BOTANY

SEED PLANTS

BLOCK I	GYMNOSPERMS
BLOCK II	PLANT ANATOMY
BLOCK III	TAXONOMY
BLOCK IV	EMBRYOLOGY

Dr. B. R. AMBEDKAR OPEN UNIVERSITY
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COURSE TEAM

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PREFACE

This book deals with the seed plants included in the syllabus for the second year of the B.Sc. course offered by the Andhra Pradesh Open University. The topics generally cover the area of the subject to be studied in the Second Year of the Three Year Degree Course in Science. The syllabus, for the sake of conveniance, is divided into Blocks each of which comprises a number of units. Each Block generally covers a specific area of the subject. The units are prepared by the specialisits in accordance with a format so designed as to enable the student to read and understand them without much diffculty. Each unit begins with a statement of its objectives followed by synopsis. Each unit has at its end assignments intended to test the Students comprehension of the subject matter. Techinical terms with which the student may not be generally familier are also given at the end of each Block under the head "Glossary".

Only important genera have been included so as to give the student a broad idea of each major group. As for as possible, recent classificalory system has been presented for each group. For the sake of comparison, some of the important older classification have also been mentioned.

Andhra Pradesh Open University hopes that this material will help the students to get aquainted with the principal issues of Botany in general and Gymnosperms. Plant Anatomy, Taxonomy and Embryology in particular. Critical suggestions for improving the text are most welcome and they will be incorparated in the future edition.

CONTENTS

BLOCK - I

GYMNOSPERMS

UNIT-1 : GENERAL CHARACTERS AND CLASSIFICATION OF GYMNOSPERMS

Contents

1.1. OBJECTIVES

By the end of the unit you will be able to:

1. list out the vegetative and reproductive characters of Gymnosperms,
2. differentiate the classificatory systems of Chamberlain, Arnold, Pant and Sporne.

1.2. INTRODUCTION

The term "Gymnosperms" was used by Greek botanist **Theophrastus** in 300 B.C. for the plants which have unprotected seeds (Greek, **Gymnos**=naked; **sperma**=seed). The gymnosperms are very ancient group of seed plants dating back most probably to the Upper Devonian, about 350 million years ago and are defintely known from the lower carboniferous age, about 300 million years ago. They have attained their peak of development during the jurassic-lower cretaceous periods of the Mesozoic Era. The angiosperms appeared probably during lower cretaceous about 110 million years ago, and rapidly attained the dominance by the Upper Cretaceous pushing the gymnosperms into the second position. Inspite of their overall numerical decline the gymnosperms even now spread over extensive forests in the north temperate to Sub- Arctic regions. They are of great economic importance as they provide valuable timber, wood pulp resins and other useful materials.

1.3. GENERAL CHARACTERS

The modern gymnosperms constitute about 70 known genera encompassing about 72 species. There are a number of fossil gymnosperms recorded from various geological horizons from all over the world (e.g., Pteridospermales, Bennettitales, Pentoxylales, Cordaitales Caytoniales etc.)

1.3.1. Vegetative Characters

The gymnosperms are essentially xerophytic, evergreen, woody, arborescent or shrubby perennials. The conifers often attaining a pyramidal shape are mostly gigantic forest trees living for about a few hundred years. The red-wood tree of California (U.S.A.), *Sequoia semiperviren* attains a height of 140 meters. In *Sequoiadendron giganteum*, the tree grows to a diameter of 10 meters and height of 120 meters. In Mexican cypress, *Taxodium mexicanum*, the trunk is known to reach a diameter of 17 meters. The cycads, on the other hand, are palm-like i

habit and much smaller in structure compared to that of conifers (Fig.1.1). The trunk is usually columnar and unbranched and terminates in a crown of large palmately compound leaves. The Gnetales resemble a typical dicotylendon in their habit and are either small trees or shrubs or sometimes woody climbers.

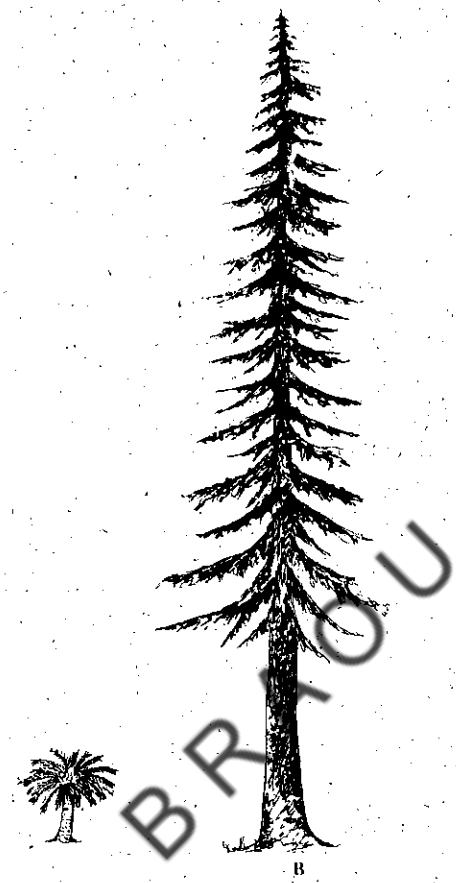

Fig. 1.1. Diagram showing the habit and the comparative size in cycadopsida and coniferopsida. *A. Cycas B. Pinus.*

The embryo is straight, endoscopic and embedded in the endosperm. The number of cotyledons may be two (*Cycas*) or many (*Pinus*). The radicle gives rise to well developed tap-root system. The root system is generally associated with mycorrhizal fungus (*Pinus*) or endophytic algae (*Cycas*). The roots are mostly diarch, triarch or tetrarch.

The stems are woody, erect and profusely branched (unbranched in cycadales). The branches are dimorphic consisting of the long shoots of indeterminate and dwarf shoots of determinate growth.

The gymnosperms are mostly evergreen plants; however a few conifers like *Larix, Taxodium* are deciduous. The foliage is of two types *viz.*, brown scale-like leaves and green simple or compound leaves. The simple leaves may be linear, lanceolate, spathulate or needle-like while the compound leaves are large frond-like, megaphylls (cycads, cycadeoids) (Fig.1.2). Phyllotaxy may be spiral (*Podocarpus, Tazus, Taxodium*) or opposite decussate (*Ephedra, Gnetum*) or whorled (Cupressaceae). The venation may be reticulate *(Gnetum)*, Parallel *(Welwitschia)* or dichotomous (*Ginkgo*). The stomata are of two types *viz.* haplochelic (cycadales and conifers) and syndetochelic (cycaedeoids and some species of *Gnetum)*. The leaves are hypostomatic. In *Cycas* the young leaves show **circinate vernation**, a typical pteridophytic character. The mesophyll of the leaves is with or without palisade tissue. The foliar bundles are diploxylic

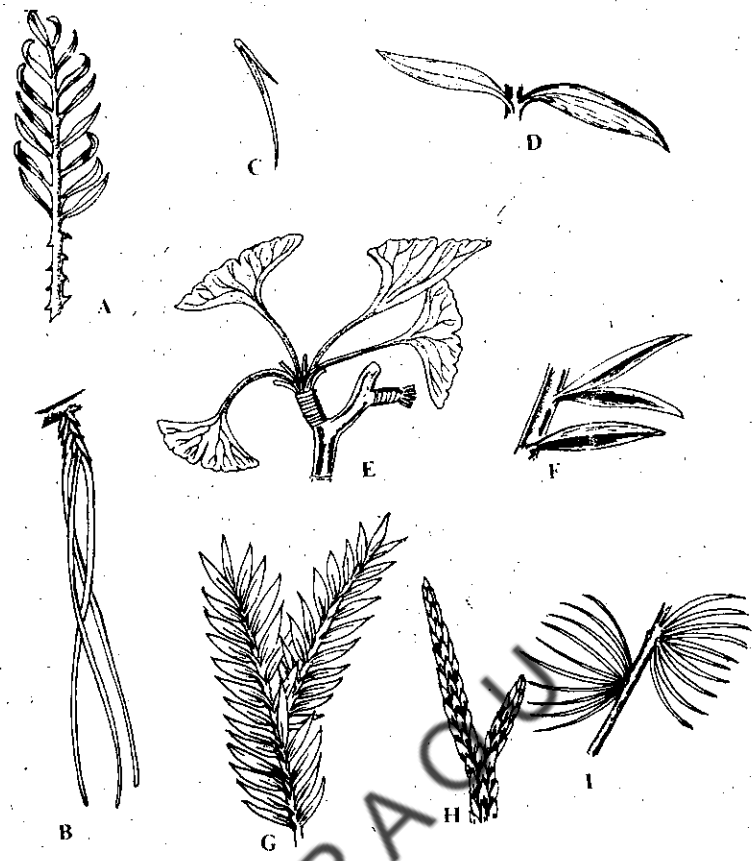

Fig. 1.2. Foliage in Gymnosperms. A. Frond of *Cycas revoluta*. B. Dwarf shoot of *Pinus roxburgii* with three needles. C. A single leaf of *Picea*. D. Leaves of *Araucaria bidwillii*. E.A dwarf shoot of *Ginkgo* with foliage. F. Leaves of *Taxus baccata*. G. Leaves of *Sequoia sempervirens*. H. Leaves of *Cupressus sempervirens*. 1. Needle leaves in *Cedrus deodera*.

(with centripetal and centrifugal xylem) in cycads and the normal collateral type in others. Transfusion tissue is present in the leaves of many genera. The needles of many conifers (*Pinus, Cedrus, Abies*) possess resin canals. The stems are eustelic as in dicotyledons. The vascular bundles are arranged in a ring enclosing a pith in the centre. Each bundle is collateral, conjoint, endarch and open. The rays present in between the two vascular bundles are called medullary rays. They are usually broad and parenchymatous.

Secondary growth is a common feature of the gymnosperms resulting in profuse secondary xylem and some amount of secondary phloem. The senondary wood shows distinct growth rings. The secondary wood in the gymnosperms is of two types i.e., (1) Manoxylic and (2) Pycnoxylic. The former is present in the members of Cycadopsida while the latter is present in Coniferopsida members. The manoxylic wood is loose and with large and relatively thin walled tracheids. The lumina of the manoxylic tracheids are large. In addition to the trachieds the manoxylic wood also consists of abundant xylem parenchyma and many xylem rays. Hence it is of no commercial importance. The pycnoxylic wood is hard and compact with narrow rays. The trachieds are small in size and thick walled with small lumina and the wood shows little or no xylem parenchyma. Pycnoxylic wood constitutes a good commercial timber. The xylem in gymnosperms is made up of tracheids and some xylem parenchyma. With the exception of Gnetales, the vessels are, as a rule, absent in gymnosperms. Bordered pits with well defined 'tori' are the conspicuous feature of the secondary wood. These pits are mostly confined to the

radial walls of the trachieds. The radial pitting is of two broad types *viz.*, (1) Araucarian and (2) Abietinian. The Araucarian type of radial pitting consists of usually two to many seriate, angular, contiguous, rounded and alternate pits. The Abietinian radial pitting is composed of usually uni- or bi-seriate, circular and separate pits. When biseriate the pits are opposite. The secondary wood shows resin canals in a number of conifers (***Pinus, Picea, Pseudotsuga*** etc.). Each resin canal has a resinous cavity surrounded by a layer of epithelial cells and may be of the vertical horizontal type. The vertical resin canals are found in a diffuse condition among the tracheids while the horizontal canals are confined to the fusiform xylem rays. The secondary phloem consists of sieve cells, phloem perenchyma and phloem fibres. Companion cells are, as a rule, absent (except in Gnetales).

Check Your Progress - 1

What are the differences between mannoxylic wood & pycnoxylic wood?

Note: (a) Write the answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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1.3.2. Reproductive Characters

The gymnosperms are unisexual and may be dioecious or monoecious. The microspores called as pollen grains are produced in microsporangia borne on microsporophylls. The microsporophylls are generally aggregated to form male cones. The megaspores are produced in the ovules, borne on megasporophylls which are generally aggregated to form female cones (Fig. 1.3). In *Cycas, Ginkgo* and *Taxus* female cones are absent. Similarly in some of the fossil orders of gymnosperms like Pteridospermales, there are no distinct cones, either male or female. Depending upon whether the ovules are leafborne or stem borne, the gymnosperms are either Phyllospermic or Stachyospermic. For example, the cycadophyta are phyllospermic and the Coniferophyta are stachyospermic. The microsporophylls (stamens) may be broad, foliar (*Cycas*) or peltate (*Taxus*). The microsporangia are in groups of two to many in the adaxial surface of the microsporophylls. Each microsporangium develops in a eusporangiate manner and contains numerous, small microspores (pollen grains). The pollen grains of the gymnosperms are typically monosulcate (i.e., having single furrow-like aperture on the distal surface) and with or without wings (sacci). When present the wings may be one (monosaccate), two (bisaccate) or three (trisaccate). Winged pollen grains are encountered in conifers (Pinaceae, Podocarpaceae), and some fossil orders of gymnosperms. In Cycadales, Ginkgoales and some fossil orders, the pollen grains are non-saccate, elliptical to ovate and monosulcate. Pollination in gymnosperms is of the anemophilous type. The pollen grains are often produced in enormous quantity (Pinaceae). During pollination, the ovule secretes a mucilaginous fluid that fills up the micropyle of the ovule and exudes to its outside as a **pollination drop**. Pollen grains are caught in this pollination drop and as it dries up the pollen grains are gradually sucked into the pollen chamber. As a rule germination of the pollen grain is shed from the microsporangium. The pollen grain, thus represents a partially developed male gametophyte.

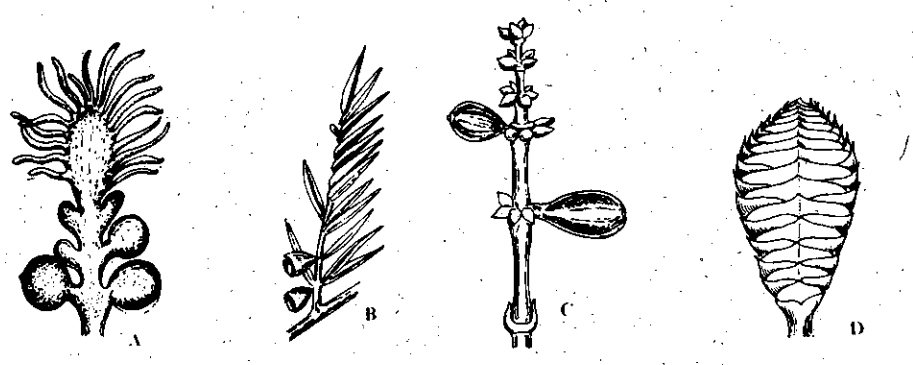

Fig. 1.3. Female cones of some Gymnosperms. A. Megasporophyll of *Cycas revoluta*. B. Female strobilus in *Taxus baccata*. C. Female cone of *Gnetum ula*. D. Female strobilus of *Welwistchia*.

On germination each pollen grain forms one (*Cycadales*), two (*Ginkgo, Pinus*) or many **prothallial cells** and a large **antheridial cell**. In Taxaceae, Cupressaceae, Taxodiaceae etc. there are no prothallial cells in the male gametophyte. The antheridial cell further divides into a small **generative cell** and a large **tube cell**. The generative cell later on divides into a **sterile cell** (stalk cell) and a large **spermatogenous cell** (body cell). The spermatogenous cell subsequently divides into two non-motile **male cells**. In Cycadales and Ginkgoales, the sperms (male cells) are multiflagellate and motile. The development of the male gametophyte is completed within the pollen chamber. The pollen tube develops from the apertural region of the pollen grain wall. In Cycadales, the pollen tube is extensively formed and is haustorial in nature. In most of the gymnosperms, however, the pollen tube is simply a carrier of the non-motile sperms.

The ovules (megasporangia) in gymnosperms are naked and not enclosed in a carpel as in the angiosperms. The ovule is usually orthotropous, and unitegmic. The single integument is massive and divisible into three discrete layers, the outer and inner fleshy layers (sarcotesta) and the middle stony layer (sclerotesta). The integument is either free from or fused with the nucellus. Further, the integument is either vasculated or non-vasculated and form a distinct micropyle towards the distal end of the ovule. Towards the microplar region, some of the cells of the nucellus break down to form a cupule (cup-like) depression termed as **pollen chamber**. After pollination, the pollen grains are generally lodged here. The megaspore mother cell (formed towards the micropylar end of the nucellus) divides meiotically to produce a linear tetrad of megaspores, the basal one represent the functional megaspore, while the other spores abort. The functional megaspore enlarges and by repeated divisions develops into the female gametophyte. In the formation of the female gametophyte the megaspore nucleus first exhibits a number of free nuclear divisions resulting in a number of free nuclei. Cell plate formation takes place subsequently in a centripetal fashion and ultimately the entire female gametophyte becomes cellular. It is now designated as the **endosperm**.

The **archegonia** develop from the hypodermal archesporial cells towards the micropylar end of the endosperm. The archegonia in gymnosperms are of reduced type, possessing a short neck with a venter canal cell and an egg. No archegonia are formed in *Gnetum* and *Welwitschia*.

Fertilisation in gymnosperms may be termed as **siphonogamic** as the gametes are carried by pollen tubes.

The first phase in the embryogeny is the occurence of **free nuclear division** in the zygote. This is the most characteristic feature of the gymnosperm embryology. The number of free nuclei formed before walls are laid down between the nuclei shows a lot of variation. In Cycadales 256 to 1000 free nuclei are formed; in Taxales upto 30 or more free nuclei are formed. The free nuclei formed in the early embryogeny of Coniferales are few in number.

Free nuclear divisions are absent in the early embryogeny of Gnetales. After free nuclear divisions, cell walls are laid down and the **proembryo** is differentiated. More or less distinct **suspensor** is formed in the gymnosperms towards the micropylar end of the developing embryo. This helps in pushing the developing embryo deep into the endosperm (female gametophyte) so that it could obtain better nourishment.

Polyembryony is a common feature in gymnosperms, and this may be of the cleavage type or simple type. If more than one embryo is formed from a single fertilized archegonium from a number of embryonal cells it is described as **cleavage polyembryony. Simple polyembryony** involves development of many embryos from more than one zygote. In most of the cases, however, ultimately only one embryo is developed fully in each seed owing to problems created by lack of available space and enough nutrition. The fully developed embryo is either dicotyledonous (Cycadales) or polycotyledonous (Conifers) and possesses a **hypocotyl, plumule** and **radicle.**

The **seed** is the resultant product of fertilisation and consequent elaboration and modification of the ovule. The integument of the ovule is modified into the **seed coat** in which the outer fleshy layer and the middle stony layer are retained but the inner fleshy layer turns membranous and highly reduced.

The seed germinates after a brief period of rest or dormancy. The germination of the seed in gymnosperms is usually of the **epigeal** type.

Check Your Progress - 2

Define the different types of polyembryony that we come across in gymnosperms.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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1.4. CLASSIFICATION

A number of systems of the classification of gymnosperms have been proposed to date by various authors. The following is a brief discussion of the more significant systems of classification.

As early as 1917, **Coulter** and **Chamberlain**, divided the gymnosperms directly into seven orders *viz.*, Cycadofilicales, Bennettitales, Cycadales, Cordaitales, Ginkgoales, Coniferales and Gnetales. Subsequently **Chamberlain** (1934), based upon the over-all general habit of the plants, leaf form, wood anatomy and seed structure, divided the gymnosperms into two broad classes *viz.*, 1. Cycadophyta, comprising the orders Cycadofilicales, Cycadeoidales and Cycadales; 2. Coniferophyta, which includes Cordaitales, Ginkgoales, Coniferales and Gnetales.

In the system of classification proposed by **Arnold** (1948) the gymnospermous plants,

treated under the Division - **Pteropsida**, were classified into three classes *viz.*, Cycadophyta, Coniferophyta and Chlamydospermophyta. Under Cycadophyta were included the orders Pteridospermales, Cycadeoidales, and Cycadales. The Coniferophyta, comprises Cordaitales, Ginkgoales, Taxales and Coniferales. The Chlamydospermophyta includes Ephedrales and Gnetales. It should, however, be mentioned here that in accordance with the International Code of Botanical Nomenclature, the ending of a formal Division should be **phyta** and that of the class, **opsida**. It is significant to note that Arnold (1948) has dispensed with the word "Gymnospermae" in his system of classification.

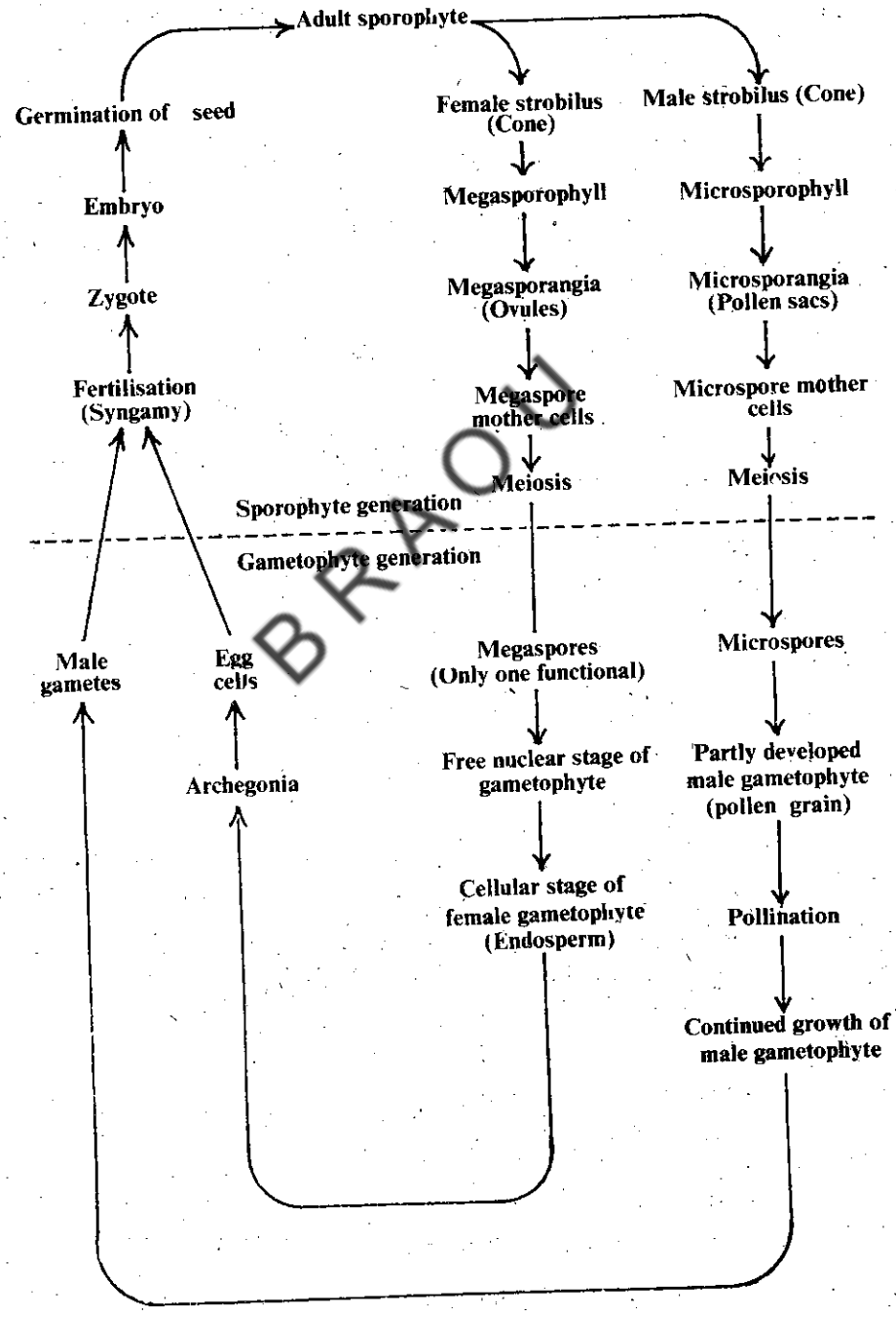

Fig. 1.4 Graphic life cycle of a gymnosperm

This is because of his firm belief that the gymnospermous plants do not constitute a unified group with a single focus of origin, but are **Polyphyletic** in nature. This idea has been accepted by most of the subsequent workers.

Pant (1957) divided the gymnosperms into three Divisions viz., Cycadophyta, Coniferophyta and Chlamydospermophyta. The Cycadophyta consists of four classes. Pteridospermopsida, Cycadeoidopsida, Pentoxylopsida and Cycadopsida. The Coniferophyta similarly includes four classes, Coniferopsida, Ephedropsida, Czekanowskiopsida and Taxopsida. The Chlamydospermophyta, however, includes only a single class, Gnetopsida. Under each class are included various orders and families. Pant (1957) has given considerable importance to the fossil members of gymnosperms in his system of classification.

Some of the recent workers like **Lyman Benson** (1957), and **Andrews** (1961) classify the gymnosperms into more than three divisions which incidentally point towards extreme **polyphylesis** of this group of plants. For the present purpose, the author adopts the system of classification proposed recently by Sporne (1965).

Sporne (1965) has recognised three classes among the gymnosperms *viz.*, Cycadopsida Coniferopsida and Gnetopsida. The Cycadopsida is characterized by manoxylic wood, large frond- like foliage, and mostly radially symmetrical seeds. The Coniferopsida on the other hand, is distinguishable by pycnoxylic wood, simple needle- like, paddle-shaped or fan-shaped leaves and usually bilaterally symmetrical seeds. The Gnetopsida shows secondary wood with vessels and flowers with perianth. The flowers are organized into inflorescences or compound strobili. The following is the abridged version of the scheme of Sporne's classification.

Class-I	**Cycadopsida**	(includes 4 orders and 14 families)
	Order-1 :	**Pteridospermales** **FAmily: Lyginopterodaceae** e.g *Lyginopteris*
	Order-2 :	**Bennettitales** **Familly : Williamsoniaceae** e.g: *Willamsonia*
	Order-3 :	**Pentoxylales**
	Order-4 :	**Cycadales**
Class-II	**Coniferopsida**	(includes 4 orders, 15 families)
	Order-1 :	**Cordaitales**
	Order-2 :	**Coniferales** **Family : Pinaceae** e.g. *Pinus*
	Order-3 :	**Taxales**
	Order-4 :	**Ginkgoales**
Class-III	**Gnetopsida**	(includes single order and 3 families)
	Order-1 :	**Gnetales** **Family : Gnetaceae** e.g. *Gnetum*

1.5. SUMMARY

The gymnosperms, characterized by the possession of naked seeds are mostly arborescent and evergreen plants with profuse secondary growth. Tracheids are the chief conducting elements of the xylem. The reproductive structures are as a rule, unisexual and the micro- and mega-sporophylls are borne in more or less distinct cones. The pollen grains are saccate or nonsaccate and generally monosulcate. The male gametophyte is considerably reduced and the male gametes are either motile or nonmotile. The fertilization in gymnosperms is of the siphonogamic type. The ovule is monotegnic and the endosperm is formed before fertilization.

1.6. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The Manoxylic wood is a loose wood with large and relatively thin walled tracheids where as the pycnoxylic wood is a hard wood with small and thick walled trachieds. The cell lumina is large in manoxylic wood and it is small in pycnoxylic wood. The manoxylic wood consists of abundant xylem parenchyma and many xylem rays where as the pycnoxylic wood consists of little or no xylem parenchyma and narrow rays.

2. There are two types of polyembryony in gymnosperms. 1. Simple polyembryony. and 2. Cleavage polyembryony. The development of many embryos from more than one zygote is called simple polyembryony and the development of more than one embryo from a single fertilized archegonium is called cleavage polyembryony.

1.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about in 30 lines each.

1. Discuss in brief the general characters of gymnosperms.
2. Write a brief account on the classification of gymnosperms.

II. Answer the following questions in about 10 lines each.

1. Write briefly the Sporne's system of classification.
2. What are the angiospermic features of gymnosperms.

UNIT-2 : *PINUS*

Contents

2.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the external features of the stem, branches, leaf & root of *Pinus*,
2. draw the internal structure and label the parts of the stem, leaf and root of *Pinus*,
3. distinguish the structure of the male cone from a female cone of *Pinus*,
4. describe the pollination mechanism and fertilisation process in *Pinus*,
5. describe the development of embryo and endosperm and also the dispersal mechanism and germination process of the seed of *Pinus*.

2.2. INTRODUCTION

There are about 18 genera and 200 species in the family Pinaceae. It is essentially a Northern family. The family is characterized by (1) having spiral arrangement of the parts (2) ovuliferous scales free from bract scales (3) two ovules per scale (4) two pollen sacs in each microsporophyll (5) biwinged pollen and cleavage polyembryony (6) Seeds are dry and winged. The important taxa of the family are *Pinus* (90 spp), *Abies*(40 spp), *Picea*(40 spp), *Keteleria* (4 spp), *Tsuga* (14 spp), *Pseudotsuga* (7 spp), *Larix* (10 spp), *Cedrus* (4 spp), *Pseudolarix* (1 sp).

2.3. DISTRIBUTION AND HABIT

There are about 90 species in the genus. These are widely spread out in temperate and cool temperate regions of the Northern hemisphere.

The pines are evergreen arborescent, perennials. Usually they are majestic trees, few are shrubs (*Pinus pumillo*). *Pinus aristata* is supposed to be the oldest (4,600 years) living tree on the earth.

In the Indian sub-continent the genus is represented by about six naturally occuring species. They are:

1. ***Pinus excelsa syn. P. wallichiana*** **(silver fir; blue pine or kail)**

This occurs at an altitude of 1200 to 3,500 meters above mean sea level and is in distribution in Kashmir, Pakistan, Himachal Pradesh, Punjab, Sikkim, Nepal, Bhutan, Garhwal and Simla hills, Kulu valley and NEFA. It is a beautiful tree reaching 8 to 10 feet in diameter and attaining a height of 100 to 150 feet.

2. ***Pinus longifolia syn. P. roxburghii*** **(chir)**

This is spread over in the hills forming pure and mixed forests on the slopes at an elevation of 450 to 2,250 meters in the Himachal Pradesh, Punjab, Nepal and Uttar Pradesh. It is a tall tree, reaching a height of more than 160 feet with a diameter of 8 - 10 feet.

3. ***Pinus gerardiana*** **(chilgoza pine)**

This is spread over at an altitude of 2100 to 3300 meters on the dry and arid regions of North West Himalayas, Kashmir, Pakistan and Afghanistan.

4. ***Pinus armandi*** **(Armand Pine)**

This grows at 1200 to 3,600 meters above sea level. Common in Arunachal Pradesh, Assam, NEFA and China.

5. ***Pinus khasyas syn. P. insularis*** **(Khasi-pine)**

This occurs in Khasya and Jayantia hills of Arunachal Pradesh, in Chittagon of Assam and Burma, at an altitude of 700 to 3,000 meters. The plant attains a height of 30 meters and its distribution is confined to Eastern Himalayas only.

6. ***Pinus merkusii*** **(Merkus pine)**

This is Common at an altitude of 150 meters and is confined to Assam, Arunachal Pradesh, Meghalaya and Bengal; reaches about 3 meters in height.

2.4. EXTERNAL FEATURES

The external features of stem, root, branches and leaves are given below.

2.4.1. Stem

The species of *Pinus* are mostly large trees, reaching a height of 70 to 200 feet and about 10 to 12 feet in diameter. The main stem (shaft) is erect woody and covered with rugged scaly bark. The apical bud of the stem is very active and grows continuously and rapidly throughout its life time. The over-all shape of the plant is cone-like or pyramidal. The branching is monopodial, regular and, as a rule, symmetrical. The branches arise laterally from the axils of scale-leaves every year. The branches at the lower region of the stem are larger and those higher up gradually become shorter. The symmetry, however, is lost by age in the plant due to the death of some older branches (Fig 1.1 B).

2.4.2. Root

It is typical tap-root type and short-lived because the trees often grow in shallow soil overlying rocks. Henceforth, it is compensated by the strongly developed roots, which spread larger areas but fails to grow vertically deep into the soil. The roots are associated with an ectophloic mycorrhizal fungus.

2.4.3. Branches

The branches are dimorphic and represented by i) Branches of indeterminate growth or long shoots, which exhibit indefinite growth and ii) Branches of determinate growth or **dwarf shoots** or **spur shoots** (Fig. 2.1). These arise on the long shoots from the axils of brown scale-leaves and exhibit very much limited growth because of the early cessation of the activity of their apical buds. The dwarf shoots are themselves clothed by brown scales.

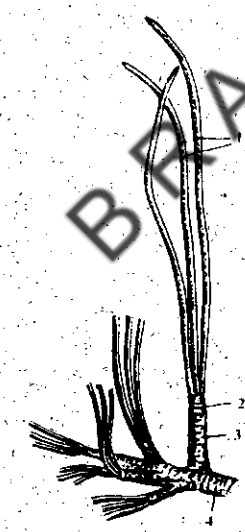

Fig. 2.1. *Pinus* dwarf shoots with needles. 1. Needle leaves. 2. Brown scale leaves. 3. Dwarf shoots. 4. Long shoot.

2.4.4. Leaves

The leaves are also dimorphic and represented by 1.**Brown scale-like leaves** (cataphylls) and 2. **green foliage leaves.** The cataphylls are borne on long and dwarf shoots. These fall off when the branches mature. The Green foliage leaves are called needles, because of their characteristic shape. The needles occur only on the dwarf shoots. They persist for a number of years and fall only when the spur is shed as a whole. A dwarf shoot with its cluster of green needles is also designated as **spur shoot.** The number of needles per dwarf shoot is definite. Depending upon species, this number varies from one to five. In *P.longifolia*, *P. insularis* and *P.gerardiana* there are three needless for dwarf shoot (Trifoliar spur) In *P.sylvestris* and *P. pinaster* there are two needles per dwarf shoot (bifoliar spur). In *P.monophylla*, each dwarf shoot is with a single needle (unifoliar spur). In *P.quadrifolia* each dwarf shoot is with four

needles. Each dwarf shoot bears five needles as in *P.excelsa* and *P. armandi*.

Check Your Progress - 1 & 2

1. How many types of branches are there in *Pinus*? What are they?
2. What are the different types of leaves that are present in *Pinus*.

Note: (a) Write your answer in the space given below.
(b) Compare your answer with the one given at the end of this unit.

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2.5. INTERNAL STRUCTURE

2.5.1. Stem

Primary Structure of the Stem: The stem in *Pinus* is eustelic and shows the same general arrangement of tissues as in the dicots (Fig. 2.2). The **epidermis** is single layered and irregular in outline. The outer walls of the epidermis are highly cutinized and stomata are scattered.

The **cortex** is multilayered. It is differentiated into an outer sclerenchymatous hypodermis and inner parenchymatous zone. The most characteristic feature is the ocurrence of resin canals. Each resin canal is lined by a layer of glandular epithelial cells. The resin exudes from the injured parts of the plant body and on oxidation solidifies, thus sealing the wounded region.

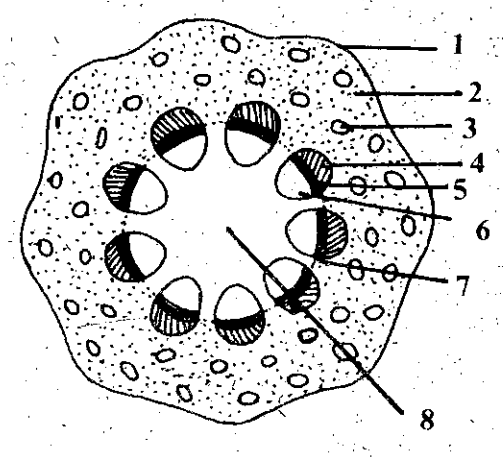


Fig. 2.2. T.S. of young stem of *Pinus* (diagrammatic) 1. Epidermis. 2. Cortex. 3. Resin canal. 4. Phloem. 5. Cambium. 6. *Xylem* 7. Medullary ray. 8. Pith.

The **endodermis** is single layered and inconspicuous with casparian thickenings on their radial walls.

The **Pericycle** is few layered, inconspicuous and parenchymatous.

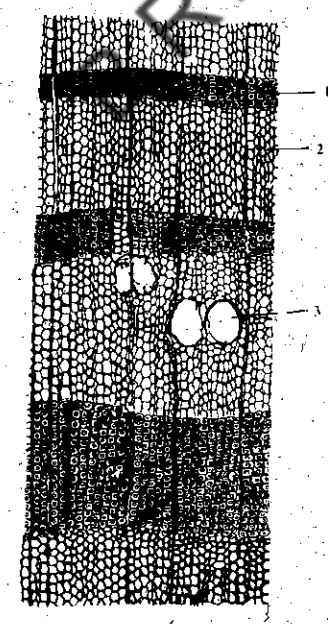
The **Stele** consists of a ring of 6-8 vascular bundles, surrounding a central pith. Each vascular bundle is a conjoint, collateral, open and endarch (protoxylem elements towards pith and the metaxylem towards the pericycle). The protoxylem consists of annular to spiral tracheids. The metaxylem tracheids are with bordered pits on their radial walls. Vessels are absent. Xylem parenchyma is present. The phloem consists of sieve cells, phloem parenchyma and albuminous cells. Companion cells are absent. Alternating with the vascular bundles are seen the medullary rays joining the pith to the cortex.

The **Pith** is scanty and parenchymatous. Primary medullary rays which run in between the two vascular bundles are very narrow.

Secondary Structure of the Stem: *Pinus* exhibits profuse secondary growth. The secondary thickening takes place as in a typical dicotyledon. The secondary wood is produced abundantly. It is pycnoxylic and shows distinct rings. The autumn wood is composed of narrow thick walled tracheids with small lumina and the spring wood consists of relatively broader thin walled tracheids with large lumina (Fig. 2.3). The secondary wood consists of tracheids, xylem rays and resin canals. Xylem parenchyma is absent.

The tracheids show conspicuous bordered pits on their radial walls. The pits are uni-to bi-seriate, when uniseriate they are circular and separate and when biseriate they are oppositely placed. This type of radial pittings of conifers is called **Abietinean type of pitting**. A number of species of *Pinus* shows bar-like thickening in between the bordered pits and these thickenings constitute **crassulae**.

They represent the thickening on the inner layer of the secondary wall of the tracheids. The xylem rays are of two types viz., short, uniseriate rays and moderately large, fusiform multiseriate rays. Some of the fusiform rays show the presence of horizontal resin canals. In *Pinus* (as in



2.3. part of secondary wood of *pinus* showing autumn wood and spring wood. 1. Autumn wood. 2. spring wood. 3. Resin canal.

the case of many members of Pinaccae) the xylem rays possess, in addition to parenchyma cells, some tracheid-like cells called **ray tracheids**. These are usually confined to the margins of the rays (Fig.2.4).

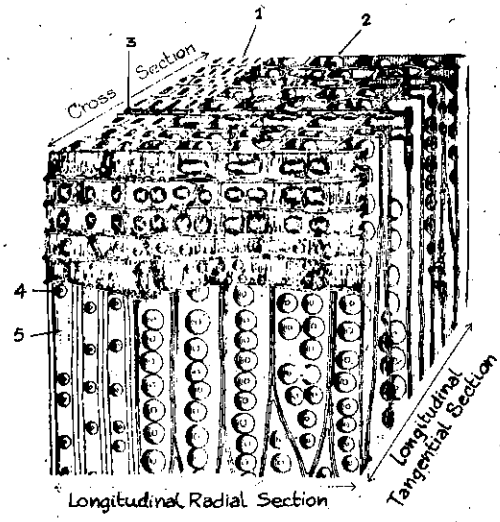


Fig. 2.4. Three dimensional view of the wood of *pinus*. showing transverse, longitudinal tangential and longitudinal radial sections. 1. Autumn wood. 2. Spring wood. 3. Pith ray. 4. Bordered pit. 5. Tracheid.

The resin canals represent important diagnostic feature of the *Pinus* wood. The canals are of two types viz., vertical and horizontal. The vertical resin canals are seen scattered among the tracheids and the horizontal canals are found in the fusiform xylem rays.

The secondary phloem consists of sieve cells, phloem parenchyma, fibres and phloem rays.

Secondary growth also involves the production of **cork** and **bark**. Phellogen formed in the outer layer of cortex gives rise to **secondary cortex** or **phelloderm**, **cork** or **phellum** and **bark**.

2.5.2. Root

The internal structure of the root resembles that of the dicot root. The young root is differentiated into piliferous layer, cortex and the stele (Fig. 2.5).

The **Piliferous layer** arises from periblem. It is single layered and develop root-hairs which are often less or absent. Ectophloic mycorrhiza is found surrounding this layer in the place of root-hairs.

The **Cortex** is a wide zone of parenchymatous cells and is present beneath the piliferous layer.

The **Endodermis** is single layered with suberised broad cells. The radial walls are with casparian thickenings.

The **Pericycle** is multilayered and parenchymatous.

The **Vascular bundles** of the roots are mostly diarch to tetrach with 2 to 4 exarch xylem strands alternating with 2 to 4 phloem strands. Often there is a resin duct facing each protoxylem point.

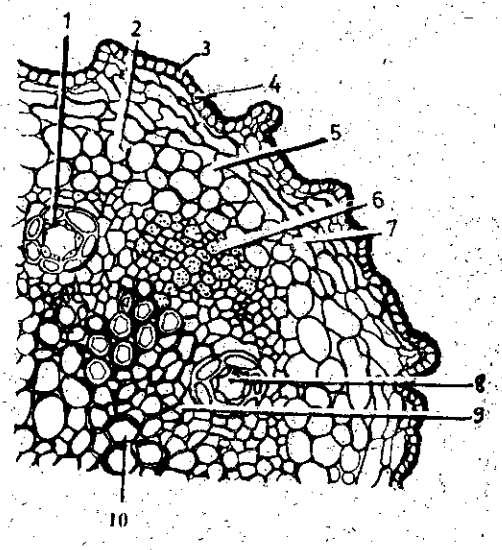


Fig. 2.5. T.S. of *Pinus* root. 1. Epithelial layer. 2. Endodermis. 3. Cuticle. 4. Epidermis. 5. Cortex. 6. Phloem. 7. Pericycle. 8. Resin canal. 9. Protoxylem. 10. Metaxylem.

Secondary thickening in *Pinus* root is similar to that of the root of a typical dicotyledon. This results in the production of an abundant secondary xylem and some amount of secondary phloem. No growth rings are seen in the secondary xylem of roots.

2.5.3. Leaf

In cross section, outline of the needle shows variations in different species. In *Pinus monophylla* the needle is circular in cross section, in *P. sylvestris* it is semi-circular and in *P. longifolia* and *P. strobus* etc., it is almost triangular in outline. However the internal structure is uniform in all the species (Fig. 2.6.)

The **epidermis** is single layered and thick-walled. The outer walls are heavily cutinized. The stomata are uniformly distributed all around the leaf and are deeply sunken. They are developed in longitudinal rows. The guard cells of the stomata are situated well below the level of the epidermis.

The **hypodermis** is composed of one to few layers of thick walled sclerenchymatous cells. It is absent beneath the stomata. It is strongly developed at the angles.

The **mesophyll** is undiffirentiated into spongy and palisade tissues and composed of essentially thin-walled chlorophyllous parenchymatous cells. The inner walls of the mesophyll cells drawn inwards to form peg-like or warty structures. The presence of peg-like ingrowths is a characteristic feature of the mesophyll cells of *Pinus*. These serve to increase the absorptive, aerating and excreting surface of the protoplasm in each cell and thus compensate for reduced leafy surface. The mesophyll tissue is the seat of photosynthetic activity as it contains numerous chloroplasts and abundant starch.

The **endodermis** consists of conspicuous, single layered and barrel shaped cells, with casparian thickenings.

The **pericycle** is multilayered and present beneath the endodermis. It consists of several types of cells. The majority of the cells constituting the pericycle are parenchymatous cells, containing starch. Embedded in them are two other types of cells, viz., 1. **albuminous cells** and 2. **tracheidal cells**. The albuminous cells are parenchymatous and rich in proteins. The tracheidal

cells resemble the tracheids and are radially elongated. They serve to carry fluids from the xylem to the mesophyll. These special kinds of cells collectively constitute the **transfusion tissue.** Besides these tissues, the pericycle possesses few sclerenchymatous fibres near and between the bundles. Each needle has two vascular bundles which are **conjoint, collateral** and **open.**

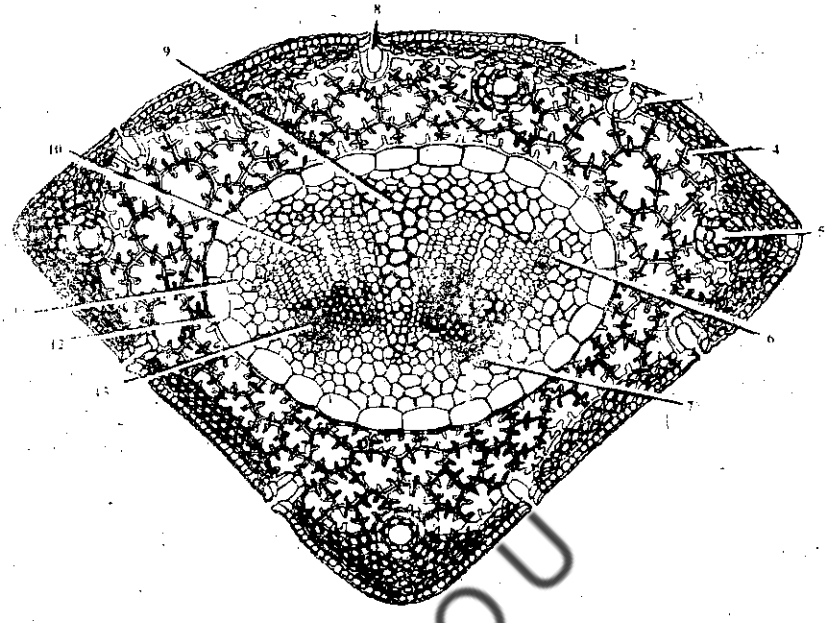


Fig. 2.6. *Pinus* needle in T.S. 1. Cuticle. 2. Epidermis. 3. Hypodermis. 4. Mesophyll. 5. Resin canal. 6. Albuminous cells. 7. Tracheidal cells. 8. Stoma. 9. Sclerenchymatous patch. 10. Phloem. 11. Pericycle. 12. Endodermis. 1 3. Xylem.

Pinus needles exhibit a number of **xerophytic characters** such as the presence of thick-walled, heavily cutinized epidermis, sunken stomata, prominent hypodermis and mesophyll cells with peg-like ingrowths. Added to these features, is the needle shape of the leaves which incidentally reduces the transpiring surface.

Check Your Progress - 3

What is transfusion tissue?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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2.6. REPRODUCTION

Pinus is monoecious i.e., both male and female cones are borne by the same plant but on different branches.

2.6.1. Male Cone (Staminate Strobilus)

The male cones occur in clusters, each in the axil of a scale leaf at the base of a terminal vegetative bud. They are concealed amidst the previous year's foliage. The male cones replace the dwarf shoots at the base of the developing bud or shoot of the current year. They are seen on the pine tree in the beginning or middle of March in the hills and in January or February in the plains. The shedeing of pollen grains starts at the end of April and continues till the beginning of June. After the pollen is shed, the male cones fall off from the trees. A male cone is ovoid and 3-4 cms, in length (Fig. 2.7). The male cone is shortly stalked and consists of an elongated central axis, on which are borne a number of microsporophylls (stamens) in a spiral manner (Fig. 2.8.). The microsporophyll is triangular in outline with a short stalk and a sterile terminal drawn out tip. Two microsporangia (pollen sacs) are present adaxially on each microsporophyll. These pollen sacs contain many, two-winged microspores or pollen grains.

The development of **microsporangium** is **eusporangiate.** A group of hypodermal cells divide periclinally to form an outer parietal layer and inner sporogenous layer. The outer layer divides further to form a three celled thick wall layer of the sporangium. The sporogenous layer gives rise to the archesporial tissue which form the microspore mother cells. Each microspore mother cell undergoes meiosis to produce four haploid microspores or pollen grains.

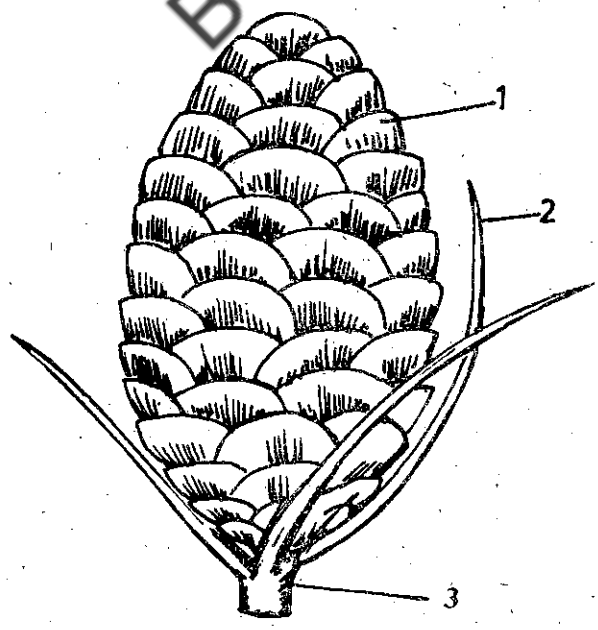

Fig. 2.7. Male cone of *Pinus*. 1. Microsporophyll. 2. Needle. 3. Stalk.

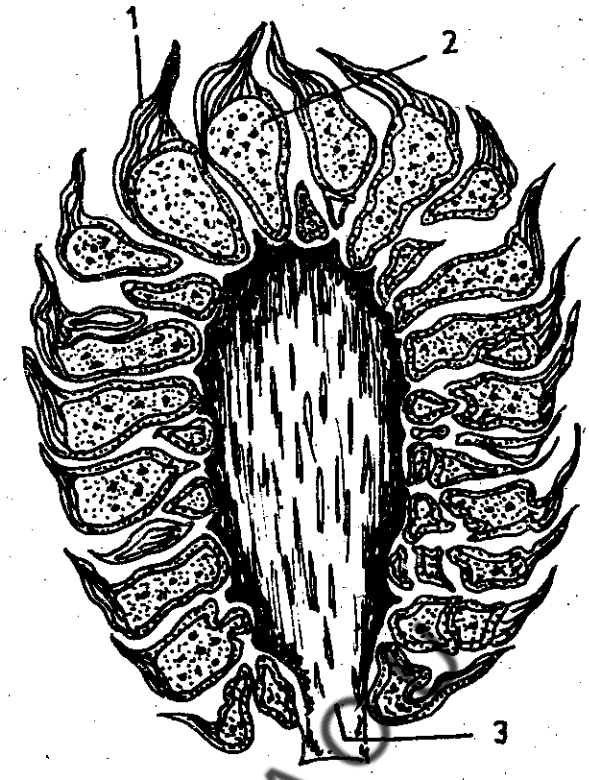

Fig. 2.8. L.S. of male cone of *Pinus* 1. Microsporophyll. 2. Microsporangium. 3. Cone axis.

The **Microspore** (Pollen grain) has outer exine, the middle exointine (sexine) and the innermost intine. The pollen grains are bisaccate (two winged) with the sacci placed more towards the distal facet. The wings of each pollen grain are formed by the separation of the outer part of the exine (ectexine) from its inner part (endexine). These wings are supposed to help in the pollen dispersal. The pollen grains are heteropolar, radiosymmetric with a longitudinal furrow (sulcus) on the distal side. These pollen grains partly germinate (to the 4-celled stage) before they are liberated.

2.6.2. Female Cone (Ovulate Strobilus)

The female cone replaces a long shoot. One to four female cones arise in the axils of the brown scale-leaves. The young female cone is a small, erect, reddish green structure, with an elongated central axis and a short stalk. The elongated central axis of the cone bears many spirally arranged megasporophylls. The female cone is a hard and woody structure at maturity (Fig. 2.9). Each megasporophyll is a compound structure having a **bract scale**, which is thin, membraneous and dry and a short woody triangular shaped **ovuliferous scale** which is borne on the upper surface of the bract scale in its axil (Fig.2.12). The terminal broad sterile portion of the ovuliferous scale is called **apophysis**. The apophysis is directed outwards concealing the bract scales from the view. The surface of the cone is marked by rhomboidal areas each with a small central conical point, the **umbo**. These rhomboidal areas are the outlines of the

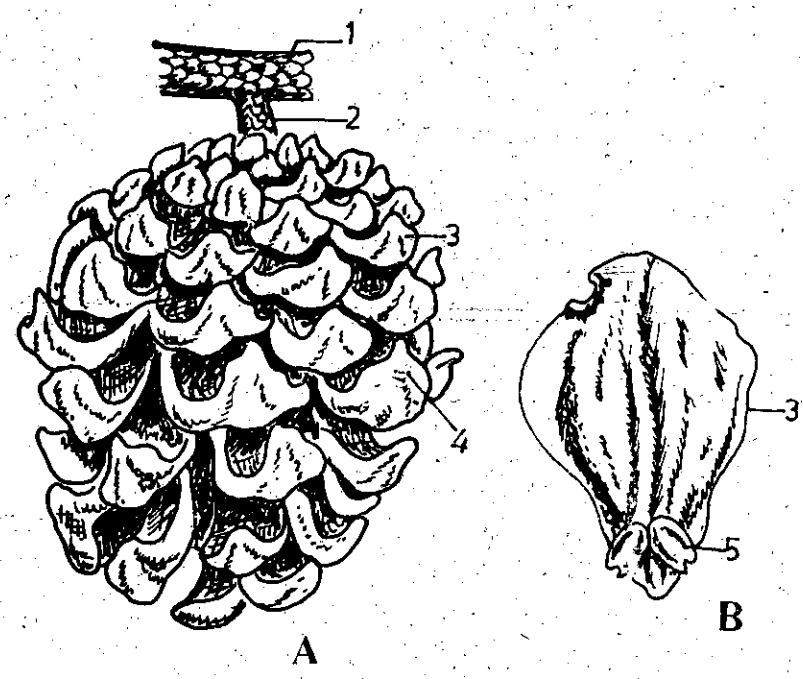

Fig. 2.9. Female cone and ovuliferous scale of *Pinus*. A. Three year old mature female cone of *Pinus*. B. Ouliferous scale with two ovules. 1. Long shoot. 2. Stalk. 3. Ovuliferous scale. 4. Apophysis. 5. Ovule.

broad sterile portions of the apophysis of the ovuliferous scales. There are about 80 to 90 megasporophylls in a single female cone (Fig. 2.10).

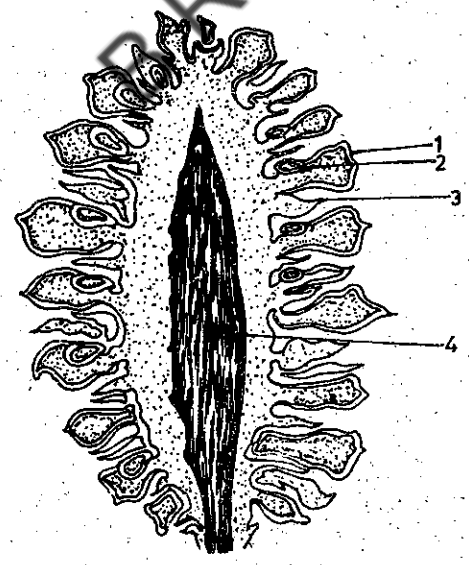

Fig. 2.10. *Pinus* female cone in L.S. 1. Overliferous scale. 2. Ovule. 3. Bract scale. 4. Cone axis.

The morphological nature of the female cone of *Pinus* (and other conifers) has been one of the most thoroughly debated problems. Broadly speaking there are two mutually divergent aspects that are generally considered in this connection, viz., i) is the female cone of conifers (*Pinus* for instance) a single flower (strobilus) or ii) is it an inflorescence (compound strobilus) made up of a main axis with secondary fertile short shoots (flowers) in the axils of bracts. In other

words, do the bracts subtending the ovuliferous scales represent carpels (i.e., megasporophylls) or do the ovuliferous scales with their ovules constitute flowers in the axils of bracts?

Sachs (1868) and **Eichler**, considered the bract scales as open carpels and the ovuliferous scale as an outgrowth (exerescence) of the bract scale, comparable to a ligule or placentum. According to them, the female cone of *Pinus* is equivalent to a single flower.

Delpino, who also interpreted the female cone as a single flower regards the ovuliferous scale to be a by product of the fusion of two inwardly turned lobes of the bract scale.

On the basis of his extensive and critical studies of the ovule-bearing reproductive structures of some fossil gymnosperms such as cordaitales and the Permian (Late paleozoic) and Triassic (Early Mesozoic) conifers, **Florin** (1951, 1954) has provided convincing evidence for regarding the female cone of *Pinus* (and other conifers) as equivalent to the inflorescence of angiosperms and hence a compound strobilus. According to Florin, the cone axis represents the inflorescence axis, each bract scale a true bract in the axil of which is a short, highly modified and reduced reproductive shoot- the ovuliferous scale. Florin's interpretation is now accepted more or less universally. In view of this, the earlier opinions on the morphology of the seed scale complex of conifers are of historical interest only.

The development of ovule starts only a year after the female cone is formed. Ovule arises as a small hump of cells developing on the upper surface of the ovuliferous scale. The ovule gradually increases in size to form **nucellus** or **Megasporangium**. From the base of the nucellus arises a covering known as **integument**. This integument does not cover the ovule completely, but leaves a small opening known as **micropyle** which allows the pollen grains to enter and come in contact with the megasporangium. The integument and the nucellus together constitute the ovule. The integument consists of three wall layers i.e., the **outer fleshy sarcotesta**, the **middle hard sclerotesta** and the **inner fleshy sarcotesta**. The nucellar tissue towards the micropylar end of the ovule, soon initiates the development of fertile archesporial cells which are prominent in size with distinct nucleus in each. The archesporial cell divides particularly into an outer parietal cell and an inner sporogenous cell or **megaspore mother cell**. The megaspore mother cell undergoes reduction division to produce four haploid cells which form a **linear tetrad**. Of these four megaspores, usually the upper three cells disorganise, while the basal megaspore will be functional.

2.6.3. Pollination

The pollen grains are produced in enormous numbers and the pollination is **anemophilous**. The pollen sacs dehisce releasing the pollen. Because of the enormous production of pollen grains after anthesis and their release into atmosphere they could be seen as yellowish clouds in the vicinity of pine forests. The pollen grains measure about 75x40 μm in diameter, with two baloon-like wings attached to their distal facets. The ovuliferous scales of the female cone (one year old by this time), open at this time to receive the wind blown pollen grains. Much of the pollen produced is wasted and only few pollen grains reach the micropyles of the ovules and are caught in the **pollination drops**. As the pollination drop dries up, the pollen grains entangled in the drop are gradually drawn inside the ovule, through the micropyle and finally settle in the pollen chamber. After pollination, the female cone gets inverted and before that the ovuliferous scales are closed tightly.

Check Your Progress - 4

What is the difference between ovaliferous scale and bract scale.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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2.6.4. Development of Male Gametophyte

As said earlier, the pollen grains germinate partly even before they are shed from the pollen sacs. To start with, the pollen grain divides to form a small lenticular **Prothallial cell** and a large

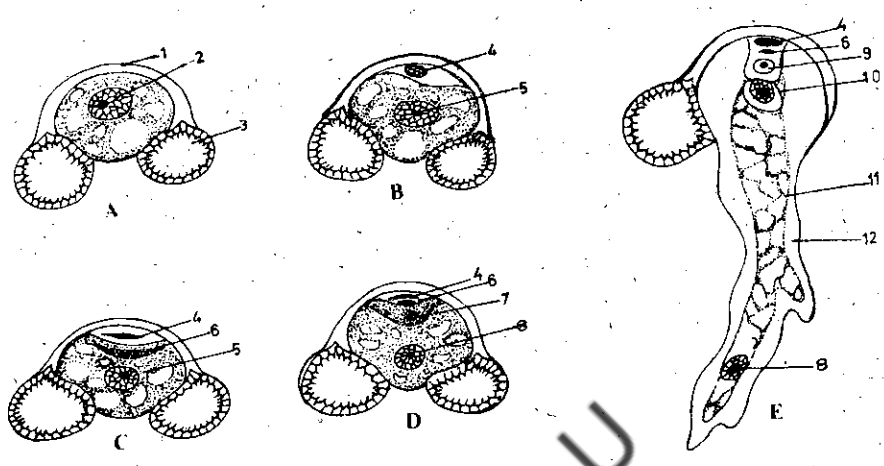
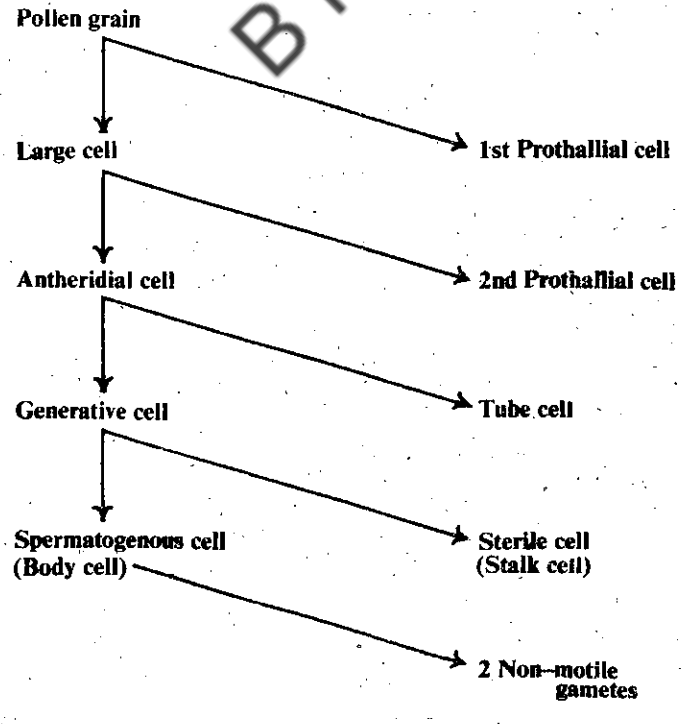


Fig. 2.11. Development of male gametophyte in *Pinus*. 1. Exine. 2. Nucleus 3. Wing. 4. Prothallial cell. 5. Antheridial cell. 6. Second prothallial cell. 7. Generative cell. 8. Tube nucleus. 9. Stalk cell. 10. Body cell. 11. Cytoplasm. 12. Pollen tube.



cell (Fig. 2.11 A-E). The latter divides to form another (second) small prothallial cell and a large cell, the **antheridial cell**. The antheridial cell then divides to form a **generative cell** (towards the prothallial cells) and a **tube cell**. The pollen grains are shed at this 4-celled stage. The two prothallial cells degenerate and are distinguishable by two vestigial lenticular markings. The rest of the male gametophyte development takes place in the pollen chamber. The tube cell forms a short **pollen tube** which emerges out through the sulcus. The pollen tube does not grow further into the nucellus. In the mean time the generative cell moves into the tube and divides into a **sterile cell (stalk cell)** and a **spermatogenous cell** (body cell). The latter will again divide to form two non-motile male gametes. All this development takes place a week before fertilisation, meanwhile the pollen tube pierces through the nucellus and reaches the archegonium. The following is a schematic representation of the development of male gametophyte in *Pinus*.

2.6.5. Development of Female Gemetophyte

The functional megaspore nourished by the nucellar tissue enlarges and undergoes repeated free nuclear divisions. The free nuclei occupy parietal position leaving a large central vacuole. As a result of further free nuclear divisions as many as 2000 free nuclei are formed and the central vacuole becomes smaller and smaller and finally disappears. The developing female gametophyte now consists of numerous free nuclei spread all over it. Then wall formation takes place in a centripetal manner i.e., from periphery towards centre and the female gametophyte becomes entirely cellular. This cellular female gametophyte in gymnosperms is **endosperm**. The endosperm in *Pinus* is formed before fertilisation and is haploid in nature, unlike in angiosperms where it is formed only after fertilisation and is usually triploid. The female gametophyte (endosperm) below the micropylar region develops 3 - 5 archegonia. Each **archegonium** develops from a single superficial cell in the endosperm and is a oval shaped structure with a small neck and a venter. The venter contains a venter canal cell and a large egg cell or oospore. The neck is short and consists of two tiers of four cells or of a single tier of four cells (as in *P. roxburghii* and *P. wallichiana*). There are no neck canal cells. The neck is over grown by the adjacent cells of the female gametophyte and the archegonium therefore comes to lie in a depression called the archegonial depression(Fig. 2.12).

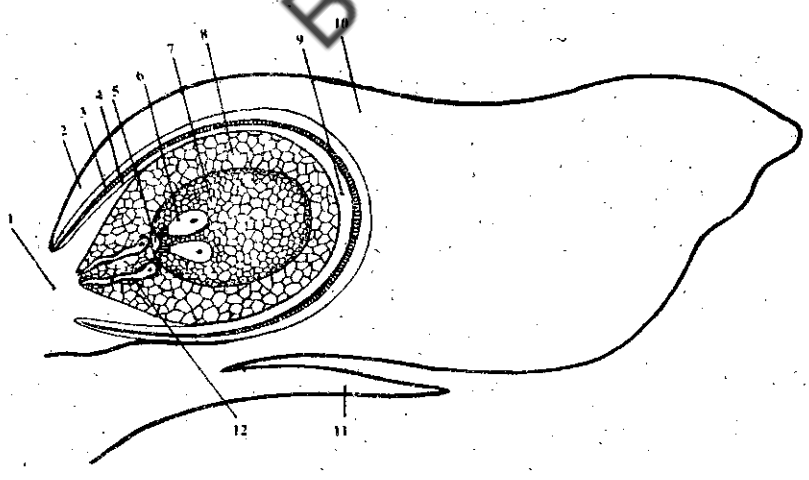


Fig. 2.12. L.S. of mature ovule of *Pinus*, bearing the archegonia. 1. Micropyle. 2. Outer sarcotesta. 3. Middle sclerotesta. 4. Inner sarcotesta. 5. Archegonial chamber. 6. Archegonium. 7. Female gametophyte 8. Nucellus. 9. Chalazal end. 10. Ovuliferous scale. 11. Bract scale. 12. Pollen tube.

2.6.6. Fertilisation

The pollen tube elongates till it reaches the neck of the archegonium, which is embedded in the endosperm. The pollen tube wall at its tip gets dissolved and releases the two motile male gametes. One of the male gametes fuses with the egg cell and the other male gamete usually aborts.

2.6.7. Development Of The Embryo (The Young Sporophyte)

The fertilized egg or the **oospore** (zygote) is diploid and constitutes the first cell of the sporophyte generation. This on further development will give rise to the **embryo**. The embryogeny in *Pinus* involves two stages, the first proembryonal stage and the second embryonal stage.

Proembryo : The early phase of embryogeny involves free nuclear division. The nucleus of the zygote divides twice to form 4 nuclei. They move to the bottom of the zygote. Now another division results in the formation of 8 nuclei arranged in two tiers of four nuclei. Walls appear between the nuclei of the basal tier. The upper most tier of four cells are free, open and are not separated by walls from the rest of the cytoplasm of the zygote above. Where as the lower tier of cells undergo further divisions to form yet another tier of cells, thus resulting in three tiers of four cells each. Later on again, the lower most tier undergoes one more division resulting ultimately in four tiers of four cells each. This 16-celled structure is called the **proembryo** (Fig. 2.13 F). The lower most tier of the proembryo is said to be the **embryonal tier.** The next tier i.e., the one over the embryonal tier, is called the **suspensor tier**. The cells of this tier will give rise to suspensors. The suspensors elongate considerably and may some times form **secondary suspensors** after undergoing division. The main function of the suspensors is to thrust the developing embryo deep into food laden endospermic tissue. The tier of the cells above the suspensor tier is the **rosette tier** above which lies the **open tier**. The proembryo in *Pinus* is a symmetrical and well organized structure with a definite number of tiers of cells, each with a specific function (Fig.2.13 A-I).

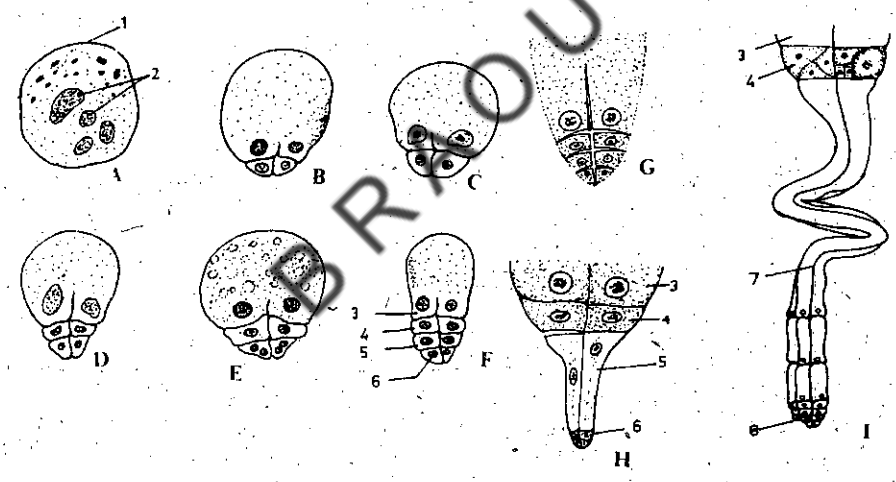


Fig. 2.13. Embryogeny in *Pinus*. A-F: Proembryo. G-I. Stages in the development of the embryo. 1. Wall of the zygote cell. 2. Free nuclei of the zygoyte. 3. Open tier. 4. Rosette tier. 5. Suspensor tier. 6. Embryonal tier. 7. Secondary suspensor. 8. Embryo proper.

Embryo: The cells of the lower most tier of the proembryo called embryonal cells, give rise to embryo proper. Usually these four cells get separated as a result of the cleavage undergone by the four suspensor cells situated above, and each of them develops into an embryo proper. Thus four potential embryos are formed from the embryonal tier. This type of polyembryony is common in *Pinus*. Some times more than single archegonium gets fertilised and develop into 3 to 4 embryos resulting in simple polyembryony. Occassionally the cells of the rosette tier may also give rise to embryos. However, as a rule, in all the cases only one embryo grows fully and reaches maturity in any one seed. The rest of the embryos abort at various stages of their development. The embryo consists of a short axis bearing a ring of upto ten slender, yellowish **cotyledons**. The axis is differentiated into the **radicle** towards micropylar end. The radicle with a prominant hypocotyl ends in several cotyledons. The plumule is present in between the cotyledons. The tip of the radicle is attached to the coiled thread-like structure, the suspensor.

2.6.8. Seed

Development of the Seed: The ovules after fertilisation become seeds. The integument of the ovule transforms into seed coat. The outer fleshy sarcotesta disappears, the middle solerotesta forms hard seed coat, the **testa** of the seed; while the inner fleshy sarcotesta becomes membranous and forms the **tegmen**.

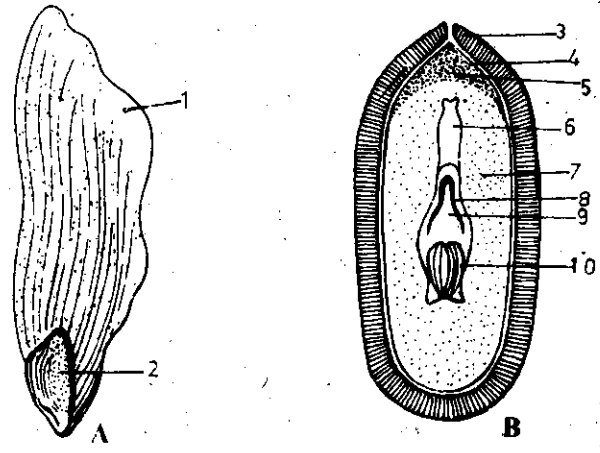


Fig. 2.14. *Pinus seed.* A. seed of *Pinus* with wing. B.L.S. of the seed of *Pinus*. 1. Wing. 2. Seed. 3. Testa. 4. Tegmen. 5. Nucellus (Perisperm). 6. Suspensor. 7. Endosperm. 8. Radicle. 9. Hypocotyl. 10. Cotyledons.

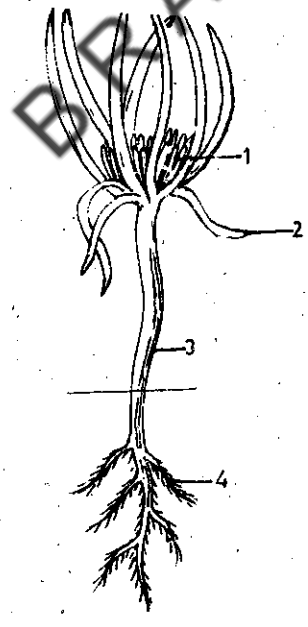


Fig 2.15. Young seedling of *Pinus* 1. Primary leaves. 2. Cotyledons. 3. Hypocotyl. 4. Radicle.

The seed is endospermous. **Perisperm** is the thin layer towards micropylar end and represents the remains of the nucellus. The embryo is **polycotyledonous** and usually has 3 to 10 cotyledons. The seed in *Pinus* is winged, and the wing is formed from the outer layer of the adaxial surface of the ovuliferous scale (Fig. 2.14 A).

Dispersal of the seed: The female cone take three years to mature fully. It is now dry, brown and woody structure. The ovuliferous scales turn into hard woody structures with pairs of winged seeds. The ovuliferous scales on separation produce a cracking sound releasing the seeds into atmosphere. The winged seeds are later on disseminated by wind currents to fairly long distances(Fig. 2.14 A).

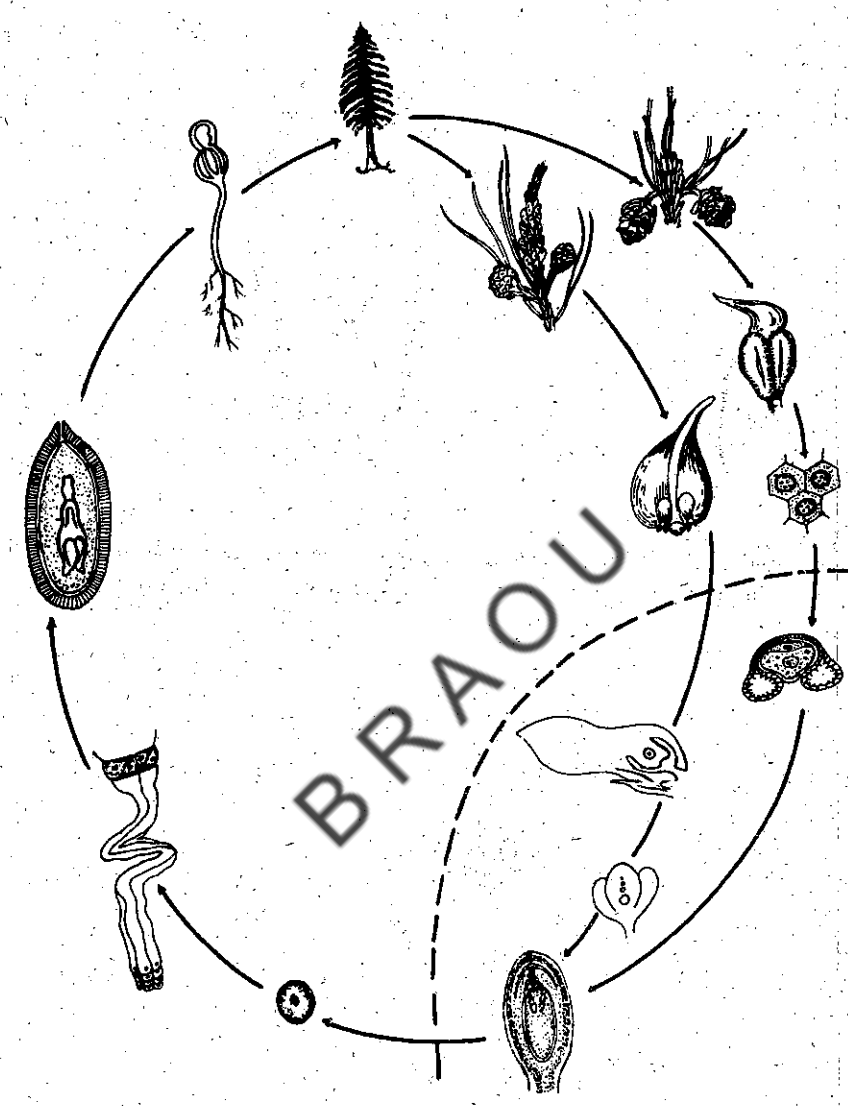


Fig. 2.16. Life cycle of *Pinus* (Diagrammatic).

Germination of the seed: The germination of the seed is **epigeal**. The seeds may germinate with or without a period of rest. The seed coat splits open and the **radicle** grows downwards forming the primary root. Then follows the **plumule**, which grows upwards producing 3 to 10 green cotyledonary leaves. Further growth of the plumule initiates the growth of the long shoot, dwarf shoot, brown scale leaves and foliar photosynthetic (needle) leaves (Fig. 2.15).

2.7. ECONOMIC IMPORTANCE

The wood of *Pinus* is a source of good commercial timber and wood-pulp, *Pinus sylvestris* yields valuable resin and turpentine. The seeds of *Pinus gerardiana* (chilgoza) are edible. The wood and the dried cones are used as fuel during winter months by the hilly people.

2.8. SUMMARY

Pinus, Confined mostly to the temperate belt of the northern hemisphere, is a large genus. Both the shoots and leaves exhibit dimorphism. The needle-like photosynthetic leaves are borne on dwarf shoots. The wood is pycnoxylic and with resin canals. The male cones are small and replace the dwarf shoots; the female cones are large and arise in place of long shoots. Each microsporophyll bears two abaxial pollen sacs (microsporangia) containing numerous two-winged pollen grains. The megasporophyll is a compound structure consisting of a small bract scale and a large ovuliferous scale with two ovules on its adaxial side.

The pro-embryo is 16-celled with four superimposed tiers of four cells each. Cleavage polyembryony is the normal type in *Pinus*.

2.9. CHECK YOUR PROGRESS : MODEL ANSWERS

1. There are two types of branches in *Pinus*. They are (1) Branches of indeterminate growth or long shoots and (2) Branches of determinate growth or dwarf shoots or spur shoots.
2. There are 2 types of leaves in *Pinus*. They are (1) Brown scale leaves (cataphylls) and (2) Green foliage leaves.
3. Embedded in the cells of the pericycle of the leaf of *Pinus* there are 2 other types of cells viz., (1) Albuminous cells and (2) Tracheidal cells. These special cells collectively constitute transfusion tissue.
4. The megasporophyll of *Pinus* consists of a thin membranous and dry bract scale in the axil of which arise the short woody triangular shaped ovuliferous scale bearing 2 ovules.

2.10. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write briefly about the general characters and distribution of *Pinus* in India.
2. Draw a well labelled diagram and describe the internal structure of the needle of *Pinus* and comment upon its xerophytic characters.
3. Describe the internal structure or the stem of *Pinus* with the help of a diagram.
4. Describe the male cone and microsporophyll in *Pinus*.
5. Discuss the development of embryo in *Pinus*.

II. Answer the following questions in about 10 lines each.

1. Write about the economic importance of *Pinus*.
2. Write briefly about the dispersal mechanism and germination process of the seed of *Pinus*.
3. Write briefly about the pollination in *Pinus*.
4. Write briefly about the ovuliferous scale of *Pinus*.

UNIT - 3 : *GNETUM*

Contents

3.1. OBJECTIVES

By the end of this unit you will be able to :

1. describe the external features of the sporophyte of *Gnetum*,
2. draw the internal structure and label the parts of the primary, secondary stem and stem with anomalous secondary growth and also the leaf and root,
3. distinguish between the structure of the male and female strobilus of *Gnetum*,
4. describe different interpretations of different scientists to the three envelopes of *Gnetum* ovule,
5. differentiate the developmental stages of a male gametophyte from a female gametophyte,
6. describe the pollination mechanism and fertilisation process in *Gnetum*,
7. describe the development of embryo & endosperm of *Gnetum* and
8. list out the various uses of *Gnetum* plant.

3.2. INTRODUCTION

The family Gnetaceae is represented by a single genus *Gnetum*, whose distribution is restricted to tropical rain forests. Reticulate venation of leaves, presence of vessels in the wood, presence of perianth in the male flowers, tetrasporic embryo sac and absence of archegonia are some of the significant features of this family.

The genus *Gnetum* is represented by about 40 species and they are distributed all through in the equatorial and tropical rain forests of the world. Various species are found in the Amazon basin of tropical Africa, South America and Asia. In Asia the genus is present in India, Bangladesh, Burma, Siam, China and Malaysia. In Malaysia the plants are cultivated on a large scale for the edible fruits of *Gentum gnemon*. No species occurs in Australia, North America and the entire Europe. In India, *Gnetum* is represented by five species as follows :

i) G. **gnemon** : Fully grown plants are trees, rarely scandant, found common in Jayantia, Garo hills of Arunachal Pradesh, hills of Assam and Manipur. In south India, it is seen in the Coonoor and Nilagiri hills of Tamil Nadu and in Quilon area of kerala.

ii) G.**ula** : This is a woody-climber (Liana). This is commonly found in Konkan, Malabar, Coorg etc. and in the Nilagiri and Palani hills in Tamil Nadu. It is also recorded from the Ananthagiri hills of Araku Valley in Andhra Pradesh, Mayurbhang district in Orissa and Andaman and Nicobar islands.

iii) G. **latifolium** : This is an evergreen climber. This is recorded from the Andaman and Nicobar islands.

iv) G. **montanum**: This is also a liana. This is commonly found in Sikkim, Assam, Darjeeling, Khasia and Jayantia hills in Arunachal Pradesh.

v) G. **contractum** : This is a scandant shrub. This is commonly found in Travancore area in Kerala and Coonoor and Nilagiri hills in Tamil Nadu.

3.3. EXTERNAL FEATURES

The sporophyte resembles a dicotyledonous plant in its general habit. The plants are generally climbers with twinning stems, having anomalous secondary growth (*G. ula*). A few are trees (*G. gnemon*) and some of them are shrubs (*G. latifolium*, *G. contractum* and *G. oblongum*). *G. trinerve* is a parasite on cinchona plants.

The branches are of two types viz., long shoots of unlimited growth and dwarf shoots of limited growth. However, in tree members such as *G. gnemon* there is no differentiation of the branches. The dwarf shoots bear 2-6 pairs of simple, opposite and decussate leaves.

The leaves are dorsi-ventral, simple, exstipulate, shortly petiolate, broadly elliptical or oval with entire margins. Venation is reticulate. Thus, the leaf of *Gnetum* resembles very much a typical dorsi-ventral dicotyledonous leaf (Fig. 3.1).

The stem is monopodial and much branched. The plant possess a well developed, much branched root system.

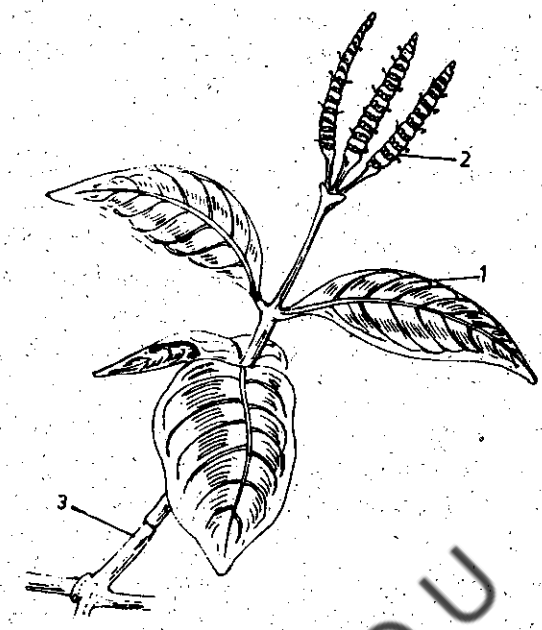


Fig. 3.1. *Gnetum* twig bearing simple opposite decussate leaves and the strobili. 1. Simple leaf. 2. Male strobilus. 3. Stem.

3.4. THE INTERNAL STRUCTURE

The internal structure of the stem, leaf and root are given below.

3.4.1. Stem

The internal structure of the stem resembles that of a dicot stem. The stem apex consists of a mass of meristematic tissue that is clearly differentiated into **tunica** and the **corpus** zones, as in dicotyledons. Both tunica and corpus tissues help in the formation of primary structures of the plant.

Primary Structure of the Stem : In transverse section, the stem is differentiated into epidermis, cortex and the stele. It is circular in outline (Fig.3.2.). The **epidermis** is single layered. Stomata are sunken and they interrupt the continuity of the epidermis. **Cortex** is multilayered and is differentiated into outer **chlorenchymatous** cortical zone which is 5 to 7 layered, the middle thin-walled **parenchymatous zone**, and the innermost 2-5 layered **sclerenchymatous zone.** The cells of the **sclerenchymatous zone** are spicular and polygonal. This zone is more conspicuous in older stems. **Endodermis** and **pericycle** are single layered and inconspicuous. The stele is a **eustele.** The **vascular** region consists of 20 to 24 (the number may vary from species to species) **conjoint, collateral, open** and **endarch** vascular bundles arranged in the ring. The xylem consists of tracheids and vessels, xylem fibres are absent and the xylem parenchyma scanty or even absent. The vessels of primary xylem bear circular bordered pits. The tracheids consists of spiral or reticulate thickenings. The primary phloem consists of sieve cells and phloem parenchyma. The medullary rays present in between the two vascular bundles are broad and parenchymatous. The central part of the stem is occupied by the parenchymatous pith.

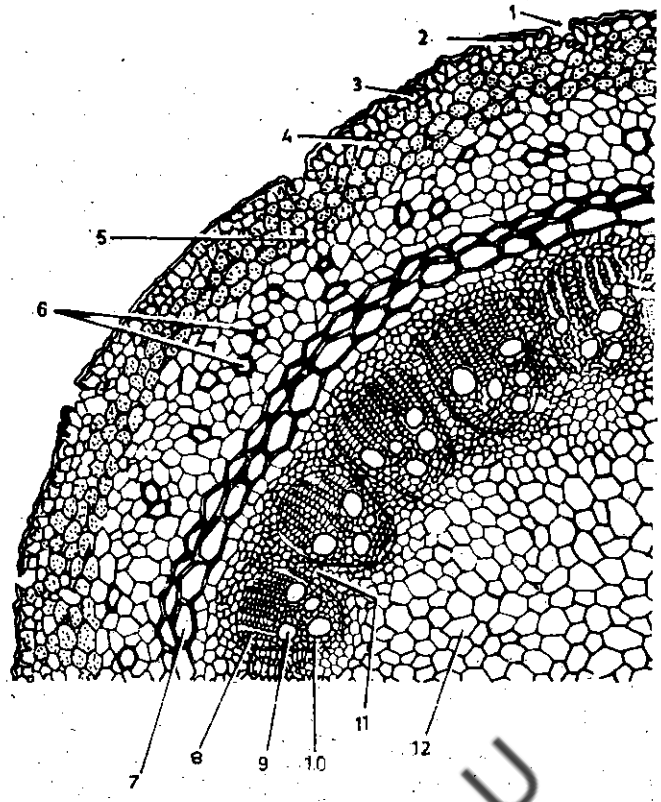


Fig.3.2. Young stem of *Gnetum* in T.S. 1. Stoma. 2. Cuticle. 3. Epidermis. 4. Sclerenchymatous cortex. 5. Parenchymatous cortex. 6. Fibre cells. 7. Ring of Scleranchymatous cells. 8. Phloem. 9. Xylem vessel. 10. Tracheid. 11. Medullary ray. 12. Pith.

Secondary Structure of the Stem : The secondary growth in the trees and shrubby members of the genus is of normal type. A complete ring of vascular cambium consisting of fascicular and interfascicular strips is formed in the ususal manner. It produces secondary phloem towards the periphery and secondary xylem towards the inner side of the stem. The ray initials of the cambium form xylem and the phloem rays in the secondary xylem and phloem respectively. The amount of secondary wood produced is profuse when compared to that of secondary phloem. The phloem elements consist of **sieve cells**, phloem parenchyma and albuminous cells. In some species sieve tubes and companian cells are also present. Unlike Angiosperms, the companion cells and the sieve tube members are formed from different mother cells. The **sieve cells** are elongated, thin-walled with blunt or tapering end walls. The **sieve areas** occur on the end walls as well as the lateral walls. **Phloem parenchyma** occurs in the form of distinct rows, alternating with sieve elements. The cells are small, thin-walled, vertically elongated and devoid of starch contents. These cells of phloem parenchyma look like companion cells, but they do not occur in the same radial row. They have no connection with the sieve cells. **Albuminous cells** may occur in radial files or scattered. They are associated with the sieve cells and have connections with small sieve areas of adjoining seive cells. The albuminous cells are narrow with ovoid slime bodies. These cells are with denser cytoplasmic contents, an ovoid protein body and dispersing slime. In *G.ula* phloem fibres are also recorded.

The secondary xylem consists of tracheids,xylem parenchyma and vessels. The **tracheids** are long cells with thick, lignified walls and narrow lumina. The tracheids have circular, uniseriate bordered pits on their tangential and radial walls. The cells of **xylem parenchyma** are thin-walled, simple pitted and with living protoplasts. **Vessels** are a characteristic feature of the wood of *Gnetum*. The vessels are made up of elongated vessel members, possessing bordered pits. The end walls of vessel members are perforated. There may be a single row of

perforations (*G.africanum, G.gnemon*) or a single large simple perforation on the end walls (*G.ula and G.paniculatum*) as in the angiosperms. There are also vessels in which the end walls possess some pits that are closed while others are perforated. This indicates a transitional stage between the tracheids and vessels. The vessels in *Gnetum* originate by the dissolution of the pit membranes, tori and borders of the circularly bordered pits at the end walls of the tracheids (Fig. 3.3). In angiosperms, however, the vessels are formed by the dissolution of the pit membranes of the scalariform bordered pits on the end walls of the tracheids. Thus, ontogenitically, the vessels of *Gnetum* are quite different from those of the angiosperms.

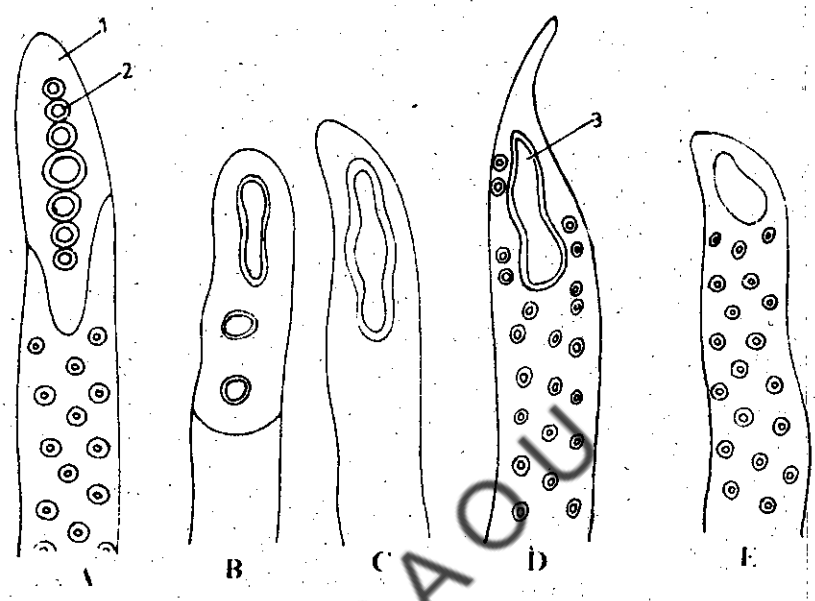


Fig. 3.3 Illustrations of the perforations of the end walls of vessels in *Gnetum africanum* (A-E). 1. End wall 2. Bordered pit. 3. End wall with large simple perforation.

The xylem rays are broad, multiseriate and of considerable height. Some times uni-and bi-seriate rays are also observed. The ray cells are thin or thick-walled, radially enlongated, often containing the crystals of calcium oxalate. In tangential section, the multiseriate xylem rays appear boat-shaped. The ploem rays are also multiseriate.

The cork cambium or the phellogen generally arises in the epidermis and may not form a complete layer around the stem. With the result there may be many layers of cork and at other places there may not be any cork layer. A strip of phellogen may develop in epidermal layer and another in the sub-epidermal layer, and still another in the deep layers of cortex. These strips may join laterally and form an irregular layer of cork-cambium resulting in the formation of cork and bark.

Anomalous (Eccentric) Secondary Growth in Stem

In woody - climbing species of the genus such as *G. ula, G. africanum, G. latifolium* and *G. montana*, the secondary growth is normal to begin with but at a later stage successive rings of cambium develops in the deeper layers of cortex resulting in the formation of anomalous secondary growth (Fig. 3.4.). These cambia cut-off secondary rings of phloem and xylem. Broad rays develop in the secondary tissue so that distinct wedge-shaped vascular bundles are seen. The first ring of cambium stops functioning after some time. The second ring appears outside the first ring and produces a ring of secondary vascular bundles. These bundles are separated by broad rays. Like-wise it stops functioning, and the third cambial ring develop external to the second and produces the third ring of vascular bundles. The process continues forming successive rings, sometimes these successive rings are incomplete and result in the formation of eccentric rings.

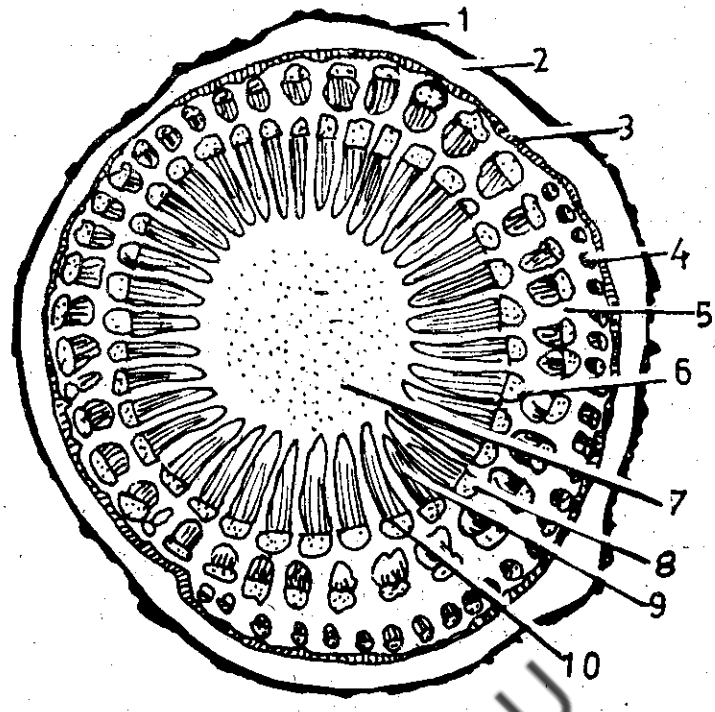


Fig. 3.4. Anomalous secondary growth in the stems of *Gnetum ula* in T.S. 1. Periderm. 2. Cortex. 3. Ring of sclerotic cells. 4. Third ring of vascular bundles 5. second ring. 6. First ring. 7. Pith. 8. Pholem. 9. Xylem, 10. Cambium.

Check Your Progress -1

Describe the anomalous secondary growth in the stem of *Gnetum.*

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of the unit.

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3.4.2. Root

Tihe young root has conspicuous cortex made up of several layers of parenchyma cells. The endodermis is distinct and filled with starch grains. The pericycle is made up of 4 to 6 layers of parenchyma cells. The xylem is **exarch** and **diarch**, alternating with the phloem bundles (Fig. 3.5.).

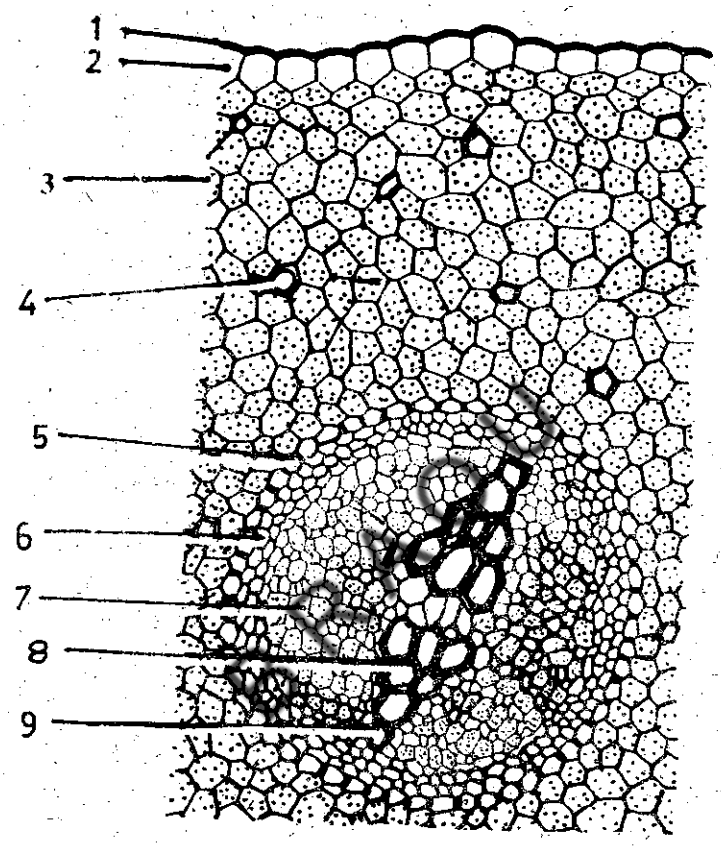

Fig. 3.5. Young Root of *Gnetum* in T.S. showing exarch-diarch xylem. 1. Cuticle. 2. Epidermis. 3. Cortex containing starch cells. 4. Fibre cells. 5. Endodermis. 6. Pericycle. 7. Phloem. 8. Metaxylem. 9. Protoxylem.

The secondary growth is of normal type and is effected by a complete cambial are formed internal to phloem groups and external to the xylem strands. The secondary xylem consists of tracheids, vessels and xylem parenchyma. The xylem rays are multiseriate and exclusively made up of thin-walled cells. The cork-cambium develop from the outer cortical layer and form the periderm.

3.4.3. Leaf

The leaf in *Gnetum* is dorsi-ventral with distinct upper (dorsal) and lower (ventral) epidermal layers (Fig. 3.6). The epidermal cells have undulate walls and those of the upper epidermis are heavily cutinized. The stomata are confined to the epidermis, but absent in the regions of mid-rib and the veins. The stomatal apparatus is made up of two guard cells and two subsidiary cells. The subsidiary cells are located parallel to the guard cells. According to **Takeda** (1913) and **Florin** (1931), the stomatal development in *Gnetum gnemon* is of the **syndetochelic type** i.e., the development of the guard cells and the subsidiary cells from the same mother cell. **Maheshwari** and **Vasil** (1961), however, stated that the development of stomata in *G. gnemon*

and *G. ula* is of **haplochelic type** i.e., the development of the guard cells and the subsidiary cells from different mother cells.

The **mesophyll** of the leaf is distinguishable into **palisade** and **spongy tissues**. The palisade is single layered and consists of the elongated, columnar cells filled with numerous chloroplasts. The spongy tissue consists of cells which are thin-walled, parenchymatous, loosely arranged, containing few chloroplasts and large multicellular spaces between them. Thick walled, lingnified and **stellate sclereids** are seen confined towards the lower side of the spongy tissue. **Scattered fibres** with lignified walls occur in groups around the midrib region. Some **latex tubes** are also found scattered around the midrib region. The vascular region in the mid-rib consists of an arc of few (up to 6) vascular bundles. The phloem lies towards the lower epidermis, whereas the xylem faces the upper epidermis. The bundles are conjoint, collateral and endarch. Each bundle has a capping of a patch of thick-walled cells. The phloem consists of sieve cells and phloem parenchyma. The xylem consists of tracheids, vessels and xylem parenchyma.

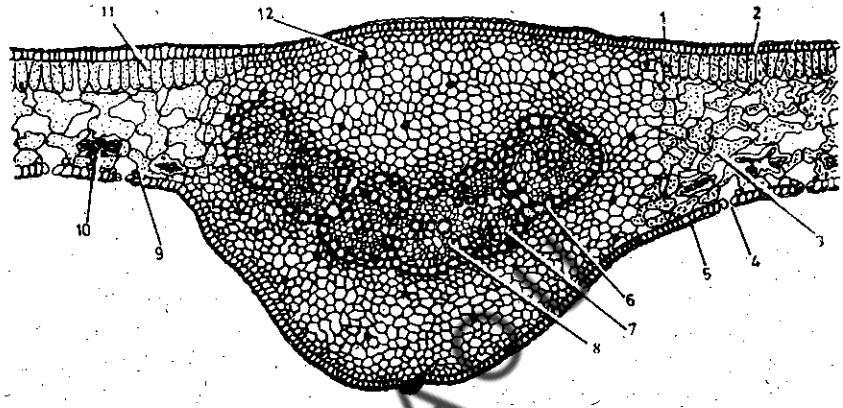

Fig. 3.6. T.S. of the Leaf *Gnetum*. 1. Cuticle. 2. Upper epidermis. 3. Spongy tissue. 4. Stomata. 5. Lower epidermis. 6. Fibre cells. 7. Phloem. 8. Xylem. 9. Substomatal cavity. 10. Sclereid. 11. Palisade tissue. 12. Latex cell.

3.5. REPRODUCTION

The sporophyte of *Gnetum* is dioecious and bear male and female reproductive organs on separate plants. The reproductive organs are in the form of cones or strobili which are organised into panicle type of inflorescenes. These panicles may arise singly or in groups in the axils of paired scale leaves. The panicles are in the axils of paired bracts which arise connate at their bases.

3.5.1. Male Strobilus

It consists of an elongated axis with a number of nodes and internodes. The internodes are short. The nodes bear a number of scaly bracts in whorls. These bracts fuse to form a connate ring-like structure called the cupule or the collar. The number of collars corresponds to the number of nodes. Often the nodes may vary from 10 to 25. Each collar at the node bears 3 to 6 rings of male flowers and each ring with many male flowers(Fig.3.7.). Above the rings of male flowers, there is one ring of abortive female flowers (ovules). Rarely the male flowers in the successive rings are arranged alternately as in *G. africanum*. Often the female flowers (ovules) in this ring may be fertile thus making the strobilus bisexual.

The apical region of the cone is generally sterile. The male cone when young is completely enveloped within the basal bracts. As it matures the internodes elongate and the male cone emerges out of the connate bracts. It is extremely compact at this stage.

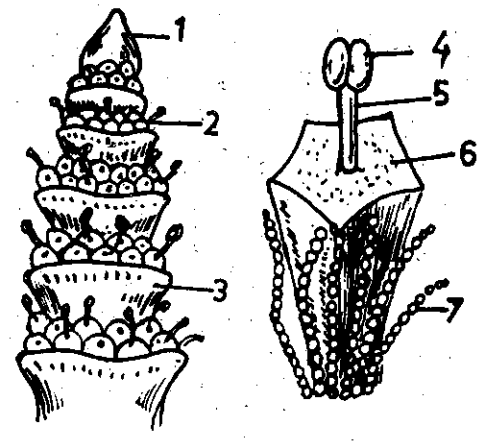

Fig. 3.7. Male strobilus of *Gnetum* A. Male strobilus entire B. Single male flower enlarged. 1. Apical sterile region. 2. Male flower. 3. Cupule or Collar 4. Anther sac. 5. Stalk. 6. Perianth. 7. Uniseriate multicellular hair.

Male Flower: The male flower is enclosed within a sheath-like perianth (Fig. 3.7 B). It bears a small stalk with two anthers at its apex. Each anther has a single microsporangium. At maturity the stalk of the flower elongates beyond the perianth, and the two anther lobes are now visible clearly outside the perianth. The male flowers are interspersed by uniseriate and multicellular hairs. There is a much variation in the number of anther lobes. In *G. gnemonoides*, the stalk bears only one anther lobe, while in *G. ula*, *G. gnemon* and *G. africanum* the number of anthers on one stalk varies from two to four.

Check Your Progress - 2

What is a cupule?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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3.5.2. Female Strobilus

The organisation of the female cone is similar to that of the male cone, except that in this case there is only a single ring of 4 to 10 ovules above the collar at each node (Fig. 3.8.). The ovules themselves represent the female flowers. When young it is difficult to distinguish a male and female cone because of their close similarity in the development. During the early stages

of the development of the female cone, all the ovules borne on the cone are of the same size. But as they mature some may grow bigger, while others remainsmallerandmayfall down. Only a few of the ovules produced by the cone become seeds. The apical part of the cone may not bear any ovules.

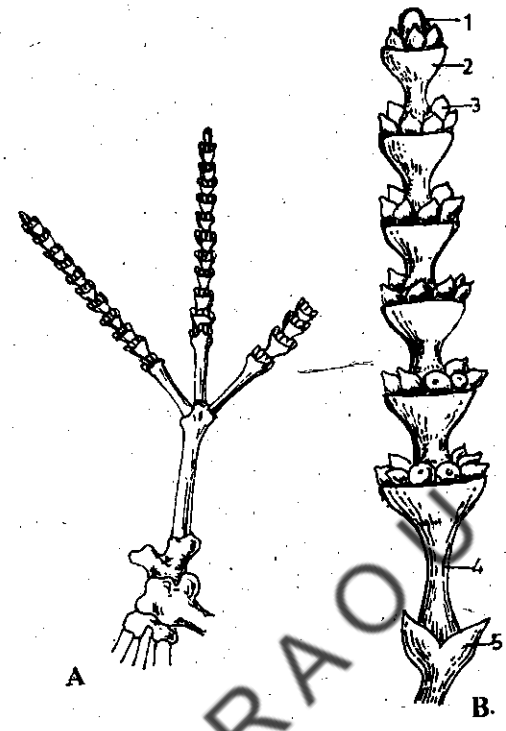

Fig. 3.8. Female strobilli of *Gnetum*. A. Entire. B. Apical part enlarged.
1. Sterile apical portion. 2. Collar. 3. Ovule 4. Cone axis. 5. Bract.

Ovule : It consists of a central mass of cells called the **nucellus** (megasporangium). The nucellus is surrounded by three envelopes. The inner envelope grows beyond the middle one and forms a narrow, cylindrical tube called the **micropylar canal.** The nucellus contains the female gametophyte. A rudimentary **pollen chamber** is also present at the nucellar apex. Out of these three envelopes, the outermost one is called the **perianth,** the middle one is designated as the **outer integument** and the innermost one is called the **inner integument.** This innermost envelope often fuses with the nucellus at its base and is free above. The ovules are stalked in *G.ula* (Fig. 3.9.) and are sessile or sub-sessile in others.

Morphyology of the Envelopes: The morphology of the three envelopes of *Gnetum* ovule has been interpreted variously.

Strasburger (1872) regarded them to be the three layers of an integument. **Beccari** (1877) later supported this theory. **Chamberlain** (1936) concluded that the inner two envelopes are the outer and inner integuments and the outer envelope is the perianth. This view is accepted by many workers. **Van Tieghem** (1869) considered the outer envelope as an ovary (or analogous to ovary) and the other two were regarded as the two integuments. **Lignier** and Tilson (1912) and **Thompson** (1916) regarded the inner envelope as an ovary and the outer two as perianth lobes. This was subsequently supported by **Vasil** (1959).

3.5.4. Microsporangium

The hypodermal cells of anther lobes metamorphose to form two archesporial cells. The repeated divisions of the archesporial cells result in the formation of many celled **archesporium.** The cells of the outermost layer in the archesporium tissue divide periclinally to form a layer **parietal cells** and the inner layer of **sporogenous cells.** The parietal layer undergoes another periclinal division to produce an outer **wall layer** and inner **tapetal layer.** The sporogenous cells undergo a few divisions to form the **microspore mother cells.** The microspore mother cells undergo meiosis resulting each into four haploid microspores in the form of a tetrad. The microspores are uni-nucleate, enveloped by thick, spiny exine and a thin intine. It is wingless. The dehiscence of the anther sac wall releases the microspores or pollen grains into the atmosphere.

3.5.5. Male Gametophyte

Microspore or pollen grain is the structure of the male gametophyte. It is uninucleate and spherical in outline. The wall layers are composed of an outer spiny exine and inner thin intine layer. The pollen grain matures partly before it is released into the atmosphere. It is released at 3 nucleate stage. There are various views regarding the nature of the three nuclei of the male gametophyte.

Pearson (1914) studied the development of male gametophyte (Fig. 3.10A) in *G.gnemon* and *G.africanum*. He calls the three nuclei as the **prothallial, tube** and **generative** nuclei. Of these, the prothallial nucleus plays no role in the further development of the male gametophyte and never enters the pollen tube and often it may degenerate.

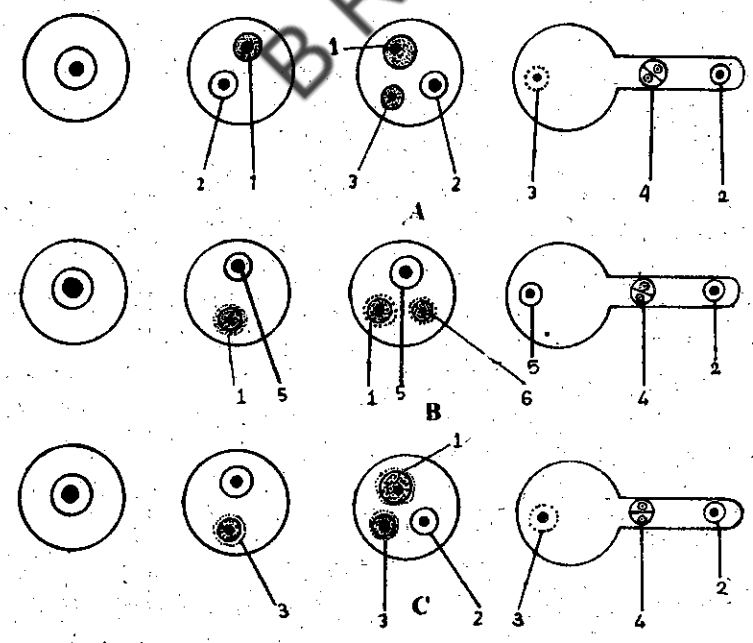

Fig. 3.10. Diagrammatic illustration of the three prevalent views regarding the development of Male gametophyte. A. Pearsons view. B. Thomsons view. C. Negi and Madhulatas view. 1. Generative nucleus. 2. Tube nucleus 3. Prothallial nucleus. 4. Male cell. 5. Stalk cell. 6. Body cell

The 3 celled pollen grain now lodged in the pollen chamber of the ovule germinates further by producing a pollen tube out of intine. The tube nucleus migrates first followed by the generative nucleus. Subsequently the generative nucleus divides into two male nuclei or **male gametes.**

Thompson (1916) studied the development of male gametophyte in *G.gnemon* and concluded that the microspore nucleus divides directly into two nuclei, the **tube nucleus** and the **generative nucleus.** No prothallial cell is formed in the male gametophyte as in angiosperms (Fig. 3.10B).The generative nucleus divides to form the **stalk** and **body cells.** Of these the stalk cell is retained in the microspore and will never move into the pollen tube. The body cell move into the pollen tube and divides again into two **male gametes.**

The recent view, stated by **Negi** and **Madhulata** (1957) (Fig.3.10C) from studies on *Gnetum ula* and *G.gnemon,* is as follows : The microspore nucleus first cut off a small lenticular nucleus. Later, this will develop a sheath around it and is retained in the body. This is the **prothallial cell.** This may often degenerate taking no part in the further development of the gametophyte. The large nucleus undergoes further division to produce a tube nucleus and a **generative nucleus.** The tube nucleus will move into the pollen tube followed by the generative nucleus. The latter will further divide into two **male gametes.** This view is widely accepted by many workers.

3.5.6. Female Gametophyte

The four nuclei of the coenomegaspore undergo repeated free nuclear divisions resulting in 256 (*G.gnemon*), 512 (*G. africanum*) or 1500 (G.*ula*) free nuclei (Fig.3.10 A-F). Except one, the remaining developing female gametophytes degenerate. The free nuclei of the female gemetophyte occupy parietal position leaving a large central vacuole. Cell walls are formed between the nuclei at the chalazal end of the female gametophyte, and this part become cellular. But the micropylar end continues to show only free nuclei. Thus the gametophyte is partly cellular and partly nuclear (Fig.3.11). *Gnetum* does not possess any archegonia. Some of the nuclei at the micropylar end of the female gametophyte become larger and function directly as eggs.

In *G. ula* it was noticed by **Vasil** (1959) that a few small groups of cells are differentiated at the micropylar end of the female gametophyte and one cell in each such group functions as the egg.

3.5.7. Pollination

It is of anemophilous type. The pollen grains released into the atmosphere are carried away by the wind and are caught in the pollen drop produced at the micropylar end of the ovule. As the pollen drop dries up, the pollen grains are gradually drawn in and are settled in the pollen chamber for further development. As a rule 2-4 pollen tubes reach the female gametophyte but ultimately only one would be successful in fulfilling the act of fertilisation. The others abort.

3.5.8. Fertilisation

The pollen tube germinates, pierces the female gemetophyte and reaches the egg cells present at the micropylar end. The tip of the pollen tube bursts releasing the male gametes. One of which fuses with the egg cell to form the zygote. Both the male gametes are functional and can fertilise two eggs. Many zygotes, could be seen in the female gemetophyte.

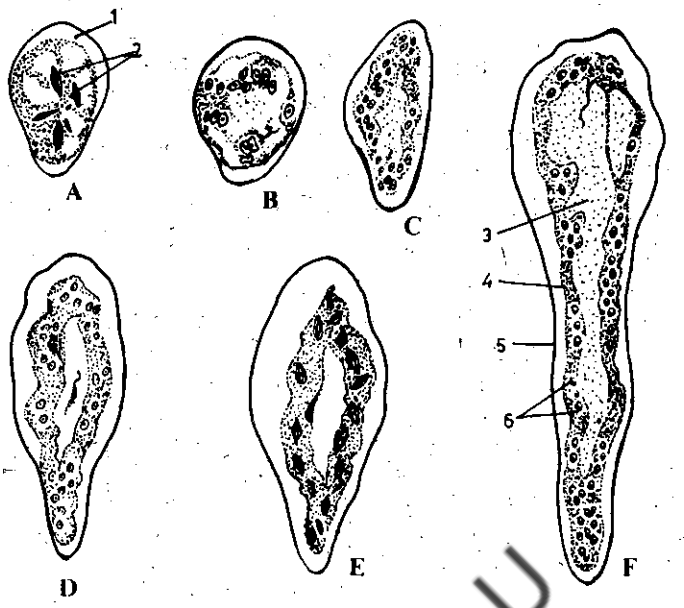

Fig. 3.11. Early stages in the development of female gametophyte of *Gnetum ula* showing five nuclear divisions (A-F). 1. Female gametophytic cell. 2. Free nuclei. 3. Vacuole. 4. Cytoplasm. 5. Female gametophyte. 6. Coenomegaspores.

3.5.9. Endosperm

After fertilisation the upper part of the female gametophyte too becomes cellular so that the whole of the gametophyte is now cellular. This may be described as endosperm. *Gnetum* resembles the angiosperms in that the endosperm formation is completed only after fertilisation. However, it should be noted that in *Gnetum* all the female gametophyte nuclei participate in the endosperm formation, where as in angiosperms only two polar nuclei of the female gemetophyte (embryosac) take part in endosperm formation.

3.5.10. Embryogeny

The development of embryo in *Gnetum* exhibits variation in various species. **Vasil** (1959) studied the embryogeny in *G.ula*. There are no free nuclear divisions in the early embryogeny. The zygote in this species divides into two cells by wall formation (Fig.3.12 A-E). These two cells elongate considerably to form tube-like structures. One of the two tubes divides into two to three cells. These tubes are called **primary suspensor tubes**. These are variously coiled. The top of the tubes become dense. Some of these tubes penetrate deep into the tissue of the endosperm and some pierce through the female gametophyte. Majority of the tubes grow down into the centre of the endosperm. Many of these tubes degenerate or stop branching further. It takes about six or seven months time for the zygote to reach this stage. Later, the nucleus at the tip of the primary suspensor tube divides into two unequal nuclei. The smaller

nucleus is cut off from the rest of the tube by a cell wall. This is called the peculiar cell. This **peculiar cell** underoes division further periclinally into two cells which lie one above the other. The second division results in the formation of four cells. Yet another division results in the 8-celled condition. further divisions are irregular and a mass of tissue (embryonal cells) is formed. This mass increases in size by further repeated divisions. The cells towards the tube increase in size and form elongated **secondary suspensors.** The cells of secondary suspensors are thin-walled, uni- nucleated and vacuolated. The cells at the top remain small with dense cytoplasmic contents and develop into embryo proper. Now the primary suspensors cease to elongate while the secondary suspensor cells start elongating which push the **embryonal cells** deep into the endosperm tissue.

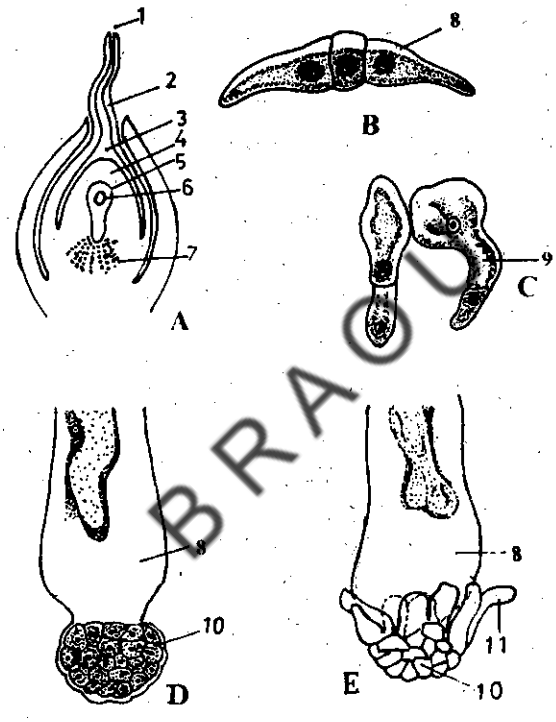

Fig. 3.12. Development of embryo in *Gnetum ula*. A. L.S. of the Ovule of *Gnetum*. *B-G*. Various stages of embryonal development. 1. Micropyle. 2. Inner envelope. 3. Pollen chamber. 4. Nucellus. 5. Embryo sac. 6. Zygote. 7. Pavement tissue. 8. Primary suspensor. 9. Two celled primary suspensor. 10. Embryo. 11. Secondary suspensor.

The **stem tip** is differentiated at the end of the emnbryonal mass. It is surrounded by **two cotyledons** that develop between the stem and the root tips and becomes distinct. It is called the **feeder**. The feeder shows distinct epidermis, cortex and vascular tissue. There is a distinct **hypocotyl** which is conspicuous in the earlier stages and soon it is superseded by the fast growing feeder. Meanwhile, the suspensors shrivel up and look like fine threads attached to the root tip.

Polyembryony is the norm in *Gnetum* as large number of zygotes starts developing into embryos. More over each zygote produces many tubes and the tip of each tube develops into an embryo. Secondary suspensors may also give rise to additional embryos. Sometimes, the primary suspensor tubes may produce more than one mass of embryonal cells at its tip. Ultimately, however, only one embryo which grows faster than the others attains maturity and is fully formed. The others abort.

3.5.11. Seed

The seed consists of three layers. The outer layer is green and succulent. The middle layer is stony, and composed mostly of sclereids and fibres. The inner layer is parenchymatous. This layer forms the micropylar tube. The cells lining the micropylar tube are heavily cutinized. These three layers enclose the massive endosperm in which lies the dicotyledonous embryo.

The **seed germination** is of epigeal type. First the root tip comes out of the seed coat, elongates and grows down into the soil. Then the hypocotyl elongates, pushes the cotyledons out of the seed coat and then carries them above the soil. The feeder remains within the seed. The cotyledons form the first green leaves. Now the plumule grows and produces the first pair of foliage leaves at right angles to the cotyledons (Fig.3.13). The cotyledons soon wither off.

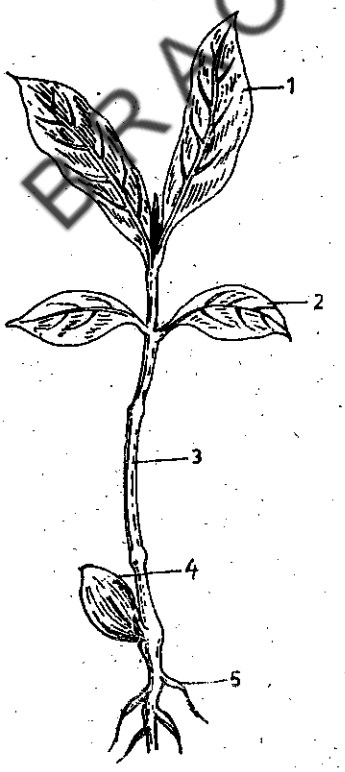

Fig. 3.13. Germination of seed in *Gnetum*. 1. Foliage leaf. 2. Cotyledonary leaf. 3. Hypocotyl. 4. Seed coat. 5. Primary root.

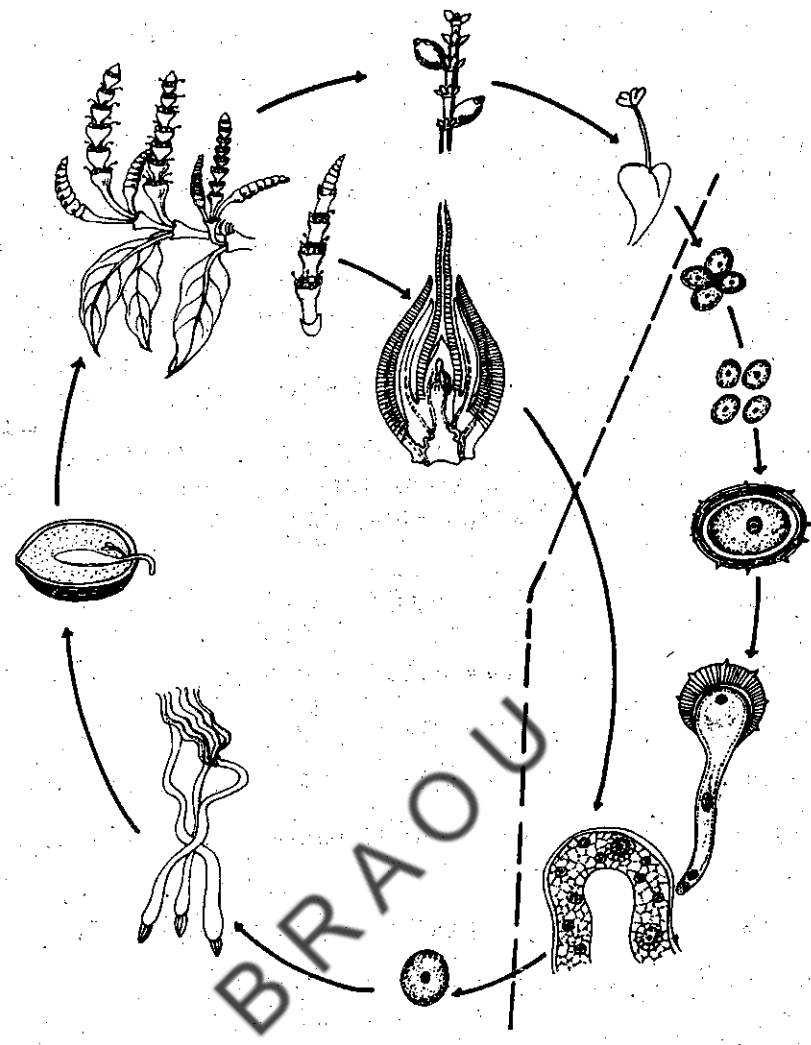

Fig. 3.14. Life Cycle of *Gnetum* (Diagrammatic).

3.6. ECONOMIC IMPORTANCE

The seeds of *G.ula, G.gnemon* and *G.latifolium* are roasted and eaten. In Malaysia, the plants of *G.gnemon* are cooked as vegetable. The fibres seen in the bark of this species are used in rope making. The kernels of *G.ula* yield an oil which is used as a massage oil in rheumatism and also for illumination purposes. The plant of *G.montanum* is used as a good fish poison.

3.7. SUMMARY

The species of *Gnetum* are woody climbers, trees or shrubs and are found in moist tropical forests. The leaves of *Gnetum* are simple, pinnately reticulate and show striking resemblances with the leaves of dicotyledonous angiosperms. The xylem is characteristic in the possession of vessels with simple perforations as in many angiosperms. The plants are dioecious. Each male flower is with a distinct perianth and a stalk terminating in two microsporangia. The ovule represents the female flower and shows three distinct envelopes, the outer considered as perianth and the inner two of the nature of integuments. The inner envelope becomes very

much prolonged to form a long mioropyle. The embryosac is of the tetrasporic type and there are no archegonia as in angiosperms.

3.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Anomalous secondary growth in *Gnetum* takes place due to the formation of successive rings of cambia in the deeper layers of cortex. The first ring stops functioning after sometime i.e., after the production of a ring of vascular bundles, and the second ring appears outside the first ring and produce another ring of vascular bundles. Due to the separation of the vascular tissues with broad rays they appear as wedge shaped vascular bundles. In a similar way several such cambial rings appear and cut off several rings of vascular bundles.

2. Male strobilus of *Gnetum* consists of an elongated axis with several nodes and internodes. Several scaly bracts are present in whorls at the nodes. All these bracts fuse with one another and form a cup-like structure called cupple or collar.

3.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Describe the internal structure of the stem of *Gnetum* with the help of a diagram.
2. Describe the male strobilus and male flower of *Gnetum* with the help of a diagram.
3. With a well labelled diagram describe the morphology and anatomical features of the ovule of *Gnetum*.
4. Discuss in detail the male and female gametophytes in *Gnetum*.
5. Discuss about the development of embryo in Gnetum.

II. Answer the following questions in about 10 lines each.

1. With the help of a diagram describe the internal structure of an young stem of *Gnetum*.
2. Write briefly about the anomalous secondary growth in the stem of *Gnetum*.
3. Write briefly about the internal structure of the root of *Gnetum*.
4. Write a brief account of the internal structure of the leaf of *Gnetum*.
5. Discuss in detail the various views regarding the morphology of the three envelopes of *Gnetum* ovule.
6. Write briefly about the various views regarding the nature of the three nuclei of the male gametophyte of *Gnetum*.
7. Write briefly about the pollination & fertilisation in *Gnetum*.

UNIT - 4 : FOSSIL GYMNOSPERMS *LYGINOPTERIS* AND *WILLIAMSONIA*

Contents

4.1. OBJECTIVES

By the end of this Unit you will be able to:

1. define and differentiate the petrifactions and impression fossils; form genera and organ genera,
2. recognise the reasons for giving different names for the stems, leaves and male and female flowers of *Lyginopteris* and *Williamsonia*,
3. draw the figures and describe the external features, the trunks and the structure of the stems of *Lyginopteris* and *Williamsonia* and
4. distinguish between the male flowers and female flowers of *Lyginopteris* and *Williamsonia*.

4.2. INTRODUCTION

The gymnosperms are well known for their extensive and fascinating fossil history. Many of the orders of gymnosperms are represented only as fossils. To this category belong the Pteridospermales, Cordaitales, Cycadeoidales (Bennettitales) etc. Our knowledge of these extinct plants is based upon the study of their diverse fossil remains. Of the various types of fossils the structurally preserved fossils called **petrifactions** are more important and significant as they provide information on the anatomical details of the plants. The gross morphology of the plants, however, is obtained from the **impression fossils.**

It is unusual that an entire plant (exceptions are provided by some microscopic algae etc.) is preserved with all its components intact. As a rule, various parts of the plants like stems, leaves reproductive structures etc are detached from each other during fossilization and are then preserved as independant entities. These individually preserved components are described under different **form genera** or **organ genera,** depending upon their known or unknow botanical

affinities. The fossil gymnosperms are no exception to this rule. Our knowledge of these plants is based upon a critical comparative morphological and anatomical studies of various detached fossil specimens of stems,roots, leaves and reproductive organs in constant association. Some lucky discoveries of fossils share organic connection between various parts.

The fossil gymnosperms in the present syllabus are represented by one example in each of the Pteridospermales and Bennettitales (Cycadeoidales).

4.3. *LYGINOPTERIS*

Class - Cycadopsida
Order - Pteridospermales
Family - Lyginopteridaceae
Genus - *Lyginopteris*

The order Pteridospermales was formally instituted by **Oliver** and **Scott** (1903). The Pteridospermales include the most archaic seed-bearing plants showing similarities with ferns on one side and the cycads on the other. The Pteridosperms first appeared in the Lower Carboniferous age (about 350 million years ago). They attained the peak of their development during the Upper Carboniferous and Permian (about 280 million years ago) periods when they constituted one of the dominant elements of the then Euramerican coal swamp floras. This order was represented in the Triassic period of Mesozoic Era by the families, such as Pteridospermaceae, Caytoniaceae etc. Some time during the Jurassic period (about 200 million years ago) it disappeared.

The distinguishing characters of Pteridospermales are as follows: i) The leaves are very large (megaphylls), and they are of the nature of fern fronds, ii) the leaftraces are either single or of several strands, iii) the primary xylem strands are usually mesarch, iv) stems are with a solid or medullated protostele or reduced to circummedullary strands (vascular bundles); sometimes polystelic, v) secondary growth is common and the secondary wood is manoxylic, vi) seeds are borne directly upon leaves,and vii) the microsporangiate organs are often in the form of synangia.

The following eight families are usually included in Pteridospermales.

1. Lyginopteridaceae. 2. Medullosaceae. 3. Callistophytaceae 4. Calamopityaceae. 5. Glossopteridaceae. 6. Peltaspermaceae. 7. Corystospermaceae. 8. Caytoniaceae.

Of these, the first four families are confined to the Palaeozoic Era. They represent the **Palaeozoic Pteridosperms**. The last four families are either confined to Mesozoic Era or extend from the Late Palaeozoic to Mesozoic and constitute the **Mesozoic Pteridosperms**.

The members of the family Lyginopteridaceae are preserved in the form of impressions, compressions or petrifactions. They are represented by the stems, leaves, pollen-bearing organs and seeds.

Stems: ***Lyginopteris, Heterangium***

Leaves: ***Sphenopteris***

Seeds: ***Lagenostoma, Sphaerostoma.***

Pollen-bearing Organs: ***Crossotheca, Telangium***

The best known member of the family is ***Lyginopteris oldhamia***. The name ***Lyginopteris*** was orginally applied to the stems in detached condition. It is now, however, referred to the entire plant. Foliage and seeds referable to this genus are known more or less definitely. There is some degree of uncertainity with regard to the Pollen-bearing organs.

4.3.1. External Features

Lyginopteris oldhamia (syn. *Calymmatotheca hoeninghausii*) is known abundantly from the Lower Carboniferous Coal fields of England and has also been recently discovered from America. In general habit, Lyginopteris resembles a woody liana or a straggler. The stem is slender, 3-4 cms in diameter and bear adventitious roots. The leaves are large,frond-like,spirally arranged and upto 0.5 meter long. Prominent glandular hairs are seen on all parts of the plant body excepting the roots (Fig 4.1).

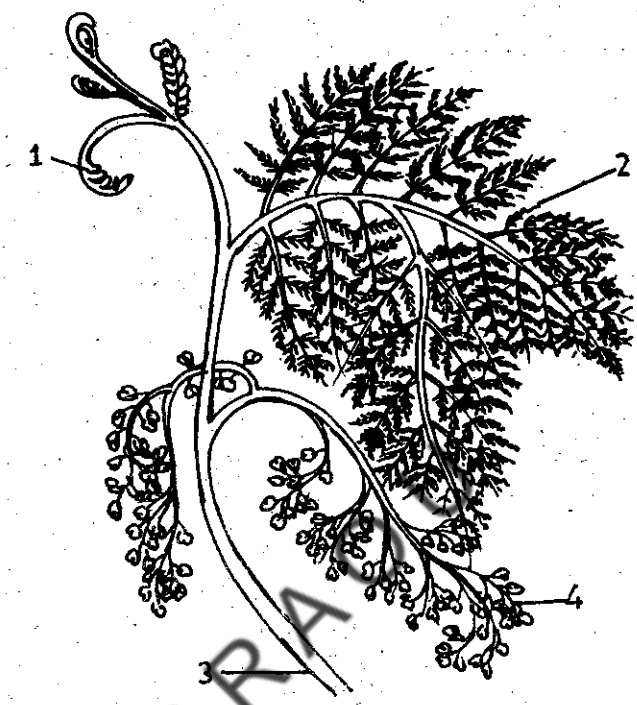

Fig. 4.1 Twig of *Lyginopteris oldhamia*. 1. Young leaf showing circinate vernation. 2. Vegetative compound leaf. 3. Stem. 4. Microsporophyll.

4.3.2. Internal Structure of the Stem

The stem of *Lyginopteris oldhamia* (Fig 4.2) is more or less circular in outline. Next to the epidermis is a fairly broad cortex which is divisible into two zones i.e., the piter cortex and the inner cortex. The outer cortex is characteristic of the genus as it consists of vertical network of anastomosing fibres, with thin-walled parenchyma in the lumina of the meshes. This type of cortex is designated as **Dictyoxylon cortex**. In cross section these anastomosig strands of fibres simulate "Roman Numerals' on the face of a clock. The inner cortex consists of parenchymatous cells. Next to the cortex is the pericycle with thick walled cells, often filled up with dark contents. The stele is a *eustele*, with 5 to 8 conspicuous, conjoint, collateral and mesarch primary vascular bundles surrounding the pith. A strip of cambium is also seen sometimes in each bundle in between the xylem and phloem. The pith is made up of parenchymatous cells and they are intermingled with groups of thick-walled cells, the **sclerotic nests**.

Secondary thickening is a common feature, but only a limited quantity of secondary wood is produced. The wood is manoxylic and it consists of large thine walled tracheids and multiseriate parenchymatous rays. The radial walls of the tracheids possess numerous irregularly aligned, multiseriate and angular bordered pits. Secondary phloem is often seen preserved and can be traced immediately outside the secondary xylem.

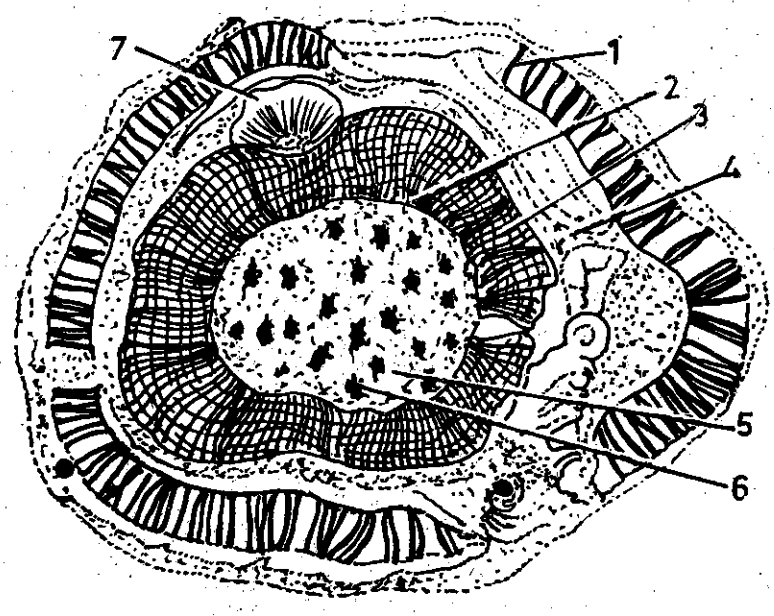

Fig. 4.2. T.S. of the stem of *Lyginopteris oldhamia* showing secondary structure . 1. Outer cortex (Note the Dictyoxylon cortex). 2. Primary wood. 3. Secondary wood. 4. Inner cortex. 5. Pith. 6. Sclerotic nests. 7. Leaf trace.

The leaf trace orginates as a single strand by the tangetial splitting of a primary vascular bundle and divides into two as it passes through the cortex. But ultimately, the two bundles unite again to form a single V-shaped bundle at the base of the petiole.

Check Your Progress -1 & 2

1. What is dictyoxylon cortex ?
2. What are scelerotic nests?

Note: (a) Write your answers in the one given below.

(b) Compare your answers with those given at the end.

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4.3.3. Reproductive Structures

The seeds (ovules) referable to *Lyginopteris* are borne in cup- like protective sheaths called **cupules** (Fig. 4.3). The cupules bear characteristic,capatite glands similar to those on the young twigs and fronds and thus are clearly affiliated with the latter. During the recent years the gland studded cupules have been found in organic connection with the twigs of *Lyginopteris.*

The seeds (ovules) of *Lyginopteris oldhamia* in detached condition are known as *Lagenostoma spp.* They were originally described by **Oliver** and **Scott** (1904). The seeds are small (5.5 X 4.2 mm), barrel-shaped, radially symmetrical and orthotropous. Though the seeds were borne in cupules when immature,the mature seeds appear to have been shed these cupules.

The integument of *Lagenostoma lomaxi* is massive and consists of an outer thick-walled zone, the **sclerotesta** and an inner thin- walled zone,the **sarcotesta.** The integument is completely fused with the **nucellus** except at the extreme tip of the seed. The nucellus is prolonged into a flask-shaped structure,the **lagenostome,** that projects into the **micropyle.** The lagenostome of the nucellus consists of a central solid column of tissue all around which is a narrow annular cavity, the pollen chamber(Fig 4.3 B,C).

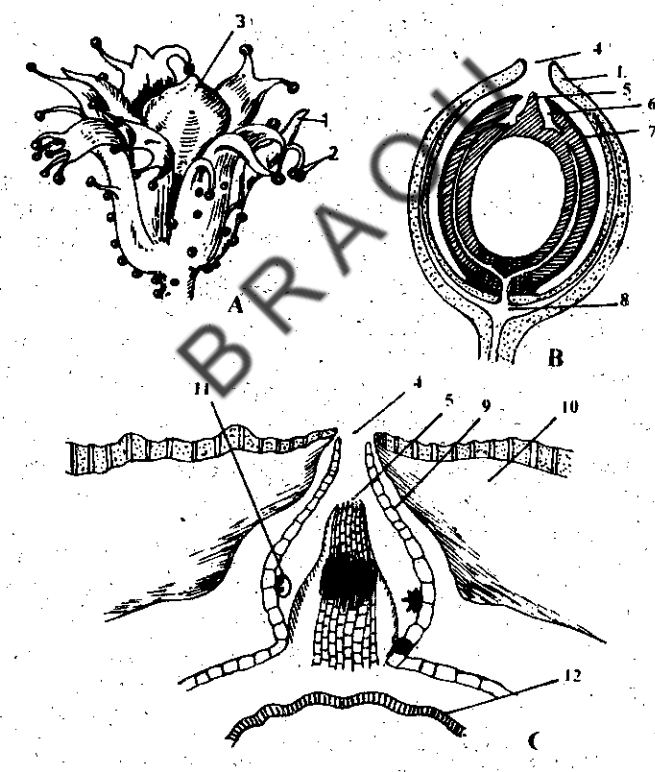

Fig. 4.3. The seed of *Lagenostoma lomaxi* enclosed in a cupule (Note the occurance of glandular hairs on the cupule). B. L.S. of the ovule of *Lagenostoma lomaxi.* C. Enlarged upper portion of the ovule of the same. 1. Cupule. 2. Glandular hairs. 3. Seed. 4. Micropyle. 5. *Lagenostome.* 6. Pollen chamber. 7. Female gametophyte. 8. Vascular supply. 9. Sclerotic cucellar flask. 10 Integument. 11. Pollen grain. 12. Membrane of the female gametophyte.

In *Lagenostoma ovoides, Long* (1944) described well preserved **prothallus** with **archegonia** at its micropylar end. In all probability the pollen grains germinated within the pollen chamber and liberated the sperms, which fertilized the eggs of the archegonia in the same manner as in the recent cycads (*Cycas*).

The Pollen-bearing organs of the *Lyginopteris* are believed to be of the *Crossotheca* type. So far, no organic connection has been discovered between *Crossotheca* and the twigs of *Lyginopteris*. *Telangium* is another Pollen-bearing organ referable to *Lyginopteris*.

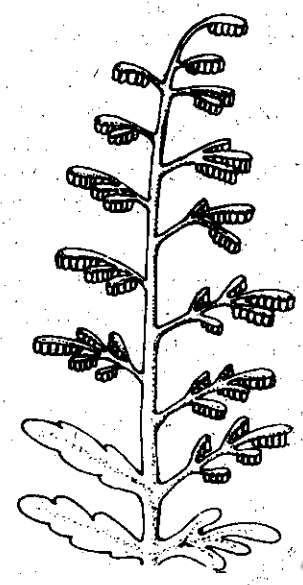

Fig. 4.4. A pollen bearing organ,with pendant microsporangia of *Crossotheca hoeninghausii*.

Crossotheca hoeninghausii (Fig 4.4) is a pinnately branched microsporangiate organ. The lateral branches (pinnae are spatulate and bear numerous bilocular,pendant sporangia underneath their dilated portion. Most of the *Crossotheca* specimens have been found in organic connection with *Sphenopteris* fronds.

Check Your Progress - 3

What is a Langenostome ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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4.4. *WILLIAMSONIA*

Class : **Cycadopsida**
Order : **Bennettitales (Cycadeoidales)**
Family : **Williamsoniaceae**
Genus : ***Williamsonia***

The order **Bennettitales** is another extinct group of gymnosperms included in the syllabus. The members of this group are almost exclusively confined to the Mesozoic Era and attained their peak of development during the Upper Jurassic Cretaceous age. The important characters of Bennettitales are as follows : 1. Stems are upright, stocky, columnar or slender, branched

and ensheathed generally by rhomboidal leaf basses and ramental hairs. The stems are eustelic. 2. Leaves are mostly pinnately compound. 3. Reproductive structures, described as flowers, are bisexual *(Cycadeoidea)* or unisexual *(Williamsonia)* and show broad similarties with flowers of *Magnolia* of angiosperms. 4. Flowers with prominent receptacle (or thalamus) bearing ovules and surrounded by microsporangiate organs. 5. A whorl of perianth-like bracts protect the essential organs.

The order includes three families viz., 1. Wielandiellaceae, 2. Williamsoniaceae and 3. Cycadeoidaceae.

The members of the family *Williamsoniaceae* are with columnar, sparsely branched trunks; the flowers are borne terminally on short lateral shoots. The stem is ensheathed by rhomboidal leaf bases and ramental hairs. The leaves are pinnately compound. The flowers are unisexual. The family is best represented in the middle Jurassic - Cretaceous period of the Mesozoic Era. The following are the various genera in detached condition.

Stem	: *Bucklandia*
Fronds	: *Ptilophyllum, Pterophyllum, Dictyozamites, Otozamites* etc.
Male Flowers	: *Bennettistemon, Weltrichia, Williamsonia*
Female Flowers	: *Williamsonia, Bennetticarpus* etc.

The name *Williamsonia* was originally applied to the flowers in detached condition. Subsequently, however, it has come to represent the entire plant. The best known species of this genus is *Williamsonia sewardiana* described by Birbal Sahni (1932) from the Jurassic of Rajmahal hills, Bihar, India. Sahni gave a reconstruction of this plant, which more or less look like a modern cycad (*Cycas*).

4.4.1. External Features

Williamsonia sewardiana (Fig. 4.5, A)has a columnar sparsely branched trunk of 2 meter tall. The main trunk terminates in a crown of pinnately compound leaves. The same is the case with the short, stumpy lateral shoots. The trunk is beset with rhomboidal leaf bases. The leaves are of two types : simple scale-like more or less pointed leaves, and pinnately compound foliage leaves.

The leaves in detached condition are called *Pilophyllum (P.cutchensis)*. The *Ptilophyllum* leaves are common fossils of the Jurssic -Lower Cretaceous deposits in various parts of India, such as Rajmahal hills in Bihar, Kutch in Gujarat, Pranhita- Godavari, Krishna basins in Andhra Pradesh, Cauvery and palar basin of Tamil Nadu etc. The Pinnae (leaf-lets) are attached to the upper surface of the rachis by their entire bases (Fig . 4.5 B). Each pinna is with an entire margin, blunt to pointed apex and many parallel veins.

4.4.2. Internal Structure of the Stem

The stem in detached condition is called *Bucklandia*. In cross section the stems of *Williamsonia sewardiana* is some what circular. It shows a broad parenchymatous cortex with secretory cavities. The pith is narrow and parenchymatous. The primary vasculature is in the form of a ring of conjoint, collateral, endarch and open vascular bundles around the pith. The adjacent bundles are separated by broad parenchymatous medullary rays. The secondary wood formed is fairly extensive. It is pycnoxylic (unlike the wood of the other Cycadopsida) and consists of compact tracheids with scalariform to circular bordered pits on their radial walls. The circularly bordered pits are multiseriate and opposite. The xylem rays are mostly one to two seriate.

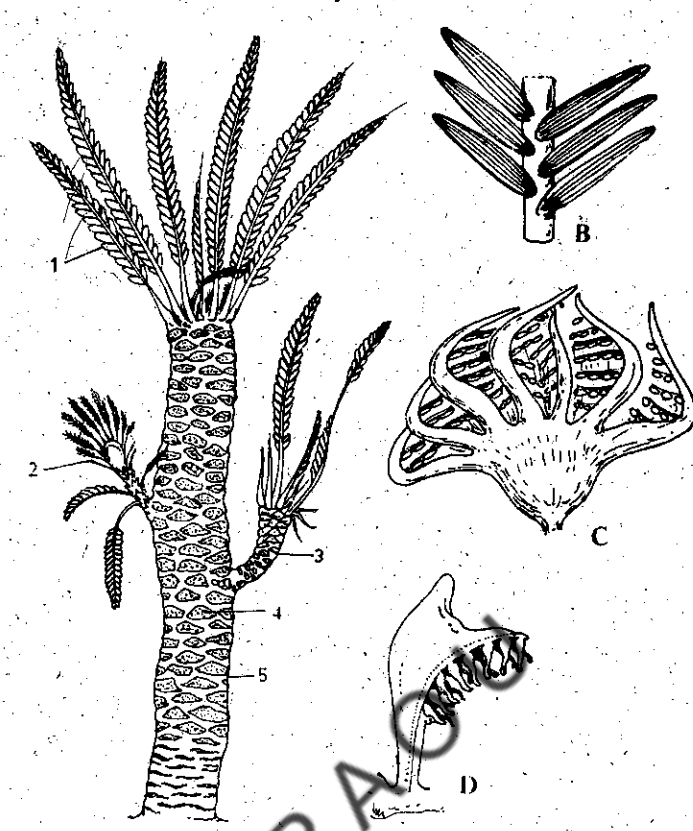

Fig. 4.5. *Williamsonia.* A. Reconstruction of *Williamsonia sewardiana* (after Sahni). B. Part of Ptolophyllum leaf. C. Male flower of *Williamsonia spectabilis* (after Wieland) D.Male flower of *Williamsonia santalensis* (After Sitholey and Bose 1. Vegetative compound leaf 2. Female shoot. 3 Lateral branch. 4. Rhomboidal leaf base. 5. Trunk.

4.4.3. Reproductive Structures

The flowers are unisexual and the *Williamsonia* plant is presumably dioecious. In *Williamsonia sewardiana* only female flowers are known. Male flowers of *Williamsonia,* however, have been described under different species. The female flowers in *W. sewardiana* are borne terminally on the short lateral shoots.

Female Flowers: The female flowers of *Williamsonia sewardiana* and *W. gigas* (Fig.4.6. A,B) possess a prominent conical or pyramidal receptacle surrouded by simple perianth-like bracts with many ramenta. Placed on the receptacle in close spiral are the stalked ovules intermingled with sterile interseminal scales. The tip of the receptacle is generally naked. There is a general resemblance of the flower of *Williamsonia* with that of *Magnolia* of the angiosperms. The ovule placed on a rather elongated stalk is with the nucellus fused with the integument. The interseminal scales are with fleshy expanded tips that are tight fitted forming a protective covering with numerous small pores through which the micropyles of the ovules project outside. The interseminal scales are usually considered as homologous to the stalked ovules. *Williamsonia scotia, W. indica* and *W. mexicana* are some of the other female flowers of this genus. The seeds of *Williamsonia* are dicotyledonous and endospermic.

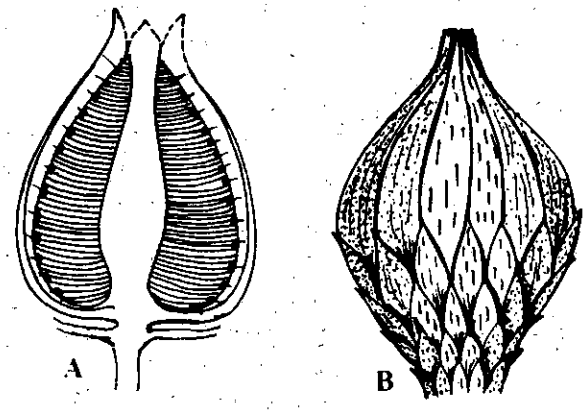

Fig. 4.6. *Williamsonia gigas.* A.L.S.of Ovuliferous flower of *Williamsonia gigas.* B.A. floral bud of the same

Male flowers: *Williamsonia* includes many species based on male flowers,the important ones of which are *W. spectabilis* and *W. whitibiensis.* There is another significant species *W. santalensis* described from the Rajmahal hills of Bihar in India by **Sitholey** and **Bose** (1953). This is now called however as *Weltrichia santalensis* (fig 4.5 D). In *Williamsonia spectabilis* (Fig 4.5 C) the flowers are stalked. There is a whorl of microsporophylls which are more or less united basally to form a cup. The microsporophylls in this species are somewhat pinnately branched structures with two rows of synangia on each branch. In *Williamsonia whitibiensis* the male flowers are sterile and synangia are borne in two rows directly on the adaxial (inner) surfaces of the microsporophylls. The microsporophylls as in *W. spectabilis* are united proximally to form a basal cup.

Finally it may be interesting to note that among the various cycadeoidean families it is only the Williamsoniaceae that is found abundantly in the Indian Jurassic- Lower Cretaceous deposits. This family constitutes one of the dominant elements of the Jurassic-Lower Cretaceous flora of the Indian subcontinent.

Check Your Progress - 4

To which part of the plant the name *Williamsonia* was applied for the first time?

Note : (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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4.5. SUMMARY

The gymnosperms have extensive fossil history. This unit deals with two important fossil gymnosperms,Viz., *Lyginopteris* referrable to Pteridospermales and *Williamsonia,* to Cycadeoidales.

The slender stem of *Lyginopteris* is eustelic with a ring of mesarch vascular bundles. The outer cortex of the stem is with a charachteristic net work of fibres, which in cross section resembles Roman Numerals. The leaves known as *Sphenopteris hoeninghausii* in detached condition, are large frond-like with pinnules irregularly lobed and dichotomously veined. The seeds (ovules) designated as *Lagenostoma* are small, radially symmetrical, cupulate and a with

characteristic pollen chamber. The pollen bearing organs known as *Crossotheca* are pinnate structures with abaxial pendant microsporangia.

Williamsonia shows a columnar or sparsely branched trunk. The main trunk and the branches possess a crown of pinnately compound leaves, known as *Ptilophyllum* in detached condition. The stem is eustelic and the wood is pycnoxylic. The reproductive structures are unisexual. The female flowers possess a prominent receptacle on which are borne the ovules and interseminal scales. At the base of the receptacle is a whorl of bracts. The male flowers bear a whorl of pinnately branched or simple microsporophylls fused proximally.

4.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The cortex of the stem of *Lyginopteris* is divisible into outer cortex and inner cortex. The outer cortex consists of vertical network of anastomosing fibres with thin walled parenchyma in the lumina of meshes. Such type of cortex is called dictyoxylon cortex.
2. The pith of the stem of *Lyginoptreris* consists of thin walled parenchymatous cells. The cells are intermingled with groups of thick walled cells called sclerotic nests.
3. The nucellus in the ovule of *Lyginopteris* projects like a flask shaped structure into the micropyle. This is called Lagenostome.
4. To the flowers in detached condition the name *Williamsonia* was originally applied.

4.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give an account of the vegetative and reproductive features of *Lyginopteris*.
2. Write a detailed account on *Williamsonia*.

II. Answer the following questions in about 10 lines each.

1. Write briefly about *Lagenostoma*.
2. Give a brief account of *Crossotheca*.
3. Write a detailed account on *Ptilophyllum*.
4. Write briefly about *Williamsonia*.
5. Write a brief accont on the order *Bennettitales*.
6. Give a brief account on the order *Pteridospermales*.

4.8. GLOSSARY

Aperture	: A thin area in the exine of the spore or pollen grain.
Carboniferous	: Ecological period (after Devonian period) of the Palaeozoic Era.
Compression	: The compressed remains of the plants of the past, possessing thin carbonaceous films of the original organic matter.
Cretaceous	: The youngest geological period of the Mesozoic Era.
Devonian	: A geological period of the Palaeozoic Era.
Distal facet	: The side of the pollen grain away from the centre of the tetrad.

Eustele	: An advanced type of stele found in seed plants,consisting of a number of conjoint, collateral and open vascular bundles surrounding a central pith.
Fossils	: The remains of organisms of the past, may be of plants or animals, preserved in the earth's crust by natural agencies.
Impression	: An imprint of the original plant material preserved in the sediments, where there are no traces of organic matter.
Mesozoic Era	: A major division of the geological time scale younger to the Palaeozoic Era.
Palaeozoic Era	: An earlier major division of the geological time scale.
Permian	: The uppermost geological period of the Palaeozoic Era.
Petrifaction	: A structurally preserved fossil.
Sulcus	: A longitudinal furrow on the distal facet of the pollen grain.
Triassic	: The lowermost geological period of the Mesozoic Era.

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BLOCK - II

PLANT ANATOMY

UNIT - 5 : THE CELL WALL

Contents

5.1. OBJECTIVES

By the end of this unit you will be able to :

1. draw the structure and label the various parts of the cell wall,
2. list out the general and specialised components of cell wall,
3. describe the orientation of microfibrils, growth of the cell wall, intercellular spaces, plasmodesmata and pits and
4. describe the process of the formation of the cell wall.

5.2. INTRODUCTION

Plant anatomy (ana=as under; temnein= to cut) is a branch of botany dealing with the structure and oraganization of the plants. It is also known as **Internal Morphology**. Though recent in origin compared to morphology and taxonomy,evidences exist to show that ancient Hindus and Greeks had some knowledge of this subject. Indians distinguish five parts in the plant body viz,. **tvac** (skin), **mansa** (soft tissues) **asthi** (wood or bone), **majja** (pith) and **snayu** (fibres in the bast). Among the Greeks, Theophrastus (371-285 B.C), a pupil of Aristotle (384-322 B.C.) is considered to be the father of botany and plant anatomy in particular.

Real progress in plant anatomy started only with the invention of miocroscope. As early as 1665, Robert Hooke examined a piece of bottle cork under a crude microscope and noted the cells and their pattern. Later on, Nehemiah Grew (1641-1712) and Marcello Malphigi (1628-1694) conducted many investigations on plant anatomy. Grew introduced common terms like parenchyma, vessels, cortex etc. Malphigi discovered spiral vessels and stomata. Not

much progress was made in the next century. Again in the nineteenth century interest in plant anatomy gained momentum by the studies of Mirbel (1776-1854), Sprengel (1766-1833) and others. Around the same time valuable information about the structure of cell could be provided by Robert Brown (1773-1858). Hugo von Mohl (1805-1872), Schleiden (1804-1881) and Schwann (1810-1882).

Hugo von Mohl carried on many investigations in the field of plant anatomy and explained nature and formation of vessels, structure of the epidermis, cork, bark and lenticels and also traced the course of vascular bundles in stems and roots. Carl von Nageli (1817-1891) who introduced the terms xylem and phloem also contributed to our understanding of the primary and secondary meristems and types of vascular bundles.

De Bary, Solereder and Heberlandt were the prominent anatomists of the early decades of this century. The more recent workers include, I.W.Bailey, Cheadle, Faster, Metcalfe, Esau, Fahn and B.G.L. Swamy, who have enriched this field with their critical and valuable contributions.

Unlike the animal cells,plant cells are generally characterized by the presence of a non protoplasmic cell wall.

The cell wall gives the shape and determines the texture. It provides the supportive and protective function and helps the aerial parts of the land plants to overcome the stresses of gravitational forces and desiccation. The cell wall also plays a role in absorption, transpiration, translocation and secretion.

During recent years, studies on the cell wall structure gained importance because of the many industrial uses of cellulose and its derivatives. New techniques such as polarized light, X-rays and electron microscopy have helped us to learn the details of the cell wall.

5.3. CLASSIFICATION OF WALL LAYERS

Three principal layers are found in the plant cell wall : (1) The **middle lamella** or the intercellular space, (2) the **Primary wall** and (3) the **secondary wall.**

5.3.1. Middle Lamella

It is the cementing material which usually binds the two adjacent cells in a tissue (Fig. 5.1 &5.2).It is therefore, present between two primary walls of neighbouring cells. It consists

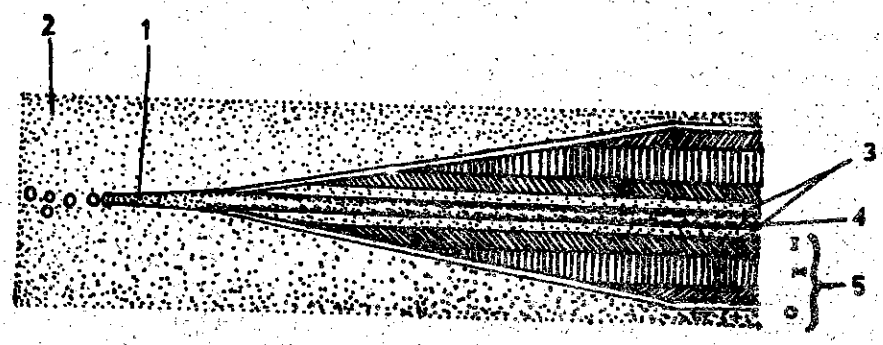

Fig. 5.1. Formation of cell wall showing origin of cell plates, its transformation into middle lamella and deposition of Primary and secondary wall. I. Inner secondary wall. M. Middle secondary wall. O. Outer secondary wall. 1. Cell plate. 2. Cytoplasm. 3. Primary wall. 4. Middle lamella. 5. Secondary wall.

of colloidal matter that is amorphous and optically inactive (isotropic). It is composed of pectic substances and usually impregnated with calcium and magnesium. In wood,the middle lamella is also lignified. The middle lamella is not termed as a wall but intercellular substance.

5.3.2. Primary Wall

As the name implies, it is the first formed wall by the cell (Fig.5.1 & 5.2) and in many types of cells, it is the only wall that occurs. It is composed of celluloses, hemicelluloses and other polysaccharides. Cellulosic content makes the wall optically anisotropic. Sometimes the primary wall is composed of alternate layers of cellulose and pectins as in the walls of epidermal cells.

Primary walls are normally associated with living contents. They are mostly seen in the growing meristematic cells and other tissues which show physiological activities. Therefore, in some tissues, seasonal fluctuations may be witnessed in the thickness of the primary walls e.g. cambium.

The primary wall formation is initiated much before the cell enlargement. Hence, the primary wall undergoes surface growth as well as increase in thickness.

5.3.3. Secondary Wall

This is formed inside to the primary wall facing the cell lumen (Fig. 5.1 & 5.2). It appears usually after the cell ceases to grow. Hence, surface growth is normally absent in it.

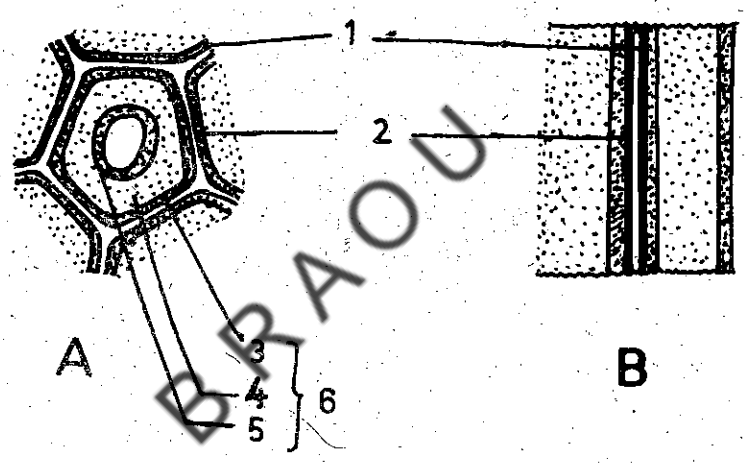

Fig. 5.2. Cell wall. A. Diagram showing three layers of secondary wall in T. S. B. Longitudinal view. 1. Middle lamella. 2. Primary wall. 3. Outer, 4. Middle 5. and Inner 6. layers of Secondary wall respectively.

The secondary wall is composed of cellulose, hemicelluloses and lignin. Because of high cellulosic content, it is strongly anisotropic. Hemicelluloses are less in the secondary wall when compared to the primary wall. The secondary wall is a complex one and is made up of three layers, the outer (S_1), central (S_2) and inner (S_3) layers (Fig 5.1 & 5.3). Of these ,the central one is the thickest. Sometimes,a new term-tertiary wall or terminal layer is applied to the inner layer (S_3). The tertiary wall (S_3) also differs from the other layers of the secondary wall in its chemical composition. The S_3 layer is covered by a noncellulosic film often with lumps called warts and known as warty layer. This may be formed by the remnants of a disorganised protoplast e.g., conifer tracheids and fibres and vessels of many dicotyledons.

The secondary wall provides mechanical strength to the plant body and is usually associated with non-living tissues at maturity. It is also characteristically found in cells which undergo irreversible changes in their development.

5.4. COMPONENTS AND STRUCTURE OF THE CELL WALL

Usually cell wall components are, celluloses, hemicelluloses, pectin, lignin, suberin, cutin, proteins etc. The proportions of these substances differ from species to species. Of these, the architecture of the cell wall is mainly based on cellulose. It is a polysaccharide with linear chains

of glucose $[(C_6H_{10}O_5)_n]$.*In* the cell wall, cellulose forms the frame work interpenetrated by the **matrix** representing the noncellulosic substances (e.g. lignin).

An electron microscopic study reveals that the cellulose consists of many fine strands or bundles known as **microfibrils**. Microfibrils are combined to form macrofibrils which are also visible under light microscope. An orderly arrangement of cellulose molecules (in chains) in a microfibril imparts a **crystalline structure** to it. These crystalline aggregates or bundles in a microfibril are considered as **micelles** or **crystallites**.

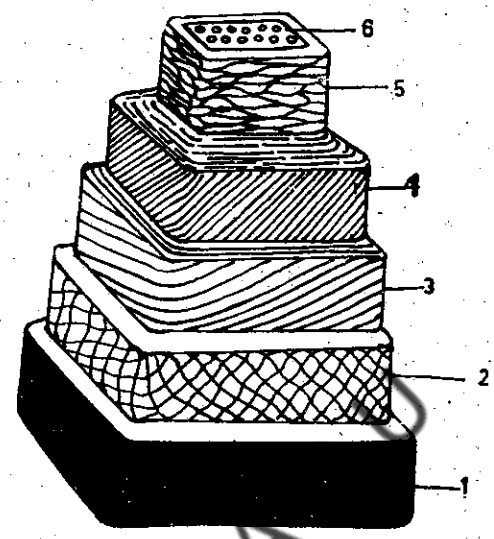

Fig. 5.3. Diagram of a piece of tracheid wall illustrating layers and microfibrillar organisation.
1. Middle lamella. 2. Primary wall. 3. S_1 layer. 4. S_2 layer. 5. S_3 layer. 6. Warty layer.

The spaces among the micellar strands constitute intermicellar spaces. Thus the microfibrillar system of cellulose is interprenetrated by a system of intermicellar spaces (capillaries) of various sizes. These capillaries are filled with noncellulosic substances and water as mentioned earlier. Though these capillaries are filled with these materials, other substances can still pass through them, thus rendering the cell wall porous.

5.4.1. Orientation of Microfibrils

In the cell wall, orientation of microfibrils is in various ways. In the primary wall the microfibrils are randomly oriented transverse to the long axis in the first instance subsequently becoming longitudinally inclined as the primary wall starts growing. In the secondary wall, separation of three S layers is mainly based on the orientation of the microfibrils. The helix of microfibrils is lax and nearly horizontal in S_1 and S_3, and steep in S_2 (Fig. 5.3), which is the thickest. The primary wall differs from the secondary wall by possessing random orientation of the microfibrils. The chemical composition of these layers also differs.

5.4.2. Specialized Cell Wall Components

The fatty substance cutin is associated with epidermal cells and forms the cuticle. Similarly, suberin -another fatty substance is associated with cork (see unit -9) and also with the endodermis of the roots forming the casparian strips and the basal cells of some secretory trichomes.

5.4.3. Growth of the Cell Wall

Two theories have been proposed to explain the wall growth in thickness. They are 1. **Intussusception** and 2. **Apposition**. In intussusception, new microfibrils are supposed to be laid down between the existing ones (Fig 5.4A) and in apposition new microfibrils are supposed to be laid down over the existing ones leading to the formation of a new layer (Fig 5.4B).

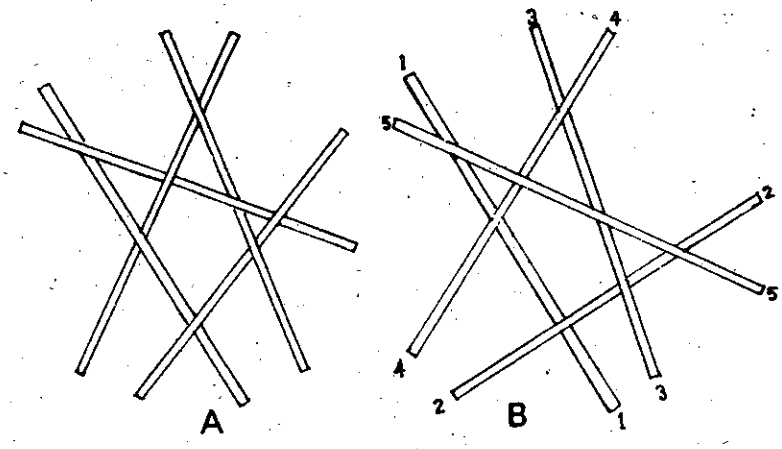

Fig. 5.4. Microfibrils in a primary cell wall. Diagrams showing growth by intussusception (A) and apposition (B). The First formed fibril is 1 the second is 2 etc.

Presently, it is considered that growth in thikness is mainly through apposition,though some growth is also possible through intussusception. The longitudinal growth is due to the stretching of the microfibrils parallel to the long axis of the cell concerned.

Check Your Progress - 1

What are the two theories that are proposed to expalin the growth of the wall thickness? Describe them.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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5.4.4. Intercellular Spaces

There is a well organised intercellular space system in the plant body and it is characteristic of the mature tissues, e.g. mesophyll of the leaves, and submerged organs of water plants. Intercellular spaces arise by one of the two methods. 1. **Schizogeny** (schizo =split) (Fig. 5.5. A): In this method separation of the middle lamella starts at a corner where two or more cells are together, most probably by the enzymic action. e.g., Resin ducts of **pinus** 2. ***Lysigeny*** (lysis =loosening) (Fig 5.5.B): This method involves the complete break down of the cells (arising by dissolution) to form the intercellular spaces e.g. secretory cavities of *Citrus* and *Gossypium*.

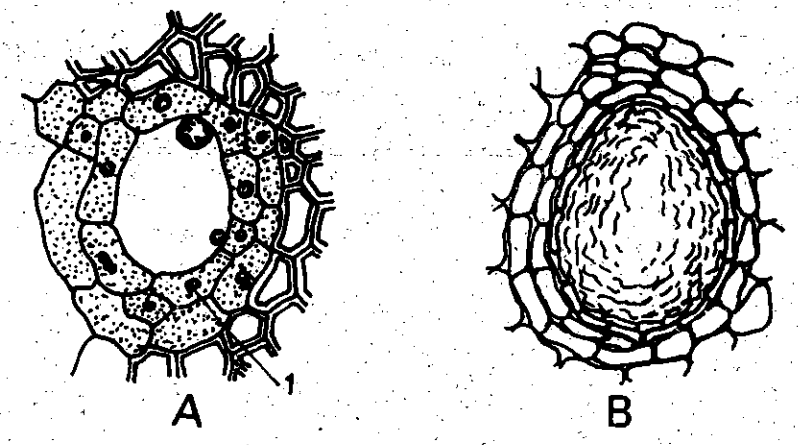

Fig. 5.5. Specialised intercellular spaces. A. Resin duct of *pinus* (schizogenous). B. Oil-cavity of Citrus fruit (lysigenous) 1. Epithelial cell.

Check Your Progress -2

Describe the two methods with regard to the formation of the intercellular spaces with examples.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one give at the end.

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5.4.5. Plasmodesmata

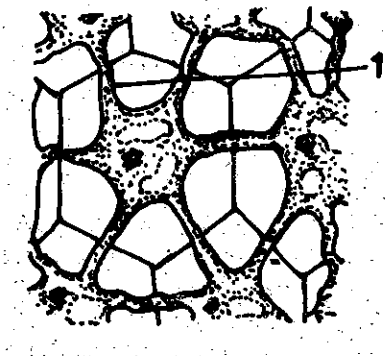

Fig. 5.6. Plasmodesmata in the cells of endosperm of seed of *Phoenix* (date palm). 1. *Plasmodesmata.*

The cytoplasm of the adjacent cells is connected by thin strands known as plasmodesmata which run across the cells at intervals. They also pass through thick cell walls of the endosperm of certain seeds of date, coffee etc. (Fig. 5.6). The plasmodesmata, characteristic of the living protoplasts, act as channels for transport of substances and relay of stimuli.

5.4.6. Primary Pit Fields

Though the primary walls of the young cells grow in surface area and thickness, certain areas of them remain thin. These thin areas form depressions termed primary pit fields or simply primary pits (Fig. 5.7). Plasmodesmata usually traverse through the primary pit fields Pits of the secondary wall are normally formed over the primary pit field.

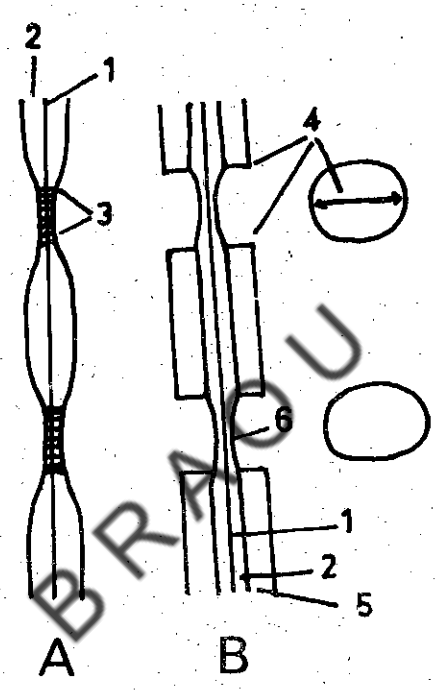

Fig. 5.7. Primary Pit-fields and pits. A. Primary pit fields. B. Pits. 1. Middle lamella. 2. Primary wall. 3. Primary Pit - field with plasmodesmata. 4. Pit aperture. 5. Secondary wall. 6. Pit membrane.

5.4.7. Pits

Pits are characteristic of the secondary wall. They correspond to the interruptions in the secondary wall where secondary wall material is not laid down over the primary wall (fig.5.8 A-F). A pit consists of **pit cavity** (cavity formed by the break in secondary wall) and **pit** (closing) **membrane** (which comprises the middle lamella and a thin layer of primary wall). The opening of the pit towards the cell lumen is termed **pit aperture** (Fig. 5.8B & C). Normally, a pit has a corresponding pit exactly opposite to it in the wall of the neighbouring cell. This results in the formation of a **pit-pair** which is a structural and functional unit (Fig. 5.8. C).

Pits are of two types: **Bordered pits and Simple pits.** In bordered pits the secondary wall forms an overarching roof on the pit cavity with a central narrow pore (Fig. 5.8 C & G)e.g. Tracheary elements and fibre tracheids. In simple pits no such overarching of the secondary wall is present (Fig. 5.8.A) e.g. thick walled parenchyma, libriform fibres and sclereids.

If two simple pits form a pair, it is a **simple pit-pair** (Fig. 5.8 B). Instead, if two bordered pits form a pair it is a **bordered pit-pair** (Fig.5.8 C). A half bordered **pit-pair** results if the pit

on one side is bordered and the other side simple (Fig. 5.8. D). When the complementary pit is absent in the adjacent wall, it is termed as **blind pit** (Fig. 5.8 E & F).

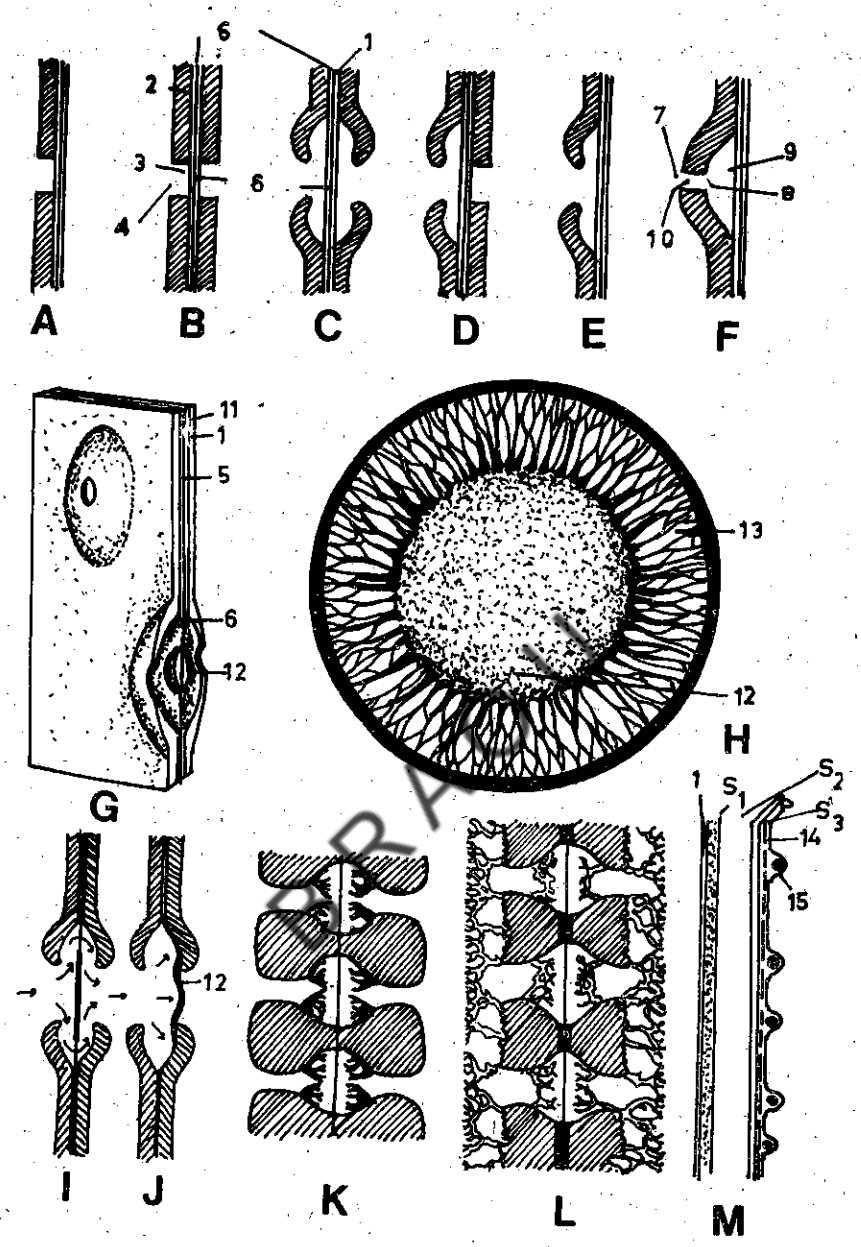

Fig. 5.8. Structure of pits. A. Simple pit. B. Simple pit pair. C. Bordered pit pair. D. Half bordered pit pair. E,F. Blind pits. G. Three dimensional diagram of a portion of the adjacent walls of two tracheids showing the perforations in the membrane. H. Pit membrane and torus of *Pinus*. I,J. L.S. of the wall of adjacent vessels with vestured pits. K. Diagram of wall section showing a warty layer. 1. Primary wall. 2. Secondary wall. 3. Pit aperture. 4. Pit cavity. 5. Middle lamella. 6. Pit membrane 7. Inner aperture. 8. Outer aperture. 9. Pit chamber. 10. Pit canal. 11. Torus. 12. Margo. 13. Plasmalemma. 14. Tonoplast. 15. Wart.

Bordered pits are more complicated than the simple pits and variously shaped. The secondary wall is very thick and it forms a **pit canal** between the pit chamber and cell lumen (fig. 5.8F). Then the pit canal has an **outer aperture** facing pit chamber and an **inner aperture** facing cell lumen (Fig 5.8 F).

In some bordered pits, the pit membrane (primary wall) in its central portion shows a disc-shaped thickening termed **torus** (Fig 5.8 G) and the surrounding portion of the membrane is called **margo.** The margo consists of microfibrils radiating from the torus (Fig. 5.8 H). The margo being flexible,under certain conditions of stress moves towards one or the other side of the border resulting in the closure of the aperture by the torus (Fig 5.8 I & J).

The bordered pits of many Coniferales and Gnetales are characterized by the presence of distinct torus which is rare in angiosperms.

Certain dicotyledons (e.g., Fabaceae, Brassicaceae, Myrtaceae and Caprifoliaceae) are characterized by the presence of bordered pits with projections from the overhanging secondary wall on the side facing the cavity. Thy are termed vestured pits (Fig 5.8 K & L).

Check Your Progress - 3

What is the difference between the simple pit & bordered pit?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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5.5. FORMATION OF THE WALL

At the time of cell division, the two daughter nuclei are separated by the formation of a cell plate. It is formed by the fusion of vesicles derived from the golgi bodies on the equatorial plane of the **phragmoplast** (Fig 5.9 A).

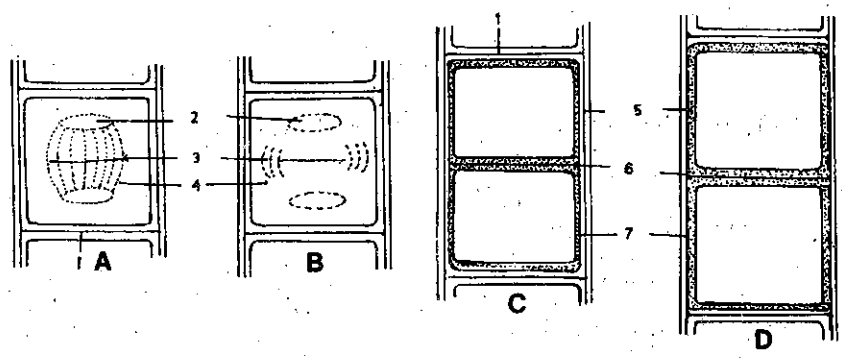

Fig. 5.9. Formation of wall during cell division. A. Formation of cell plate in the equatorial plane of phragmoplast at telophase. B. Phragmoplast appears along the margin of the circular cell plate. C. Each sister cell with its own primary wall. D. Enlarged sister cells. 1. Middle lamella. 2. Nucleus. 3. Cell Plate. 4. Phragmoplast. 5. Wall of mother cell. 6. New middle lamella. 7. Wall of daughter cell.

Initially, the cell plate is formed inside the phragmoplast and in that region, the phragmoplast becomes invisible but regenerated at the free margins of the cell plate to extend laterally until it joins the mother cell walls. Ultimately the cell plate becomes the middle lamella with pectic substances and it is destined to form the cell wall by the deposition of additional wall material on either side (Fig 5.9 C & D).

5.6. SUMMARY

The plant cell wall is made up of cellulose, hemicellulose, hemicellulose, pectin, lignin, suberin and proteins. The neighbouring cells are bound together by a middle lammella, a cementing substance of pectates of Calcium and Magnesium.

The primary wall is associated with living protoplasts. The secondary wall seen in non-living tissues is generally differentiated into three descrete layers, the S_1, S_2 and S_3 layers of varying orientation of microfibrils. Local depressions known as primary pit fields are seen on the primary walls and simple and bordered pits of various kinds are seen on the secondary walls.

5.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Intussusception and apposition are the 2 theories that are applied to explain the growth of the wall in thickness. In intussusception new microfibrils are laid down in between the existing ones whereas in Apposition they are laid down over the existing ones.

2. The intercellular spaces are formed by schizogeny and lysigeny. In schizogeny the intercellular space is formed due to the separation of the middle lamella present in between the cells due to the hormonal action. e.g., resin ducts of *Pinus*. In lysigeny they are formed due the complete breakdown of the cells e.g., secretory cavities of *Citrus* and *Gossypium*.

3. The secondary wall forms an overarching roof on the pit cavity with a central narrow pore in bordered pits and no such overarching is seen in simple pits.

5.8. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write a critical account on the plant cell wall layers.
2. What are the various cell wall components ? How are they involved in the structure of the cell wall ?
3. Give an account of various types of pits encountered in the plant cell wall.

II. Answer the following questions in about 10 lines each.

1. Write briefly about primary wall.
2. Write breifly about secondary wall.
3. Give a brief account of Pits.
4. Write briefly about the formation of the cell wall.

UNIT - 6 : MERISTEMS

Contents

6.1. OBJECTIVES

By the end of the unit you will be able to:

1. define the terms meristems, promeristem, protoderm, procambium, ground meristem, mass meristem, rib meristem and plate meristem,
2. differentiate the primary growth & secondary growth,
3. list out the cytological characteristics of the meristematic cells,
4. differentiate the apical, intercalary and lateral meristems,
5. describe various theories and concepts of apical organisation and
6. list out the differences between the stem apex and root apex.

6.2. INTRODUCTION

During the embryonic stages of plant body, all the cells undergo division. But at the time of further growth, addition of new cells through embryonic tissues is restricted to certain parts of the plant body. These persisting embryonic tissues are termed as **meristems**. The meristematic tissue shows repeated cell divisions throughout the life of the plant. To emphasise this special feature the tissue is so named (Greek: meristos = divisible). Some examples of meristems are apices of stem and root, leaf primordia and vascular cambium.

The derivatives of the meristems get transformed gradually into permanent tissues. Nowadays, the term permanent element is used only with reference to sieve elements, tracheids, vessel elements and cork cells which underwent an irreversible differentiation. The initial growth of the successively formed roots and vegetative and reproductive shoots by their respective meristems is commonly termed as '**primary growth**' of the plant body. Many vascular cryptogams and monocotyledons consist only of primary plant body e.g. paddy. On the other hand, most of the gymnosperms and dicotylendons show an increase in thickness of stem and root by the activity of the vascular cambium or cork cambium. This constitutes the '**secondary growth**' of the plant body. The tissues formed by the vascular cambium and cork cambium are referred to as 'secondary tissues'. e.g. wood, bark.

6.3. CYTOLOGICAL CHARACTERISTICS

The meristematic cells are usually thin-walled, isodiametric, with dense cytoplasm, conspicuous nuclei and small vacuoles (Fig.6.1.A). They are, as a rule, devoid of ergastic substances. This type of meristem is termed as **'eumeristem'** (true meristem) for descriptive purposes. However, there is certain degree of variation among the structure of meristems of different plant groups. For example, cambial initials have thick primary walls with conspicuous primary pit fields. Similarly, highly vacuolated cells are seen in some cryptogams and gymnosperms and also in vascular cambium and plant hair cells (Figs. 6.1 B & C). It is found that vacuolization increases corresponding to the increase in the size of meristematic cell. Further, it is not always possible to determine the meristematic nature of cells. For this, experimental evidence obtained through induced polyploidy (by the use of **colchicine** -c-mitosis) and growing apices *in vitro* is necessary.

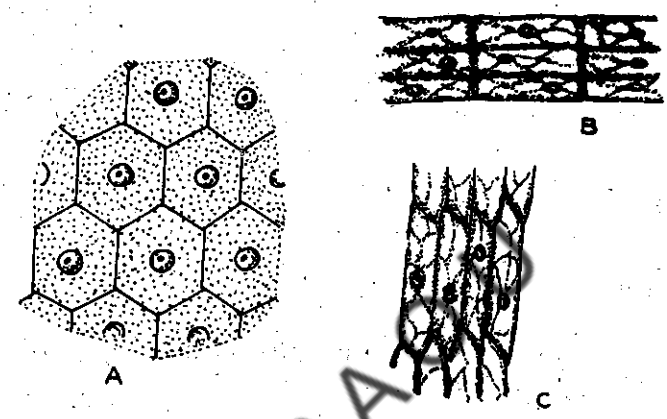

Fig. 6.1. Meristematic cells. A. Typical meristematic cells. B. Cambium cells in T.S. C. same in L.S.

6.4. CLASSIFICATION OF MERISTEMS

Meristems are classified on the basis of their position (topography), origin, stage of development, function etc.

On the basis of their position of the plant body, the meristems are categorized into three groups (Fig.6.2). a) **Apical meristems:** Found in the terminal parts of the growing shoots and roots; b) **Intercalary meristems:** Found intercalated between the permanent tissues e.g. internodes and leaf sheaths of grasses, *Equisetum* etc., c) **Lateral meristems:** Found parallel to the long axis of the organ in which they are seen e.g., vascular and cork cambia.

When the nature of originating cells is considered, the meristems are designated as **primary** and **secondary**. Accordingly, whenever the embryonic cells are directly involved, the meristem is primary while the secondary meristem is the one which develops from mature cells (those already underwent differentiation)e.g. Interfascicular cambium. However, this classification is no longer popular as it is not accurate. For example, it is difficult to place the vascular cambium in these two categories as it develops from the apical meristem and functions belatedly. Therefore, the primary meristems and secondary meristems are used in connection with the relative time of origin of the meristem. If they are correlated with the classification based on position, the primary meristem corresponds to apical meristem and the secondary to lateral meristem.

In the shoot and root apices, it is possible to recognise different regions in various stages of differentiation. The term '**promeristem**' is applied to initiating cells(apical initials) and their most recent derivatives. Promeristem is also known as **primordial meristem, urmeristem** or **embryonic meristem.** A little away from the promeristem lies partly differentiated meristematic zone consisting of three meristems: 1. **protoderm**, which forms the epidermal tissue system. 2. **procambium**, which forms the primary vascular tissue system (primary xylem and phloem) and 3. **ground meristem**, which forms the ground or fundamental tissue system (cortex and pith). The initials of the meristems continuously divide and one of the resultant daughter cells continues to act as an initial similar to the parent cell while the other one differentiates and matures into a specific element of the various tissue systems.

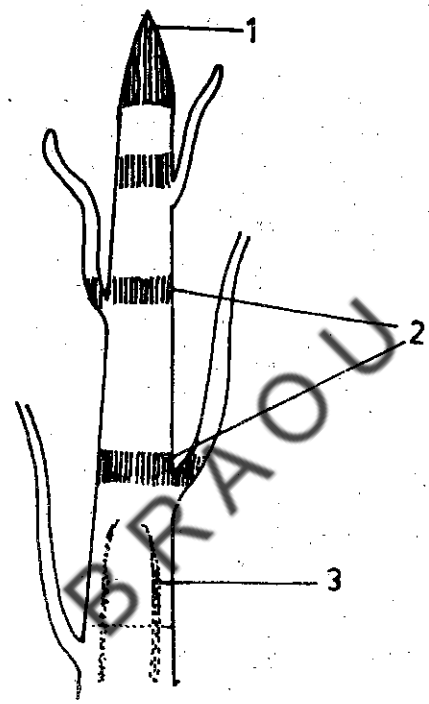

Fig. 6.2. Positions of meristems in the L.S. of a shoot. 1. Apical meristem. 2. Intercalary meristem. 3. Lateral meristem.

Based upon the plane of cell division, the meristems are also referred to as (a) **mass meristem** or **block meristem**, (b) **rib meristem** or **file meristem** and (c) **plate meristem.** The mass meristem grows by divisions in all planes and produces either isodiametric or spheroidal cells or products with no definite shape. e.g., spores, sperms, endosperm and embryos. The rib meristem divides by divisions perpendicular to the longitudinal axis of the plant organ resulting in parallel longitudinal rows of cells in cylindrical plant parts. e.g., cortex and pith of stem and cortex of root. The plate meristem divides mostly by anticlinal divisions (divisions perpendicular to the surface) resulting in surface growth as in leaf blades of angiosperms and epidermis in particular.

Check Your Progress - 1

What are the different meristems that are recognised depending upon their positions in the plant body.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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6.4.1. Apical Meristems

In higher algae, this meristematic activity is restricted to the terminal cell of the filament. Such a cell is called **apical** cell. Growth by apical cell also takes place in the bryophytes and pteridophytes. However, in higher plants viz., gymnosperms and angiosperms, growth takes place by a group of initials and their immediate derivatives (**protomeristem**, according to Esau, 1965). More often than not, the term **apical meristem** is used to refer to these initials and their immediate derivatives. The terms **shoot apex** and **root apex** are used as synonyms of apical meristem. Usually the part just above the youngest leaf primordium in a shoot apex is considered as apical meristem (Esau, 1965).

6.4.2. Theories and Concept of Apical Organization

Wolff (1759) recognised for the first time that the shoot apex was responsible for the growth of plant body. Since then, it has attracted the attention of several workers in the last two centuries. Initially efforts were made to learn about the number of initials involved in the meristem. later researchers tried to know problems concerning cyto-histological division of the apex into zones and cellular activities of the various zones.

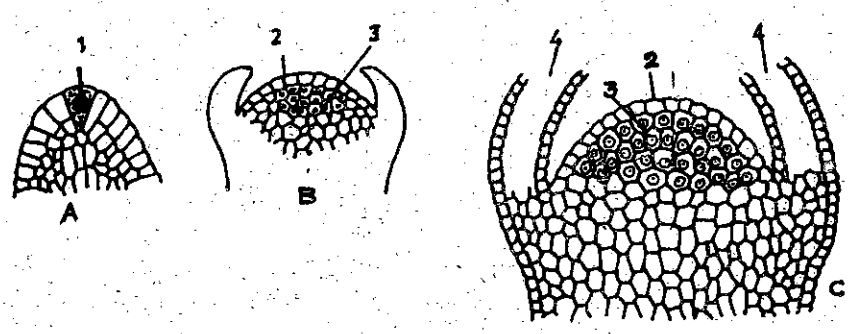

Fig. 6.3. Apical meristems. A. Apical cell in a pteridophyte. B, C. Tunica and corpus layers. 1. Apical cell. 2. Tunica. 3. Corpus. 4. Leaf.

In the past, work on cryptogams led to the belief that single apical cell acts as a structural and functional unit of the apical meristem (Fig.6.3 A). Based on this assumption, Nageli (1878) proposed **apical cell theory**. It was considered that apical cell is ultimately responsible for the total growth of plant by constant division. Around the same time, Hanstein (1868) proposed **'Histogen Theory'** after studying several angiosperm shoot apices and embryos. He conceived that the plant body develops from a mass of meristematic cells even quite away from the apex and it consists of three main parts of **Histogens** (Fig. 6.4 & 6.5.). Hanstein stated that they

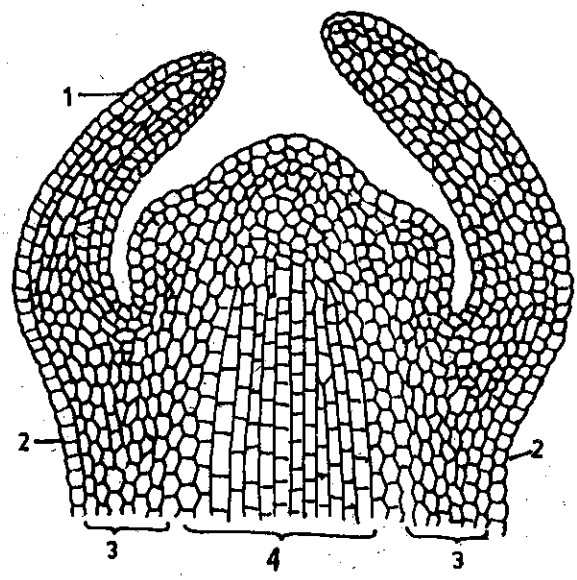

Fig. 6.4. Stem apex in median L.S. 1. Young leaf. 2. Dermatogen. 3. Periblem. 4. Plerome.

develop from independent groups of initials. The three histogens (tissue builders) are: 1. **dermatogen** 2. **periblem** and 3. **plerome** which give rise to the epidermis, cortex and the stelar region of the axis respectively.

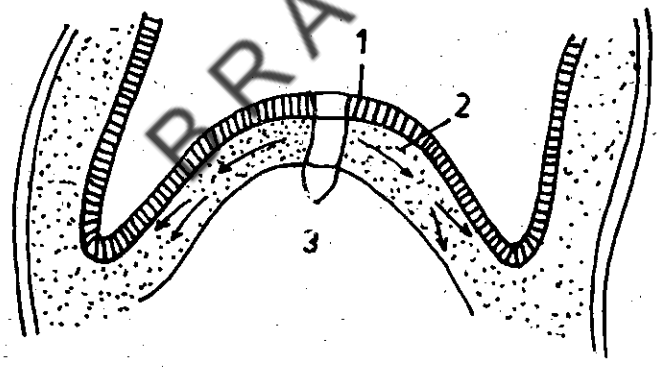

Fig. 6.5. Diagram of shoot apex according to Hanstein's interpretation. 1. Dermatogen. 2. Periblem. 3. Plerome.

For a long time Hanstein's theory found acceptance. However, later research showed that these histogens could not be well established in the shoot apex. There are two objections against this theory. 1. In the higher plants (spermatophytes), it is not possible to demarcate periblem and plerome. 2. No predetermination of the future tissues can be traced to the initials of the apical meristem.

Schimdt (1924) proposed **'tunica-corpus theory'** based mainly on the planes of cell division in the apical meristem. The meristem is divisible into two discrete zones: 1. the outer **tunica**, which consists essentialy of one or more layers (Fig. 6.6) and 2. **Corpus**, consisting of the zone inner to the tunica (Fig.6.3 B & C). The cells of the tunica show always anticlinal divisions resulting in the surface growth. The corpus cells show divisions in all planes; this leads to growth in volume. The number of layers of tunica is usually one or two.

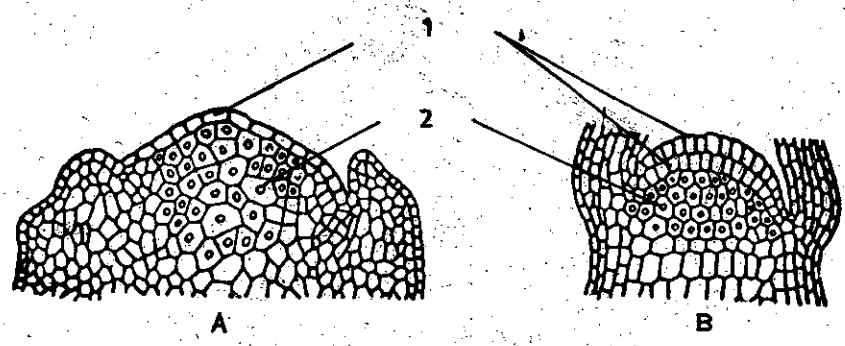

Fig. 6.6. L.S. of shoot apex. A. one layered tunica. B. Two layered tunica. 1. Tunica. 2. Corpus.

Each layer of tunica arises from a small group of initials. Similarly, the corpus also has its own initials. Therefore, tiers of initials could be expressed as equal to the number of layers of tunica plus one (initials of corpus tier).

Among the lower vascular plants, the tunica-corpus differentiation is not seen in the shoot apex. e.g. *Lycopodium, Selaginella, Pteridium.* In the gymnosperms, this concept is found to be unsuitable. The tunica-corpus concept, however is accepted more or less universally for the shoot apex of the angiosperms.

Check Your Progress - 2

Describe the Histogen Theory.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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6.4.3. Root Apex

The root apex is different from the stem apex in many respects (Fig.6.7). They are as follows:

1. Nodal and internodal differentiation is absent and the root apex grows more uniformly than the stem apex.
2. As the leaf primordia are also absent in the root apex there are no periodical changes in shape and structure of the root apex.
3. Branch primordia are absent.

4. **Lateral roots** arise a little away from the apex and they are endogenous in origin (from the pericycle).

5. Root cap is present and it makes the root apex sub-terminal in position.

6. Growth in the form of new cell formation in the root apex is bidirectional i.e. cells are formed towards the axis and also away from it for the root cap.

7. The elongating root apex is characteristic of rib-meristem type of growth.

8. The apical meristematic tissue is limited.

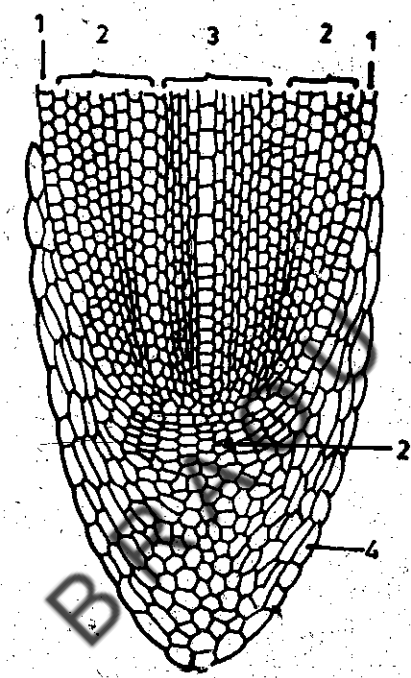

Fig. 6.7. Root apex in L.S. 1. Dermatogen. 2. Periblem. 3. Plerome. 4. Calyptrogen. 5. Root cap.

In the root apex, the number of initials ranges from one to many. Wherever they are more than one, they are organised into one to four fairly distinct uniseriate groups (Fig .6.8). Further, in each group one to many initials are present. Though, it is now established that the histogens are not clearly recognizable in the shoot apex, Hanstein's histogen concept, however, is still widely used in our understanding of the root apex. The young roots show more or less clear separation of **dermatogen** (outer part), **periblem** (middle part) and **plerome** (central cylinder) (Fig.6.7). The details of the organization of the root apex in the vascular plants is presented below.

Among the lower vascular plants, e.g., *Selaginella, Equisetum* and in some Ferns, the entire root develops from a single apical cell (in the Marattiaceae the root develops from few initials), The single apical cell is usually tetrahedral and it cuts of cells on four faces and produces the various tissues of the root cap e.g. *Marselia* (Fig.6.8.A).

In many gymnosperms, two sets of initials are present, the inner giving rise to the central cylinder and the outer to the cortex and root cap. A little away from the tip, the outer most layer differentiates into epiblem. A similar organization of the root apex is also witnessed in some of the angiosperms e.g. *Casuarina* (Fig.6.8C).

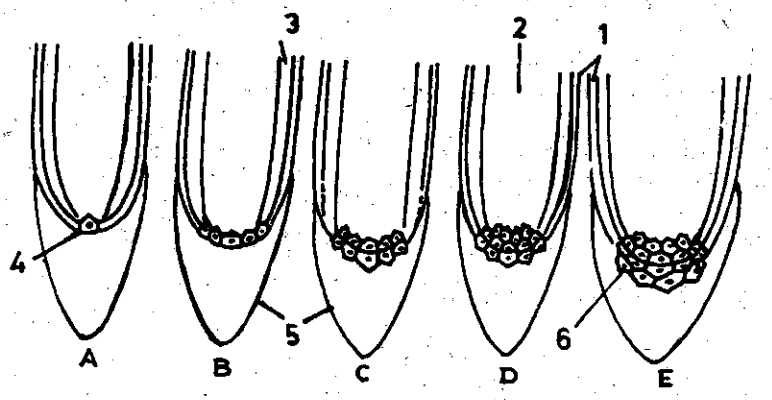

Fig. 6.8. Types of root tips. A. Type found in pteridophytes with solitary apical cell. B. Ranalian type. C. *Casuarina type*. D. Typical dicot type. E. Maize type. 1. Epiblem. 2. Stele. 3. Cortex. 4. Apical cells. 5. Root cap. 6. Calyptrogen.

Among the dicotyledons,three categories of root tips are encountered. In the first category, all regions of the root, including the root cap, develop from one set of initials only. The epidermis differentiates from some of the cells of root cap. e.g. some members of the Ranunculaceae, Fabaceae, Proteaceae (Fig.6.8 B). In the second as discussed under the gymnosperms, there are two sets of initials, one forming the central cylinder and the other the cortex and root cap. (Fig. 6.8 C). The third category, which is more common, is characterised by the presence of three sets of initials. Of these, the outer one (**dermatocalyptrogen**) forms the root cap and epiblem, the middle (periblem) forms the cortex and the inner (plerome) gives rise to the central cylinder (Fig.6.8 D).

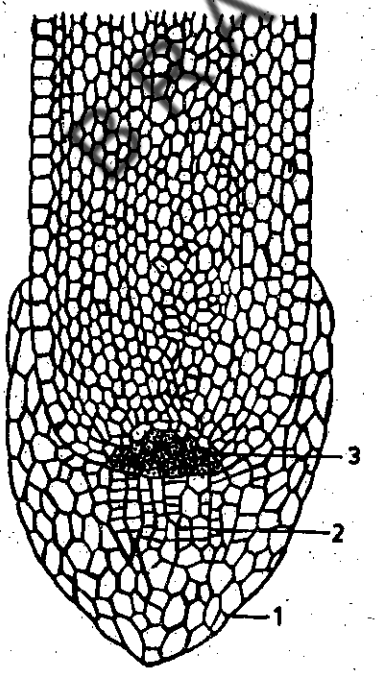

Fig. 6.9. Root tip of Maize showing the quiescent centre. 1. Root cap. 2. Calyptrogen. 3. Quiescent centre.

Among the monocotyledons, in addition to the three categories of root apices described earlier, a fourth category is also witnessed. In this, four sets of initials are found and they correspond to the root cap, epiblem, cortex and the central cylinder (Fig. 6.8. E). Whenever the root cap differentiates from its own set of initials, the term **calyptrogen** (Janczewski, 1874) is employed (Gr. **calyptra, veil** ; **genos**, offspring).

Clowes (1961) discovered an inactive zone between the root cap and the active meristematic region. This he termed as **'quiescent centre'** (Fig.6.9). The cells of this zone show very low mitotic activity. Quiescent centre also functions as a site of hormone (auxin) synthesis and maintains the geometry of the root apex. Further, it produces new initials replacing the previous active cells when damaged.

Check Your Progress - 3

What is a quiscent centre?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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6.5. SUMMARY

The persisting embryonic tissues of the plant body are known as meristems. Meristems give rise to permanent tissues of the plant body. They are classified into several categories on the basis of their position, origin, stage of development, functions etc.

Apical cell, histogen and tunica-corpus theories are prominent among the several theories proposed to explain the apical organisation of the plants. The tunica-corpus concept is the most accepted one for the shoot apex of the angiosperms and the histogen concept is used extensively for the elucidation of the root apex.

6.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Depending upon the position in the plant body the meristems are classified into 3 categories. They are (1) Apical meristems (2) Intercalary meristems and (3) lateral meristems.
2. Histogen theory was proposed by Hanstein in 1868. According to him the apical meristem consists of 3 different parts or histogens. They are (1) dermatogen which gives rise to epidermis (2) periblem which gives rise to cortex and (3) plerome which gives rise to the stelar region.
3. In the root tip between the root cap and the active meristematic zone there is a zone of inactive or mitotically low active cells called quiscent centre.

6.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write a detailed account on the classification of meristems.
2. What are the various theories concerning the apical organisation ? Explain them in detail ?
3. Write an account of the root apex and add a note on the differences between root apex and shoot apex.

II. Answer the following questions in about 10 lines each.

1. Write a brief account of shoot apex.
2. Explain the histogen theory briefly.
3. Explain the Tunica-corpus theory briefly.

UNIT - 7 : SIMPLE TISSUES

Contents

7.1. OBJECTAIVES

By the end of this unit you will be able to :

1. define simple tissues,
2. draw the structure and label the parts of various types of parenchyma,, collenchyma, sclerenchyma and laticifers,

3. recognise and list out the differences between parenchyma, collenchyma and sclerenchyma,

4. list out the functions of parenchyma, collenchyma, sclerenchyma and laticifers, and

5. describe the economic importance of fibres and latisifers.

7.2. INTRODUCTION

The mature plant body is made up of several tissues. A tissue is usually defined as a group of cells having common origin, structure and function.

On the basis of number of cell types, the tissues are divided into **simple** and **complex** types. In simple tissues all the cells are of the same type. In other words they are **homogenous in** nature. e.g. **parenchyma, collenchyma, sclerenchyma, laticifers** etc.,

7.3. PARENCHYMA

Parenchyma is the most common and least specialized tissue encountered in the plant body. It is a simple tissue with living protoplasts. It is also referred to as fundamental tissue or ground tissue and constitutes generally the bulk of the plant body. The apical meristems and the sporogenous tissue are also parenchymatous in nature. Most of the lower plants are composed of this tissue only.

7.3.1. Occurence

Parenchyma is seen commonly in 1. cortex (stem and root), 2. pith (stem and root), 3. pericycle, 4. mesophyll (leaf), 5. Pulp of fleshy fruits, 6. embryo, 7. endosperm (seeds), 8. xylem parenchyma and 9. phloem parenchyma.

7.3.2. Origin

Parenchyma of the primary body, i.e., cortex, pith, mesophyll and also of the floral parts develops from the ground meristem. Likewise, the parenchyma of the vascular tissues develops from the procambium or the cambium. Parenchyma of the secondary cortex (phelloderm) develops from the cork cambium.

7.3.3. Structure

The cells of parenchyma are usually isodiametric and polyhedral in shape. In a homogenous tissue, they have upto 14 sides (**tetrakaidecahedron**). They are usually thin walled. They are living cells at maturity. Intercellular spaces are prominent in parenchyma tissue (Fig. 7.1. A-C).

Parenchyma cells also show considerable variation in their structure. They have thick walls in storage tissues e.g.endosperm of date-palm , coffee etc. (Fig 7.1 C). The thickness of walls is due to the deposition of hemicelluloses. In the secondary xylem, the parenchyma possesses lignified walls.

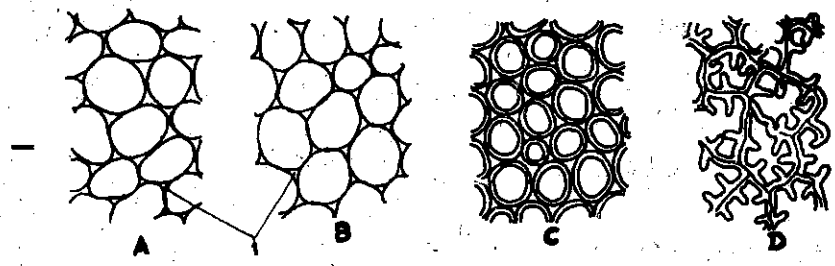

Fig. 7.1. Parenchyma. A. thin-walled prenchyma from cortex of *Helianthus* (Sunflower). B. Same from pith. C. Thick walled parenchyma. From leaf of *Pinus*. 1. Intercellular space.

The shape of parenchyma cells depends mostly on the pressure and surface tension created by the adjacent cells. They are elongated in the palisade tissue of leaves (Fig 7.2), variously lobed in the spongy tissues, stellate in the leaves of *Canna* and stem pith of *Juncus* and plicate in the mesophyll of *Pinus* needles (Fig 7.1 D). On the other hand, intercellular spaces are absent in the endosperm of many seeds and they are well developed in the hydrophytes (Fig 7.3).

7.3.4. Types

On the basis of the structure and function of its constituent cells, the parenchyma tissue is classified into various types.

1. Chlorenchyma: The cells contain chloroplasts and take part in the photosynthesis. e.g. mesophyll of leaves (Fig 7.2).

2. Aerenchyma: This is parenchyma with large intercellular spaces. These spaces are filled with air which helps the plants to keep afloat, e.g., lotus and other hydrophytes (Fig 7.3).

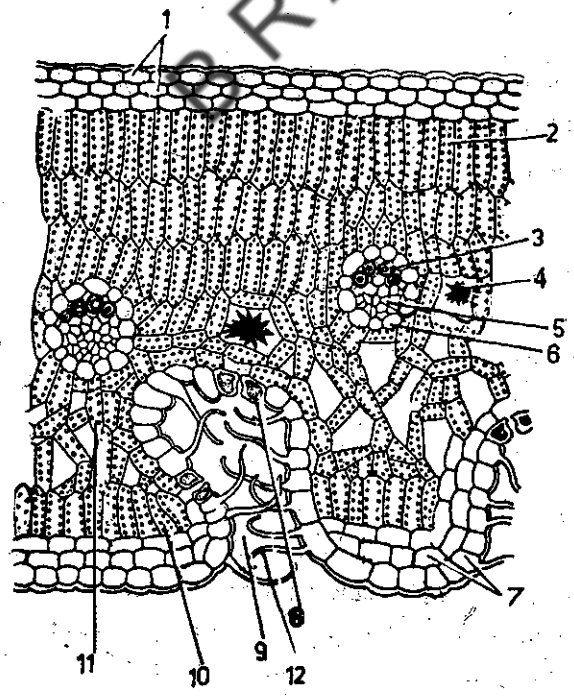

Fig. 7.2. T.S. of the leaf of *Nerium*. 1. Upper epidermis. 2. Upper palisade (Mesophyll). 3. Xylem. 4. Crystals. 5. Phloem. 6. Bundle sheath. 7. Lower epidermis. 8. Stoma. 9. Stomatal pit. 10. Lower palisade. 11. Spongy parenchyma 12. Hair.

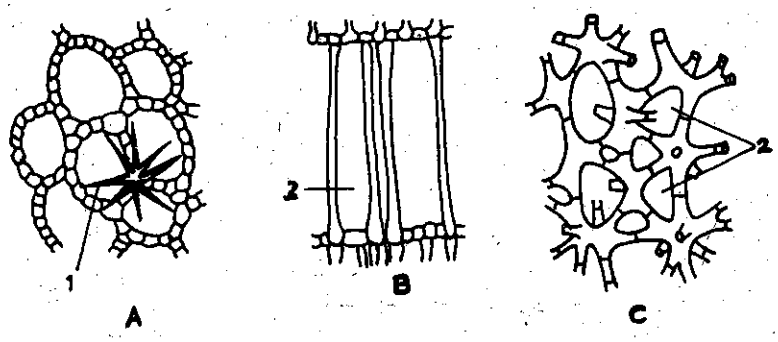

Fig. 7.3. Aerenchyma. A. From the pertole of *Nymphaea*. B. From the stem of *Jussiaea*. C. From lacunae of the petiole of *Canna*. 1. Tricho-sclereid. 2. Airchamber.

3. Storage parenchyma : This is parenchyma packed with reserve food materials. Foods are stored either in the form of a liquid in cell sap (sugars,other insoluble carbohydrates, amides and proteins-e.g., beet root and scales of onion) or solid particles or liquid in cytoplasm (starches, proteins, oils and fats. e.g., potato)

4. Water storage tissue: Succulents like *Aloe* and *Agave* store large quantities of water in parenchyma cells. The parenchyma cells here are large, thin -walled and mucilaginous.

7.3.5. Function

Parenchyma tissue plays a vital role in many life-activities of the plant such as photosynthesis, assimilation, respiration, storage, secretion etc. A parenchyma which is a constituent of a mature tissue is capable of behaving like a meristematic cell at times.

7.3.6. Idioblasts

In many plants, parenchyma cells have tannins, mineral substances, myrosin (e.g., Brassicaceae, Capparidaceae), oil substances (e.g., Lauraceae), mucilaginous substances (e.g., many monocotyledons, Malvaceae, Cactaceae) and resinous substances (e.g., Meliaceae, Rutaceae, Rubiaceae). These cells significantly differ in size, structure or contents from other parenchyma cells. These specialized cells are known as **idioblasts** (Gr. idio= peculiar).

7.3.7. Transfer Cells

In some taxa, parenchyma cells are characterized by the presence of unlignified secondary wall in the form of **wall ingrowths** (Fig 7.4). These cells with wall ingrowths are known as

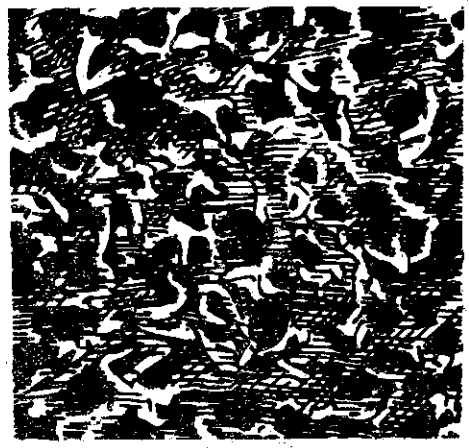

Fig. 7.4. Part of the wall of transfer cell of *Impatiens balsaminea*

transfer cells. The plasma membrane in these cells forms a lining over the wall ingrowths thus resulting in an increase in the surface area of these cells.

Transfer cells are present in nectaries, salt glands and vascular parachyma (Fig 7.5.). Their main function is short distance transfer of metabolites in the tissues.

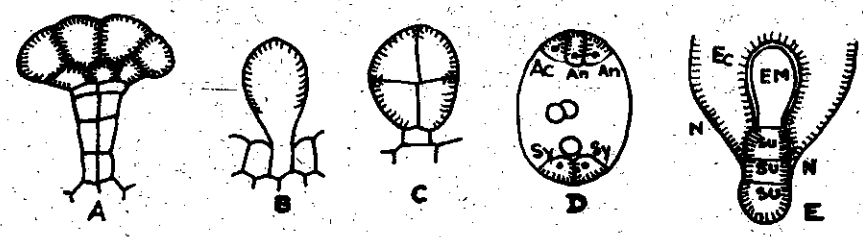

Fig. 7.5. Locations of transfer cells. A. Glands with ingrowths on exterior walls. B. Nectariferous trichome. C. Glandular hair with wall ingrowths on exterior walls. D. Embryosac of an angiosperm with wall ingrowths in synergids. F. Young embryo.

Check Your Progress - 1

What are idioblasts?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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7.4. COLLENCHYMA

Collenchyma is a simple tissue with elongated cells lending support to the plant body. From the functional point of view, collenchyma and sclerenchyma are termed as **stereome** (Heberlandt 1918).

7.4.1. Occurence

Collenchyma is usually seen in the peripheral parts of the plant body i.e. below the epidermis. Collenchyma is present in young stems, leaves, floral parts and fruits. In stems, it is present either as a complete cylinder or in longitudinal strips. Collenchyma is generally absent in the monocotyledons.

7.4.2. Origin

Collenchyma has its origin from the elongated cells which resemble procambium or from isodiametric cells of the ground meristem.

7.4.3. Structure

Collenchyma cells are living at maturity. As in parenchyma , chloroplasts may also be present in these cells. Occasionally, tannins are also observed. The cell walls are primary and consist of celluloses, pectins and hemicelluloses. Lignin is totally absent. The thickening of the cell wall is not even in all its parts.

Collenchyma cells are variable in size and shape. They are either short, prismatic or linear. When elongated, they measure upto 2 mm in length and the tips are acute. Usually the central cells of collenchymatous strands are longer than those of the peripheral ones.

7.4.4. Types

On the basis of the nature of wall thickening 4 types of collenchyma have been distinguished.

1. **Angular collenchyma:** In these cells, the thickening of the wall is mostly confined to the corners or angles of the cells, e.g. petioles of *Cucurbita, Vitis, Begonia, Coleus* or stems of *Nicotiana, Solanum, Datura, Dahlia* and *Atropa*. This is the most common type of collenchyma (Figs. 7.6 A & B).

2. **Lamellar or plate collenchyma:** The cells of this type show pronounced thickening on the tangential walls than the radial walls. e.g., stem cortex of *Sambucus* or *Rhamus* (Fig. 7.6. A).

3. **Lacunar collenchyma:** In this type intercellular spaces are seen between the adjacent thickened cells e.g., petioles of *Malva, Althaea, Asclepias* and the asteraceae (Fig 7.6 C).

4. **Annular collenchyma:** The cell lumen appears circular in cross section e.g.leaf of *Nerium oleander.*

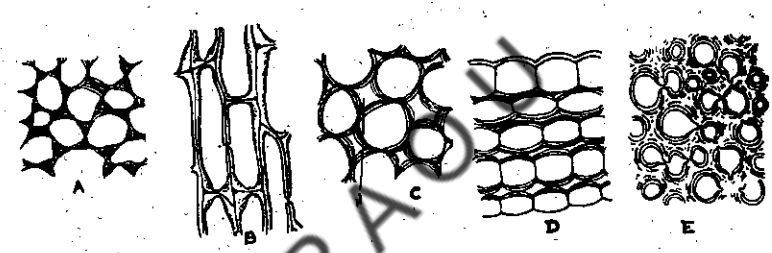

Fig. 7.6. Collenchyma. A. Angular collenchyma (T.S). B. Angular collenchyma (L.S). C. Lacunate collenchyma (T.S.) D. Lamellar collenchyma (T.S.). E. Annular collenchyma (T.S) of the midvein of the leaf of *Nerium oleander*. 1. Intercellular space.

7.4.5. Function

The collenchyma tissue provides stength to the juvenile forms, leaves and herbaceous stems. It contains considerable tensile strength with flexibility and plasticity. In tensile strength, the collenchyma cells are comparable with fibres. In weak-stemmed plants, collenchyma becomes sclerified.

Check Your Progress - 2

What is the difference between angular collenchyma & lamellar collenchyma?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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7.5. SCLERENCHYMA

Sclerenchyma is a simple but hard tissue consisting of thickened secondary walls. It is primarily a supporting tissue and consists of dead cells at maturity. Sclerenchyma provides protection to the soft tissues of the plant body from stretching, bending, weight and pressure and other forces..

Usually the sclerenchyma is divided into two groups : 1. **Sclereids** (sclerotic cells) and 2. **Fibres**. Sclereids are short cells. On comparison, the fibres are much elongated. However, many intermediate forms do occur between the sclereids and fibres.

7.5.1. Occurrence of Sclereids

Sclereids show wide distribution in plant body. Generally. they are seen in the cortex and pith of gymnosperms and dicotyledons. They are found either in groups or singly. They are also associated with the phloem. e.g., bark of cinnamon (*Cinnamomum*). Sclereids are also seen in roots (e.g. *Nymphaea*), leaf mesophyll (e.g. *Nymphaea. Trochodendron*), flesh of fruits (e.g. pear) and seed coat (e.g. bean, pea). The hardness and strength of seed coats is mostly due to their sclereids e.g. leguminous seed coats. Sclereids also form a protective layer in bud sclaes of garlic (*Allium sativum*).

7.5.2. Origin and Development of Selereids

Randomly distributed sclereids are formed from the parenchyma cells. First, they become distinguishable from the adjacent cells by their large nuclei. Later, these cells grow rapidly and send out branches into neighbouring intercellular spaces. Terminal sclereids associated with the veinlet endings in the leaf mesophyll are formed from the procambial strand (meristem) forming the veinlet.

7.5.3. Types of Selereids

Sclereids are usually classified into five types which are as follows:

1. **Brachysclereids** (or stone cells): They are more or less diametric. Their shape often, is like that of parenchyma cells. They are found in the cortex and pith of stems, phloem and fleshy parts of fruits. e.g. pear. cinnamon, guava, custard apple, sapota. coconut etc. (Fig. 7.7 A & B).
2. **Macrosclereids** (Rod cells or Malpighian cells): They are rod like or columnar in shape. e.g. seed coats of the Fabaceae (pea, bean etc) (Fig. 7.7 C).
3. **Osteosclereids**: They are also columnar but with swollen ends similar to a bone. These are again found in seed coats (e.g. *Pisum sativum*) and also in leaves (e.g.*Hakea*) (Fig. 7.7D & E)
4. **Astrosclereids/Asterosclereids**: These are branched and star-shaped and occur in the petioles and leaves e.g. tea, lotus and *Trochodendron* (Fig. 7.7 F).
5. **Trichosclereids** : These are much elongated and hair (trichome) like, and may be branched. e.g., aerial roots of *Monstera* and leaves of *Olea (olive)* (Fig. 7.7 G & H).

7.5.4. Fibres and Their Occurrence

Fibres are much elongated elements with acute end walls, narrow lumina and thick secondary walls (Fig 7.8). In some instances, they have septa and then designated as **septate fibres**. Sometimes they are so long that they reach upto 55 cm in length as in ramie (*Boehmeria nivea* - Urticaceae). Ramie fibres are the longest cells in higher plants and used in cardage. Mature fibres are mostly dead cells. Recent studies, however, indicate that septate cells at maturity are living cells.

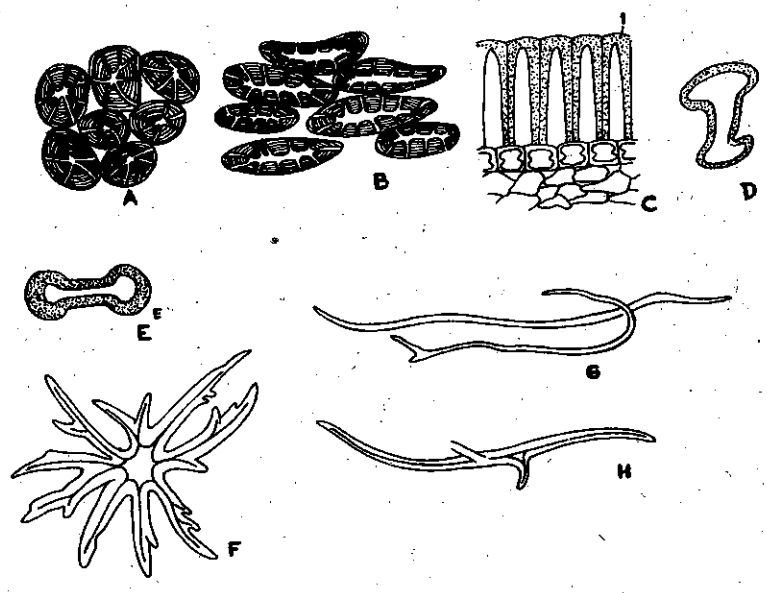

Fig. 7.7. Sclereids. A. Brachysclereids in the flesh of pear. B. The same in coconut shell (endocarp), C. Macrosclereids from the epidermis of *Phaseolus*. D, E. Osteosclereids in the seed coat of pea. F. Astrosclereid of *Trochodendron*. *G,H. Filiform* sclereids from the leaf of *Olea*. 1. *Macrosclereids*.

Fibres are found in stem, root, leaves and fruits. Occasionally, they occur singly (e.g. leaflets of *Cycas*) or more commonly as bundles or hollow cylinder. Fibres are found in association with vascular bundles as bundle sheath.

7.5.5. Classification of Fibres

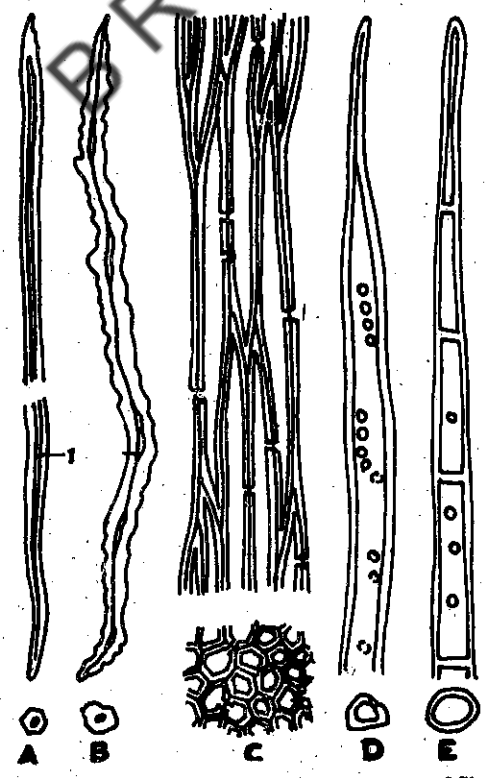

Fig. 7.8. Fibres. A,B. Fibres with highly thickened walls. C. A group of fibres showing interlocked ends and simple pitted thickenings. D. A. fibre trachied. E. A. Septate fibre trachied. 1. Lumen.

The fibres are classified into two distinct types -1 xylary and 2. extraxylary fibres.

1. Xylary fibres: They are an integral part of the xylem and develop from the same meristem which gives the other xylem elements. Though their origin is same, the fibres are of different shapes. On the basis of wall thickness and the nature of pits, two main types are distinguishable among the xylary fibres - **a. Libriform fibres** and **b. Fibre-tracheids.**

The **libriform fibres** are longer than the tracheids with which they occur. Further. the libriform fibres are with extremely thick walls and narrow lumina, and simple often lenticular pits (Fig 8.1. I).

The **fibre- tracheids** show medium wall thickness. They have walls thicker than the tracheids but less thicker than the libriform fibres. The fibre-tracheids are relatively shorter than the libriform fibres and possess small narrowly bordered pits. By and large, fibre–tracheids show intermediate character when compared with libriform fibres and tracheid (Fig 7.8. D.).

The fibres of the branch wood in the dicotyledons are characterized by the presence of innermost layer (G-layer) of the secondary wall with much α-cellulose and little of lignin. They are known as **gelatinous or mucilaginous fibres.**

2. Extraxylary fibres: They occur in parts other than the xylem tissue. When encountered in the phloem they are also known as bast fibres. On the basis of their occurrence, the extraxylary fibres are sometimes classified into a) **Phloem fibres**, b) **cortical fibres** and c) **perivascular fibres.**

7.5.6. Economic Importance of the Fibres

In industry and commerce, the term fibre has a loose application. Many elements which are not fibres botanically are also included under the term fibre. For example, the epidermal hairs of seed coat of cotton (*Gossypium*) and fibres obtained from the monocotyledonous leaves (e.g., *Agave, Musa textilis*) are not fibres in the real sense. The latter includes the vascular bundles along with the surrounding sheaths of fibres. Similarly the vascular system of roots of *Muhlenbergia* and the entire plant of *Tillandsia* are used as commercial fibres. Likewise, kapok fibres of *Ceiba pentandra* originate as hairs from the inner surface of the capsule (fruit).

Most of the important commercial fibres are associated with the phloem. They are flax (*Linum usitatissimum*), jute (*Corchorus capsularis* and *C. olitorius*) and ramie (*Boehmeria nivea*).

Commercial fibres are divided into **hard fibres** (with high lignin content) and **soft fibres** (with little or no lignin content). Hard fibres are from the monocotyledons e.g., *Agave sisalana (sisal), Tillandsia usneoides* (spanish moss), *Musa textilis* (abaca or manila hemp) etc. Soft fibres are flax, hemp (*Cannabis sativa*), ramie, jute, kenaf (*Hibiscus cannabinus*) and kapok. All these fibres are of great use to the mankind. They also provide mechanical strength to the plants in which they are present.

7.5.7. Comparison of Collenchyma with Parenchyma and Sclerenchyma

Structurally collenchyma is closely related to parenchyma. Both tissues have protoplasts capable of resuming meristematic activity. In both, the cell walls are primary and cellulosic. When collenchyma and parenchyma lie side by side, they intergrade with each other. The main difference between these two tissues is in the thicker walls of the collenchyma. Further the collenchyma cells are elongated than parenchyma cells.

On the other hand. the collenchyma though constituting supporting tissue like sclerenchyma, differs from the latter, in the nature of its cell wall and protoplast. Sclerenchyma has rigid. lignified secondary walls and is a dead tissue at maturity.

Check Your Progress - 3

What is the difference between macro sclereids & osteosclereids ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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7.6. LATICIFERS

Laticifers contain a liquid called **latex**. Many metabolic by-products are suspended in this latex as particulate matter. Laticifers occur either in single cells or series of cells forming tubes or vessels. As the latex is under pressure in the laticifers, the latex oozes out when the laticifers are cut. Laticifers are distributed in all parts of the plant body including the embryo. However, they are commonly associated with phloem tissue. Laticifers present in about 20 angiospermous families.

Latex is present as a suspension or as an emulsion. Its chemical nature varies from species to species. It may contain carbohydrates, organic acids, alkaloids etc, in solution and terpenes, oils, resins, rubber particles, starches as dispersed particles. The colour of latex is milky white in *Euphorbia*, *Lactuca*, *Asclepias*, yellow in *Anemone*, yellow-brown in *Cannabis*, Yellow-orange in *Papaver* or colourless in *Morus*.

7.6.1. Types

Laticifers are divided into two main types. 1. **Non articulated laticifers**. They are also called as latex cells or simple laticifers. 2. **Articulated laticifers**. They are also called as **latex vessels** or **compound laticifers**.

1. Non articulated laticifers (Fig 7.9 A) : They are single cells. They arise from some of the meristematic cells of the embryonic stage or from the meristem of developing shoot. As the plant grows, the latex cells also develop and enlarge. They enter into other tissues. The latex cells show apical growth and they branch out. Non articulated latex cells show multinucleate (coenocytic) condition with scanty cytoplasm and thicker walls than the neighbouring cells. The non articulated laticifers are found in the Apocynaceae, Euphorbiaceae, Moraceae and Urticaceae. The non articulated laticifers may be branched (e.g. *Nerium oleander*) or unbranched (e.g. *Catharanthus*).

2. Articulated laticifers (Fig 7.9 B): They are compound in origin i.e. they develop from a series of cells whose cross walls break down completely or partially. Ontogenetically, these compound laticifers are comparable to the xylem vessels and sieve tubes of phloem. The articulated laticifers are coenocytic. Like non articulated laticifers, the articulated laticifers also originate from the embryonic stage.

Articulated laticifers are found in the Asteraceae. Convolvulaceae, Euphorbiaceae, Papavaraceae, Caricaceae, Sapotaceae. Liliaceae, Musaceace. Some common examples are poppy, banana, rubber plant (*Hevea brasiliensis*) and *Ipomoea*.

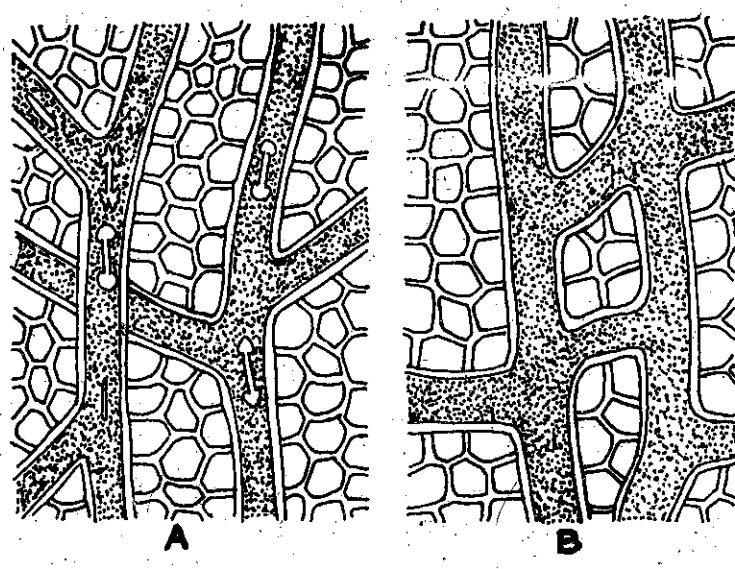

Fig. 7.9. Laticiferous tissue. a. Latex cells B. Latex vessels.

7.6.2. Functions

Some of the supposed funcitons of laticifers are as follows:

1. Laticifers are considered to represent excretory system.
2. Laticifers are supposed to form a secretory system in the plants.
3. Latex is of nutritive value in the plants.
4. Latex is considered to be a reserve material.
5. latex contains metabolic by-products.

7.6.3. Economic Importance

Commercially, latex is the most useful one among the plant secretions. Rubber is obtained from the latex of bark of *Hevea brasiliensis* (para rubber plant) of the Euphorbiaceae . The latex of this plant contains about 30% rubber. It yields about 2,000 lbs. of rubber per acre annually. *Manihot glaziovi, Ficus elastica* (Indian rubber plant), *Cryptostegia grandiflora. Parthenium argentatum* also give rubber but their yields are very low when compared to *Hevea*. The latex of *Papaver somniferum* (Opium poppy) gives opium whose importance in medicine needs no emphasis. Guttapercha is obtained from the latex of *Palaquium* and employed in the manufacture of dentures, golf balls, underground and underwater cables. Chicle obtained from the latex of *Achras sapota,* is used in the preparation of chewing gum. Latex screted by the plants of the Euphorbiaceae contains hydrocarbons and other substances similar to petroleum.

Check Your Progress - 4

What are laticifers ? How many types of laticifers are there? What are the differences between them?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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7.7. SUMMARY

A group of cells having common origin, structure and function constitute a tissue. Simple and complex tissues are seen in plants. In a simple tissue all the cells are of the same type.

The parenchyma is the most common simple tissue (ground tissue) and of different types such as chlorenchyma, aerenchyma etc. The parenchyma cells are living cells at maturity. The cells of collenchyma are thick-walled with the thickenings confined to specific areas of the cell wall. The sclernechyma tissue is a dead tissue at maturity with thick-walled (lignified) cells that give mechanical strength and rigidity to the plant body. Laticifers which also constitute a simple tissue contain latex and occur as single cells or tubes.

7.8. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Idioblasts are some specialised parenchymatous cells with tannins, mineral substances, myrosin, oil substances and resins.
2. The thickenings are confined to the angles of the cells in angular collenchyma where as the tangential walls are only thickened in lamellar collenchyma.
3. Both macrosclereids and osteosclereids are rod shaped or columnar in shape but the osteosclereids have swollen ends.
4. Laticifers are the cells which contain a milky white, yellow brown, yellow orange or colourless liquid called latex. Laticifers are of 2 types. They are (a) Non articulated and (2) Articulated laticifers. Non articulated laticifers are single cells whereas articulated laticifers are formed due to the fusion of cells end to end by the breakdown of the cross walls.

7.9. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write briefly about the structure, types and function of parenchyma.
2. Give a detailed account of collenchyma.
3. Write a detailed account on sclereids.
4. What do you know about the plant fibres? Give a brief description of various fibres. Add a note on the economic importance.

5. what are laticifers? Give an account on the types of laticifers with a note on their economic importance.
6. Describe briefly the different types of simple tissues encountered in the plant body.
7. Compare and contrast the parenchyma, collenchyma and sclerenchyma.

II. Answer the following questions in about 10 lines each

1. Write a brief account on Parenchyma
2. Give a brief account on collenchyma.
3. What are the different types of sclereids? Explain them with examples.
4. How are the fibres classified? Write a brief account on each one of them.
5. Write about the economic importance of fibres.
6. How are the laticifers divided? write briefly about each one of them.
7. What are the functions of laticifers? Add a note on the economic importance of laticifers.

UNIT-8 : COMPLEX TISSUES AND TISSUE SYSTEMS

Contents

8.1. OBJECTIVES

By the end of this unit you will be able to:

1. list out the different kinds of elements that are present in xylem and phloem,

2. draw and describe the structure of tracheary elements, xylem fibres, xylem parenchyma, sieve elements, companion cells, albuminous cells, phloem parenchyma and phloem fibres,

3. list out and differentiate diverse types of perforation plates of vessels,

4. distinguish the three components of epidermis-epidermal cell complex, stomatal complex and trichome complex,

5. draw the structure and label the parts of epidermal cells, costal cells, special epidermal cells and stomatal cells,

6. list out and distinguish between various trichome types and

7. list out the differences between root epidermis and shoot epidermis and also the functions of epidermis.

8.2. INTRODUCTION

The complex tissues are composed of more than one type of cells. They are thus, **heterogeneous** in nature, e.g. **xylem** and **phloem**. Two or more types of tissues form a **tissue system**. On the basis of topography of the tissues, three tissue systems are recognised. 1. **epidermal tissue system**, 2. **ground or fundamental tissue system** and 3. **vascular tissue system**.

8.3. XYLEM

Xylem (Gr. xylos = wood) is a complex tissue. It is the principal water conducting tissue in the vascular plants. Along with phloem, it forms the vasculature of the plants. The xylem is present in all the land plants viz., pteridophytes, gymnosperms and angiosperms. Therefore, all these plants together constitute the Trachaeophyta. The xylem has thick lignified and hard walls.

Xylem elements conduct and transport water and minerals to all parts of plant body. Further, they also provide the mechanical support. The xylem originates from two sources. 1. **Procambium of the apical meristem**, which gives rise to the **primary xylem** of the primary body; and 2. **Vascular cambium**, which gives rise to the secondary xylem. The first formed primary xylem elements are referred to as **protoxylem** and those developed later as **metaxylem**.

In the xylem tissue, different kinds of elements are encountered. They are **tracheary elements (tracheids** and **vessel members), fibres, xylem (wood) parenchyma** and **xylem rays**. Of these, only the xylem parenchyma and xylem rays are living and the rest are dead cells at maturity.

8.3.1. Tracheary elements

The trachieds and vessel members together represent the **tracheary elements**. They are linear in shape.

Trachieds (Sanio, 1863) originate from single cells. The end walls of tracheids are imperforate (Fig.8.1G). On the other hand, vessel members are joined end to end to form tube like structures called **vessels (Trachea)**. The fundamental character of the vessel members is that their end walls are perforated where they are in contact with the other vesel members. The individual cells which participate in the formation of the vessels are called vessel members or vessel elements (Figs. 8.1 A - F & 8.2).

Nature of perforation plates of vessels: The portions of the cell wall which bear the perforations are called as **perforation plates**. These are as a rule, mostly confined to the end walls of the vessel members. The perforations are of diverse types viz., 1) **simple**, 2) **scalariform**, 3) **reticulate** and 4) **foraminate**. Of these, the latter three types are together referred as compound or multiple perforations.

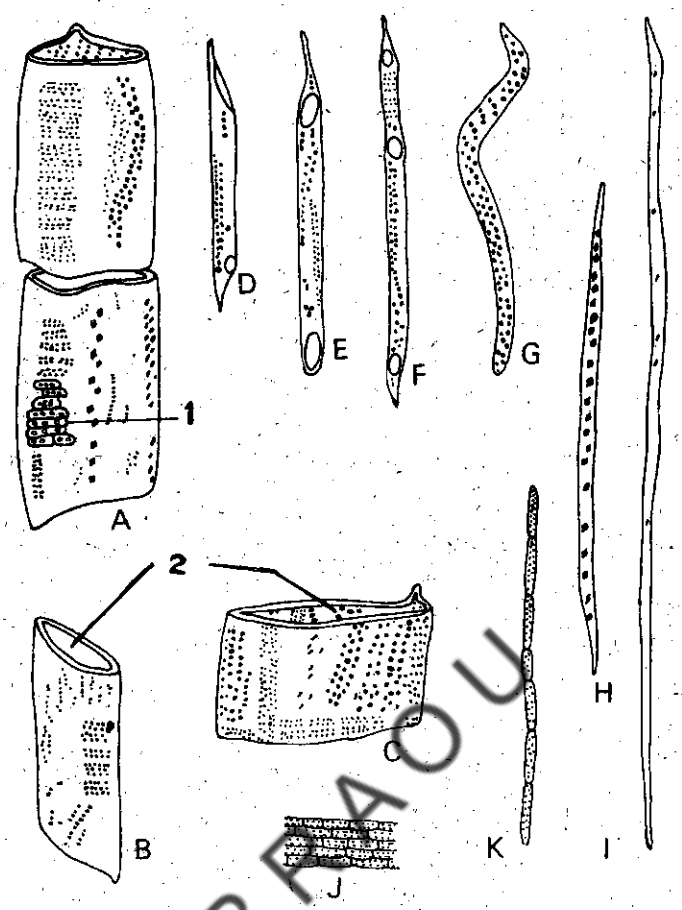

Fig 8.1. Cell types in secondary xylem. A-C. Wide vessel members. D-F. Narrow vessel members. G. Tracheid. H. Fibre-tracheid. I. Libriform fibre. J. Ray parenchyma cells. K. Axial parenchyma strand. 1. Ray cells. 2. Simple perforation.

1. **Simple perforations**: When single large perforations are seen at the end wall of the vessel member they are described as simple perforations (Figs. 8.1 B & C; 8.2 C).

2. **Scalariform perforations**: These are represented by many more or less transversely elongated or bar - like perforations (Fig. 8.2 A,B,D).

3. **Reticulate perforations**: Perforations forming a reticulum or net-work, at the end walls of the vessel members.

4. **Foraminate perforations**: These are represented by a number of more or less rounded perforations at the end walls of the vessel members.

The scalariform perforations are considered primitive, and the simple perforations, the most advanced.

The tracheid is the fundamental element of the xylem tissue and is considered more primitive than the vessel member. The vessel members have developed from the tracheids. Vessel members are shorter than the tracheids. While the tracheids are found in all vascular plants, the vessels, however, outside the angiosperms, are encountered in the Gnetales of gymnosperms and *Selaginella*, *Equisetum*, *Pteridium* and *Marselia* of the pteridophytes.

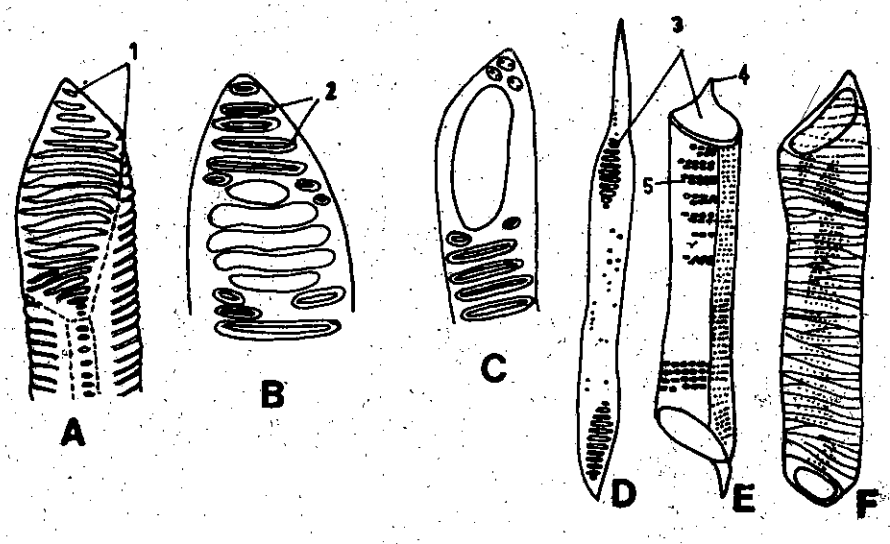

Fig 8.2. Vessel members. A - C. End wall of vessel members with perforations. A,B. vessel members, scalariform perforations. C. Simple perforations. D. Scalariform perforation plates. E. Simple perforation plates. F. Simple perforation plates, 1. Perforation Plate. 2. Bordered pits 3. Perforation plates. 4. Tail. 5. Spiral thickenings.

Intermediate forms between typical tracheids and vessels also occur. They are called **vessel - tracheids** or **vessel member-tracheids** which are analogous to **fibre -tracheids.**

Check Your Progress - 1

What is the difference between Tracheids and vessels ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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Structure of secondary wall: The secondary wall of tracheary elements is moderately thick, hard and lingnified. The secondary wall deposition of tracheary elements varies considerably. On the basis of thickening patterns, the tracheary elements are distinguished into the following types (Fig. 8.3). 1. **annular** (secondary wall confined to rings over the primary wall) 2. **spiral** or **helical** (secondary wall as helices), 3. **scalariform** (secondary wall ladder like), 4. **reticulate** (secondary wall as a net) and 5. **pitted** (secondary wall deposition completely covers the primary wall excepting small unthickened areas called pits) (Fig. 8.3). There is a gradual increase in the secondary wall deposition over the primary wall starting form the annular type where the deposition is confined to rings. The maximum secondary wall formation is seen in pitted tracheary elements (Fig. 8.3).

Of the above, the first formed ones are the annular, spiral and reticulate thickenings. They are found in the protoxylem. Pitted elements are characteristic of the late primary xylem and secondary xylem. However, all these elements need not be present in the same plant. Further, intermediate forms are also present e.g. scalariform - reticulate thickening.

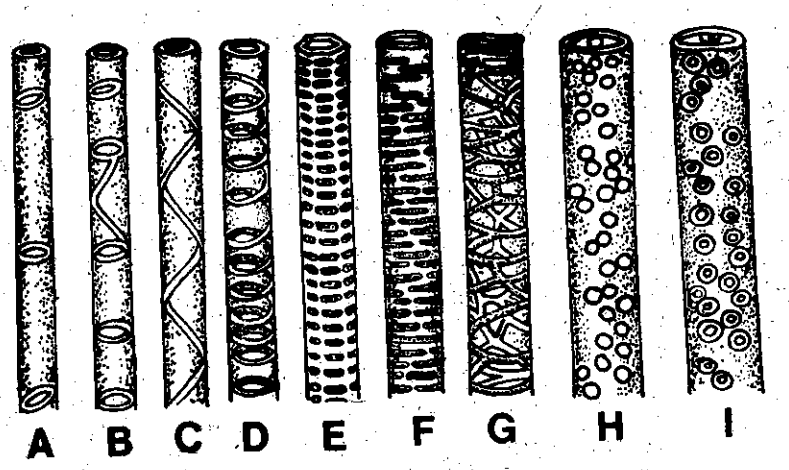

Fig 8.3. Different types of localized thickenings of the cell wall in L.S. A-B. Annular, C-D. Spiral. E-F. Scalariform. G. Reticulate. H. Pitted (simple). I. Pitted (bordered).

Pitting: Tracheary elements communicate with the adjacent cells through the pits. The pits are bordered. Bordered pit pairs are seen between two neighbouring tracheary elements and constitute the intervascular pitting. Between tracheary elements and fibres very few or no pit connections exist. Tracheary contact with a xylem parenchyma is through a half-bordered pit pair, i.e. bordered pit on the tracheid side and a simple pit on the side of parenchyma.

On the basis of arrangement of pits of tracheary elements, three patterns are discernible (Fig.8.4).

1. Scalariform pitting: The pits are transversely elongated and arranged in longitudinal rows (Fig.8.4 A).

2. Opposite pitting: The pits are circular and elliptical and arranged in horizontal rows (Fig 8.4 B).

3. Alternate pitting: The pits are again circular or oval and arranged in oblique or diagonal rows (Fig. 8.4.C).

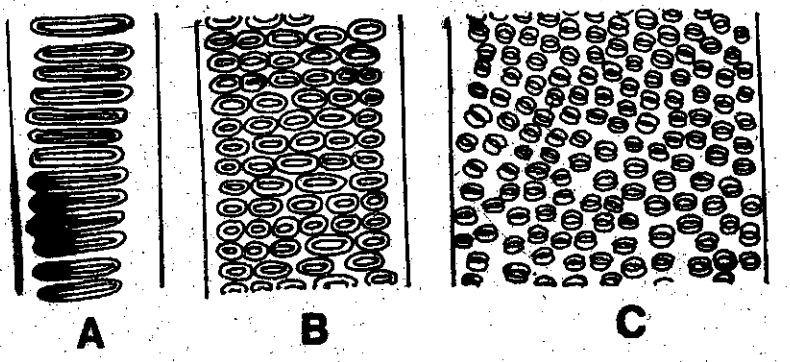

Fig. 8.4. Arrangement of bordered pits in vessel wall. A. Scalariform *(Magnolia)*. B. Opposite *(Liriodendron)*. C. Alternate *(Salix)*.

Of these, the scalariform pitting is the most primitive and found commonly in lower vascular plants (pteridophytes).

8.3.2. Xylem Fibres

As has been described earlier under 'sclerenchyma' (unit 7) the fibres are associated with the xylem and provide the mechanical strength to the plant body. Xylem fibres are of two types: 1. **Fibre tracheids** (Fig.8.1 H) and 2. **libriform fibres** (Fig.8.1 I). The libriform fibres resemble the phloem fibres. For further details, refer to the xylary fibres under sclerenchyma.

8.3.3. Xylem (Wood) Parenchyma

It is the only living component of the xylem. The cell walls are thin or thick walled. They are particularly meant for storage of starches or fats. Other materials like tannins, crystals etc. may also be present in these cells. Further, parenchyma cells are also involved directly or indirectly with the translocation of water and mineral salts. In the secondary xylem, parenchyma occurs chiefly in two forms:

1. **Axial parenchyma**: The parenchyma cells are arranged end to end in vertical rows among the treacheary elements. These cells are rectangular to elongate with horizontal end walls (Figs.8.1 K & 8.5 A).

2. **Ray parenchyma**: This is represented by parenchyma cells aligned horizontally or radially (Figs. 8.1 J & 8.5 B).

8.4. PHLOEM

The phloem is also a complex tissue like the xylem. These two tissues together constitute the conducting system of vascular plants. The phloem is mainly involved with the conduction of food products from leaf - the seat of photosynthesis to the areas of consumption and storage.

The term phloem was first coined by Nageli (1858). The phloem was also referred to as **bast** or **leptome**. Similar to the xylem, the phloem also develops from two sources - **procambium** and **vascular cambium**. The procambium gives rise to **primary phloem** and the vascular cambium to **secondary phloem**. The primary phloem consists of **protophloem** and **metaphloem**.

The secondary phloem is always produced in limited quantities than that of secondary xylem. As the tree ages, part of the secondary phloem gets crushed and becomes nonfunctional.

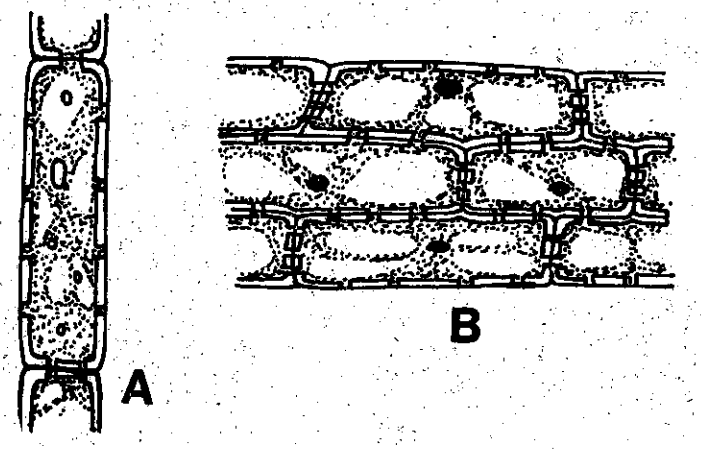

Fig. 8.5. Xylem parenchyma. A. Axial parenchyma. B. Ray parenchyma.

The phloem is composed of **sieve elements (sieve cells, sieve tubes), companion cells, phloem parenchyma, phloem fibres** and **phloem rays**. The phloem is associated with xylem in the vascular tissue system.

8.4.1. Sieve Elements

The sieve elements are greatly specialized cells in the phloem and are represented by 1. **sieve cells** and 2. **sieve tube members**. These are primarily involved with the conduction of organic solutes.

Sieve cells: They are narrow and linear with the end walls pointed. The sieve cells are joined end to end wherein their inclined end walls overlap. The **sieve areas** are sieve like wall areas with pores through which protoplasts of adjoining sieve cells are interconnected. The pores in sieve areas are narrow (Fig.8.6 E). They are present on lateral walls in gymnosperms and pteridophytes. The important difference between the sieve cells and sieve tube members is that the former show only sieve areas and do not possess any sieve plates on their end walls. Sieve areas are comparable to the primary pit fields with plasmodesmata. Sieve cells are an important component of phloem in the lower vascular plants and gymnosperms.

Sieve tubes: A sieve tube is a series of sieve tube members connected end to end in vertical rows, by means of sieve plates (Figs. 8.6-8.8). **Sieve plates** represent highly specialized sieve areas with relatively larger pores and restricted to specific regions. The sieve tubes in the phloem are the counter parts of vessels in the xylem.

Sieve plates: are mostly confined to the end walls of the sieve tube members and aligned transversely or obliquely (Fig.8.6 - 8.8). Sieve plates are distinguished into two types on the basis of number of sieve areas. They are : 1. **Simple sieve plate**- Wherein only one sieve area is present. e.g. *Cucurbita*. 2. **Compound sieve plate**-wherein many discrete sieve areas are present (Fig. 8.6). e.g. *Vitis, Pyrus malus* etc.

Sieve plates are characteristic of angiosperm phloem. They are comparable to the perforation plates of the vessels. Through the wide pores of sieve plates, the protoplasts of the neighbouring sieve tube elements are connected in the form of connecting strands (Fig. 8.7 A). Sieve tube members with compound sieve plates are primitive and those with simple sieve plates are advanced.

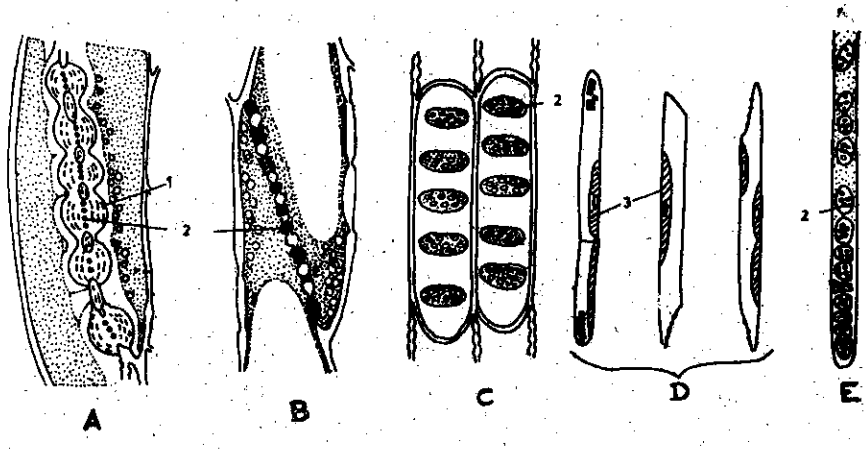

Fig. 8.6. Sive - tube members of *Vitis*. A-B. L.S of compound sieve plates between two elements. C. Surface view of two compound sieve plates. D. Sieve tube elements with companion cells. E. Portion of the sieve cell of *Pinus*. 1. Definitive callus. 2. Sieve area. 3. Companion cell.

As mentioned earlier, the sieve cells and sieve tubes together are called sieve elements. Some important characters of the sieve elements are considered.

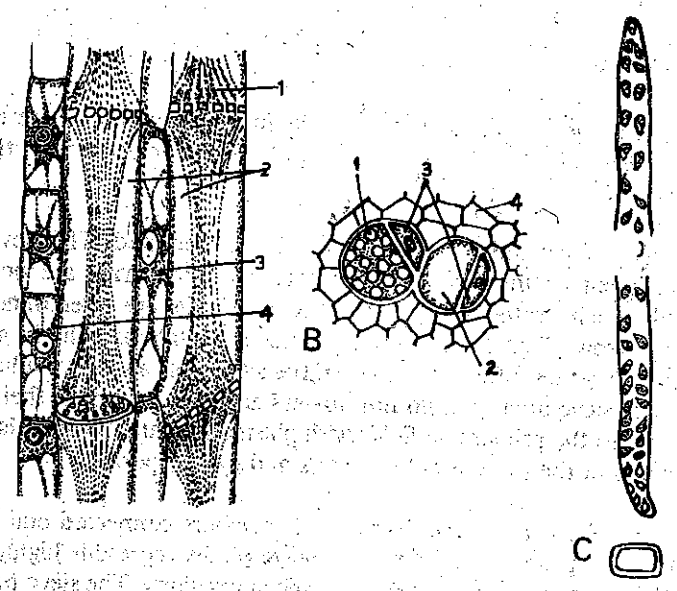

Fig. 8.7. Sieve elements. A. Sieve tubes in L.S. B. Sieve tubes in L.S. C. Sieve cell in L.S. and T.S. 1. Sieve plate. 2. Sieve tubes. 3. Companion cells. 4. Phloem parenchyma.

Callose: The connecting strands are the connections of protoplasts of neighbouring sieve elements. The connecting strands are surrounded by a small cylinder of callose - a carbohydrate that stains blue with aniline blue. In other words each pore is lined with callose (Fig. 8.8).

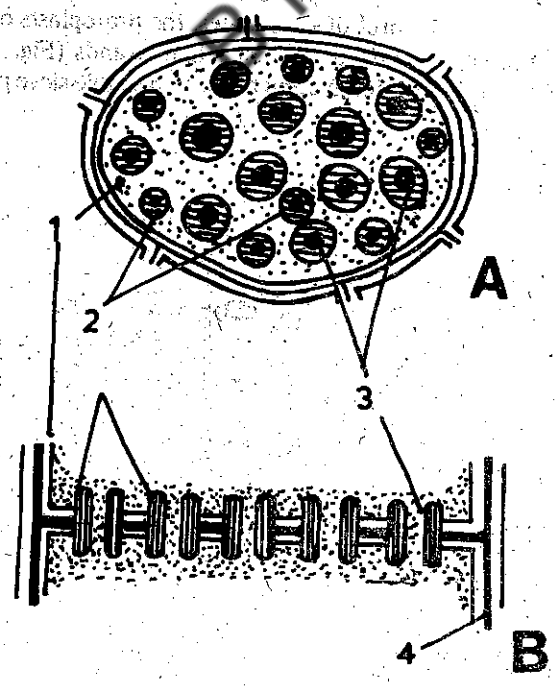

Fig. 8.8. Structure of sieve area of an angiosperm in surface (A) and sectional (B) views (diagrammatic). 1. Primary wall. 2. Callose cylinder. 3. Connecting strands. 4. Middle lamella.

The callose is characteristic component of the sieve elements. The callose accumulates rapidly in response to injury in the sieve elements. When the callose increases considerably, it forms **callus pad**. The deposition of callose increases during inactive season and decreases in the active season (spring time). Further, as the sieve element ages more and more callose accumulates and the pore gets constricted and later more or less completely obliterated.

Cell wall of the sieve elements: The sieve elements possess cellulosic primary walls only. The thickness of the wall varies considerably among the plants. In fresh sections, the wall of sieve elements show shiny appearance and termed as **necreous** (having a pearly lustre) e.g. *Magnolia*.

Protoplast: The phloem is an unique tissue with many intriguing characteristics. One important feature of the mature sieve element is that its nucleus usually degenerates (Fig 8.9). The degenerated nucleus may either remain as a collapsed body or disappears completely. As the maturation of sieve element takes place, the endoplasmic reticulum (ER) diminishes in amount and the ribosomes and dictyosomes are not discernible. Though the plasmalemma continues to function, the tonoplast breaks down and no distinction is maintained between the cytoplasm and the vacuole (Fig 8.9 D). Only plastids and mitochondria remain in the sieve elements.

A proteinaceous material called **P-protein** is commonly present in the sieve elements (Fig. 8.9 B). It was formerly known as **slime**. It readily stains with cytoplasmic stains. In the later stages, the slime accumulates at the ends of the sieve tube elements. These accumulations are termed as slime plugs.

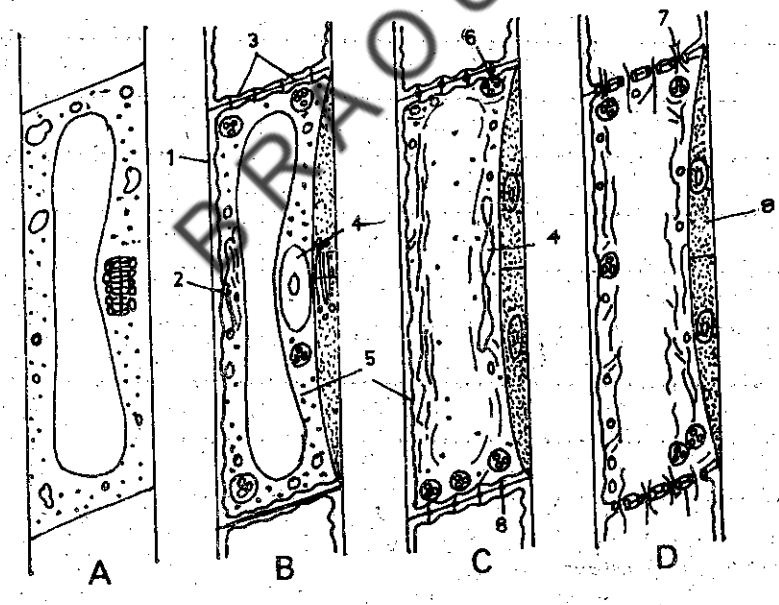

Fig. 8.9. Diagrams illustrating the differntiation of a sieve element. A. Precursor of sieve element in division. B. After division sieve element with nacreous wall and P- Protein body, dividing companion cell precursor (strippled). C. Nucleus degenerating, tonoplast partly broken down, P-protein dispersed, median cavities in future sieve plates, two companion cells (strippled). D. Mature sieve element, pores in sieve plates open, they are lined with callose and contain some P-protein, no endoplasmic reticulum is shown. 1. Necreous wall. 2. Protein. 3. Plasmodesmata. 4. Nucleus. 5. Tonoplast. 6. Plastid. 7. Pore. 8. Companion cell.

8.4.2. Companion Cells and Albuminous Cells

Companion cells are parenchyma cells associated with sieve tubes, and participate in controlling the translocation of food materials (Figs. 8.6 D, 8.7 & 8.9). They originate from the

same mother cell which gives rise to the sieve tube element. The companion cells retain the nuclei throughout their life. Each sieve tube element is generally associated with one to many companion cells. The companion cells cannot be easily separated from the sieve tube elements. The length of the companion cell varies considerably. They may be as long as or shorter than the sieve tube elements. The walls between the sieve tube elements and the companion cells are connected with one another by means of sieve areas on the side of sieve tubes and primary pit fields on the side of the companion cells.

In the gymnosperms no companion cells are present. Instead, **albuminous cells** (which possess albumin, a proteinaceous substance) associated with the sieve cells are seen. They are also readily stainable with the cytoplasmic stains. The main difference between the albuminious cells of the gymnosperms and the campanion cells of angiosperms is that the former are not ontogenetically related to the sieve cells as is the case with companion cells and sieve tubes. However, the albuminous cells show morphological and physiological relationship with the seive cells.

Check Your Progress - 2

What are the companion cells and albuminous cells ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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8.4.3. Phloem Parenchyma

In addition to the companion cells, the phloem also possesses phloem parenchyma. They are tabular, subspherical or polyhedral in shape. Parenchyma cells contain several ergastic substances such as starches, crystals, tannins etc. In the secondary phloem they are in two forms: 1. **Axial parenchyma** and 2. **Ray parenchyma**. The former is vertically placed parallel to the longitudinal axis of the sieve elements. The latter is horizontally aligned and constitutes the phloem rays.

8.4.4. Pholem Fibres

In many seed plants, fibres are one of the components of the phloem. They are present in the primary and secondary phloem. The phloem fibres are of considerable commercial importance. The details of these fibres have been presented under 'sclerenchyma'.

8.5. EPIDERMIS

Epidermis (Gr. **epi** = upon ; **derma** = skin) represents the protective covering layer of primary body of land plants. It is one of the three fundamental tissue systems recognised in the plant body (Haberlandt, 1914). Unlike the other two systems (viz., the ground and vascular tissue systems), the epidermis displays greater diversity in structure and function, as it is directly exposed to the environment.

Epidermis is normally one layered (**uniseriate**). In some plants, however, the protodermal cells divide periclinaly and result in a multi-layered (**multiseriate**) epidermis e.g. *Nerium*, *Ficus*, velamen of orchid aerial roots (Fig. 7.2).

In plants showing tunica - corpus organization of the shoot apex, the epidermis is derived from the tunica. In those plants without such organization the epidermis arises from **protoderm** - the outermost layer of the apical meristem (Haberlandt, 1914). However, in the root (which later produces root hairs), the **epiblem** or **rhizodermis** has a common origin either with the cortex or root cap (unit 6).

A layer of **cutin** (fatty material) is generally deposited as a special layer over the surface of the epidermal cell walls of the shoot system of land plants (Fig. 8.10). This layer is termed **cuticle (cuticularization)**. Sometimes, cutin does not form a continuous layer but is confined to localized areas in the cell walls of the epidermis (**cutinization**). The cutin is also present on the radial walls of the **epidermis** e.g. *Musa*.

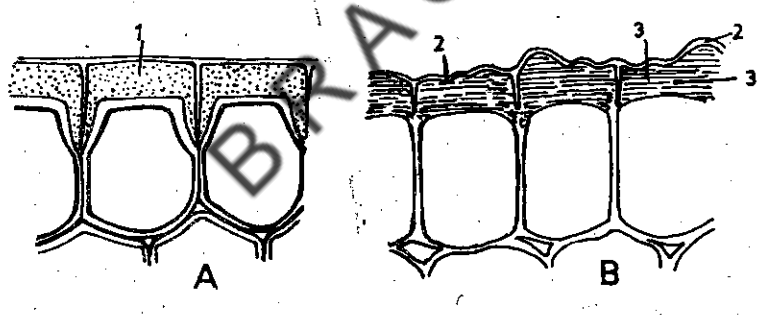

Fig. 8.10. Epidermal cells. A. *Aloe*. B. *Allium* (Onion). 1. Cutinised layers. 2. Cuticle. 3. Cellulose layers.

The thickness of cuticle varies in different plants. Plants in dry habitats show thicker cuticles. Distinctive cuticular patterns often preserve many of the characteristic features of the underlying epidermis.

The cuticle is impervious to water and restricts transpiration besides providing protection (Fig. 8.11.) It is also resistant to micro-organisms as well as decay and this explains its usual representation in fossil plants.

Wax occurs as surface deposit (Fig. 8.11) in the form of **'bloom'** in many glaucous leaves and fruits e.g. lotus leaf, grapes. The wax may be deposited in large or small flakes or granules, rods, sheets etc. Knowledge about the wax coating of plant parts is vital in the use of herbicides and fungicides, as waxes resist wetting by sprays.

The plant epidermis is distinguished into three components: 1. **Epidermal cell complex**, and 2. **Stomatal complex** and 3. **Trichome complex**.

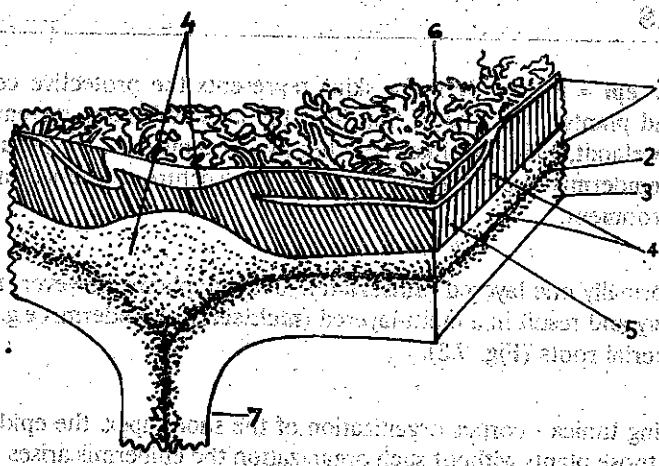

Fig. 8.11. Diagrammatic representation of the outer cell wall of the upper epidermis in *Pyrus* leaf, with details of the cuticular and waxy layers. 1. Cuticle. 2. Pectic substances. 3. Cellulose cell wall. 4. Matrix of cutin. 5. Birefringent wax embedded in cutin. 6. Epicuticular wax. 7. Anticlinal wall.

8.5.1. Epicermal Cell Complex

It forms bulk of the epidermis. It consists of epidermal, costal and special epidermal cell types.

1. Epidermal cells: They are compactly arranged into a single layer without intercellular spaces. The cells are tubular in cross - section and isodiametric or linear in surface view. The protoplasts of epidermal cells are highly vacuolated and usually devoid of chloroplasts. In surface view, the walls of epidermal cells are straight, curved, wavy or deeply sinuated (U,V or W - shaped). The cuticular surface is either smooth, striated or variously ornamented (Fig. 8.12).

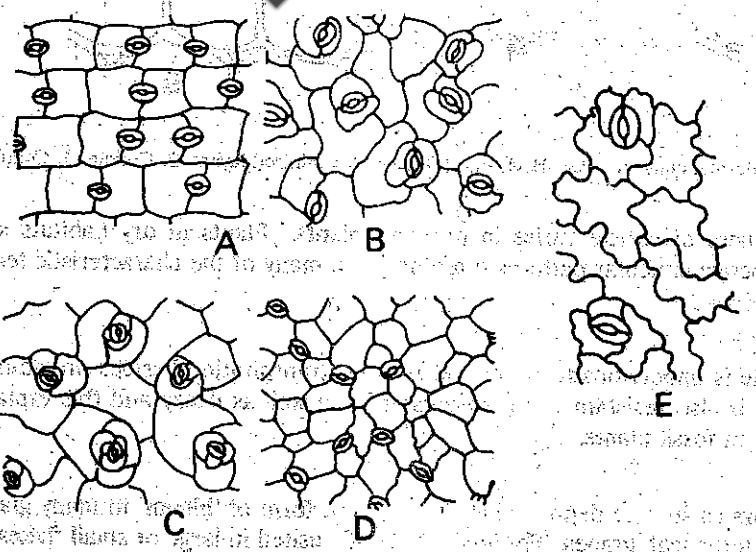

Fig. 8.12. Epidermis in surface views. A. Diacytic. B. Paracytic. C.&E. Anisocytic. D. Anomocytic.

2. Costal Cells: These cells are confined to areas overlying the veins and differ from the other epidermal cell elements. They are, in general, elongated in shape and oriented parallel to the long axis of the veins concerned (Fig. 8.13).

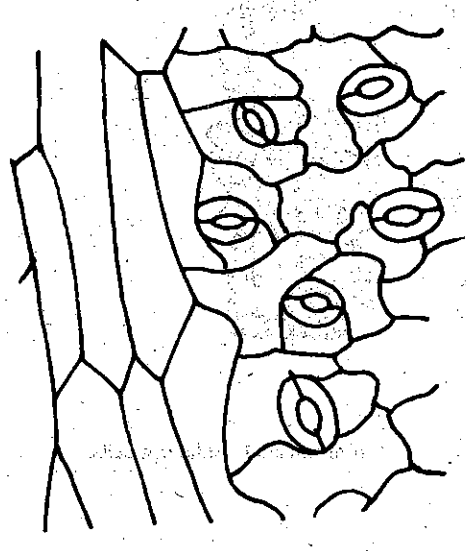

Fig. 8.13. *Sida cordata*-Surface view of lamina abaxial with costal cells on the left side.

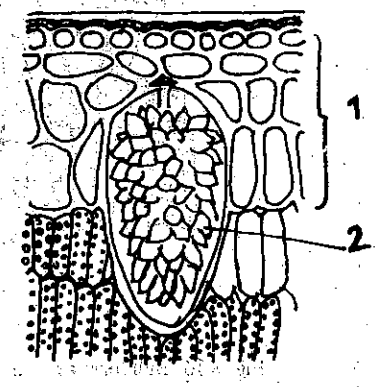

Fig 8.14. T.S. of the leaf of *Ficus elastica*. 1. Multiple epidermis. 2. Cystolith.

3. Special Epidermal Cells: These differ from either of the above elements in some specific character e.g. **mucilage cells** (Malvaceae. Lythraceae), tannin cells (Saxifragaceae), myrosin cells (Brassicaceae), **cystoliths** (Moraceae) (Fig. 8.14). **Silica** and **cork cells** (Poaceae) (Fig. 8.15 B) and **bulliform (motor) cells** (Poaceae) (Fig. 8.16) etc.

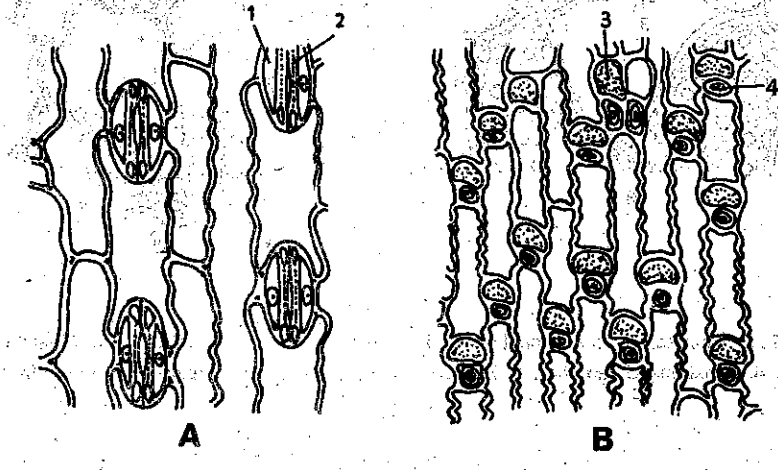

Fig. 8.15. Epidermis of sugar cane *(Saccharum)* in surface views. A. Lower epidermis of leaf with stomata. B. Epidermis of stem with cork cells and silica cells. 1. Subsidiary cell. 2. Guard cell. 3. Cork cell. 4. Silica cell.

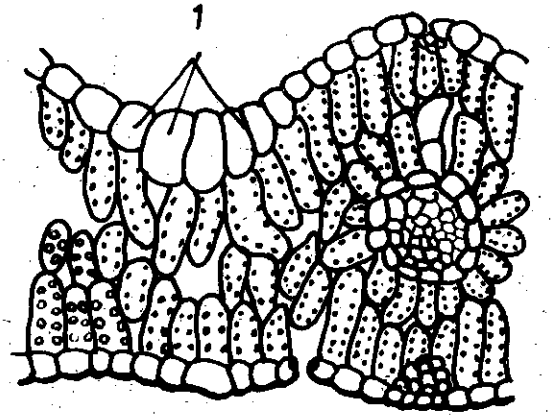

Fig. 8.16. Bulliform cells in a section of a leaf of wheat. 1. Bulliform cells.

8.5.2. Stomatal Comoplex

The epidermis shows numerous openings or pores called **stomata** or stomates (Gr.stoma = mouth). The stomata consist of two **guard cells** enclosing a pore between them. Epidermal cells abutting the guard cells are called **subsidiaries (Subsidiary** or **accessory cells)**. The stoma with its subidiaries is termed stomatal complex or **stomatal apparatus** (Fig. 8.17 B). A cavity is present beneath the stoma, known as **sub-stomatal chamber** which communicates with the intercellular spaces of the mesophyll (Fig.8.17 A).

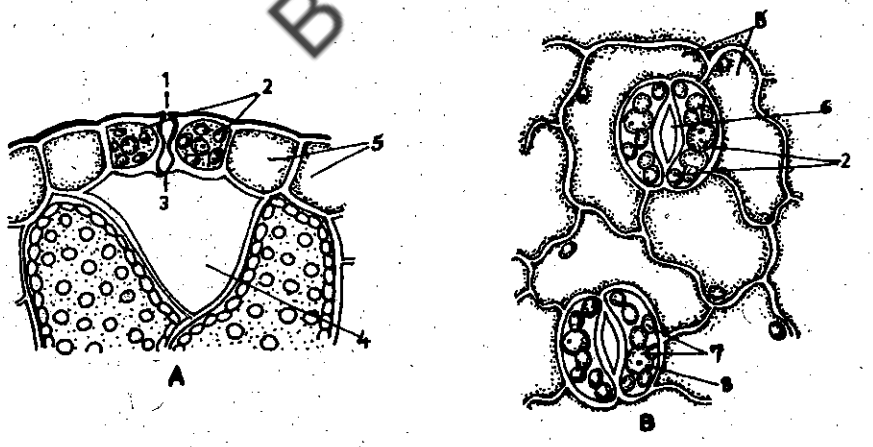

Fig. 8.17. Stomata. A. In sectional view. B. In surface view. 1. Outer ledge. 2. Guard cells. 3. Inner ledge. 4. Substomatal chamber. 5. Epidermal cells. 6. Stomatal aperture. 7. Chloroplasts. 8. Nucleus.

Distribution of Stomata: Stomata are present on all parts of the shoot including the floral parts. They may be non-functional on some parts of the plant body. However, they show their maximum concentration in the green leaves (Fig. 8.12). Stomata are absent in the submerged plants. On the basis of stomatal distribution, the following three categories of leaves are recognizable.

1. **Amphistomatic**: Stomata present on both surfaces of leaf: e.g. most of the herbs.

2. **Hypostomatic**: Stomata confined to the abaxial (lower) surface of leaf. e.g. most of the trees.

3. **Epistomatic**: Stomata confined to the adaxial (upper) surface of leaf. e.g. *Nymphaea.*

In the amphistomatic leaf, the stomata are usually more frequent on the abaxial surface. Further more than one stomatal type may be encountered in any plant surface, but normally only a single type predominates.

The stomata are variously oriented and irregularly scattered in the leaves of dicotyledons (Fig. 8.12). In the leaves of monocotyledons, however, they are oriented and arranged parallel to the veins (Fig. 8.15).

The guard cells may be either above, below or in flush with the rest of the epidermal cells. In some plants, stomata are confined to the depressions in the leaf-the **stomatal crypts**. e.g. *Nerium* (Fig. 7.2.).

Guard Cells: These are generally elliptic (cresent or kidney shaped) or circular in surface view (Fig. 8.17 B). In grasses, the guard cells are characteristically dumb - bell shaped (Fig. 8.19G.). The guarad cells are nucleated and possess many chloroplasts. They may also have **ledges** or **projections** of thick wall of cuticle (Fig. 8.17 A).

Structural Types of Stomata: The mature stomata are classified into various categories on the basis of their overall configuration. For this purpose, the number and arrangement of subsidiary cells in relation to the guard cells are taken into consideration. Further, the structure, distribution and frequency of stomata are found to be diagnostic and hence of taxonomic importance. The important stomatal types are as follows:

1. Anomocytic or **Irregular - celled (Ranunculaceous)**: Stoma with four or more subsidiaries variable in size, shape and position and indistinguishable from rest of the epidermal cells e.g. *Tridax procumbens. Boerhavia diffusa. Cleome* spp. etc. (Fig. 8.12 D).

2. Anisocytic or **Unequal - Celled (Cruciferous)**: Stoma with three subsidiaries of which one is conspicuously smaller or larger than the other two. e.g. Malvaceae, Brassicaceae etc. (Fig 8.12 C, E, 8.13, 8.17 B).

3. paracytic or **Parallel - Celled (Rubiaceous)**: Stoma with two subsidiaries parallel to the guard cells with conjoint walls at the poles. e.g. *Rubiaceae. Ipomoea palmata* etc. (F.g 8.12. B).

4. Diacytic or **Cross - Celled (Caryophyllaceous)**: Stoma with two subsidiaries, polar in position with conjoint walls at right angle to the guard cells. e.g. *Acanthaceae, Caryophyllaceae,* many *Lamiaceae* etc. (Fig. 8.12. A).

5. Tetracytic: Stoma with four subsidiaries of which two are polar and two lateral as in many monocotylendons (Fig 8.15 A & 8.19 F & G).

Developmental Types of Satomata: The following is the classification of stomata based upon their development.

1.Mesogenous: All the subsidiaries and guard cells develop from the same mother cell **(Meristemoid)** to form the stoma. e.g. *Malvaceae* (Fig. 8.18).

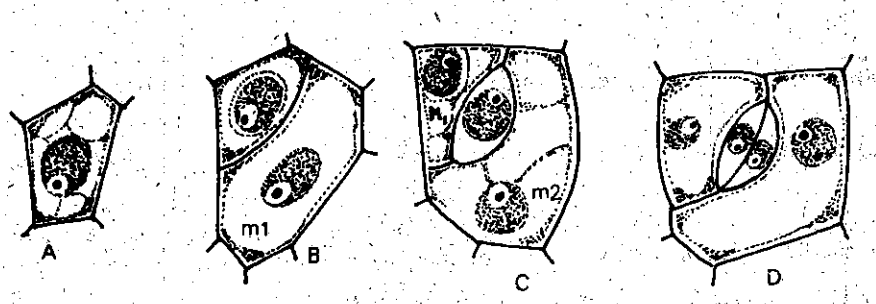

Fig. 8.18. Mesogenous pattern leading to paracytic stoma. m_1 First mesogene. m_2. Second mesogene.

2. Perigenous: In this stoma, the subsidiaries and the guard cells are not formed from the same mother cell. e.g. monocotyledons (Fig.8.19).

3. Mesoperigenous: A stoma in which one or more subsidiaries develop from same mother cell as that of guard cells (mesogenous) whereas the remainder are from different mother cell (perigenous e.g. Cucurbitaceae, Caryophyllaceae and Malvales (Fig. 8.20).

Check your Progress - 3

What are amphistomatic and hypostomatic leaves ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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8.5.3. Trichome Complex

The outgrowths which are purely epidermal in origin are designated as **trichomes** or **hairs**. On the other hand, some epidermal outgrowths may also consist of sub-epidermal tissues, known as **emergences**. The emergences may consist of epidermal, ground and vascular tissues (Fig. 8.21).

Trichome complex constitutes an important component of the plant tissues in general, of the epidermis in particular. Trichomes (Gr. a growth of hair) usually exhibit great diversity in their structure and hence offer valuable information in the identification of plant material. Some families can be identified by the occurrence of specific trichome types. They are also useful in the classification of many genera and sepecies.

Trichomes occur on all parts of a plant. They live throughout the life of an organ or they are short lived. Even the trichomes may remain alive or dead cells at maturity. Trichomes are unicellular or multicellular, glandular or non-glandular (Fig. 8.22).

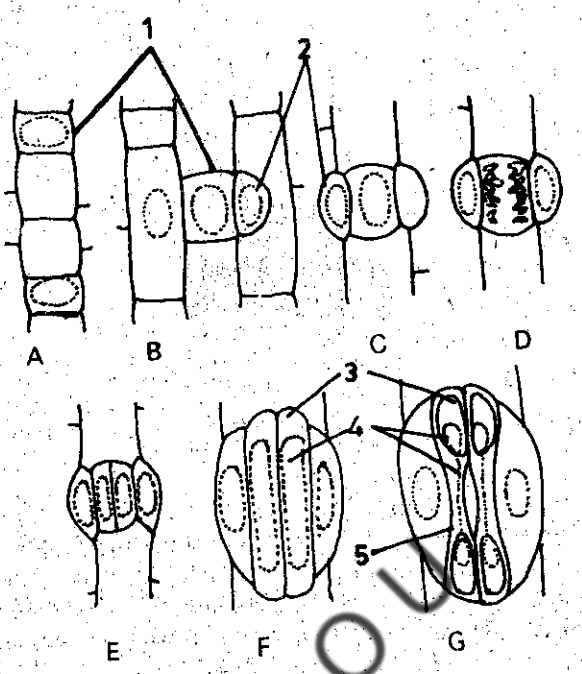


Fig. 8.19. A-G. Development of stomatal complex in Oat (*Avena sativa*) internode. The subsidiary cells are perigenous. 1. Guard cell precursor. 2. Subsidiary cells. 3. Guard cell. 4. Nucleus. 5. Cell wall.

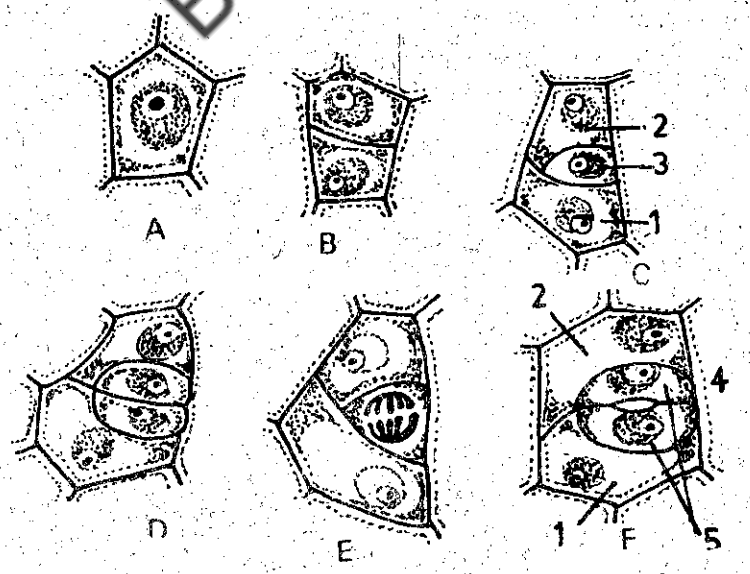


Fig. 8.20. A-F. Mesoperigenous pattern leading to the formation of anisocytic stoma. 1. First mesogene. 2. Second mesogene. 3. Guard cell mother cell. 4. Perigene. 5. Guard cells.

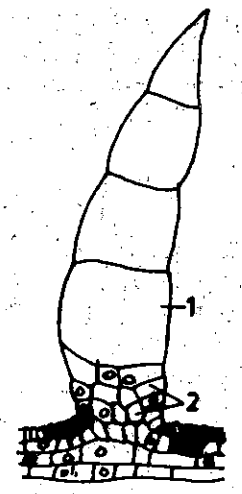


Fig. 8.21. Uniseriate macroform conical hair substended by an emergence. 1. Trichome. 2. Emergence.

Morphologically trichomes are distinguished into two parts, the **foot** and the **body**, the former representing the embedded part of the trichome while the latter, the emergent part (Fig.8.22 B- D). The body may be entire or differentiated into the **stalk** (proximal part) and the **head** (distal part) (Fig.8.22 B-D). The body of the trichome shows a high degree of structural diversity. It may be **conical, filiform, clavate, pyriform, vesicular, stellate, peltate, tufted, flagellated** or **candelabrum** like etc. (Fig.8.22).

There are number of trichome types which secrete various substances like salt solution, sugar solution (nectar, terpenes and gums (polysaccharides). These secretory trichomes are known as **glandular trichomes.**

Salt and Chalk Secreting Trichomes: They usually occur in halophytes and help in removing the excess salt. Each of these consists of a bladder - like secretory cell at the end of a narrow stalk. At maturity, the secretory cell dries out, the salt content remains on the leaf as white powdery layer.

The salt glands are often in the form of many - celled trichomes e.g. *Limonium, Avicennia, Tamarix* (Fig. 8.23 A).

Chalk secreting glands occur on the leaves of *Plumbago capensis* and *Armeria maritima* (Fig. 8.23 B).

Mucilage secreting glands: Mucilage or slime secreting trichomes occur in *Rumex* and *Rheum.* The secreted mucilage is mainly a polysaccharide and extrudes through the pores in the cuticle or by its rupture (Fig. 8.23 C).

Nectar secreting trichomes: In many plants nectar is secreted through unicellular (in the *corolla* of *Lonicera japonica* and *Tropaeolum majus)* or multicellular hairs (*Hibiscus, Abutilon* and many other Malvaceae) (Fig. 8.22 C). Nectar Secreting hairs and also epidermal cells are especially rich in endoplasmic reticulum (ER).

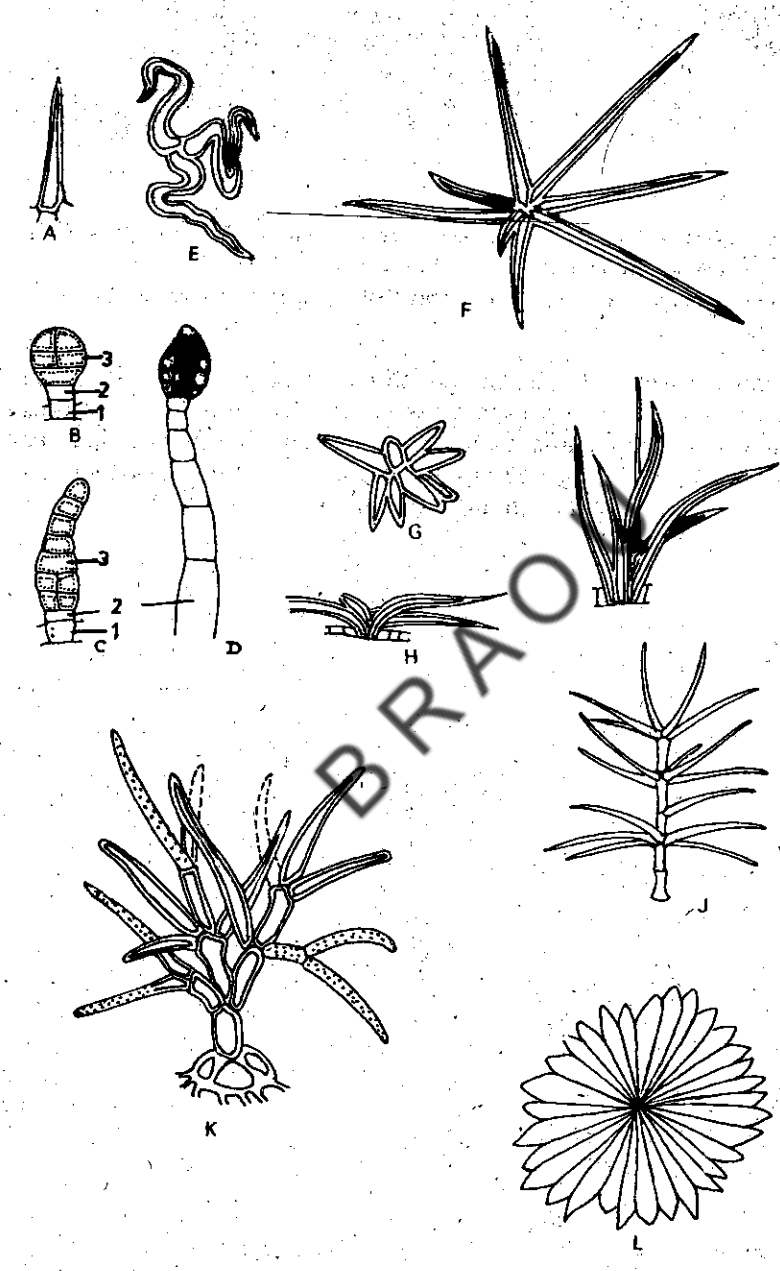
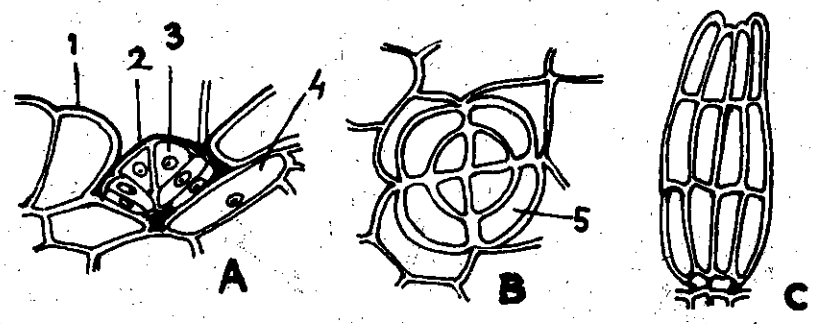


Fig. 8.22. Trichome types. A. Unicellular conical hair. B. Uniseriate filiform clavate hair. C. Uniseriate filiform pyriform hair from nectary located at the base of sepal adaxial. D. Uniseriate filiform clavate hair with long multicellular stalk. E. Multiseriate aseptate flagellate hair. F,G. Multiseriate aseptate stellate hair. H. Same in T.S. of stem. I. Multiseriate aseptate tufted hair in T.S. of stem. J. Candelabrum like trichome from the leaf of *Verbascum*. K. Dendroid hair from lavender leaf. L. Multiseriate aseptate peltate hair. 1. Foot. 2. Stalk. 3. Head.



8.23. Glandular trichomes A. T.S. of the leaf of *Tamarix* showing a multicellular salt gland. B. chalk gland of *Plumbago capensis* in surface view of the epidermis. C. Slime secreting trichome of *Rumex maximus*. 1. Cuticle 2. Pore. 3. Secretary Cells 4. Collecting cells. 5. Gland.

Stinging hairs: The stinging hairs are a highly specialized category of glandular hairs. The trichome here, has a broad bladder like base and a distal needle-like secretary cell impregnated with silica at its tip and with calcium a little lower. When touched, the spherical tip resembling the tip of a syringe breaks off and easily penetrates the skin, into which the poisonous, irritating cell contents (histamine and acetylcholine) are injected e.g. *Urtica* (Fig. 8.24).

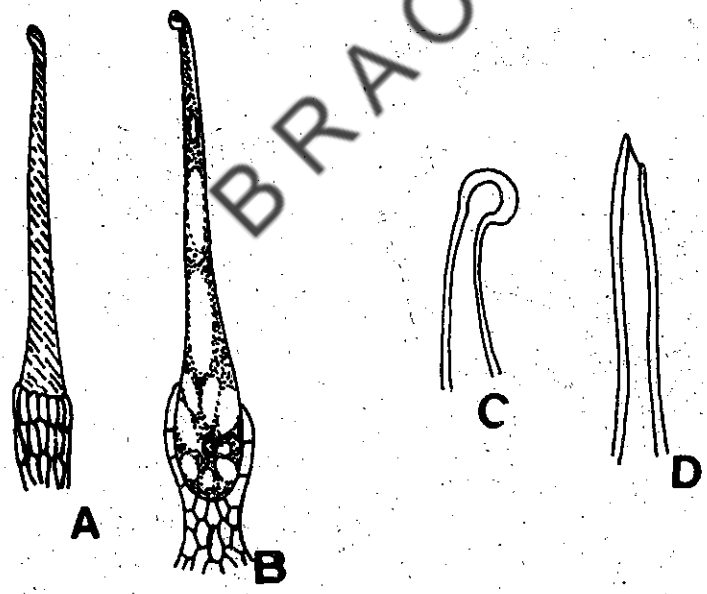


Fig. 8.24. Stinging hair of *Urtica dioica*. A. With the hair focus on the surface of the trichome. B. Focus on the centre of trichome. C. Intact tip. D. Trichome with broken tip.

Based upon their structure, the trichomes are distinguished into various categories viz., 1. Unicellular trichomes, 2. Uniseriate trichomes (filiform and macroform), 3. Biseriate trichomes and 4. Multisaeriate trichomes.

8.5.4. Rhizodermis and Root Hairs

The root epidermis is often described under a separate name - **rhizodermis** or **epiblem** (Linsbauer, 1930). The rhizodermis differs from the shoot epidermis in origin, structure and function.

Root hairs are distinguishable from the other epidermal hairs in several ways. They are mere tubular extensions of the rhizodermal cells, a little distance away behind the root tip. In some plants, the rhizodermal cells giving rise to root hairs are smaller and with dense cytoplasm. They are termed **trichoblasts** or **piliform cells** e.g. grasses (Fig. 8.25).

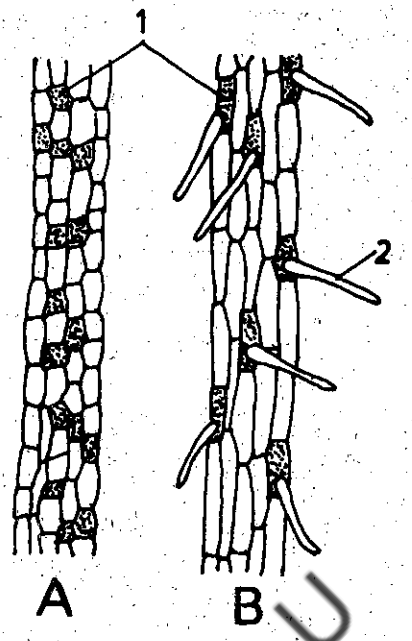


Fig. 8.25. Epiblem of root. A. Young root before forming trichoblasts. B. Similar cells after root hairs had developed from them. 1. Trichoblast. 2. Root hair.

Root hairs usually have a thin wall made of cellulose and pectic substances. Root hairs live for a few days only and constantly new ones replace the old ones.

Root hairs increase the absorbing surface of the root. The main biological advantage of the root hairs is that by means of their lateral extension, they come into contact with otherwise untapped sources of water (Rosene, 1954).

8.5.5. Epidermis of Grasses

The epidermis in grasses possesses parallel rows of **long cells** and two types of **short cells** viz., **silica cells** and **cork cells**. The short cells usually occur together in pairs (Fig.8.15 B). The silica cells contain silica bodies of various shapes and impart rough texture to the surface of leaves. The cork cells show suberized walls and filled with solid organic substances.

Many of the grasses possess some specialized cells called **"Bulliform cells" (or motor cells)**, here and there in their epidermis (Fig 8.16). The bulliform cells literally mean 'cells shaped like bubbles'. They are large, thin-walled (with cellulose and pectin) and highly vacuolated. The bulliform cells are mainly filled with water. They are hyaline and generally associated with the rolling and unrolling of leaves, depending upon their loss or uptake of water. Another opinion is that the bulliform cells play a role in the opening of the rolled leaf by their sudden expansion during a certain stage of leaf development.

The guarad cells of the stomata of grasses are dumb-bell shaped with bulbous ends and narrow middle portion. In between the dilated ends of the two guard cells,cross walls are incomplete and EM revealed that the protoplasts of these cells are confluent. In grass leaf blades, the stomata are confined to interveinular areas and absent over the veins (Fig. 8.15A)

8.5.6. Functions of Epidermis

1. Epidermis is primarily concerned with protection but variously modified to carry other functions.
2. The stomata normally regulate water and gas exchange but they may be modified into **hydathodes** (water pores) and also help in secretion of nectar.
3. Root hairs are specialized for water and mineral absorption.
4. Hairs (trichomes) of aerial parts are useful in the dispersal of seeds and fruits, triggering of floral parts into action, pollination and as secretory structures like nectaries, salt glands, mucilage glands and digestive glands.
5. The hairy covering of the epidermis provides defence against insect attack.

Check Your Progress - 4

What are piliform cells ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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8.6. SUMMARY

The xylem and phloem represent structurally and functionally complex tissues. The xylem is meant for conduction of water and mineral salts and imparts mechanical strength to the plant. The tracheary elements (trachieds and vessel members), xylem parenchyma and fibres are the principal components of the xylem. The phloem is mostly concerned with conduction of food materials. The sieve elements, companion cells, phloem parenchyma and fibres represent the main components of the phloem.

A fairly detailed account of the epidermal tissue system encompassing the epidermal cell complex and trichome complex is also dealt with in this unit.

8.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Tracheids are single cells with imperforate end walls whereas in vessels the vessel members are joined end to end and form tube like structures.
2. In angiosperms associated with sieve tubes there are some living parenchymatous cells which arise from the same mother cell of the sieve tube. These are called companion cells. In Gymnosperms, instead of companion cells albuminous cells are present. These are ontogentitically not related to the sieve tubes.
3. If the stomata are present on both surfaces of the leaves they are called amphistomatic leaves and if the stomata are present only on the lower surface they are called as hypostomatic leaves.
4. The rhizodermal cells from which the root hairs arise are smaller and with dense cytoplasm. These cells are called piliform cells.

8.8. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Describe briefly the various elements of xylem and explain their functions.
2. Describe briefly the various elements of phloem and explain their functions.
3. Give an account of the various elements that constintute the vascular tissues in typical dicotyledonous plant and briefly explain their respective functions.
4. Give an account of various components of plant epidermis.
5. What is the importance of stomata ? Explain briefly various structural types of stomata.
6. Write a critical account of the hairy covering of the epidermis. Add a note on the functions of epidermis.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the nature of perforation plates of vessels.
2. What are pits ? Write briefly about scalariform, opposite and alternate pitting.
3. Write briefly about xylem parenchyma.
4. Write a brief account on sieve elements.
5. Write briefly about the distribution of stomata.
6. Write briefly about the important stomatal types.
7. What is rhizodermis? List out the differences between rhizodermis and shoot epidermis.
8. Write a brief account on the epidermis of grasses.
9. List out the functions of epidermis.

UNIT-9 : SECONDARY GROWTH IN DICOT STEM AND ROOT

Contents

9.1. OBJECTIVES

By the end of this unit you will be able to :

1. define secondary growth,
2. differentiate the terms vascualr cambium and cork cambium and also fascicular cambium and interfascicular cambium,
3. differentiate the 2 types of initials of vascular cambium,
4. describe the formation of secondary xylem and secondary phloem due to cambial activity,
5. differentiate between heart wood and sapwood,
6. describe the structure of tyloses,
7. distinguish between phellogen, phellum and phelloderm, and
8. describe the formation of periderm and the structure and de

9.2. INTRODUCTION

Growth in girth or thickness, a little distance away fro
growth. **Secondary growth** does not help in increasing the l
mentioned in unit - 6, secondary growth occurs due to t
vascular cambium and **cork cambium**. The vascular ca
tissues and the cork cambium forms the periderm.

9.3. SECONDARY GROWTH IN DICOT ST

Secondary growth is present in most of the gymnos
however, secondary growth of the normal type is
secondary growth is exhibited by Isoetes (Lycopsid

9.3.1. Vascular Cambium

In the dicotyledonous stems, the vascular bundles are usually collateral, conjoint and open (Fig. 9.1. A). The cambium present insidethe bundles produces the secondary tissues. It arises from a portion of procambium localized in vascular bundles and is known as **fascicular cambium** (Fig. 9.1 B). The strips of fascicular cambium in the vascular bundles normally joined by additional strips of cambium, known as **interfascicular cambium** (Fig. 9.1 B.). This interfascicular cambium is formed due to the redifferentiation of the interfascicular parenchyma but not an extension of procambium. Therefore, the interfascicular cambium is secondary in origin (unit 6). The fascicular and interfascicular strips of cambia are joined with each other and form a continuous **cambium ring** or **cylinder** throughout the length of main axis of the plant. This constitutes the **vascular cambium**. In most of the dicotyledons and gymnosperms. the cambial cylinder is laid down between the primary xylem and phloem and this position is retained throughout the plant life. By its continuous meristematic activity. the cambial cylinder produces more secondary xylem **centripetally** (inwards) than secondary phloem **centrifugally** (outwards) (Fig. 9.1 C & D).

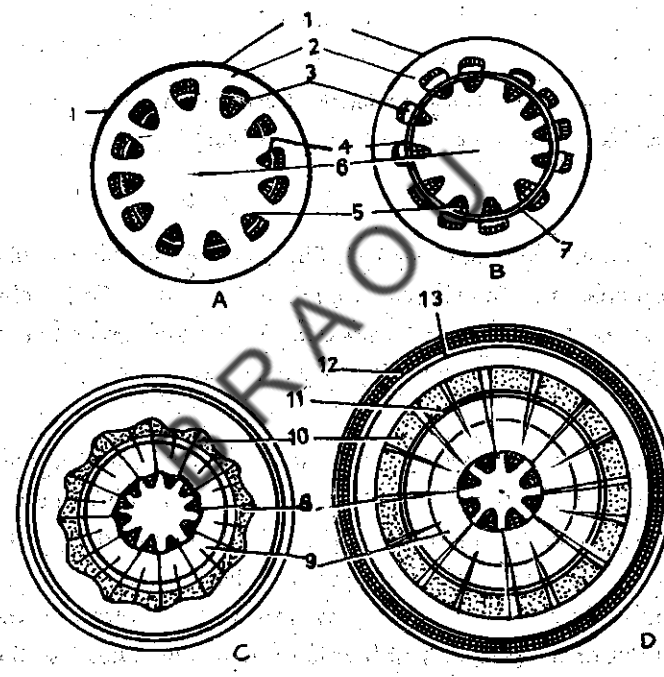

Fig. 9.1. Secondary growth is dicot stem upto two years (diagrammatic). A-D. Stages in T.S. 1. Epidermis 2. Cortex. 3. Primary Phloem. 4. Fascicular cambium. 5. Primary xylem. 6. Pith. 7. Interfascicular cambium. 8. Phloem ray. 9. Secondary xylem. 10. Secondary Phloem. 11. Cambium ring. 12. Phellem or cork. 13. Phellogen.

Components of Vascular Cambium: The vascular cambium consists of two types of initials.

1. Fusiform initials : They are elongated cells with tapering ends and prism-shaped. Fusiform initials divide periclinally and produce secondary xylem and secondary phloem oriented parallel to the long axis of the plants (Fig. 9.2).

Two patterns are discernible in the arrangement of fusiform initials. When they are arranged in regular superimposed tiers, the cambium is called **storied cambium**. When the fusiform inititials are irregularly aligned, the cambium is called **non-storied** (or **non-stratified**) (Fig.9.2).

2. Ray initials: They give rise to the xylem and phloem rays oriented perpendicular to the long axis of the plant body (Fig.9.2).

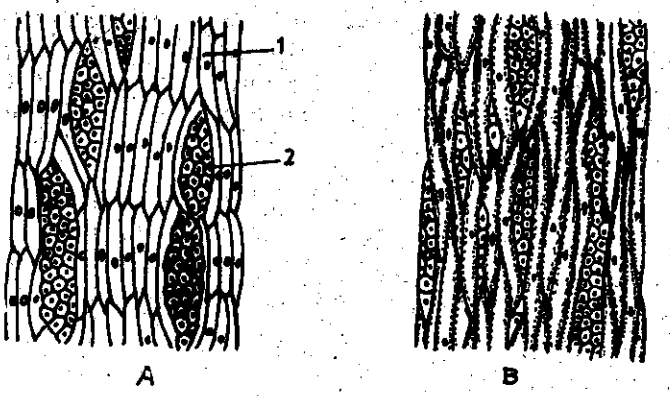

Fig. 9.2. Fusiform initials and ray initials of cambium in L.S. A. Storied cambium. B. Non storied cambium 1. Fusiform initials. 2. Ray initials.

Cambial Activity: Vascular cambium is one-called in thickness. At the time of cambial division, it is difficult to differentiate the cambial cells from their derivatives. The cambial cells and their immediate derivatives together form a **cambial zone**. Unlike the apical meristematic cells, the cambial initials are characterized by the highly vacuolated condition.

A fusiform initial divides into two daughter cells and one of which becomes either a xylem mother cell or a phloem mother cell depending on its position, while the other one remains meristematic. The xylem or the phloem mother cell by further differentiation or division gradually transforms into secondary xylem or secondary phloem (Fig. 9.3.). In this way, cambial cells produce secondary tissues. The secondary xylem is laid down towards the centre and the secondary phloem towards the periphery of the stem. As a consequence of the addition of the secondary tissues primary xylem and phloem of the plant are pushed farther and farther away from each other. In the tropics, the cambial activity is normally seen all through the year. In temperate regions, however, cambial activity is strictly seasonal. During the favourable season, the cambium is active and operational but as the unfavourable season approaches the cambium becomes sluggish and subsequently there is a near cessation of its activity.

9.3.2. Secondary Xylem

The secondary xylem (wood) constitutes the bulk of woody plants. It takes care of the transport of water, mineral salts and mechanical support besides storage of food in the wood parenchyma.

The secondary xylem is made up of vertical and horizontal systems of elements which are closely integrated with one another.

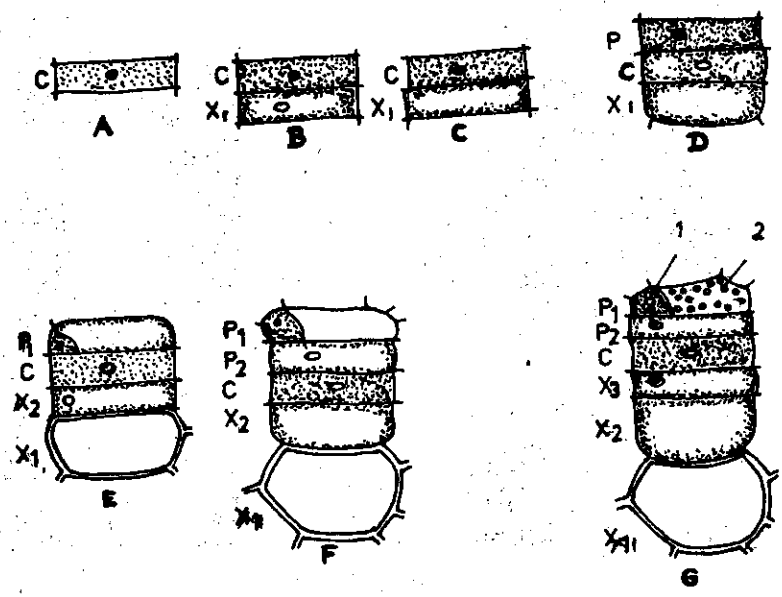

Fig. 9.3. Formation of secondary xylem and secondary phloem by the cambium. 1. Companion cell. 2. Sieve-tube

Vertical system: This is composed of tracheary elements. xylem parenchyma and fibres. usually aligned in regular radial seriations (as seen in cross section).

Distribution of Vessels: Among the dicotyledonous woods, two main patterns of vessel distribution are present.

1. **Diffuse-porous wood** : When the vessels of more or less same diameter are distributed uniformly throughout the growth ring (diffusely) the wood is termed duffuse-porous wood (Fig.9.4 A). The vessels look like holes or pores in transection of wood e.g. *Dalbergia, Pterocarpus* etc.

2. **Ring-porous wood** : In the vessels, spring wood is conspicuously larger and more closely placed (forming a discrete zone). In autumn wood they are much smaller and more widely spaced (Fig. 9.4 B). e.g. *Robinia, Quercus, Betula* etc.

Distribution of axial parenchyma: The cells of axial parenchyma are with live protoplasts and store food materials like starches or fats. Tannins and crystals are also commonly present in these cells. The axial parenchyma is also called the **xylem parenchyma**. The xylem parenchyma is either absent, scarce or abundant in the dicotyledonous woods. The distributional pattern of axial parenchyma is of varoius types. There are two basic types of distribution of the axial parenchyma.

1. **Apotracheal**: In this. the axial parenchyma is independent of and not associated with the vessels in its distribution.

2. **Paratracheal** : The axial parenchyma is consistently associated with the vessels.

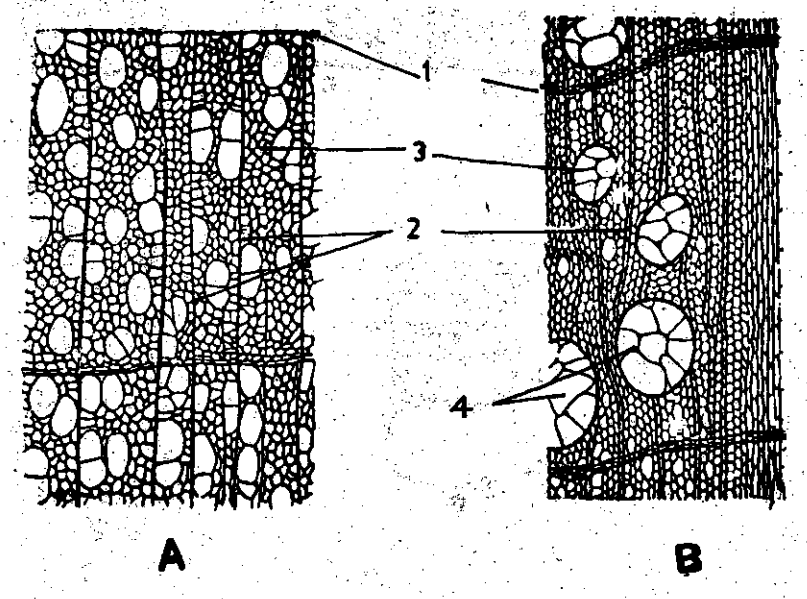

Fig. 9.4. T.S. of Secondary xylem. A. Diffuse porous wood. B. Ring porous wood. 1. Late wood. 2. Rays. 3. Early wood. 4. Tyloses.

Each of the above types is further divided into various fairly characteristic subtypes, which are quite useful in the identification of woods.

Horizontal System

Xylem rays : The xylem rays are part of the horizontal system and remain arranged perpendicular to the long axis of the plant body. They originate from the ray initials and are composed of parenchymatous cells. The xylem rays are continuous with the phloem rays on the other side of the cambium. The xylem rays maintain contact with the living components of the vascular tissues. The xylem rays are involved in the storage of food, transport of water and also facilitate the gaseous exchange across the vascular tissues.

Depending upon the width of the ray cells, the xylem ray may be **uniseriate** (one cell wide), **biseriate** (two cells wide) or **multiseriate** (many cells wide) (Fig. 9.5.). The ray cells are of two types according to their form. viz. **procumbent** and **upright** (or vertical) (Fig. 9.5). The procumbent cells have their long axes oriented radially and the uprigt cells are axially (vertically)elongated. If in a ray, either procumbent or upright parenchyma cells alone are present, the ray is termed **homocellular**. On the other hand, when both the procumbent and upright cells occur together, the ray is termed **heterocellular**. If the ray system of a wood is entirely with homocellular ray, it is described as **homogenous**. On the other hand, a **heterogenous** ray system is one where in both homocellular and heterocellular rays are present.

Annual Rings : In the trees of temperate regions, the cambial activity is mostly seasonal. The growth of the tree in terms of secondary xylem in an year is termed as **annual ring**. However. in the subtropical and tropical regions also presence of annual rings in the secondary wood is not uncommon. e.g. *Tectona grandis* (teak). *Dalbergia sissoo* (sissoo). *Albezzia lebbeck* (sirish).

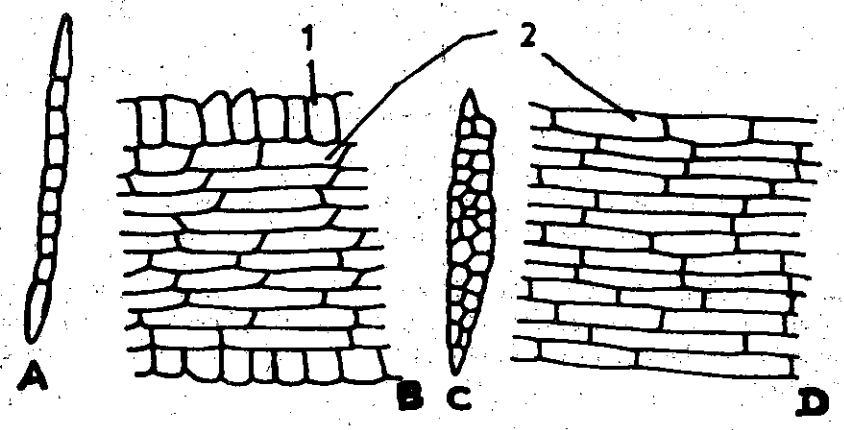

Fig. 9.5. Two types of rays as seen in tangential (A,C) and radial (B,D) sections. 1. Upright ray cell. 2. Procumbent ray cell.

The appearance of annual rings in transection of wood is because of the different types of wood produced during the favourable (spring)and unfavourable (autumn, winter) seasons. In the spring season, large vessels and tracheids are formed to meet the requirements of water for assimilation. This wood produced in larger quantities which is less dense is called **early wood** or **spring wood** (Fig. 9.6). However, in autumn/winter, the assimilatory rate is low in temperate plants and hence smaller quantities of secondary wood of compact and more thick - walled elements called **late wood** or **autumn wood** is formed (Fig 9.6).The early wood gradually merges with the late wood. However in some the demarcation between the early and late wood is quite sharp, making the annual rings more pronounced in appearance.

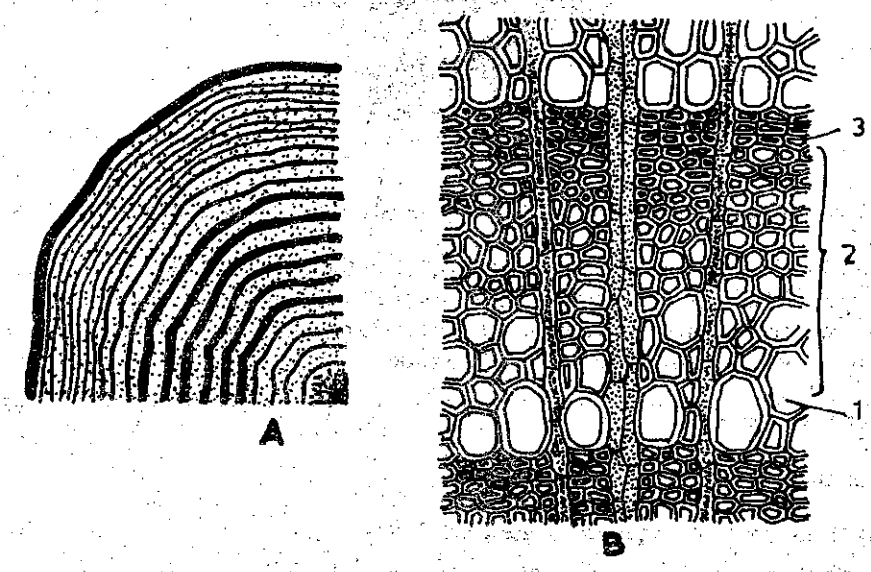

Fig. 9.6. Cut surface of stem. A. Annual rings. B. Annual ring in section. 1. Spring wood 2. Annual ring 3. Autumn wood.

Under adverse climatic conditions. the cambial activity is disturbed temporarily and consequently, false rings are formed. Thus occasionally two or more false rings may be formed annually.

Sapwood and Heartwood: In trees, after the formation of considerable quantity of secondary wood, two parts are distinguishable in it : 1. **sapwood** and 2. **heartwood** (Fig 9.7).

1. Sapwood or alburnum : The outer relatively narrow zone of the secondary xylem which is recently formed and is still made up of living components is termed as sapwood. The sapwood is light in colour. Sapwood carries the physiological activities such as conduction and storage.

2. Hieartwood or duramen: The inner relatively broad zone of the secondary xylem which was formed earlier and composed only of dead elements is termed as heartwood. The heartwood is dark in colour, more durable than sapwood and provides the main source of mechanical strength for the tree.

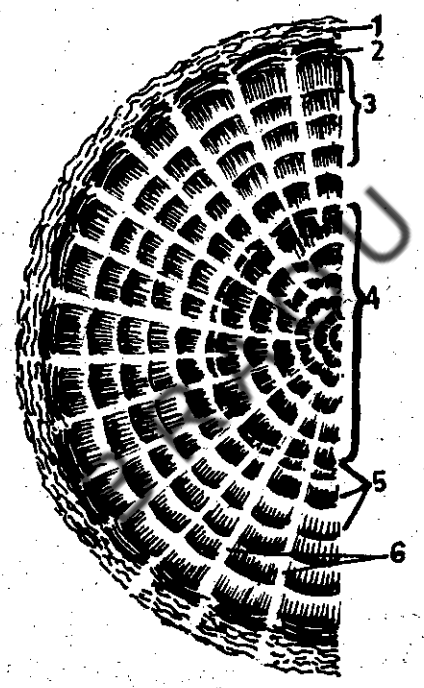

Fig. 9.7. Sapwood and heartwood. 1. Bark. 2. Phloem. 3. Sapwood. 4. Heartwood. 5. Annual rings. 6. Xylem rays.

The tissues of the heartwood show disintegration of the protoplasts, loss of cell sap, removal of reserve materials, increased number of tyloses, accumulation of oils, gums, resins, tannins, coloured substances and aromatic compounds. These changes make the hart wood more resistant to decay and easy to recognise from that of sapwood.

Check Your Progress - 1

What are annual rings ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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Tyloses : Parenchyma cells present next to the vessels send balloon like out growth into the vessels through pit cavities. when the latter become inactive or injured. These outgrowths are called **tyloses** (Fig. 9.4 & 9.8). Tyloses block the lumina of vessels and reduce the permeability of wood. These are often more abundant in the heartwood than in the sapwood. Tyloses are abundantly seen in the woods of *Quercus, Robinia, Fraxinus, Junglans* etc.

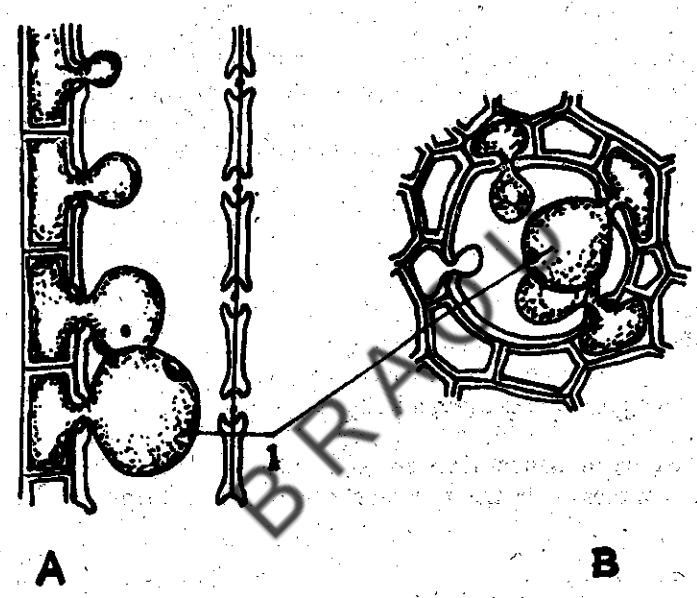

Fig. 9.8. Tyloses. A. longitudinal view B. Transverse view. 1. Tyloses.

When tyloses are formed, part of the cytoplasm along with nucleus of the parenchyma shift into the protrusion. The tyloses contain starches, resin and other materials. Their walls are either thin or lignified. Sometimes tyloses get transformed into sclereids. Presence of tyloses makes the translocation of solutes and entry of fungal hyphae into the wood, a difficult proposition.

Resin ducts in gymnospermous woods: Resin ducts are found in the vertical and horizontal systems of the secondary xylem of many gymnosperms. The ducts are formed among the resin producing parenchyma cells when the cells separate from each other and produce intercellular spaces (shizogenous). The cells which line the resin ducts are known as **epithelial cells**. The walls of the epithelial cells are either thin or lignified. The resin ducts may be seen in vertical or and horizontal systems of the wood.

Resin ducts may be formed in the secondary xylem of certain conifers as a response to injury either due to wounding, frost or wind. These are called traumatic resin ducts e.g. *Sequoia*. Resin is regarded as chemical defence mechanism. It promotes wound healing and is repellant to animal marauders.

Gum ducts in dicotyledonous woods : Intercellular ducts similar to resin ducts also occur in the vertical and horizontal systems in dicotyledonous woods. e.g. Dipterocarpaceae, Anacardiaceae, Burseraceae etc. These are called **gum ducts** or **secreting canals.** Though the ducts contain several substances like gums, oils, resin and mucilages, they are collectively known as gum ducts. Gum ducts may also originate due to injuries (traumatic gum ducts) e.g. *Terminalia.*

9.3.3. Secondary Phloem

The amount of secondary phloem formed outward by the vascular cambium is much less than that of secondary xylem. However, the basic plan of the arrangement of its various components is similar to that of secondary xylem. The secondary phloem also consist of vertical and horizontal systems. In most of the plants, the primary phloem gets crushed after secondary growth takes place and the recently formed secondary phloem is the functional unit. It carries out the physiological activity of transporting the organic solutes for considerable time.

Vertical System

The principal components of the vertical system of secondary phloem are the sieve elements, phloem parenchyma and phloem fibres. The sieve elements of the secondary phloem originate from the fusiform initials of the cambium and they are primarily connected with vertical conduction of food materials. By and large, there is not much difference between the elements of primary phloem and secondary phloem.

Horizontal System

Phloem rays : They originate from the ray initials of the cambium and they establish continuity with the xylem rays on the inner side of cambium. The phloem rays are especially parenchymatous and uniseriate to multiseriate. They are either homocellular or heterocellular. The older portions of phloem become nonfunctional and are periodically sloughed off.

Unlike the secondary xylem, annual rings are as a rule, absent in the secondary phloem. Further no distinction is witnessed in the early and late formed phloem and the phloem is uniform in appearance.

9.4. SECONDARY GROWTH IN DICOT ROOT

Most of the tap roots and main lateral roots of dicotyledonous plants show secondary increase in thickness. As a rule, no secondary growth is present in monocotyledonous roots. The secondary tissues of the root are more or less similar to those of dicotoyledonous stem but their initiation is some what different in the former.

9.4.1. Origin and Activity of Cambium

The primary xylem (with exarch protoxylem) and phloem tissues are arranged in separate radii in the dicotyledonous roots (Fig. 9.9). Pith is usually absent. Parenchyma cells present beneath each phloem patch become meristematic and form cambial strips. The number of cambial strips is equal to the number of phloem patches present. For example, a tetrarch root is with four strips of cambium and a triarch root with three strips. Subsequently the pericycle cells outside the xylem ridges also become meristematic and join the cambial strips formed beneath the phloem groups (Fig. 9.9 A). The cambial ring thus is initially in the form of a wavy ring, and starts producing new derivatives by periclinal divisions both inwards and outwards. The cambium also increases in circumference by anticlinal divisions. This wavy cambial ring passes internal to the primary phloem and external to the primary xylem groups (Fig.9.9 C). As has been the case in the stem, secondary xylem produced by the cambium is more in quantity than the secondary phloem. After a while, the wavy outline of the cambium assumes circular shape (Fig. 9.9 D).

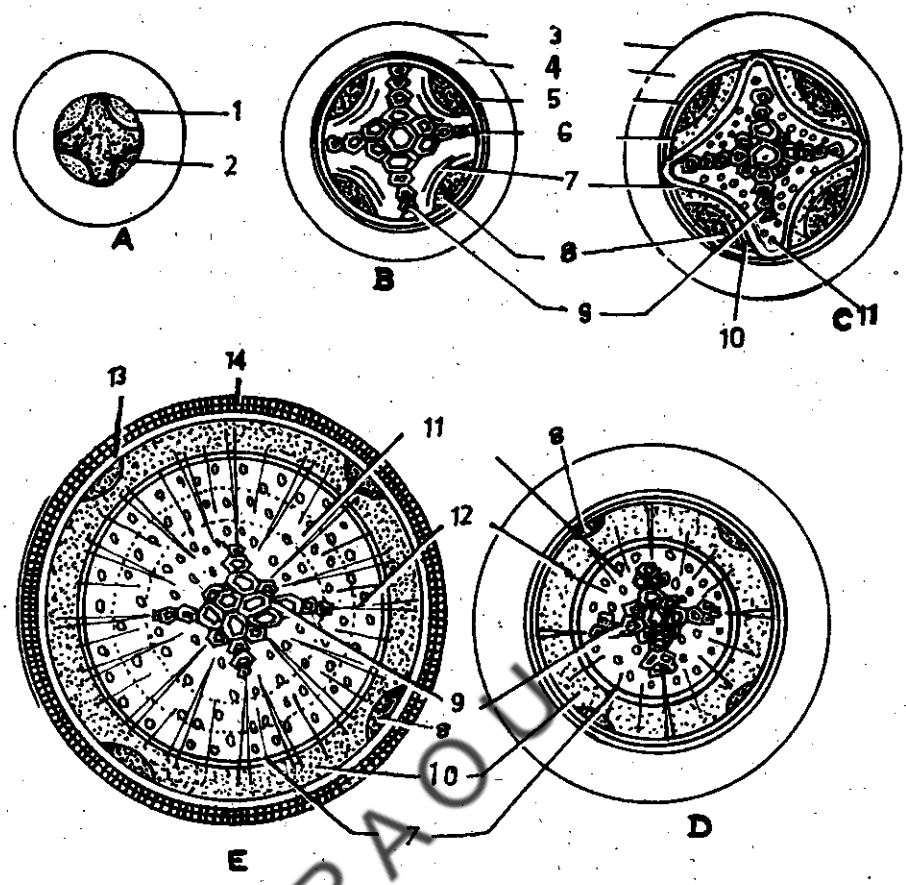

Fig. 9.9. Stages in the secondary growth of a dicotyledonous root. 1. Phloic procambium. 2. Xylary Procambium. 3. Epidermis. 4. Cortex. 5. Endodermis. 6. Pericycle. 7. Cambium 8. Primary phloem. 9. Primary Xylem. 10. Secondary phloem. 11. Secondary xylem. 12. Rays. 13. Phellogen. 14. Cork.

As a consequence of secondary xylem formation, the primary xylem is pushed to the central part of the root. The primary phloem elements especially the sieve elements get crushed. At this juncture, the root is identified mainly by the radial position of the exarch primary xylem in the central region (Fig. 9.9 E). Normally ray initials are differentiated in the cambial ring in the region just opposite to the primary xylem. They ultimately produce broad vascular rays running across the secondary vascular tissues in roots. In addition to these, narrower phloem rays are seen within the phloem tissue.

To compensate the ruptured epiblem, due to increased diameter of the root consequent upon secondary thickening, periderm is produced in the outer tissues of the root (Fig. 9.9 E). Basically the periderm of the roots is similar to that of the stems.

9.4.2. Periderm

As a rule. the primary plant body is covered by the epidermis as a protective covering layer. After the commencement of secondary growth, initially the epidermis stretches to accommodate the newly formed tissues. However, as a consequence of the rapid secondary growth, the epidermis gets ruptured. This results in the formation of **periderm**, a protective tissue of secondary origin from the extra stelar region.

The periderm is seen in most of the woody dicotyledons and gymnosperms, It is also seen in the older parts of the stem and root of herbaceous dictyledons. Occasionally monocotyledons also form periderm.

Bark is a nontechnical term employed rather loosely in the literature. All the tissues outside the vascular cambium are usually designated as bark. It then includes secondary phloem, primary tissues present outside the secondary phloem, the periderm and the dead tissues outside the periderm. It may thus be noted that periderm is a part of the bark. However, many workers restrict the term bark to those tissues present outside the phellogen.

The periderm is composed of three parts- 1. **phellogen** or **cork cambium** - the meristem which produces the cork, 2. **phellem** - normally dead tissue formed outward by the phellogen and generally called **cork** and 3. **phelloderm** - a living parenchyma tissue formed inward by the phellogen and also known as **secondary cortex**.

1. Phellogen (Cork- cambium): The phellogen is a secondary meristem and by virtue of its position, it represents a lateral meristem. It originates mostly from the outer layers of the cortex, wihch are potentially meristematic (Fig.9.10). The phellogen may also develop from deeper layers of the cortex or from the phloem tissue itself.

The phellogen is made up of rectangular and radially flattened cells. The phellogen cells are vacuolated and possess chloroplasts and tannins. The phellogen shows both active and inactive phase of cell division activity.

2. Phellem (Cork): The cork cells are polygonal in tangential section and flattened radially in cross-section. They are arranged compactly without intercellular spaces. The cork cells are derived outward from the phellogen (Fig. 9.10). They are dead cells at maturity and characterized by suberization of their walls. The suberin is a fatty substance and occurs as layers over the primary cellulose wall. The cork cells are brownish or yellowish and impervious to water. The non-suberized cells of the phellem seen in many plants are called **phelloids**. Cork is light in weight and has thermal insulating qualities. Imperviousness to water, and insulating qualities make the cork an important protective layer on the plant surface.

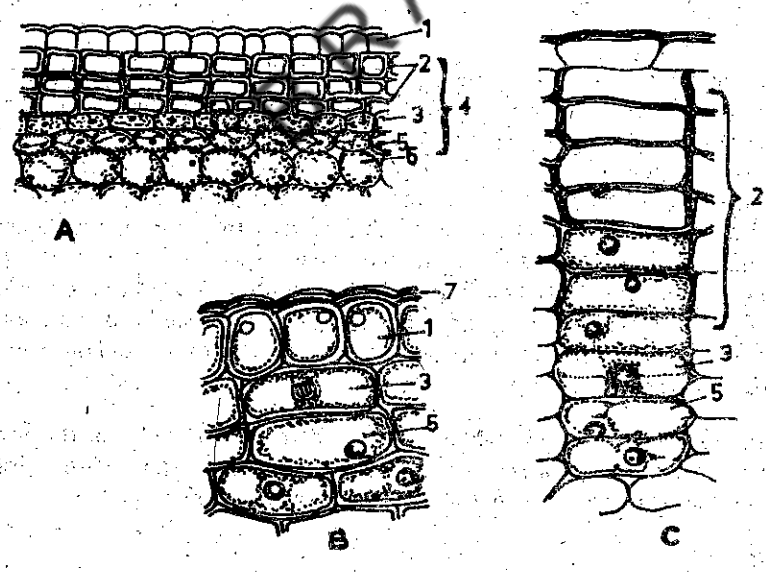

Fig. 9.10. Stages of periderm formation. 1. Epidermis. 2. Phellem. 3. Phellogen. 4. Periderm. 5. Phelloderm. 6. Cortex. 7. Cuticle.

3. Phelloderm (secondary cortex): The phelloderm or secondary cortex is a living tissue at maturity . The phelloderm cells resemble the parenchyma cells in the nature of their walls and contents (Fig. 9.10). However, the phelloderm could be distinguished from the normal cortex by the uniformly radial arrangement of its cells which clearly indicate its derivation from the phellogen.

Periderm Formation : The phellogen initial undergoes periclinical divisions and results in the formation of two similar cells. Of these. the inner cell becomes a phelloderm component. The outer cell undergoes another periclinal division resulting in the formation of two cells. The resultant outer cell becomes the cork cell and the inner one behaves like a phellogen element. Occasionally phellogen cells undergo anticlinal divisions to keep pace with the increase of the diameter of the plant part concerned. Normally more phellem layers are formed than the phelloderm layers Fig.9.10).

As the secondary growth continues, the first formed periderm may be replaced by the new ones formed from the deeper tissues of the stem.

9.4.3. Lenticels

In the periderm, locally, loosely arranged groups or masses of either suberized or non-suberized cells occur. The loose patches of cells with intercellular spaces are called **lenticels** (Fig.9.11). Lenticels are slightly elevated than the surrounding tissue. This is because of the formation of more number of loose cells in those areas. They normally replace single stoma or groups of stomata. Because of the loose arrangement of cells, the lenticels are regarded as structures to facilitate free gaseous exchange across the periderm. Lenticels are found normally on stems and roots.

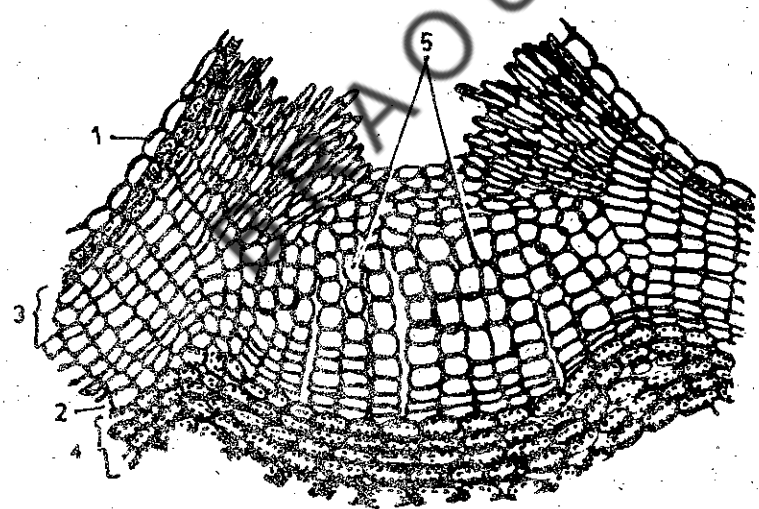

Fig. 9.11. Well developed lenticel in T.S. 1. Epidermis. 2. Phellogen. 3. Phellem. 4. Phelloderm. 5. Complementary cells.

Development and structure of lenticel : Lenticel is formed by the activity of **lenticel phellogen**. The cells of substomatal region divide in different directions and produce a loose tissue. Later, these divisions progress inward through the cortex. Finally these divisions are oriented periclinally [illegible] lenticel phellogen. As a result of these divisions in the substomatal region and [illegible] phellogen towards outside, loosely arranged cells with many [illegible] **entary cells** or **filling cells** (Fig .9.11). [illegible] uptured. The cell walls of the [illegible] Cork is resilient

Check Your Progress - 2 & 3

2. What is the difference between phellum and phelloderm?

3. What are lenticels ?

Note (a) Write your answers in the space given below.

(b) Compare your answers with those given at the end.

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9.5. SUMMARY

The secondary growth in dicotyledonous plants involves increase in girth by the addition of newly formed tissues. The secondary xylem and phloem are formed by the vascular cambium . Seasonal activity of the vascular cambium results in the production of annual rings in the stem wood.

The outer, rather narrow zone of the secondary xylem, light in colour and partly made up of living components, is called the sap wood. The inner, fairly broad zone of the secondary xylem, dark in colour and composed of dead elements represents the heart wood.

The secondary growth in dicot roots is similar to that of the stem but for the difference in the production and organisation of the vascular cambium. The phellogen or cork cambium, originating in the outer layers of the cortex, forms the cork and phelloderm, both in the stem and root.

9.6. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The tracheids and vessels formed in spring se[illegible] winter/autumn season are [illegible] sharp making th[illegible]

9.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give a brief account of secondary growth in a typical dicot stem.
2. Write a brief account of the secondary growth of dicot stem .
3. Describe the various activities of vascular cambium and its activity.
4. Discuss the role of different elements of periderm.

II. Answer the following questions in about 10 lines each.

1. Write briefly about vascular cambium.
2. Give a brief account of secondary xylem.
3. Write briefly about annual rings.
4. Briefly write about the sap wood and heart wood.
5. Write briefly about secondary phloem.
6. Give a brief account of xylem rays and phloem rays.
7. Write briefly about periderm.
8. Give a brief account of lenticels.

UNIT -10 : ANOMALOUS SECONDARY GROWTH

Contents

10.1. OBJECTIVES

By the end of this unit you will be able to:

1. define and differentiate the normal growth and abnormal growth and also non-adaptive type and adaptive type,

2. Describe the various methods of abnormal growth, and

3. Draw, label the parts and describe the primary structure and abnormal growth in the stems of *Aristolochia, Boerhaavia, Dracaena* and the root of *Beta.*

10.2. INTRODUCTION

The seed plants exhibit continual accretion of secondary vascular tissues all through their life by the activity of the normal vascular cambium. This is usually described **as normal secondary growth.** The details of which were already given in unit-9. In a number of angiosperms, however,

secondary growth takes place in a way that is different from that of the normal type, and is then described as **anomalous secondary growth.** This is also termed **abnormal secondary growth** or **unusual secondary growth.**

According to Haberlandt (1914), from the physiological point of view, the anomalous secondary growth may be of the **Non- adaptive** and **Adaptive** types.

Non-adaptive type: The anomalous secondary growth exhibited by some herbaceous plants (e.g. *Boerhaavia, Amaranthus, Achyranthes* etc) is not of any functional significance to these plants and may be described as of non-adaptive in nature.

Adaptive type: If the anomalous secondary growth is of definite functional advantage to the plant, it is then described as of adapative type. e.g., *Woody climbers* (Lianas).

Woody Climbers (Lianas): The mechanical requirements of liane stems are quite different from those of the ordinary woody plants. The stem of a woody climber must be flexible so that it would be able to twist and twine around its support in an efficient way. And at the same time it should be strong enough to support the weight of its own foliage. The above factors, hence, are responsible for the anomalous types of secondary growth exhibited by these plants.

Further, a solid mass of vertical trunk does not serve the purpose of a woody climber. On the contrary, a woody climber requires a stem that is supple and flexible enough to enable it to survive around its support efficiently and with ease. As a result of anomalous secondary growth, such a type of stem is produced in a liane.

10.3. METHODS OF ABNORMAL GROWTH

In general, anomalous secondary growth takes place through one of the following methods:

1. Abnormnal position of cambium.
2. Abnormal activity of cambium.
3. Formation of more than one cambial ring.
4. Formation of interxylary (included)phloem.
5. Formation of interxylary cork.

10.3.1. Abnormal Position of Cambium

In young stems of *Thionouia scandens* (Woody climber of the Bignoniacae), the cambium is not circular but is with ridges. Later, the cambial ridges get separated and act as individual cambia forming separate steles. Consequently the secondary growth becomes abnormal with separate steles with individual secondary phloem and secondary xylem resulting in a peculiar shape in the mature stem (Fig. 10.1 A).

In *Serjania* and *Paullinia* (Sapindaceae), the primary stems have individual strands of xylem surrounded by separate strips of cambia. After the secondary growth, separate cylinders of vascular tissues give the appearance of separate stems fused together like the strands of a rope (Fig. 10.1 B,C).

In *Bauhinia longsdorffiana* (Fabaceae) (Fig. 10.2 A) the parenchyma of secondary xylem and secondary phloem tissues undergo intercalary growth resulting in excessive amounts of parenchymatous tissues termed **dilation parenhyma.** This makes the secondary tissues along with cambium split into many strands.

10.3.2. Abnormal Activity of Cambium

In *Bauhinia rubiginosa* (Fig. 10.2B), the secondary vascular cylinder appears in the form of ridges and grooves. This is due to the abnormal activity of the cambial ring. Some parts of the cambium in the cambial ring produce more secondary vascular tissues whereas the other parts are more or less inactive.

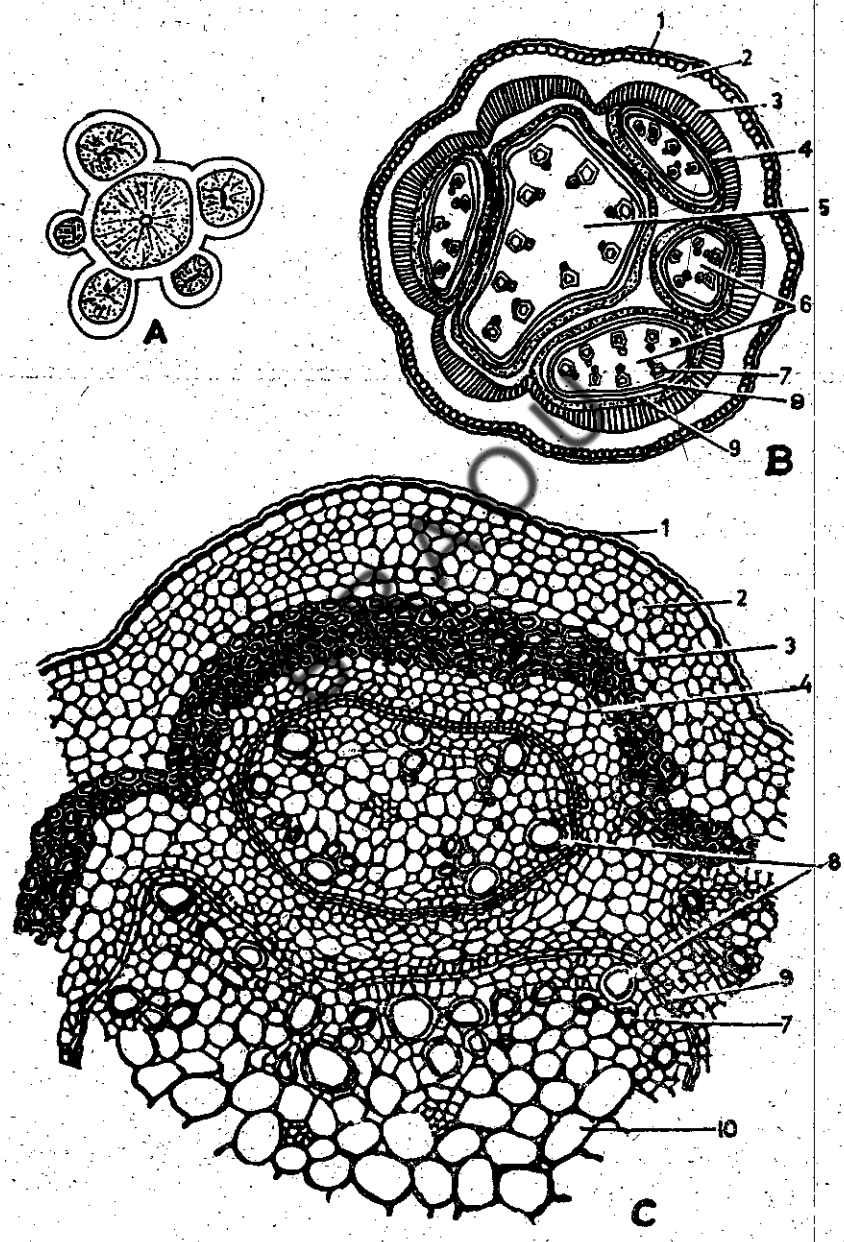

Fig. 10.1. Anomalous secondary growth. A. T.S. of the Stem of *Thionouia Scandens*. B. T.S. of the stem of *Serjania*. C. Magnified view of a part of B. 1. Epidermis. 2. Parenchyma. 3. Starch sheath. 4. Sclerenchymatous band. 5. Central stele. 6. Peripheral stele. 7. Xylem. 8. Cambium. 9. Phloem. 10. Pith.

In **Bignoniaceous climbers**, the output of secondary wood is relatively less from the beginning at **four points**, which are arranged in the form of a **cross**. At these points, however, the secondary phloem tissues are more. Consequently, the stem appears to be provided with four longitudinal furrows (Fig10.3). These grooves become constantly deeper, as the secondary growth proceeds. Later, the woody cylinders become split up into separate strips.

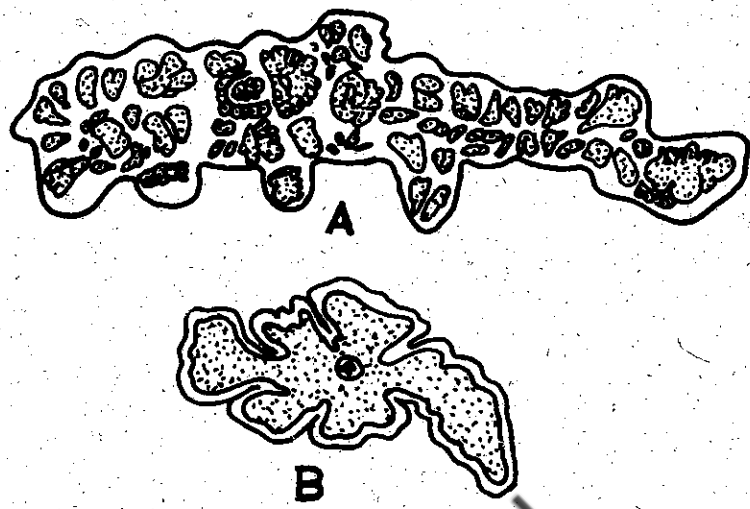

Fig. 10.2. Abnormal secondary growth. A. T.S. of the stem of *Bauhinia longsdorffiana* B. T.S. of the stem of *B. rubiginosa*.

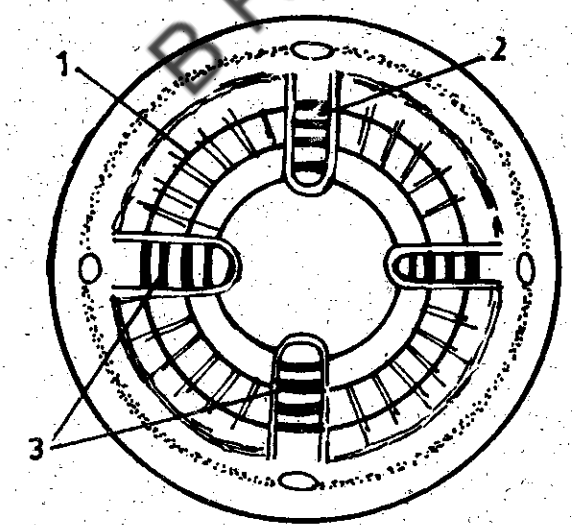

Fig. 10.3. T.S. of the stem of *Bignonia* showing secondary phloem supported by bars of sclerenchyma wedged in between secondary xylem (Diagrammatic). 1. Secondary xylem. 2. Secondary phloem. 3. Bars of sclerenchyma.

10.3.3. Formation of more than one Cambial Ring

In some angiosperms (*Boerhavia diffusa, Bougainvillea, Mirabilis*), normal vascular cambium ceases to function after the production of a limited quantity of vascular tissues. New cambia

are, however produced successively, in the pericycle and cortex (Fig. 10.4B & 10.4 C). About 28 families of dicotyledons show the formation of accessory cambia.

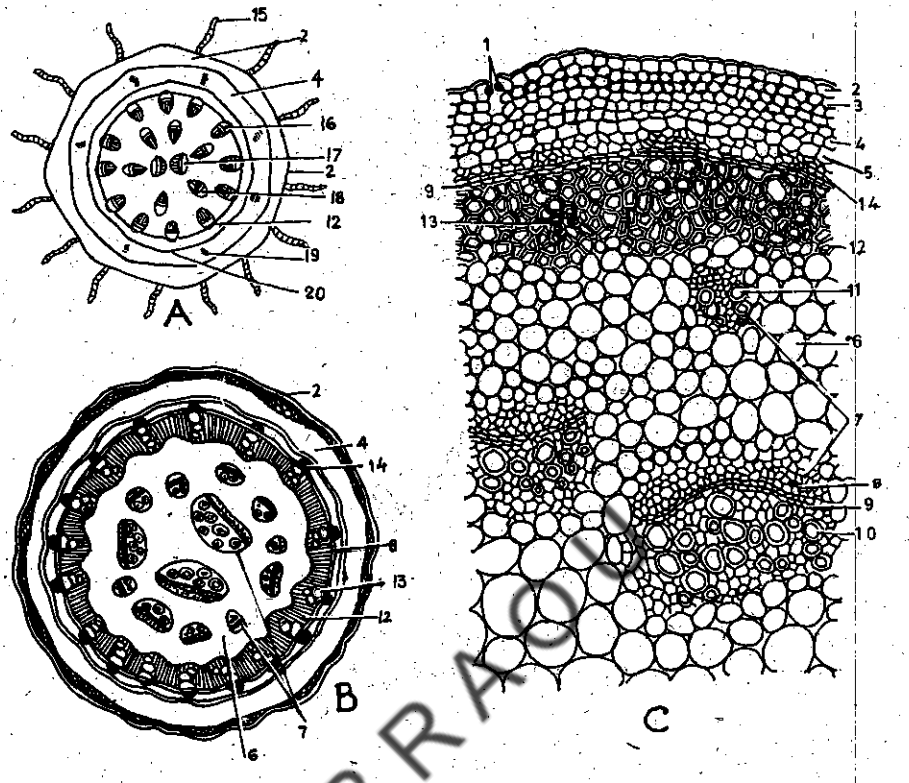

Fig. 10.4. *Boerhavia*. A. T.S. of the young *Boerhavia stem*. B. T.S. of the stem of *Boerhavia* showing anomalous secondary growth. C.A Portion of B enlarged. 1. Stoma. 2. Epidermis. 3. Hypodermis. 4. Parenchyma. 5. Starch sheath. 6. Ground tissue. 7. Medullary bundles. 8. Phloem. 9. Cambium. 10 Xylem. 11. Primary bundle. 12. Conjunctive tissue. 13. Secondary xylem. 14. Secondary phloem. 15. Hair. 16. Outer ring of vascular bundles. 17. Inner ring of vascular bundles. 18. Middle ring of vascular bundles. 19. Raphides. 20. Endodermis

In the Amaranthaceae (*Amaranthus*) (Fig. 10.5) and Chenopodiaceae (*Chenopodium*), the normal type of vascular cambium is absent. At the time of secondary growth, the first cambial ring is formed within the pericycle (extra-stelar cambium).

10.3.4. Formation of Interxylary (included) Phloem

Interxylary phloem is seen in about 25 families of the dicotyledons. In these plants, islands of secondary phloem are found embedded within the secondary xylem e.g. *Combretum, Entada* and *Strychnos*.

In *Strychnos* (Fig.10.6), the cambium produces the secondary xylem and secondary phloem in a normal manner and after sometime, ceases to be active. Later, new cambium is produced external to the secondary phloem. This cambium again functions normally by producing secondary xylem inwards and secondary phloem outwards. Thus the first formed secondary phloem is covered by secondary xylem on either side and gets **included**. Interxylary phloem plays significant role in some xerophytic plants as it remains functionally active even during drought conditions when other tissues desiccate and become non-functional.

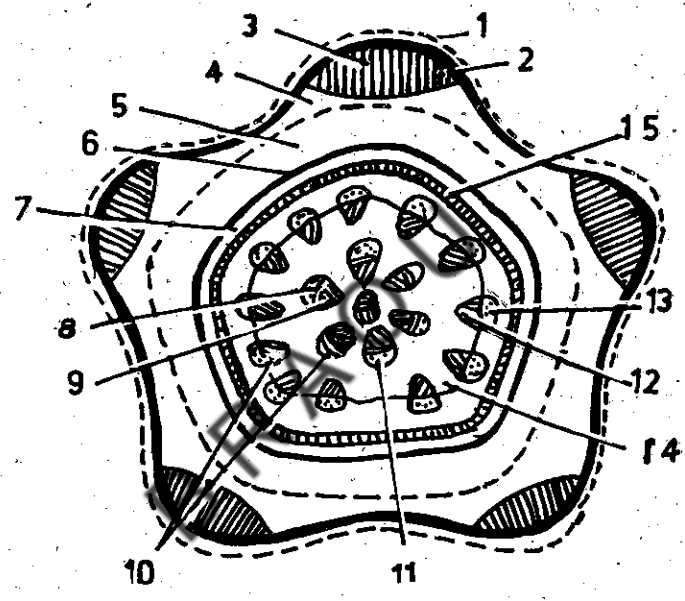

Fig. 10.5. T.S. of *Amaranthus* stem showing medullary bundles and extrastelar cambium (Diagrammatic). 1. Cuticle. 2. Epidermis. 3. Collenchyma. 4. Chlorenchyma. 5. Cortex. 6. Endodermis. 7. Pericycle. 8. Phloem. 9. Xylem. 10. Cambium. 11. Medullary bundle. 12. Secondary xylem. 13. Secondary phloem. 14. Conjunctive tissue. 15. Extrastelar cambium.

10.3.5 Interxylary Cork

Cork produced between two growth[illegible]ings of secondary xylem is known as **interxylary cork.** e.g. *Artemesia tridentata* (Asteracea[illegible] (Onagraceae). In these,

a cork cambium produces interxylary periderm in the parenchymatous zone in secondary wood. It is considered that such a cork in parennating organs helps to tide over unfavourable conditions of drought.

The following is the detailed account of the anomalous secondary growth in the stems of *Aristolochia*, *Boerhaavia* (dicotyledons), *Dracaena* (monocotyledon) and *Beta vulgaris* (Beet root).

Check Your Progress - 1

What is anomalous secondary growth ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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10.4. ANOMALOUS SECONDARY GROWTH IN *ARISTOLOCHIA* STEM

The genus is a member of th[illegible]d consists of herbs and woody plants.

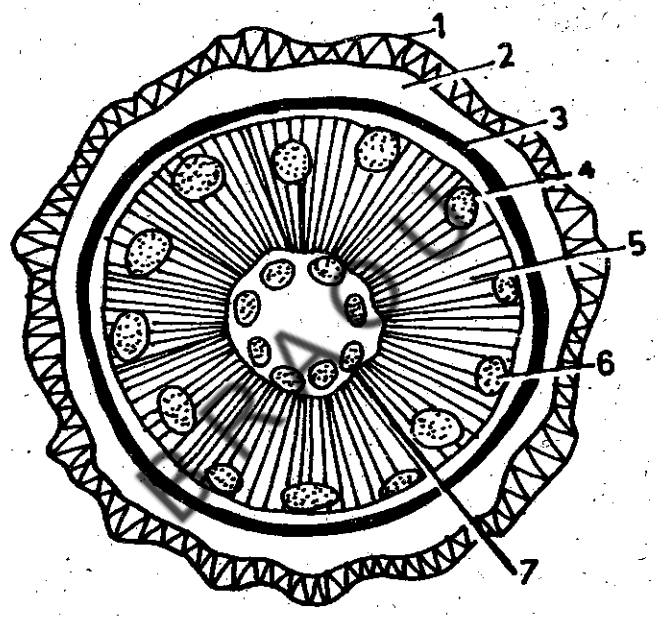

Fig. 10.6. T.S. of the stem of *Strychnos* sp. 1. Cork. 2. Cortex. 3. Sclerenchyma. 4. Secondary phloem. 5. Secondary xylem. 6. Interxylary (included) phloem. 7. Intraxylary Phloem.

10.4.1. Primary Structure

A transverse section through the young stem shows the following structure (Fig. 10.7 A,B)

Epidermis: It is one-layered and covered by a moderately thick cuticle and multicellular hairs.

Cortex: It is multilayered and of i) hypodermis, ii) general cortex iii) endodermis

Hypodermis: Consists of a few layers of collenchyma.

General Cortex: is the central part of the cortex. These layers are with chlorenchymatous thin walled cells with intercellular spaces.

Endodermis: is innermost layer of cortex and it consists of barrel shaped cells with starch grains.

Pericycle: It consists of a cylinder of perivascular sclerenchymatous fibres.

Vascular system: This is represented by a ring of few wedgeshaped vascular bundles. The vascular bundles are conjoint, collateral, endarch and open. In between the bundles are large paranchymatous medullary rays.

Pith: A parenchymatous pith is in the centre of the stem.

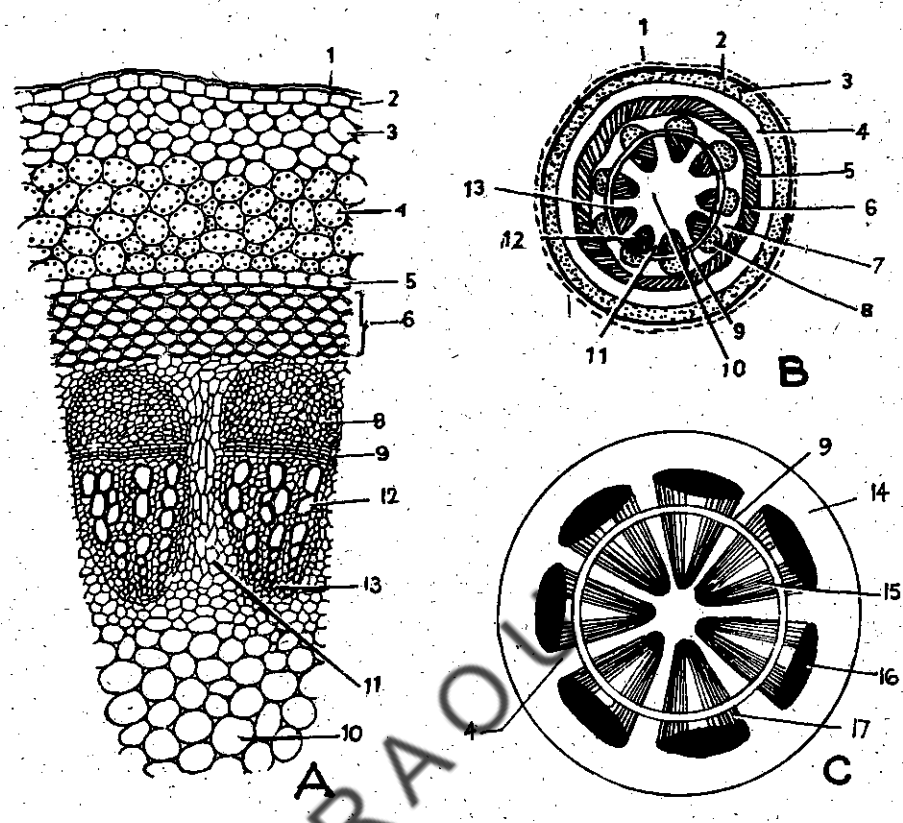

Fig. 10.7. *Aristolochia*. A. Young stem showing primary structure. B, C. T.S. of the stems of Aristolochia. 1. Cuticle. 2. Epidermis. 3. Collenchymatous cortex. 4. Chlorenchymatous cortex. 5. Endodermis. 6. Pericycle with perivascular fibres. 7. Parenchyma. 8. Phloem. 9. Cambium. 10. Pith. 11. Medullary ray. 12. Metaxylem. 13. Protoxylem. 14. Cortex. 15. Secondary xylem. 16. Primary phloem. 17. Secondary phloem.

10.4.2. Abnormal Secondary Growth

During the secondary growth, the parenchymatous cells of the medullary rays adjacent to the fascicular cambium become meristematic to form interfascicular strips of cambium. The interfascicular cambium behaves abnormally by producing only the parenchymatous cells (Fig. 10.7 B,C) On the other hand, the fascicular cambium of the vascular bundles behaves normally producing secondary xylem and phloem within the vascular bundles. Concomitantly, the vascular bundles, gradually increase in size but continue to maintain their individuality. A cork cambium meanwhile develops in the hypodermal collenchyma and produces cork externally and secondary cortex internally.

10.5. ANOMALOUS SECONDARY GROWTH IN *BOERHAAVIA* STEM

This is a common weed belonging to the Nyctaginaceae.

10.5.1 Primary Structure

A transverse section of the young stem reveals the following features (Fig 10.4)

Epidermis: It is one-layered, wavy with multicellular epidermal hairs.

Cortex: It consists of an outer collenchyma of 3 or 4 layers of cells followed by a 4 to 6 layered chlorenchyma. **Endodermis** is the innermost layer of cortex and consists of one layered thick-walled barrel-shaped cells.

Pericycle: It is parenchymatous and often with small isolated patches of sclerenchymatous fibres.

Vascular system: This is made up of three rings of vascular bundles. The inner ring is with two large oval, medullary bundles. These bundles face each other with xylem inwards and phloem outwards. The middle ring consists of 6-14 oval or circular vascular bundles which are smaller than those of the inner ring. On the other hand, the outer ring is of 12-20 still smaller bundles. Vascular bundles of all the three rings are conjoint, collteral, endarch and open.

10.5.2. Abnormal Secondary Growth

The vascular cambium in the bundles of the inner and middle rings produce limited amount of secondary xylem and secondary phloem resulting in the increase in size of the individual bundles. As no interfascicular cambium is produced, the original bundles though enlarged because of the addition of secondary vascular tissues, maintain their individuality.

On the other hand, a continuous cambial ring of fascicular and interfascicular strips is formed in the outer ring of vasculature. The cambium in this zone behaves abnormally producing secondary vascular tissue in the fascicular region and lignified conjunctive tissue in the interfascicular regions. The cambial activity declines soon. Subsequently, a new cambium arises in the parenchymatous region outside the outer ring of vasculature. In this way, four or five new accessory cambia arise outwards, and produce successive rings of collateral vascular bundles embedded in the conjuctive tissue.

Consequent to the formation of secondary tissues inside, cork cambium develops in the hypodermal collenchyma, and produces cork and secondary cortex in the usual way.

10.6. ANOMALOUS SECONDARY GROWTH IN *DRACAENA* STEM

Occurrence of secondary growth is an unusual phenomenon among the monocotyledons. Some members of the Liliflorae show abnormal secondary growth e.g. *Dracaena, Yucca, Cordyline, Agave, Aloe* etc. A cross - section through the stems of *Dracaena* reveals the following characters.

10.6.1. Primary Structure

Epidermis: It is made up of a single layer of compactly placed cells covered by a thin cuticle.

Cortex: The parenchymatous zone outside the region of primary vascular bundles is sometimes termed cortex.

Vascular bundles and ground tissue: The ground tissue forms the bulk of stem in which are embedded many vascular bundles in a scattered condition. The primary vascular bundles are oval and generally concentric. They are of the amphivasal type with a central patch of phloem sorrounded by the xylem. Some of these vascular bundles are simply collateral and conjoint.

10.6.2. Abnormal Secondary Growth

The secondary growth is initiated by the differentiation of the cambium in the cortex outside the zone of primary vascular bundles. The activity of this cambium is unusual. It produces more cells inwards than outwards (Fig.10.8). The cells produced inwards get transformed into parenchymatous **conjunctive tissue** and secondary **amphivasal or collateral bundles**. The secondarily formed bundles are more or less in regular radial rows.

The cells formed **outwards** by the cambium are parenchymatous and constitute the **secondary cortex**. They are thick-walled lignified and are arranged in regular radial rows.

Formation of Storied Cork: The parenchyma of the cortex divide many times periclinally and the products of these divisions, aligned in distinct radial rows (storied cambium) become suberized. The cork of this type is called the **storied cork**.

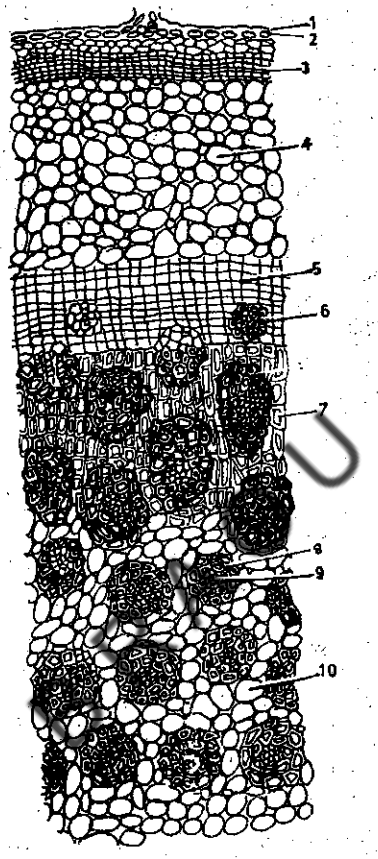

Fig. 10.8. T.S. of *Dracaena* Stem (detailed). 1. Cuticle. 2. Epidermis. 3. Cork cambium. 4. Paranchyma. 5. Cambium. 6. Seondary bundle 7. Secondary tissue. 8. Xylem. 9. Phloem. 10. Ground tissue.

10.7 ANOMALOUS SECONDARY GROWTH IN THE ROOT OF *BETA*

It belongs to the Chenopodiaceae family. The primary vasculature of the Beta (Beet root) is diarch.

The secondary growth is initiated by the formation of a cambium in the interstitial parenchyma, except opposite the two protoxylem groups where it is from the pericycle. This cambium gives rise to the innermost ring of essentially collateral vascular bundles separated by narrow bands of parenchyma. After sometime, the cambium ceases to function and another cambium arises from the phloem parenchyma of the first ring of vascular bundles. This cambium produces a second ring of vascular bundles separated by large radial channels of storage parenchyma.

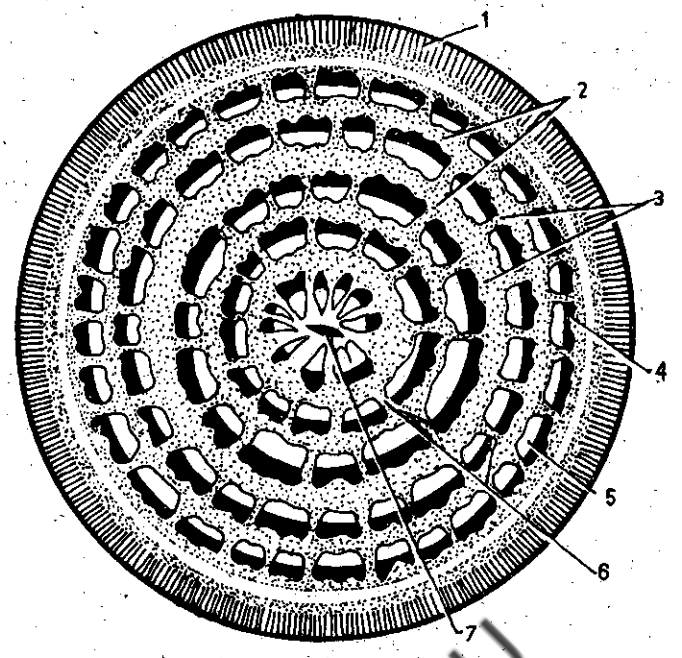

Fig. 10.9. T.S. of the storage root of *Beta vulgaris* (diagrammatic) 1. Periderm. 2. One growth layer. 3. Storage parenchyma. 4. Secondary phloem. 5. Secondary xylem. 6. Vascular cambial ring. 7. Primary xylem.

Soon a third ring of vaascular bundles is produced from yet another cambium derived either from phloem or pericycle, and it also behaves in the same way as the earlier cambia. Thus a number of accessory cambia are produced and contribute to the successive rings of vascular bundles alternating with parenchyma.

The vascular bundles produced in successive rings by the accessory cambia consist more of parenchyma and less of xylem elements.

10.8. SUMMARY

In a number of angiosperms, anomalous secondary growth takes place in diverse ways e.g. production of cambium in abnormal position, abnormal activity of cambium, formation of accessory cambia etc. The anomalous secondary growth is of adaptive and non-adaptive types, the former seen in various woody climbers and the latter in many herbaceous plants.

The details of anomalous secondary growth in the stems of *Aristolochia, Boerhaavia,* and *Dracaena* and the root of *Beta vulgaris* have been described.

10.9. CHECK YOUR PROGRESS: MODEL ANSWERS

1. If the secondary growth is different in any way from the normal type, it is called anomalous secondary growth.

10.10. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. What do you understand by anomalous secondary growth? Illustrate your answer with reference to some forms you have studied.
2. Give an illustrated account of anomalous secondary growth in the stems of one dicotyledonous and one monocotyledonous plant.
3. With suitable diagrams explain the anatomical peculiarities found in the stems of climbing plants.
4. Describe how secondary growth takes place in monocots.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the anomalous secondary growth.
2. How does anomalous secondary growth takes place due to the abnormal position of cambium?
3. Explain briefly the anomalous secondary growth that takes place due to the abnormal activity of cambium.
4. Write briefly about the anomalous secondary growth in *Aristolochia* stem.
5. Give a brief account of the abnormal secondary growth that takes place in the stem of *Boerhaavia.*
6. Explain briefly the anomalous secondary growth that takes place in *Dracaena* stem.
7. Write a brief account on the abnormal secondary growth in Beet root.

10.11. GLOSSARY

Amphivasal	: Concentric vascular bundle in which the phloem is surrounded by the xylem.
Anisotropic	: Applied to bodies which vary in size in different directions.
Anticlinal division	: Orientation of cell wall or plane of division perpendicular to the nearest surface.
Auxin	: A plant hormone or growth promoting substance. e.g. Indole Acetic Acid (IAA).
Cambium	: Layer of meristematic cells between the xylem and phloem tissues.
Centrifugal	: Developing or maturing from the centre towards outside.
Centripetal	: Developing or maturing from the outside towards centre.
Colchicine	: An alkaloid used to produce polyploidy and extracted from *Colchicum*, a genus of Liliaceae.
Collateral	: A vascular bundle with the phloem (outwards) only on one side of the xylem (inwards)
C-mitosis	: Mitotic cell divisions induced by the application of colchicine.

Histogen	: Term used by Hanstein for a meristem in stem apex or root apex that forms a definite tissue system in the plant.
in vitro	: In glass; hence in a test tube or beaker.
Isotropic	: Having the same properties in all directions.
Lianas	: Any contorted woody climbing plants usually seen in tropical forests.
Periclinal division	: Orientation of cell wall or plane of division parallel to the circumference or the nearest surface.
Polyploidy	: Having more than two sets of chromosomes.
Primordium (Pl.Primordia)	: The rudiment or beginning of a part.

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BLOCK - III

TAXONOMY

UNIT-11 : TAXONOMIC RANKS

Contents

11.1. OBJECTIVES

By the end of this unit you will be able to:

1. list out the principal ranks of taxa in the plant kingdom,
2. differentiate the specific endings of various ranks as per the rules of the International Code of Botanical Nomenclature and
3. define binomial nomenclature.

11.2. INTRODUCTION

When plants are divided into groups according to the similarity of their characters, they are called taxonomic "ranks". They form various steps of the classification ladder. The taxonomic groups of any rank may be referred to as **taxa** (singular = taxon).

11.3. TAXONOMIC RANKS

The basic unit of various ranks is **the species.** It is a physical entity. The next rank in the ascending order is the **genus** formed by one or more species. The ranks above species represent a **"mental picture"** but not a physical entity as they are often based on more than one physical entity (=species). One or more genera constitute a **family.** The next rank in the ascending sequence is the **order** which is made up of one or more families. A **class** is made up of one or more orders. A **division** is based on one or more classes.

A **Kingdom** is formed on the basis of several divisions.

Thus the principal ranks of taxa are:

English	Latin
Kingdom	Regnum
Division	Divisio
Class	Classis
Order	Ordo
Family	Familia
Genus	Genus
Species	Species

The above taxonomic ranks may be further subdivided by adding the prefix **sub** to any rank or by the introduction of supplementary terms e.g., subfamily, subgenus, etc. Within the species, a number of taxonomic ranks such as subspecies, varieties etc. are also recognised.

As per the rules of International Code of Botanical Nomenclature the various ranks should have specific "endings" and the endings of the principal ranks are as follows.

Rank	Ending	Example
Kingdom	**--a,ae**	Phyta (Plantae) Mycetae (Fungi)
Division	**--phyta** **--mycota (fungi)**	Pterophyta Eumycota
Class	**--opsida** (Embryophyta) **--phyceae** (Algae) **--mycetes** (fungi)	Lycopsida Chlorophyceae Basidiomycetes
Order	**--ales**	Magnoliales
Family	**--aceae**	Magnoliaceae.

Taxonomic Ranks and Their Naming as per Botanical Code : The scientific name of a plant is made up of two epithets (binomial) consisting of the genus name followed by the species name. e.g., *Launaea procumbens* Ramayya & Rajagopal. The name(s) after the specific epithet represents its author(s) name. This type of nomenclature is called **Binomial nomenclature** and it was introduced by Linnaeus.

	Example 1	**Exaple 2**
Division	Magnoliophyta (Angiosperms)	Magnoliophyta
Class	Magnolidae	Liliatae
Subclass	Asteridae	Lilidae
Order	Asterales	Orchidales
Family	Asteraceae	Orchidaceae
Genus	*Launaea*	*Habenaria*
Species	*procumbens*	*ramayyana*

Recently some botanists preferred to introduce new taxonomic ranks by prefixing ; 'super" e.g., Super Kingdom. **Eukaryota** = organisms with membrane bounded nucleus.

Check Your Progress -1

What are taxonomic ranks ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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11.4. SUMMARY

Taxonomic ranks are instituted by grouping plants according to their similarity. The principal taxonomic ranks in ascending order are species, genus, family, order, class, division and kingdom. The species is the basic unit of the taxonomic ranks and constitutes a physical entity.

The scientific name of the plant is made up of 2 parts - (a) generic epithet and (b) specific epithet.

11.5. CHECK YOUR PROGRESS: MODEL ANSWERS

1. According to the similarity of characters, the plants are divided into groups called Taxonomic Ranks.

11.6. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write about different taxonomic ranks in the plant kingdom substantiating their endings as per botanical code.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the specific endings of various ranks as per the rules of International Code of Botanical Nomenclature.
2. Describe briefly the Binomial system of nomenclature.

UNIT-12 : CLASSIFICATION OF BENTHAM AND HOOKER AND PHYLOGENETIC CONSIDERATIONS

Contents

12.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the classification of Bentham and Hooker,
2. list out the merits and demerits of Bentham and Hooker system of classification, and
3. list out the primitive characters and advanced characters of plants.

12.2. INTRODUCTION

Classification of plants is a fascinating subject. Broadly speaking, classificatory systems dealing with plants, can be divided into (1) classifications based on habit, (2) artificial systems based on numerical classification, (3) systems based on form relationships (natural systems) and (4) systems based on Phylogeny (blood relationship). Bentham and Hooker system of classification represents the culmination point of "systems based on form relationships". **George Bentham** and **Sir Joseph Dalton Hooker**, two British botanists, published their work in Latin, as a 3-volume work *"Genera Plantarum"* during 1862-1883. The work contains names and descriptions of all genera of seed plants known upto the period of its publication and arranged according to their system of classification. Two thirds of the *"Genera Plantarum"* was written by Bentham and the rest by Hooker, during a span of dedicated effort of about 25 years.

The Bentham and Hooker system is in general based on de Jussieu's, de Candolle's and Lindley's works. The system includes classification of seed plants only and deals with about 97,205 species.

12.3. BENTHAM AND HOOKER SYSTEM

Bentham and Hooker divided the seed plants into three major groups: I. Dicotyledones, II. Gymnospermae and III. Monocotyledones. Each group is further divided into Series, Cohorts and Natural orders. A broad outline of the classification is as follows:

Phanerogams (Seed Plants)

- Dicotyledones
  - Polypetalae
  - Gamopetalae
  - Monochlamydeae
- Gymnospermae
- Monocotyledones

12.3.1. Dicotyledones

The group Dicotyledones is divided into 3 subgroups *viz.*, polypetalae, Gamopetalae and Monochlamydeae.

Polypetalae

i) Flowers with two worls of Perianth

ii) Inner whorl or Petals free.

Series 1. Thalamiflorae

i. Sepals usually distinct or free from ovary

ii. Petals and stamens hypogynous

Cohort 1. Ranales

Families.
1. Ranunculaceae
2. Dilleniaceae
3. Calycanthaceae
4. Magnoliaceae
5. Annonaceae
6. Menispermaceae
7. Berberidaceae
8. Nymphaeaceae

Cohort 2. Parietales

Families
1. Sarraceniaceae
2. Papaveraceae
3. Cruciferae
4. Capparidaceae
5. Resedaceae
6. Cistineae
7. Violaceae
8. Canellaceae
9. Bixineae

Cohort 3. Polygalineae

Families
1. Pittosporeae
2. Tremandreae
3. Polygaleae
4. Vochysiaceae

Cohort 4. Caryophyllineae

Families
1. Frankeniaceae
2. Caryophyllaceae
3. Portulacaceae
4. Tamariscineae

Cohort 5. Guttiferales

Families
1. Elatineae
2. Hypericineae
3. Guttiferae
4. Ternstroemiaceae
5. Dipterocarpeae
6. Chlaenaceae

Cohort 6. Malvales

Families
1. Malvaceae
2. Sterculiaceae
3. Tiliaceae

Series 2. Disciflorae

i. Sepals distinct or united, free or adnate to ovary

ii. Conspicuous Disc present at the base of ovary

iii. Stamens generally definite in Number

iv. Ovary superior.

Cohort 1. Geraniales

Families 1. Lineae 2. Humiriaceae
3. Malpighiaceae 4. Zygophyllaceae
5. Geraniaceae 6. Rutaceae
7. Simaroubaceae 8. Ochnaceae
9. Burseraceae 10. Meliaceae
11. Chailletiaceae.

Cohort 2. Olacales

Families 1. Olacineae 2. Ilicineae
3. Cyrilleae

Cohort 3. Celastrales

Families 1. Celastrineae 2. Stackhousieae
3. Rhamneae 4. Ampelideae

Cohort 4. Sapindales

Families 1. Sapindaceae 2. Sabiaceae
3. Anacardiaceae

Anomalous Families

1. Coriarieae
2. Moringeae

Series 3. Calyciflorae

i. Sepals united and adnate to ovary
ii. Flowers perigynous or Epigynous
iii. Disc adnate to the base of calyx
iv. Ovary half inferior or inferior

Cohort 1. Rosales

Families - 1. Connaraceae 2. Leguminosae
3. Rosaceae 4. Saxifragaceae
5. Crassulaceae 6. Droseraceae
7. Hamamelideae 8. Bruniaceae
9. Halorageae

Cohort 2. Myrtales

Families - 1. Rhizophoraceae 2. Combretaceae
3. Myrtaceae 4. Melastomaceae
5. Lythraceae 6. Onagraceae

Cohort 3. Passiflorales

Families - 1. Samydaceae 2. Loaceae
3. Turneraceae 4. Passiflorae
5. Cucurbitaceae 6. Begoniaceae

7. Datisceae

Cohort 4. Ficoidales

Families 1. Cactaceae 2. Ficoideae

Cohort 5. Umbellales

Families 1. Umbelliferae 2. Araliaceae

3. Cornaceae.

Gamopetalae

i. Flowers with distinct calyx and corolla

ii. Petals united.

Series 1. Inferae

i. Stamens generally as many as Petals

ii. Ovary Inferior

Cohort- 1. Rubiales

Families - 1. Caprifoliaceae 2. Rubiaceace

Cohort - 2. Asterales

Families - 1. Valerianeae 2. Dipsacaceae

3. Calycereae 4. Compositae

Cohort - 3. Campanales

Families 1. Stylideae 2. Goodenoviae

3. Campanulaceae.

Series 2. Heteromerae

i. Stamens either equal to the number of Petals or double the number of Petals or indefinite.

ii. Carpels more than two.

iii. Ovary superior.

Cohort - 1. Ericales

Families 1. Ericaceae 2. Vaccinieae

3. Monotropeae 4. Epacrideae

5. Diapensiaceae 6. Lennoaceae

Cohort 2. Primulales

Families - 1. Plumbagineae 2. Primulaceae

3. Myrsineae

Cohort 3. Ebenales

Families - 1. Sapotaceae 2. Ebenaceae

3. Styraceae

Series 3. Bicarpellatae

i. Stamens Epipetalous, as many as or fewer than petals.

ii. Carpels usually two.

iii. Ovary superior.

Cohort - 1. Gentianales

Families - 1. Oleaceae 2. Salvadoraceae
3. Apocynaceae 4. Asclepiadaceae
5. Loganiaceae 6. Gentianaceae

Cohort - 2. Polemoniales

Families - 1. Polemoniaceae 2. Hydrophyllaceae
3. Boranaceae 4. Convolvulaceae
5. Solanaceae

Cohort - 3. Personales

Families - 1. Scrophulariaceae 2. Orobanchaceae
3. Lentibulariaceae 4. Columelliaceae
5. Gesnaraceae 6. Bignoniaceae
7. Pedalineae 8. Acanthaceae

Cohort - 4. Lamiales

Families - 1. Myoporineae 2. Selagineae
3. Verbenaceae 4. Labiateae.

Anomalous Family - Plantagineae

Monochlamydae

Flowers generally with one whorl of Perianth of Sepaloid nature; sometimes Perianth altogether absent.

Series 1. Curvembryae

Families - 1. Nyctagineae 2. Illecebraceae
3. Amarantaceae 4. Chenopodiaceae
5. Phytolaccaceae 6. Batideae
7. Polygonaceae

Series 2. Multiovulate Aquaticae

Family - 1. Podostemaceae

Series 3. Multiovulate Terrestres

Families - 1. Nepenthaceae 2. Cytinaceae
3. Artistolochiaceae.

Series 4. Micrembryae

Families - 1. Piperaceae 2. Chloranthaceae
3. Myristiceae 4. Monimiaceae

Series 5. Dephnales

Families 1. Laurineae 2. Proteaceae
3. Thymeliaceae 4. Penacaceae
5. Elaegnaceae

Series 6. Achlamydosporae

Families - 1. Loranthaceae 2. Santalaceae
3. Balanophoraceae

Series 7. Unisexuales

Families 1. Euphorbiaceae 2. Balanopseae
3. Urticaceae 4. Plantanaceae
5. Myricaceae 6. Casuarineae
7. Cupuliferae

Anomalous Families 1. Salicaceae
2. Lacistemaceae
3. Empetraceae
4. Ceratophylleae

12.3.2. Gymnospermae

Gymnospermae is divided directly into 3 families

Families 1. Gnetaceae 3. Cycadaceae
2. Coniferae

12.3.3. Monocotyledones

Monocotyledones is divided into 7 series.

Series 1. Microspermae

Families 1. Hydrocharideae 2. Burmanniaceae
3. Orchideae

Series 2 - Epigynae

Families 1. Scitamineae 2. Bromeliaceae
3. Haemodoraceae 4. Iideae
5. Amaryllideae 6. Taccaceae
7. Dioscoriaceae

Series 3. Coronarieae

Families 1. Roxburghiaceae 2. Liliaceae
3. Pontederiaceae 4. Phylidraceae
5. Xyrideae 6. Mayacaceae
7. Commelinaceae 8. Rapateaceae

Series 4- Calycineae

Families 1. Flagellariaceae 2. Juncaceae
3. Palmae

Series 5. Nudiflorae

Families - 1. Pandaneae 2. Cyclanthaceae
3. Typhaceae 4. Aroideae
5. Lemnaceae

Series 6. Apocarpae

Families 1. Triurideae 2. Alismaceae
3. Najadaceae

Series 7 - Glumaceae

Families 1. Eriocauleae 2. Centrolepidea
3. Restiaceae 4. Cyperaceae
5. Gramineae

12.3.4. Merits and Demerits

The taxonomic ranks of Bentham and Hooker and their equivalents in accordance with the International Code of Botanical Nomenclature are as follows:

Group	=	Division	e.g., Dicotyledones
Subgroup	=	Subdivision	e.g., Polypetalae
Series	=	Class	e.g., Thalamiflorae
Cohort	=	Order	e.g., Ranales
Natural Order	=	Family	e.g., Magnoliaceae

For seed plants, Bentham and Hooker recognised about 202 families of which 163 represent the Dicotyledones, 34 the Monocotyledones and 3 the Gymnosperms. They divided Dicots into three subgroups - **Polypetalae, Gamopetalae** and **Monochlamydeae** based on the nature of perianth. These are further divided into series. The Polypetalae is divided into 3 series, **Thalamiflorae, Disciflorae** and **Calyciflorae**, based on the nature of ovary and the presence of hypogynous disc. In Thalamiflorae the ovary is superior and the disc is absent. In Disciflorae ovary is superior and the disc is present. In Calyciflorae the ovary is superior to inferior and is accompanied by the fusion of calyx and corolla (e.g. Cucurbitaceae). On the other hand, in Gamopetalae the emphasis is based on fusion of petals and reduction of stamens. In this group 3 series are recognised: **Inferae** (with inferior ovary and five stamens), **Heteromerae** (with superior ovary and 1 or 2 series of stamens), and **Bicarpellatae** (with bicarpellary ovary and a trend showing reduction of stamens from 5 to 2).

The Monochlamydeae represents a heterogeneous group of members which could not be accommodated either in Poly - or Gamo- petalae as it shows absence of non-essential floral parts or their reduction, accompanied often by unisexual flowers. The treatment of the Monocotyledones by Bentham and Hooker is slightly different, and unlike Dicotyledons, they have not recognised cohorts within the series. The series are followed directly by natural orders (families). In all, seven series are recognised among monocots.

Apart from the above treatment, they also recognised few anomalous families such as Coriarieae, Moringeae, and Plantagineae etc.

The system of classification proposed by Bentham and Hooker is said to be "natural system" because it is a byproduct of an extensive comparative study of vegetative and floral characters of plants, indicating natural affinities. One can recognise the following trends in this system: (i) a trend from woody to herbaceous/aquatic habit in any group, (ii) Floral parts free and numerous to floral parts few and variously fused (e.g., Polypetalae to Gamopetalae) and (iii) Superior ovary to inferior ovary condition, with exception in Gamopetalae and Monocots.

The major merit of Bentham and Hooker's Genera Plantarum is, the presentation of description of genera based on their personal observation of plants, available at Kew Herbarium, and collected from various parts of the world. Further, most of the genera are subdivided into subgenera or sections, each of which is named, diagnosed, and clearly circumscribed.

The other significant aspect of the system is, employing more than one character, for instituting the groups.

This system is followed in all the Commonwealth countries and it withstood the test of time as an efficient and practical system for the identification and classification of species.

The major defects in Bentham and Hooker system are (a) inclusion of Gymnosperms between Dicots and Monocots, (b) Accepting the dogma of constancy and immutability of species, (c) institution of a heterogenous group the monochlamydeae and (d) treatment of certain families as anomalous ones, without incorporating them in the main body of the classification.

Check Your Progress 1, 2 & 3

1. What is the title of the book written by Bentham & Hooker.
2. What is the criteria taken to divide the group dicots into sub-groups ?
3. What are the major defects in the classification of Bentham & Hooker ?

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end.

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12.4. PHYLOGENETIC CONSIDERATIONS

Phylogeny is the evolutionary history of the organisms. Information regarding the origin and development of a taxon is provided in **Phylogenetic Studies**. The fundamental objective

of phylogenetic studies of plants is to determine the origin and relationships of taxa (both past and present) and to classify them according to their genetic (blood) relationship. To provide a sound genetical kin-ship, it is essential to have data on the past-history (Paleobotanical evidence) of plants. The lack of adequate Paleobotanical evidence for the origin and early development of Angiosperms, however seems to be a major obstacle in arriving at a uniform opinion on phylogenetic studies of these plants. Accordingly, systematists like Bessy (1915), Hutchinson (1926,1971), Sporne (1949, 1954), Smith (1967) etc., postulated certain phyletic concepts based on extensive comparative morphological study of diverse members of the modern Angiosperms.

The general phylogenetic dicta concerning the primitivity and advancedness of various characters accepted by the majority of botanists are as follows:

Primitive condition	Advanced condition
1. Woody habit	1. Herbaceous habit.
2. Xylem without vessels	2. Xylem with vessels
3. Perennial habit	3. Biennial and annual habit
4. Terrestrial plants	4. Aquatic and epiphytic plants
5. Stipules present	5. Stipules absent
6. Simple leaves	6. Compound leaves
7. Bisexual flowers	7. Unisexual flowers
8. Solitary flowers	8. Flowers in inflorescens
9. Entamophily	9. Anemophily
10. Floral parts spirally imbricate	10. Floral parts whorled or valvate
11. Undifferentiated perianth	11. Differentiated perianth
12. Petals present	12. Petals absent
13. Actinomorphic flowers	13. Zygomorphic flowers
14. Hypogyny	14. Perigyny and epigyny
15. Stamens free and many	15. Stamens united and few
16. Monosulcate pollen	16. Monoporate pollen
17. Carpels many and free	17. Carpels few and united
18. Placentation laminar	18. Placentation axile, parietal etc.
19. Fruit a follicle	19. Fruit a capsule, berry, drupe etc.
20. Seeds large, embryo small endosperm abundent and nuclear type	20. Seeds small, embryo well developed, endosperm little or none and cellular or helobial type.

12.5. SUMMARY

Bentham and Hooker system of classification of seed plants is a "natural system" based upon an extensive comparative study of the plant characters indicating their natural affinities. It is an efficient and practical system followed in all the Commonwealth countries. According to this system, the seed plants are divided into three major groups *viz.*, Dicotyledones, Gymnospermae and Monocotyledones. Each major group is further divided into series, cohorts and natural orders (families). The following trends are recognizable in this system (1) a trend from woody to herbaceous /aquatic habit, (2) floral parts free and numerous to few and variously fused and (3) superior to inferior ovary.

Phylogeny is the evolutionary history of the organisms. Determination of the origin and interrelationship of the taxa and to classify them according to their genetic code are the fundamental objectives of the genetic code.

12.6. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The title of the book written by Bentham & Hooker is Genera Plantarum.
2. Nature of perianth parts is the criteria taken to divide the group dicots into sub-groups.
3. The major defects in the Bentham & Hooker system of classification is : (a) inclusion of Gymnosperms between dicots & monocots, (b) accepting the dogma of constancy and immutability of species, (c) institution of a heterogeneous group, namely, the monocotyledonae & (d) traeatment of certain families as anomalous families.

12.7. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Give a brief account of Bentham and Hooker system of classification and discuss its merits and demerits.
2. Why is Bentham and Hooker system of classification called as a natural system of classification.
3. What is meant by phylogenetic consideration in plant classification.

II. Answer the following questions in about 10 lines each.

1. Describe briefly the merits and demerits of the classification of Bentham & Hooker.
2. Write briefly about the primitive and advanced characters of plants.
3. Write briefly about the salient features of the classification of Bentham & Hooker.

UNIT-13 : MAGNOLIACEAE

Division	:	Dicotyledons
Sub Division	:	Polypetalae
Class	:	Thalamiflorae
Order	:	Ranales
Family	:	Magnoliaceae.

Contents

13.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of different members,
2. list out the important genera,
3. list out the distinguishing characters, and
4. describe the economic importance of the family Magnoliaceae.

13.2. INTRODUCTION

The family consists of 25 genera and 450 species and cofined to tropics and subtropics of India, East Asia and America; mostly trees, shrubs and few climbers *(Kadsura)*, Oil passages are often present in the parenchyma of the stems. Xylem with scalariform perforated vessels.

13.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Leaves simple with paracytic stomata. Stipules are united to form a hood over the younger leaves. They are thrown off as the leaves expand leaving a round scar on the node x (Magnolia). In *Kadsura* species stipules are absent.

Flowers mostly solitary, actinomorphic, either terminal or axillary; bisexual or unisexual (*Komneria*). Bracts spathaceous and deciduous, perianth in multiple of three, in three or more whorls, mostly petaloid; in some cyclic (*Magnolia*) and spiral in others; hypogynous.

Stamens numerous, spirally arranged, flat, bilobed, dehiscing longitudinally, introrse or latrorse (*Magnolia, Michelia*) or extrorse (*Liriodendron*) ; pollengrains, bilaterally symmetrical, monosulcate.

Gynoecium superior, carpels numerous, apocarpus; arranged spirally on long torus. Ovary one -loculed, ovules one to many, parietal and anatropus, Style one, stigma one.

Fruit an aggregate of follicles (*Magnolia*) or samara (*Liriodendron*) or berry (*Schisandra*). Seeds with small embryo and with copious endosperm; mostly suspended by an elongated funiculus. Testa of the seeds is coloured (*Magnolia - reddish*)

The species of *Magnolia, Taluma* and *Michelia* are cultivated as ornamentals. *Liriodendron tulipifera* (Tulip tree) yields useful timber and is used in making furniture. The wood of some species of *Magnolia (M. acuminata*-cucumber tree) is used for cabinet work. In India from *Michelia champaca* flowers champaca oil (a perfume) is extracted.

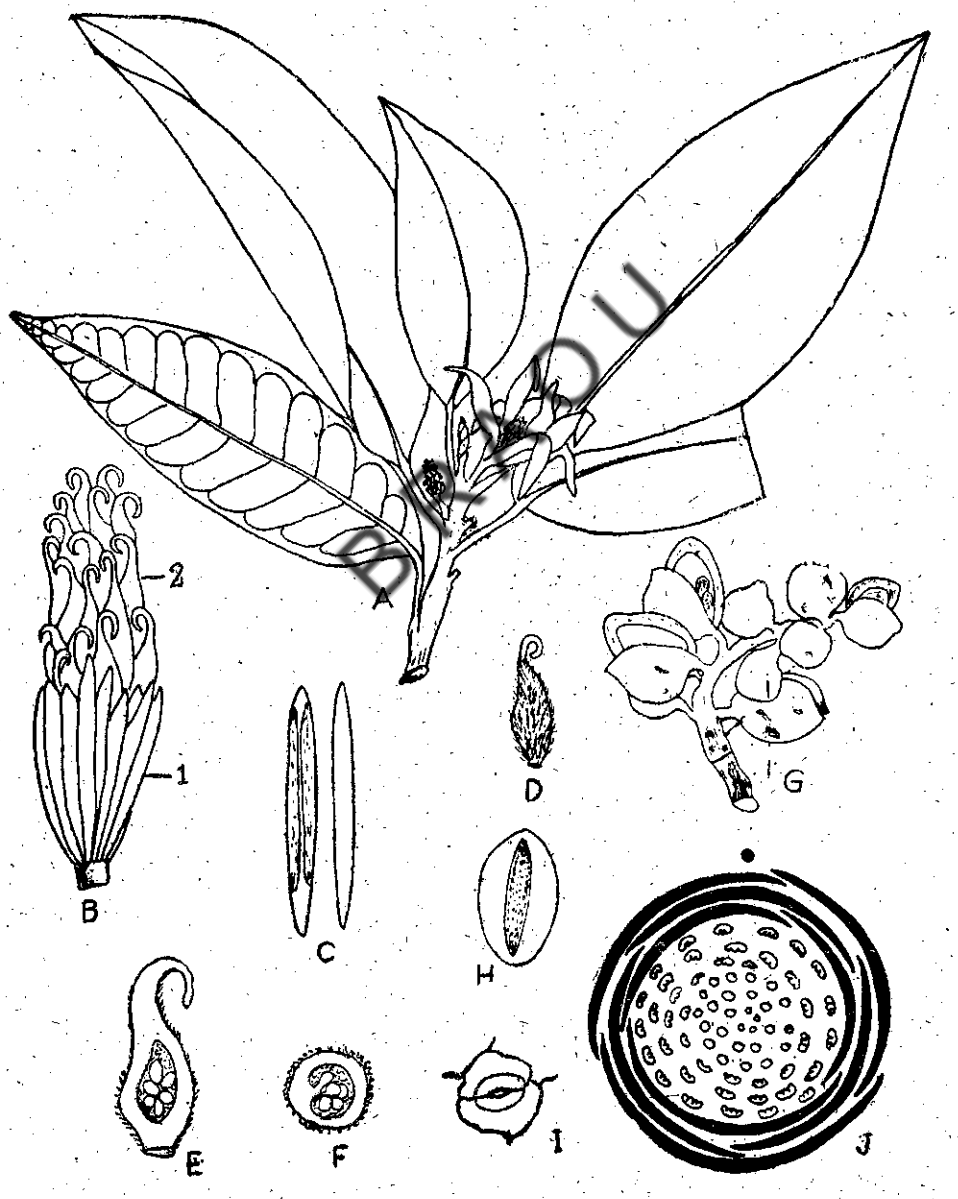

Fig. 13.1. *Michelia* 13. 1. *champca*. A. Twig. B. Essential organs. C. Stamems. D. Gynoecium. E. L.S. of Gynoecium. F.T.S. of Ovary. G. Aggregate of follicles. H. Pollen grain. 1. Paracytic stomata. J. Floral diagram 1. Stamens. 2. Gynoecium.

13.4. IMPORTANT PLANTS

Important genera and species of ths family are:

1. *Illicium verum* *
2. *Kadsura roxburghiana*
3. *Liriodendron tulipifera*
4. *Michelia champaca*
5. *Michelia fuscata*
6. *Michelia nilagirica*
7. *Magnolia acuminata*
8. *Magnolia grandiflora*
9. *Euptelea* *
10. *Kmeria* *
11. *Wintera* *
12. *Trochodendron* *
13. *Schisandra* *
14. *Manglietia*

* These genera in the recent classificatory systems are separated from Magnoliaceae and treated under separate families (*Viz. Iliciaceae, Trochodendraceae, Eupteleaceae, Winteraceae* and *Schisandraceae*).

Check Your Progress -1

Write the economic importance of the family Magnoliaceae.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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13.5. FLORAL FORMULA

Br, Brl, ⊕, ⚥ or ♂♀ $\frac{P3+3+3}{K3,C3+3}$, A∞, $\underline{G\infty}$

13.6. DISTINGUISHING CHARACTERS

a) Dendroid habit, b) Simple leaves with paracytic stomata, c) Vessels with scalariform perforations, d) Flowers solitary, actinomorphic and mostly bisexual, e) Floral parts numerous and free, f) Stamens and carpels spirally arranged, g) pollen grains monosulcate.

The above characteristic features of Magnoliaceae point towards the primitiveness of the family among the dicots.

13.7. SUMMARY

The Magnoliaceae is a primitive family characterized by dendroid habit, vessels with scalariform perforations, flowers actinomorphic and bisexual with floral parts free and numerous, prominent torus (receptacle) and monosulcate pollen.

Magnolia and *Michelia* are the typical members of this family.

13.8. CHECK YOUR PROGRESS: MODEL ANSWERS

1. Timber for making furniture is obtained from *Liriodendron tulipifera*. The wood of *Magnolia* spp. is used for cabinet work. Champaka oil is obtained from the flowers of *Michelia champaca*. Species of *Magnolia*, *Talauma* & Michelia are grown as ornamentals.

13.9. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. "Magnoliaceae is considered as a primitive family" - support the statement with proper facts.

II. Answer the following questions in about 10 lines each.

1. What are the distinguishing characters of Magnoliaceae.
2. Name 10 important plants of Magnoliaceae.

UNIT-14 : BRASSICAEAE (CRUCIFERAE)

Division	:	Dicotyledones
Sub Division	:	Polypetalae
Class	:	Thalamiflorae
Order	:	Parietales
Family	:	Brassicaceae

Contents

14.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of different members,
2. list out the important genera,
3. describe the economic importance of the members of Brassicaeae, and
4. list out the distinguishing characters.

14.2. INTRODUCTION

The family Brassicaceae consists of 375 genera and 3200 species. In general these occur in all parts of the world, but mostly confined to temperate and mediterranian regions. Mostly herbs or perennials.

14.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Leaves simple, mostly alternate and exstipulate; entire *(Iberis)* or variously dissected *(Brassica)*. Stomata typically anisocytic (Cruciferous type). Hairs simple or branched and often used in identification.

Flowers arranged in a raceme or Corymb; regular, bisexual and hypogynous

Sepals four in two whorls (2+2), the outer two often slightly gibbous at base.

Petals 4, in one whorl, spread out in the form of cross (Cruciform) and often clawed.

Stamens in two whorls, an outer of 2 short and an inner of 4 long (tetradynamous); stamens rarely 2 *(Senebara didyma)*, anthers introrse, dihiscence longitudinal. Pollen grains radialy symmetrical, tricolpate and reticulate.

Carpels 2, syncarpous, placed transversly; placentation parietal but divided into two chambers due to antero-posterior partition *(replum* or false septum) which is an outgrowth of the placentae; ovules numerous, anatropous or campylotropous. Style short, stigmas two.

Fruit a capsule, when it is three times as long as broad it is **siliqua**, and if shorter, a **silicula**. It is divided into two by a thin membrane (replum). Fruit dehiscence Valvular, the valves break away from below upwards, leaving the seeds left appressed to replum. Some times the fruit is jointed between seeds as in a lomentum. In some achene-like one seeded fruits occur and in *Cardamine*, the fruit is subterranean and indehiscent.

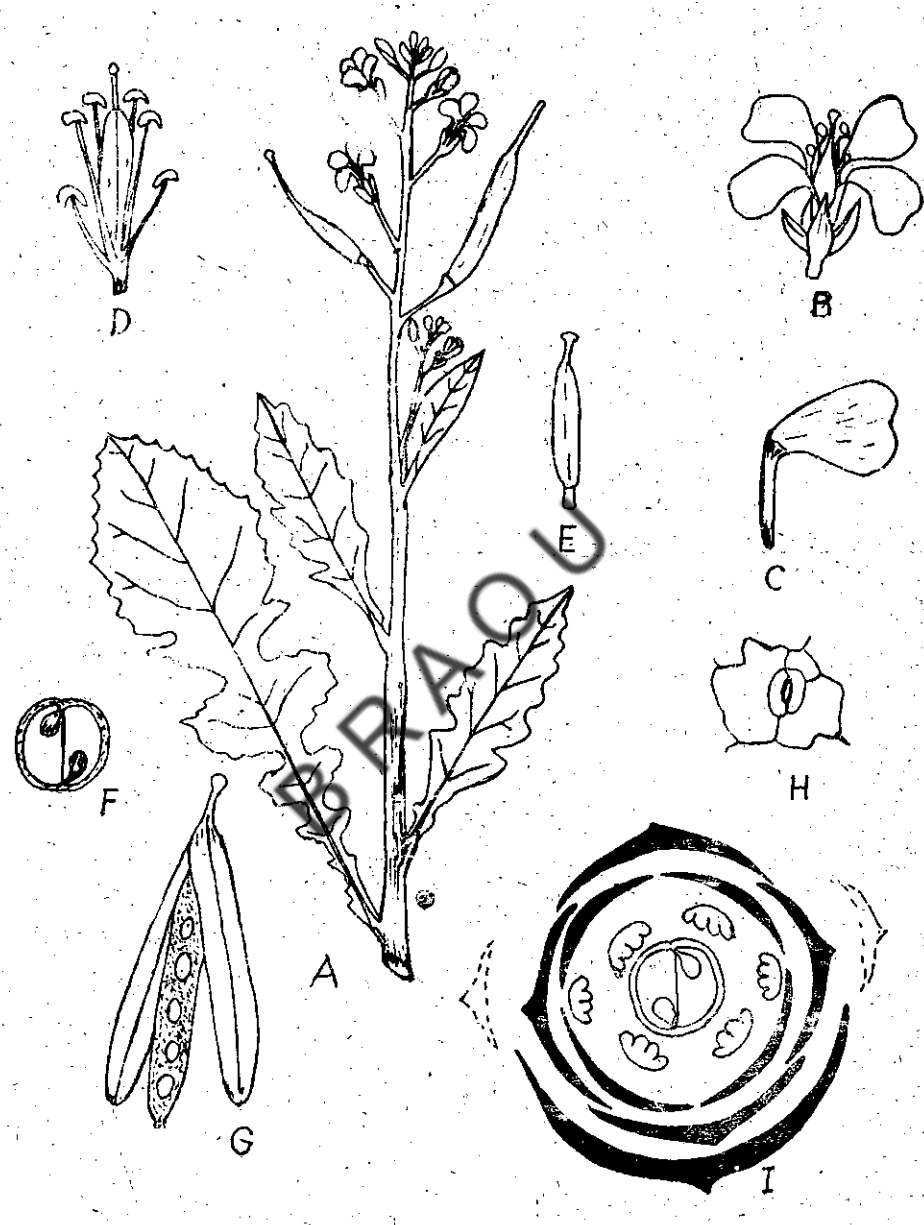

Fig. 14.1. *Brassica Campestris* A. Twing B. Flower C. Petal. D. Stamens and Pistil. F. T.S. of ovary G. Siliqua. H. Anisocytic stomata. 1. Floral Diagram

Seeds exalbuminous; testa often mucilaginous (Mustard seeds), Embryo often curved, usually radicle in one half of the seed and cotyledons in the other.

Pollination entomophylous. Nectaries are present at the bases of stamens. This helps cross pollination by insects.

All members of this family are often rich in suphur compounds and are useful in the treatment of scurvy disease.

The following species are known as vegetables:

Brassica oleracea var. *acephala* (Karam say); *B. oleracea* var. *botrytis* (cauliflower, H-Pool gobhi); *B. oleracea var. capitata* (Cabbage, H-Band Gobhi); *B. oleracea var. gonygylodes* (Knol-Kohl); *B. compestris* (turnip); *B. pekinensis* (Chinense Cabbage); *Nasturtium officinale* (water-cress, H-Brahmi sag); *Raphanus sativus* (Raddish; H-Muli, T-Mullangi)

Edible oil is obtained from seeds of *Brassica hirta* (white *mustard, H-Safed Rai, B. Juncea* (H-Rai, T.Aavalu); *B. napus* (Rape; H-Kalisarson).

The seeds of *Brassica nigra* (black mustard) are used as condiment.

The following plants are cultivated as ornamentals : *Eruca sativa; Iberis amara* (Rocket candytuft); *Iberis umbellata* (Candytuft); *Cheiranthus cheiri* (wall flower); *Matthiola incana* (stock)

Capsella bursapastoris is a common weed in North India.

Check Your Progress -1

List out the important vegetable species of this family ?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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14.4. FLORAL FORMULA

Ebr, Ebrl, ⊕, ⚥, K 2 + 2, C 4, A 4 +2, G (2)

14.5. DISTINGUISHING CHARACTERS

(a) Predominently herbs, (b) Leaves simple with anisocytic stomata, (c) Flowers mostly regular, bisexual, hypogynous (d) Corolla cruciform. (e) Stamens mostly tetradynamous (f) Gynoecium syncarpous, apparently bicarpellary (due to false septum - replum) with parietal placentation, (g) Fruit a siliqua and (h) embryo curved.

14.6. SUMMARY

The Brassicaceae, known for many vegetable yielding plants, is mostly herbaceous and shows regular and bisexual flowers, cruciform corolla, tetradynamous stamens and parietal placentation.

The various species and varieties of the genus *Brassica* are the commonly encountered members of this family.

14.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. (a) *Brassica oleracea var. acephala* (Karam say) (b) B.*oleracea var. botrytis* (Cauliflower) (c) *B. oleracea var. capitata* (Cabbage (d) *B. oleracea var. gonygylodes* (knol kohl), (e) *B. compestris* (Turnip (f) *B. pekinensis* (Chinese cabbage) (g) *Nasturtium officinale* (water cress) (h) *Raphanus sativus* (Raddish).

14.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. What are the salient features in the floral structure of the family Brassicaceae. Add a note on its economic importance.

II. Answer the following questions in about 10 lines each.

1. Write about the distinguishing characters of Brassicaceae.
2. Give a brief account of the economic importance of Brassicaceae.

UNIT-15 : MALVACEAE

Division	:	Dicotyledons
Sub division	:	Polypetalae
Class	:	Thalamiflorae
Order	:	Malvales
Family	:	Malvaceae

Contents

15.1. OBJECTIVES

By the end of this unit you will be able to :

1. describe the various taxonomic characters of different members of this family,
2. list out the important genera,
3. describe the economic importance of Malvaceae, and
4. list out the distinguishing characters of this family.

15.2. INTRODUCTION

Malvaceae known as cotton family is composed of about 82 genera and 1500 species and cosmopolitan in distribution.

Herbs (*Malva, Sida, Abelmoschus, Abutilon*), shrubs (*Hibiscus rosa-sinensis. Gossypium* sp.) or trees (*Thespesia* and *Bombax* sp.).

The stem and leaves often covered with stellate and tufted hairs. Mucilaginous cells and cavities present in all parts of the plant.

15.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Leaves alternate, simple, entire, serrate, usually palmately veined and lobed. Stipules present, often cauducous. Stomata mostly anisocytic.

The flowers solitary and axillary (*Hibiscus* and *Urena*) or terminal (*Abutilon*), occasionally terminal recemes (*Althaea rosea*).

Flowers showy, variously coloured, actinomorphic, mostly bisexual, pedicillate, bracteate, pentamerous and hypogynous, Epicalyx frequently present (*Hibiscus, Gossypium*), absent in some genera (*Sida* and *Abutilon*).

Sepals five mostly united at least at base, valvate.

Petals five, free, slightly connate at the base and to the staminal tube. Aestivation generally twisted.

Stamens numerous monadelphous. Anthers monothecous and reniform, basifixed and extrorse. Pollen grains large spheroidal robustly spiny and periporate. In *Bombax* the pollen is tricolpate and reticulate.

Ovary superior, usually pentacarpellary, syncarpous, pentalocular with one or more ovules in each locule. Ovules anatropous. Placentation axile. Style simple and long and passes through the hollow of the staminal tube. Stigmas capitate or discoid equal to or twice the number of carpels and emerge out of the staminal tube.

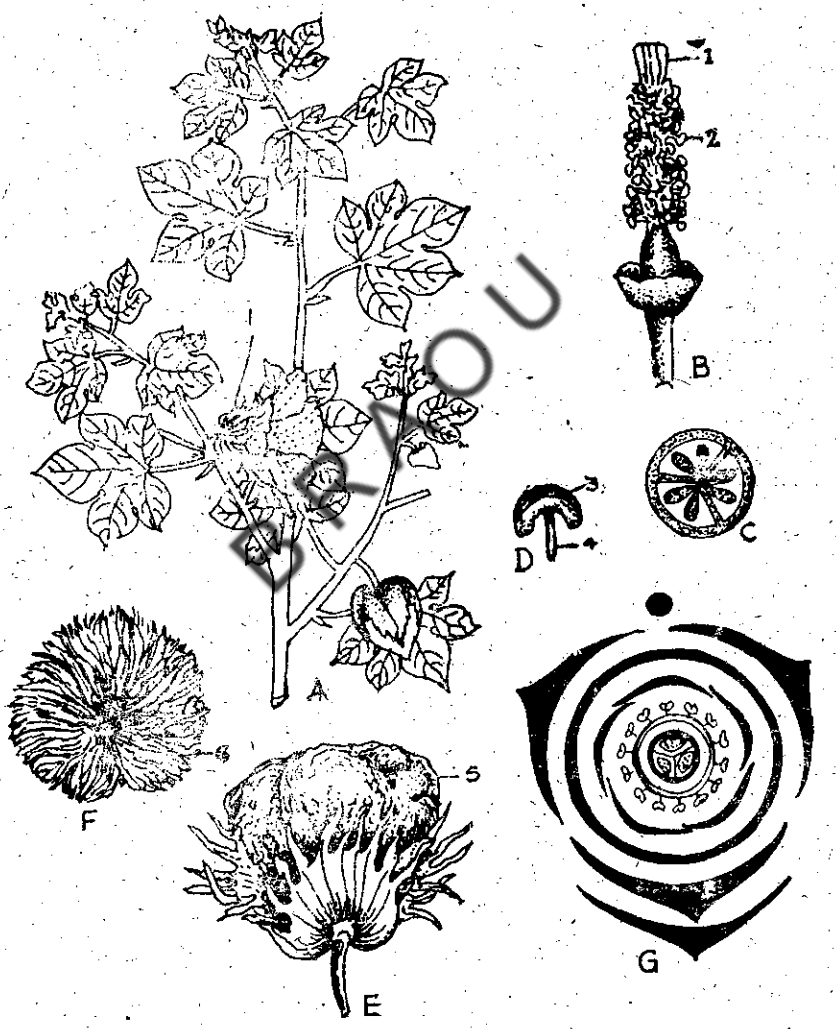

Fig. 15. *Gossypium herbaceum*. A. Twig. B. Essential organs. C.T.S. of ovary D. Stamen. E. Mature fruit. F. seed. G. Floral diagram. 1. Stigmas. 2. Stamens. 3. Monothecous anther. 4. Filament. 5. Cotton. 6. Comose hair

Fruit typically a loculicidal capsule (*Hibiscus, Gossypium*), often a schizocarpic carcerulus (*Althaea, Malva, Sida*), sometimes a berry (*Malvaviscus*).

Seeds often pubescent. In *Gossypium* the seeds are comose and the tomentose hairs are the extensions of the epidermal cells. Embryo straight or curved, endospern often oily.

Pollination mostly entomophilous. Self pollination however takes place in *Hibiscus esculentus* and *Abutilon.*

This family is of great economic importance due to fibre yielding plants as *Gossypium* sp. (Cotton, H.Kapas., T.Patte). *Hibiscus cannabinus* & *H.sabdariffa*, (T.Gongura) *Urena lobata* and *Urena sinuata* also yield fibre. The common species of *Gossypium* are, *Gossypium arboreum, Gossypium indicum, Gossypium hirsutum, Gossypium herbaceum* etc. The hairy outgrowth from the seeds yield the commercial cotton. Cotton is used for filling pillows, mattresses and upholstery. Yarn is used in textile industry. Cotton forms the basic raw material for cellulose industry. Cotton seed oil is edible and the hydrogenated oil is used as Vanaspati & also in soap industry. Cotton seed and cotton cake is used as cattle feed.

The stem fibres of *Hibiscus cannabinus* & *H. sabdariffa* are used for making ropes, fishing nets, gunnybags, floormats etc. The fibre has lustre similar to jute.

The fruits *Abelmoschus esculentus* (H. Bhendi, T. Benda Kai) are used as vegetables, and the leaves of *Hibiscus sabdariffa* and *Hibiscus cannabinus* as leafy vegetables.

Silk cotton is obtained from the capsular fruits of *Bombax ceiba Syn. Salmalia malabaricum* (Red silk cotton, T. Buruga), *Bombax insigne* and *Ceiba pentandra* (Kapok tree, or white silk cotton). Silk cotton is mostly used for stuffing pillows and cushions.

The following are some of the common ornamental plants & weeds.

1. *Hibiscus rosa-sinensis* (shoe flower, T. Mandara)
2. *Hibiscus schizopetalus*
3. *Hibiscus ceriaceus*
4. *Hibiscus mutabilis*
5. *Malvaviscus arboreus*
6. *Abutilon crispum*
7. *Althea rosea (Holly hock)*
8. *Thespesia populnea* (T.Gangiravi) - A popular avenue plant with yellow showy flowers.
9. *Hibiscus micranthus*
10. *Sida cardifolia*
11. *Sida spinosa*
12. *Sida acuta*
13. *Sida rhombifolia*
14. *Abutilon indicum*
15. *Pavonia zeylonica*
16. *Malva parviflora*
17. *Kadia calycina*
18. *Malathra capitata*
19. *Malvastrum tricuspidatum*
20. *Adansonia digitata* (Baobab tree of Africa)

The genera *Bombax & Ceiba* are treated under separate family, Bombacaceae in the recent systems of classification.

Check Your Progress 1 & 2.

1. What type of stamens and anthers we come across in Malvaceae ?
2. Name 2 genera which yield fibre.

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end of this unit.

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15.4. FLORAL FORMULA

Br, Brl, ⊕, , epicalyx, K(5), C 5, A (∝) , G (5)

15.5. DISTINGUISHING CHARACTERS

a) Leaves stipulate.

b) Presence of epicalyx.

c) Monadelphous stamens. Monothecous and reniform anthers.

d) Pollen grains large, robustly spiny and periporate.

e) Fruit typically a loculicidal capsule or carcerulus.

15.6. SUMMARY

This is an economically important family with plants yieldling cotton, silk-cotton, hemp etc. The malvaceae is characterised by usually palmately veined leavaes regular bisexual flowers, monadelphous stamens and loculicidal capsules. *Hibiscus, Sida* and *Gossypium* are the most commonly encountered members of this family.

15.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. In Malvaceae the stamens are monadelphous and anthers are monothecous and reniform.
2. (a) *Gossypium* sp. and (b) *Hibiscus* sp.

15.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write briefly about the general characters of the family Malvaceae and add a note on its economic importance.

II. Answer the following questions in about 10 lines each.

1. Write the botanical names of any 10 members of this family.
2. Write briefly about the economic importance.

UNIT-16 : RUTACEAE

Division	:	Dicotyledons
Subdivision	:	Polypetalae
Class	:	Disciflorae
Order	:	Geraniales
Family	:	Rutaceae

Contents

16.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of different members of this family,
2. list out the important genera,
3. describe the economic importance of Rutaceae, and
4. list out the distinguishing characters of this family.

16.2. INTRODUCTION

The Rutaceae includes 140 genera and 1300 species, distributed in temperate and tropical regions especially in South Africa and Australia.

Shrubs *(Murraya, Glycosmis)* or trees *(Aegle marmelos, Citrus* sp., *Zanthoxylum)*, rarely herbs *(Ruta graveolens)*

The stem in woody plants is sometimes armed with thorns (*Aegle* and *Citrus*).

16.3. TAXONOMIC CHARCTERS AND ECONOMIC IMPORTANCE

Leaves alternate or opposite, exstipulate,pinnately compound *(Murraya)*, sometimes reduced to unifoliate conditions *(Citrus)*, leaves gland dotted, aromatic and contain volatile oils. Stomata mostly anemocytic.

Flowers arranged in axillary (*Citrus*, *Murraya*) or sometimes terminal cymes (*Skimmia*). They are mostly actinomorphic, bisexual (unisexual in *Evodia*), hypogynous, generally tetra-or penta-merous.

Sepals four or five, free or united, imbricate and quincuncial.

Petals four or five, free, imbricate, disc present between the stamens and ovary.

Stamens many, generally 8 or 10 obdiplostemonous, sometimes polyadelphous (*Citrus*),

stamens 3-5 (*Zanthoxylum*), 30-60 (*Aegle*), 20-60 (*Citrus*). Filaments free, inserted around the disc, anthers 2 celled, introrse, dehisce longitudinally.

Ovary superior with four or five carpels, syncarpous, placentation axile (parietal in *Feronia*), Locules four or five each with 1,2 or many ovules. Styles as many as Carpels, distinct or connate. Stigma Capitate, ovules anatropous.

Fruits are of various types, a capsule or a leathery rind berry (*Zanthoxylum*) or a berry (*Murraya*). Sometimes a globose berry with rough woody rind (*Feronia limoni*).

Seeds albuminous or exalbuminous. Embryo straight or curved. Pollination entomophilous, protandry helps cross pollination. Self pollination takes place in some genera (*Ruta graveolens*).

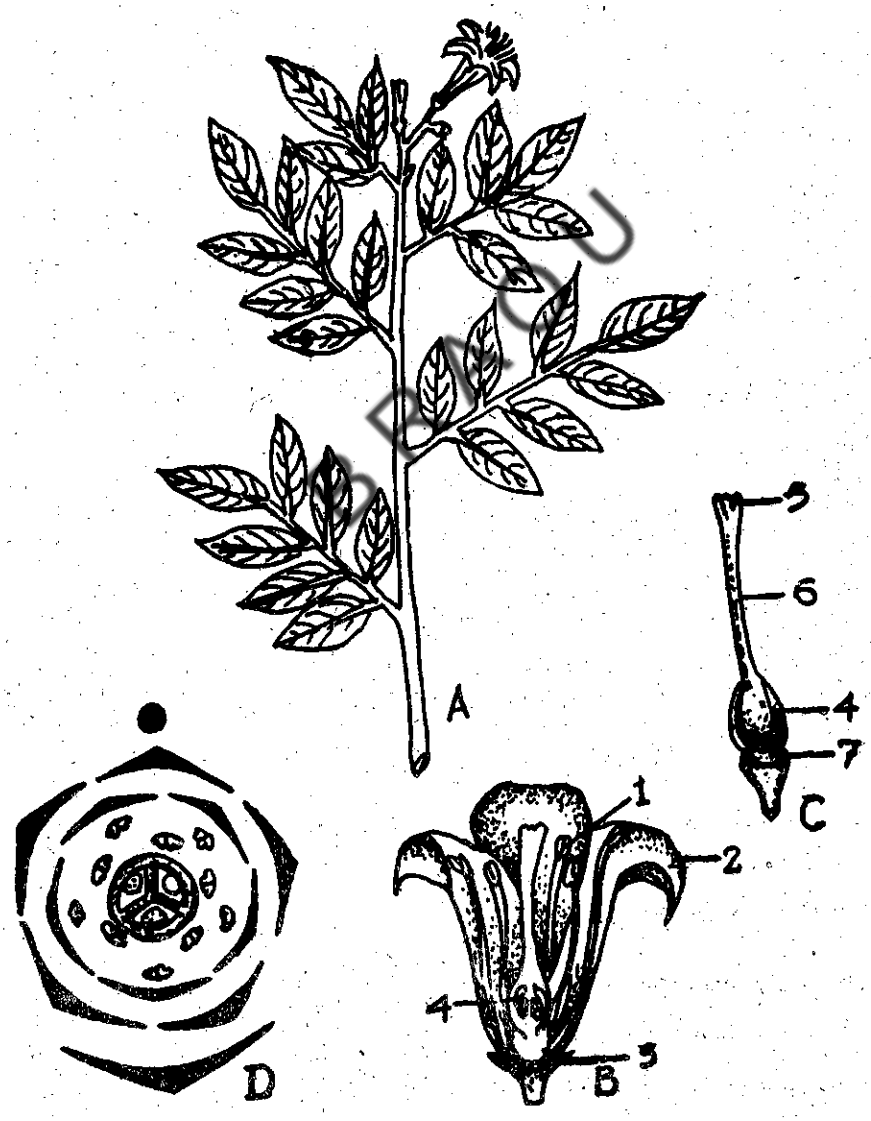

Fig 16.1. *Murraya exotica.* A. Twig. B. L.S. of flower. C. Pistil. D. Floral diagram. 1. Stamen. 2. Petal. 3. Sepal. 4. Ovary. 5. Stigma. 6. Style. 7. Disc.

The family is of considerable economic importance. *Aegle marmelos* (H. Bel; T. Maredu) has nutritious fruit pulp rich in tannic acid. Edible fruits are obtained from *Feronia elephantum* (wood apple, H. Kavit, T. Velaga). The genus *Citrus* has a number of fruit yielding species - *Citrus aurantium* (Orange., T. Narinja), *C. decumana* (Shaddock-chakotra), *C. sinensis* (Mosambi), *C. medica Var. limetta* (Sweet lime) *C. paradissi* (grape fruit T. Dabba Pandu), *C. reticulate* (Suntara), C. *medica* var. *acida* (T. Nimma), C. *limon* (lemon).

Leaves of *Murraya koenigii* (curry leaf, T. Karivepak) are used as condiment for flavouring food. The wood of *Zanthoxylum alatum* is used in making walking sticks and tooth picks.

Ruta graveolens (Rue, T. Sadapak), *Skimmia* sp. and *Toddalia aculeata* are medicinal plants. *Cusparia* yields a substitute for quinine. Leaves of *Boenninghousia* have insecticidal properties.

Ornamental plants of this family are *Phellodendron* (Cork tree), *Zanthoxylum* (Prickly ash), **Ruta** (Rue), *Murraya exotica* (Chinese box), *Clausenia pentaphylla* (aromatic ornamental shrub,) *Calodendrum* (Cape-Chestunt), *Dictamnus* sp., and **Luvunga scandens** (Lavanga lata).

Check Your Progress 1, 2 & 3

1. Name 2 genera which yield edible fruits.
2. What is the reason for including this family in Disciflorae ?
3. Name 2 genera which are medicinally important.

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end.

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16.4. FLORAL FORMULA

Br, Ebrl, ⊕, ⚥, K 4 or 5, C 4 or 5, A 8 or 10, $\underline{G}$ (4 or 5)

16.5. DISTINGUISHING FEATURES

a) Presence of aromatic oil glands in leaves, fruits and other plant parts.

b) Leaves usually pinnately compound or unifolite as in *Citrus*.

c) Flowers regular, bisexual, hypogynous, tetra or penta-merous.

d) Stamens many obdiplostemonous, sometimes polyadelphous *(Citrus)*.

e) Ovary elevated on a characteristic disc.

f) Fruit generally hesperidium *(Citrus)* or a drupe or berry.

16.6. SUMMARY

The Rutaceae, commonly known as citrus family, is characterized by gland-dotted compound leaves, regular, bisexual flowers, prominent disc and numerous stamens. The ovary is superior with many ovules on axile placentation. The various species of *Citrus* and *Murraya* are the commonly encountered members of this family.

16.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. *Feronia* sp. & *Citrus* sp.
2. Due to the presence of disc in between stamens and ovary this family is included under disciflorae.
3. *Ruta* sp. and *Skimmia* sp.

16.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write about the general characters of Rutaceae adding a note on its economic importance.

II. Answer the following questions in about 10 lines each.

1. Write about the economic importance of this family.
2. What are the distnguishing characters of this family.

UNIT-17 : FABACEAE (LEGUMINOSAE)

Division	:	Dicotyledons
Sub-division	:	Polypetalae
Class	:	Calyciflorae
Order	:	Rosales
Family	:	Fabaceae

Contents

17.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the fmily fabaceae and sub families Mimosoideae, Caesalpinioideae and Papilionoideae,
2. list out the important genera of the 3 sub- families,
3. describe the economic importance of the 3 sub- families, and
4. list out the distiinguishing characters of the family & also the 3 sub-families.

17.2. INTRODUCTION

The name **'Fabaceae'** is alternative to **'Leguminosae'** which is commonly known as legume family. The **Fabaceae** is divided into three distinct subfamilies,*viz., Mimosoideae, Caesalpinioideae* and *Papilionoideae* (or *Faboideae*). But many modern taxonomists prefer to elevate the three subfamilies to families and restrict the use of the Fabaceae to the *Papilionaceae* (= *Papilionoideae*). In this unit, *the Fabaceae* is treated in the larger sense (*Sensu lato*).

The *Fabaceae* is the third largest family of angiosperms, constituting about 700 genera and 13,000 species and is cosmopolitan in distribution.

17.3. TAXONOMIC CHARACTERS OF FABACEAE

Being one of the largest families, the *Fabaceae* shows a wide range of variation in its vegetative and floral characters. Plants are either herbs, shrubs or trees. Climbers are common. Roots of many *Papilionoideae* develop nodules which contain nitrogen fixing bacteria *(Rhizobium species)*. Leaves alternate, compound, stipulate, in a few (like *Crotalaria* species) simple; in Mimosoideae usually bicompound. Leaf base pulvinous in some and such members exhibit sleep-movements. e.g., *Phaseolus* species).

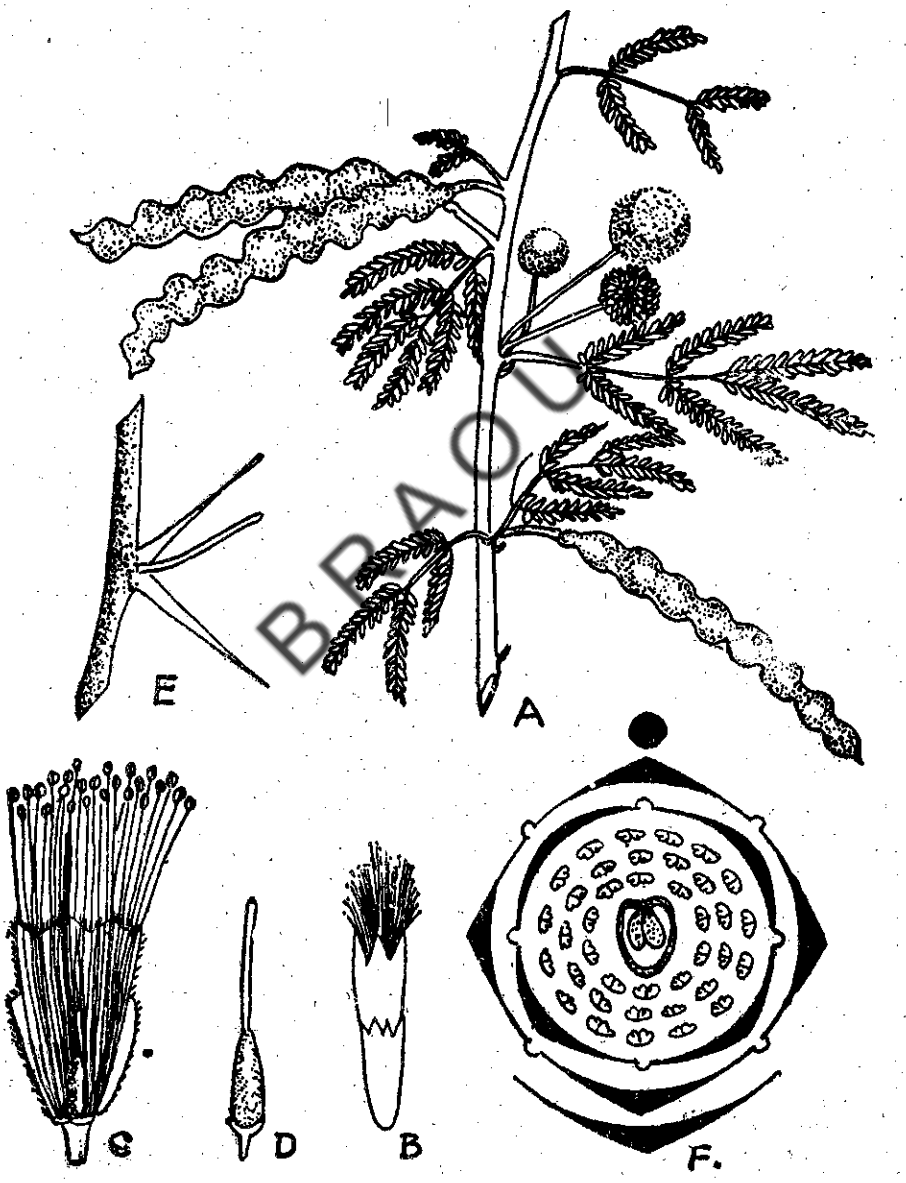

Fig. 17.1. *Acacia nilotica.* A Twig. B. Flower. C. L.S. of flower. D. Gynoeium. E. Stipules. F. Floral diagram

Inflorescence mainly a raceme or panicle; head or spike in many members of *Mimosoideae.* Flowers bracteate bracteolate in some, complete, hermaphrodite, pentamerous (tetramerous in some), actinomorphic or zygomorphic, perigynous or hypogynous. Sepals 5, free or united, odd

one anterior, petals 5(rarely absent as in *Saraca*) or reduced in number as in *Tamarindus*, free or united. Aestivation valvate or imbricate. In **papilionoideae**, the posterior petal is the largest and forms the standard (*vexillum*); the lateral pair constitutes wings (*alae*); the anterior pair which is partly united (or free in some), is the keel (carina). Stamens 10 or many, free or diadelphous or monadelphous. Anthers dithecous, introrse and dehisce longitudinally (in some, as in *Cassia* species, the dehiscene may be by terminal pores). Gynoecium monocarpellary. Gynophore present in some. Ovary unilocular; ovules 2 to many on marginal placentation. Fruit a legume or lomentum; indehiscent in few (e.g., *Dalbergia* species). Seed nonedospermic.

Pollination, in general, entomophilous. In **Mimosoideae** the inflorescence becomes attractive by exerted and variously coloured stamens. In *Caesalpinioideae* the flowers are large and showy. In *Papilionoideae* different mechanisms occur for pollination by long tongued insects like bees. Flowers, in general, are showy by the presence of a large standard petal. The wing petals act as landing place for insects. The keel encloses the essential organs. Nectar is secreted at the bases of stamens and accumulates around the ovary. On landing,the insects by their weight cause the wings to be depressed. As the wings and the keel, at their base, are connected by a protruberance and a depression, along with the wings the keel also is lowered. Lowering of the keel brings out the stigma and the anthers for effecting cross pollination. Since stigma is at a higher level, it first receives the foreign pollen attached to the body of the insect. Afterwards the pollen of the flower is dusted onto the body of the insect. In genera like *Melilotus* and *Trifolium*, the stigma and stamens return to the keel after the insect takes off from the flowers. In such cases, the flowers are suitable for repeated visits by insects. In a few members, like the species of *Medicago*, essential organs in the keel are kept under tension and explode at the first visit of the insect. In such cases pollination takes place in only one visit . In genera like *Lupinus* and *Lotus*, pollen is deposited inside, at the top of the keel. It is slowly squeezed out in small quantities by the piston-like action of the united filaments. In certain genera like *Pisum* and *Phaseolus*, styles have hairs which help in sweeping out (like a brush) the pollen in small quantities from the lip of the keel. In *Pisum* and some other genera, in the absence of cross pollination, self pollination takes place.

Three subfamilies of *Fabaceae* are distinguishable on the basis of the following characters.

S.No.	Plant part	Mimosoideae	Caesalpinioideae	Papilionoideae
1.	Inflorescence	Head or spike	Raceme	Raceme
2.	Flower	Actinomorphic	Zygomorphic	Zygomorphic (corolla papilionaceous)
3.	Petals	United, valvate	Free, ascendingly imbricate	Free (Keel with partial union) descendingly imbricate
4.	Stamens	Many, free or monadelphous	10, free	10, diadelphous (monadelphous in some)

Economically the Fabaaceae is one of the most important families of angiosperms. For convenience, economically important members and common plants of the family, are presented separately under the three subfamilies.

Check Your Progress - 1

What is the difference between the three subfamilies of Leguminosae in the aestivation of petals.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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17.4. SUB-FAMILY MIMOSOIDEAE

Acacia nilotica (T: Tumma; H:Babul), *Albizia lebeck* (T: Dirisana; H: Siris), *Xylia xylocarpa* (T:konda tangedu; H.Boja) and many others yield valuable timber. Fibres for making ropes, are

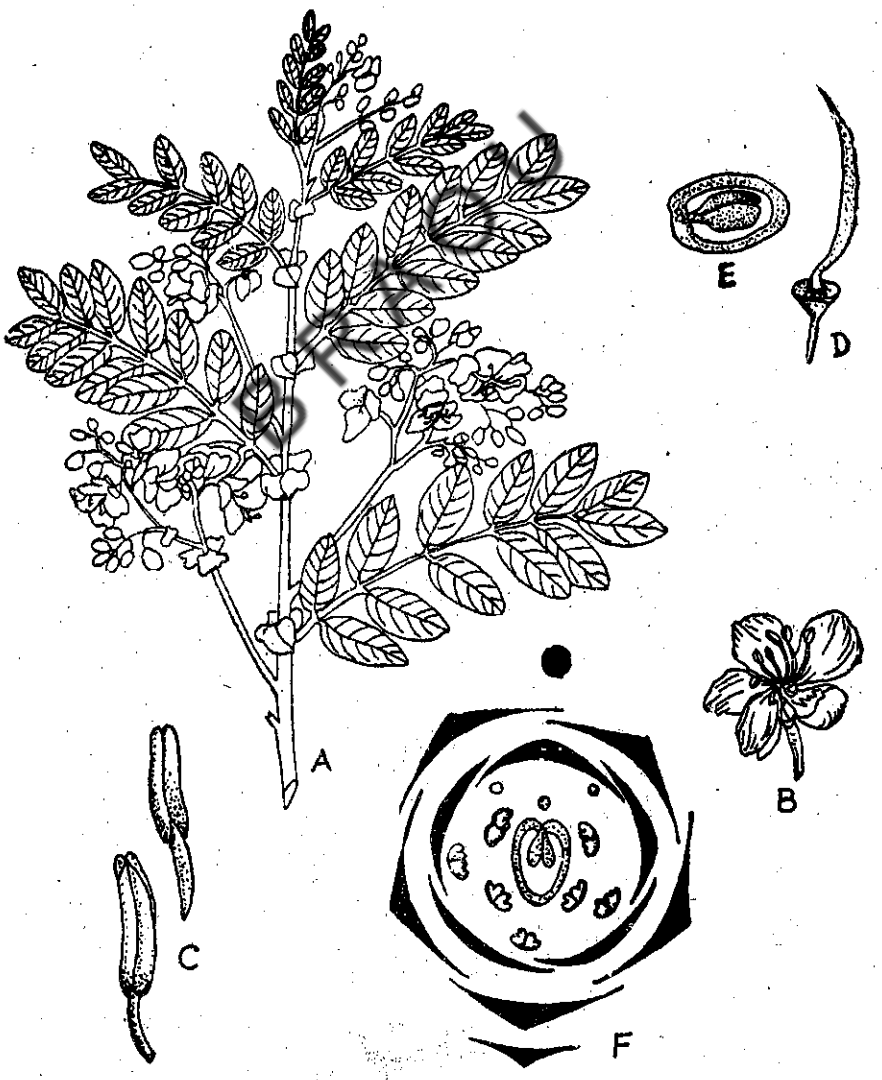

Fig. 17.2. *Cassia auriculata*. A. Twig. B. Flower. C. Stamens. D. Gynoecium. E.T.S. of ovary. F. Floral diagram

extracted from the stems of *Acacia leucophloea* (T.Tella tumma; H. safed babul) and *A. pinnata*. *A.nilotica* gives 'gum acacia'. The pods of *A. concinna (T. Sikai)* are used as a detergent. Arils of *Pithecolobium dulce* (T. Seema chinta) are edile. Wood of *Acacia catechu* (T. kaachu; H. Khair) yields 'cutch'. *Neptunia triquetra* is a weed of pasture lands. *Mimosa pudica* (T: Lajawathi; H: Lajwanthi) is the sensitive plant. *Dicrostachys cinerea* (T: Velture; H.vartuli)is common on dry rocky lands. *Prosopis spicigera* (T: Jammi; H.Jhand) is occasional around villages. *P. juliflora* (T: Seema or Sarkar tumma) is grown as a hedge plant around cultivated fields. *Albizia lebbeck* and *Samanea saman* (T: Nidra ganneru) are planted as avenue trees.

17.5. SUBFAMILY CAESALPINIOIDEAE

Tamarindus indica (T: Chinta; H: Imli) gives tamarind from fruits. *Hardwickia binata* (T: Yepi; H. Anjan) provides timber. *Cassia auriculate* (T: Tangedu; H. Tarwar) and many species of *Bauhinia* like *B. rasemosa* (T: are; H: Gurial) and *B. malabarica* (T: Pulichinta, Pedda are; H. Maljan) yields tannins from their bark. The leaves of *B. vahlii* (T: Adda; H. Amlosa) are used for preparing 'leaf-plates'. Haematoxylin, a stain used in microscopy, is extracted from the wood of *Haematoxylon campuchianum*.

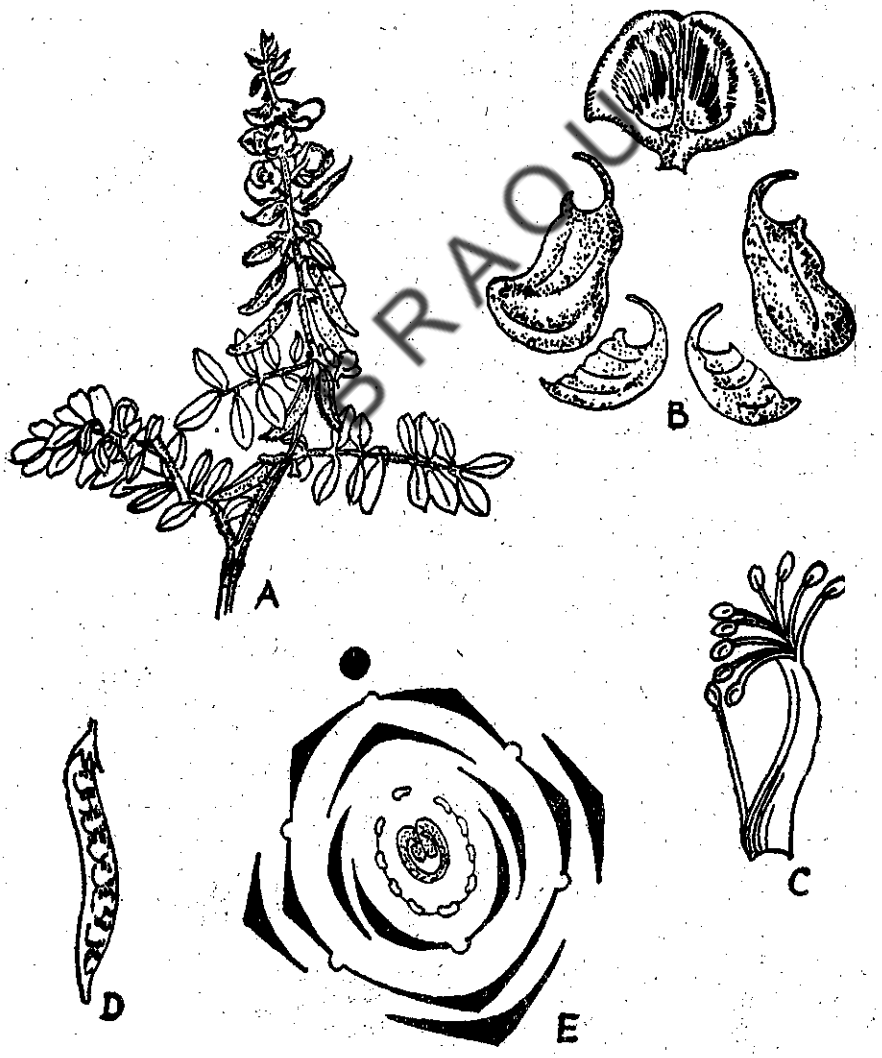

 Fig. 17.3. *Tephrosia purpurea*. A. Twig. B. Corolla. C. Androecium. D. Gynoecium. E. Floral diagram

Cassia occidentalis (T: Cashchinta; H: Kasondi) and *C.tora* (T: Tantipu; H: Chakunda) are common herbs. *Caesalpinia crista* (T: Gatchkai; H: Kat Karanj) is a large, straggling shrub. *Delonix elata* (T: Sankesula) is a wild tree member. *Peltophorum pterocarpum*, sometimes, is planted as an avenue tree. *Parkinsonia aculeata* a large shrub with phyllodes and small leaf lets, is occasionally grown as hedge plant. *Bauhinia purpurea* (T: Kanchanam; H: Khairwal), *B. variegata, Caesalpinia pulcherimma, Cassia fistulla* (T: Rela; H: Amaltas), *C. marginata, C. siamea, Delonix regia* and *Saraca indica* (T: Asoka; H: Asok) are grown as ornamental trees.

17.6. SUBFAMILY PAPILIONOIDEAE

Many members yield pulses. They include *Cicer arietinum* (T: Sanaga; H: Chana), *Cajanus cajan* (T: Kandi; H: Tuvvar), *Phaseolous aureus* (T: Pesara; ;H: Mung), *P. mungo* (T: Minumu; H: Mash) and *Pisum sativum* (T: Batani ; H: Batana). The pods of *Dolichos lablab* (T : Chikkudu; H . Sem), *D.biflorus* (T: ulavalu : H: Kalti), *Vicia faba, V. sinensis, Cyamopsis tetragonoloba* (T: Goruchikkudu, Chevulakaya, Godarikaya) and the flowers of *Sesbania grandiflora* (T: Avisa, Agisa) are edible. The seeds of *Trigonella corniculata* (T. Menthulu ; H: Menthi) are used for flavouring. *Crotalaria junea* (T: Janumu), *Phaseolus trilobus* (T: Pillipesara) and many others are used as cattle feed and as green manure. *Arachis hypogea* (T: Verusanga, Nela sanaga; H.Palli) is cultivated for its edible seeds which also yield oil. Indigo dye is extracted from *Indigofera tinctoria* (T and H: Neeli). Many trees like *Dalbergia latifolia* (T: Jittegi; H: Shisham), D. *sissoo* (H.Sissu), *Pterocarpus marsupium* (T: Peddegi; H: Bijasal) and *P.santalinus* (T: Raktha or yerra chandanum) yield valuable timber. The wood of *Aeschynomene aspera* (T. Jilugu ; H: Sola) is light and is used for making sholahats and fishing floats. The leaves of *Butea monosperma* (T: Modugu; H: palas) are made into 'leaf- plates'. Its flowers yield a red dye used in textile industry.

Several herbs liks *Crotalaria bifaria, C. hirsuta, C. linifolia, C.calycina, C.verrucosa, Indigofera linnaei, I. glandulosa, I. trifoliata, Tephrosia hirta, T.procumbens, T.purpurea* and *Alysicarpus rugosus* are common in Andhra Pradesh. *Pongamia pinnata* (T: Kanaga ; H : Karanj) is a tree member. *Abrus precatorius* (T:Gurivinja ; H : Gunchi) and *Clitoria ternata* (T: Sankupulu; H : Khagin) are climbers. *Erythrina variegata* and *E. indica* (T: Baditha; H: Pangra) are ornamental trees.

Check Your Progress - 2

List out the pulse yielding plants of papilionoideae.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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17.7. DISTINGUISHING CHARACTERS AND FLORAL FORMULAE

17.7.1. Fabaceae

a) Flowers either peri - or hypogynous.

b) Gynoecium monocarpellary.

c) Ovary unilocular.

d) Ovules on marginal placentation.

e) Fruit a legume or lomentum.

17.7.2. Mimosoideae

a) Inflorescence a head or spike.

b) Flowers actinomorphic.

c) Petals united, valvate.

d) Stamens numerous; filaments free or united.

Floral Formula

Br, Brl or Ebrl, ⊕, ⚥, K(4) or (5), C (4) or (5), A 10 or ∝ or (∝), G1.

17.7.3. Caesalpinioideae

a) Flowers zygomorphic.

b) Petals free, ascendingly imbricate.

c) Stamens 10, free.

Floral Formula

Br, Brl or Ebrl, %, ⚥, K 5, C 5, A 10, G1.

17.7.4. Papilionoideae

a) Flowers zygomorphic

b) Corolla papilionaceous.

c) Petals descendingly imbricate

d) Stamens 10, usually diadelphous

Floral Formula

Br, Brl or Ebrl, %, ⚥, K(5), C(2) +2+1, A(9) +1 or (10), Gl

17.8. SUMMARY

The Fabaceae is a large cosmopolitan family comprising three subfamilies, *viz.*, Mimosoideae, Caesalpinioideae and Papilionoideae. The family on the whole is characterized by compound leaves, bisexual flowers with ten to many stamens, monocarpellary and unilocular ovary with ovules on marginal placentation. The fruit in Fabceae is usually a legume. *Acacia, Albizzia, Cassia, Crotalaria* and *Tamarindus* are some of the commonly encountered members of this family.

17.9. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The aestivation of petals is valvate in Mimosoideae whereas it is ascendingly imbricate in Caesalpinioideae & descendingly imbricate in Papilionoideae.

2. The pulse yielding plants of papilionoideae are: a) *Cicer arietinum* (b) *Cajanus cajan* (c) *Phaseolus aureus* (d) *P. mungo* and (e) *Pisum sativum.*

17.10. MODEL EXAMINATION QUESTIONS

I. Answer the followaing questions in about 30 lines each.

1. Compare and contrast the 3 subfamilies of Fabaceae.
2. Write about the taxonomic characters and economic importance of Papilionoideae.

II. Answer the following questions in about 10 lines each.

1. Write about the economic importance of the family Mimosoideae.
2. Give an account of the economic importance of the family Caesalpinioideae.
3. Write briefly about the economic importance of the family Papilioniodeae.
4. Write botanical names of 10 important members of Papilionoideae.
5. Give an account of the pollination mechanism in Papilionoideae.

UNIT-18 : APIACEAE (UMBELLIFERAE)

Division	:	Dicotyledons
Sub-division	:	Polypetalae
Class	:	Calyciflorae
Order	:	Umbellales
Family	:	Apiaceae

Contents

18.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the members of this family,
2. list out the important genera,
3. describe the economic importance of this family, and
4. listout the distinguishing characters.

18.2. INTRODUCTION

The name '*Apiaceae*' is alternative to '*Umbelliferae*. The Apiaceae, though widely distributed throughout the world, is abundant, in north temperate zone. There are about 275 genera and 2,850 species.

18.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORATANCE

Plants mostly herbs; aromatic due to the presence of essential oil or resin. Stems fistular. Leaves pinnately compound or bicompound but simple in *Centella, Hydrocotyle* and *Bupleurum*. Leaf-base is sheathing.

Inflorescence a compound umbel. Some genera like *Hydrocotyle* and *Bupleurum* possess simple umbels. Flowers small, hermaphrodite, actinomorphic, pentamerous, epigynous. In *Coriandrum*, peripheral flowers of the umble show zygomorphy. An epigynous, bilobed disc is present. Calyx tube adnate to the ovary; teeth 5, small, sometimes absent. Petals 5, free, often bifid (sometimes unequal as in peripheral flowers of *Coriandrum*). Stamens 5, free, alternate with petals. Anthers basi-or dorsi fixed, dithecous, introrse; their dehiscence longitudinal. Ovary inferior, bilocular with a single pendulous anatropous ovule in each loculus on axile placentation. Styles 2, often dilated at the base into stylopods. Stigmas capitate. Fruit a cremocarp. the two indehiscent mericarps are attached to a forked axis called carpophore. Each mericarp has five longitudinal ridges (costae or jugae). In between the ridges, furrows (valleculae) are present. The pericarp is traversed by oil-ducts (vittae). Seed endospermic. Endosperm cartilaginous and oily.

Pollination entomophilous. Self-pollination is prevented by protandry. The epigynous disc secretes nectar which is easily available even to the short-tongued insects. Though small,the flowers are made conspicuous by aggregation into umbels. Cross pollination takes place while the insects crawl over the flowers in search of nectar.

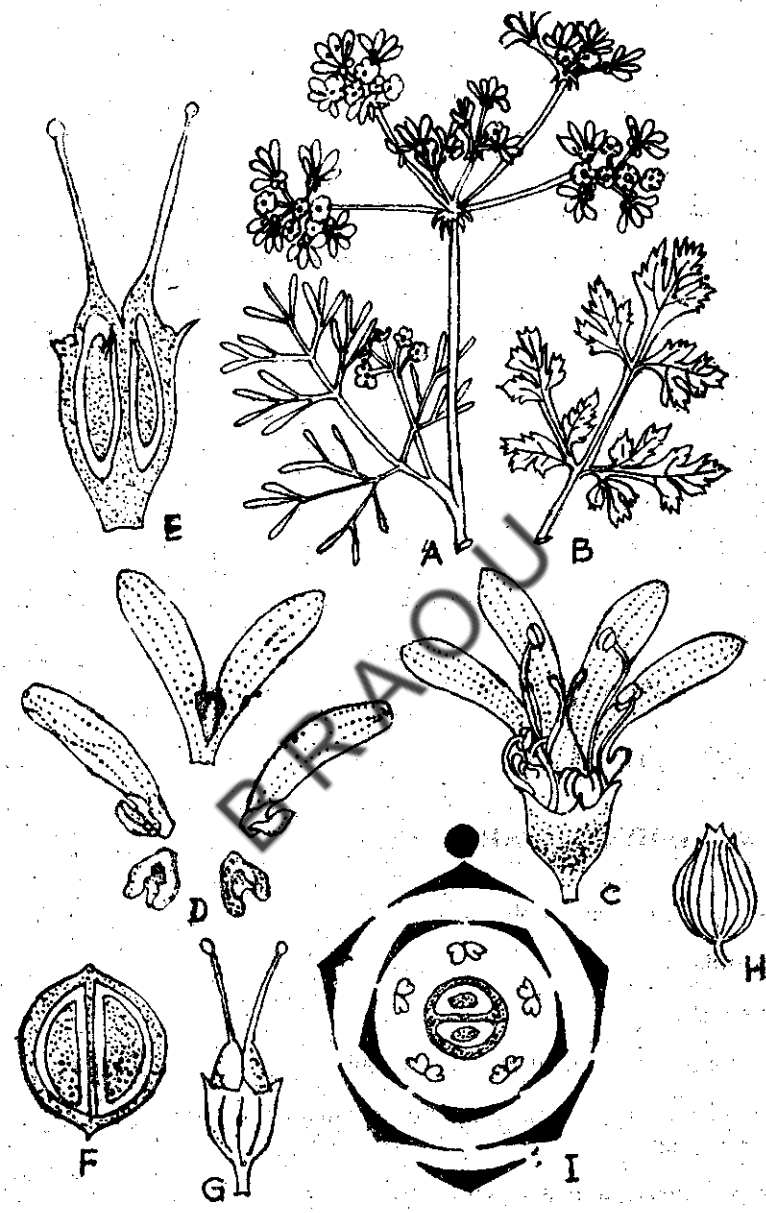

Fig. 18.1 *Coriandrum stivum* A. Twig. B. Lower leaf C. Flower D. Corolla E. L.S. of Gynoecium. F. T.S. of ovary G. Gynoecium. H. Fruit I. Floral diagram

Economically, the Apiaceae is of great importance. 'Angelica oil' is extracted from *Angelica archangelica* and is used in confectionery. Dried latex from the roots of *Ferula asafoetida* is asafoetida (T:Inguva; H: Heeng). *Centella asiatica* (T: Saraswathi Aku; H: Brahma manduki, Brahmi), commonly found along the rice fields and bunds of irrigation channels, has considerable medicinal value. The fruits of *Carum carvi* (T: Vamu) are used for stomaache. Fruits of *Cuminum cyminum* (T: Jilakarra), *Coriandrum sativum* (T: Dhaniyalu, Kottimera) and *Foeniculum vulgare*

(T. Sompu) are used as condiments. Leaves of *Apium graveolens* and tap roots of *Daucus carota* (T: Gajara gadda; E: carrot) are used as vegetables.

Species like *Hydrocotyle rotundifolia, Pimpinella heyneana, P. monoica* and *peucedanum dhana* are occasional in forests of Andhra Pradesh.

Check Your Progress 1 & 2

1. What is the type of fruit we find in Apiaceae ?

2. Name 2 economically important plants & mention their use.

Note: (a) Write the answers in the space given below.

(b) Compare your answers with the given at the endof this unit.

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18.4. FLORAL FORMULA

Br, Ebrl, ⊕ or %, ⚥K5, C5, $\bar{G}$(2)

18.5. DISTINGUISHING CHARACTERS

(a) Plants usually aromatic herbs.

(b) Stem fistular

(c) Leaf-base sheathing.

(d) Inflorescence a compound or a simple umbel.

(e) Flowers pentamerous, hermaphrodite, actinomorphic and epigynous with a disc at the top of the ovary.

(f) Style-bases dilated into stylopods.

(g) Fruit a cremocarp with characteristic ridges, furrows and oil-ducts.

(h) The two mericarps suspended by a forked carpophore.

18.6. SUMMARY

The Apiaceae with mostly herbaceous members shows aromatic plant parts, simple or compound leaves, umbel inflorescence, epigynous flowers and cremocarpic fruits.

Coriandrum sativum and *Daucus carota* are the commonly encountered members of this family.

18.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The type of fruit we find in Apiaceae is cremocarp.

2. (a) *Angelica* oil which is extracted from *Angelica archangelica* is used in confectioners

   (b) Asafoetida (Inguva)is extracted from the latex obtained from the roots of *Ferula as afoetida* and is medicinally important.

18.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write breifly about the general characters and economic importance of the family Apiaceae.

II. Answer the following questions in about 10 lines each.

1. Write the economic importance of this family.

2. What are the distinguishing characters of Apiaceae ?

UNIT-19 : RUBIACEAE

Division	:	Dictyledons
Sub-Division	:	Polypetalae
Class	:	Inferae
Order	:	Rubiales
Family	:	Rubiaceae

Contents

19.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the members of this family,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

19.2. INTRODUCTION

The Rubiaceae, commonly known as the madder family, includes about 500 genera and 6,000 species which are mostly tropical.

19.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Members mostly trees,some of them herbs or shrubs. Leaves simple, opposite decussate (sometimes whorled as in species of *Rubia*), entire, stipulate. Stipules usualy interpetiolar.

Inflorescence cymose. In species of *Anthocephalus*, *Adina*, *Mitragyna* and others, it is condensed into head. Flowers actinomorphic, hermaphrodite,tetra-or penta merous, epigynous. Sepals 4 or 5 , united, valvate; calyx-tube adnate to ovary, petals 4 or 5, united. Aestivation valvate, twisted or imbricate. Stamens 4 or 5, epipetalous; anthers dithecous, introrse, their dehiscence longitudinal. Carpels 2, united. Ovary inferior, bilocular (in *Gardenia* unilocular). Disc epigynous. Ovules 1 to many in each locule on axile (parietal in *Gardenia*) Placentation. Style simple; stigma bifid or capitate. Fruit a capsule (e.g.*Oldenlandia*) or berry (e.g. *Coffea*). Seeds endospermic.

Pollination entomophilous. Nectar is secreted by the epigynous disc. Self- pollination is prevented by either protandry or heterostyly.

Economically, the Rubiaceae is of considerable importance. Members like *Anthocephalus cadamba* (T: Kadamba ; H: Kadam), *Adina cordifolia* (T: Bandaru; H: Haldu), *Mitragyna parvifolia* (T. Battganam) and *Gardenia latifolia* provide timber. Seeds of *Coffea arabica* and

allied species yield coffee. Quinine (an alkaloid used in controlling malaria) is extracted from the bark of *Cinchona officinalis*. A spirit is distilled from the flowers of *Anthocephalus cadamba*. Yellow dye is extracted from the bark of *Morinda angustifolia*.

Oldenlandia corymbosa, O. umbellato, O. dichotoma, O. diffusa and *Borreria articularis* are common herbs. *Canthium parviflorum* (T: Balusu) and *Randia dumetorum* (T; Manga) are shrubs of dry rocky areas. *Morinda tinctoria* (T; Togaru mogili) and *Ixora parviflora* (T: Korivi) are common in Andhra Pradesh forests. *Mussaenda frondosa, Ixora coccinea, I. arborea Gardenia jasminoides, Pentas lanceolata* and many others are grown as ornamentals.

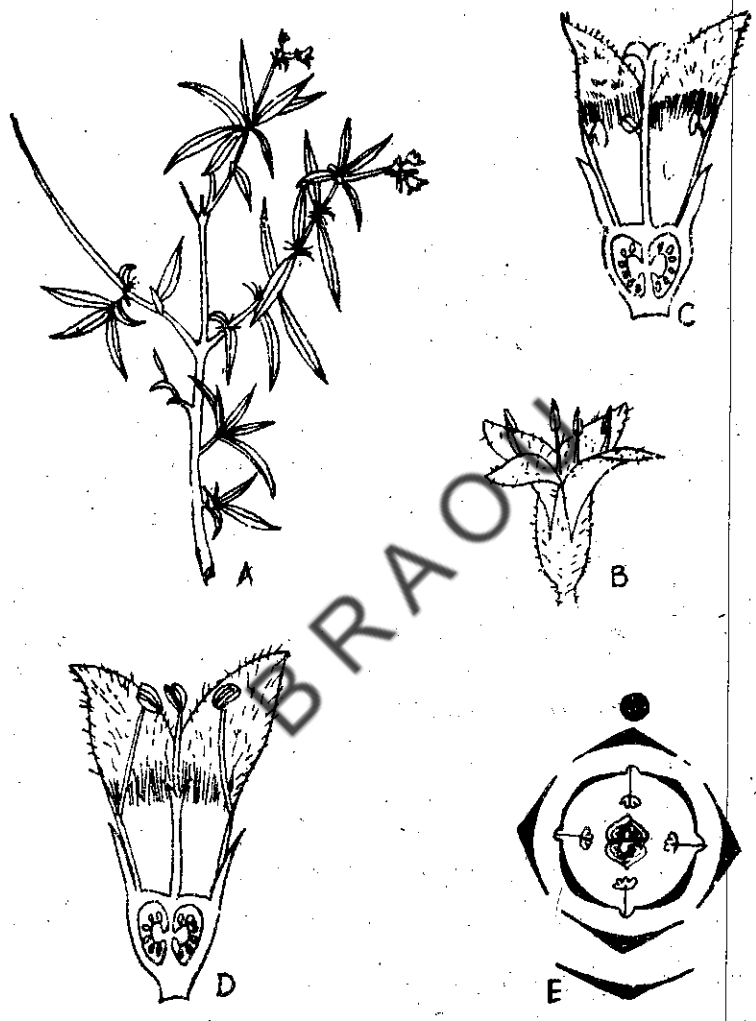

Fig. 19.1. *Oldenlandia umbellata* A. Twig b. Flower c. L.s. of flower with long style. D. L.S. of flower with short style. E. Floral diagram.

Check Your Progress 1 & 2

1. The self pollination in Rubiaceae is prevented by _____.
2. Quinine is extracted from _____.

Note: (a) Write the answer in the space given below.
(b) Compare your answer with the one given at the end of this unit.

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19.4. FLORAL FORMULA

Br, Ebrl, ⊕, ⚥, K(4-5), C(4-5) A 4 or 5, $\bar{G}$(2)

19.5. DISTINGUISHING CHARACTERS

(a) Leaves opposite decussate.

(b) Stipules usually interpetiolar.

(c) Flowers actinomorphic, hermaphrodite, tertra-or penta-merous and epigynous.

(d) Gynoecium bicarpellary and syncarpous.

(e) Ovary bilocular with 1 to many ovules on axile placentation.

19.6. SUMMARY

The Rubiaceae shows interpetiolar stipules and regular, epigynous flowers. The family is of considerable economic importance in the possession of plants yielding commercial timber,coffee and quinine.

Ixora, Mussaenda, Coffee and *Cinchona* are some of the important members of this family.

19.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. Protandry or heterostyly
2. Bark of *Cinchona officinalis.*

19.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Give the distinguishing characters of Rubiaceae with a note on its economically important plants.

II. Answer the following questions in about 10 lines each.

1. Write about the economic importance of Rubiaceae.
2. List out the distinguishing characters of Rubiaceae.

UNIT-20 : ASTERACEAE (COMPOSITAE)

Division	:	Dicotyledons
Sub-Division	:	Gamopetalae
Class	:	Inferae
Order	:	Asterales
Family	:	Asteraceae

Contents

20.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the members of this family,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

20.2. INTRODUCTION

The name 'Asteraceae' is alternative to 'Compositae' which is commonly known as 'sunflower family'. The Asteraceae is the second largent family of angiosperms, with about 900 genera and 13,000 species representing more than ten per cent of the flowering plants. The members occur throughout the world, though a majority are confined to temperate zones.

20.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Plants mostly herbs. *Helianthus tuberosus* has rhizomatous stems, while tuberous roots in species of *Dahlia*. In some members like *Cichorium, Crepis* and *Lactuca*, latex is present. Leaves usually alternate, rarely opposite as in *Ageratum* or *Helianthus*, or whorled as in some species of *Eupatorium*, simple or rarely compound, exstipulate.

Inflorescence a homo-or hetero-gamous head, subtended by an involucre of bracts. In *Echinops* and few others , the number of flowers in a head., is reduced to one and a number of heads are aggregated into a single inflorescence (in which case,it can be called a compound head). Flowers much reduced and referred to as florets. In general,two types of florets can be recognised,the outer ray or ligulate florets and the inner disc florets. Calyx in both reduced to a ring (two in some) of hairs called pappus, or scales, or absent. Corolla ligulate in ray florets and tubular in disc florets. Androecium absent in ray florets. In disc florets stamens 5, epipetalous, syngenesious. Anthers dithecous, introrse, connective usually prolonged; dehiscence longitudinal. Gynoecium, in both types, bicarpellary syncarpous; ovary inferior, unilocular with a single anatropous ovule on basal placentation; style simple; stigma bifid. Fruit a cypsela crowned by persistent pappus which helps in dispersal (acting like a parachute). Seed non-edospermic

Pollination entomophilous. Though flowers are small, they are made conspicuous by aggregation into heads. Presence of ray florets further enhances attraction. Nectar is secreted at the base and collects inside the corolla tube. A single visit of insect may pollinate a large number of florets in the inflorescence. Self-pollination prevented by protandry. If cross-pollination fails, self -pollination is achieved by recurving stigmas.

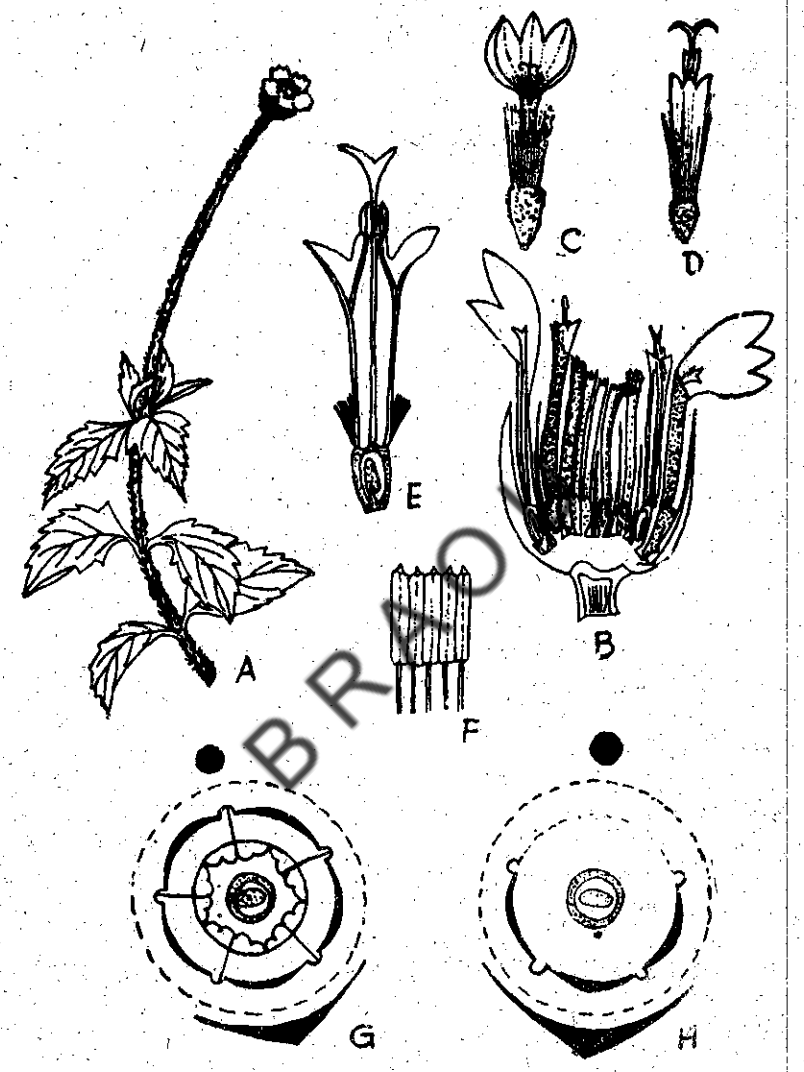

Fig. 20.1. *Tridax procumbens.* A. Twig, B. L.S. of inflorescene. C. Ray floret. D. Disc floret. E. L.S of disc floret. F. Androecium. G. Floral diagram of disc floret. H. Floral diagram of ray floret.

Economically the *Asteraceae* is important, though the importance is not proportional to the size of the family. *Lactuca sativa* is cultivated as a salad crop. *Helianthus tuberosus* gives edible tubers. The roots of *Chicorium intybus* yield chicory. Oil is extracted from the seeds of *Carthamus tinctorius* (T: Kusuma) and *Helianthus annus* (T: Suryakantham, Proddutirugudu). Species of *Chrysanthemum* like *C. coccineum* and *C. cinerariaefolium* yield the insecticide pyrethrum. *Artemisia absinthium* is used as a tonic. Seeds of *Vernonia anthelmintica* have anthelminthic properties. The juice of *Eclipta alba* (T: Guntagalajara; H: Bhangra) with a pinch of salt, is effective against scorpion- sting.

A large number of plants occur as weeds. They include *Vernonia cinerea, Ageratum conyzoides, Blumea wightiana, Blainvillaea rhamboidea, Glossocardia bosvallea, Tridax procumbens, Emilia sonchifolia* and *Echinops echinatus. Caesulia axillaris* occurs in marshes. A large number of species of different genera are cultivated as ornamentals. They include *Helianthus annus, Tagetus erecta* (T: Banthi) , *Dahlia pinnata, Chrysanthemum carinatum, C. coronarium, C. Cinerariaefolium* (T: Chamanthi), *Cosmos bipinnatus, Zinnia elegans, Gaillardia pulchella, Calendula officinalis* and *Aster grandiflorus.*

Many txonomists consider the Asteraceae as highly advanced among dicotyledons. Presence of a large number of species, cosmopolitan distribution, preponderance of herbaceous habit, head inflorescence, epigynous flowers, syngenesious stamens,dispersal mechanism with persistent pappus, admirable adaptability for cross-pollination by insects and ability for self-pollination when cross-pollination fails,are all characters that indicate the advanced nature of the family.

Check Your Progress 1, 2,& 3

1. Name two oil yielding plants of Asteraeceae.
2. The plant which is grown as a salad crop is _____.
3. The calyx in flowers of Asteraceae is usually reduced to _____.

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end.

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20.4. FLORAL FORMULA

1. Ray floret: Br, Ebrl,%, ⚥, K (∝), C (3+2), $\bar{G}$(2)
2. Disc floret: Br, Ebrl ⊕, ⚥, K (∝), C (5), A (5), $\bar{G}$(2)

20.5. DISTINGUISHING CHARACTERS OF THE FAMILY

1. Plants mostly herbaceous.
2. Inflorescence a homo-or hetero-gamous head with an involucre of bracts.
3. Flowers epigynous.
4. Calyx reduced to hairs or scales or absent.
5. Corolla either tubular or ligulate.
6. Stamens syngenesious.
7. Ovary unilocular, with a single basal ovule.
8. Fruit a cypsela, usually crowned by persistent pappus.
9. Seeds nonendospermic.

20.6. SUMMARY

The predominently herbaceous Asteraceae is the second largest family of Angiosperms. The family is characterized by hom-or heterogamous heads of inflorescence,epigynous flowers , syngenesious stamens and unilocular ovary with a single basal ovule.

Helianthus, Tagetus, Chrysanthemum, Aster, Zinnia and *Tridax* are some of the commonly encountered members of this family.

20.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. (a) *Carthamus tinctorius* and (b) *Helianthus annus*
2. *Lactuca sativa*
3. hairs called pappus.

20.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Give a detailed account of the floral structure of the family Asteraceae. Add a note on the pollination mechanism.

II. Answer the following questions in about 10 lines each.

1. Write about the economic importance of the family Asteraceae.
2. Give an account of the economic importance of this family.

UNIT-21: ASCLEPIADACEAE

Divsion	:	Dicotyledons
Sub-Division	:	Gamopetalae
Class	:	Bicarpellatae
Order	:	Gentianales
Family	:	Asclepiadaceae

Contents

21.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the members of this family,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

21.2. INTRODUCTION

Asclepiadaceae is a moderately sized family. It consists of about 175 genera and 2,200 species. The plants are mostly confined to tropics and subtropics.

Plants are either herbs (e.g. *Asclepias*) or shrubs (e.g. *Calotropis*) or climbers (e.g. *Pergularia* and *Tylophora*). They contain latex in branched laticiferous tubes. Vascular bundles are bicollateral.

21.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Leaves opposite decussate, exstipulte or with minute stipules, entire. In some like *Sarcostemma* leaves are absent.

Inflorescence cymose. Umbellate in plants like *Asclepias* and *Calotropis*. Flowers actinomorphic, hermaphrodite,pentamerous and hypogynous. Sepals 5, united, quincuncial. Petals 5, united, valvate or twisted. Corona of hairs may be present at the mouth of coralla tube. Stamens 5, epipetalous. Staminal corona (of 5 lobes) usually present. Filaments free in united. Anthers appressed against or adnate to stigma. Pollen in tetrads or in pollinia. Translators present; either spoon shaped or λ shaped. Gynoecium bicarpellary, syncarpous. Ovaries 2, unilocular. Ovules many, anatropous marginal, Styles 2, simple. stigma 1, enlarged. 5 sided with anthers adhering to the sides forming the compound gynostegium. Fruit is a pair of follicles. Seeds endospermic,usually with a tuft of hairs.

The family is divided into two subfamilies as follows:

1. **Periplocoideae**: Pollen in tetrads; translotor spoon shaped and provided with adhesive disc. e.g. *Hemidesmu* and *Cryptostegia.*

2. **Cynanchoideae**: Pollen in pollinia; translator 'λ' shaped and provided with corpusculum (disc) and retinacula (stalks).e.g. *Asclepias* and *Calotropis.*

Pollination is entomophilous. The mechanism is highly advanced. Removal of pollen is by translators which are present in androecium. In **Periplocoideae** the pollen is shed into the spoon- shaped translator which has a basal sticky disc. Nectar secreted by glandular corona,

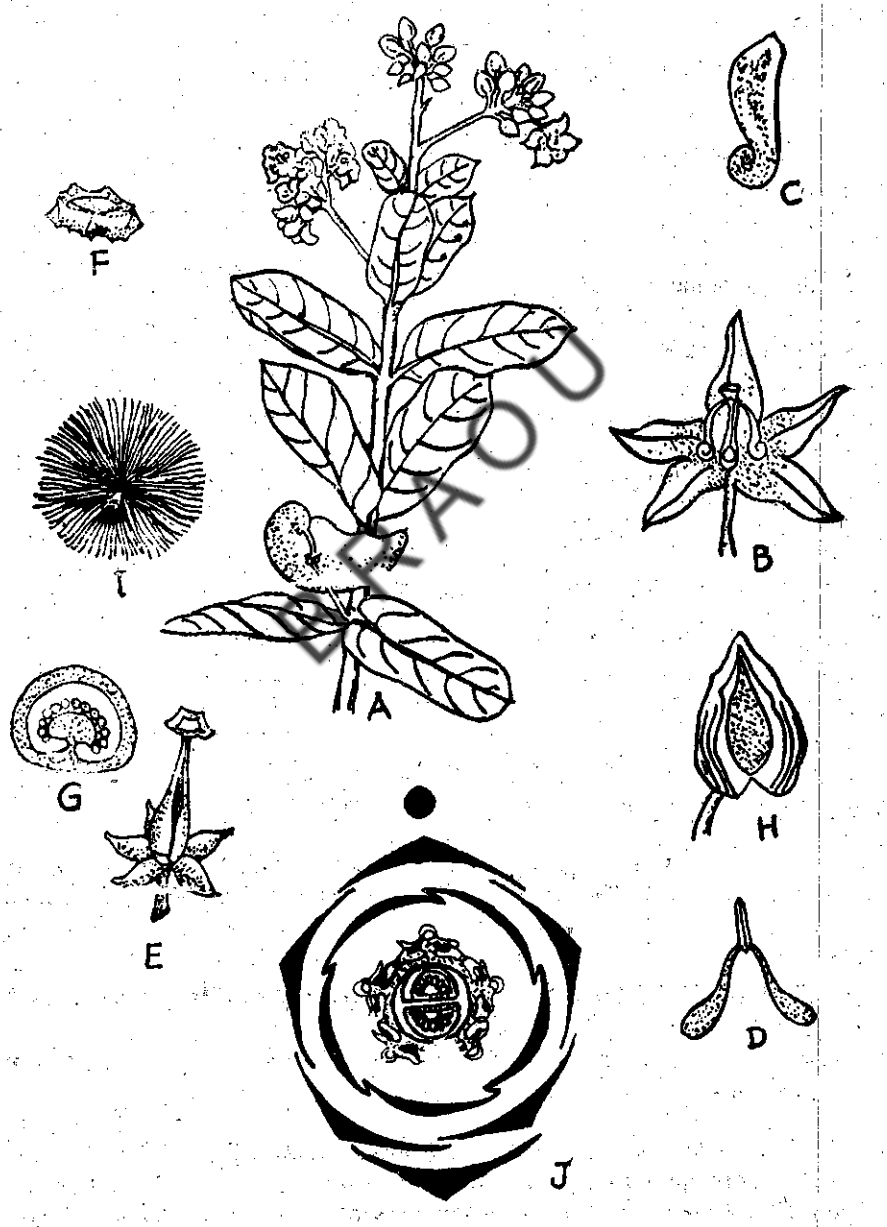

Fig. 21.1 *Calotropis gigantea.* A. Twing. B. Flower. C. A part of corona D. Translator with pollinia E. Gynoecium F. Gynostegium. G. T.S. of ovary H. Fruit. I. Seed. J. Floroal diagram.

collects at the base of corolla tube. The entire translator which gets attached to the head of the insects by the sticty disc, is carried away from the flower. The pollen is deposited on the stigmatic surface when the insect visits another flower. In *Cynanchoideae*, the pollen is aggregated into waxy masses called pollinia. Pollinia are extended into thread- like structures called retinacula. Retinacula of adjoining anthers unite into a disc called corpusculum. When the insect visits a flower and probes for nectar, its legs or proboscis come in between retinacula. As the insect flies off from the flower, the entire translator (with two pollinia) is lifted out of the flower. Retinacula being hygroscopic on exposure, cross or twist around the legs or proboscis. Thus the translator firmly adheres to the body of the insect. The pollinia are deposited on the stigmatic surface when the insect visits another flower.

Economically, the family is of limited importance. Later from *Cryptostegia grandiflora* is a source of rubber. Tubers of *Ceropegia pusilla* and flowers of *Holostemma annulare* are edible. Fibres are extracted from *Leptadenia reticulata* (T: palatiga; H: Dori) and species of *Calotropis*. Roots and leaves of *Tylophora indica* are used in treating asthma. Dried roots of *Hemidesmus indicus* (T: Sugandhipalu; H: Anantamul) are useful as blood purifier. Latex from *Calotropis procer* and *C.gigantea* (T: Jilledu; H: Akand) is used in tanning hides. Hairs from seeds of many members, are useful as insulating material. *Calotropis gigantea* and *C. procera* are common shrubs. *Tylophora indica, Leptadenia reticulata* and *pergularia daemia* are climbers occurring frequently on hedges. *Caralluma attenuata, C. diffusa* and *C. umbellata* are succulents of dry, rocky areas. Plants like *Cryptostegia grandiflora, Ceropegia woodii, stapelia gigantea* and *Asclepias curassavica* are grown as ornamentals.

Check Your Progress - 1, 2, & 3

1. What is a gynostegium?
2. The rubber yielding plant of Asclepidaceae is _____.
3. What are pollinia _____.

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end.

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21.4. FLORAL FORMULA

Br, Brl or Ebrl , ⊕, ⚥, K (5), C (5), A(5), G(2).

21.5. DISTINGUISHING CHARACTERS OF THE FAMILY

1. Plants with latex.
2. Leaves opposite decussate.
3. Flowers actinomorphic, hermaphrodite, pentamerous,hypogynous.
4. Staminal corona.
5. Translators present in androecium.

6. Ovaries and styles 2 but stigma one.
7. Fruit is a pair of follicles.
8. Seeds with a tuft of hairs.

21.6. SUMMARY

The Asclepiadaceae is characterised by the possession of latex, opposite decussate leaves, regular, hypogynous flowers with staminal corona and gynostegium. The fruit is of the nature of a pair of follicles.

Calotropis and *Leptadenia* are the commonly encountered members of this family.

21.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The five sided enlarged stigma with anthers adhering to it form a compound structure called gynostegium.
2. *Cryptostegia grandiflora*
3. In the sub family cynancoideae the pollen is aggregated into waxy masses called pollinia.

21.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write about the floral structure and economic importance of the family Asclepiadaceae.

II. Answer the following questions in about 10 lines each.

1. Write briefly about the pollination mechanism in Asclepiadaceae.
2. Write briefly about the economic importance of this family.
3. What are the distinguishing characters of Asclepiadaceae.

UNIT-22 : SOLANACEAE

Divsion	:	Dicotyledons
Sub-Division	:	Gamopetalae
Class	:	Bicarpellatae
Order	:	Polemomiales
Family	:	Solanaceae

Contents

22.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the members of this family,
2. list out the important genera,
3. describe the economic importance of this family,and
4. list out the distinguishing characters.

22.2. INTRODUCTION

The Solanaceae (commonly called 'Potato', 'brinjal' or 'nightshade' family) is a moderately sized family with about 90 genera and 2,200 species which are distributed in tropical and temperate regions

22.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Plants are herbs or shrubs (very rarely small trees). In *Solanum tuberosum* (potato) stem tubers are present. Vascular bundles are bicollateral. Leaves simple, alternate,exstipulate, entire or lobed.

Inflorescence cymose, terminal or axillary, sometimes extraxillary. Flower solitary in *Datura*. Flowers usually actionomorphic, hermaphrodite, pentamerous, hypogynous. Sepals 5, united, usually persistent and enlarged in fruit. Petals 5, united, often plaited. In *Schizanthus* corolla is zygomorphic and bilabiate. Stamens 5, epipetalous. Filaments usually unequal. Anthers introrse, dithecous, sometimes connivent as in species of *Solanum*. Dehiscence longitudinal or by apical pore. Disc hypogynous. Gynoecium bicarpellary, syncarpous; carpels obliquely placed. Ovary superior, bilocular (in some, more than 2-loculed by false septa). Ovules usually many (few in *Cestrum*), anatropous, on axile placentation. Style simple. Stigma bilobed. Fruit a berry (e.g. *Solanum*) Seeds endospermic.

Pollination is entomophilous. Nectar is secreted by the hypogynous disc. In *Solanum tuberosum*, probably,self-pollination occurs. The style curves back and makes the stigmatic lobes touch the anthers.

Economically the family is very important. Fruits of *Capsicum annum* and, *C. frutescens* (T: Mirapa; H. Mirchi) are used as condiment. Tubers of *Solanum tuberosum* (T & H; Alu; E: Potato) and fruits of *S. melangena* (T: Vanga, Vankaya; H: Baingun) and *Lycopersicon esculentum* (E: Tomato) are important vegetables. Berries of *Physalis peruviana* (E. Raspberry)are edible. A number of plants have medicinal value. Roots of *Atropa belladonna* (E: Belladonna) yield the alkaloid atropine which is used in controlling muscular spasms. Leaves of *Nicotiana tabacum* (T: Pogak) contain the alkaloid nicotine and are used in manufacturing cigars, cigarettes, snuff etc. Roots of *Withania somnifera* (T: Pennerugadda; H: Asgandh) are used as nervine tonic. Leaves of the *Datura stramonium* yield the alkaloid daturin used in treating spasms and parkinsonism.

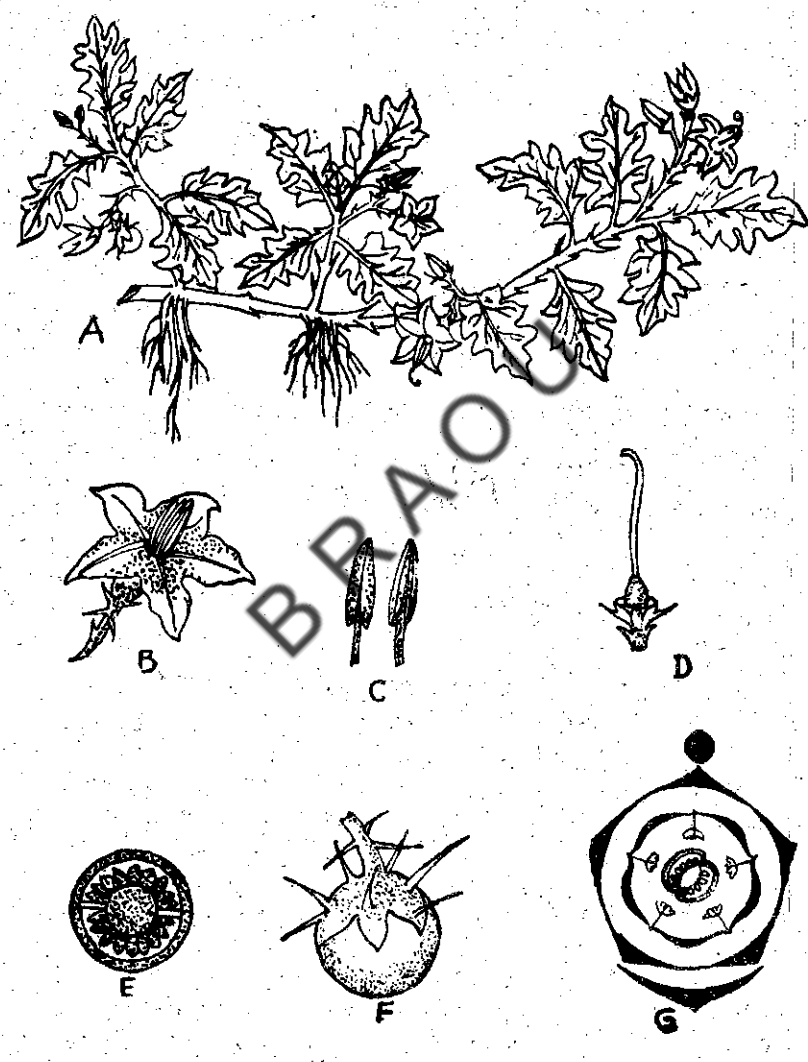

Fig. 22.1. *Solanum surattense*. A. Twig. B. Flower. C. Stamens D. Gynoecium. E. L.S of ovary F. Fruit. G. Floral diagram.

Solanum surattense (T: Jidduvasti), *S. nigrum* (T: Kamanchi), *Datura innoxia*, *D. metel* (T: Ummetta; H: Dhatura) and *Physalis minima* (T: Kuppanti) are common weeds. *Solanum jasminoides*, *Petunia hybrida*, *P. violacea*, *Brunfelsia americana*, *Nicotiana alata*, *Cestrum nocturnum* (T. Rerani; H: Rath ki Rani) and C. *diurnum* (H: Din ka Raja) are commonly cultivated as ornamentals.

Check Your Progress 1, 2 & 3

1. Name 2 genera whose fruits are used as avegetables.
2. The leaves of ..... is used in the manufacturing of cigarettes.
3. The alkaloid which is used in treating parkinsonism is obtained from .....

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end.

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22.4. FLORAL FORMULA

⊕, ⚥, K (5), C (5), A 5, G(2)

22.5. DISTINGUISHING FEATURES OF THE FAMILY

1. Vascular bundes bicollateral.
2. Leaves alternate, exstipulate.
3. Flowers hermaphrodite, pentamerous, hypogynous.
4. Hypogynous disc.
5. Gynoecium bicarpellary, syncarpous, carpels oblique.

22.6. SUMMARY

The Solanaceae, an economically important family possesses simple leaves; regular, hypogynous flowers and bicarpellary, syncarpous ovary with many ovules on axile placentation.

Various species of *Solanum*, *Capsicum*, *Lycopersicn* and *Datura* are the more commonly encountered members of this family.

22.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. (a) *Solanum melangena* (b) *Lycopersican esculentum*
2. *Nicotiana tabacum*
3. *Datura stramonium*

22.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write about the taxonomic characters and economic importance of Solanaceae.

II. Answer the following questions in about 10 lines each.

1. Give an account of the economic importance of Solanaceae.
2. Write briefly about the floral characters of Solanaceae.

UNIT-23 : LAMIACEAE (LABIATAE)

Divsion	:	Dicotyledons
Sub-Division	:	Gamopetalae
Class	:	Bicarpellatae
Order	:	Lamiales
Family	:	Lamiaceae

Contents

23.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of the members,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distnguishing characters.

23.2. INTRODUCTION

Lamiaceae is a large family of about 200 genera and 3200 species and cosmopolitan in distribution, but chiefly confined to the mediterranean regions.

23.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Mostly herbs (*Leucas, Lavendula, Ocimum*), undershrubs (*Salvia*), rarely small trees (*Meriandra bengalensis*). Some are marsh plants (*Mentha and Lycopus*). *Scultellaria* (Lianous type) and *Stenogyne* are climbing plants. *Rosmarinus* is a xerophytic shrub. Plants usually with aromatic oil glands.

Stems quadrangular. Leaves simple, exstipulate opposite decussate, in some whorled (*Ocimum*). Aromatic oil glands are present. Leaf margin entire, lobed or dissected (*Salvia*), surface hairy. Stomata diacytic.

Inflorescence usually a verticillaster or in some thyrsus (*Ocimum basilicum*), rarely solitary (*Scutellaria*). Sometimes a condensed cymose head (*Leucas*).

Flowers mostly zygomorphic, hypogynous and pentamerous.

Sepals five , united, campanulatae, tubular or bilabiate (*Salvia, Thymus*), persistent and imbricate.

Corolla with five united petals, bilabiate and in 2+3 condition (upper lip two lobed lower lip three lobed). Aestivation imbricate.

Stamens usually four, didynamous, with the anterior pair longer, epipetalous, sometimes only two *(Salvia)*. Anthers introrse. Pollen grains polycolpate (the number of colpi ranging mostly from 4 to 6) and reticulate. Ovary superior, hypogynous nectiferous disc often present between stamens and ovary. Bicarpellary, bilocular, appearing 4-locular due to false septum, ovules anatropous, one in each loculus. Style simple and gynobasic, stigma 2-lobed. Placentation axile.

Fruit made up of 4 nutlets or achenes each containing one seed. Fruit enclosed within the persistent calyx. Seed with scanty or no endosperm.

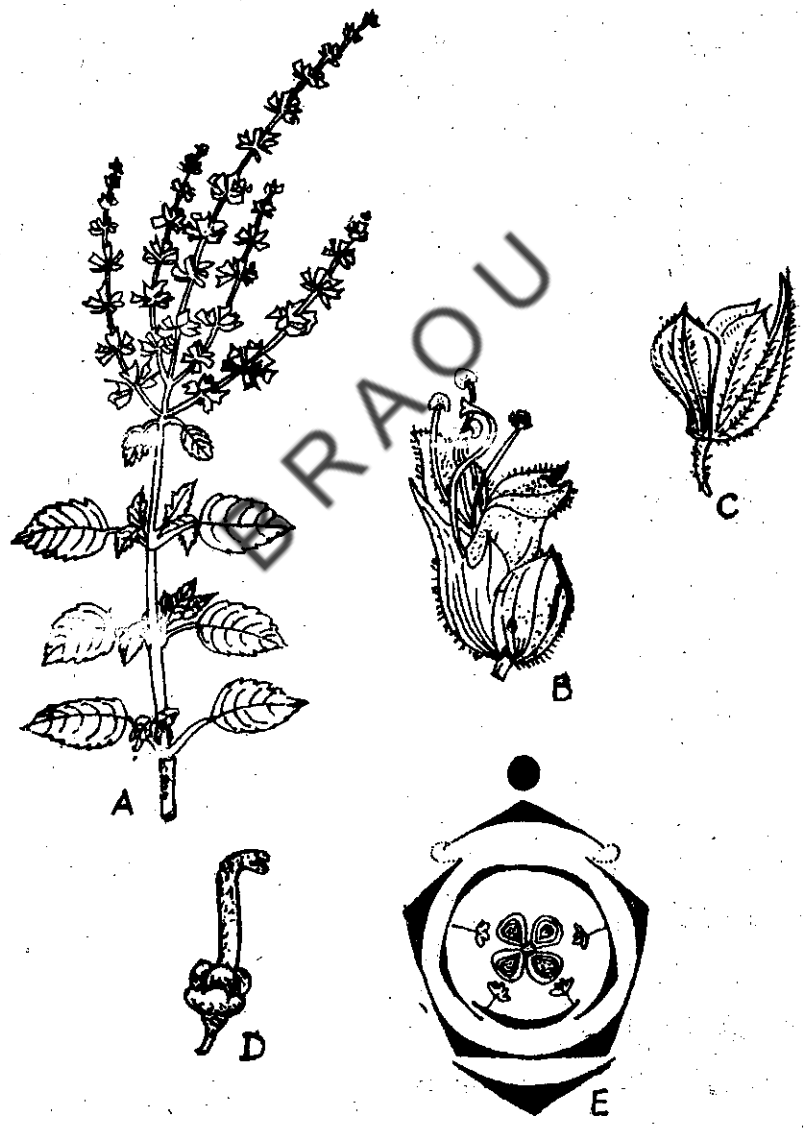

Fig. 23.1. *Ocimum sanctum*. A Twig. B. Flower. C. Calyx. D. Pistil. E. Floral diagram

Pollination is entomophilous. Protandry promotes cross pollination. Nectiferous disc present between the stamens and the ovary and provides nectar to the insects. The bilabiate

corolla ensures the insect visitor a landing place on the lower lip. It also acts as a flag to attract the insects. The essential organs are enclosed in the upper lip. Hence when the insect probes for nector at the base of the flower the stamens which are shattered by the upper lip touch the back of the insect and shed the pollen grains (*Lamium*). In *Salvia*, there are only two stamens. The stamens have short filaments and elongated connectives. The fertile anther lobe at the top, and the sterile anther lobe below are separated by the elongated connective. When an insect visits *Salvia* flower and probes for nectar, it touches the lower sterile lobe and the upper fertile lobe swings like a lever on the back of the insect, shedding the pollen grains. Hence lever mechanism is observed in the pollination of *Salvia* flowers.

In *Hyptis* the anterior (lower) lip is more protruded and encloses the essential organs. Nectar is secreted on the upper side of the disc. While the insect lands on the lower lip and probes for nectar, its belly and legs get smeared with pollen grains.

The type of insect visitor varies according to the length of the corolla tube. Mostly bees, butterflies and humming birds pollinate the flowers of Lamiaceae. The family is economically important due to volatile oil produced by the plants. Essential oils used in perfumery are obtained by distillation from *Lavendula officinalis* (Lavendar), *Rosmarinus sp.* (Rosemary) *Mentha piperita* (gives menthol), *Mentha arvensis* (Mint, T. Pudina), *Pogostemon, Thymus serphyllum* (yields Thymol), *Ocimum basilicum* (T: Sabja) *O. sanctum* (T: Tulasi) and *Origanum marjoranum* (T.maruvam) are useful to impart aroma for flavouring foods. *Ocimum sanctum, O. basilicum* and *Marrubium sp.* are used in medicinal preparations. Fruits of *Hycopus europeans* yield a green dye. The common ornamental plants are *Salvia officinales* (Sage), *Coleus* sp., *Lamium sp., Thymus sp., Lavendula sp.* and *Melissa sp.* etc.

Check Your Progress 1 & 2

1. What is the special type of inflorescence that we come across in this family ?
2. Menthol is obtained from _____.

Note: a) Write the answers in the space given below.

b) Compare your answers with those given at the end.

.....

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23.4. FLORAL FORMULA

Br, Ebrl, %, ⚥, K(5), $\overset{\frown}{C(2+3)}$, A 2+2, G (2)

23.5. DISTINGUISHING CHARACTERS

1. Leaves opposite decussate and aromatic.
2. Stems quadrangular.
3. Inflorescence a verticillaster or thyrsus.
4. Bilabiate corolla.
5. Stamens usually four, didynamous, epipetalous.
6. Style gynobasic.
7. Fruit composed of four achenes or nutlets.

23.6. SUMMARY

The Lamiaceae is an essentially herbaceous family of aromatic plants. It shows verticillaster or thyrsus type of inflorescence, zygomorphic, hypogynous flowers with bilabiate corolla and gynobasic style.

Ocimum and *Salvia* are the most commonly encountered members of this family.

23.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The special type of inflorescence that we come across in this family is thyrsus.
2. *Mentha piperita*

23.8. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write about the distinguishing characters of Lamiaceae and add a note on its economic importance.
2. Describe the floral structure and pollination mechanism in Lamiaceae.

II. Answer the following questions in about 10 lines each.

1. Write the pollination mechanism in Lamiaceae.
2. What are the distinguishing characters of Lamiaceae.

UNIT-24 : LORANTHACEAE

Divsion : Dicotyledons
Sub-Division : Monochlamydeae
Class : Achlamydosporeae
Family : Loranthaceae

Contents

24.1. OBJECTIVES

By the end of this unit you will be ble to:

1. describe the various taxonomic characters of this family,
2. list out the important genera,
3. describe the economic importance of this family, and
4. list out the distinguishing characters.

24.2. INTRODUCTION

Chiefly a tropical family with 30 genera and 1100 species. They extend into temperate zones also.

Dendrophthoe falcata (Syn. *Loranthus longiflorus*) and *Viscum* sp. are common in India. Some of the species of *Viscum* occur in temperate regions.

24.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Herbs or shrubs, partial parasites on branches of trees, attached to their hosts by haustoria (usually regarded as modified adventitious roots).

Stems usually dichotomously branched, nodes generally swollen (stem flattened in *Viscum*). An outgrowth of considerable size is often seen where the parasitic root joins the host. The parasitic root usually branches within the tissue of the host (Mistletoe).

Leaves evergreen, persistent and leathery, mostly opposite, sometimes whorled, simple,entire, exstipulate, coriaceous, sometimes reduced to scales.

Flowers solitary or in panicles, recemes or spikes, bisexual or unisexual (if unisexual, plants dioecious)e.g., *Viscum*. Flowers large and brightly coloured, actionomorphic (*Dendrophthoe*). Sometimes inconspicuous and epigynous . Perianth borne on the cup shaped receptacle green and petal like or coloured, biseriate with 2 similar whorls, 2-3 merous, and petaloid, the parts free or united. A calyculus is formed below the Perianth, as an outgrowth of the axis in the form of a small fringe (eg. *Denorophthoe*). Calyculus absent in *Viscum*.

Stamens as many as number of perianth parts, and attached to them at their base, or on the cup (epiphyllous). Anthers 2 celled (or transversely multilocular), dehiscing longitudinally or by terminal pores or transverse slits.

Ovary inferior, l-locular, embedded in the receptacle probably with 3 or 4 carpels; the ovules not differentiated from the basal placentum; style simple, stigma capitate.

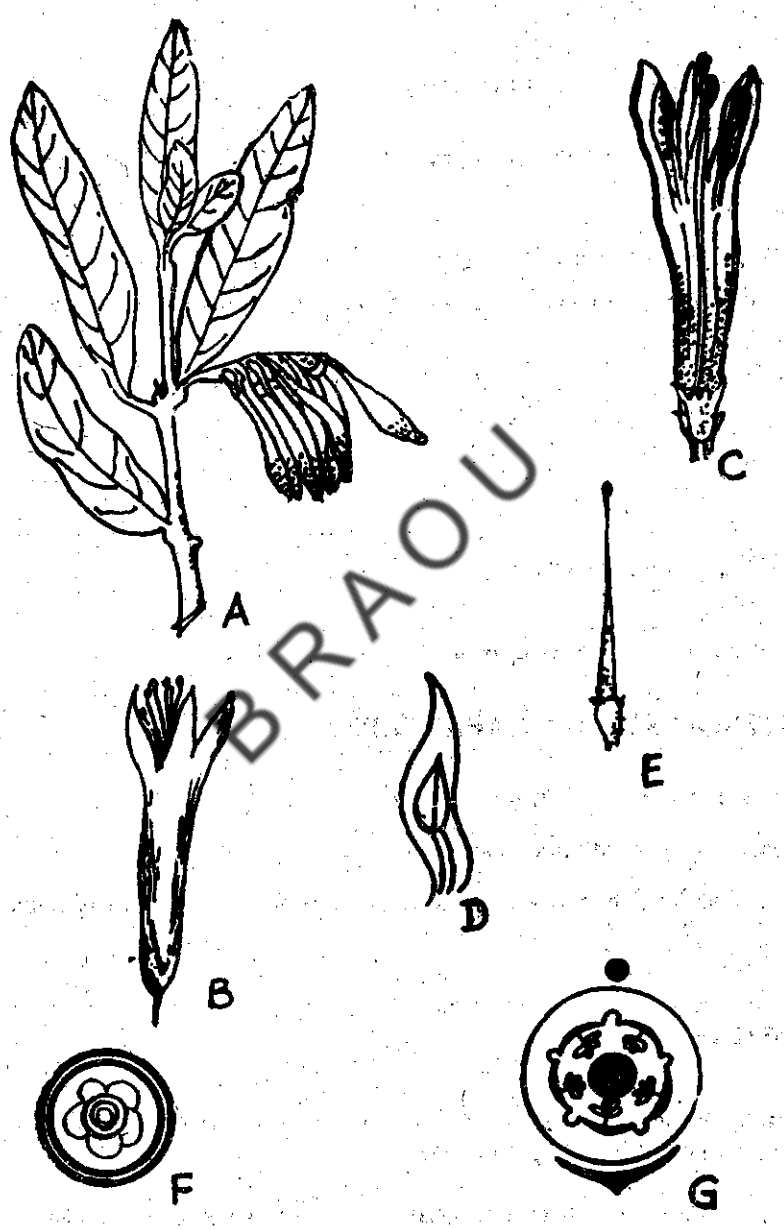

Fig. 24.1. *Loranthus longiflorus.* A. Twig. B. Flower. C. Flower opened. D. Perianth with epiphyllous stamens. E. Pistil. F. T.S. of ovary. G. Floral diagram.

Fruit a pseudoberry (fleshy part is the receptacle) or drupe. It is often viscid because of viscin (a sticky) around the seed.

Seed without testa, endosperm abundant, each seed has 2-3 embryos.

Pollination anemophilous in unisexual flowers and entomophilous in brightly coloured bisexual flowers.

Dendrophthoe sp. is semiparasitic on a number of plants such as Neem (Vepa), Mango, Guava, Custard apple etc. *Viscum album* is the mistletoe of Europe, while *Phoradendron* is the American mistletoe. *Viscum articulatum* found in India is used in the indigenous medicine.

Check Your Progress - 1 & 2

1. Name two parasitic genera of this family.

2. Pollination in unisexual flowers is by ..... and in bisexual flowers is by .....

Note: (a) Write your answer in the space given below.
b) Compare your answers with those given at the end.

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24.4. FLORAL FORMULA

⊕, ⚥, Calyculus, $\overset{\frown}{P\ 5, A\ 5}$, $\bar{G}$ (3 or 4)

24.5. DISTINGUISHING CHARACTERS

1. Plants mostly stem parasites.
2. Presence of perianth and epiphyllous stamens.
3. Receptacle cup-shaped, ovary inferior, ovules not clearly distinguishable.
4. Fruit viscous.

24.6. SUMMARY

The Loranthaceae is mostly a tropical family of partial parasities. It shows bisexual or unisexual flowers, perianth and inferior ovary.

Loranthus is the commonly encountered partial stem parasite of this family.

24.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. *(a) Dendrophthoe sp.* (b) *Viscum*

2. Pollination is anemophilous in unisexual flowers and entomophilous in bisexual flowers.

24.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write an account of the general characters of Loranthaceae.

II. Answer the following question in about 10 lines.

1. Write briefly about the floral characters of Loranthaceae.

UNIT-25 : EUPHORBIACEAE

Divsion	:	Dicotyledons
Sub-Division	:	Monochlamydeae
Class	:	Unisexuales
Family	:	Euphorbiaceae

Contents

25.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of this family,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

25.2. INTRODUCTION

A family of cosmopolitan distribution, chiefly subtropical and warm temperate. A large family having 283 genera and 7300 species.

25.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Herbs (*Euphorbia hirta, Phyllanthus niruri*), shrubs (*Jatropha and Ricinus*), trees (*Hevea sp.* and *Putranjiva roxburghii*). Milky latex is often present in laticiferous cells.

Stems erect, thick fleshy and succulent (*Euphorbia*) and many resemble cactaceae. Sometimes prostrate. In some the stem is ridged, armed with thorns.

Leaves mostly alternate or opposite (*Euphorbia hirta*), sometimes whorled. Leaves simple or sometimes compound (*Hevea sp.*), stipulate. Sometimes stipules reduced to hairy glands *(Jatropha)* or spines (*Euphorbia melii*), leaves variegated. Leaves caducous (*Euphorbia*), venation reticulate, unicostate (*Jatropha*) or multicostate *(Ricinus)*.

Infloresence of various types. Terminal raceme (*Ricinus, Croton*), terminal cymes (*Jatropha*). drooping catkins (male flowers of *Trewia* and *Acalypha*) and cyathium (*Euphorbia sp*). Bright red large upper bracts in *Euphorbia pulcherrima* makes the cyathium inflorescence apear conspicuous.

Flowers usually small or minute,unisexual (plants monoecious or dioecious). Mostly actinomorphic and hypogynous. Both calyx and corolla may be distinct (*Jatropha*). Flowers may be apetalous with only a sepaloid perianth (*Phyllanthus* and *Ricinus*). Many male flowers are arranged around a single female flower in an involucre forming a cyathium *(Euphorbia)*.

In staminate flowers stamens one (*Euphorbia*) to indefinite (*Croton*), sometimes connate and repeatedly branched (*Ricinus*). When corolla is present, stamens are equal or double the number of petals. Anthers 2 celled, dehiscing longitudinally or transversely. Intrastaminal disc present in multistaminate flowers. Pollen grains tricolporate.

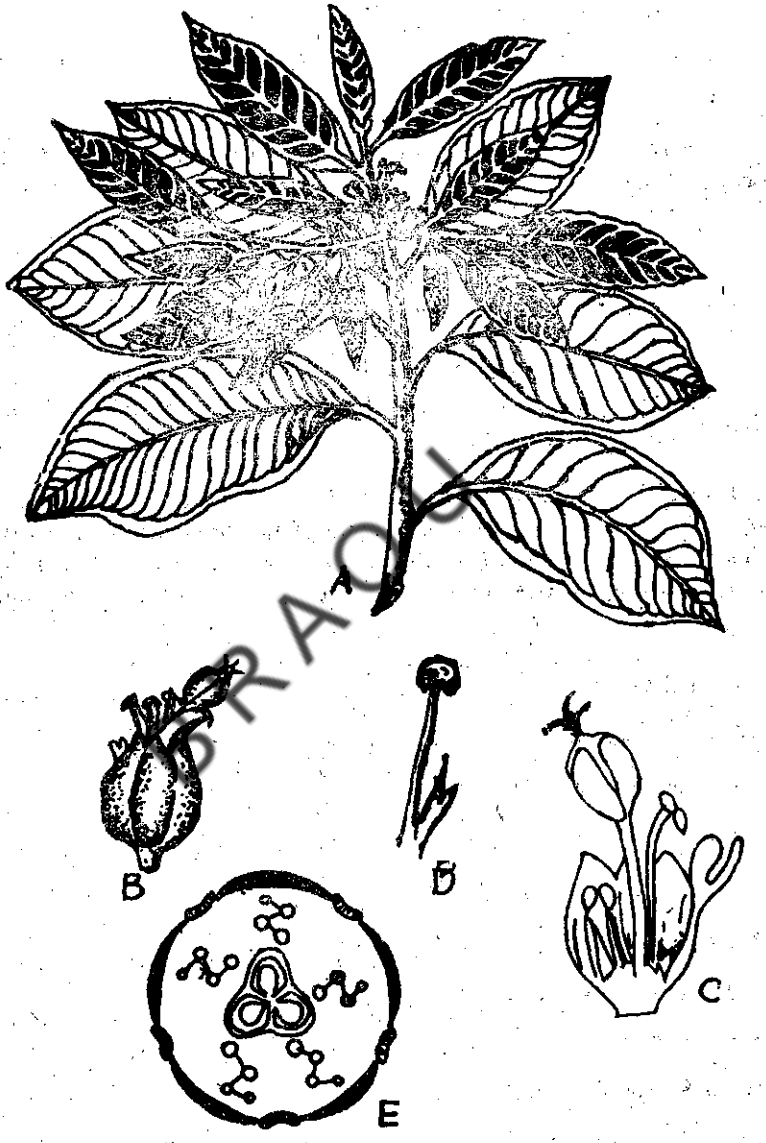

Fig. 25.1. *Poinsettia pulcherrima*. A. Twig. B. Cyathium. C. L.S. of cyathium D. Male Flower. E. Floral diagram.

In pistillate flowers ovary superior and syncarpous and tricarpellary. Placentation axile. Ovules anatropous and pendulous with ventral raphe. Ovules 1 or 2 in each loculus. Styles 3, distinct, basally connate, terminally forked. Stigmas 3 or 6 papillate or form filiform segments.

Pollination chiefly entomophilous. Brightly coloured bracts (*Euphorbia pulcherrima*) and extra floral nectaries favour entomophily. Sometimes anemophilous.

Fruit a schizocarpic capsule *(Jatropha)*, regma *(Castor)*, drupaceous (*Trewia, Bischofia*), drupe (*Phyllanthus emblica, Putranjiva*).

Seeds albuminous, with abundant endosperm. Endosperm oily (*Ricinus*) or fleshy. Caruncle often present (*Ricinus*).

Several members of this family are econmically important. Rubber is obtained from the latex of *Hevea brasiliensis* and other species of *Hevea* and *Manihot glaziolii.*

Edible roots as casava and tapioca are obtained from *Manihot utilissima* and *Manihot palmata.*

Castor oils is obtained from *Ricinus communis*, tung oil from *Aleurites foredii*, croton oil from *croton tiglium* and other sp. of croton. All these oils are used as purgative in medicine and as lubricants (castor oil).

Fruits of *Emblica officinalis* (H.Amala, T.Usirika) are pickled and used medicinally. It is rich in Vitamin C and is an ingredient of Ayurveic medicine.

Some of the wood yielding plants are *Bischofia javanica, Bridelia retusa, Flueggea macrocarpa, Cleistanthus sp.* The wood is used in making agricultural implements, in the construction of bridges, boats and poles.

The bark of *Sapium insigne* yields a dye. *Emblica officinalis, Glochidion velutinum* and *Mallotus phillipines* are used in tanning. Some of the ornamental plants of this family are *Euphorbia pulcherrima, E. tirucalli, E.melii, Jatropha multifida, Codiaeum sp.* (crotons) and *Pedilanthus sp. Putranjiva rozburghii* is an avenue tree. Other common plants and weeds of this family are :

1. *Euphorbia hirta*
2. *Euphorbia royleana*
3. *Euphorbia antiquorum*
4. *Euphorbia nivulea*
5. *Acalypha indica (T.Kuppi)*
6. *Acalypha fruticosa*
7. *Acalypha lanceolata*
8. *Tragia cannabina*
9. *Chrozophora parviflora*
10. *Phyllanthus niruri* (H.Jar Amla) medicinally used in jaundice.
11. *Croton sparsiflorus.*
12. *Croton oblongifolius.*

Check Your Progress 1, 2 & 3

1. What is the type of inflorescence that is seen in *Euphorbia* sp.
2. Name 2 genera which yield rubbe1.
3. Name 2 oil yielding plants and also the names of the oils.

Note: (a) Write your answers in the space given below.

(b) Compare your answers with those given at the end.

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25.4. *JATROPHA* FLORAL FORMULA

Male flower: Br, ⊕, ♂, P 5+5, A 5+5, G (0)

Female Flower: Br, ⊕, ♀, P 5+5, A 0, G(3)

25.5. DISTINGUISHING CHARACTERS

1. Milky latex is present in many plants.
2. Inflorescence a cyathium (*Euphorbia*) or spike, raceme, catkin (*Acalypha*) or terminal cyme (*Jatropha*).
3. Unisexual flowers.
4. Ovary tricarpellary, trilocular, placentation axile.
5. Ovules 1 or 2, pendulous with ventral raphe.
6. Fruit a schizocarpic capsule, regma (castor), drupe (*Phyllanthus*).
7. Caruncle often present.

The members of this family are gaining prominence in recent times as they contain hydrocarbons in their latex, as well as in oil obtained from the seeds. UNESCO is taking much interest in this project.

25.6. SUMMARY

The Euphorbiaceae is a large family of latex bearing plants. It has unisexual flowers. The male flowers show one to many stamens and the female flowers are with a tricarpellary syncarpous, trilocular ovary with one or two ovules in each loculus on axile placentation.

Ricinus, *Euphorbia* and *Jatropha* are the commonly encountered members of this family.

25.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The inflorescence found in *Euphorbia* sp. is cyathium.
2. *Hevea* sp. and *Manihot* sp.
3. Castor oil is obtained from *Ricinus communis* and tung oil is obtained from *Aleurites foredii*.

25.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write about the distinguishing characters and economic importance of Euphorbiaceae.

II. Answer the following questions in about 10 lines each.

1. Write a brief account of the economic importance of Euphorbiaceae.
2. What are the distinguishing characters of Euphorbiaceae?

UNIT-26 : ORCHIDACEAE

Divsion : Monocotyledons
Class : Microspermae
Family : Orchidaceae

Contents

26.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of this family,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

26.2. INTRODUCTION

A large family of Monocotyledons with 450 genera and 10,000 species. They are cosmopolitan in distribution. Chiefly tropical, less abundant in temperate regions.

Perennial herbs, terrestrial in temperate zones, many of them epiphytic (*Vanda*) in tropics.

The plants exhibit three distinct growth forms.

1. A monopodium in which the main axis steadily grows, bearing flowers on its lateral branches. e.g. *Vanda, Polyrrhiza.*
2. An acranthous sympodium in which the main axis is composed of annual portions of successive axes. Each of this axis begins with a scale leaf and ends in an inflorescence. e.g., *Zeuxine, Dendrobium.*
3. A pleuranthus sympodium in which the growth is strictly seasonal. In this type the inflorescence is lateral.

The roots or rhizomes are with endotrophic mycorrhiza *(Rhizoctonia)*. The terrestrial forms have fibrous or thickened cord like roots. Epiphytic orchids possess three types of roots. (a) the clinging roots. (b) absorptive roots that penetrate the humus which collects between plant and its support, and (c) the pendant aerial roots with velamen tissue absorbing moisture from the atmosphere.

26.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Stems leafy or scapose.

Leaves simple, alternate, rarely opposite or whorled, linear, ovate or orbicular. Exstipulate, sessile (*Zeuxine*) or petiolate. Leaves rarely reduced to scales (*Neottia*). Sometimes membranous or succulent. Leaf base sheathing.

Inflorescence recemose, often as spikes or racemes or panicles. Sometimes flowers solitary.

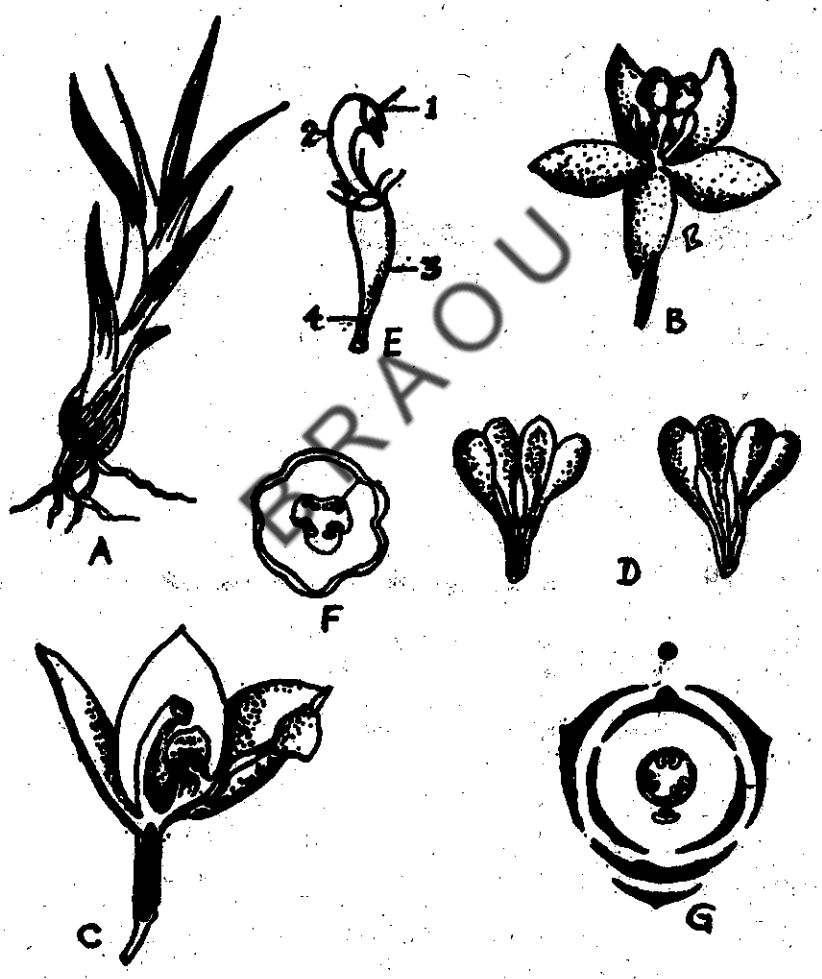

Fig. 26.1. *Spathoglottis sp* A. Twig. B. Flower. C. Opened flower D. Pollinia E. Pistil. F. T.S. of ovary G. Floral diagram. 1. rostellum. 2. Gynandrium. 3. Inferior ovary 4. Pedicel.

Flowers bisexual, rarely unisexual, zygomorphic, trimerous, ovary epigynous and prominently elongated. Flowers bracteate, pedicillate or sessile.

Perianth leaves free in two whorls of three each. Outer whorl sepaloid or petaloid, free, regular and valvate. Inner whorl petaloid, the odd lobe or labellum is posterior in bud and on resupination (a curvature of ovary through 180°) becomes anterior. The labellum is highly modified and frequently drawn out into a basal spur.

The essential organs in orchidaceae are enclosed in the gynandrial column formed by the union of the stamens and style. This column ends in a beak like rostellum.

A solitary terminal stamen in the monandrous type (*Vanda, Dendrobium, Orchis*). Two lateral stamens in the diandrous type (*Cypripedium, Neuwiedia*). In the monandrous type the gynandrial column is with one anther and two fertile stigmas (often confluent). The rostellum represents the third stigma. In the diandrae two stamens of the outer whorl are completely supressed and the third one is modified to a staminode. Of the inner whorl of stamens, however, one is completely supressed and the other two seen on either side of the gynandrial column remain fertile. Anthers 2 celled and introrse. Pollen grains often granular usually in irregular masses called pollinia. In some the pollen grains are released in tetrads.

Ovary inferior, twisted, tricarpellary, syncarpous, unilocular, with numerous minute ovules on parietal placenta. Styles and stamens variously adnate to form the gynandrium. Stigmas 3, situated below the rostellum.

The fruit a capsule. Seeds numerous, and minute.

The peculiar structure of the orchid flowers favours cross pollination. Nectar is secreted in the spur or below the labellum. The bright coloured flowers, the sweet smell and the labellum attract the insects for pollination. Due to the resupination of the flower, the labellum occupied the anterior position and offers a landing place for the insects. In the genus *Orchis*, the flowers are arranged in dense spikes. The anther is basitonic and well above the stigmas. An insect landing on the labellum probes the spur for nectar. In this process the back of the insect comes into contact with the rostellum. It depresses the pouch in which the pollinia are placed in the viscid substance. The viscid substance adheres to the insect as it drills the tissue of the spur for honey and the caudicles of the pollinia get attached to the body of the insect. Thus when the insect leaves the flower, it carries the pollinia which are upright on their caudicles. When the insect visits another flower the pollinia are caught by the stigmatic surface.

If the flowers are not pollinated, they remain fresh for a long time.

The family orchidaceae is of great horticultural importance because of its various ornamental plants of epiphytic and terrestrial habitats. The terrestrial ornamental genera of temperate regions are *Cypripedium, Habenaria and Bletella.* The chief epiphytic genera of the tropics and subtropics are *Dendrobium, Cymbidium, Cattleya, Odontoglossum, Epidendrum, Vanda, Laetia, Corlogyne.* Some of the terrestrial plants are *Epipactus, Zeuxine, Pagonia, Goodyera* and *Spathoglottis.*

Capsules of *Vanilla planifolia,* are the source of vanilla scent used in confectionary and icecream.

Leaves of *Calantha veratrifolia* yield a glycoside "indican" from which indigo blue is extracted.

Tubers of *Eulophia epidendrae* are used as vermifuge. *Vanda roxburghii* is useful in scorpion bite and for rheumatism.

Check Your Progress 1, 2 & 3

1. What are the roots of epiphytes that absorb water from atmosphere ?
2. The scent that is used in icecreams is obtained from _____
3. List out 3 epiphytic genera.

Note: (a) Write your answers in the space given below.

(b) Compare your answers with those given at the end.

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26.4. FLORAL FORMULA

Br, %, $\overset{\uparrow}{\varphi}$, P 3+3, $\overset{\frown}{A_{1-2}, \bar{G}(3)}$

26.5. DISTINGUISHING CHARACTERS

1. Plants herbaceous, many of them epiphytic.
2. Leaves simple, alternate, leaf base sheathing.
3. Flowers zygomorphic, trimerous and epigynous.
4. One of the leaves of the inner whorl of perianth modified into a labellum.
5. Essential organs enclosed in gynandrium, the beak - like tip of which is the rostellum.
6. Stamens 1 or 2
7. Ovary inferior, tricarpellary, syncarpous. Ovules numerous on parietal placenta.
8. Fruit a capsule, seeds minute and numerous.

26.6. SUMMARY

The Orchidaceae is a large family of great horticultural importance. It has showy bisexual, epigynous flowers with a diseriate perianth. The posterior lobe of the inner whorl of perianth is modified into a labellum. A gynandrial column encloses the essential organs. The ovary is tricarpellary, syncarpous but unilocular with numerous ovules on parietal placentation.

Vanda, Vanilla and *Dendrobium* are the more frequently encountered members of this family.

26.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The roots that absorb water from the atmosphere are velamen roots.
2. *Vanilla planifolia*
3. (a) *Dendrobium sp.* (b) *Epidendrum* and (c) *Vanda.*

26.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. **Describe the floral structure and pollination mechanism in Orchidaceae.**

II. Answer the following questions in about 10 lines each.

1. **Write about the economic importance of Orchidaceae.**
2. **What are the distinguishing characters of Orchidaceae?**
3. **Write briefly about the pollination mechanism in Orchidaceae.**

UNIT-27 : ARECACEAE (PALMAE)

Divsion : Monocotyledons
Class : Calycinae
Family : Arecaceae (Palmae)

Contents

27.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the various taxonomic characters of this family,
2. list out important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

27.2. INTRODUCTION

Arecaceae consists of about 217 genera and 2500 species distributed in tropical and subtropical zones.

Palms, mostly, have a typical vegetative habit, with a crown of leaves at the end of often unbranched stem; stem exhibits various forms and they are: (a) a short rhizome or stock bearing 'radical' leaves and often branching below ground (*Nypa, Phytelephas*); (b) thin reed-like stem with long internodes, sometimes showing climbing habit (*Geonoma, Calamus, Desmoncus*); (c) erect stems attaining considerable height with crown of leaves at the top (majority of palms). Some times stem is covered with thorns or remains of old leaf-sheaths.

27.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Palm leaves are typical and are mostly very large; palmately compound (fan palms-*Borassus*) or pinnately compound (feather palms-*Cocos*). A prominent sheath present at the base of petiole makes a firmer attachment to stem. Pinnae are folded where they meet main stalk of the leaf; sometimes upwards (in duplicate, V- shaped in cross section) or downwards (reduplicate, A-shaped), these features are taxonomically important. Stout sheathing base of the petiole often persists on the stem for sometime even after the leaves fall.

Monocarpic palms such as *Corypha taliera* produce a large single terminal inforescence (panicle) after the vegetative growth ceases and then die . In polycarpic plants, however, axillary inflorescences are produced every year. Inflorescence is often subtended by a large bract (spadix). Flowers dioecious or monoecious; trimerous and actinomorphic.

Perianth 3+3, homochlamadeous and varying in texture.

Stamens 6 in two whorls (3+3), anthers 2-celled, dehiscing by vertical slits. Pollen grain elliptical to oval, monosulcate and smooth to variously ornamented.

Carpels 3, syncarpous, one-loculed (*Cocos nucifera*) or 3-loculed (*Borassus flabellifer*).

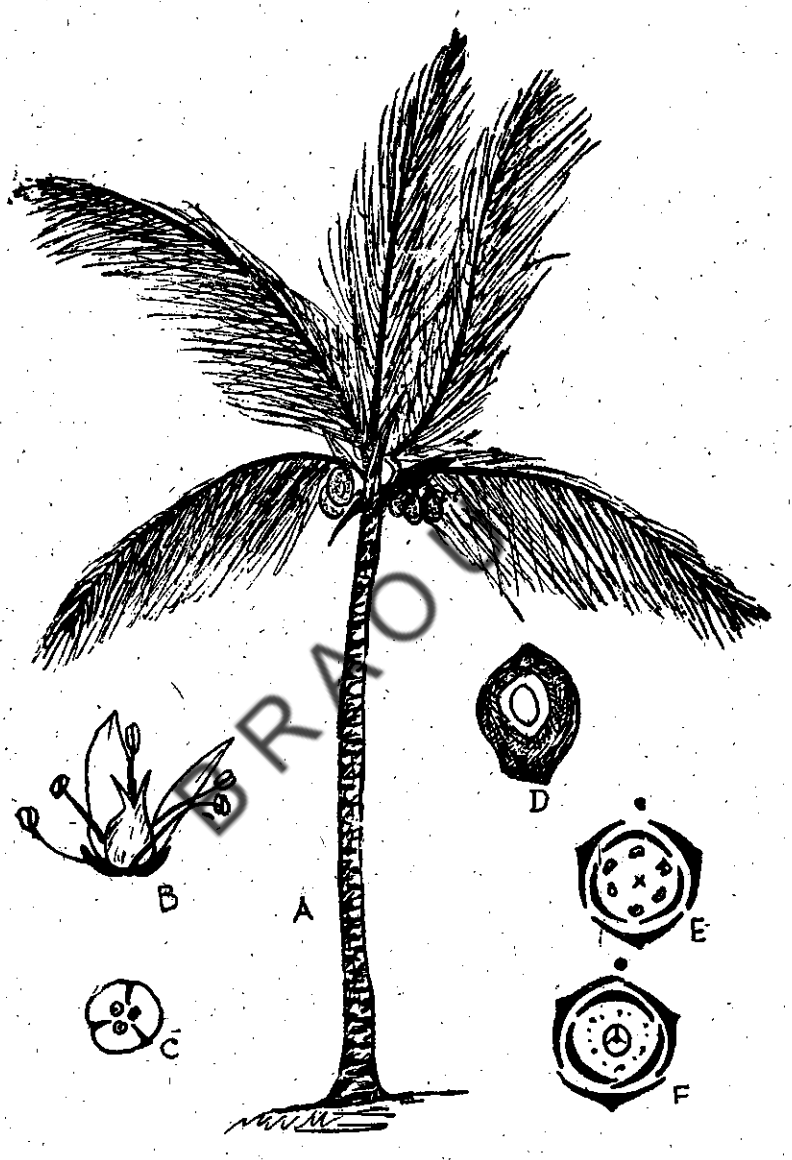

Fig. 27.1. *Cocos nucifera*. A. Plant. B. Flower. C. Fruit showing carpellary scars. D. L.S. of fruit. E. Floral diagram of male flower. F. Floral diagram of female flower.

Fruit a berry (*Phoenix*) or drupe (*Cocos*); endosperm large, in some very hard (date, vegetable ivory).

Pollination mostly anemophilous, occasionally entomophilous. In most palms flowers protandrous, thus avoiding self pollination.

Arecaceae economically is one of the important families of tropics.

Oil is obtained from endosperm of *Elaeis guinensis* (palm oil), *Cocos nucifera* (coconut oil).

Fruit of *Phoenix dactylifera* (date) and endosperm of *Cocos nucifera* are edible.

Palm starch (sago, T-saggu biyyam, H.Sabudana) is obtained from stem pith of *Metroxylon rumphii, M.leave and Caryota urens.*

Toddy (intoxicant-sap of the plant) is tapped from *Borassus flabellifer* and *Phoenix species.*

Leaves of palms (*Borassus, Cocos* etc.) are used in the preparation of mats, fans, baskets and many decorative articles. They are also used for roofing the huts.

Betel nut (H.shupari, T-vakka or pokalu) is obtained from fruits of *Areca catechu.*

Vegetable ivory, hard endosperm of *Phytelephas* species is used for preparing billiard balls and toys.

Fibre (coir) obtained from the mesocarp of *Cocos nucifera* fruits is variously used for rope making, mattresses etc.

Stems of *Borassus* and *Cocos* are used as beams in house construction.

Many palms are grown as ornamentals e.g., *Roystonea regia, Livistona chinensis, Corypha* species.

Check Your Progress 1, 2 & 3

1. Name two oil yielding plants of Arecaceae.
2. Name two toddy yielding plants.
3. The billiard balls are prepared from .....

Note: (a) Write your answers in the space given below.

(b) Compare your answers with those given at the end.

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27.4. FLORAL FORMULA

Br, ⊕, ⚥, ♂, ♀, P 3+3, A 3+3, G(3)

27.5. DISTINGUISHING CHARACTERS

1. Palms mostly have typical vegetative habit with a crown of leaves at the end of branched stem.
2. Stems often ornamented with leaf scars.

3. Leaves large, fan-like (palmate) or feather like (pinnate).

4. Flowers in large panicle (spadix), regular, unisexual or bisexual, trimerous and hypogynous.

5. Fruit a berry or drupe.

27.6. SUMMARY

The Arecaceae, an economically important tropical family, includes various kinds of palms. The characteristic habit of palms consists of a columnar trunk with a crown of large fan-like (palmate) or feather-like (pinnate) leaves. The flowers seen in large inflorescences are generally unisexual, regular and trimerous.

Cocos, *Phoenix* and *Borassus* are the most commonly encountered members of this family.

27.7. CHECK YOUR PROGRESS : MODEL ANSWERS

1. The oil yielding plants are *Elaeis guinensis* and *Cocos nucifera*.

2. The toddy yielding plants are *Borassus flabellifer* and *Phoenix* sp.

3. Hard endosperm of *Phytelephas* sp.

27.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Write about the general characters and economic importance of Arecaceae family.

II. Answer the following questions in about 10 lines each.

1. Write about the economic importance of Arecaceae.

2. What are the distinguishing characters of Arecaceae?

UNIT-28 : POACEAE (GRAMINEAE)

Divsion : Monocotyledons
Class : Glumaceae
Family : Poaceae (Gramineae)

Contents

28.1. OBJECTIVES

By the end of this unit you will be able to :

1. describe the various taxonomic characters of this family,
2. list out the important genera,
3. describe the economic importance of this family and
4. list out the distinguishing characters.

28.2. INTRODUCTION

The Poaceae constitutes one of the biggest families of angiosperms with about 620 genera and 10,000 species. They occur all over the world (cosmopolitan). Annuals (*Eragrostis poides*), biennials (*Bromus mollis*) or perennials (Bamboos). The plants are seen often in tufts or spreadout forming a mat. Mostly branched. The branches arise from base of the enveloping leaf-sheath or from within the enveloping leaf-sheath. Silica bodies often present in epidermal cells.

28.3. TAXONOMIC CHARACTERS AND ECONOMIC IMPORTANCE

Stems of grass are called culms. Culms vary much in size and rigidity; mostly cylindrical, rarely compressed (*Poa compressa*); often hollow, sometimes solid (*Zea*).

Leaves alternate and are of two parts: (a) leaf sheath which clasps the culm, and (b) leaf blade. Sometimes small claw-like teeth (auricles) are present on margin where sheath joins blade.

Ligule usually thin or rigidly membranous structure present at juncture where the blade meets sheath. Ligule sometimes absent or variously divided or modified into a small ridge.

Blade of grasses often described as 'leaf', usually long and narrow with parallel sides and tapering to pointed end (lanceolate). Stomata of typically 'graminaceous' type, with dumb-bell shaped guard cells.

The structure which encloses grass flowers is called spikelet. Spikelets vary in size, shape and degree of denseness or looseness. Spikelets are arranged in panicles (when borne on stalks-*rachilla*, on branches), racemes (stalked directly on main axis) or spikes (when seated on main axis itself).

Spikelets are made up of one to many *florets* subtended by two sterile structures called glumes (glume one =lower glume; glume two = upper glume). Florets are made up of outer two structures, *lemma* and *palea* enclosing often a bisexual flower. Sometimes florets are either sterile or unisexual (*Zea mays*). Glumes, *lemma* and *palea* vary in their shape, size, texture and nervation and are of taxonomic importance.

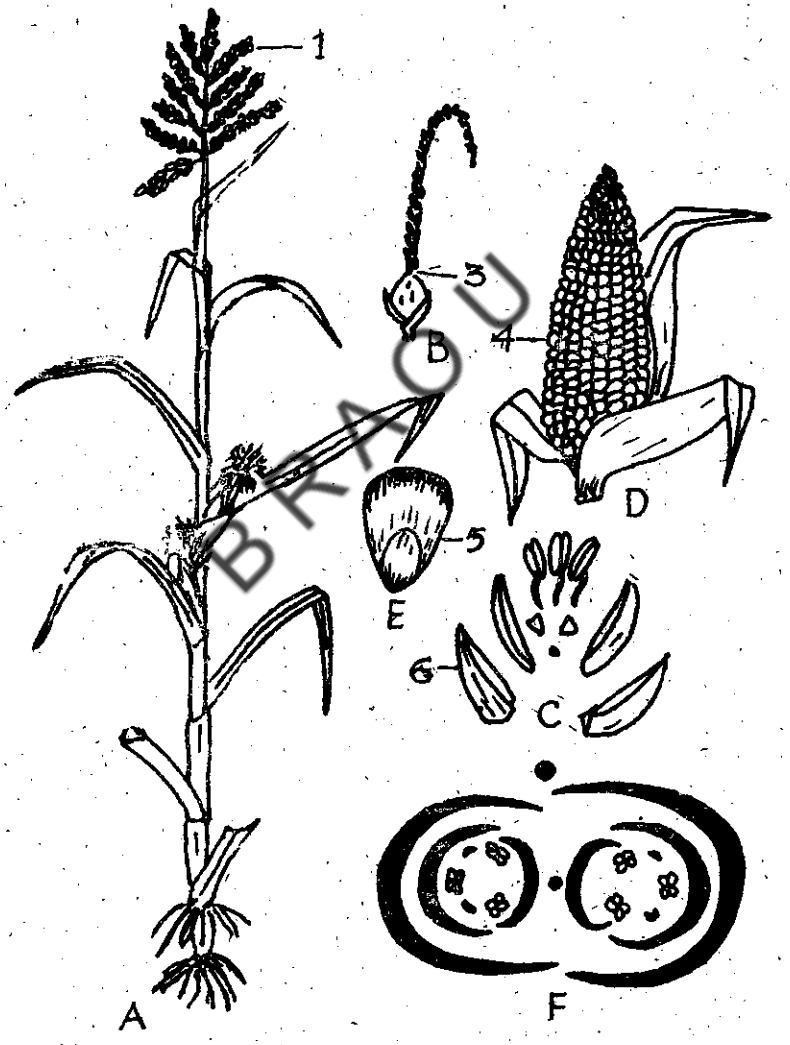
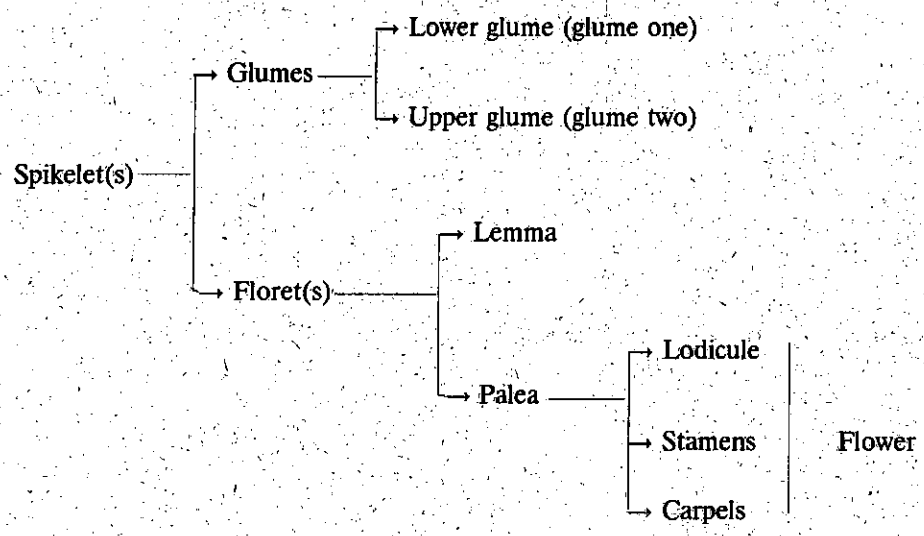


Fig. 28.1. *Zea mays*. A. Plant. B. Gynoecium. C. Parts of male spikelet. D. Cob. E. Grain. F. Floral diagram.

Flower consists of (a) two minute scales - **lodicules** (regarded as reduced perianth); (b) 3 or 6 stamens with 2-celled anthers, basifixed but deeply sagittate and at anthesis appearing as if versatile. Pollen grains spheroidal, monoporate; (c) carpels 3, superior, syncarpous, ovary with two (sometimes 3) feathery stigmas on slender style. Ovule one, anatropous, adnate to the adaxial side of ovary. Pollination anemophilous. Fruit mostly caryopsis, rarely utricle.



Schematic representation of Spikelet

Economically Poaceae is the most important family, as it provides staple food not only to man but also to animals. Thus it is said "all flesh is grass" because directly or indirectly almost all members of animal kingdom depend upon grass.

Plants which provide staple food to man and animals are: *Oryza sativa* (paddy-rice, T. Vari, H. Dhan); *Triticum aestivum, T. dicoccum T. durum, T. sphaerococcum* (wheat, T. Godumalu, H. Gehu); *Avena sativa* and species (Oats, H. Jai); *Sorghum sativa* and species (H. Jowar, T. Jonnalu); *Pennisetum typhoidium* (Pearl millet, H. Bajra, T. Sajjalu); *Zea mays* (Maize or corn, H. Makai, T. Mokkajonna); *Setaria italica* (Italian millet H. Kangini, T. Korralu); *Eleusine coracana* (Finger millet. T. Ragulu). Sugar is obtained from *Saccharum officinarum*

Fodder yielding grasses are; *Pennisetum purpureum* (elephant grass); *Sorghum sudanense* (Sudan grass); *Setaria species; Eleusine indica, Dicanthium* species; *Echinochloa* species.

Lawn grasses: *Agrostis tenuis; Cynadon dactylon; Holcus mollis* etc.

Aromatic oil (Rusa oil) is obtained from *Cymbopogan* species particularly - *Cymbopogon martini.*

Bamboos, *Bambusa* species are used for making baskets, mats, roofing material and paper.

Apart from the few economic aspects mentioned above Poaceae provides basic raw materials for the following industries: (a) beverages: sake (rice), whiskey (ray, barley, corn), rum (sugarcane molasses); (b) Corn products: corn oil, popcorn, corn starch; (c) Ethyl alcohol (sugarcane, cereals and millets etc.).

About 80 genera are known to be cultivated as ornamentals e.g., *Panicum variegatum, Melica altissima, Elymus arenarius, Poa glauca, Saccharum species.*

Check Your Progress 1,2 & 3

1. What is the shape of the guard cells in the members of poaceae ?
2. Write the botanical names of rice, Wheat, jowar and maize.
3. Rusa oil is obtained from _____

Note: (a) Write your answers in the space given below.

(b) Compare your answers with those given at the end.

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28.4. FLORAL FORMULA

Glume 2 or 1 or O, Lemma 1, Palea 1, Lodicules 2 or 3, A 3 or 6, G(3)

28.5. DISTINGUISHING CHARACTERS

1. Mostly herbaceous members with hollow culms.
2. Leaves alternate, lanceolate with sheathing bases.
3. Guard cells of stomata dumb-bell shaped.
4. Monoporate, spheroidal pollen grains.
5. Flowers in spikelets made up of glumes, lemma and palea.
6. Stamens mostly 3 or 6.
7. Ovary superior with feathery stigmas.
8. Fruit caryopsis.

28.6. SUMMARY

The Poaceae, one of the largest families of angiosperms is mostly herbaceous and cosmopolitan. The flowers borne in spikelets are mostly bisexual, trimerous, regular and hypogynous. Economically this is a very important family as it provides staple food to man.

Oryza, Triticum, Sorghum and *Zea mays* are the most important crop plants of this family.

28.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. Dumb-bell shaped guard cells are found in Poaceae.
2. The botanical names of rice, wheat, jowar and maize are *Oryza sativa, Triticum* sp. *Sorghum sativa* and *Zea mays* respectively.
3. *Cymbopogan* sp.,

28.8. MODEL EXAMINATION QUESTIONS

I. Answer the following question in about 30 lines.

1. Describe the floral structure and economic importance of the family poaceae.

II. Answer the following questions in about 10 lines each.

1. Give an account of the economic importance of the family Poaceae.

2. What are the distinguishing characters of Poaceae.

28.9. GLOSSARY

Actinomorphic	: Regular, symmetrical.
Adnate	: United with another (different) part.
Anatropous	: Reversed seed or ovule whose opening (micropyle) is close to the point of attachment
Apocarpous	: With carpels free
Berry	: Pulpy, indehiscent fruit.
Bicollateral	: With phloem on both sides (outer and inner) of xylem.
Bifid	: Cleft into two.
Calyculus	: It is a slightly toothed, irregular rim like structure present first below the perianth. It is sometimes considered as a calyx.
Calyx-tube	: The tube of gamosepalous calyx sometimes used for hypanthium.
Carpophore	: A wiry stalk of carpellary origin that supports each half (carpel) of the dehiscing fruit.
Cartilaginous	: Tough and hard but not bony.
Capitate	: Headed; head like.
Capsule	: A dry, dehiscent fruit developing from a compound ovary.
Corona	: Any appendage or extention that stands between the petals and stamens.
Cremocarp	: A dry, dehiscent, 2 seeded fruit, each half a mericarp borne on a hair-like carpophore.
Cyathium	: A special type of inflorescence. It consists of many male flowers represented by single stamen arising from scaly bract like structures. A single female flower is present on a raised stalk represented by tricarpellary ovary.
Cypsela	: Small, indehiscent fruit with presistent calyx and developing from inferior ovary.
Diadelphous	: Stamens in two sets or bundles by union of filaments.
Didynamous	: Stamens are of two different lengths, two long and two short stamens attached to the corolla tube.
Dithecous	: Two-chambered.
Entomophilous	: Insect-pollinated.

Epicalyx	: A whorl of green sepal-like structures representing the bracteoles and it is present just below the calyx.
Epigynous	: Above the ovary.
Epipetalous	: Borne on or arising from the petals or corolla.
Epiphytic plants	: Plants growing on other plants. They attach themselves to the supporting plant by clinging roots.
Fistular	: Hollow.
Floret	: Small flower of the members of compositae or grasses.
Follicle	: Dry, dehiscent fruit developing from a monocarpellary pistil and opening on the dorsal suture.
Gynandrium	: Androecium and gynoecium together form a column called the gynandrium.
Gynophore	: Stipe of an ovary.
Gynostegium	: Compound structure formed by the union of anthers and stigma.
Hermaphrodite	: Bisexual.
Hesperidium	: A fleshy fruit developed from superior polycarpellary syncarpous pistil. The pericarp has an outer leathery rind, a middle white spongy mesocarp and a thin endocarp. There are numerous juicy hairs inside the endocarp which is edible.
Heterogamous	: With more than one kind or form of flower.
Heterostyly	: Having different lengths of styles.
Homogamous	: With one kind or form of flower.
Hypanthium	: Cup-like receptacle derived usually from the floral envelopes and androecium.
Hypogynous	: Below the ovary.
Imbricate	: Overlapping; inner member posterior in ascending and outer one posterior in descending types.
Interpetiolar	: Stipules lying between the two leaves.
Introrse	: Facing in ward or towards the axis.
Latex	: Milky sap.
Legume	: Simple dry fruit developing from a monocarpellary pistil and dehiscing on both sutures.
Lomentum	: Leguminous fruit constricted between the seeds and breaking into one seeded segements at maturity.
Monadelphous stamens	: When all the stamens of the androecium are united into one bundle by their filaments and the anthers remaining free, it is known as monadelphous condition.

Obdiplostemonous stamens	: Stamens are arranged in two whorls, with outer whorl of stamens being antipetalous and inner whorl antisepalous.
Opposite decussate	: Two leaves (at each node) alternating at right angles and forming 4 rows.
Panicle	: Branched raceme.
Parkinsonism	: A chronic progressive disease of the nervous system.
Perigynous	: Around the ovary.
Plaited	: Plicate; folded
Polyadelphous stamens	: When the filaments of the stamens are united and the anthers remaining free it is called adelphous condition. In this way if many bundles of stamens are formed it is called polyadelphous condition.
Protandry	: Pollen being released before the stigma (of the same flower) is receptive.
Pulvinous	: Cushion-shaped, swollen.
Quincuncial	: With overlapping of 2 completely outer, 2 completely inner and 1 partially in and out floral parts.
Regma	: A schizocarpic fruit, which breaks into 3 one seeded parts.
Spasms	: Involuntary and sudden muscular contraction.
Stylopodium	: A dish-like enlargement at the base of the style.
Syncarpous	: With carpels united in full or in part
Syngenesious	: With connate anthers but free filaments.
Thyrsus	: A mixed type of inflorescence. In this racemose branches are formed on the inflorescence axis on which at each node, two cymose inflorescences are placed opposite to each other. These cymes may be branched also.
Translator	: Plant part (in androecium) for removing pollen.
Twisted	: With regular overlapping.
Valvate	: Without overlapping.
Verticillaster	: This is a condensed inflorescence in which the apparent whorls are found to be consisting of two cymose inflorescences, each forming a dichasium of three flowers.
Weed	: Undesirable (usually herbaceous) plant of a locality.
Zygymorphic	: Divisible into equal halves in one plane only.

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BLOCK - IV

EMBRYOLOGY

UNIT-29: DEVELOPMENT OF MALE AND FEMALE GAMETOPHYTES

Contents

29.1. OBJECTIVES

By end of this unit you will be able to:

1. describe the development of the male gametophyte,
2. describe the behaviour of the vegetative nucleus,
3. describe the X-bodies and pollen embryo sacs and
4. describe the development of different types of monosporic, bisporic and tetrasporic types of embryo sacs.

29.2. INTRODUCTION

The process of microsporogenesis in the sporogenous tissue of the anther results in the formation of microspores (pollen grains). Microspore is the starting point of the development of male gametophyte. It starts germinating within the microsporangium and is released at 2-nucleate or 3-nucleate condition. The male gametophyte is formed after the division of microspore nucleus.

29.3. DEVELOPMENT OF MALE GAMETOPHYTE

The first division of the microspore results in the formation of two unequal cells, the large vegetative cell and the smaller generative cell. These cells do not posssess distinct cell walls and are bounded only by cell membranes (Fig. 29.1)

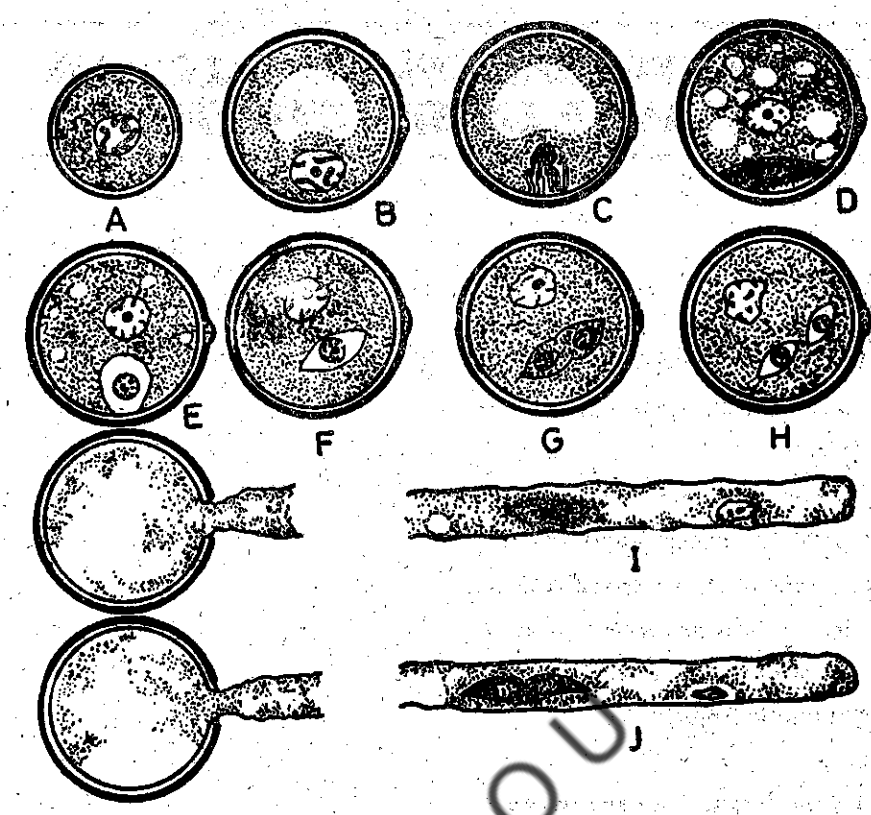

Fig. 29.1. Diagramm to illustrate important stages in the development of male gametophyte. A. Newly formed microspore. B. Older stage showing vacuolation. C. Microspore with dividing nucleus. D. Completion of division. E. Generative cell losing contact with wall. F. Generative cell lying free in cytoplasm of vegetative cell. G,H. Division of generative cell in pollen grain. I,J. Division of generative cell in pollen tube.

The two cells of the male gametophyte exhibit significant histological variations. The generative cell has meagre amount of cytoplasm with scanty RNA and proteins. Its nucleus is conspicuous with high DNA content. The vegetative cell, on the other hand,has denser cytoplasm with high RNA and protein contents. Its nucleus is less conspicuous and with meagre DNA but the nucleolus is large and conspicuous. The generative cell attached to the pollen wall gets departed, becomes spherical, elliptical or lenticular and lies freely within the cytoplasm of the vegetative cell. The pollen grain is usually shed in the 2- celled condition. In a number of families, however, pollen grains are released in a 3-nucleate condition. In these cases the generative cell also divides to form two male gametes before the dehiscence of anther lobe and the shedding of the pollen grain.

The pollen tube develops when the pollen grains reach stigmatic surface in pollination. The intine protrudes through one of the apertures or germ pores. The nucleus of the vegetative cell along with some of its cytoplasm generally moves first into the pollen tube. In all those cases where the pollen is shed in 2- nucleate stage, the generative nucleus divides resulting in two male nuclei. This division may take place in the pollen grain or in the pollen tube. The two male nuclei become surrounded by their own cytoplasmic sheaths and thus appear distinctly as male gametes(sperms)

29.3.1. Behaviour of the Vegetative Nucleus

Normally, the vegetative nucleus remains in the pollen grain and degenerates ultimately. In some cases the vegetative nucleus finds its way into the pollen tube. Occasionally, it is found lying close to the sperms. But it has no role to play. It disintegrates at one stage or the other. Degeneration is due to loss of proteins resulting in shrinkage of nuclear membrane.

Subsequently the chromatin disintegrates, DNA content is reduced and the nucleolus is also lost.

29.3.2. X-Bodies

The pollen tube discharge has been reported to contain certain unknown structures. These are called X-bodies. X-bodies are reported to be spherical or rod shaped. These are refractive bodies which show intense staining. The nature of X-bodies is controversial. They are variously considered as remnants of synergid nucleus, supernumerary sperm cells, vegetative nucleus and so on. X-bodies have been shown to be DNA positive. Therefore, they might be from the nuclei of some cells in or around the pollen tube discharge.

29.3.3. Pollen Embryo Sacs

In the petaloid anthers of *Hyacinthus orientalis*, Nemec (1898) observed pollen embryo sacs for the first time. Usually the mature pollen grains are 2-or 3-celled. Rarely, the male gametophyte shows more than three nuclei. This leads to the formation of a structure resembling the female gametophyte. Similar observations were later made by Geitler (1941) in *Ornithogalum nutans.*

Nemec's observations showed that some of the pollen grains enlarge and develop into sac like structures. The nucleus in the enlarged pollen grain divides three times mitotically resulting in 8-nucleate embryo sac like structure. The pollen embryo sac is associated with large number of dead pollen grains. The dead grains are supposed to secrete "necrohormones" due to which an increase in the size of pollen embryo sac results.

Check Your Progress 1 & 2

1. What are X-bodies?
2. Describe the pollen embryosacs.

Note: (a) Write your answers in the space given below.
(b) Compare your answers with those given at the end.

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29.4. DEVELOPMENT OF FEMALE GAMETOPHYTE

The female gametophyte develops in the megasporangium. The megasporogenesis takes place by the meiotic division of the megaspore mother cell. The first meiotic division results in two haploid dyad cells. The dyad cells undergo another division forming linear tetrad of megaspores. The three micropylar megaspores are smaller and degenerate in due course. The larger chalazal megaspore enlarges. This is the functional megaspore which develops into the female gametophyte. Megasporogenesis thus involves the formation of four megaspores from megaspore mother cell (Fig 29.2). Magagametogenesis or development of female gametophyte is from one or more megaspores.

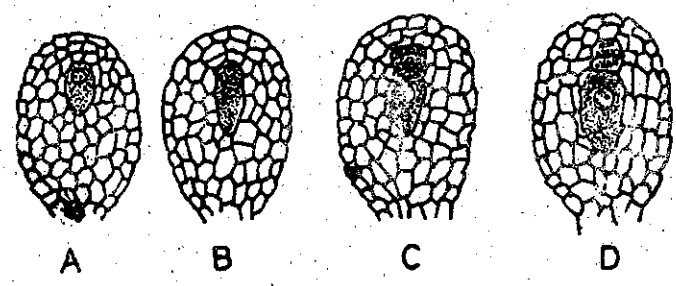

Fig. 29.2. Different stages in megasporogenesis. A. With megaspore mother cell. B. Unequal division of megaspore mother cell. C. The Second equal division in the upper cell and unequal division in the inner cell. D. Linear tetrad of four megaspores; the lower largest is the functional megaspore.

The female gametophyte (embryo sac) development in angiosperms is of three types: monosporic, bisporic and **tetrasporic**. In the **monosporic** type only one of the four megaspores (formed by the meiosis of megaspore mother cell) takes part in the female gametophyte development this is the most common type among the angiosperms. In the **Bisporic** type the female gametophyte is formed from two megaspores. All the four megaspores take part in the tetrasporic type of female gametophyte ontogeny.

29.4.1. Development of Monosporic Embryo Sac

Maheswari (1950) recognised two types of monosporic ontogeny: 8- nucleate and 4-nucleate.

In the 8-nucleate type, two nuclei are formed by the first division of the functional megaspore. These are designated as primary micropylar and primary chalazal nuclei. These two nuclei divide once again and form a pair at each end. Subsequent (third) division forms the 8-nucleate stage with four nuclei each at the micropylar and chalazal end. By this time the embryo sac elongates considerably. A large vacuole is seen between the two poles. This is formed by the activity of endoplasmic reticulum.

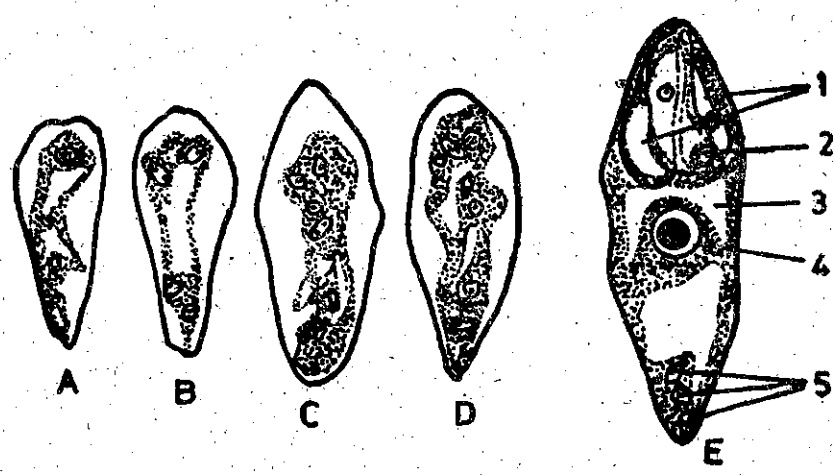

Fig. 29.3. Different stages in the megagametogenesis in *Morina longifolia* A. Megaspore after post meiotic mitosis. B. Four nucleate stage. C. Eight nucleate stage. D. Older eight nucleate stage showing 3+2+3 distribution. E. Mature embryo sac. 1. Synergids. 2. Egg. 3. Central Cell. 4. Secondary nucleus. 5. Antipodals (After Vijayaraghavan and Sarveshwar, 1968).

The nuclei at each pole now start organising (Fig 29.3). Three out of four micropylar nuclei begin to appear as cells due to the formation of partial membranes around them. These cells are pyriform or saccate in shape. In two of these cells the nuclei are situated towards the micropylar side, while the chalazal end shows a vacuole. The micropylar (apical) portion of these cells develops the filiform apparatus-a longitudinally oriented fibrous structure. These two cells are designated as synergids. The third cell in this group is called the egg. In the egg cell the nucleus is towards the chalazal end. The vacuole is micropylar in position. The two synergids and the egg are collectively called the **egg apparatus**.

The developmental organisation at the antipodal end shows variation. Of the four nuclei three remain either nuclear or become membranous cells. They are then called antipodal nuclei or antipodal cells. The antipodal nuclei often become polyploid due to endoduplication.

The two polar nuclei (Fourth nucleus at each end) meet more or less at the central region of the embryo sac and fuse to form the secondary nucleus. In this process, the antipodal polar nucleus travels towards the micropylar side and joins the other polar nucleus. The fusion product, the secondary nucleus, is usually located below the egg apparatus. A membrane shows all the cell organelles.

The embryo sac development described above is the most common type in the angiosperms (80 percent of them show this) and hence is also known as the "Normal type". It was first described by **Strasburger** (1879) in *Polygonum divaricatum*. Hence it is also designated as "*Polygonum type*".

In the **4- nucleate monosporic type** of development the megaspore nucleus divides only twice to form four nuclei at the micropylar end. The four nuclei organise into egg apparatus and a single polar nucleus. The antipodals and the chalazal polar nucleus are not formed (Fig 29.4). This type is known as *Oenothera type*. So far, it is reported only in the family Onagraceae.

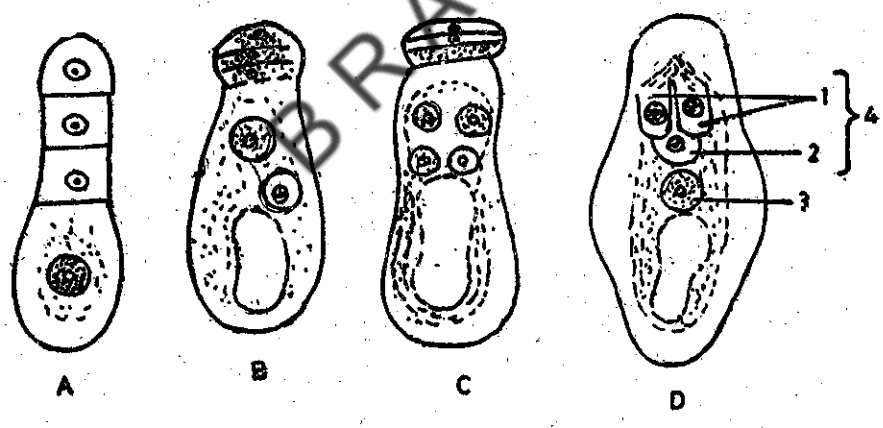

Fig.29.4. Diagrammatic representation of the 4-nucleate (Monosporic) *Oenothera* type of embryo sac development. A. Megaspoe tetrad. B. 2- nucleate embryo sac. C. 4-nucleu embryo sac. D. Mature embryosac. 1. Synergids. 2. Egg. 3. Polar nucleus. 4. Egg apparatus.

The biochemical nature of the different cells of female gametophyte is specific. This is perhaps the basis for their characteristic developmental behaviour. The synergids show meagre quantities of nucleic acids. The DNA and proteins are abundant in egg. The polar nuclei show DNA positive reaction. RNA is abundant in the cytoplasm around the polar nuclei. Abundant DNA, histones and proteins,but low RNA are found in the antipodals.

29.4.2. Development of Bisporic Embryo Sac

The bisporic embryo sacs resemble the monosporic type at maturity in being 8-nucleate. Strasburger (1879) described the bisporic ontogeny in *Allium fistulosum* for the first time. Hence, this is also known as "*Allium type*".

At the end of meiosis -I in the megaspore mother cell, the dyad nuclei are separated by walls. Normally, chalazal cell of the dyad is functional. The chalazal dyad cell shows the meiosis-II,while the micropylar one degenerates. After meiosis-II wall formation does not take place between the daughter nuclei of the functional dyad cell. The two nuclei move to the opposite poles. These function as primary micropylar and primary antipodal megaspore nuclei. The 8-nucleate stage is achieved when each of these nuclei undergoes two successive free nuclear mitotic divisions. The eight nuclei thus formed organise into the egg apparatus, antipodals and the secondary nucleus in the same manner as the "Normal" *(Polygonum)* type of embryo sac (Fig 29.5).

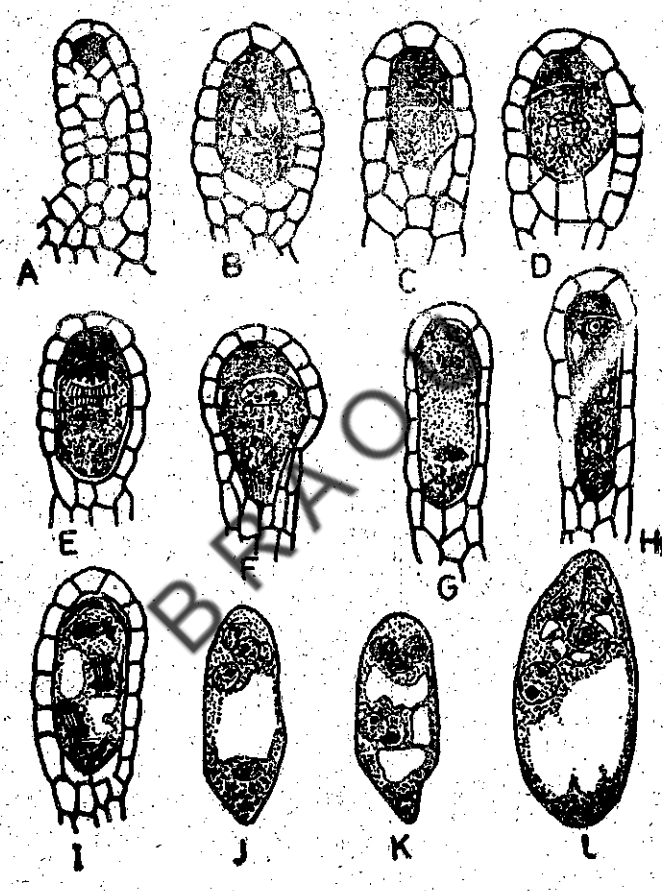

Fig. 29.5. Different stages in bisporic, *Alluim* type of embryosac ontogeny in *Xyris* (After Govindappa, 1955)

Two types of bisporic embryos sacs are recognised: 1) When the embryo sac development takes place from the chalazal dyad cell it is called *Allium type*. This is the more common type in this category. 2) When the embryo sac is derived from the micropylar cell, it is called *Endymion type*.

29.4.3. Development of Tetrasporic Embryo Sac

There is a lot of variation in this category. The megaspore mother cell after meiosis does not show wall formation. As a result all the four haploid nuclei remain in the cytoplasm of the megaspore mother cell. This structure is called coenomegaspore. All the four nuclei take part in the further development and organisation of the embryo sac. In most of the tetrasporic ontogenies, each of the four nuclei undergo two mitotic divisions and form a 16-nucleate stage. On the basis of polarity and organisation of these 16 nuclei three types "*Peperomia type*", "*Penaea type*" and "*Drusa type*" -of embryo sacs are recognised.

Before the post meiotic mitosis in the coenomegaspore, the four nuclei take different positions. Accordingly, the three types mentioned above result:

(i) The four nuclei show the 1+1+1+1 positions. In this arrangement the two nuclei are placed on either side and one each is found at the micropylar and chalazal ends respectively. These are known to form the *Peperomia, Penaea* and *Plumbago types.*

(ii) In the second category, nuclei arrange in 1+3 manner. One nucleus is at the micropylar end while the chalazal end has three. This arrangement leads to *Drusa, Fritillaria* and *Plumbagella types* of developmental oraganization.

(iii) The four nuclei show 2+2 arrangement ;two each at the micropylar and chalazal ends (e.g.*Adoxa type*)

The following criteria are considered in the classification of tetrasporic ontogenies.

A. With Nuclear Fusion

1) **Adoxa type:** Mature embryo sac resembles the Polygonum type. Only one mitotic division occurs in each of the four nuclei in the coenomegaspore. The division occurs in each of the four nuclei in the coenomegaspore and results in the 8-nucleate condition.

2). **Plumbago type:** One post -meiotic division results in the 8- nucleate condition. There is one egg cell at the micropylar end. The three nuclei are placed peripherally. Four nuclei are at the centre.

3) **Penaea type:** Four nuclei in the coenomegaspore divide twice and form 16 nuclei. The organised embryo sac shows three nuclei each in four groups. The micropylar and chalazal ends show a group each, while the other two groups are placed laterally. Four nuclei arranged at the centre are polars. The micropylar group organises into egg apparatus.

4) **Peperomia type :** 16 nuclei are formed as in the previous type. Egg apparatus comprises of an egg and a single synergid. 8 nuclei are located in the centre (Polar nuclei) and 6 nuclei are peripheral on the chalazal end.

5) **Drusa type:** This is also a 16-nucleate type. At maturity the female gametophyte shows a 3-celled egg apparatus, two polar nuclei and 11 antipodals.

B. Without Nuclear Fusion

At the end of meiosis -II a triploid nucleus is formed at the chalazal end of the coenomegaspore due to the fusion of three of the four megaspore nuclei. The haploid nucleus is at the micropylar end.

6) **Fritillaria type:** The two nuclei (one hploid and one triploid)of the coenomegaspore form four nuclei at each pole as a result of two mitotic divisions. The organised female gemetophyte shows the usual egg apparatus of three haploid cells. The chalazal end has three triploid antipodals. The polar nuclei are two (one haploid and one triploid).

7) **Plumbagella type:** The nuclear fusion takes place as described above resulting in one haploid micropylar and one triploid chalazal nuclei. 4-nucleate stage is achieved by a single division in each of the two nuclei: Two nuclei are micropylar and two are chalazal in position. Of the two micropylar nuclei one forms the egg and the other is the polar nucleus. The two chalazal triploid nuclei organise into an antipodal and a lower polar nucleus (Fig 29.6).

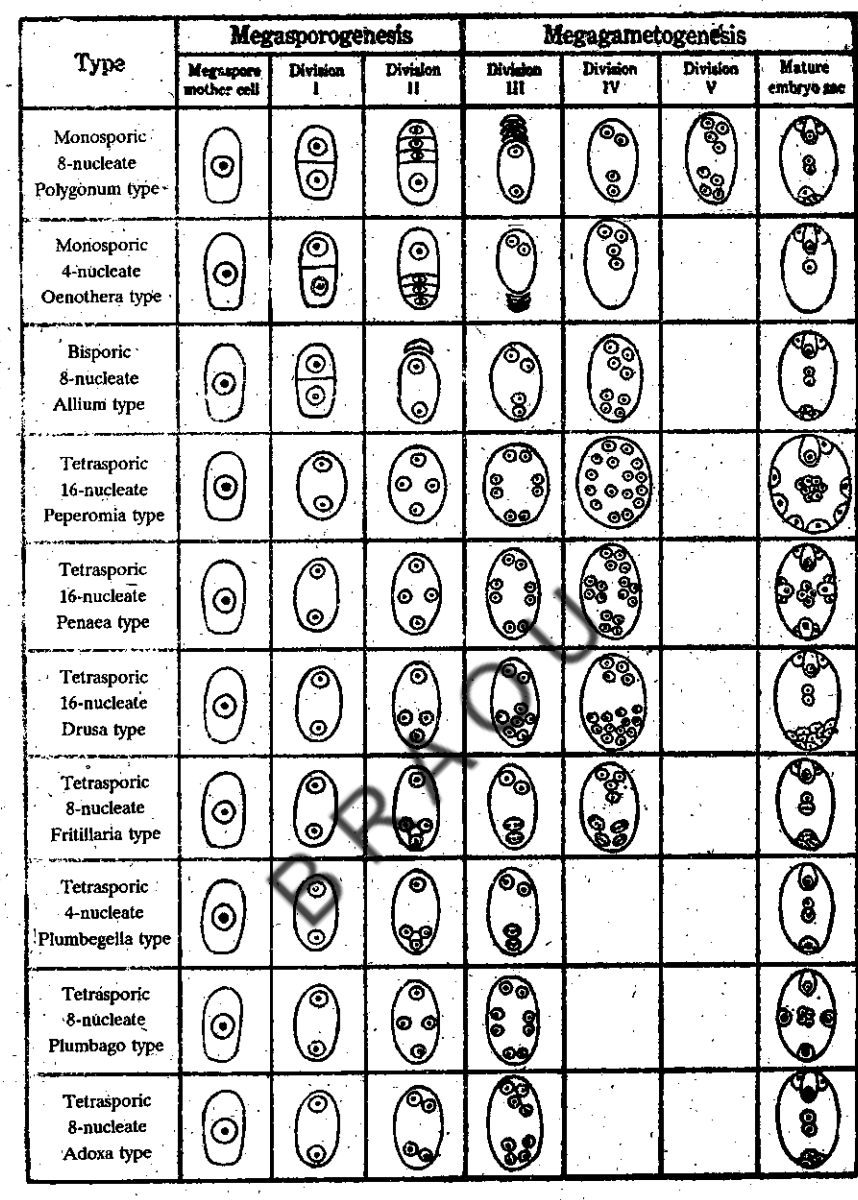

Fig. 29.6. Diagrams showing important types of embryo sacs in Angiosperms.

Check Your Progress - 3

What are the three broad types of the development of the female gametophyte?

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end.

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29.5. NUTRITION OF THE EMBRYO SAC

The ovular morphology suggests that nutrients enter the embryo sac through the chalazal end. Nutrients have to pass through the nucellus as it surrouds the embryo sac. The funicular strands end at the base of the integuments. From there the nutrients pass through the nucellar cells to the chalazal end of the embryo sac. **Hypostase** (a group of specilised cells) is usually present between the vascular supply and the chalazal end of the embryo sac. Hypostase is involved in the transfer of food materials to the embryo sac. Its cells may be designated as **transfer cells.** The entire embryo sac surface seems to absorb the nutrients from the surrounding nucellar cells. In several taxa the embryo sac totally absorbs the surrounding nucellar tissue, and thus comes into direct contact with the integuments. In such cases the inner layer of the inner integument becomes glandular. This layer is designated as *endothelium* or *integumentary tapetum.* This is supposed to draw nutrients from the other tissues and pass onto the embryo sac. In some species , embryo sac is reported to grow out of the ovular tissues. It then becomes haustorial and draws nutrients from the ovular and carpellary tissues.

29.6. SUMMARY

The microscope is the starting point for the development of male gametophyte. A large vegetative cell and small generative cell constitute the male gametophyte. The generative cell divides and forms two male gametes. The megasporogenesis results in a linear tetrad of megaspores. The development of female gametophyte in Angiosperms is of three types, viz., monosporic, bisporic and tetrasporic. Of these, the monosporic type is the most common.

29.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. The pollen tube discharge is reported to contain some sphericle or rod shaped refractive bodies which shows intense staining. These are called X-bodies.
2. The anthers of *Hyacinthus orientalis* and *ornithogalum nutans* showed enlarged pollen grains with 8 nuclei, instead of showing 2 to 3 cells. These are called pollen embryo sacs.
3. The 3 broad types of the development of female gametophyte are (a) Monosporic (b) Bisporic and (c) Tetrasporic.

29.8. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the development of male gametophyte in angiosperms.
2. Draw illustrative figures to explain the development of female gametophyte in angiosperms.
3. Describe the different developmental types of female gametophyte in angiosperms
4. Discuss the organisation of mature embryo sac. Add a note on its nutrition.

II. Answer the following questions in about 10 lines each.

1. What are pollen embryo sacs?
2. Describe briefly about the oenothera type of embryo sac development.
3. Describe briefly about the polygonum type of embryo sac development.
4. Describe briefly about the structure and development of pollen tube.

UNIT-30 : FERTILISATION AND DEVELOPMENT OF EMBRYO AND ENDOSPERM

Contents

30.1. OBJECTIVES

By the end of this unit you will be able to:

1. describe the structure and development of pollen tube,
2. define syngamy and triple fusion,
3. describe the anomalous fertilisation,
4. describe the different stages in the development of the embryo of dicots and monocots,
5. describe the cellular,nuclear and helobial emdosperm, and
6. describe the endosperm haustoria.

30.2. INTRODUCTION

After fertilisation, the zygote divides and develops into the embryo. The development of embryo in dicots is different from the development of embryo in monocots. Five main types of embryo development was recognised by Maheswari (1950) in dicots and they are crucifer type, Asterad type, Solanad type, Caryophyllad type, and Chenopodiad type.

The fusion product of the sperm and the secondary nucleus is called the primary endosperm nucleus. It divides and gives rise to the endosperm. The major types of endosperm development are cellular type, Nuclear type and Helobial type.

30.3. FERTILIZATION

Fusion of male and female gametes is called fertilization. It is found in all the sexually reproducing plants. In gymnosperms only one sperm in the pollen tube is utilized in syngamy while the other degenerates (*single fertilization*). In angiosperms the process is called (*double fertilization*). Here, both the sperms are utilized in fusion -- one with the egg cell and the other with the two polar nuclei. Since the fusion here involves two polar nuclei and one sperm it is called " *triple fusion*". The product of triple fusion is the primary endosperm nucleus.

The pollen grain germinates on the stigmatic surface and the pollen tube passes through the style and ultimately enters the ovule. The length of the pollen tube depends on the distance between the stigma and ovules (Fig. 30.1) **Nawaschia** and **Guignard** discovered the process of double fertilization independently in 1898.

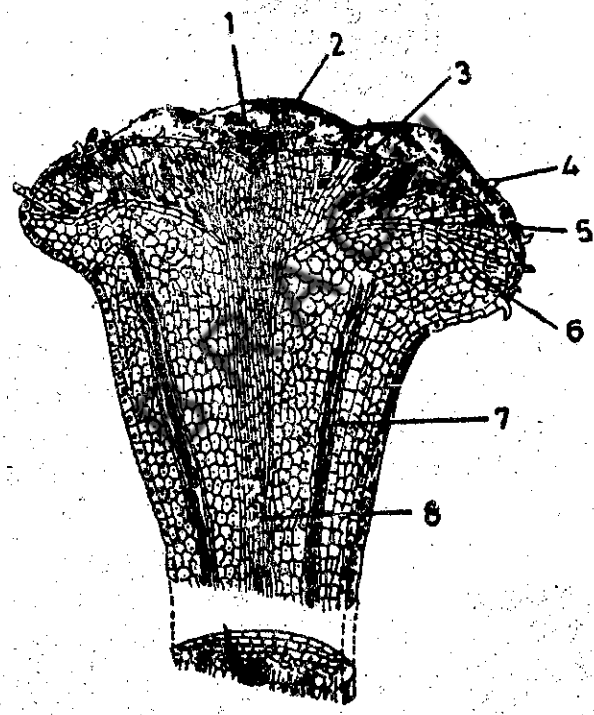

Fig. 30.1. Stigma of *Petunia hybrida* just before pollination. 1. Central cavity. 2. Stigmatic exudate. 3. Epidermis. 4. Papillae. 5. Secretory zone 6. Storage zone. 7. Vascular trace. 8. Stigmatoid tissue (After R.N. Konar).

30.3.1. Structure and Development of Pollen Tube

Germination of pollen grain after pollination requires some time. In herbaceous taxa,pollen grain germination starts earlier than in the woody trees. Inherent pollen viability, stigmatic compatibility and external factors such as light and temperature also have a significant influence on pollen germination. Stigmatic secretions help in catching the pollen grains and also their germination.

The pollen tube emerges through the germ pore. Normally, only one tube grows out in a pollen grain. In Malvaceae and Cucurbitaceae many pollen tubes emerge from the various germ pores, but only one of them carries the sperms to the ovule. The pollen tube tip (4-7 μ

carries the entire contents of the pollen grain. This is the real growing region. A callose plug separates this region from the other region. The pollen tube wall is cellulosic. The cytoplasm of the pollen tube tip has several enzymes like amylases, invertases, phosphatases, pectinases and lipases (Fig.30.2).

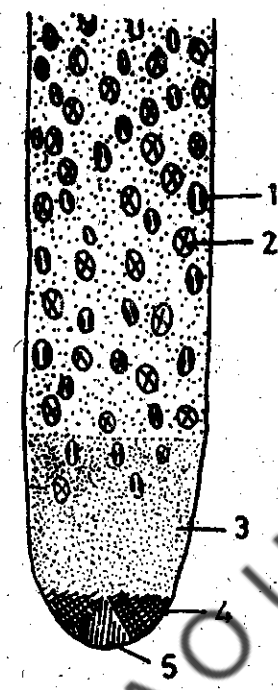

Fig. 30.2. Pollen tube of *Lilium* showing the distribution of cytoplasmic particles and chemical constituents as revealed by cytochemical tests. 1. Lipid. 2. Starch. 3. Proteins and mitochondria. 4. Polysaccharides. 5. RNA (Adopted from rosen, 1964).

Histological nature of style determines the further course of growth in the pollen tube. In the *Open type of styles*, lined with a glandular transmitting tissue, the pollen tubes show

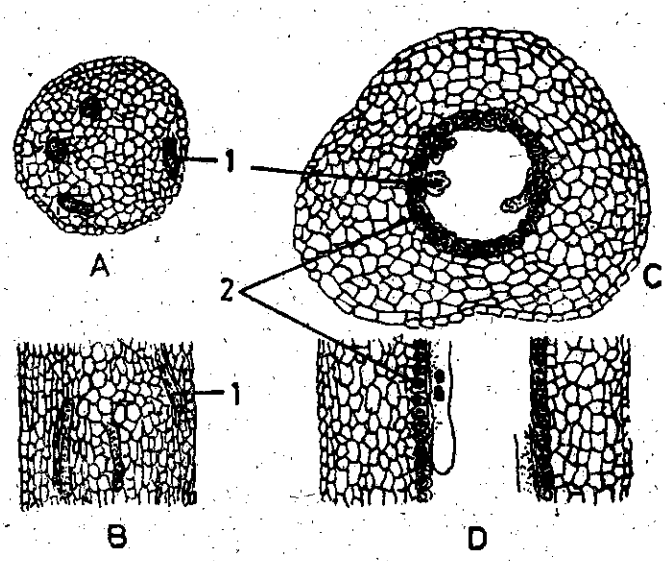

Fig. 30.3. Closed (A,B) and Open (C,D) types of style. A,C. Transverse sections. B, D. Longitudinal sections 1. Pollen tube. 2. Transmitting tissue.

ectotropic growth (e.g. *Lilium*). The pollen tube grows between the rudimentary cells of the transmitting tissue in the half closed styles (e.g., *Artabotrys*). In closed styles the pollen tube grows in between the cells and passes down the stylar tissue. If the tube is broad it has to make its way by destroying the cells (e.g., *Gossypium, Datura*) (Fig.30.3).

Ultimately the pollen tube comes into the funicular tissue after passing through the locule and placental surface. Then it enters the micropyle. This is called porogamy. In some (e.g. *Casuarinaceae, Betulaceae*) pollen tube enters through the chalaza. This is called chalazogamy (Fig.30.4.A). Another method of pollen tube entry is known as mesogamy (30.4.C). Here the pollen tube enters the ovule through the funiculus (e.g. *Pistacia)* or through the integuments (e.g., *Cucurbita*) (Fig.30.4.B).

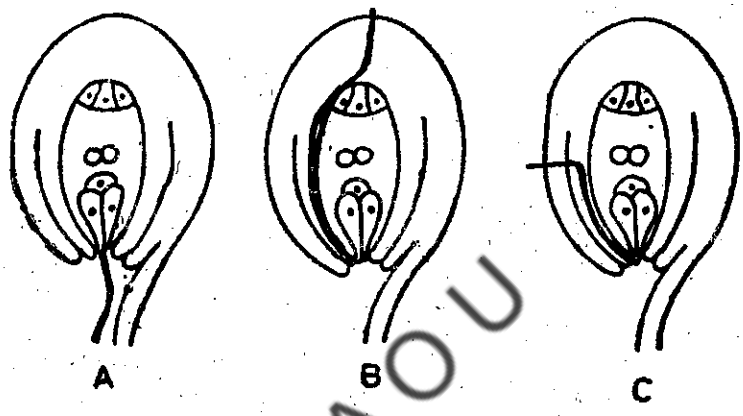

Fig. 30.4. Modes of pollen tube entry into the ovule. a. Porogamy. B. Chalazogamy. C. Mesogamy.

Pollen tube enters into the embryo sac through the micropylar end where the egg apparatus is situated. At the time of entry: (a) it may enter in between the egg and one of the two synergids, or (b) it may enter between the embryo sac wall and one of the synergids, or (c) it enters directly into the synergids. Generally, the pollen tube contents are discharged into the synergid. The pollen tube growth stops at this stage. The pollen tube secretes pectinase and dissolves the embryo sac membrane at the time of entry.

30.3.2. Contents of the Pollen Tube Discharge

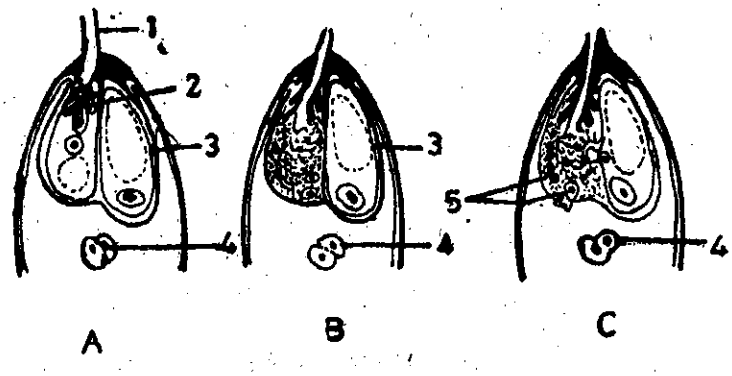

Fig. 30.5. Pollen tube entry. A. Entry into one of the synergids. B. Release of its contents into the synergid. C. Movement of the male gametes towards their destination. 1. Pollen tube. 2. Filiform apparatus. 3. Egg. 4. Secondary nucleus. 5. Male gametes (Adopted from Jenson, 1973).

After the pollen tube entry into the embryo sac one or both the synergids are damaged. Electron microscope studies, however, have revealed that the synergid that receives the pollen tube degenerates even before the pollen tube entry (Fig. 30.5).

The pollen tube enters through the filiform end and growth stops as soon as it reaches the synergid cytoplasm. The pollen tube contents are discharged through a sub apical pore into the degenerating synergid cytoplasm. The pore is plugged after the discharge. From the discharge the two sperms, come out through another opening formed at the base of the synergid. The second synergid may remain unaffected even after fertilization.

30.3.3. Syngamy and Triple Fusion

Syngamy and triple fusion are the two steps in the process of double fertilization (Nawaschin, 1898)_ a phenomenon unique to angiosperms.

The sperms from the pollen tube discharge are membrane bound with hyaline cytoplasm. Until fusion the sperm nuclei show telophasic picture. They reach the egg and secondary nucleus in an autonomous manner.

On the basis of light microscopic studies two stages of fusion- *Plasmogamy* and *Karyogamy* - were suggested. Ultrastructural investigations, however, did not confirm the plasmogamy. Sperm nucleus alone is involved in fusion but not its cytoplasm.

Syngamy is the fusion between the egg and sperm nuclei. At this stage, the nucleus and nucleolus of egg enlarge. Sperm nucleus also shows enlargement. Both these nuclei show low DNA levels. Mutual attraction between these two nuclei is said to be brought about by a difference in their electrical charge.

Double fertilization involves the fusion between the second sperm nucleus and the two polar nuclei (or their fusion product- secondary nucleus). As fusion of three nuclei is seen, it is called the triple fusion. Triple fusion precedes syngamy.

30.3.4. Anomalous Fertilization

Polyspermy: When more than two sperms are found in any embryo sac the situation is described as polyspermous . This may arise either due to occurrence of more than two sperms in a pollen tube or due to entry of more than one pollen tube in an embryo sac. This may lead to the fertilization of an egg by more than one sperm. The extra sperms may also fuse with synergid or antipodal cells. *Heterofertilization* i.e., fusion of sperms from different pollen tubes with the egg and secondary nucleus may also occur under such circumstances.

Branching of the Pollen Tubes and their Persistency: This is another abnormal feature in fertilization. In the usual circumstances the pollen tube (which is unbranched throughout) degenerates after fertilization. Sometimes, the pollen tubes persist for a long period . Occasionally, the pollen tube tip branches (e.g., *Cucurbita*). Branching may occur in the style or in the micropyle. In some (e.g. *Spinach*) the pollen tube branching may take place after fertilization (Wils, 1974).

Check Your Progress 1, 2 & 3

1. What is the difference between porogamy & Chalazogamy ?

2. What is syngamy & triple fusion ?

3. What is polyspermy ?

Note: (a) Write the answers in the space given below.

(b) Compare your answers with those given at the end of this unit.

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30.4. DEVELOPMENT OF EMBRYO (EMBRYOGENY)

Syngamy produces the zygote. The zygote divides in a highly organised and predetermined manner and develops into a mature embryo. During embryogenesis physiological and biochemical factors interact with genetic control and determine the developmental pattern.

The zygote, to start with, shows large vacuoles in its upper region. Gradually, the vacuoles disappear and the cytoplasm becomes homogeneous. Before the first division, vacuoles may reappear throughout the cell. The resting period of zygote is variable in different species. The zygote shows polarity. It is an ovoid cell which is tapered at the micropylar end. The antipodal end has the nucleus. There is a vacuole at the micropylar pole. The organelles are found surrounding the nucleus. The ER is closely placed along the plasma membrane. Thus, there is a histological diversity between the two poles of the zygote. This is of significance in the development of embryo.

The zygote undergoes the first division in a transverse manner in most of the angiosperms. The two cells are conventionally called apical cell, *ca* (towards the antipodal pole) and basal cell, *cb* (towards the micropylar pole). The basal cell is larger. The early embryogenesis does not show any differences in the dicots and monocots. At the time of the initiation of the cotyledon(s) and shoot apex (plumule) the differences start.

30.4.1. Proembryo

The early phase of embryogeny (from the 2-celled stage to the embryonal organogenesis) is called proembryo stage. The basal cell, *cb*, may undergo a transverse division and the daughter cells are designated as *m* and *ci*. The division in ca may be vertical or transverse. Accordingly, the 4-celled proembryo may be T-shaped or linear. The *linear proembryo* produces an octant by two vertical divisions at right angles to each other in each of the two daughter cells (1, 1) of *ca*. The Octant has four cells in two superposed tiers. The *T-shaped embryo* also produces a similar octant by undergoing one transverse and one vertical division. It can also be a different type of octant where all the eight cells may be in one tier *(q)*. Here there are four central cells

surrounded by four peripheral cells. The future ontogenetic pattern of the various octant cells are determined at the is stage (Fig.30.6).

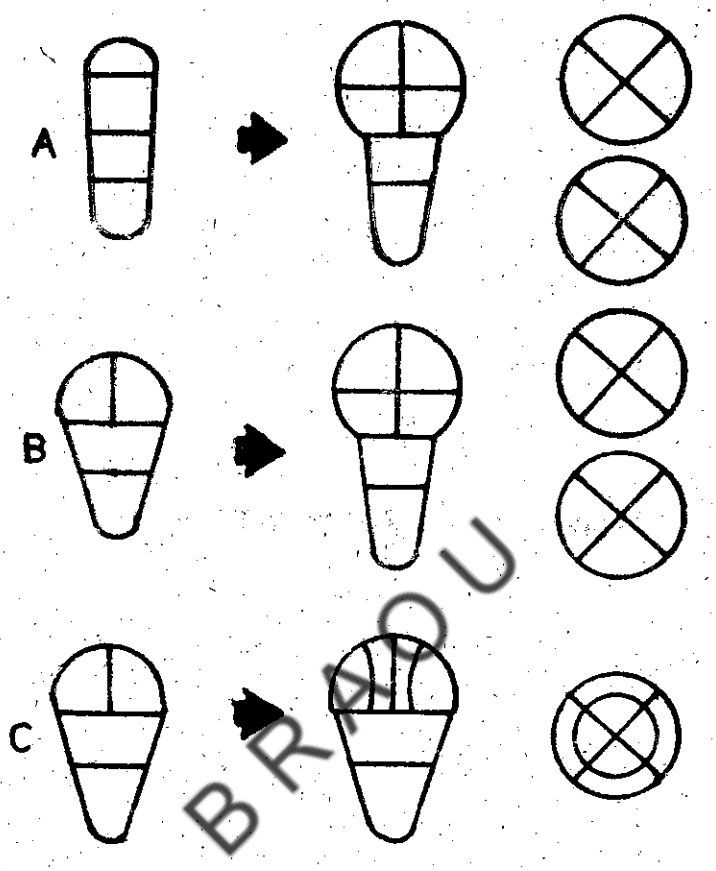

Fig. 30.6. Formation of two different types of octants. Transverse sections are given on the extreme (After Swamy, 1962)

30.4.2. Embryo Development in Dicotyledons

Maheshwari (1950) recognised five main types of embryogeny in dicotyledons on the basis of the followng criteria: (a) Plane of division in the apical cell. (b) Role of *ca* and *cb* (basal cell) in the development and organisation of embryo.

The five types of Maheshwari (1950) are as follows:

1. In the 2-celled proembryo the apical cell undergoes a vertical division.

   a) In the subsequent embryogenesis the role of the basal cell is insignificant or none- *Crucifer type or Onagrad type* (Onagraceae, Cruciferae, Annonaceae, Ranunculaceae, Pedaliaceae, Scrophulariaceae).

   b) Both the apical and basal cells are responsible for the development of embryo- *Asterad type* (Balsaminaceae, Vitaceae, Compositae, Violaceae).

II. In the 2-celled proembryo the apical cell undergoes a transverse division.

   1. In the subsequent development of embryo basal cell has only a minor role to play.

c) A suspensor is formed by the basal cell-*Solanad type* (Campanulaceae, Theaceae, Linaceae, Solanaceae).

d) No divisions occur in the basal cell. If the suspensor is present, it is derived from the apical cell only - *Caryophyllad type* (Crassulaceae, Caryophyllaceae, Haloragaceae)

2. e) Both the apical *(ca)* and basal *(cb)* cells contribute to the embryo development - *Chenopodiad type* (Chenopodiaceae, Boraginaceae).

Johason (1950) proposed a sixth type the *Piperad type.* Here the zygote divides vertically (e.g. Loranthaceae, Piperaceae)

Crucifer type: As an example of the development of embryo in the dicotyledons the embryogeny of *Capsella bursa-pastoris* which belongs to the crucifer type is described below.

The zygote undergoes the first division transversely forming basal *(cb)* and a terminal *(ca)* cell. A four celled inverted T- shaped proembryo is produced by a transverse division in cb and a longitudinal division in *ca.* Both the terminal cells divide vertically at right angles to the first wall and produce a quadrant. The quadrant cells now form an octant by transverse division. Out of the eight cells in the octant the lower four initiate the plumule and cotyledons.

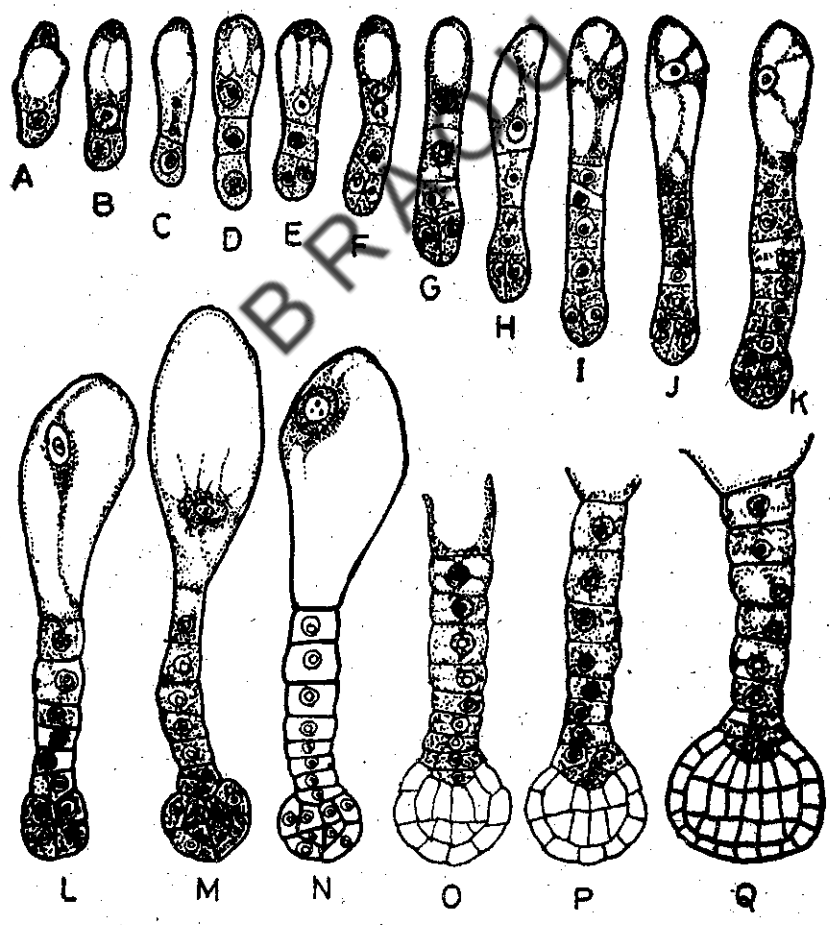

Fig. 30.7. Different stages in the development of embryo in *Capsella bursa pastoris* (After Souges, 1914, 1919).

The upper four give rise to the hypocotyl. At this stage all the octant cells undergo a periclinal division. The outer cells constitute the dermatogen. The inner derivatives divide further and

form the initials of periblem and plerome. In the meantime the upper two cells *(ci* and *cm)* of the four celled proembryo undergo transverse division and form a suspensor of 6-10 cells. The upper cell *(v)* of the suspensor gets swollen to function as haustorium. The lowest cell *(h)* is the hypophysis. Subsequently the hypophysis cell *(h)* undergoes transverse division. The two daughter cells divide twice by walls at right angles to each other forming eight cells. Of these, the initials of root cortex are formed from the lower four cells. Root cap and root epidermis are formed from the upper four cells (Fig. 30.7).

Simultaneously, the cells in the embryo proper divide further. The divisions are more at two points in the lower tier which would form the cotyledons. At this stage a heart shaped embryo is produced. The elongation of the hypocotyl and cotyledons takes place by the division of their initials which are mostly transverse. The cotyledons during further development bend and the embryo becomes horse-shoe shaped (Fig.30.8).

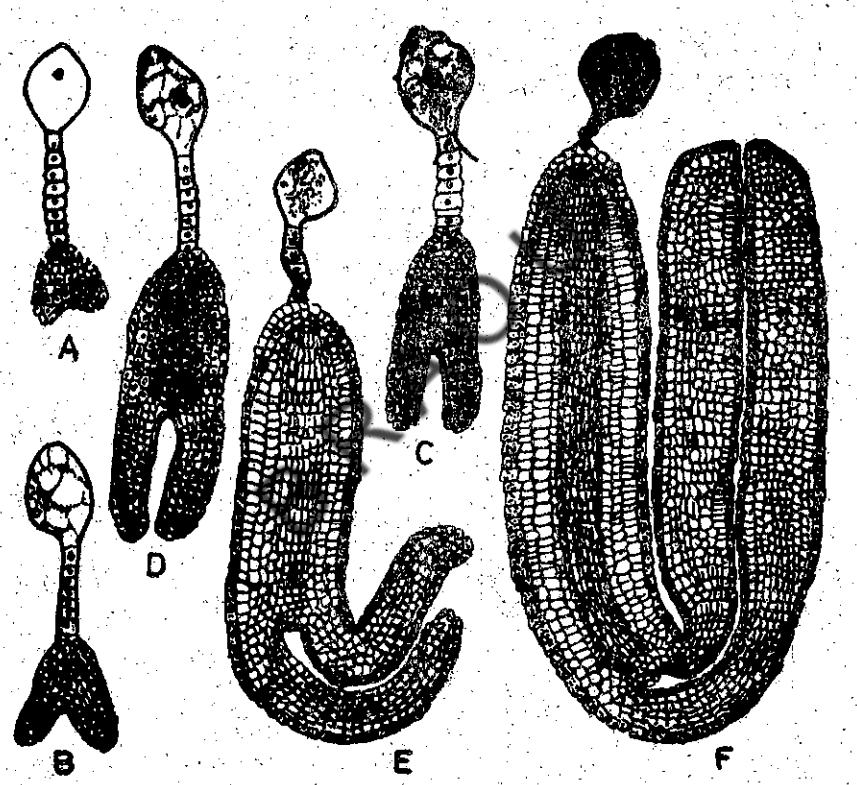

Fig. 30.8. Older stages in the development of the embryo of *Capsella bursa-pastoris* (After Schaffner)

30.4.3. Embryo Development in Monocotyledones

The embryogeny of *Najas laurata* which was worked out by Swamy and Lakshmanan (1962) is described below as an illustration of embryo development in the monocotyledones.

The zygote divides transversely forming a larger basal cell (cb) and a small terminal cell *(ca)*. The basal cell forms a large one-celled haustorium without undergoing any division. The terminal cell *(ca)* divides and forms the entire embryo. This *(ca)* undergoes a transverse division forming *c* and *d* and *d* undergoes one more transverse division. Thus, a four celled *(c,m, ci* and *cb)* proembryo is produced. *c* and *m* divide twice vertically. Now, two superposed 4-celled tiers, *q* and *m* are formed. *ci* divides transversely and forms *n* and n^1. Then, *n* undergoes a vertical and n^1 a transverse division forming two cells, *o* and *p*. Again *p* divides in a transverse manner and gives rise to two cells, *h* and *s*.

At this stage, a periclinal division occurs in all the quadrant cells. This results in the formation of four peripheral cells which initiate the dermatogen. These encircle the four central cells. The entire tier *m* divides twice vertically and transversely. *m* is now in two tiers. The embryo at this stage is almost spherical. Now, the proembryo starts to elongate as the *m* and *n* tiers divide transversely. The embryo now appears ovoid. Plerome initials now differentiate from *q*, *m* and *n* tiers.

Of the eight cells in *q*, four are central and four are peripheral. Three central cells divide faster than the fourth. Proembryonal symmetry is now altered. The tip of the proembryo now shows a notch. The fast growing cells of *q* organise the single cotyledon. Epicotyl is formed from the derivatives of the slowly dividing fourth cell *q*. The derivative cells from *n* form the radicle. Ontogenetically the cotyledon and epicotyl are terminal structures.

The hemispherical terminal cell of the filamentous proembryo is rightly the centre of initiation of the shoot apex. In monocots half or three fourths of the potential of the embryonic shoot apex is engaged in the development of cotyledon. The remaining is used in the formation of epicotyl. This is the cylindrical mature cotyledon in monocots. The important aspect of monocot embryogenesis is that the loci for the epicotyl and cotyledon are in the same tier and located mutually adjacent to each other. Both these are terminal on the axis of the embryo. Therefore, the earlier concepts that the epicotyl is lateral and cotyledon is terminal does not stand to this evidence (Fig.30.9).

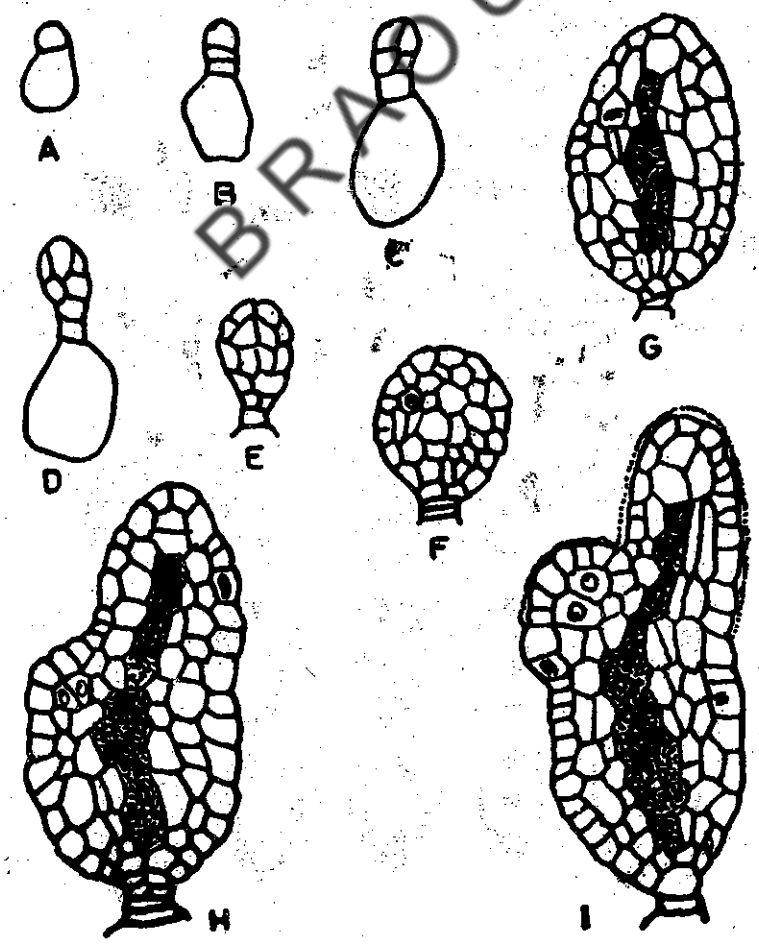

Fig. 30.9. Development of embryo in *Najas lacerata* (After Swamy & Lakshmanan, 1962)

Check Your Progress - 4

List out the five types of embryogeny recognised by Maheswari in Dicots.

Note: (a) Write your answer in the space given below.

(b) Compare your answer with the one given at the end of this unit.

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30.5. DEVELOPMENT OF ENDOSPERM

The primary endosperm nucleus (the fusion product of a sperm and the secondary nucleus) divides to form nuclei or cells which are called endosperm. It is the nutritional source for the embryo. In the gymnosperms the endosperm is haploid. The female gametophyte in the gymnosperms continues as endosperm after fertilization. In the angiosperms all the three nuclei are haploid and the fusion product of triple fusion is therefore triploid. In some families of angiosperms (Orchidaceae, Podostemaceae and Trapaceae) the endosperm formation is suppressed. The seeds in angiosperms are classified as endospermous or non-endospermous. If the developing embryo consumes endosperm (e.g., *Pisum sativum*) the seeds become non-endospermous. When the endosperm remains persistent, the seeds are called endospermous. This is used by the embryo during seed germination (e.g. castor).

The endosperm development in angiosperms is of three types: nuclear, cellular, helobial.

Ontogeny of endosperm in dicots is either ab initio cellular or ab *initio nuclear*.

30.5.1. Cellular Endosperm

In the ab *initio cellular type* when the primary endosperm nucleus undergoes the first division, it is accompanied by cytokinesis (cell-wall formation). In the *ab initio nuclear type*,

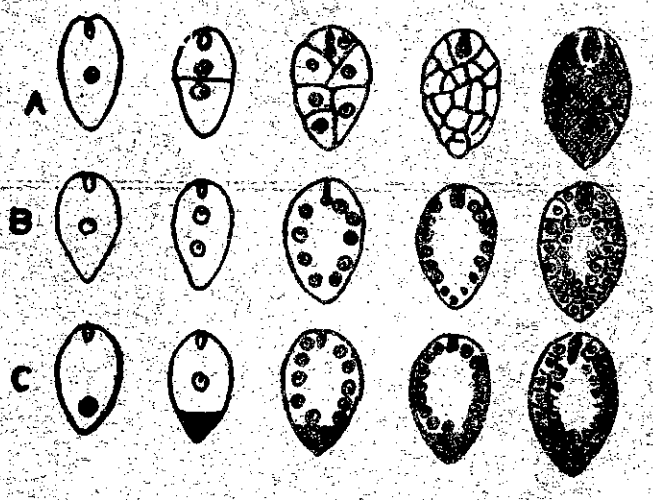

Fig. 30.10. Major types of endosperm development. A. Cellular type. B. Nuclear type. C. Helobial type. (After swamy & Krishnamurthy).

the first and subsequent divisions of the primary endosperm nucleus are un-accompanied by wall formation. The cell walls are formed and the cell divisions are followed at later stage in the nuclear ontogeny. Ultimately this endosperm is not distinguishable from the cellular type (Fig. 30.10).

The endosperm development in the monocotyledons is nuclear or helobial type. In the helobial ontogeny the primary endosperm nucleus moves to the antipodal end and divides in *situ*. The first division is immediately followed by a wall resulting in a large micropylar and a small chalazal cell. In the micropylar cell the other divisions are nuclear. Tlhe chalazal cell may or may not divide. If it divides he divisions are few.

30.5.2. Nuclear Endosperm

In the nuclear endosperm development the free nuclear period is different in different taxa. In some plants (e.g. *Coffea*) walls appear at the 4-nuclear stage. The wall formation in many free nuclear taxa is delayed until many nuclei are formed. The free nuclei are enveloped in a cytoplasmic sheath. In some species the endosperm remains nuclear. The cellular phase does not appear (Fig. 30.11).

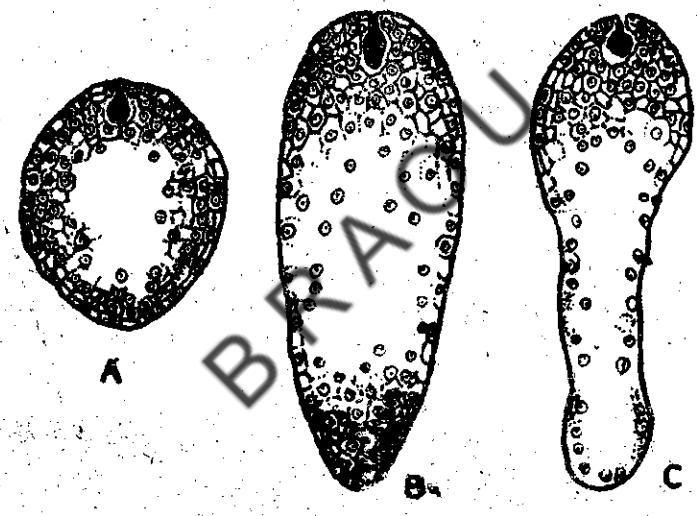

Fig. 30.11. Wall formation in a nuclear endosperm. A. Wall formation in centripetal directions. B. Wall formation from both the poles towards the centre. C. wall formation in the chalazal direction

After fertilization the embryo sac shows quick enlargement. The first few nuclear divisions are synchronous. The free nuclei then become peripheral. The free nuclei and the encircled cytoplasmic sheath keep pace with the increasing size of the embryo sac. The growing region of the embryo sac shows faster rate of division in the endosperm nuclei. The number of endosperm nuclei increases in the chalazal direction.

30.5.3. Helobial Endosperm

The following are the important features of this type:

The primary endosperm nucleus divides in *situ* after it comes to the chalazal end near the antipodals. Wall formation takes place producing a large micropylar and a smaller chalazal cell. The chalazal cell is densely cytoplasmic and deep staining. Before dividing, the nucleus in the micropylar daughter cell moves away. The first few divisions are essentially free nuclear. Wall formation is much delayed if at all it occurs. (Fig. 30.12).

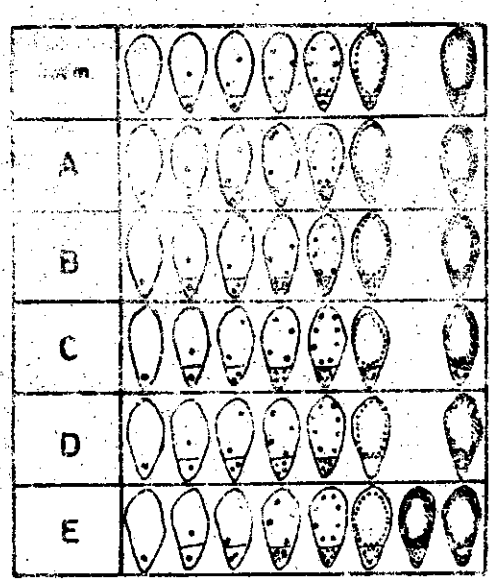

Fig. 30.12. Ontogenetic variations in helobial endosperm (After Swamy & Parameswaram, 1963).

Helobial endosperm along with the nuclear type (exclusively or in combination) is reported in 42 percent families of the nonocotyledones. It is not reported in the dicotyledones so far.

30.5.4. Endosperm Haustoria

Endosperm occasionally produces special structures at the embryo sac pole(s). These have morpho-histologic organisation distinct from the remaining endosperm. Presumably they help in the nutrition of the embryo and seed. They are supposed to be haustorial in function.

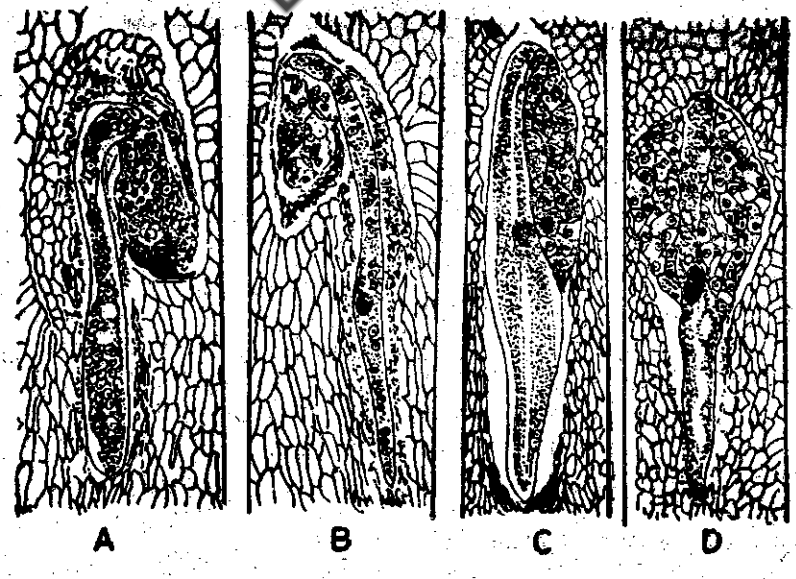

Fig. 30.14. Development of endosperm haustorium in *Cansjera rheedii* A. mature female gametophyte with neighbouring tissue. B. Embryo sac after fertilisation segmented into micropylar and chalazal chambers. C. Early stage in the development of cellular endosperm in the micropylar chamber and the elongation of the haustorial cell. D. Same at a later stage.

Haustoria in Nuclear Endosperm : Free nuclear divisions in the chalazal region are faster, hence, the greater density of nuclei and cytoplasm in this part. Polyploid nuclei are also formed in the rapidly dividing nuclei when some adjacent spindles fuse. DNA control and metabolic rate also increase due to this. Thus, the chalazal part is considered haustorial in nature. The micropylar part, in contrast, is poorly organised with no haustorial organization. Coenocytic haustorial structures are formed in Leguminosae, Cucurbitaceae, Proteaceae etc.

Haustoria in Helobial Endosperm : As mentioned earlier the nucleus of the basal apparatus is hypertrophied. At a later stage this nucleus shows repeated endomitotic divisions as in other haustorial cells. The nucleus becomes lobed and the nucleous is fragmented. The lobe are sometimes pinched off and appear like nuclei. The cytoplasm of the basal apparatus is dense, deep stained with vacuoles of various sizes dispersed haphazardly. In the coenocytic basal apparatus, the nuclei are hypertrophied. Endoduplication of chromosomes takes place in these nuclei. Thus, this cell is structurally and functionally haustorial in nature.

Haustoria in Cellular Endosperm : A derivative cell from the first division of primary endosperm nucleus might function as haustorium. This is the simplest type. In the cellular endosperm haustoria are reported in *Opilia amentacea* (Swamy and Dyanand Rao, 1963) *Canspera rhedi* (Swamay 1960). *Impatiens leschenoultii* (Narayana, 1965) etc. In these taxa the haustoria ramify and proliferate through the intercellular space (Fig. 30.13; 30.14).

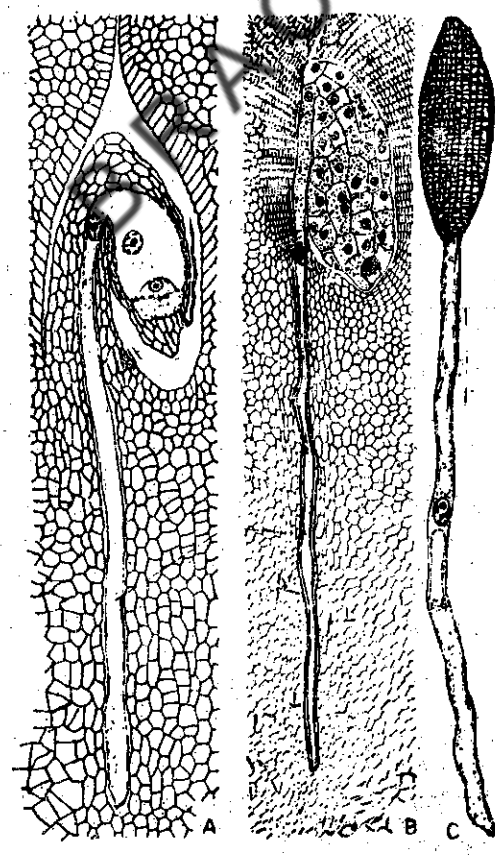

Fig. Fig. 30.13. Endosperm. A, B. Organisation of endosperm haustorium in *Opilia amentacea*. C. Whole mount showing cellular endosperm and haustorium (After Swamy & Dayanand Rao, 1963).

30.5.5. Endosperm Function

Endosperm contains growth regulators and nutrients. The controlled development of zygote to embryo is regulated by the endosperm. Seed germination and seedling growth are controlled by the endosperm in the albuminous seeds. Various substances like carbohydrates, proteins and fats, enzymes, vitamins, growth regulators etc., are formed in the endosperm. Many growth regulators like IAA, GA, nicotinic acid, xanthine, chlorogenic acid, hexitols, purine like compounds, indol pyruvic, 1,3- dipyhenyl urea, several amino acids, leucoanthocyanins etc., have been isolated from the endosperm. All these substances interact with the growing embryo and cause its development.

30.6. SUMMARY

The process of fertilization involving gametic fusion results in the zygote. After a protracted period of rest, the zygote develops into an embryo. There are five types of embryo development in dicotyledons, viz., Crucifer, Asterad, Solanad, Caryophyllad, and Chenopodiad. The development of embryo in monocots differs from that of dicots from the octant stage onwards.

Developmentally, the endosperm is of three types, viz., nuclear, cellular and helobial.

30.7. CHECK YOUR PROGRESS: MODEL ANSWERS

1. In porogamy the pollen tube enters the ovule through the micropyle and in chalazogamy it enters through chalaza.
2. Syngamy is the fusion between egg and sperm nuclei and triple fusion is the fusionbetween the second sperm nucleius and two polar nuclei.
3. The occurence of more than 2 sperms in any embryo sac is called polyspermy.
4. The five types of embryogeny recognised by Maheshwari are: (a) crucifer type or onagrad type (b) Asterad type (c) solanad type d) Caryophyllad type and (e) Chenopodiad type.

30.8. MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Mention the types of embryo development in the dicotyledons. Illustrate the crucifer type of embryogenesis.
2. Discuss the significant features of embryo development in monocots.
3. Give an illustrative account of cellular, nuclear and helobial endosperm.
4. Describe the different steps in the fertilisation process.

II. Answer the following questions in about 10 lines each.

1. Describe the structure and development of pollen tube.
2. Write briefly about syngamy and triple fusion.
3. Write briefly about cellular endosperm.
4. Write briefly about nuclear endosperm.
5. Write briefly about helobial endosperm.
6. Briefly describe the endosperm haustoria.

30.9. GLOSSARY

Antipodals	:	These are cells or nuclei present at the chalazal end of the embryo sac in angiosperms.
Archesporium	:	A group of hypodermal cells that divide periclinally and form a primary parietal layer outside and primary sporogenous layer on the inner side.
Bisporic embryo sac	:	Embryosac developing from two megaspore nuclei.
Chalaza	:	The lower (basal) part of the ovule of the vicinity of the funicle.
Chalazogamy	:	Entry of pollen tube into the chalaza through the raphe during fertilization.
Coenomegaspore	:	It is a cell with four free megaspore nuclei.
Coplus	:	A meridional furrow of the pollen grain.
Double fertilization	:	The fusion of two sperm nuclei separately with the egg (syngamy) and the secondary embryo sac nucleus (triple fusion).
Egg apparatus	:	A group of three cells, two of them representing synergids and the third the egg at the micropylar end of the embryo sac.
Exine	:	The outer part of the exine. Ektexine has three layers-tectum, columella and foot layer.
Embryo sac	:	The female gametophyte found in the seed lants. A typical embryo sac shows an egg appartus, a secondary nucleus (or polar nuclei) and antipodals.
Endexine	:	Inner part of the exine.
Endomitosis	:	A nuclear division within the nuclear membrane.
Endothelium	:	Also known as integumentary tapetum. This is derived form the inner layer (inner epidermis) of the integument and is in direct contact with embryo sac.
Filiform apparatus	:	A structure developed on the synergids.
Funicle	:	The ovular stalk connecting the ovule to the placenta or the ovary wall.
Hypophysis	:	One or a tier of 2-4 specialised cells situated at the radicular region of the proembryo.
Hypostage	:	A group of histlogically different cells in the chalazal region at the point of origin of integuments.
Integument	:	Ovular envelope.
Intine	:	It is the inner wall of the pollen grain.
Micropyle	:	A pore like opening in the integument's at the free end of the ovule.

Monosporic	:	Development of embryo sac from only one megaspore (normally the chalazal) of the megaspore tetrad.
Ovule	:	It is the integumented megasporangium of the seed plants.
Porogamy	:	Entry of pollen tube into the embryo sac through the micropyle during fertilization.
Syngamy	:	Fusion of a sperm with the egg nucleus.
Tapetum	:	A specialised nutritive layer of cells surrounding the sporogenous tissue.
Tetrasporic	:	Embryo sac developing from all the four megaspore nuclei of the megaspore.
Triple fusion	:	Fusion of the second sperm nucleus with the polar nuclei or the secondary nucleus during double fertilization.

30.10. REFERENCES

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2. Maheshwari, P. 1950. An introduction to the Embryology of Angiosperms. Mc Graw-Hill. Book Co. Ltd., New York.
3. Swamy, B.G.L. and Krishnamurthy, K.V. 1980. From Flower to Fruit : Embryology of Flowring Plants. Tata Mc Graw-Hill Pub. Co. Ltd., New Delhi.

Dr. B. R. AMBEDKAR OPEN UNIVERSITY

FACULTY OF SCIENCE

BOTANY

COURSE - I SEED PLANTS

B.SC., II YEAR

SYLLABUS

Block-I	:	**Gymnosperms**
Unit-1	:	General characters and classification of Gymnosperms
Unit-2	:	Pinus
Unit-3	:	Gnetum
Unit-4	:	Fossil Gymnosperms Lyginopteris & Williamsonia
Block-II	:	**Plant Anatomy**
Unit-5	:	The cell wall
Unit-6	:	Meristems
Unit-7	:	Simple tissues
Unit-8	:	Complex tissues and Tissues systems
Unit-9	:	Secondary growth in dicot stem and root
Unit-10	:	Anamalous secondary growth
Block-III	:	**Taxonomy**
Unit-13	:	Magnoliaceae
Unit-14	:	Brassicaceae [Cruciferae]
Unit-15	:	Malvaceae
Unit-16	:	Rutaceae
Unit-17	:	Fabaceae [Leguminosae]
Unit-18	:	Apiaceae [Umbelliferae]
Unit-19	:	Rubiaceae
Unit-20	:	Asteraceae [Compositae]
Unit-21	:	Asclepiadaceae
Unit-22	:	Solanaceae
Unit-23	:	Lamiaceae [Labiatae]
Unit-24	:	Loranthaceae
Unit-25	:	Euphorbiaceae
Unit-26	:	Orchidaceae
Unit-27	:	Arecaceae [Palmae]
Unit-28	:	Poaceae [Gramineae]
Block-IV	:	**Embryology**
Unit-29	:	Development of Male and Female Gametophytes
Unit-30	:	Fertilisation and development of Embryo and Endosperm

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FACULTY OF SCIENCES

MODEL QUESTION PAPER

SECOND YEAR (3 YEARS DEGREE COURSE) EXAMINATION

BOTANY

COURSE - 2 : SEED PLANTS

TIME: 3 Hours **Max. Marks : 75**

SECTION - A

Answer any three of the following questions

Each question carries 15 marks

Answer the following in about 30 lines each.

1. Draw a well labelled diagram and describe the internal structure of the needle of pinus and comment upon its xerophytic characters.
2. Describe the structure of different types of mechanical tissues found in plants.
3. What is annamolous secondary growth? Illustrate your answer with reference to some forms you have studied.
4. Write an account of the classification of Bentham & Hooker.
5. Write about the economic importance of Malvaceae. Solanaceae, Arecaceae and Poaceae.
6. Explain the development of male gametophyte in angiosperms.

SECTION - B

Marks 5x6=30

Answer the three of the following questions.

Each question carries 6 marks.

Answer the following in about 10 lines each.

7. Write briefly about the Sporne's system of classification.
8. Write about the ovule of Gnetum.
9. Write briefly about "Histogen Theory".
10. Write about parenchyma.
11. Describe briefly about the various components of epidermis.
12. Write about the floral structure of Lamiaceae.
13. Write about the "Bionomial Nomenclature".
14. Write about the "Taxonomic Ranks".
15. What are pollen embryo sacs?
16. Write briefly about syngamy and triple fusion.

Dr. B.R.AMBEDKAR OPEN UNIVERSITY

UNDERGRADUATE COURSE-II YEAR

SUBJECT : BOTANY

COURSE - 2 : SEED PLANTS

ASSIGNMENT NO. 1

N.B.

1. Do not copy the answer directly from any of the books.
2. As far as possible try to answer the questions independently in your own words.
3. If it is necessary to quote from any source give the correct reference.
4. Use your own foolscap pages for writing the assignments.
5. Leave sufficient margin for the comments of the evaluator.
6. Completion of this assignment normally should not take more than two hours time.

I. Answer the following questions in about 30 lines.

1. Draw a well labelled diagram and describe the internal structure of the needle of pinus Comment upon its xerophytic characters.
2. Describe the development of male gametophyte in Gnetum.
3. Write an account of williamsonla.

II. Answer the following questions in about 10 lines each.

4. Write briefly about the sporne's system of classfication of Gymnosperms.
5. Write briefly about the economic importance of Gymnosperms.
6. Write briefly about Crossotheca.

CUT HERE

Dr. B.R.Ambedkar Open University

UNDERGRADUATE COURSES II YEAR

SUBJECT : BOTANY

COURSE - 2 : SEED PLANTS

ASSIGNMENT NO. 2

N.B.

1. Do not copy the answer directly from any of the books.
2. As far as possible try to answer the questions independently in your own words.
3. If it is necessary to quote from any source give the correct reference.
4. Use your own foolscap pages for writing the assignments.
5. Leave sufficient margin for the comments of the evaluator.
6. Completion of this assignment normally should not take more than two hours time.

I. Answer the following questions in about 30 lines.

1. What are the various theories concerning the apical meristems? explain them.
2. Describe briefly different types of simple tissues encountered in the plant body.
3. Give an account of the various components of the plant epidermis.

II. Answer the folwing questions in about 10 lines.

4. Give a brief account of the secondary growth in a typical diotyledonous stem.
5. What are leticifers? Give an account of the types of laticifers.
6. Describe briefly the various elements of phloem.

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UNDERGRADUATE COURSE-II YEAR

SUBJECT : BOTANY

COURSE - 2 : SEED PLANTS

ASSIGNMENT NO 3

N.B.

1. Do not copy the answer directly from any of the books.
2. As far as possible try to answer the questions independently in your own words.
3. If it is necessary to quote from any source give the correct reference.
4. Use your own foolscap pages for writing the assignments.
5. Leave sufficient margin for the comments of the evaluator.
6. Completion of this assignment normally should not take more than two hours time.

I. Answer the following questions in about 30 lines.

1. Write an account of the classification of Bentham & Hooker.
2. Compare & concrast the 3 subfamilies of Fabaceae.
3. Write about the floral characters and economic importance of poaceae.

II. Answer the following questions in about 10 lines.

4. Give an account of the economic importance of Brassioaceae.
5. Write briefly about the poilination mechanism in Asclepladaceae.
6. Write briefly about syngamy and tripple fusion.

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