present in grasss ?
2. What is the position of ligule in the leaves of grasses ?
3. Generally what type of fruit is present in the grases ?
4. What is the position of the lodicules in the flower of grasses ?
5. Write the botanical name of pearl millet.

Answers

1. Basal **2.** Between sheath and lamina
3. Caryopsis **4.** Antero-laterally **5.** *Pennisetum typhoides.*