Indira Gandhi National
Open University
School of Sciences

BBYCT-131
BIODIVERSITY
(MICROBES, ALGAE, FUNGI AND ARCHEGONIATES)

Block

6

GYMNOSPERMS

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BLOCK 6 : GYMNOSPERMS

This Block 6 is the last block of the Paper I, Biodiversity (Microbes, Algae, Fungi and Archegoniates) for the core-course in botany. The previous Blocks 1-5, acquainted you with the biology and economic importance of microbes, algae, fungi, bryophytes and pteridophytes.

By now you are already aware of the facts that : (i) apart from the microbes, the rest of the plant groups are eukaryotes; (ii) the bryophytes are regarded as the pioneers of land habitat; (iii) the gametophytic phase in the life of bryophytes is autotrophic, and dominant, and that the sporophytes of bryophytes are partly or fully dependent on the gametophytes for support and food; (iv) the pteridophytes represent the most primitive group amongst the tracheophyta, the vascular plants; (v) unlike bryophytes, the sporophytic phase in the life of a pteridophyte is independent, vascular, autotrophic and possesses true root, stem and leaves; (vi) homosporous pteridophytes are the only land plants where the short lived gametophytic phase in the life cycle lives independent of sporophytes and they may be autotrophic/saprophytic/mycorrhizal; (vii) some pteridophytes exhibit heterospory, regarded by botanists as precursors to seed habit; (viii) the sex-organs, archegonia and antheridia in both bryophytes and pteridophytes are with sterile covering and that water is the medium for the transfer of flagellated male gametes to the archegonium.

In this Block you shall study the biology of more evolved groups of plants the gymnosperms: the group that bears archegonia on massive non-photosynthetic female gametophyte enclosed within an ovule. The male gametophytes, the pollen-grains, are relatively a few celled and are transferred to ovules mainly through air. Siphonogamy ensures direct deposition of male gametes in the vicinity of egg. Naked, uncovered ovules and seeds are characteristics of gymnosperms. The gymnosperms are in great demand for timber, lumber, paper pulp, turpentine, resin etc. Interestingly, *Sequoiadendron giganteum* (Giant Redwood) is the tallest plant known so far, standing 111.6 m tall. A 4300 year old *Pinus longaeva*, the bristle cone pine is among the longest surviving plant. The “German Sherman Tree” in Sequoia National Park, USA has the widest girth at 31 m. Some of the gymnosperms such as *Cycas*, *Ginkgo* are so rare in their occurrence and distribution that they are referred to as ‘living fossils’. The gymnosperms are also the favourites of horticulturists because of their evergreen and attractive foliage.

This block consists of 4 Units, 19 to 22. The Unit 19 deals with the general characteristics, distribution, and classification of gymnosperms along with the various patterns of the life cycles. In Units 20 and 21, you shall study the morphology, anatomy, reproduction in *Cycas* and *Pinus* respectively. The economic importance of gymnosperms is provided in Unit 22.

Objectives

After studying this block, you should be able to :

- list the important morphological, anatomical and reproductive features of gymnosperms in general and of *Cycas* and *Pinus* in particular;
- appreciate the complexities in the life-cycle patterns observed in gymnosperms;
- classify the gymnosperms upto the level of families;
- discuss the ecological and economic importance of gymnosperms; and
- compare and contrast the characteristics of gymnosperms with pteridophytes and angiosperms.

UNIT 19

GYMNOSPERMS: GENERAL CHARACTERISTICS

Structure

19.1 INTRODUCTION

The seed plants (spermatophytes) are generally divided into two groups, gymnosperms and angiosperms. Theophrastus, a pupil of Aristotle, used the word "Gymnosperm" for the first time. As the name suggests (*gymnos* = naked, *sperma* = seed), the gymnosperms, unlike the angiosperms have ovules that are exposed.

The gymnosperms comprise of only a small portion of the plant kingdom (about 70 genera and more than 700 species). In spite of being represented by such a few members, they are distributed throughout the world and, on many mountainous areas they form a dominant part of the vegetation.

The group has a long history which dates back to at least 200 or 300 million years. Their long evolutionary history contains many examples of organisms that existed and flourished for some duration and then became extinct as a result of changes in climate, topography and biological competition. Of the living (extant) gymnosperms, some have a long fossil history and are aptly called "**living fossils**".

Gymnosperms as a group are most fascinating not only because they possess some characters common to both the cryptogams and the flowering plants (angiosperms), but also because of their great importance in forestry. In the earlier blocks you have studied about the various groups of organisms from microbes to pteridophytes. In order to have a complete picture about the diversity ranging in the plant kingdom, it is necessary to learn about the gymnosperms, which constitute a small but important part of this range.

Objectives

After studying this unit, you should be able to:

- differentiate between angiosperms and gymnosperms;
- describe the distribution of gymnosperms and enlist their main morphological features;
- describe their anatomical characters and describe the mode of reproduction and depict the typical life-cycles diagrammatically; and
- categorise the various gymnosperms and know their classification.

19.2 DISTRIBUTION AND GENERAL CHARACTERISTICS

19.2.1 Distribution

The gymnosperms are represented in nearly all parts of the world. The extant Cycadales and Ginkgoales are very ancient and with a long fossil history. For this very reason and few other characters, they are called "**living fossils**". Though these orders were well represented in the past, but presently the cycads are represented by only 11 genera and Ginkgoales by a single species, *Ginkgo biloba.* They now show only limited distribution in the tropical and subtropical regions. They do not form a major part of the vegetation on the earth. Cycads such as *Chigua, Dioon*, *Ceratozamia, Zamia* are native to Western Hemisphere while genera *Encephalartos, Stangeria, Lepidozamia, Macrozamia, Bowenia* and *Cycas* are restricted to Eastern Hemisphere. Only *Cycas* is found in Indian subcontinent.

The conifers (Coniferales) are the most conspicuous and largest group of gymnosperms and contain many economically important plants. The conifers are represented by over 50 genera which are distributed in nearly all parts of the globe. Araucariaceae and Podocarpaceae are the key families found in the Southern Hemisphere. Taxodiaceae and Cupressaceae are equally represented in both Northern and Southern Hemispheres. Taxaceae (which at times are not considered a true conifer because of their distinct reproductive morphology) occur mostly in North America, Europe and Asia.

The orders Ephedrales, Gnetales and Welwitschiales are monotypic and represented by the genera *Ephedra, Gnetum* and *Welwitschia*, respectively. These plants not only show restricted distribution but also have many interesting features in their morphology and reproductive biology. *Ephedra* occurs only in arid regions and in tropical and temperate Asia and America.

Gnetum grows in tropical rain forests of Africa, Asia and S. America. *Welwitschia* is restricted to South West Africa.

Nearly 20 genera of gymnosperms have been reported from the Indian subcontinent. Of these 14 genera are native. These include conifers namely *Abies, Cedrus, Larix, Pinus, Picea, Tsuga, Cephalotaxus, Cupressus, Juniperus, Podocarpus* and *Taxus*. Besides these, *Cycas, Ephedra* and *Gnetum* are also found in the wild state.

Several genera, introduced from outside, have also been established in the hills and plains of India, these include *Ginkgo, Biota, Thuja, Cryptomeria, Agathis, Araucaria, Cunninghamia* and *Taxodium.*

19.2.2 General Characteristics

Gymnosperms are a group of plants that differ from the angiosperms in many ways. They occur mostly in the temperate regions of the world and include mostly evergreen trees and shrubs that look extremely captivating. They are an asset to horticulturists and landscape architects. Their evergreen nature bestows on them the unique advantage of a year round aesthetic appeal.

A large number of gymnosperms are economically important, particularly in forestry, horticulture and as a source of resins, drugs, essential oils and even edible seeds. The economic importance of gymnosperms will be dealt in Unit 22 of this block.

The seed plants (spermatophytes, which include both gymnosperms and angiosperms) are characterized by a very complex, large, independent sporophytic generation and a much reduced gametophytic generation which is dependent on the former. But first we must study some salient features of Gymnosperms and Angiosperms so that you will be able to appreciate the difference between them.

Characteristics of Gymnosperms

1. Plants are sporophytes, having true roots, stems and leaves.
2. Sporophytes large, perennial with active cambium producing secondary xylem. Most of them lack xylem vessels, except *Ephedra*, *Welwitschia* and *Gnetum*.
3. Sporangia borne on sporophylls which together form cones.
4. All forms are heterosporous, and the two kinds of spores produce male and female gametophytes.
5. True seeds (single megaspore retained inside a megasporangium, which in turn is enclosed by an integument); young sporophyte (embryo) is retained in ovule.
6. Gametophytes are small, dependent.
7. Pollen tube forms; pollination occurs by wind or insects.
8. Ovules and seeds borne naked (uncovered).
9. Archegonium with neck, VCC/VCN and egg.
10. Single fertilization i.e., one sperm involved in fertilization.
11. Free nuclear proembryo.
12. “Endosperm” is haploid; formed before fertilization .

Salient Features of Angiosperms (Flowering Plants)

1. Microsporangia borne on microsporophylls (anthers and filaments respectively) comprising of androecium.
2. Characterized by megasporangia (ovules) enclosed within one or more carpellary sporophylls which contain the ovary. Ovary together with style and terminal stigma constitutes gynoecium (pistil).
3. Subsequent to pollination and double fertilization, endosperm is triploid. Ovules develop into seeds within the ovary wall; leads to formation of fruit.
4. Presence of vessels in the xylem. Secondary xylem produces porous wood (some exceptions known).

Box 19.1: Living Fossils

The living representatives of the Ginkgophyta and Cycadophyta are called **living fossils**. *Ginkgo biloba* is the sole living member of the group and exists in the wild state only in certain mountains in south-east China. The cycads are also relics from the past age and are confined to some areas in the tropics and subtropics. The Cycadophytes (cycadeoids and cycads) were abundant during the Jurassic period (of geologic time scale) and it was during this time that the dinosaurs flourished. Hence, the cycads are also called "**dinosaurs of the plant kingdom.**"

SAQ 1

a) How will you define gymnosperms? How will you distinguish them from angiosperms (Give any 5 points).

b) Match the items given in column A with those of column B.

	Column A		**Column B**
i)	The gymnosperm that has vessels	a)	Haploid
ii)	The seeds of gymnosperms	b)	Conifers
iii)	Endosperm of gymnosperms	c)	*Gnetum*
iv)	Presently the largest group of gymnosperms distributed all over the globe	d)	are exposed and uncovered

19.2.3 Morphology

The gymnosperms include both large trees and woody shrubs. A few may be lianas or climbers (*Gnetum*) or rhizomatous (*Stangeria paradoxa,* *Encephalartos villosus, Macrozamia* sp.). Most gymnosperms are evergreen; a few such as *Larix and Taxodium* are deciduous. A large number of genera exhibit xerophytic characters.

The tallest trees in the plant kingdom belong to the gymnosperms. In California, USA, the two species of living red woods are renowned for their size, height and longevity. It is not uncommon for *Sequoia sempervirens* (Coastal or California redwood) to attain a height of 90 meters (295 feet) and one tree in Humboldt County, California with a height of 111.6 meters (366.2 feet) is believed to be the tallest tree in the world. The other species *Sequoiadendron giganteum* usually referred to as "Big Trees" or Giant Redwood (and confined to the eastern slopes of California) does not become quite as tall as the coastal redwood but exceeds it in total size. The 3,500 years old "General Sherman" tree in Sequoia National Park, for example is, 31 meters (101.5 feet) in circumference, 83 meters tall and it weighs 5,594 metric tons (6167 tons). (Fig.19.1) "Pine Alpha" is over 4,800 year old specimen of bristlecone pine (*Pinus longaeva*) growing in California.

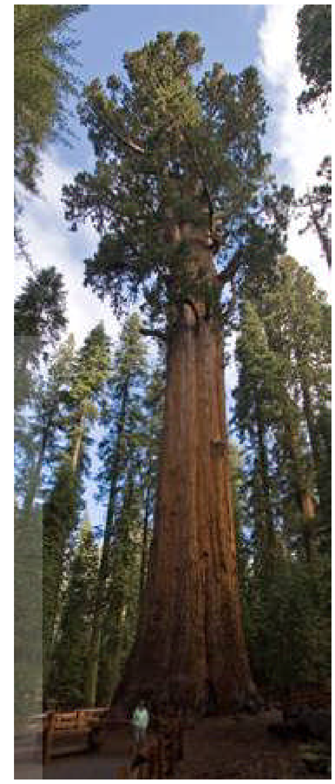


Fig. 19.1: *Sequoiadendron giganteum.*

The smallest recorded gymnosperm is a cycad, Zamia *pygmaea*, which is merely 3 to 4 cm tall.

Morphology of Root, Stem and Leaves

Root: The gymnosperms possess a tap root system. Some genera such as *Cycas* also show the development of coralloid roots while *Pinus* and other conifers show the presence of mycorrhizal roots. Both of these are symbiotic associations (with blue green algae and fungi respectively) that help in the nutrition of the plant. In mycorrhizal roots the mycelium of fungus forms an enveloping sheath called "Hartig net". You have already read about them in Unit 11(Block 3) of the course.

Stem: Aerial trunks are mostly branched. Unbranched stem is characteristic of cycads. Shoots may be dimorphic having long and dwarf shoots. Long shoots have an apical bud which grows indefinitely and bears scaly leaves while dwarf shoots arise on the long shoot in the axil of scaly leaves and have limited growth. Dwarf shoots bear leaves at their apices, and the whole structure is called a spur shoot in *Pinus.*

Leaves: Leaves show great variation in form and arrangement. The leaves may be large (megaphylls) or small (microphylls). Both simple and compound leaves occur: the shape also ranges from pinnate or fern-like in cycads to needle-like in *Pinus*. Leaves of *Ginkgo* are fan shaped, and those of *Gnetum* superficially resemble dicots. In *Welwitschia* they are strap shaped and persist throughout the life of the plant. In gymnosperms the foliage leaves are usually evergreen and protected by a thick cuticle. Besides foliage leaves, scale leaves may also be present.

Arrangement of leaves on the stem is highly variable. They are generally spirally arranged but may be whorled as in *Cedrus* or opposite decussate as in Cupressaceae and *Gnetum* (see Fig. 19.2).

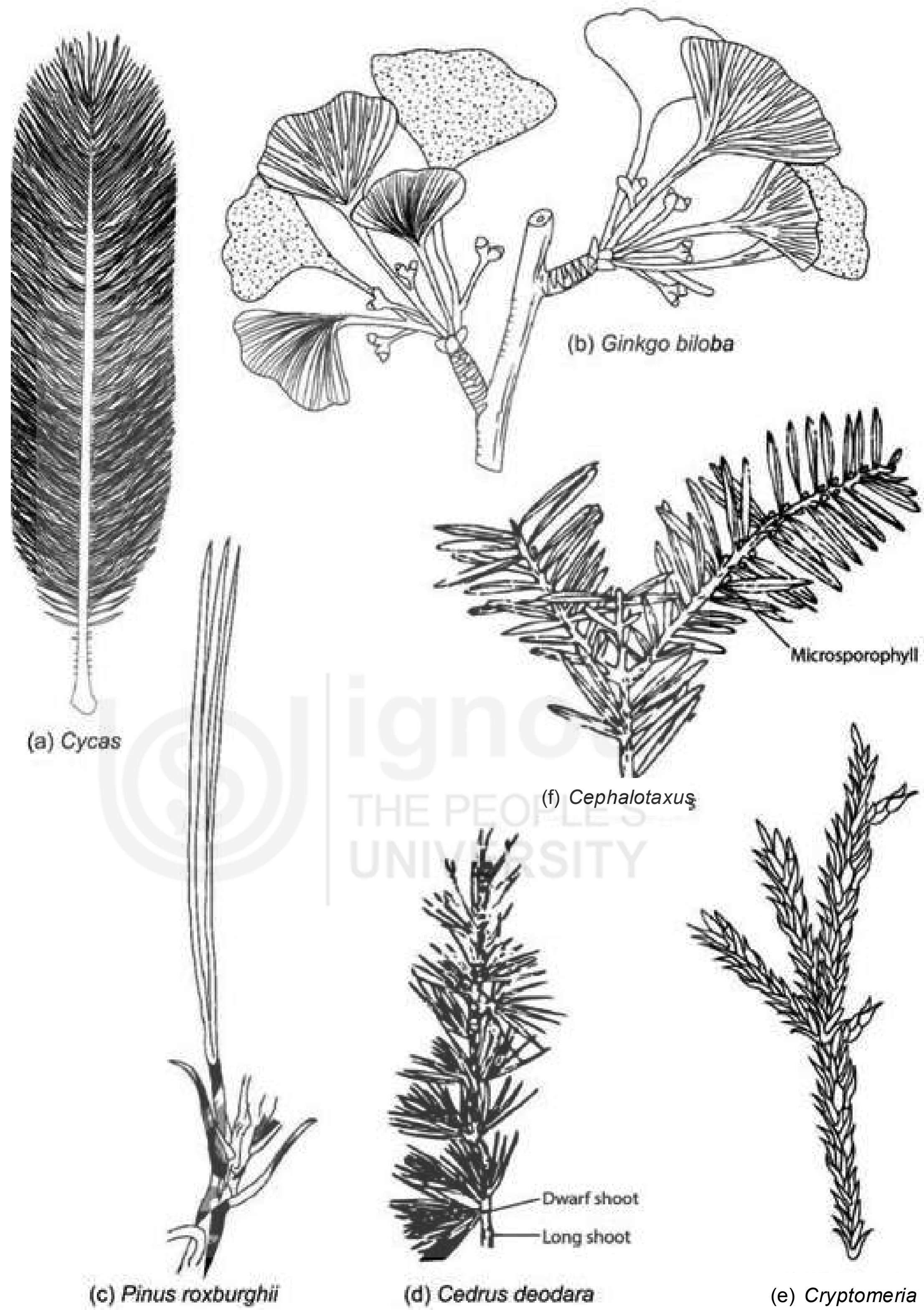


Fig. 19.2: Variations in leaf morphology amongst gymnosperm (Note these are not drawn to the same scale).

The venation also ranges from single veined in most genera to reticulate (*Gnetum*), parallel (*Agathis* and *Welwitschia*) and even dichotomous (*Ginkgo*). Resin canals occur in all conifers except *Taxus*. Stomata are usually sunken (a xerophytic character).

SAQ 2

Match items given in column A with the words/names given in column B.

	Column A		Column B
i)	Only 2 leaves are formed	a)	*Zamia pygmaea*
ii)	Leaves are fan-shaped	b)	Almost all the conifers
iii)	Mycorrhizal roots are present	c)	*Welwitschia*
iv)	The smallest gymnosperm	d)	*Taxus*
v)	Leaves superficially resemble dicots	e)	*Sequoia*
vi)	Tallest tree	f)	*Ginkgo*
vii)	Resin ducts are absent	g)	*Gnetum*

19.2.4 Anatomy

In the young stem (primary) open, collateral, endarch vascular bundles occur in a ring. Secondary growth takes place due to the activity of vascular cambium. The wood is characterised by absence of vessels (exceptions are *Gnetum, Ephedra* and *Welwitschia*). The wood comprising tracheids and parenchyma is referred to as "softwood" where the xylem fibres are absent in contrast to "hardwood" in dicots (angiosperms). There are two types of wood namely manoxylic and pycnoxylic (see Box 19.2). Phloem possesses albuminous cells. The companion cells are absent.

In roots the xylem is di-to polyarch. Tracheids constitute the major part of xylem. An important feature of gymnosperm leaf anatomy is the presence of transfusion tissue.

Box 19.2: Manoxylic and Pycnoxylic wood

There are two types of wood, namely manoxylic and pycnoxylic, depending on the amount of wood parenchyma present in it, and the size of the pith. The pycnoxylic wood is compact, has narrow xylem rays and contains small cortex and pith. On the other hand, manoxylic wood has lesser xylem and more parenchyma present in wider rays, larger pith and cortex. Pycnoxylic wood forms the main component of the trunk, hence such wood is commercially important. Manoxylic wood is not important commercially. There is another aspect: the manoxylic wood is found in forms with megaphylls and radially symmetric seeds (radiospermic) e.g. cycads; pcynoxylic wood is associated with microphyllous leaves and bilaterally symmetric seeds (platyspermic) e.g. conifers.

19.3 REPRODUCTION

Vegetative methods of reproduction are rare in gymnosperms, but cycads do propagate through bulbils. You will study about bulbils of *Cycas* in Unit 20 of this block.

Sexual Reproduction

Gymnosperms are heterosporous producing two kinds of spores in different spore-bearing structures: microsporangium or pollen sac and megasporangium or ovule.

The gymnosperms may be monoecious (*Pinus, Cedrus*) or dioecious (*Cycas, Ephedra, Ginkgo*, and bear male (Fig. 19.3) and female (Fig. 19.4) cones, except in female *Cycas* plant. The position of the strobili on the plant varies from terminal to lateral.Microsporangia are borne on the abaxial or lower surface of the microsporophyll. Ovules are generally borne on the adaxial or upper surface of the megasporophyll or the ovuliferous scale. The ovule is generally orthotropous. The spore mother cells contained in the sporangia undergo meiosis to form the microspores and megaspores respectively that represent the first cell of the haploid or gametophytic generation.

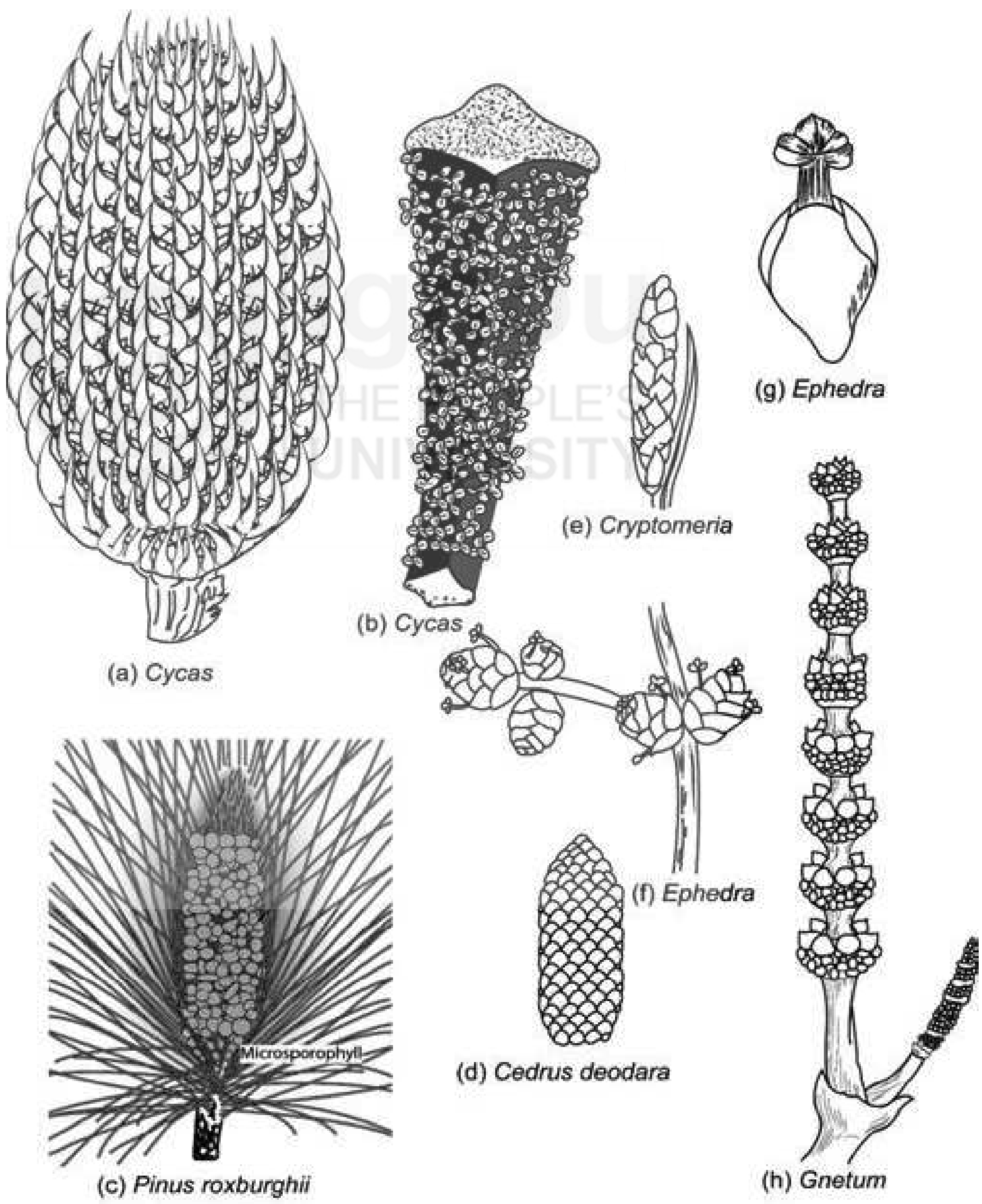


Fig.19.3: a-h) Various types of male cones, the male reproductive structures is gymnosperms (Note these are not drawn on same scale).

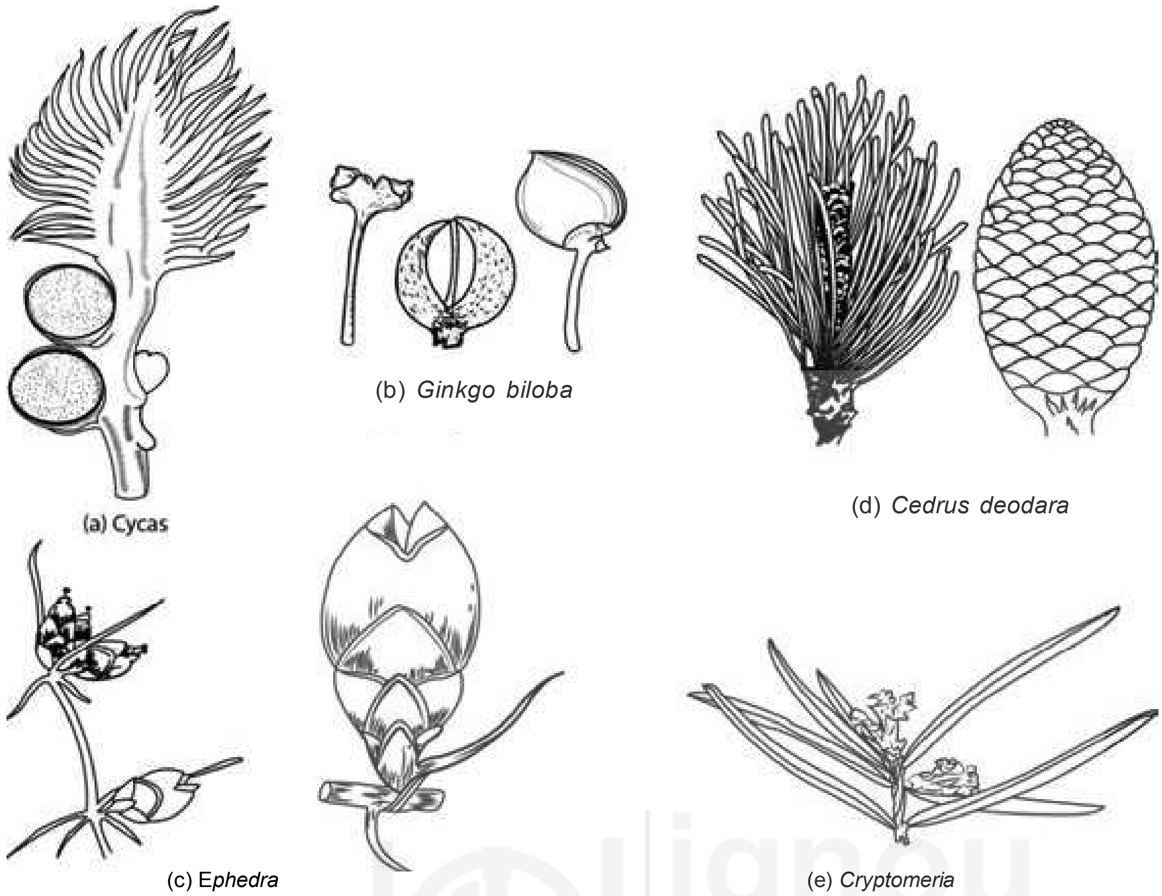


Fig. 19.4: a-e) Various types of female cones and the female reproductive structures in gymnosperms (Note these are not drawn on same scale).

19.3.1 Microsporangium and Male Gametophyte

During the development of the microsporangium, the initials from archesporial tissue form wall layers and sporogenous cells. The latter gives rise to microspore mother cells which divide meiotically to form tetrads of microspores. Each microspore undergoes mitotic division to form one or more prothallial cells, and an antheridial initial. The latter finally forms the male gametes.

The development of male gametophyte being endosporic, it takes place partly in the microsporangium and partly in the pollen chamber of the ovule.

At the time of shedding, the pollen grains are usually multicelled and contain one, two or more prothallial cells, tube nucleus and antheridial cell. In Cupressaceae, Taxodiaceae, Cephalotaxaceae and Taxaceae, pollen are shed at the uni-nucleate stage and the gametophyte development continues after pollination.

The pollen grains are winged (*Pinus, Podocarpus*) or non-winged (*Cycas, Ginkgo*). The male gametophyte either lacks a prothallial cell (*Taxodium, Cephalotaxus*) or its number ranges from one (*Cycas*) to 32 (*Agathis, Araucaria*). The male gametes are flagellate (*Cycas, Ginkgo*) or non-flagellate (*Pinus, Cedrus*). Flagellate male gamete is a characteristic feature of pteridophytes.

19.3.2 Ovule and Female Gametophyte

The ovules as you know are **naked** (i.e., they are not enclosed by megasporophyll or the subtending structures) and are borne on the adaxial surface of the megasporophylls which, in turn, are generally arranged spirally around a central cone axis. The ovules are sessile and orthotropous and each consists of a parenchymatous mass of cells called the **nucellus** or the **megasporangium**. The nucellus becomes enveloped by a single massive **integument** that grows around it leaving a small opening or the **micropyle** at the tip. The megasporangium enclosed by the integument is called an ovule. The nucellus contains a single diploid **megaspore cell** that undergoes **meiosis** to form a tetrad of **haploid megaspores** of which only one remains functional while the other three degenerate.

The functional chalazal megaspore enlarges and undergoes **free nuclear divisions**. Thus the young gametophyte develops within the megaspore. Centripetal wall formation (wall formation starts from periphery and proceeds inwards) starts around the free nuclei of the female gametophyte (for alveolus formation see Unit 21) which goes on until the whole gametophyte becomes cellular. This is the female gametophyte which also serves as endosperm. You will study in detail later in Units 20 and 21.

The apical region of the nucellus degenerates to form a **pollen chamber** in which the pollen grains will come and lie until further growth. Female sex organs or **archegonia** develop towards the micropylar end of the female gametophyte. *Gnetum* and *Welwitschia* lack distinct archegonia.

19.3.3 Pollination and Fertilization

Pollen grains are carried to the ovule and this is followed by fertilization. The male gametes are carried to the egg by means of the pollen tube. Syngamy (or fertilization) between two haploid gametes (male and female) restores the ploidy level of 2n. The new sporophyte is first represented by the zygote that later develops into embryo. Thus the cycle is complete. There is distinct alternation of generations.

Pollination is gymnosperms usually take place by means of wind (Anemophily) (See Box 19.3) and abundant pollen production ensures pollination. Entomophily has been reported in *Cycas, Ephedra, Gnetum* and *Welwitschia*.

A **pollination drop** is secreted by the ovule at the tip of the micropyle and this captures the wind-borne pollen. The partially developed male gametophytes are drawn or sucked into the ovule by the drying of the pollination drop. The exudate not only receives the pollen but also places them close to the nucellus. The pollen now lies in the pollen chamber or on the nucellus, in close proximity to the archegonia.

Box 19.3: Siphonogamous and Zooidogamous plants

The term "siphonogamous" has been used to collectively designate plants in which the sperms are directly transported to the egg by means of a pollen tube. Lower vascular plants, by contrast, have been designated as "zooidogamous" because the motile flagellated sperm are freely liberated from the antheridium into water through which they must swim (often for some considerable distance) to reach and fertilize the eggs. The evolutionary steps in the transition from zooidogamy to siphonogamy are by no means very clear, but the development of sperm-carrying pollen tubes typical of higher gymnosperms and of all angiosperms was surely a significant achievement. By means of the pollen tube the considerable chances and hazards of the aquatic zooidogamous method were eliminated and much greater assurance of fertilization was made possible. Among living gymnosperms, cycads and *Ginkgo* appear to have a primitive type of pollen tube which serves primarily as an haustorium. It seems significant in this connection that these are the only known living seed plants to have retained the flagellated type of sperm.

In the gymnosperms pollination may not be immediately followed by fertilization: sometimes a very long interval elapses between the two phenomena. During this intervening phase (called as resting phase), the ovule shows many changes and gets ready for fertilization. The micropyle is closed and the ovule enlarges in size. The pollen grains on reaching the nucellus germinate immediately or after a resting period. The pollen tube reaches the female gametophyte and finally makes contact with the neck of the archegonium.

SAQ 3

Fill in the blanks:

a) The integumented megasporangium in gymnosperms is known as ....

b) The wind borne pollen are captured by .... secreted by ovule.

c) In *Cycas* and *Ginkgo* pollen tube acts mainly as ....

19.3.4 Embryogeny

Proembryogeny in gymnosperms is quite variable. In gymnosperms (except *Sequoia* and *Welwitschia*) the initial phase of embryo development is free nuclear. In *Pinus* there are only eight free nuclei; in cycads as many as 256 or 572 free nuclei may be formed. Later wall formation starts and a cellular embryo is produced. It differentiates (at maturity) into suspensor, radicle, hypocotyl, plumule and cotyledons. The shoot end of the embryo is away from the micropyle.This kind of embryogeny is called endoscopic.

19.3.5 Polyembryony

Formation of many embryos in a single gametophyte is of common occurrence among gymnosperms. Simple or archegonial polyembryony is very frequent because more than one archegonium may be fertilized. In conifers there is **cleavage polyembryony**. Physiological competition eliminates all but one embryo that reaches maturity within a seed.

19.3.6 Mature Seed and Germination

The formation of seed is the result of fertilization and consequent enlargement of the ovule. The zygote develops into an embryo, and the endosperm is formed from the persisting female gametophyte (which provides nutrition). The nucellus gets disorganised and is visible at the micropylar tip of the seed as a thin cap. The integument forms the seed coat.

The *seed is remarkable combination of two sporophytic and one gametophytic generation.*

1. The seed coat is the old sporophyte.
2. The embryo is the new sporophyte.
3. The endosperm is the persistent female gametophyte.

The number of cotyledons varies from two to many. The detached seeds of gymnosperms remain dormant and undergo a prolonged period of rest. With the onset of favourable conditions the embryo again resumes its growth by rupturing the hard seed coat and develops into a new plant. Germination is epigeal in most genera, i.e., the cotyledons emerge above the ground.

In *Cycas* and *Ginkgo* the seeds show no dormancy, they germinate immediately on falling on a suitable substrate or else they lose their viability.

SAQ 4

a) Write whether the statement is true or false in the given brackets. Write **T** for true and **F** for false statement.

   i) The embryogeny in gymnosperms is endoscopic. [ ]

   ii) In gymnosperms always only one embryo develops in a single gametophyte. [ ]

   iii) Seed coat in a seed represents old sporophyte. [ ]

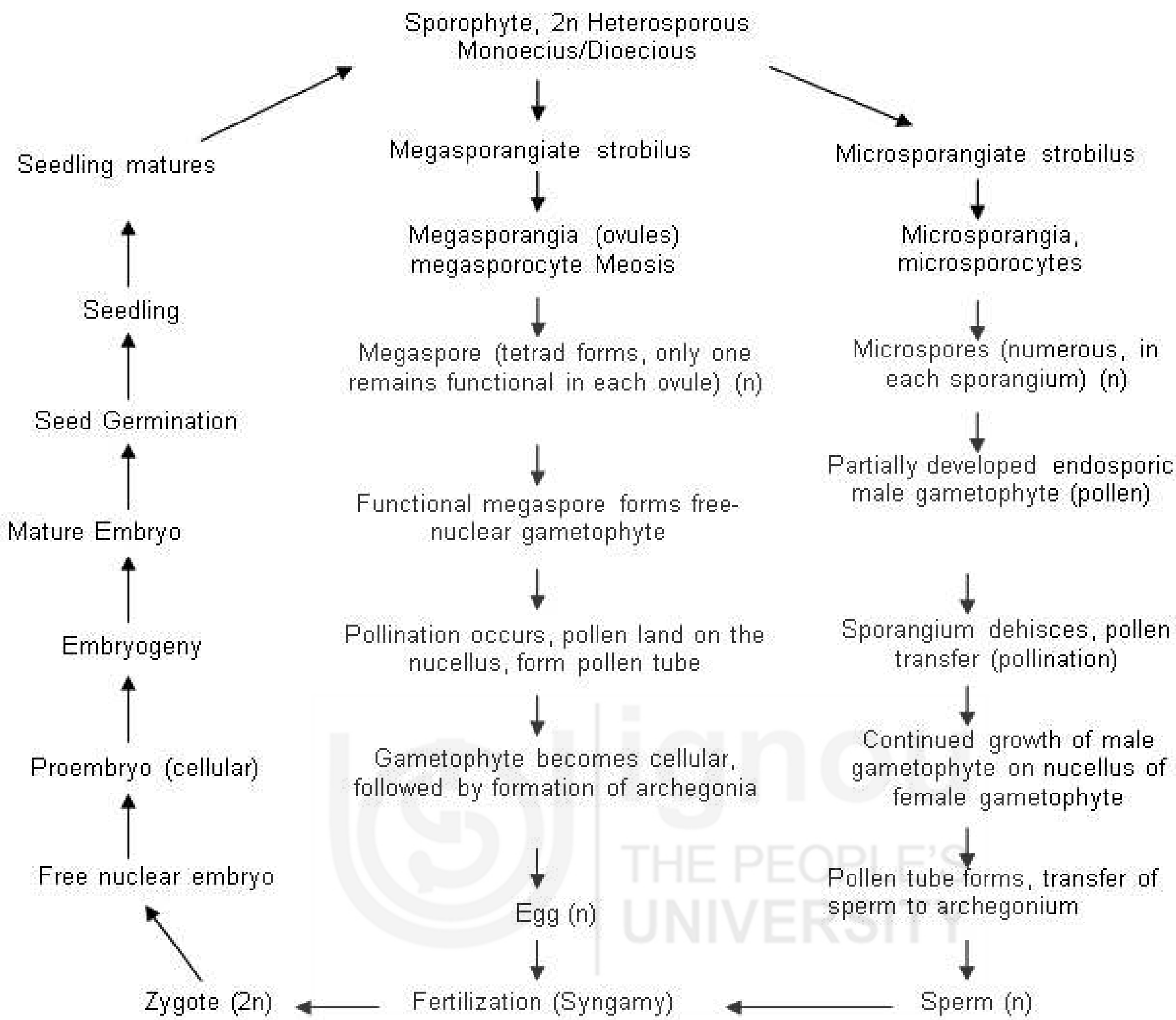
   iv) *Cycas* seeds exhibit prolonged dormancy. [ ]

   v) In *Cycas* embryo possesses 2 cotyledons. [ ]

b) Write a short note on polyembryony in Gymnosperms.

c) List three characteristics that all modern gymnosperms share with their ancient forms.

Various reproductive events in the life of a gymnosperm are summarized as follows:



19.4 PATTERNS OF LIFE CYCLE

The reproductive phases in gymnosperms are spread over a long period of time. Information on this aspect is important to foresters and plant breeders. Since many gymnosperms belong to the temperate areas, their activity is slowed down during the winter period. As a result, not only cambial activity comes to a halt, but development of reproductive structures also gets restricted and this activity is renewed in spring.

Duration of Reproductive Cycle

The male cones of most temperate or subtropical conifers take less than a year from initiation to shedding (pollination). Unlike the angiosperms where time lag between ovule initiation and seed maturity is short (few weeks), in gymnosperms the same process may take a much longer duration. The only exception appears to be *Ephedra* where the process is completed in about 3-4 months. Most other gymnosperms show 1-, 2-, or 3-year type of reproductive cycle. The counting of years is based on the number of winter rests followed by renewed growth in spring, that the ovule passes through. Most species of a genus show a similar type of reproductive cycle, but some exceptions do occur (*Podocarpus, Juniperus* and *Pinus*).

The cycads do not easily fit into this scheme of cycles partially because of lack of detailed information and more importantly because most of them are tropical or subtropical, and thus do not undergo winter rest.

A convenient method to represent the life cycle of gymnosperms with regard to time of the year using certain symbols is shown in the figure (Fig. 19.5) below. These symbols have been used in all subsequent diagrams. The numbers represent the months of year. The seasons of the year have also been indicated since they vary in the North and Southern Hemispheres.

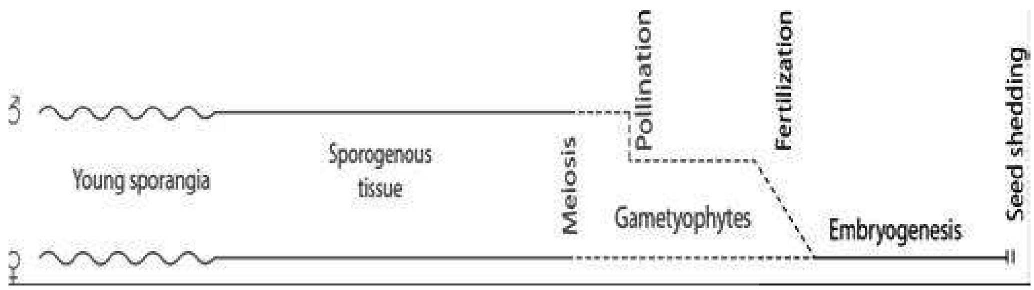


Fig. 19.5: Major events/stages in the reproductive cycle of a gymnosperm represented by different types of lines (wavy, straight, broken and parallel). These lines have been used in the subsequent four diagrams of life cycles in this chapter (after Singh, 1978).

A generalised Type of One-year Cycle showing male cone initiation in summer and female cone in autumn, overwintering in the sporogenous stages, pollination during spring, fertilization in summer and seed matures before onset of next winter.

One-year Type of Reproductive Cycle: In the reproductive cycle of *Cedrus deodara* as it occurs in the Western Himalayas. Pollination occurs in autumn and development of gametophytes also starts at the same time (Fig. 19.6 a).

One-year Type of Reproductive Cycle: In *Gnetum ula* this type of life cycle occurs in the Western Ghats. In this case embryogeny continues even after seed shedding in summer (Fig. 19.6 b).

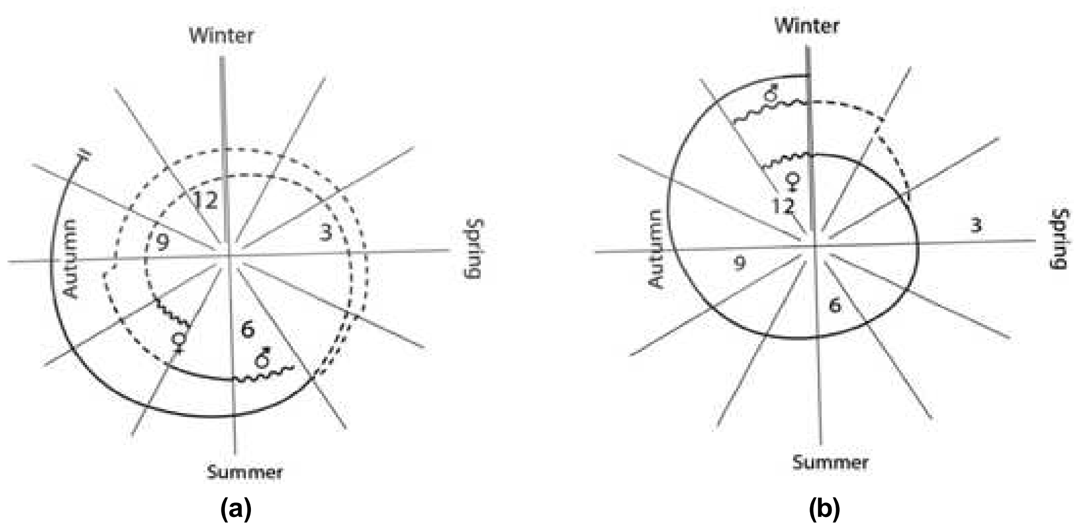


Fig. 19.6: a) One-year type life cycle represented by *Cedrus deodara;* a) and b) *Gnetum ula;* as occurring in Western Himalayas and Western Ghats of India, respectively. The numbers represent the months of the year. Pollination and development of gametophytes in *Cedrus* take place in autumn. The seeds in *Gnetum* are shed in summer but the embryogeny continues. (after Singh, 1978).

Two-year Type of Reproductive Cycle

This type of reproductive cycle occurs in *Ginkgo biloba* where pollination takes place in the spring of the first year and fertilization takes place in the early autumn of the same year but embryogeny lasts much longer and continues even after the seeds are shed (Fig. 19.7).

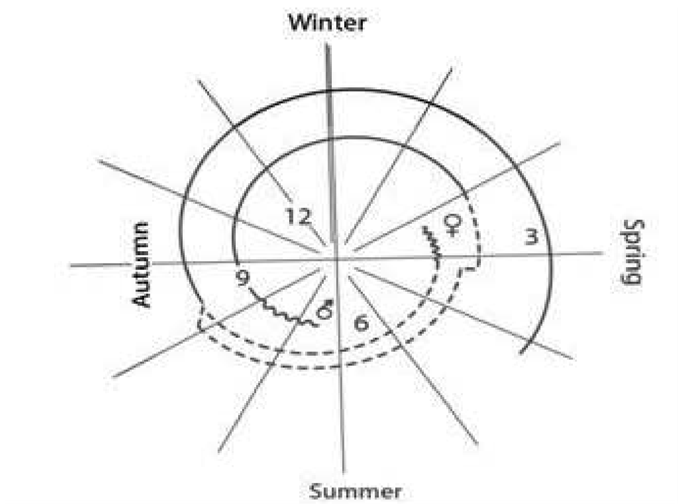


Fig. 19.7: Two-year type of life cycle in *Ginkgo biloba.*

Three-year Type Reproductive Cycle

In *Pinus roxburghii* the ovules are pollinated in spring of the first year and get fertilized in the spring of third year. Thus the time lapse is of two years. Seed shedding occurs in autumn (Fig.19.8).

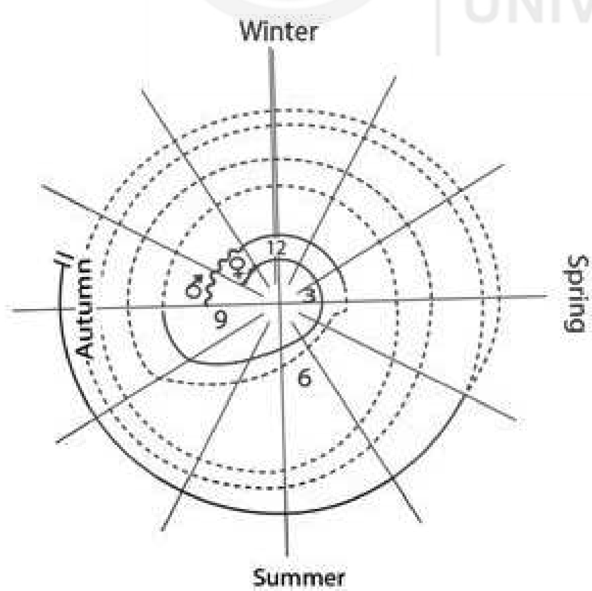


Fig. 19.8: Three-year type of life cycle in *Pinus roxburghii.*

Reproductive Cycles in Cycads

Cycas circinalis is found in South India. *Cycas* shows pollination in the first year winter, fertilization in second year summer i.e., after five months, and seed shedding in third year summer and embryogeny continues even after the seeds are shed (Fig.19.9).

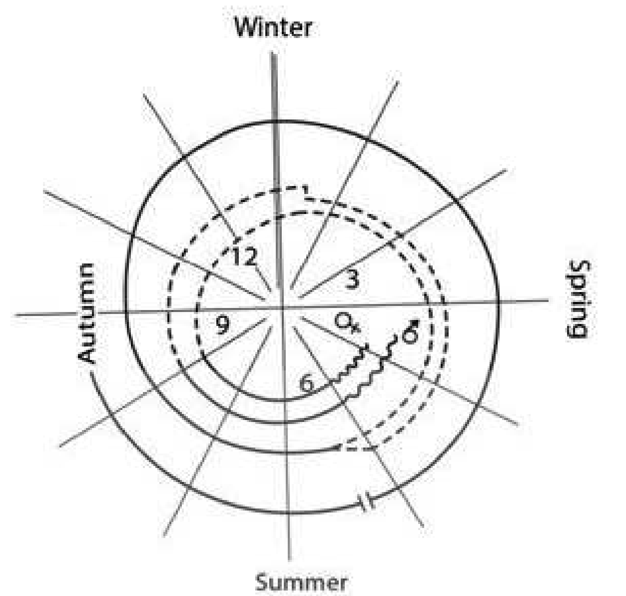


Fig. 19.9: Three-year type of life-cycle in *Cycas circinalis*.

19.5 CLASSIFICATION OF GYMNOSPERMS

Gymnosperms being an important group of plants have been variously classified by different workers. The classification being followed in this unit is after Bhatnagar and Moitra (1996). Details of these are given below:

Gymnosperms comprise both living (extant) and fossil (extinct) groups. This classification lists the various families of this group. You do not have to memorise this classification. It is given because you must have an idea about all the classes, order and families of gymnosperms.

Class I: Progymnospermopsida

Order	Aneurophytales	Only fossils
Family	Aneurophytaceae	
Order	Archaeopteridales	
Family	Archaeopteridaceae	
Order	Protopityales	
Family	Protopityaceae	

Class II: Cycadopsida

Order	Pteridospermales	Only fossils
Family	Calamopityaceae, Lyginopteridaceae Medullosaceae, Callistophytaceae	
Order	Glossopteridales	
Family	Glossopteridaceae	
Order	Caytoniales	
Family	Caytoniaceae, Corystospermaceae Peltaspermaceae	

Order Cycadales

Family Cycadaceae, Zamiaceae Living and fossil

Order Cycadeoidales (= Bennettitales)

Family Williamsoniaceae, Wielandiellaceae

Cycadeoidaceae Only fossils

Order Pentoxylales

Family Pentoxylaceae

Class III: Coniferopsida

Order Ginkgoales

Family Ginkgoaceae

Order Czekanowskiales

Family Czekanowskiaceae

Order Cordaitales

Family Cordaitaceae Only fossils

Order Voltziales

Family Voltziaceae

Order Coniferales

Families: Pinaceae, Taxodiaceae, Cupressaceae, Podocarpaceae, Araucariaceae, Cephalotaxaceae, Taxaceae.

Class IV: Gnetopsida

Order Ephedrales

Family Ephedraceae

Order Gnetales

Family Gnetaceae

Order Welwitschiales

Family Welwitschiaceae

19.6 CONSERVATION OF GYMNOSPERMS

The gymnosperms comprise only a very small portion of the flora of the world. The conifers are mostly restricted to temperate regions where they form large belts of forest area. This group consists of tall, perennial trees prized for their timber and other products like resin and pulp. The need today is to identify and propagate “elite” (or superior) trees with desired characteristics, i.e., better yield, disease and pest resistance. Screening and conservation of natural germplasm is thus essential.


Fig. 19.10: Seedling of *Cycas.*

The cycads and *Ginkgo* are some of the most ancient groups of plants present on the earth. Their natural habitats are facing pressures from civilization and are rapidly diminishing in size. These "Living fossils" would become extinct if they are not conserved by man. Both *in situ* and *ex-situ* measures are required for this.

Gymnosperms have been screened for their medicinal and food value and some like *Taxus* have shown promise as a cure for cancer. In future other members of the group may also prove to be economically important; hence there is an urgent need to conserve them.

The conifers include the world's tallest, oldest and most massive living biological organisms. As a whole, they are, with few exceptions, large statured woody plants providing most of the timber to the world. Much of the world's timber from conifers is traditionally gathered by direct exploitation of entire wild strands of trees. The exploitation is to such a great extent that in nature their population have declined drastically, especially in many tropical and southern insular regions of the world. Many of the wild species, providing the most valuable timber are slow growing but little work has been done for replanting the same species and if any replacement is done that too is with a few, introduced fast growing species such as *Pinus*. Hence now wide spread conifer species are especially of *Pinus*. Thus many other localized conifer populations are highly vulnerable and aged specimens, once common, are rare.

A specialist conifer conservation group of the International Union for the Conservation of Nature and Natural Resources has been established with its Secretariate at the Royal Botanic Gardens, Edinburgh. Some conservation backup, on an extremely modest scale, can be undertaken in conifers through seed banks and through the establishment of small selections of genetic material under cultivated conditions, sometimes species which are far from their original homes. But the slow rates of growth and very great age of some taxa cannot be matched in brief periods of cultivation. Thus successful preservation of whole strands of unfelled wild trees is essential if the greater part of these immensely useful genetic resources is not to be wholly lost for the future.

19.7 SUMMARY

In this unit you have studied that:

- Gymnosperms differ from angiosperms in their morphology, anatomy and mode of reproduction.
- Ovules and seeds are naked and uncovered.
- The sporophytes are large and perennial; whereas gametophytes are highly reduced and dependent on sporophyte.
- Single fertilization (exceptions *Ephedra* and *Gnetum*) i.e., one sperm involved in fertilization. Pollen tubes carry male gamete to the egg cell.
- The tallest trees are redwoods and big trees, both are gymnosperms.
- Gymnosperms are economically very important plants but due to their economic value and slow growth they are diminishing rapidly thus their conservation is much needed.

19.8 TERMINAL QUESTIONS

1. Enumerate differences between Gymnosperms and Angiosperms.
2. Describe pollination and fertilization in gymnosperms.
3. Why is the seed of gymnosperms considered having remarkable combination of two generations?
4. "Gametophytic generation is dependent on the sporophytic generation in gymnosperms". Comment upon this statement.
5. Write notes on the following:
   i) Distribution of gymnosperms
   ii) Manoxylic and pycnoxylic wood
   iii) Siphonogamous and zooidogamous plants
   iv) Polyembryony in gymnosperms
   v) Pollination drop
6. Describe patterns of reproductive cycles in gymnosperms with proper diagrams.

19.9 ANSWERS

Self-Assessment Questions

1. a) See Subsection 19.2.2 – Characteristics of Gymnosperms and Angiosperms and write any 5 points.

   b) i) c)

   ii) d)

   iii) a)

   iv) b)

2. i) c)
   ii) f)
   iii) b)
   iv) a)
   v) g)
   vi) e)
   vii) d)
3. a) Ovule
   b) Pollination drop
   c) Haustorium
4. a) i) T
      ii) F
      iii) T
      iv) F
      v) T
   b) See Subsection 19.3.4 – Embryogeny
   c) i) naked seed
      ii) single fertilization
      iii) haploid endosperm

Terminal Questions

1. See Subsection 19.2.2 – General characters.
2. See Subsection 19.3.3 – Pollination and Fertilization
3. See Subsection 19.3.6 – Mature Seed and Germination – point of reference and sporophytic tissues and gametophytic tissues both found in seed. Describe them in detail.
4. See Section 19.3 – Reproduction. Describe in detail how gametophytic generation is totally dependent on sporophytic generation in gymnosperms.
5. i) See Subsection 19.2.1.
   ii) See Box 19.2.
   iii) See Box 19.3.
   iv) See Subsection 19.3.5.
   v) See Subsection 19.3.3.
6. See Section 19.4 – Pattern of Life Cycle.

GLOSSARY

Cone	:	A compact aggregation of non-photosynthetic sporophylls along an axis.
Dwarf shoot	:	Branches of limited growth (short shoots) bearing prophylls and cataphylls.
Extant	:	Living organisms.
Extinct	:	Organisms are only known in the form of fossils.
Living fossil	:	Living organisms, that are sparsely distributed, and in danger of extinction. Majority of the related organisms are extinct.
Long shoot	:	Branches of unlimited growth, that bear an apical bud.
Manoxylic	:	Wood with lesser xylary elements and abundant in parenchyma; makes stem soft and commercially important. Pith, rays and cortex are large.
Ovule	:	An integumented megasporangiun.
Pyconoxylic	:	Compact secondary xylem, with narrow xylem rays, the stem has relatively less cortex and pith; important commercially; hard.
Scale leaf	:	Thin, brown, flattened, minutes structures borne on both long and dwarf shoots. Fall off with maturity of the branches. Wrap around base of needles.
Siphonogamy	:	Transfer of pollen grains to the ovule and female gametophyte though pollen-tube.

UNIT 20

GYMNOSPERMS: *CYCAS*

Structure

20.1 INTRODUCTION

In Unit 19 you have studied that class Cycadopsida consists of six orders: Pteridospermales, Caytoniales, Cycadeoidales, Cycadales, Pentoxylales and Glassopteridales. Of the above mentioned orders, members of five orders are extinct while Cycadales is the only order with living members.

Cycadales have a very ancient fossil history. They were common during the mid-Mesozoic era, and some of them are present even today. They are, therefore, also called 'living fossils'. On a casual glance all cycads resemble palms.The term 'cycads' refers to all the members belonging to Cycadales. They have a stocky, cylindrical stem bearing a crown of large, coarse, palm-like leaves. They, in fact, are true gymnosperms as their seeds are naked and are borne on modified leaves called sporophylls. Some scientists consider cycads as transitional stages between ferns and gymnosperms. The retention of ciliate male gametes, the characteristic of the lower plants (bryophytes and pteriodophytes), lends support to this assumption.

According to the system of classification,adopted by Bhatnagar and Moitra (1996) there are11 genera in the family – Cycadaceae.They exhibit an overall similarity in morphology, anatomy and reproductive biology. Most of the description in this Unit is based on *Cycas*, reference to features of special interest of the remaining genera will be made wherever necessary.

Objectives

After studying this unit, you should be able to:

- identify *Cycas* on the basis of its gross morphological, anatomical and reproductive characters;
- illustrate and describe the life cycle of *Cycas*;
- discuss the structural peculiarities of *Cycas* vis-à-vis the lower vascular plants, particularly the Filicales; and
- give reasons for the decline in the number of cycads all over the world and enlist the measures taken for their conservation.

20.2 DISTRIBUTION

Cycas is both cultivated and found growing wild. Its natural habitat is rather xeric and includes well-drained soil exposed to sun, and the sunny hill slopes. Table 20.1 illustrates distribution of *Cycas* in India.

Table 20.1: Distribution of *Cycas* in India

Species	Place of occurrence
C. beddomei	Hills of Cuddapah district of Tamil Nadu and Eastern Andhra Pradesh
C. pectinata	In the Sal Forests of Sikkim and Assam, Khasi Hills and Manipur
C. circinalis	In the deciduous forest of Western Ghats; and Orissa
C. rumphii	In the beach forests of Andaman and Nicobar Islands
C. revoluta *C. siamensis*	Cultivated in gardens

SAQ 1

Which of the items (i-v) are relevant to Cycadales?

i) Living fossils

ii) True gymnosperms

iii) Herbaceous plants

iv) Mesophytic

v) Cosmopolitan in occurrence

20.3 MORPHOLOGY

Armour of alternating bands of large and small leaf bases covers the aerial stem in a spiral manner (Fig. 20.1). The large leaf bases are the foliage leaves and the smaller ones are the scale leaves.

Two crowns of leaves are produced annually, one in spring and the other during monsoon coinciding with the favourable seasons of growth. The leaf

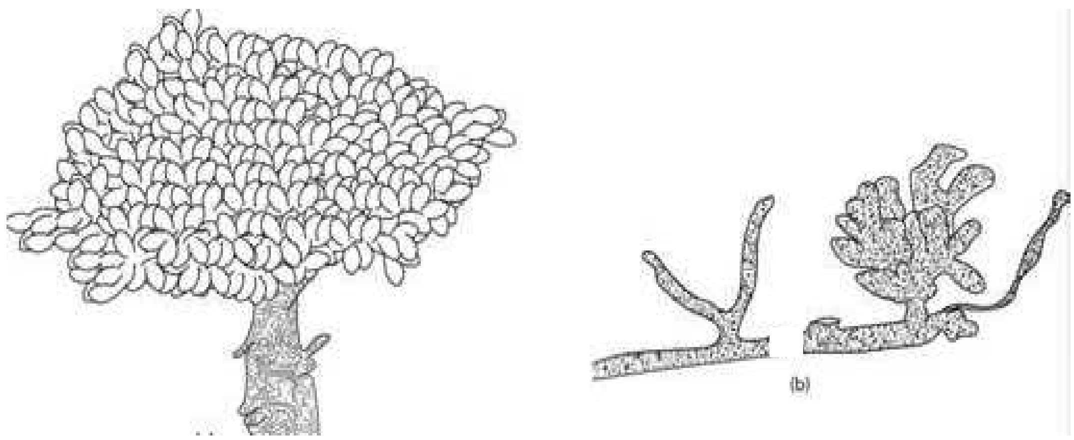
Fig 20.1: Diagrammatic sketches of: a) *Cycas circinalis*; b) *C. revoluta;* c) *C. rumphii.*

bases persist for many years, but abscise in the old trees. The trunk in such trees looks thinner in the lower region than in the upper region. The age of a *Cycas* plant can be determined by counting the number of leaf bases on the trunk and the number of leaves in the crown, and dividing this number by half as it includes the growth of two seasons in a year.

In this section the salient morphological features of vegetative structures namely root, stem and leaves are described.

20.3.1 Root

The primary root is a tap root which dies early and, in its place, an adventitious root system comprising large fleshy roots develops. Some of the roots near the soil grow upwards and from apogeotropic roots. These root branches copiously by repeated dichotomy forming dense, greenish or brown coral-like masses known as **coralloid roots** (Fig. 20.2) .Being apogeotropic, the coralloid roots also come out of the soil. It is believed that these roots, besides aiding in atmospheric nitrogen fixation, also act as aerating organs. In addition to the coralloid roots, non-coralloid aerial roots also occur in some species of *Cycas*. Such roots arise from the base of the bulbils or the leaf bases, and are positively geotropic. Both normal and coralloid roots have abundant lenticels on the surface.



(a) (b)

Fig. 20.2: *Cycas* sp. a) a bunch of coralloid roots; b) a part of a coralloid root enlarged (from Pant, 1973).

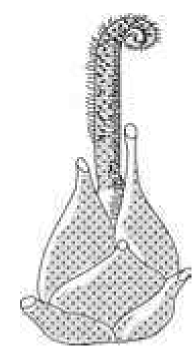


Fig. 20.3 : Bulbil of *Cycas* sp. Among the scale leaves a circinately coiled rudimentary leaf pinna can be seen (from Pant, 1973)

20.3.2 Stem

In its habit *Cycas* appears like a palm (Fig. 20.1). It possesses a columnar aerial trunk with a crown of pinnately compound leaves. The stem is normally unbranched but, sometimes, older trees do exhibit branching. A branch starts as a small bulbil (Fig. 20.3) which is actually an adventitious bud. The bulbil arises from the lower, fleshy region of the leaf base. Initially bulbil shows only scale leaves but with further growth, it starts producing a crown of leaves just like the main trunk and subsequently appears as a branch. The bulbils also serve as a means of vegetative propagation of plant, both artificially and in nature. Factors like physical injury enhance branching and one comes across highly branched *Cycas* trees in parks, whereas in an undisturbed condition they remain unbranched or poorly branched.

20.3.3 Leaf

Cycas produces two types of leaves, that is, it exhibits dimorphism. There are large, green foliage leaves and small, brown cataphylls or scale leaves. The scale leaves appear brown due to a heavy coating of bicelled hairs known as **ramenta**. Crowns of the foliage and regularly alternate with scale leaves.

The foliage leaves (Fig. 20.4 a) are unipinnately compound with numerous leathery, opposite or alternately arranged leaflets (= pinnae, singular-pinna) which are spine-tipped. The leaves have a long rachis and a short petiole. At the base of the petiole are present two rows of small stiff spines (Fig. 20.4 a arrows). The margin of the leaflet is either revolute as in *C. revolute* and *C. beddomei;* or flat, as in *C. circinalis, C. rumphii, C. pectinata*, and *C. siamensis*. A prominent midrib runs the entire length of the leaflet. The plant possesses fern-like characters such as straight or circinate rachis and circinate vernation of leaflets (Fig.20.4 b, c).

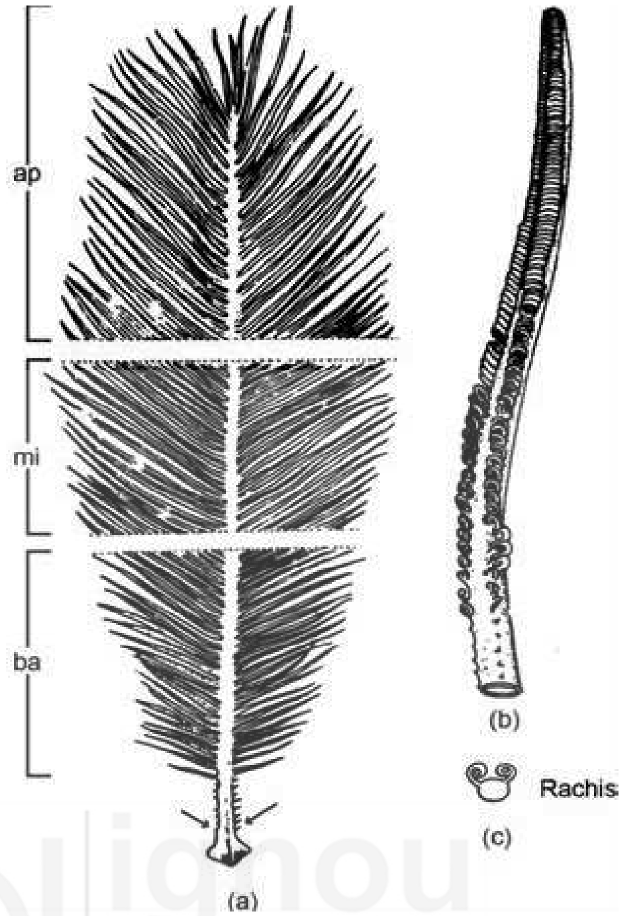


Fig. 20.4 : *Cycas revoluta.* a) Leaf sowing the apical (ap), middle (mi), and basal (ba) portions; b) Same, at younger stage showing unrolling of rows of circinate leaflets from base upwards, i.e., in acropetal succession; c) T. S. Young leaf showing two circinate leaflets on the rachis(a, After Pant, 1973; b and c after Gifford & Foster, 1989).

20.4 ANATOMY

In this section the salient anatomical features of vegetative organs such as root, stem and leaves are described.

20.4.1 Normal Root

The anatomical structure of a young, normal root of *Cycas* (Fig. 20.5 a, b) is similar to that of a dicotyledonous angiosperm. The xylem and phloem are radially arranged. The vasculature varies from diarch to triarch to polyarch condition, and the protoxylem is exarch. The centre of the root may be occupied by small parenchymatous pith or it may be occupied by metaxylem elements. The vasculature is surrounded by pericycle, which is often multi-layered, It is made up of thin-walled cells with abundant starch grains. An inner periderm often differentiated in this region. On the outer side is a single-layered endodermis. The endodermal cells are characterised by casparian thickenings. Next to the endodermis lies the cortex, which is several-layered and consists of parenchymatous cells with abundant starch grains. Occasionally sclerenchymatous cells and tannin-filled cells are interspersed in the cortex region. In addition, cells containing variously shaped

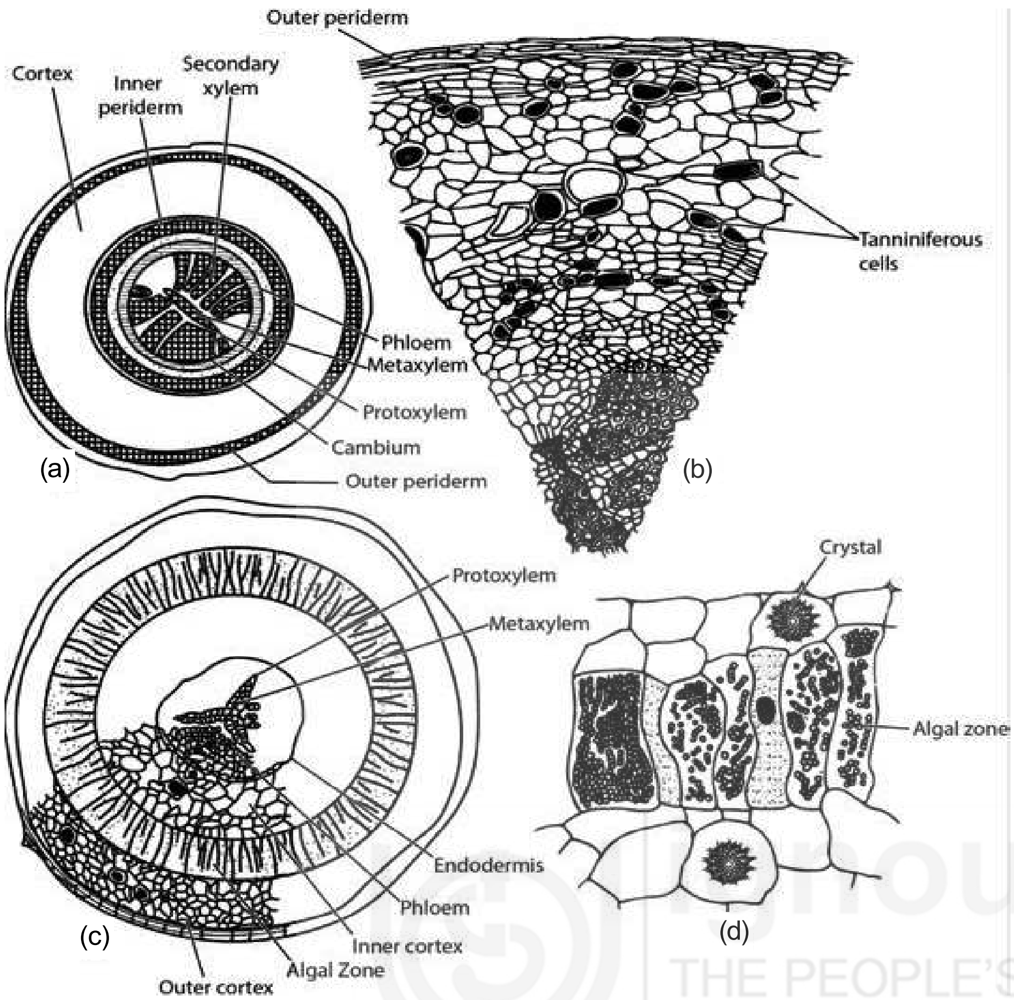


Fig. 20.5: *Cycas* sp. normal root (a, b) and coralloid root (c, d). a) Outline diagram of a transverse section of a normal root. Note the diarch condition; b) A sector of the normal root enlarged to show the cellular details; c) Outline diagram of a transverse section of a coralloid root. Mark the position of the algal zone; d) A part of the algal zone magnified to show the radially elongated cells containing the alga (a-c, after Pant, 1973; d, after Wettstein, 1935).

crystals are also commonly seen distributed in the cortex. The outermost layer is the epidermis. It develops root hairs behind the growing apex as in the other roots. Secondary growth begins with the development of arcs of cambium on the inner side of the phloem. The pericycle cells in between these arcs too become meristematic and join the arcs of cambium to form a complete cambial ring. The activity of the cambial ring generates the secondary xylem towards inside and the secondary phloem towards outside.

20.4.2 Coralloid Root

Anatomically the coralloid root is quite similar to the normal root except that it has a wider cortex with a well-defined algal zone almost in its middle (Fig. 20.5 c, d). This zone consists of thin-walled, radially elongated cell that are loosely arranged, having large intercellular spaces occupied by cyanobacteria such as *Anabaena* and *Nostoc*; some reports indicate the presence of algae such as *Ulothrix, Chroococcus* and *Calothrix*. The cortex consists of parenchymatous cells. A phellogen (cork cambium) and a few layers of cork cells are present on the periphery.

20.4.3 Stem

The stem has an irregular outline due to the persistent leaf bases. In a transverse section, large, parenchymatous pith occupies most of the central region and forms a major portion of the entire stem. The pith cells contain large amounts of starch – sago, which is commercially extracted from some species. Pith is surrounded by a ring of numerous small vascular bundles which are collateral and open. The protoxylem is endarch. Outside the vascular ring lies a wide cortex which is connected with the pith by broad medullary rays. The stem of *Cycas* is mostly parenchymatous with a scanty amount of xylem. The condition is referred to as **manoxylic** (also see Subsection 19.2.4 and Box 19.2). In such a situation mechanical strength to the stem is provided by the thick and rigid armour of leaf bases and periderm. Some cells of the pith and medullarly rays contain calcium oxalate crystals. In addition, mucilage cells are also present both in the pith and the cortex, and these form a network that extends into the branch and leaf traces as well. Mucilage helps in the conservation of water and this is a xerophytic character.

Box 20.1 : Girdle traces in Cycads

Leaf traces are the strands of vasculature that enter the leaves. In cycads, each leaf is supplied by two types of traces both arising from the primary vascular bundles. These are **girdle traces** and the **radial** or **direct traces**. The girdle traces arise on the side of the stele opposite the leaf which they will ultimately enter. In their course through the cortex, they girdle the stele on two sides just like the curve prongs in a pair of tongs, and become completely reversed while passing through the cortex. These girdle traces are characteristic of Cycadales. The radial or direct traces do not girdle the stele but take a straight path through the cortex, before entering the leaf.

Secondary growth takes place quite early. The inter-fascicular cambium develops and joins the intra fascicular cambium. The cambium cuts secondary xylem towards inside and secondary phloem towards outside. To begin with, the stem of *Cycas* is **monoxylic**, i.e., with one ring of vasculature, but becomes **polyxylic** later as a result of accessory rings of cambia that arise in the cortex (Fig. 20.6 a). Numerous leaf-traces are seen in the cortex (see Box 20.1 and Fig. 20.6 b).

20.4.4 Leaf

The leaf anatomy of *Cycas* is discussed under two subheadings – rachis and leaflet.

Rachis: The rachis is cylindrical and bears leaflets inserted on the adaxial (dorsal) side; this makes the outline appear like a shield. The epidermis is thick-walled and covered with a thick cuticle except in the region of stomata. The hypodermis consists of a mixture of sclerenchyma and collenchyma followed by parenchymatous ground tissue, in which are

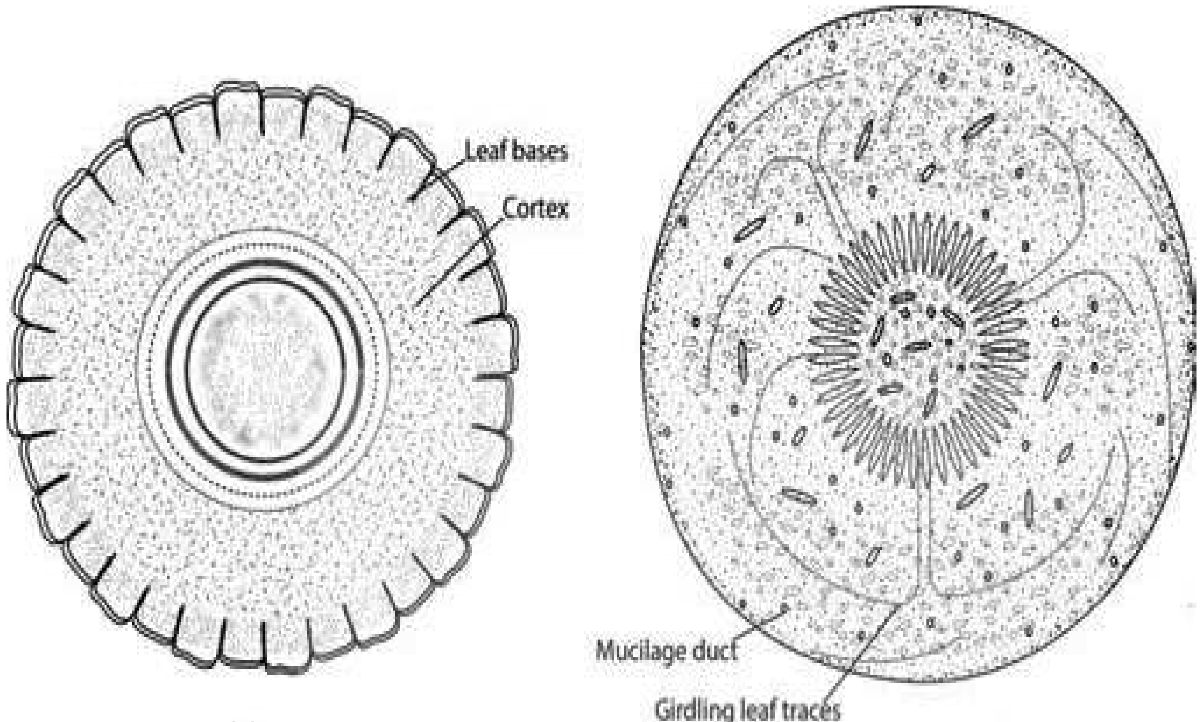


Fig. 20.6: a) *Cycas* sp., outline diagram of a stem in transaction. Note the armour of leaf bases, large cortex, pith, and the polyxylic condition; b) Prominent leaf trace girdles are seen in the cortex. Also note the manoxylic wood. A large number of mucilage ducts are scattered all over the stem, (From Bhatnagar & Moitra, 1996).

interspersed the vascular bundles. These are arranged in an arc that appears like a 'U' with arms, or like the inverted Greek letter Ω (Omega). Mucilage canals are present both on the inside and the outside of the vascular arc.

The vascular bundles of the rachis demonstrate an interesting behaviour. You may recall that two bundles of a leaf trace enter the base from the stem. At this juncture the bundles are endarch or centrifugal, i.e., the protoxylem is towards the centre and the metaxylem is towards the periphery of the rachis. The vascular bundles, as they enter the leaf, split into a number of strands and get arranged in the form of an inverted omega (see Fig. 20.7a). At this level, the xylem elements remain entirely endarch or centrifugal. After traversing some distance in the rachis, the centripetal xylem elements appear on inner side of the protoxylem. Subsequently, formation of centrifugal xylem is reduced gradually on moving towards the tip. Therefore, near the tip of the rachis the centripetal xylem is more abundant than the centrifugal xylem (Fig. 20.7b). These peculiar, diploxylic vascular bundles having both the centripetal as well as the centrifugal xylem (Fig. 20.7c) are also termed **pseudo-mesarch**. As the bundles move further into the leaflets, they become exarch with no traces of centrifugal xylem.

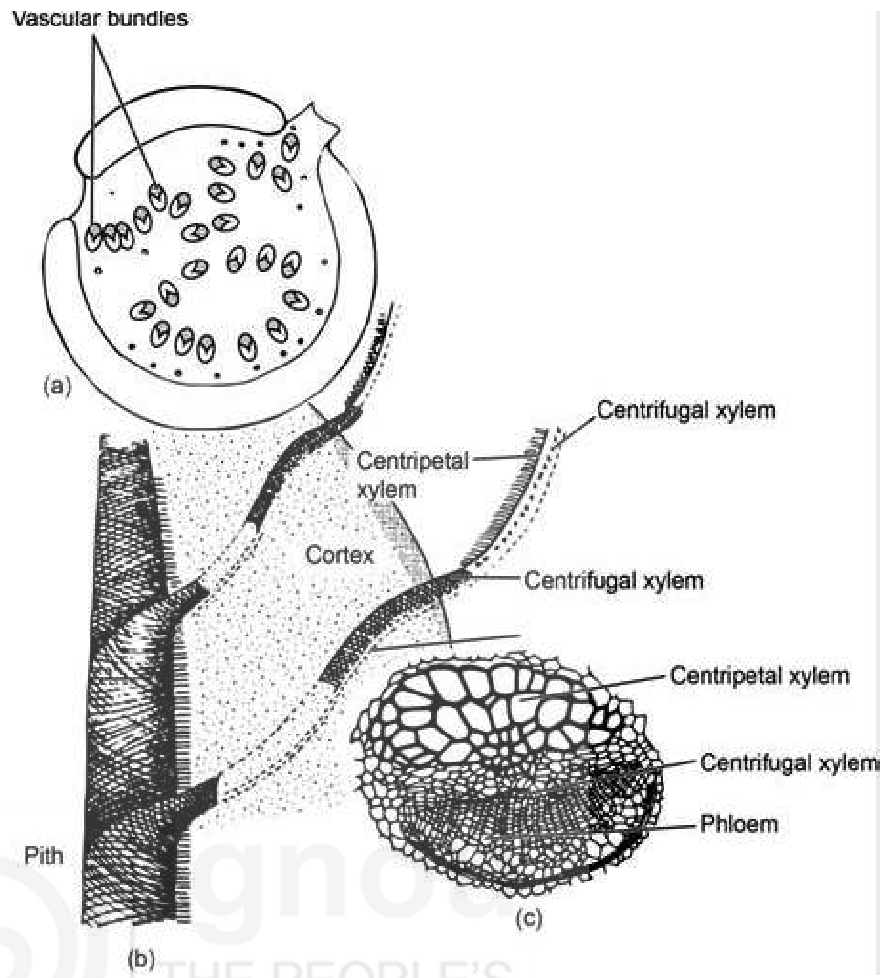


Fig. 20.7: ***Cycas*** **sp. a) Outline diagram of rachis in transaction. Note the inverted omega-shaped arrangement of vascular bundles; b) Diagrammatic representation of a part of stem with two petioles, showing the course of vascular bundle from the stem to the petiole, and the relationship of the centripetal and centrifugal xylem; c) An enlarged view of a diploxylic vascular bundle. (a, after Pant, 1973; b, after Le Goc, 1914; c, after Maheswari, 1960).**

Leaflet: The entire leaf of *Cycas* exhibits a number of xerophytic characters. Each leaflet is dorsiventral and the epidermis comprises thick-walled cuticularized cells with simple pits. The hypodermis is one - or two-layered and its cells are also cutinised and lignified.

The mesophyll is differentiated into a single-layered palisade, and multi-layered spongy parenchyma (Fig. 20.8 a, b). The vascular bundle is diploxylic. Isolated thick-walled cells extend from it to the hypodermal cells. Some tracheid – like cells with reticulate thickenings or bordered pits on their walls are present on either side of the centripetal metaxylem. These constitute the **transfusion tissue**, which is connected to the surrounding parenchymatous cells. Additionally, between the palisade and spongy parenchyma lie a few layers of empty, tracheid-like cells with reticulate thickenings and pits on their walls. These cells are arranged at right angles to the longitudinal axis of the leaf, and are present from mid rib to the margins of the lamina. These are designated as the **accessory transfusion tissue** and function as lateral conducting tissue. The stomata are sunken and occur only on the lower side (Fig. 20.8b).

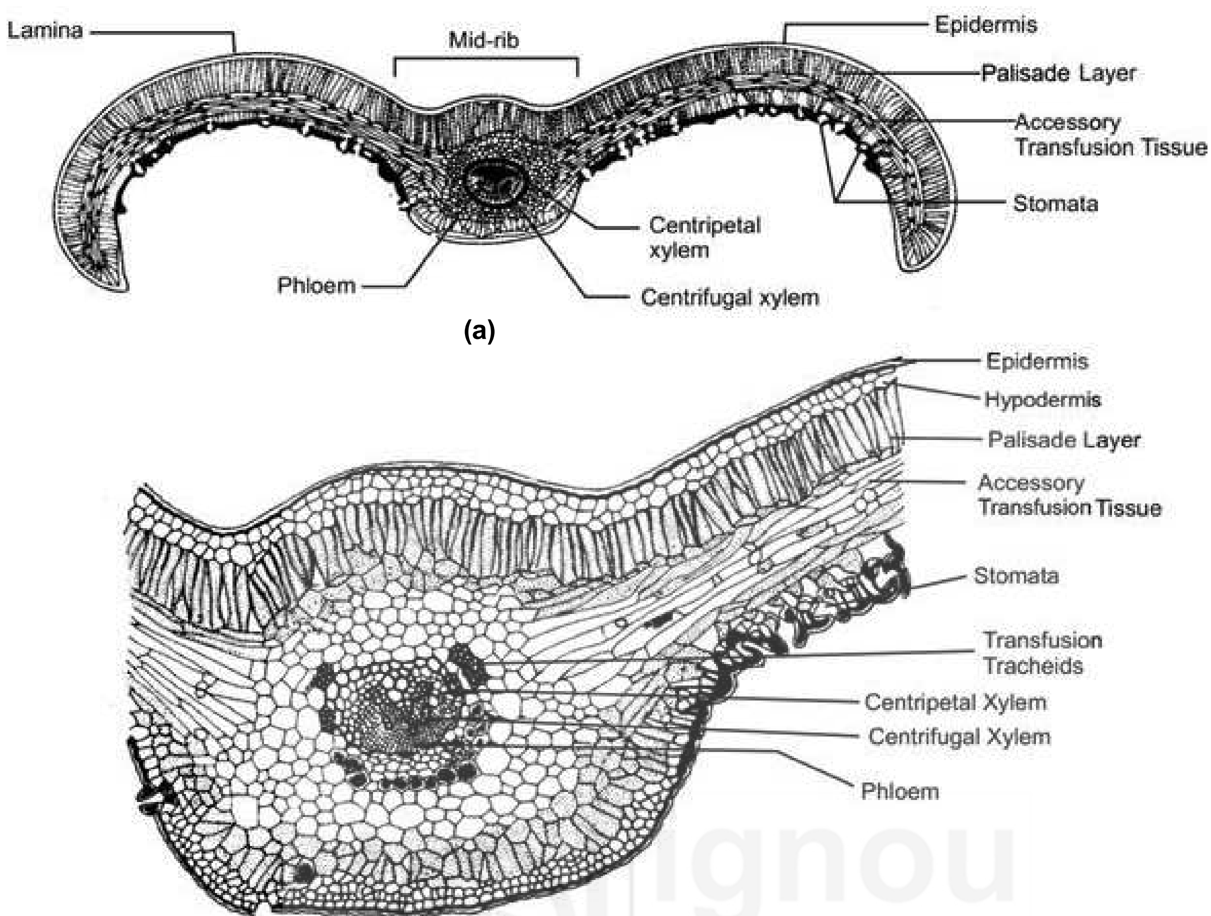


Fig. 20.8: ***Cycas*** **sp. a) Vertical section of a leaflet showing thick-walled epidermis with cuticle, and stomata, on the lower region;**
b) A portion of the same enlarged to show the diploxylic vascular bundle, and transfusion tissue (a and b, after Pant, 1973).

SAQ 2

Tick the correct word(s) given in parentheses.

a) The primary root system consists of (tap/fibrous) root(s).

b) The (coralloid/aerial) roots are apogeotropic, and help in fixing atmospheric nitrogen.

c) The coralloid root differs from normal root in having (narrow/wider) cortex region and the (presence/absence) of an algal zone.

d) The irregular outline of the stem is due to (unusual secondary growth/ persistent leaf bases).

e) The stem derives its mechanical strength from (massive xylem/leaf base armour).

f) The accessory transfusion tissue functions as (secretory tissue/ conducting tissue) in the leaflets of *Cycas*.

20.5 REPRODUCTION

Cycads are dioecious, i.e., the male and female reproductive structures are borne on separate plants. The *Cycas* plants undergo vegetative growth for about ten years and then start bearing the reproductive structures. One can not distinguish between the two sexes until the plants have borne the male and female reproductive structures. Even the bulbils meant for vegetative propagation develop into the plant of the same sex as the parent.

20.5.1 Male Cone and Male Gametophyte

The male cone is very large, oval or conical in shape (Fig. 20.9a) and usually occurs singly in the centre of the crown surrounded by scale leaves. The surface of the young cone is covered totally by brown scales. The mature cone emits a strong characteristic odour that can be smelled even from a distance.

The cone has a central axis on which the microsporophylls are arranged in a spiral manner. Each Sporophyll (Fig. 20.9b) is a hard, horizontally flattened, woody structure consisting of a wedge-shaped portion with a tapering upcurved apex. Numerous **sporangia** (singular- sporangium) are borne on the abaxial (lower) surface (Fig. 20.9b), and these are clumped together in groups of 3, 4 and 5 to form **sori** (singular– sorus). Each sorus is surrounded by single-celled soral hairs. Each sporangium has a massive stalk and dehisces by a longitudinal slit (Fig. 20.9d) that forms on the wall. About 700 sporangia per sporophyll are found in *C. circinalis* and around 1160 in *C. media.*

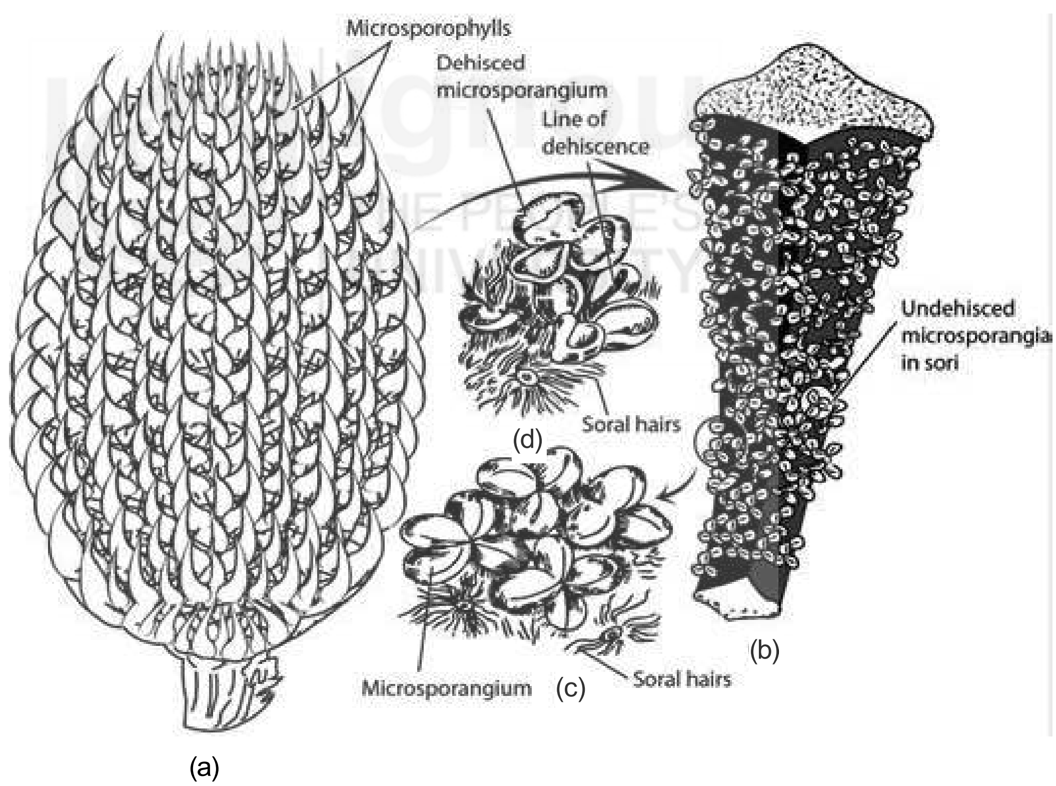


Fig. 20.9: *Cycas circinalis*. a) A mature male cone. Note the spirally arranged microsporophylls; b) A microsporophyll in abaxial view showing numerous microsporangia arranged in sori;. c) Undechisced microsporangia arranged in groups forming sori. Note the soral hairs surrounding the sori; d) Dehisced microsporangia. (Redrawn from: a, Maheshwari, 1960; b-d, redrawn from Wieland, 1906).

The male cones are terminal in position, but from the base of the peduncle arises a lateral bud that pushes the cone to one side. The new shoot apex thus formed soon produces a crown of leaves and scales, and ultimately bears another male cone. This type of growth is termed **sympodial**.

The cellular details of a microsporophyll are depicted in Fig. 20.10a, b. In addition to the vascular bundles, mucilage ducts are interspersed in the ground tissue. On the lower or abaxial side are the sporangia. Each sporangium has a characteristic **exothecium**. Inner to it lie the **tapetal tissue** and the **microspores** (Fig. 20.10b).

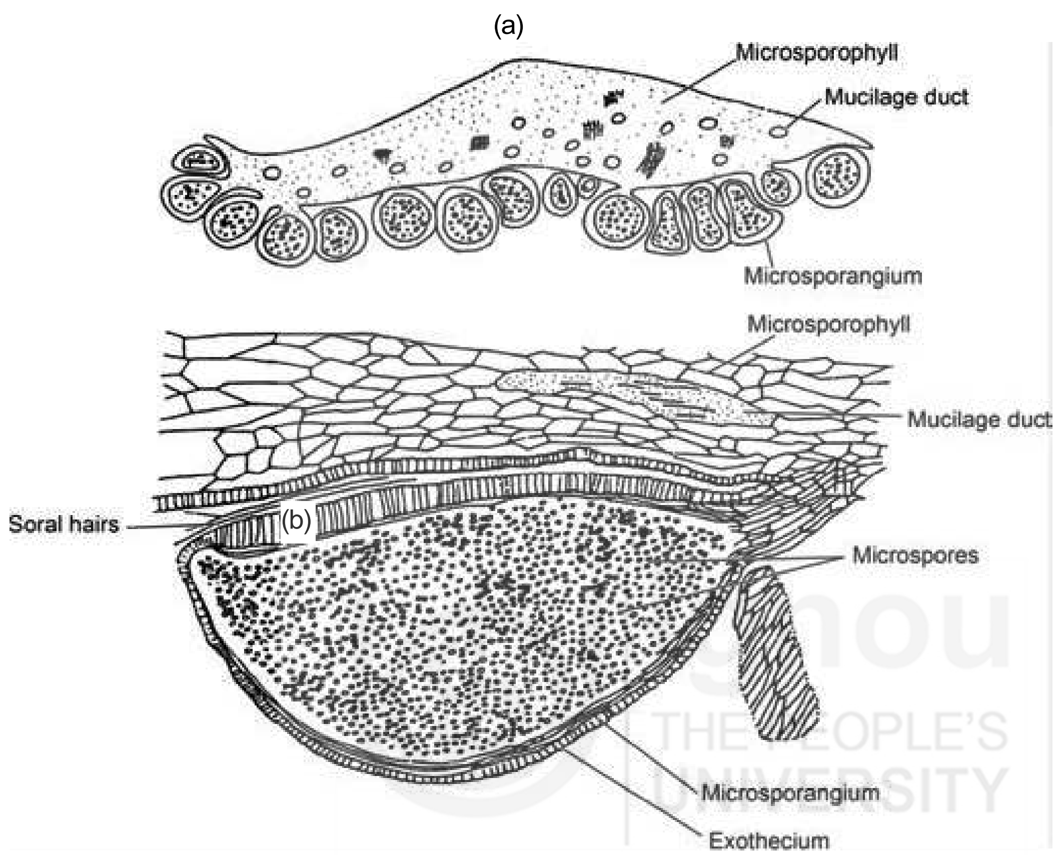


Fig. 20.10: *Cycas revoluta* a) V. S. Microsporophyll showing abaxial microsporangia. b) Same, a part enlarged. The microsporangium shown here has got cut longitudinally. (a, b, After Pant, 1973).

The microspores or the pollen grains develop from microspore mother cell (Fig. 20.11a) as a result of microsporogenesis. The microspores at various development stages are depicted in Fig. 20.11. The mature pollen grain is boat-shaped due to a depression on one side. They are shed at the 3-celled stage, i.e., one prothallial, an antheridial and a tube cell.

20.5.2 Female Strobilus and Female Gametophyte

The genus *Cycas* is unique amongst other cycads in not having a compact female cone (Fig. 20.12). The female plant bears successively the foliage leaves, cataphylls and then megasporophylls.This sequence keeps on repeating. From the point of view of origin, the megasporophylls have been compared to the foliage leaves and the two are considered to be homologous. In *C. revoluta* they appear like modified and reduced foliage leaves that are copiously covered with brown ramenta (Fig. 20.12c).

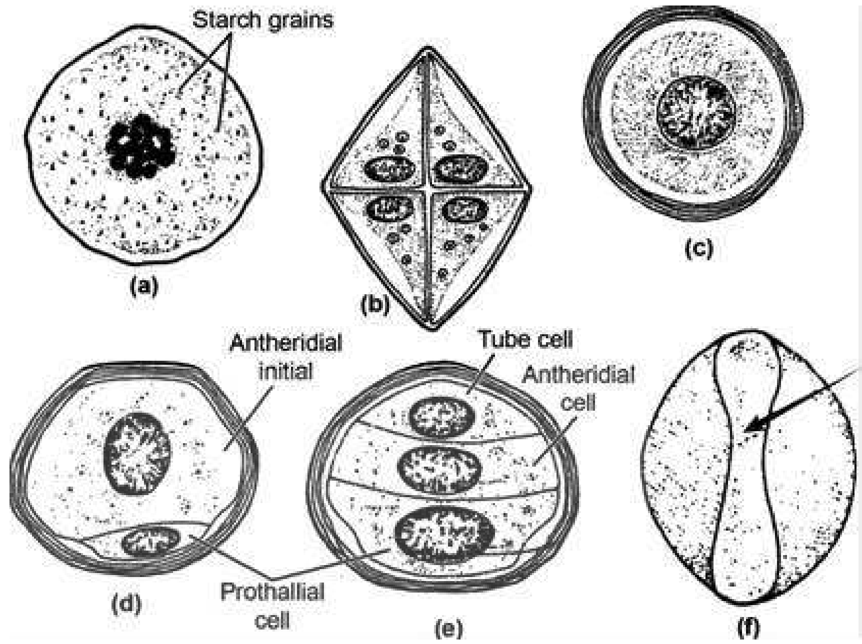


Fig. 20.11: *Cycas* sp. Development stages of the male gametophyte: a) A microspore mother cell before meiosis; note abundant starch; b) After meiosis, microspore tetrad is formed; c) Uninucleate microspore; d) Two-celled microspore with antheridial initial and prothallial cel; e) Mature pollen grain at shedding stage consists of three cells. The tube cell and the antheridial cells are the products of the antheridial initial shown in d; f) Mature pollen in side view showing a prominent furrow marked by an arrow. (After Pant, 1973).

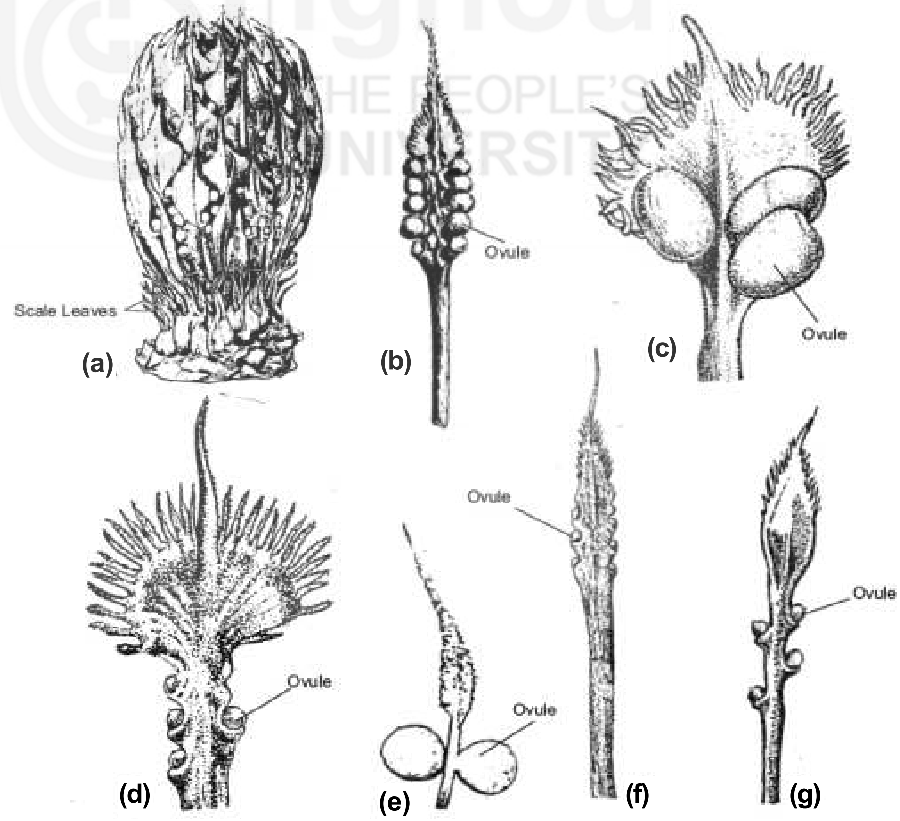


Fig. 20.12: a, b) *C. circinalis*; c) *C. revoluta.* a) Cluster of megasporophylls. Sterile scale leaves are present at their base; b) A megasporophyll enlarged. Note ovules in two rows, and oppositely arranged. The tip (arrow) portion of the megasporophyll is sterile; c) Another megasporophyll. Mark the same features as in b. The sterile tip portion is larger, flattened and fan-like; d-g) see variations in megasporophylls other species of Cycas (a, b, after Maheswari, 1960; c, redrawn from Gifford and Foster, 1989).

Each megasporophyll is about 30 cm or more in length, and it bears 2 to 12 ovules arranged in two rows. The ovules are orthotropous, short-stalked and are either oppositely or sub-oppositely arranged (Fig. 20.12 b, c,d-g). *Cycas* is known to produce the largest ovules in the plant kingdom ranging from 6-7 cm in length. In a young ovule a distinct megaspore mother cell is seen (Fig. 20.13a).

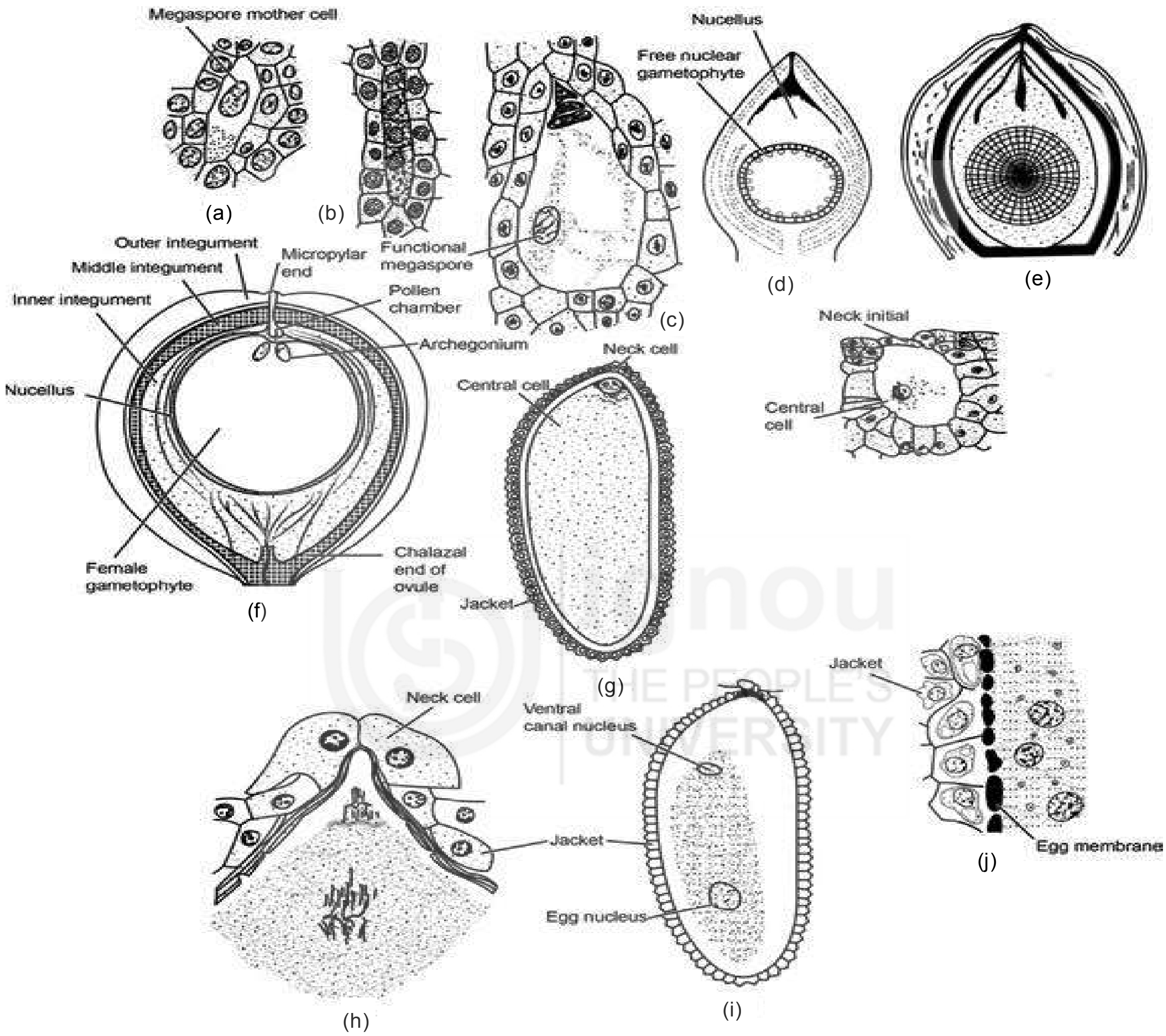


Fig. 20.13: Development stages of female gametophyte in *Cycas* sp. a-c and f-j and e) *Dioon* sp.; *Cycas* sp. a) A megaspore mother cell; b) A tetrad formed after meiosis in megaspore mother cell; c) the functional megaspore is a large, distinct cell, whereas the remaining three degenerated megaspores represented as dark masses; d, e) Stages showing formation of numerous nuclei after division of the functional megaspore. The free nuclei gradually acquire cell walls around them, as shown in; e) Note the radial arrangement of cells. In e, also note three layers – outer, middle and inner, of the integument enclosing the nucellus that has a prominent pollen chamber at the tip. Further, archegonial initials differentiate from amongst micropylar cells of the female gametophyte. This and the subsequent stages of archegonium are depicted in f to j; f) Archegonial initial divides to form a neck initial and a central cell; g) A young archegonium has a central cell, two neck cells and a distinct jacket; h) The central cell nucleus undergoes division. Note prominent neck cells at this stage; i) Mature archegonium has egg, ventral canal nucleus, and degenerated neck cells. The egg in the archegonium occupies central position; j) Part of free nuclear embryo and surrounding jacket cells. The thick egg membrane shows large pits through which cytoplasmic connection is maintained. (a-c, after De Silva and Tambiah, 1950; d, e, after Chamberlain, 1935; f, h, after Swamy, 1948; g, i, j, after Maheshwari, 1960).

It undergoes meiosis to form a linear tetrad of megaspores, of which only the lowermost is functional. This undergoes a series of mitotic divisions to first form a free nuclear female gametophyte which eventually becomes cellular. Formation of archegonia begins soon after the gametophyte becomes cellular.

As the female gametophyte develops, the micropylar surface of the gametophyte which bears archegonia separates from the covering cells to form a space called the archegonial chamber. Various developmental stages of the female gametophyte and archegonium are depicted in Fig. 20.13 a-i. Study this figure carefully.

The mature archegonium has a neck made up of a single tier of two cells; there are no neck canal cells and the ventral canal nucleus also degenerates. The egg nucleus is large, up to 500µm in *Cycas revoluta* and is visible to unaided eye. It takes about 2-3 months for the archegonia to mature.

SAQ 3

Which of the following statements are not true for cycads? Choose the correct answer from the choice given below:

i) A bulbil borne by a female plant would also produce a female plant.

ii) Most cycads bear several male cones and a single female cone.

iii) A mature female cone emits a strong characteristic smell to attract pollinators.

iv) Cone, sporangia, microsporophylls and sori is the order in which the structures are to be handled to have access to the male gametophyte.

v) The reproductive structures are devoid of mucilage ducts.

vi) The female plant sequentially bears first the foliage leaves, followed by cataphylls and then the megasporophylls.

vii) The megasporophylls are considered as the modification of the foliage leaves.

viii) Cycads are known to produce the smallest ovules in the whole plant kingdom.

Choices of Answers

a) i, ii, iii, vii

b) iii, iv, vi, vii

c) iv, v, vi, vii

d) ii, iv, v, viii

20.6 POLLINATION, FERTILIZATION AND EMBRYOGENY

After the development of male and female gametophytes, further development can take place only after these two are brought together through **pollination**, and subsequently fertilization. The pollen grains are transported to the female plants by means of wind or insects. They are caught in the pollination drop secreted at the tip of the ovule, and are subsequently 'sucked in' through the micropyle to the pollen chamber. The pollen chamber is then sealed from the outside world to prevent invasion by pathogens and to provide a congenial environment to the developing embryo. In the meanwhile, the pollen grain germinates to form a pollen tube at the end opposite to the prothallial cell and it is haustorial in nature. The antheridial cell divides into stalk and spermatogenous cell. Two sperms are formed by the division of the spermatogenous cell (see Figs. 20.11, 20.14). The continued growth of the haustorial pollen tube leads to the degeneration of nucellar tissue. The spermatozoids of cycads are the largest male gametes of the plant kingdom, and can be seen with naked eyes. The sperms are top-shaped and have a spiral band which makes six turns on the body, and to it the flagella are attached. The sperms are released in the archegonial chamber from the pollen grain through tubular growth on the side of the prothallial cell. It eventually casts off its flagellar band and its nucleus approaches the egg and sinks into it. This marks the completion of fertilization. Zygote is the product of this process. Of the two sperms produced per pollen, only one participates in fertilization, whereas the second sperm degenerates. Embryogeny begins by the division of the zygote. In early stages, the development is free-nuclear and the nuclei arrange themselves around a vacuole in the archegonium. Later, most of the nuclei move towards the base, and the upper portion has few nuclei. Wall formation starts from the base and these form the proembryo. The upper cells elongate to form the suspensor. Complete cellularization does not take place. The zone of cells separating the suspensor and free nuclear zone is called the buffer zone. Polyembryony occurs in the initial stages, but ultimately the most vigorous embryo takes the

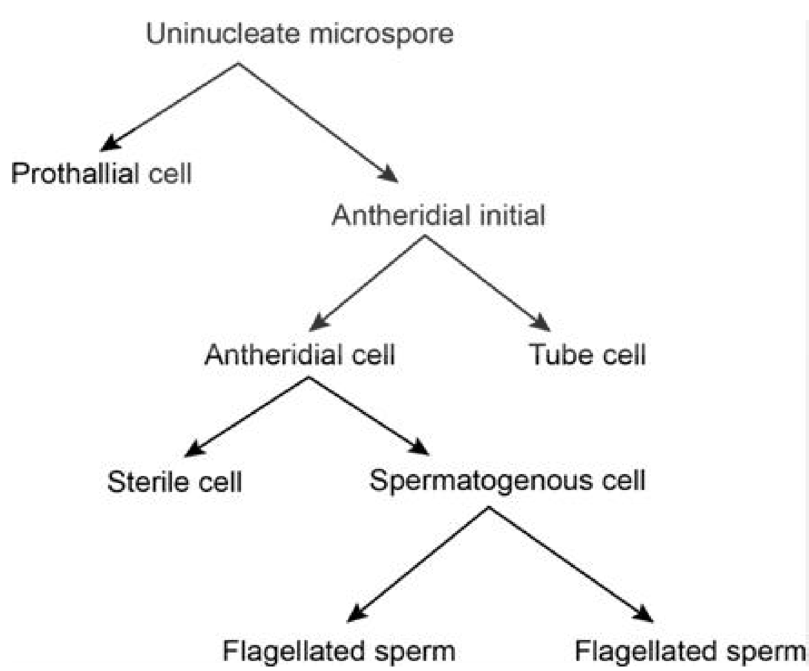


Fig. 20.14: Schematic diagram depicting stages in the development of male gametophyte in cycads.

lead and matures. The growth of embryo in the seed is very slow and it takes over a year for the embryo to mature after fertilization. Since there are several ovules per megasporphyll, one may ask, how many develop into seeds? Many of the ovules remain unpollinated and abort or remain small. Ripe seeds are broad, elliptical or egg shaped, somewhat flattened laterally and are bilobate. Young seeds are copiously covered with brown hairs. By the time the seeds become mature, these hairs are shed. The ripe seeds are fleshy and become bright orange or red. Being tropical or sub-tropical plants, cycads do not undergo winter rest. Seed germination is hypogeal (Fig. 20.15).

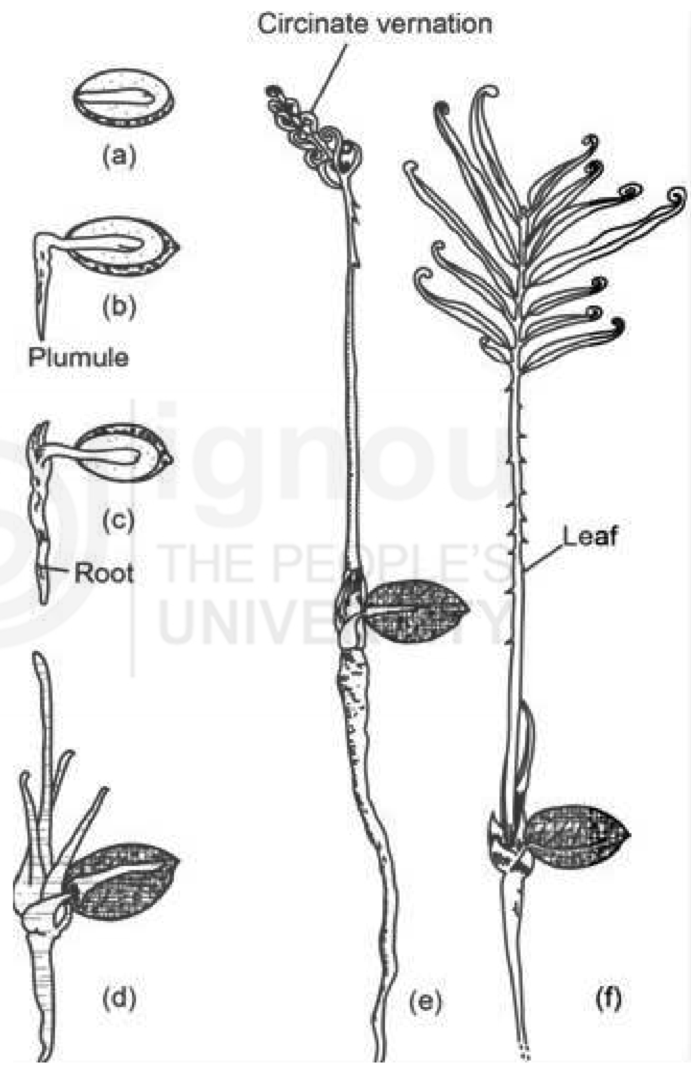


Fig. 20.15: a-f) Stages of development of a *Cycas* seedling (a-f, after Maheshwari, 1960).

SAQ 4

a) Make a concept map of the events associated with pollination leading to seed formation in cycads.

b) Write a note on *Cycas* spermatozoid.

20.7 SUMMARY

In this unit you have studied that:

- Cycadales were prevalent during the mid-mesozoic era. At present, over 100 species grouped in 11 genera are found in restricted locations, both in the Eastern and the Western Hemispheres.
- *Cycas* has a palm-like appearance with columnar, aerial trunks and a crown of leaves. The bulbils which are adventitious buds develop into branches and also contribute to the vegetative propagation of the plant. Two crowns of leaves are produced annually during the favourable seasons.
- In *Cycas*, the primary root system comprising a tap root is replaced by adventitious roots. Some of these roots branch dichotomously, turn apogeotropic and perform the role of nitrogen fixation, and are termed as coralloid roots. Anatomically young roots resemble those of angiosperms. The coralloid root anatomy is similar to the normal root but it additionally has a distinct algal zone in the middle of the cortex.
- The stem is characteristic of xerophytes. The abundant mucilage cells help in conserving water. Pith is prominent, and it occupies nearly one third area of the stem. The wood is manoxylic and stems derive mechanical strength from the persistent leaf bases present on the surface. The girdling leaf traces are the other characteristic feature of cycad stem.
- *Cycas* bears dimorphic leaves – the scale leaves and the foliage leaves produced in an alternate manner. The scale leaves have a dense coating of the rementa; and the foliage leaves are unipinnately compound having circinate vernation, rachis and leaflets. Both rachis and the leaflets exhibit xerophytic characters. The vasculature of the rachis shows distinct diploxylic (pseudomesarch) bundles.
- *Cycas* bears male and female reproductive organs on separate plants, i.e., they are dioecious. Male cone is a large terminal structure, borne singly and has a peculiar odour. The male cone consists of a large number of microporophylls, each bearing numerous sporangia present in groups on its underside. The female plant bears several megasporophylls, each bearing many exposed ovules arranged in two rows.
- Pollination is affected by means of insects or wind. The sperms are flagellate and are the largest male gametes in the plant kingdom. The product of fertilization is zygote. It develops into a seed. The ovules mature as seeds. The seeds do not undergo dormancy, and exhibit hypogeal germination.

20.8 TERMINAL QUESTIONS

1. What promotes branching in cycads?
2. Why is it that some cycads have thinner trunks near the lower region as compared to the upper part?

3. Given a *Cycas* tree, how would you determine its age?
4. Compare the normal and the coralloid roots of *Cycas*. Draw labelled figures to mark the differences.
5. With the help of labelled outline diagrams only, depict the structure of rachis at two levels in the leaflet, one, near the point it connects the leaflet, and the second, near its tip.
6. Compare the male and female reproductive structures of *Cycas.*
7. List the anatomical features that are characteristic of cycads.

20.9 ANSWERS

Self-Assessment Questions

1. i) and ii)
2. a) tap
   b) coralloid
   c) wider, presence
   d) persistent leaf bases
   e) leaf base armour
   f) conducting tissue
3. d)
4. a) Refer to Section 20.6 – Pollination, Fertilization and Embryogeny.

   Hint: Pick out the pollination related key terms from the section, arrange them in a logical sequence and connect them with arrows. You may use connecting words for linking these terms.

   b) Refer to Section 20.6.

Terminal Questions

1. Physical injury is an important factor leading to branching in cycads.
2. As the trees age, the older leaf bases, which obviously are near the lower region abscise. Therefore, the lower trunk appears thinner than the upper region.
3. Count the number of leaf bases, and the number of leaves in the crown and then divide by half. See Section 20.3.
4. Refer to Subsection 20.3.1, Figs. 20.2 and 20.5.
5. Read the descriptions given in subsection 20.4.4 and Fig. 20.7 and make outline diagrams.
6. See Subsection 20.5.1 and 20.5.2.

   Hint: It would be a good idea to bring out these differences in a tabular form. Outline diagrams can enhance the clarity of your answers. So make as much use of them as possible.

7. **Hint:** Write the anatomical peculiarities of the vegetative structures.

GLOSSARY

Bulbil	:	An adventitious bud, arising from lower, fleshy region of the leaf base; bears scale leaves in addition to crown of leaves just as main trunk : On maturity can produce new branch /plant.
Circinate Vernation	:	Characteristic upfolding pattern of leaf frond. The terminal region of the frond is youngest, growing, coiled; proximal region mature.
Coralloid root	:	Copiously, dichotomously, branched dwarf roots which are apogeotropic, appear as dense, greenish/ brown masses.
Endarch	:	A primary xylem where protoxylary elements are facing the pith.
Exarch	:	A primary xylem where protoxylem elements are facing the periphery.
Megasporophyll	:	A reproductive leaf bearing the megasporangium (Ovule).
Mesarch	:	A primary xylem where protoxylem is surrounded by metaxylem.
Microsporophyll	:	A reproductive leaf bearing microsporangium.
Ramenta	:	Bi-celled trichomes present on the scale leaves.
Transfusion tissue	:	Tracheid-like cells with reticulate thickening or borderd pits, present on either side of the centripetal metaxylem.
Sympodial	:	An axial bud grows and pushes the terminal bud aside, the growth is sympodial.

UNIT 21

GYMNOSPERMS: *PINUS*

Structure

21.1 INTRODUCTION

You have read a general account of gymnosperms and have also studied about *Cycas* in Unit 19 and in Unit 20 in detail respectively. In this unit we will study morphology, anatomy and reproduction in *Pinus*.

Conifers are woody perennials with long and dwarf shoots with foliar and scale leaves. They possess tap roots associated with ectotrophic mycorrhiza. Their reproductive organs are found in unisexual compact cones.Pollen grains (winged/non-winged) produce non-motile sperms.

The family Pinaceae to which *Pinus* belongs has 10 genera: *Abies*, *Cyathea*, *Cedrus*, *Keteleeria*, *Larix*, *Picea*, *Pinus*, *Pseudolarix*, *Pseudotsuga* and *Tsuga* of which six genera are found in the Indian subcontinent. These are *Pinus*, *Tsuga*, *Picea*, *Abies*, *Cedrus* and *Larix*.

Objectives

After studying this unit, you should be able to:

- ❖ state the general characters of conifers;
- ❖ list the various genera belonging to Pinaceae;
- ❖ state the distribution of various species of *Pinus* in India and Indian sub-continent;
- ❖ depict the morphology and anatomy of the vegetative structures in *Pinus*;
- ❖ give an account of the structural details of male and female cones, and the gametophytes contained therein in *Pinus*;
- ❖ describe an account of pollination and fertilization; and
- ❖ give details of proembryo formation and subsequent embryogeny in *Pinus*.

21.2 DISTRIBUTION

The genus *Pinus* is the most well known representative of this family and has been known to mankind since times immemorial.

Pinus, a beautiful tall evergreen (see Fig. 21.1) tree, with horizontal branches arranged in whorls, giving the tree a pyramidal appearance, is represented by over one hundred species. The pines form extensive pure forests or contrastingly form mixed forests in association with broad leaved trees. Seven species of *Pinus* occur in India, of which four are restricted to the Himalayas. The trees in later stages start losing their symmetry.

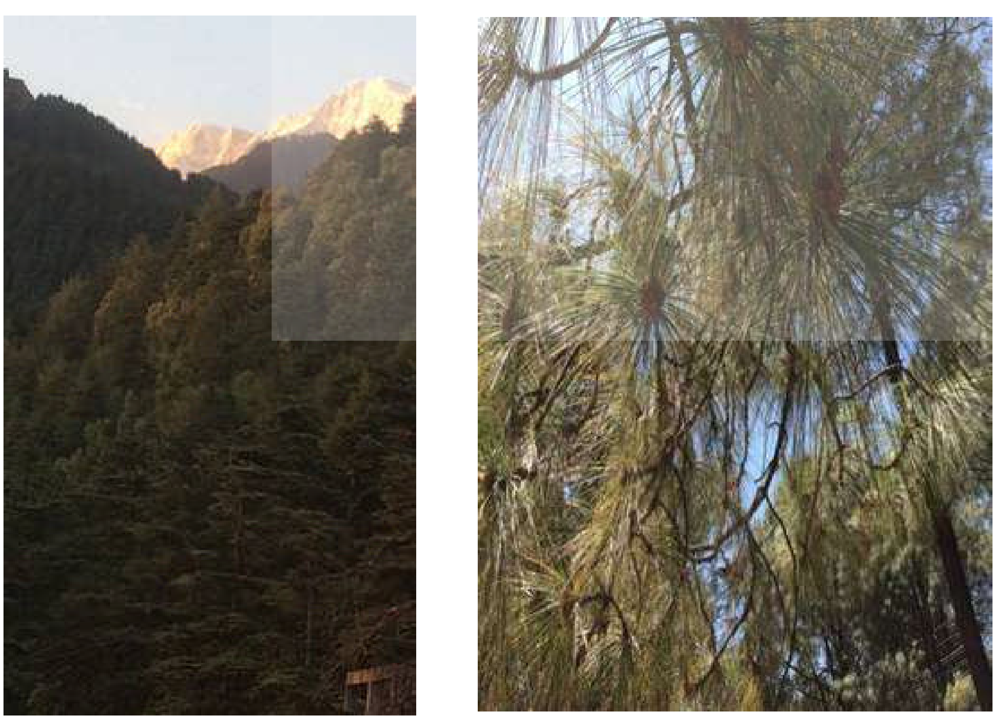


Fig. 21.1: *Pinus* trees in their natural habitat.

Box 21.1: Distribution of *Pinus* in the Indian subcontinent and neighbouring countries

Species	Place of Occurrence
P. wallichiana	From Pakistan to Arunachal Pradesh through Nepal, Bhutan, Kashmir, Himachal Pradesh, Kumaon and Sikkim
P. armandii	Arunachal Pradesh, Central and Western China and Taiwan
P. bhutanica	Arunachal and Bhutan
P. gerardiana	North West Himalayas, (Kashmir, Himachal Pradesh), Afghanistan
P. keysia	Khasi and Naga Hills, Manipur, Myanmar and Philippines
P. roxburghii	Pakistan to Arunachal Pradesh except Kashmir
P. merkusii	Myanmar, Thailand, China, Indonesia and Philippines,recently reported from Arunachal Pradesh.

21.3 MORPHOLOGY

21.3.1 Root

Pinus exhibits two types of root systems – the long roots having potential for indefinite growth constitute the main root system, while the lateral branches with restricted growth and relatively short life are the short or dwarf roots.

21.3.2 Stem

The stem is erect, woody and covered with rugged scaly bark which peels off. The branches are of two types : (i) the long shoots and (ii) the dwarf shoots. The long shoots or branches of unlimited growth bear an apical bud enclosed in bud scales. Each long shoot arises as a lateral bud in the axil of a scale leaf. These lateral buds grow horizontally on the main stem to a certain length and this is referred to as nodal growth. The spur shoots, when they fall off, leave a scar on the stem. The dwarf shoots or branches of limited growth, also called short shoots, brachyblasts or foliar spurs, are borne on long shoots and arise in the axil of scale leaves (Fig. 21.2 a-b). Each dwarf shoot bears two opposite scaly leaves, called prophylls, followed by 5-13, spirally arranged scaly cataphylls in 2/5 phyllotaxy. The pine tree grows as a result of the activity of an apical meristem.

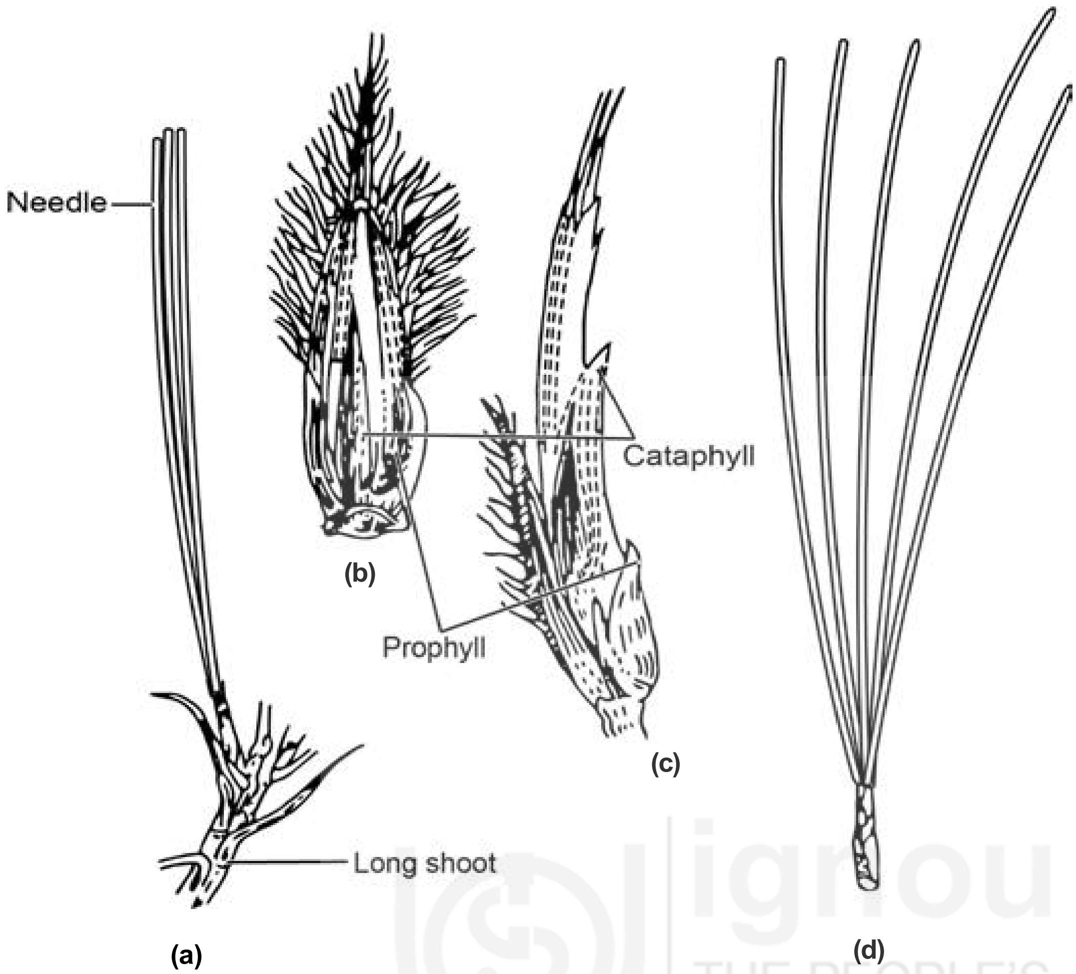


Fig. 21.2: a-c *Pinus* sp. a, b) Young dwarf shoots showing stages in the unfolding of needles; c) Part of long shoots bearing a dwarf shoot with three needles; d) Dwarf shoot bearing five needles. (a-c, after Maheshwari & Konar, 1971; d, after Konar & Ramchandani, 1958).

21.2.3 Leaf

The leaves on the dwarf shoots are of two types: 2-5, long, needle-like foliage leaves, and, the scale leaves of protective nature. **The needle number per foliar spur is constant for a species** and is used as a taxonomic character, eg., *P. monophylla* has one,*P. sylyestris* has two, *P. roxburghii* has three (Fig. 21.2 c) and *P. wallichiana* has five needles (Fig. 21.2 d).

The primary (deciduous) leaves, which are always single, appear soon after germination and function as foliage leaves. The secondary (permanent) leaves, or the needles, are borne on short shoots or brachyblasts in bundles in the axils of scale leaves.

In *P.monophylla* the solitary needle is round, in the 2-needle pine it is semicircular, and in three needle pines as in *P. roxburghii*, it is triangular.

21.4 ANATOMY

In this section you shall study the internal structures of the organs: root, stem, and leaf.

21.4.1 Root

In *Pinus* both long and short roots are diarch or tetrarch (Fig. 21.3). The structure from periphery inward show that one layered epidermis is followed by multilayered starch-filled cortex having an outer zone of small and an inner zone of large parenchymatous cells. The single-layered endodermis with casparian strips is followed by 6 or 7-layered pericycle. The xylem and phloem show radial arrangement. Each protoxylem point is associated with a resin duct (Fig. 21.3). The metaxylem elements are made up of pitted tracheids. The phloem alternates with xylem and consists of sieve cells and parenchyma. The pith cells are rich in starch. Occasionally some of them are tanniniferous. Secondary growth starts very early and the structure of the root, in later stages, is much like that of the secondary stem.

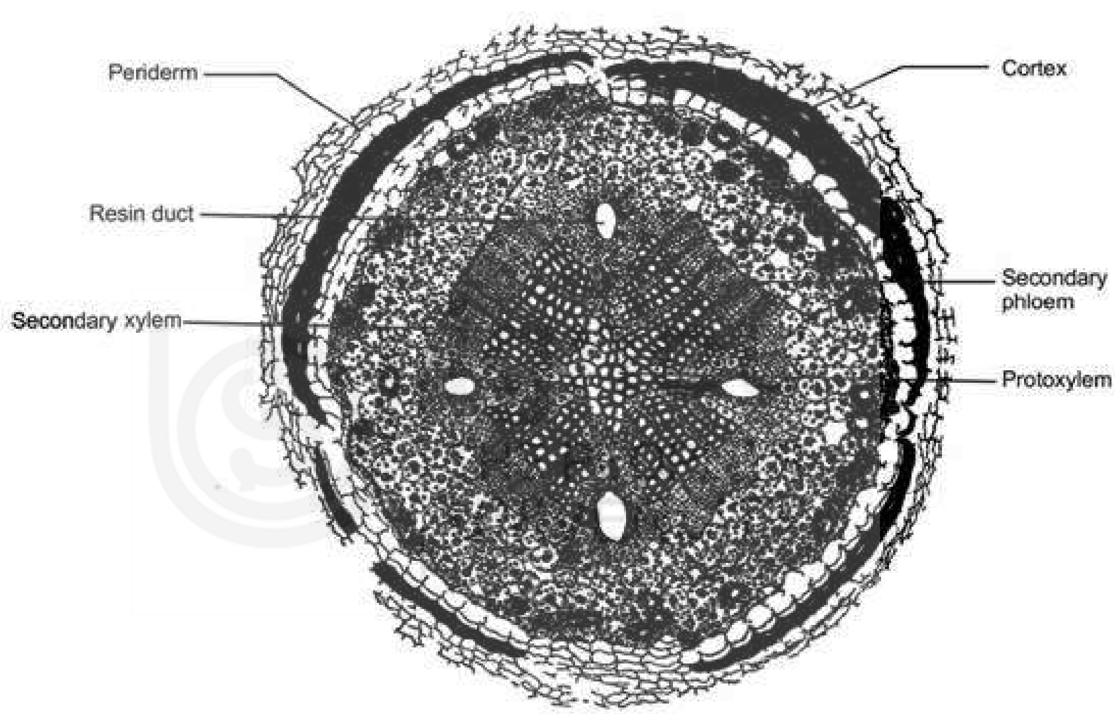


Fig. 21.3: ***Pinus*** **sp. Transverse section (T.S.) of a tetrarch root after secondary growth. The outer region is scaling off in plates. There is a resin duct opposite each of the four protoxylem element. The crushed protophloem is still visible, and outside it are cells rich in starch, and just beneath the scaling off layers are numerous resin cells.**

The dwarf root of *Pinus* is anatomically similar to the long root. It, however, differs from the long root in the absence of a root cap, resin ducts, and starch in cortical cells and does not undergo secondary growth. The cortex is smaller in the dwarf root than in the long root.

Mycorrhiza occurs in several conifers. In *Pinus* it is well developed, and has also been extensively studied. It exhibits well developed ectotrophic mycorrhizal association with over 50 different species of fungi belonging to Division Basidiomycota. The dwarf roots divide dichotomously (Fig. 21.4) and become modified into mycorrhizal system after fungal infection, when the entire rootlet is enclosed by mycelium (Fig. 21.4). The fungal hyphae penetrate the intercellular spaces in the cortical cells of the root forming the Hartig's net

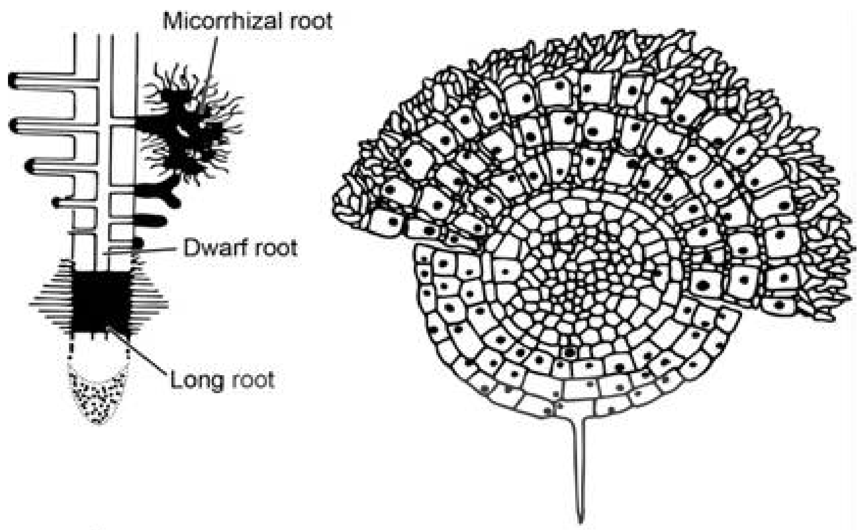


Fig. 21.4: ***Pinus*** **sp. a) Diagrammatic representation of a young root. Root hair zone is near the tip; b) T.S. root whose one half is normal and the other half (upper portion in the figure) is mycorrhizal. Cortical cells are hypertrophied and enveloped by fungal filaments forming an ectotrophic mycorrhiza in the infected part. Mycorrhiza in an enlarged view. (a after Hatch, 1937; b after Hatch and Doak 1933).**

(refer Unit 11 of Block3). The pine-fungal relationship is symbiotic, the pine tree benefits by the increased absorbing area of mycorrhizal roots and enhanced absorption of soil nutrients.

21.4.2 Stem

In T.S. of a young stem of *Pinus* you can see ridges and furrows formed due to adpressing of surrounding leaves. Epidermis is followed by a broad parenchymatous cortex, a ring of discrete collateral and open vascular bundles, and pith. Bundles are separated from each other by broad medullary rays. Resin ducts with an inner lining of thin walled, epithelial cells are present.

After a wound is inflicted, many resin ducts are formed around it. During to secondary growth, the fascicular cambium and interfascicular cambium join up forming a complete cambial ring. The cambium possesses two types of cells – the fusiform and the ray initials. The fusiform initials are elongated with tapering ends and are tangentially flattened. They give rise to the axial systems consisting of secondary xylem towards inside (adaxially) and secondary phloem towards outside (abaxially) (Fig. 21.5). The ray initials are small and isodiametric, and contribute the radial system which is composed of secondary xylem and secondary phloem rays. The tracheids of secondary xylem have bordered pits (Fig. 21.6).

The secondary phloem has sieve elements and the most characteristic feature of which is the occurrence of sieve areas, on the radial walls throughout its length.

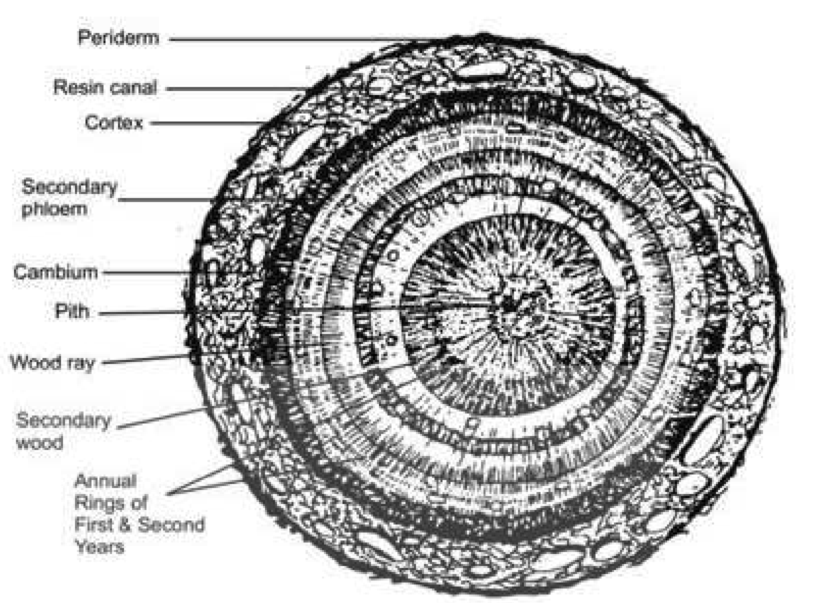


Fig. 21.5: T.S. of a secondary stem of *Pinus* with growth rings and pycnoxylic wood (After Foster 1989).

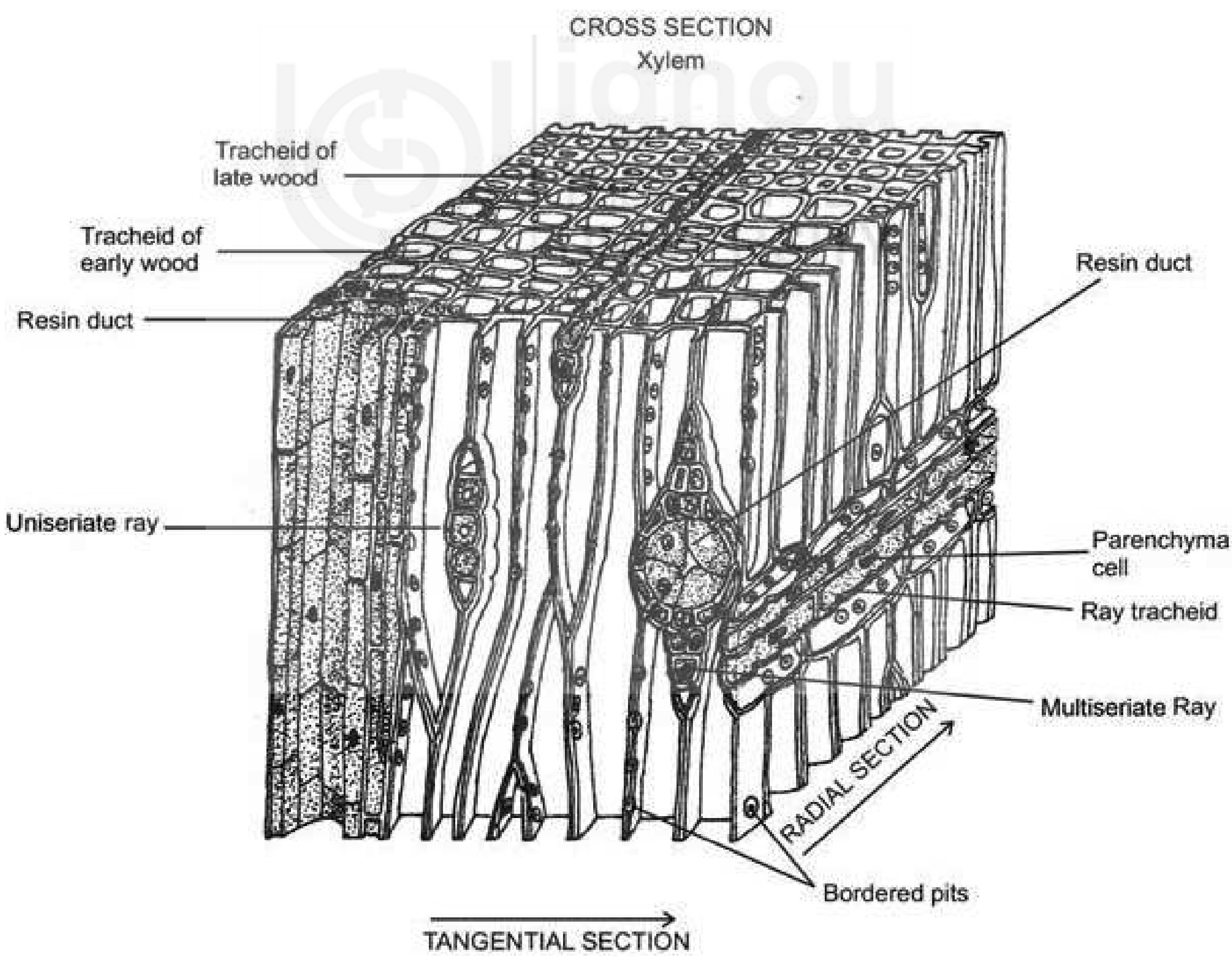


Fig. 21.6: Three-dimensional diagram of a cube of secondary xylem of *Pinus* sp.

The rays are of two types: (i) uniseriate rays, and (ii) multiseriate or fusiform rays. Most of the rays are of the uniseriate in width; in height, the ray varies from 1 to 12 cells. The multiseriate ray is always more than one cell wide and several cells in height and associated with a centrally situated resin canal (Fig. 21.6). The detailed structure of ray can be best understood by examining sections cut in all the three planes. You must study Fig. 21.6 carefully. The transverse section (T.S.) shows the width and the length of the ray. The longitudinal sections should be cut in the radial (RLS) as well as in the tangential (TLS planes). If one began cutting tangential sections and continued to cut inwards, section passing through the pith would be radial longitudinal (see Fig. 21.6). It should be understood clearly that a radial section cuts along the radius and also along the vascular rays while the tangential section cuts at right angles to vascular ray. The TLS shows the height and width of the ray. The RLS depicts the length and height of the ray. There are two kinds of cells in the rays – the inner, starch filled, living ray parenchyma and the peripheral, non-living ray tracheids. The ray parenchyma has simple pits while the ray tracheids show bordered pits.

The wood structure of *Pinus* is much simpler as compared to wood of dicotylendons. The wood consists mainly of tracheids while characteristic feature is the absence of vessels and xylem fibres. The cork cambium differentiates in the first or second layer of the cortex. It cuts off cork on the outer side and secondary cortex on the inner side.

21.4.3 Leaf

The internal structure of needle is explained in Fig. 21.7 (a-c). The (epi- and hypodermis) layers are followed by mesophyll surrounding the diarch/monoarch stele. The epidermis is a single layer of isodiametric lignified cells covered with a thick deposit of cutin. The hypodermis consists of 2 or 3 layers of uniformly thin or thick cells. The mesophyll is chlorenchymatous with varying number of plate-like or peg-like infoldings of the wall projecting into the cell cavity. Resin ducts are also present in the mesophyll.

The endodermis is a single continuous layer of barrel-shaped cells. The pericycle is parenchymatous, interspersed with transfusion tracheids. A sclerenchymatous sheath is present around the vascular bundle. In *P. roxburghii* there are two vascular bundles, placed at an angle to each other. Phloem consists of sieve cells and parenchyma. Transfusion tissue consisting of tracheids and parenchyma cells occurs on both sides of the vascular bundle; it plays a part in lateral conduction of water and nutrients. The stomata are situated in longitudinal rows and are sunken. The walls of the subsidiary cells and the guard cells are partly lignified

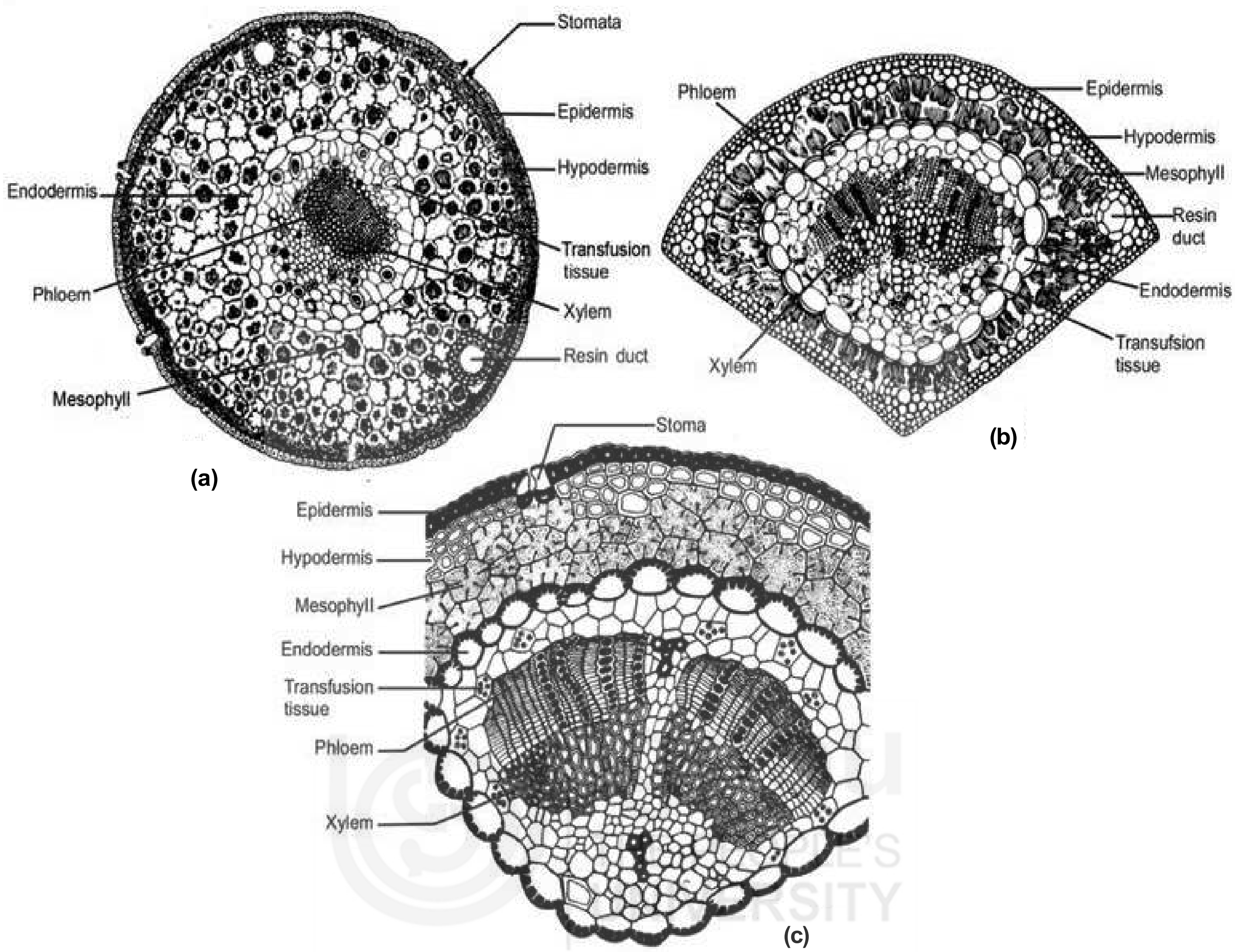


Fig. 21.7: ***Pinus* sp. a, b) T.S. needle. c) Part of a needle in T.S. enlarged to show lignified epidermis, hypodermis, and mesophyll with cells showing infolding of walls, endodermis with thickened outer walls, transfusion tissue and two vascular bundles placed at an angle. (Redrawn from Gifford & Foster, 1989, b after Konar 1963 a).**

SAQ 1

a) State whether the following statements are true or false. Write **(T)** for true and **(F)** for false given brackets.

i) The family Pinaceae has only 7 genera. [ ]

ii) The pines form extensive pure forest or contrastingly mixed forest in association with broad leaves trees. [ ]

iii) Six species of *Pinus* are indigenous to Himalayas. [ ]

iv) The number of needle per dwarf shoot in *Pinus* is constant for a species and is used as a taxonomic character. [ ]

v) A *Pinus* tree might lose its symmetry as it grows old. [ ]

b) Fill in the blanks with the appropriate words.

i) The cells of the root cortex are filled with.....................

ii) The phloem consists of ....

iii) In *Pinus* ....mycorrhizal association is well developed.

iv) The pine-fungal relationship is...........................

v) In *Pinus* vascular bundles are........................and ....

vi) The sieve cell has ....on wall throughout the length of cell.

vii) The wood of *Pinus* is devoid of ....

viii) The shape of *P. roxburghii* needle is.............................in T.S.

ix) In *P. roxburghii* the two vascular bundles are placed at an ....to each other.

x) The stomata in Coniferales are................................

21.5 REPRODUCTION

Pinus is monoecious, but the male and female cones are borne on separate branches. The male cones arise on the lower and the female cones on the upper branches.

21.5.1 Male Cone and Male Gametophyte

The male cones, which replace the dwarf shoot, occur in clusters (Fig. 21.8 a-c). The number of male cones in a cluster varies from 15 (*P. wallichiana*) to about 140 (*P. roxburghii*). Each male cone conists of a central axis on which the microsporophylls are spirally arranged (Fig. 21.8 f). Each microsporophyll bears two sporangia on the lower or the abaxial surface (Fig. 21.8 d-e). The cone axis elongates exposing microsporangia which dehisce longitudinally.

Microsporangium

One or more hypodermal cells of microsporangium differentiate as archesporial cells which divide repeatedly to form an archesporial tissue (Fig. 21.9a). The peripheral cells of the archesporium divide periclinally to give rise to a primary parietal layer and primary sporogenous cells (Fig. 21.9 b). Former cell divides both periclinally and anticlinally forming a wall of 3 or 4 layers, the innermost of which differentiates as tapetum (Fig. 21.9 c). The remaining 2 or 3 layers are the middle layers, which degenerate with the maturation of the sporangium (Fig. 21.9d). The primary sporogenous cells, on the other hand, divide in all planes producing a mass of sporogenous tissue, the last cell generation is known as microspore mother cell stage. The epidermal cells, in later stages, develop fibrous thickenings except for a few cells in rows, which mark the suture of dehiscence. The development of tapetum and sporogenous cells is simultaneous in gymnosperms (Fig. 21.9 e).

Microsporogenesis

The nucleus of the microspore mother cell undergoes reduction division which is followed by simultaneous wall formation to give rise to a tetrad of

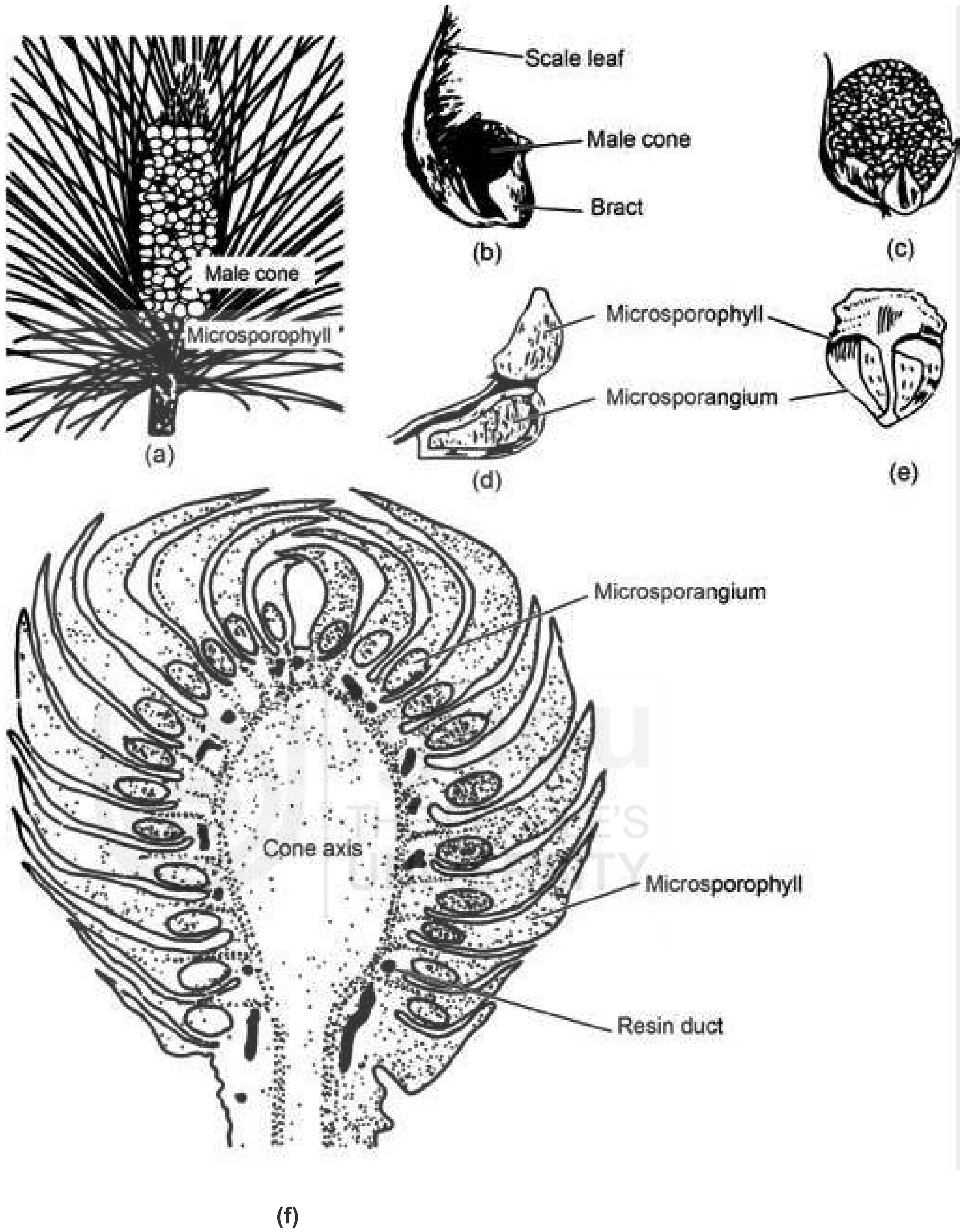


Fig. 21.8: ***Pinus*** **sp. : a) Shoot bearing cluster of male cones; b-c) Early and late stages of the male cone; d) Lateral view of microsporophyll; e) Microsporophyll bearing two sporangia on abaxial side; f) L.S. male cone.**

microspores (Figs. 21.9 c, 21.10 a-d). At the end of this division, the callose sheath surrounding the microspore mother cell is dissolved by enzymatic action and the young haploid microspores are set free. The uninucleate pollen grain is the first cell of the male gametophyte. The tapetal cells and other wall layers finally degenerate when the pollen grains are formed (Fig. 21.10 e).

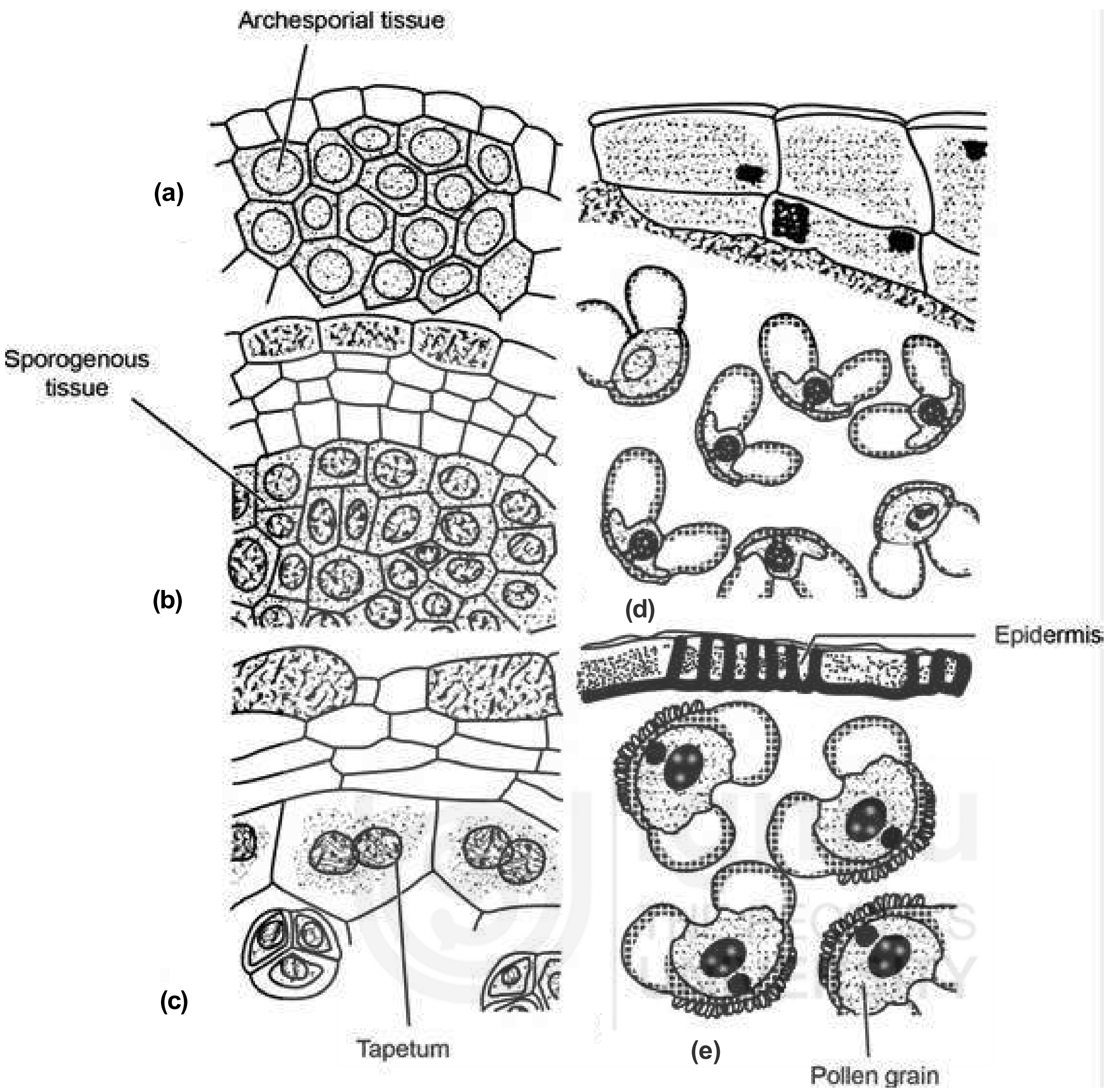


Fig. 21.9: ***Pinus*: a) L.S. young microsporangium to show hypodermal archesporial cells; b) Same, at a later stage; wall layers and sporogenous cells have differentiated; c) Microsporangium at tetrad stage, note binucleate tapetal cells; d) Slightly older microsporangium showing young bisaccate pollen grains. The tapetal layer and inner wall layers have degenerated; e) Same, at maturity with pollen grains at shedding stage. Epidermal cells have developed fibrous thickenings (a-c, after Konar, 1960; d, e after Konar and Ramchandani, 1958).**

Male Gametophyte

The microspore nucleus cuts off a small lens-shaped prothallial cell towards the proximal end and large central cell on the distal end (Fig. 21.10 f). The central cell cuts off a second prothallial cell and an antheridial initial (Fig. 21.10 g). The antheridial initial again divides to give rise to a small antheridial cell and a large tube cell. The pollen grains are shed at the four-celled stage, showing two prothallial cells, an antheridial cell and a tube cell (Fig. 21.10 h). In the microspores a thin layer of callose first develops at two sides where wings are destined to be formed and later spreads and covers the proximal end of the pollen grain. The pollen is now mature and ready to pollinate the ovule.

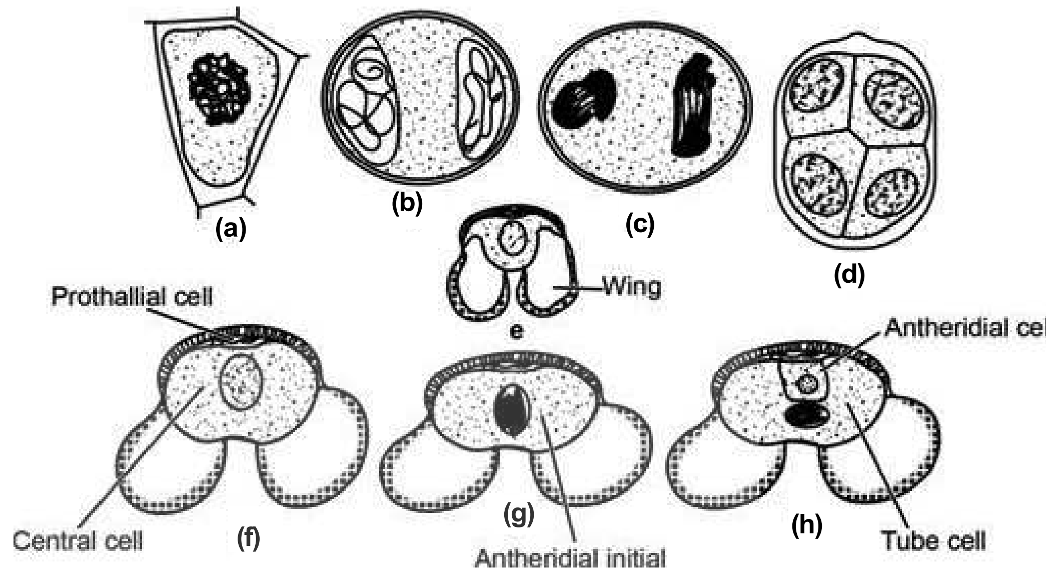


Fig. 21.10: *Pinus* **sp. : Details of microsporogenesis; a) Microspore mother cell; b, c) Meiosis I and II, respectively; d) Microspore tetrad; e) Uninucleate pollen gain;f, g) Stages in the development of male gametophyte. In g, both prothallial cells have been cut off and the antheridial initial is undergoing division; h) Mature, four-celled (two degenerating prothallial cells, an antheridial cell and a tube cell) pollen grain at shedding stage (after Konar & Ramchandani, 1958).**

21.5.2 Female Cone and Female Gametophyte

The female cones (Fig. 21.11 a) replace the long shoots and the number is variable and may be up to six. Each female cone consists of a central axis on which 80-90 megasporophylls (ovuliferous scales or ovule-bearing scales), are arranged in a spiral fashion (Fig. 21.11 b, c). The bract and the ovuliferous scales together form a seed-scale-complex (Fig. 21.11 e, f). Each megasporophyll bears two ovules on the upper or the adaxial surface (Fig. 21.11 d). The ovules are inverted with micropyle facing the axis of the cone. The ovuliferous scale is initially much smaller than the bract scale, but in post-pollination stages it overgrows the latter (Fig. 21.11 e, f).

Megasporangium and Megasporogenesis

The ovules of *Pinus* are unitegmic and crassinucellate. The integument is free from the nucellus for most part of its length, except at the chalazal end. It forms a fairly broad micropylar tube which is curved in during pre-pollination stages, but is curved-out at the time of pollination.

A hypodermal archesporial cell (rarely more) is formed at the micropylar end of the broad nucellus. It divides periclinally to form a primary parietal cell towards micropylar end and a primary sporogenous cell towards chalazal end. The former divides both anticlinally and periclinally so that the megaspore mother cell is pushed deep into the nucellus (Fig. 21.12a). It forms a linear tetrad of megaspores after meiosis (Fig. 21.12 b). The lowermost cell acts as the functional megaspore and upper three megaspores degenerate.

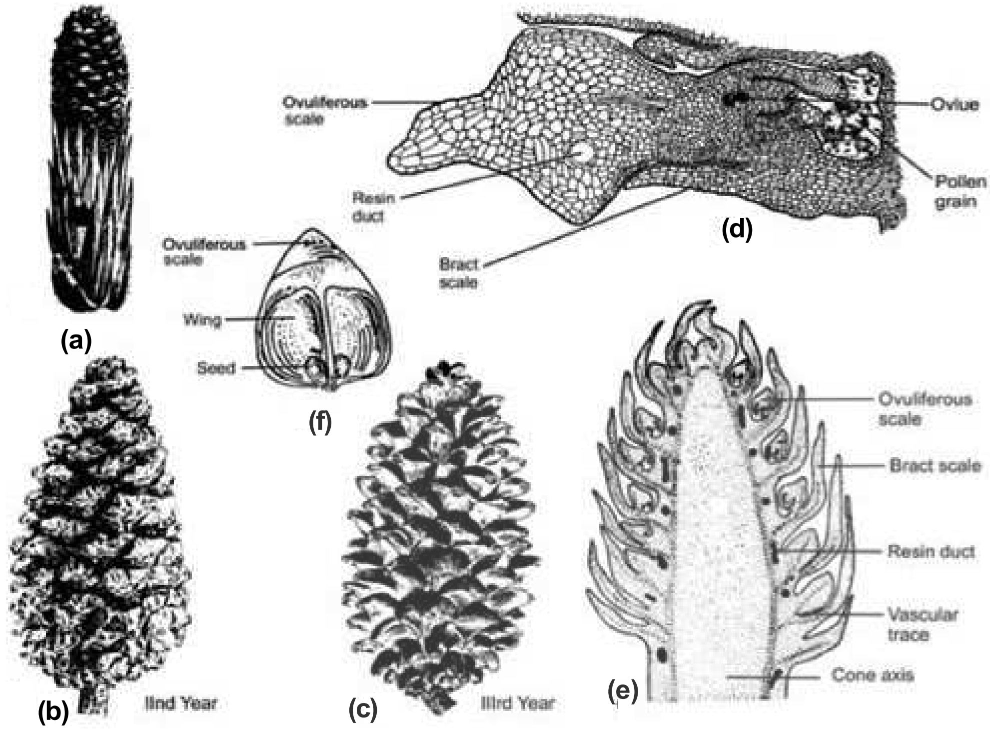


Fig. 21.11: *Pinus sp.* : a) Female cone at the time of pollination (1st year); b, c) Same during the (IInd and IIIrd year) post pollination phase and at time of seed-shedding; d) Ovulierous scale with two seeds borne on adaxial surface; e) Longisection of a young female cone at the time of pollination; f) winged seed.

Female Gametophyte

Functional megaspore enlarges considerably; its nucleus divides mitotically to give rise to the free nuclear gametophyte (Fig. 21.12 c, d). The number of nuclei in the free nuclear gametophyte is constant for a particular species. When the free nuclear gametophyte has to become cellular, the first walls are laid perpendicular to the megaspore membrane and extend to the middle of the central vacuole. These cells are like long tubes that are open towards the inside and are called “alveoli”. As a result of laying down of walls towards the center, the gametophyte becomes cellular (21.12 e).

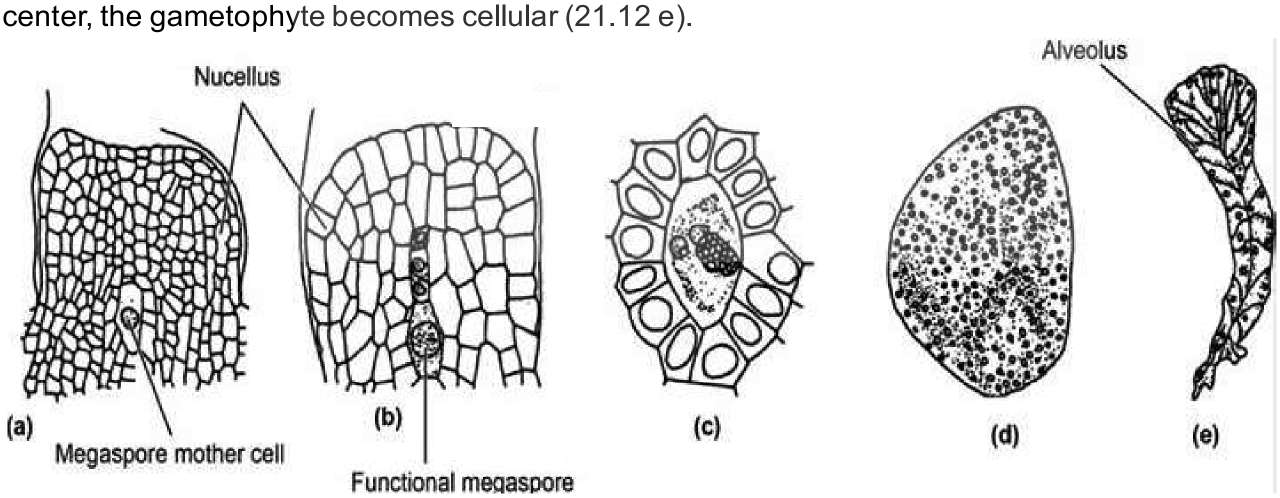


Fig. 21.12: a-c) *Pinus roxburghii*; d-e) *P. wallichiana* a) L.S. nucellus with a deep-seated megaspore mother cell; b) Linear tetrad of megaspores; the chalazal one is functional and the upper three are degenerating; c) Four-nucleate female gametophyte; d) Whole mount of gametophyte at free nuclear stage; e) Walls have been laid down through alveoli. (after Maheshwari & Konar, 1971).

A few cells (generally two or four) at the micropylar end of the female gametophyte become large and prominent, and function as archegonial initials (Fig. 21.13 a). Each archegonial initial soon divides into a large central cell and a small primary neck initial (Fig. 21.13 b). The latter is divided by two vertical walls at right angles to each other to form a neck of four cells arranged in a single tier. The central cell enlarges very rapidly so that numerous vacuoles are formed. This is referred to as the 'foam stage' of the archegonial development (Fig. 21.13 c). The central cell nucleus, meanwhile, divides into an ephemeral ventral canal cell and a large egg cell (21.13 d).

The gametophytic cells near the apical end of the individual archegonium grow vigorously resulting in the sinking of the latter. Thus each archegonium has its own archegonial chamber. Cells surrounding the archegonium form a special covering layer, the jacket (Fig. 21.13 d).

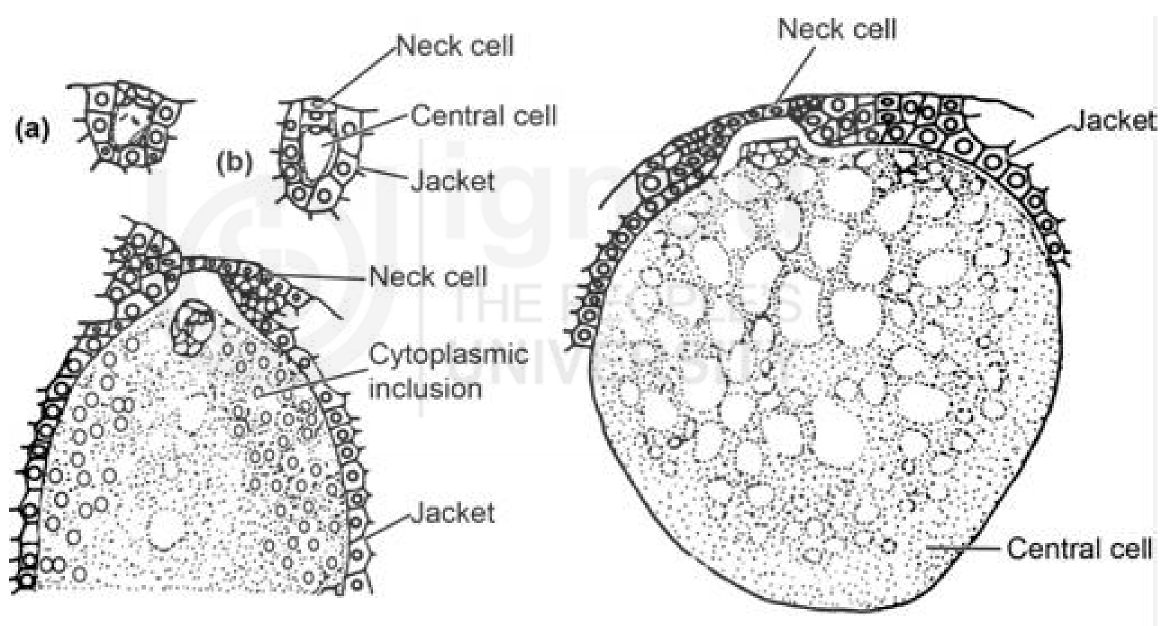


Fig. 21.13: a-d *Pinus* sp. : a) Newly formed archegonial initial and its jacket; b) The archegonial initial has been divided into neck initial and central cell; c) The central cell has undergone rapid enlargement; its cytoplasm shows numerous vacuoles. The neck initial has been divided into two neck cells; d) L.S. upper part of archegonium showing neck cells and central cell nucleus undergoing division which will result in the formation of ventral canal cell and egg cell; note cytoplasmic inclusions, (after Konar & Ramchandani, 1958).

Numerous pits are present on the inner thickened wall (facing the archegonium). The archegonium maintains contact with the surrounding gametophytic tissue through these pits. When the pit membrane breaks down, various organelles, and even whole nuclei pass from the jacket to the egg cytoplasm.

SAQ 2

State whether the following statements are **True** or **False**.

a) The *Pinus* tree is monoecious and male and female cones are borne on same branch. [ ]

b) Seed crops in *Pinus* are not annual and occur at interval of two or even more years. [ ]

c) The ovuliferous scale in post-pollination stages overgrows the bract scale. [ ]

d) A microsporophyll in *Pinus* bears many microsporangia in its axil. [ ]

e) A microspore mother cell can produce four pollen grains. [ ]

21.6 POLLINATION AND FERTILIZATION

21.6.1 Pollination

Pinus is wind-pollinated. The yellow pollen is produced in such great abundance that in a pine forest it is called 'sulphur shower'. At this time the female cone is still open (see Fig. 21.11 a, e) and the winged pollen grains easily sift in, roll down the obliquely tilted scales and finally come to rest in the vicinity of the micropyle. At this stage, the ovule secretes a drop of sugary liquid, the 'pollination drop', which fills the micropylar cavity and exudes out at the flared tip of the integument.

The secretion of the drop is reported to be a cyclic (24 h cycle) phenomenon, which occurs at night or in the early hours of morning.The wings help to orient the pollen in such a manner that the germinal pore of the grain contacts the drop and it gets sucked inside.

The pollen tube arises from the intine. While moving through the nucellus the pollen tube secretes enzymes dissolving the nucellar cell walls. As the tube emerges, the tube nucleus is the first to move into it followed by spermatogenous cell and stalk cells (Fig. 21.14 a). The spermatogenous cell eventually divides into two unequal male nuclei (Fig. 21.14 b, c).

21.6.2 Fertilization

The pollen tube enters the archegonium forcing itself between neck cells. The pollen tube on bursting releases two unequal male gametes, stalk cell and the tube nucleus with associated cytoplasm. The male nucleus enters the archegonium and moves towards egg nucleus (Fig. 21.15) and eventually fuses with it forming the zygote. Fusion of male and female gametes (syngamy) which results in the formation of zygote is known as fertilization. The zygote represents the first cell of the sporophyte of next generation.

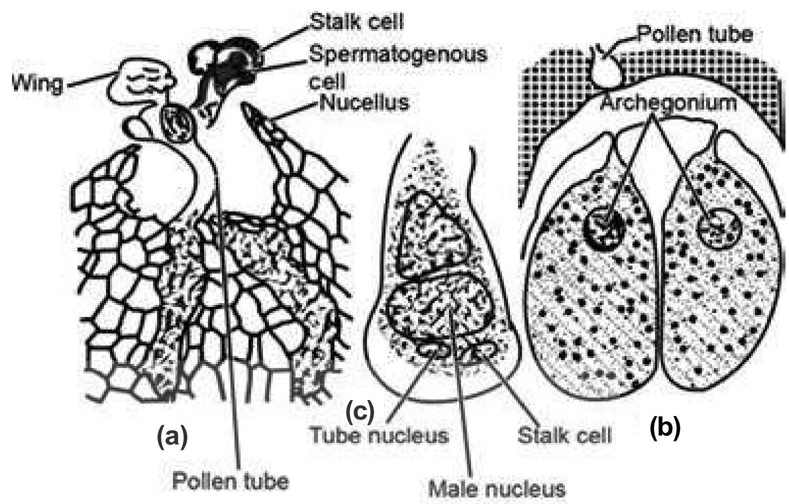


Fig. 21.14: ***Pinus*** **sp. : a) L.S. nucellar tip with three germinating pollen grains. In one of the pollen grains, stalk and spermatogenous cells are separating prior to their entry into the pollen tube; b) Same, part of ovule showing a fertilized (left) and an unfertilized (right) archegonium. A portion of the pollen tube is seen in the nucellar tissue; c) Pollen tube from b enlarged to show the two unequal male gametes, the stalk cell and the tube nucleus (after Konar, 1962).**

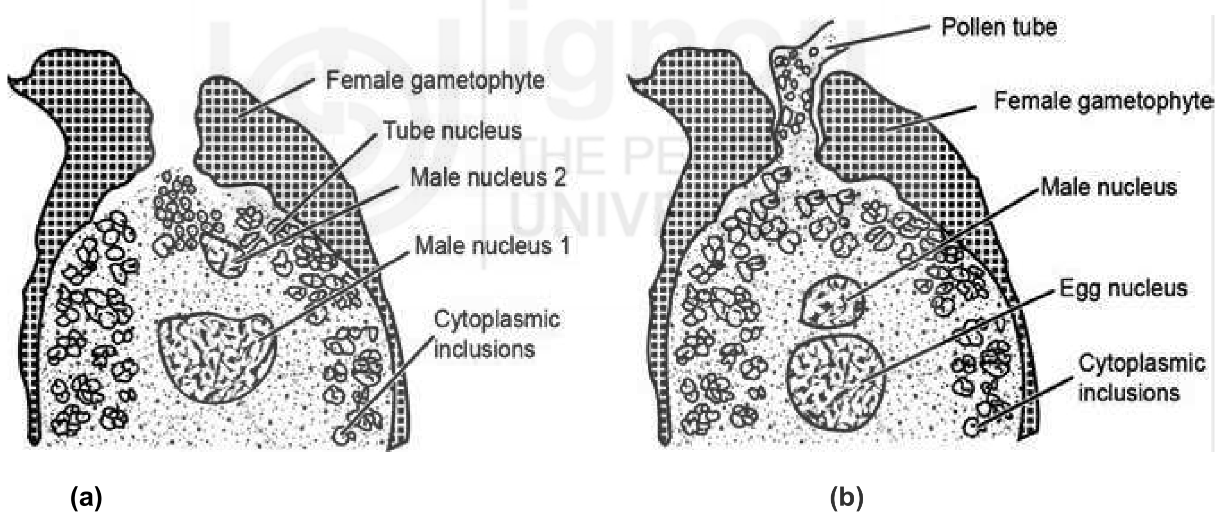


Fig. 21.15: ***Pinus*** **sp. Stages in fertilization; a) L.S. upper part of archegonium. The male nucleus is nearing the egg nucleus; part of the pollen tube is seen at the top; b) Same, showing fusion of the male and female nuclei to form the zygote. The second male nucleus and tube nucleus are visible in the upper part of egg cell. Cytoplasmic inclusions are prominent (After Konar & Ramchandani, 1958).**

21.6.3 Development of Proembryo

The zygote nucleus divides mitotically to give rise to two nuclei. The next division immediately follows and the resulting four nuclei move to the archegonium base (Fig. 21.16 a-c). A third synchronous division results in eight free nuclei. Wall formation gives rise to an upper group of cells, the primary upper tier (pU) and a lower group of cells, the primary embryonal tier (pE), each having four cells (Fig. 21.16 d). One more division occurs in both

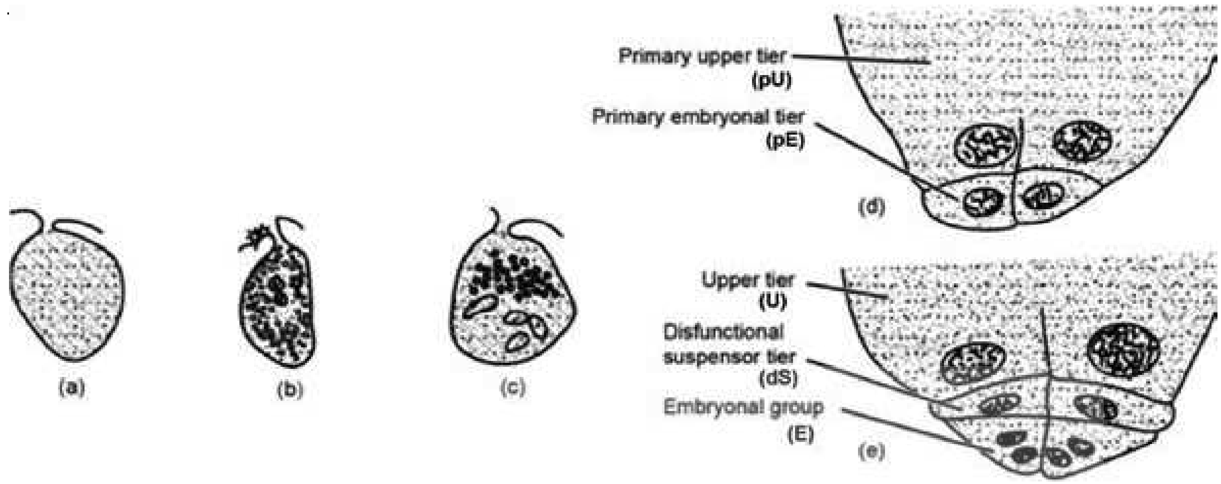


Fig. 21.16 : *Pinus* sp. a) Archegonium showing zygote nucleus in metaphase; b-c) Two and four nucleate proembryos, respectively; d) Eight-celled proembryo arranged in two tiers. Primary upper (pU) and primary embryonal (pE), of four cells each; e) Proembryo comprising of upper (U), dysfunctional suspensor (dS) and embryonal group (E) of two tiers (after Konar & Ramchandani, 1958).

tier cells) and E (embryonal group cells). There are now 16 cells, arranged in 4 tiers. The upper tier has no wall towards the upper side and is thus open (Fig. 21.6 e). The lower two tiers belong to the E group, followed by S and U tiers. The lowest tier (lower four cells of E group) gives rise to embryonal mass. Next tier (upper four cells of E group) elongates to form the embryonal suspensor (Es).

21.7 EMBRYOGENY AND SEED DEVELOPMENT

The developing embryonal cells (Fig. 21.17 a-i) are pushed deep into the gametophyte by the several fold elongation of the embryonal suspensors. In *Pinus* several crops of embryonal suspensor (Es_1, Es_2, Es_3, and ….) are produced (Fig. 21.17 a-d). Proximal cells of the embryonal mass elongate unequally forming the characteristic embryonal tubes. Four or more embryos start elongating. Both simple and cleavage polyembryony are evident. Only one embryo matures, whereas the growth of others is arrested at different stages of development.

The embryonal cell of the developing embryo divides in various planes to form a hemispherical apex towards chalazal end of ovule and suspensor system towards micropylar end of ovule. Root cap develops at the suspensor end of the embryo and shows a central column and a peripheral region. During these changes in the root cap region of the embryo, the pith region begins to differentiate in hypocotyl shoot axis. The cells of the hypocotyl region, situated between epicotyl and root apex are large, vacuolated and transversely arranged. Then cortex is differentiated followed by procambium, and finally cotyledonary primordia. The shoot apex and cotyledons are last to differentiate. The cotyledons are 3-18 in number (Fig. 21.17 h, i) and show the presence of procambial strands and mesophyll cells. The mature embryo, thus, has a distinct epicotyl root axis and a hypocotyl shoot axis with remnants of suspensor.

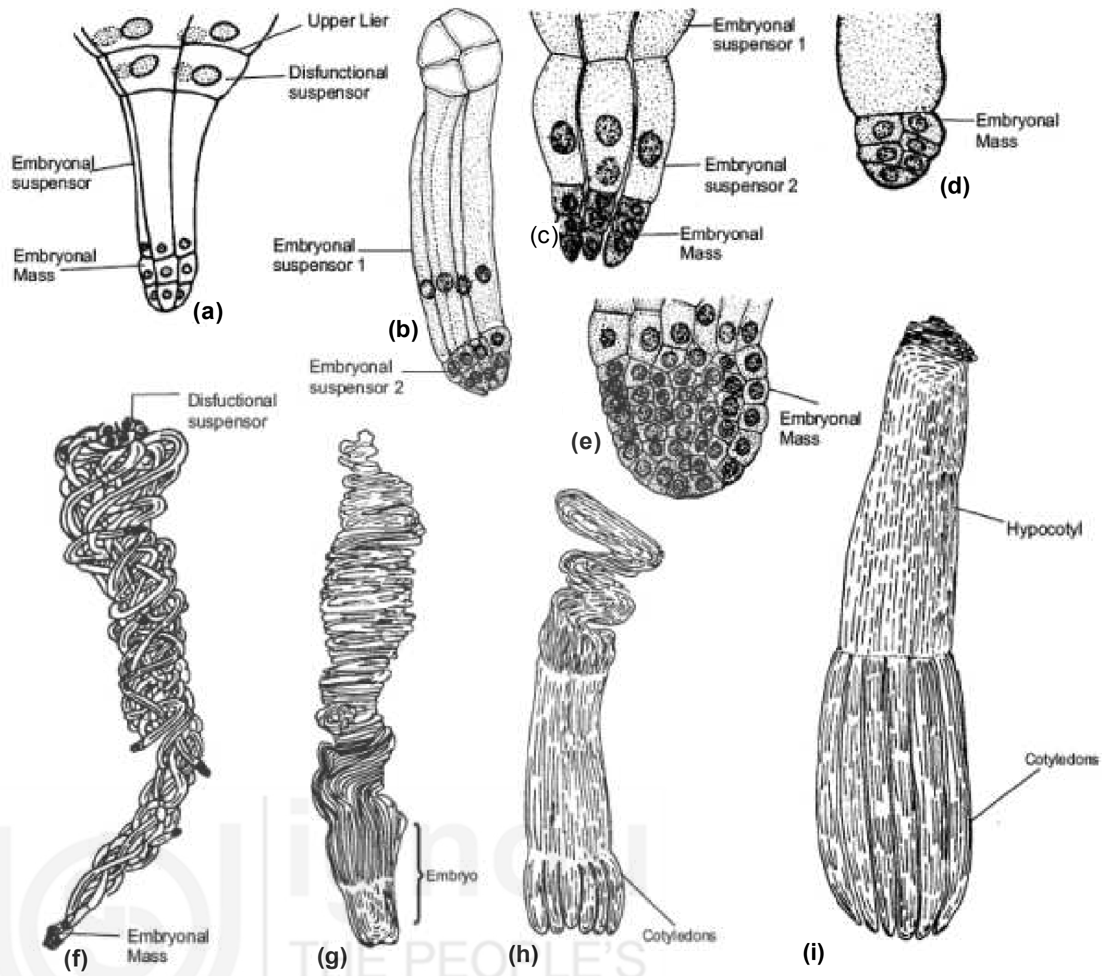


Fig. 21.17: A. *Pinus* sp. : Progressive stages in the development of embryo; a) Diagrammatic representation of proembryo showing first crop of embryonal suspensor (Es_1). The suspensor tier of proembryo does not elongate and is dysfunctional. Embryonal cells have undergone transverse division; b) The cells of the embryonal group have given rise to two crops of embryonal suspensor; note the great elongation of (Es_1). Disfunctional suspensor is seen above this tier; c- e) Further divisions in embryonal mass (e); f) Whole mount to show extremely coiled suspensor system and few proembryos at different levels; g, h) Whole mounts to show greater activity in embryonal mass (e); cotyledons have differentiated in h, i) Mature embryo showing polycotyledonous condition (a after Buchholz, 1929; b-i), after Maheshwari & Konar 1970).

21.7.1 Seed Coat

In a young ovule the integument comprises three layers. As ovule matures the integumentary cells divide and become differentiated into three zones; outer fleshy, middle stony and inner fleshy (Fig. 21.18).

The seeds of almost all pines have well developed wings; however, some species possess rudimentary wings or are wingless.

The seed coat may be hard or papery, but it is permeable to water. The pine seeds are normally dispersed by wind to long distances. Cones may also roll down and help in establishing plants at lower elevations.

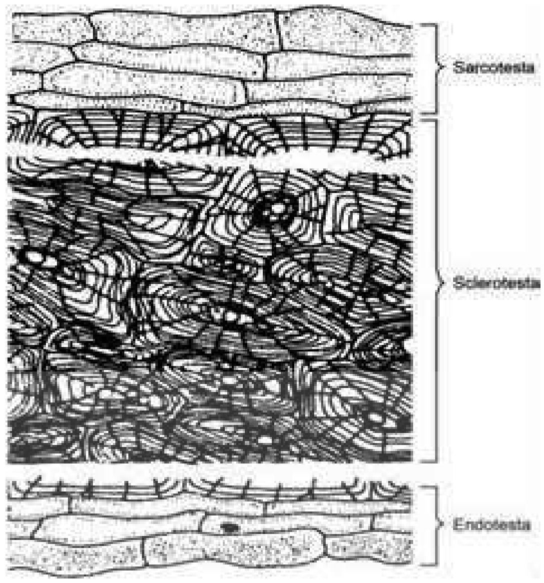


Fig. 21.18: T.S. seed coat of *Pinus roxburghii* (After Konar, 1960).

Seed crops are known in *Pinus*. These are not annual but occur at intervals of two or even more years. As the trees get old, the seed-bearing capacity declines but does not stop entirely. Pines keep on producing seeds till their death.

21.7.2 Seed Viability and Germination

In *Pinus* where female cones remain closed at maturity the seeds remain viable for a long time. The germination of seed is epigeal (Fig. 21.19 a-h). The seeds germinate within 3-4 weeks after sowing. The radicle emerges and penetrates the soil. The hypocotyl elongates, straightens and carries the remnants of seed along with the cotyledons, thus pushing them above the ground. The cotyledons absorb nutrients from the endosperm and provide it to the seedling. The cotyledons are shed only after the juvenile leaves appear and long shoot has grown.

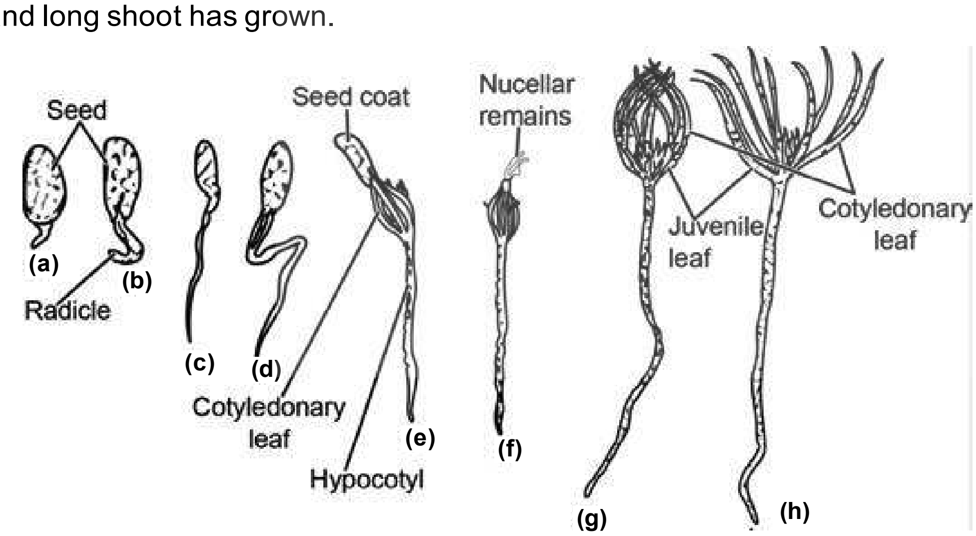


Fig. 21.19 : *Pinus gerardiana* : a-h) Stages in the germination of seed; h) Seedling with cotyledonary and juvenile leaves.

21.7.3 Life Cycle

The reproductive cycle in tropical and temperate pines is influenced by the environmental factors. The altitude at which the trees grow is also important.

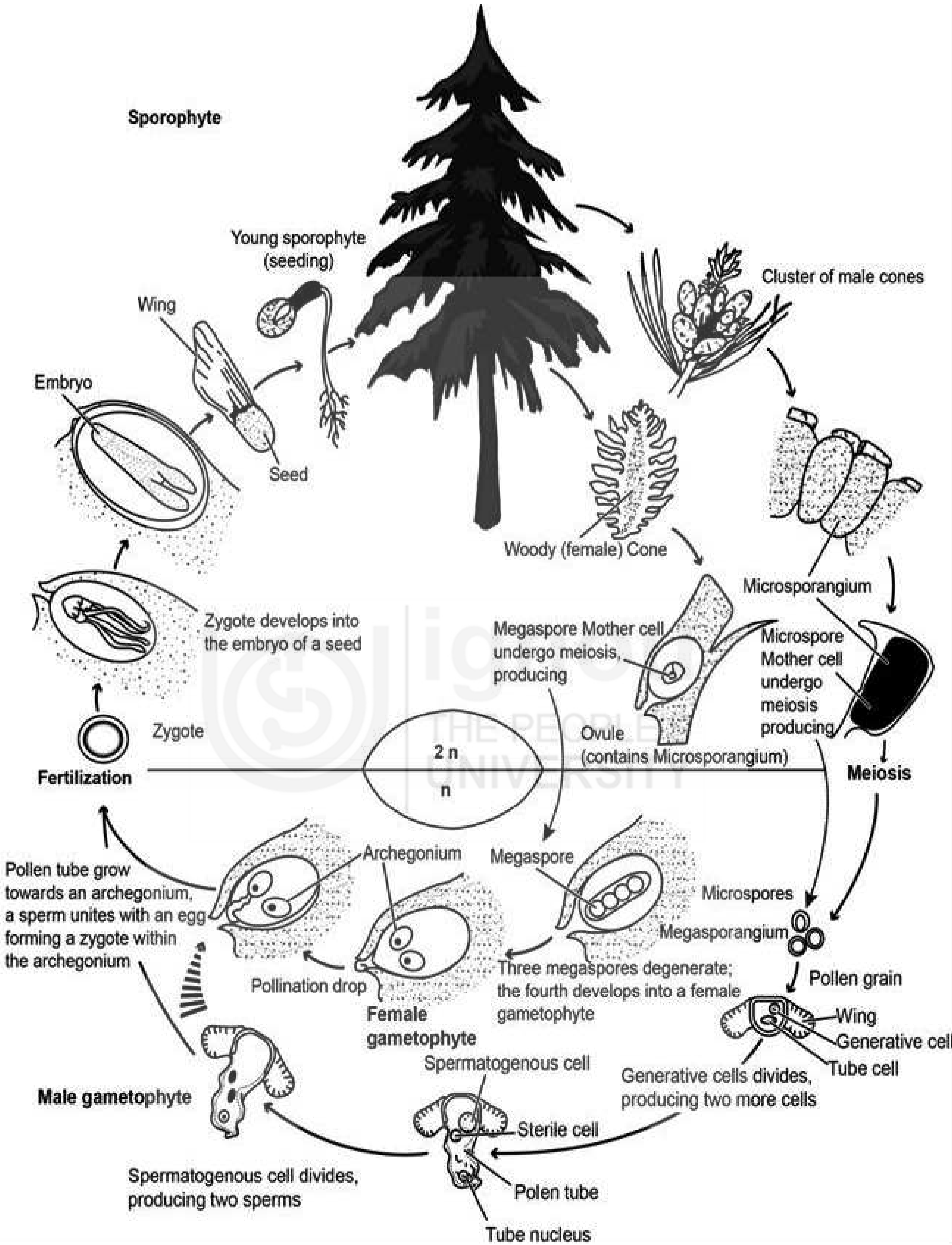


Fig. 21.20: Diagrammatic representation of Life-Cycle of *Pinus*.

In trees growing at lower altitudes (e.g. *Pinus roxburghii*) male cones are initiated in September, and pollination occurs the following March. After germination the pollen tube undergoes rest for about 10 months (May to February – 2nd year). Growth resumes in March followed by fertilization in April.

The female cones are initiated in February, pollinated in March and then undergo rest from April to January for 10 months. At the time of pollination the ovule contains a free-nuclear gametophyte. During the 2nd year when growth resumes in February, the gametophyte becomes cellular and the archegonia are formed. Fertilization takes place in April and followed by embryo development and seed is formed. The cones dehisce and shed their seeds in April-may (3rd year).

SAQ 3

a) Indicate what each of the following items, becomes or develops into.

i) megaspore mother cell……………………………..

ii) ovule …………………………………….

iii) microspore……………………………………

iv) embryo……………………………..

v) integument…………………………………..

vi) functional megaspore………………………..

vii) zygote………………………………………

viii) cover scales in pine cone………………………..

ix) ovuliferous scales in pine cone………………………..

b) Summarize the life cycle of a pine.

21.8 SUMMARY

- Coniferales are a large group consisting of 7 families. The genus *Pinus* is one of the most well known representatives of the family, Pinaceae. Seven species of *Pinus* are known from Indian sub-continent. *Pinus* is a beautiful tree with a pyramidal appearance. *Pinus* exhibits two types of roots: normal and mycorrhizal. The stem is erect and woody. Two types of branches (i) long shoots and (ii) dwarf shoots are found. The foliage leaves are needle-like and borne on dwarf shoots.

- The tree is monoecious, but male and female reproductive organs are borne on separate branches. The male cone occurs in clusters and the number varies from 15-140. The female cones replace long shoots and 2-6 in number are borne on each node. 80-90 megasporophylls are spirally arranged along the central axis. The ovuliferous scales and the bract together form a seed-scale-complex.

- Mycorrhiza is found in several conifers. In *Pinus* there is well developed ectotrophic mycorrhizal association with 50 different species of fungi. The pine-fungal relationship is symbiotic. Secondary growth occurs both in root and shoot. The wood consists mainly of tracheids.

- The *Pinus* leaf may be round, semicircular or triangular in transverse section. The leaves show xerophytic characters.

- Microsporogenesis occurs in the microsporangium and winged pollen grains are formed. In the ovule (megasporangium) megasporogenesis occurs and haploid female megagametophyte is formed. The archegonium is situated at the apical portion of the gametophyte.
- In *Pinus* pollination is through wind and after fertilization zygote is formed. The embryo develops with distinct epicotyl, root axis and a hypocotyl with shoot axis with remnants of suspensor. The seeds of almost all pines have well developed wings; however, some species are wingless. The seed scoat comprises of three layers. The seed germinates within 3-4 weeks after sowing. The reproductive cycle in *Pinus* is completed in three years.

21.9 TERMINAL QUESTIONS

1. Differentiate between long shoots and dwarf shoots.
2. Describe male and female cones of *Pinus* with diagrams.
3. What is mycorrhiza? How does it help the host?
4. Describe anatomical structure of stem.
5. Describe microsporangium, microsporogenesis and male gametophyte in detail.
6. How do pollination and fertilization take place in *Pinus*?
7. Depict the life cycle of *Pinus* through diagrams.

21.10 ANSWERS

Self-Assessment Questions

1. a) i) F ii) T iii) F iv) T v) T

   b) i) starch vi) sieve areas

   ii) sieve cell vii) vessels

   iii) ectotrophic viii) triangular

   iv) symbiotic ix) angle

   v) open, collateral x) sunken

2. a) F b) T c) T d) T e) T

3. a) i) four megaspores

   ii) seed

   iii) microgametophyte

   iv) seedling, sporophyte eventually mature in sporophyte

   v) seed coats

   vi) megagametophyte

vii) embryo

viii) woody scales of mature ovulate pine cones.

ix) wing like projection on pine seeds.

b) Refer Subsection 21.7.3 and Fig. 21.20.

Terminal Questions

1. See Subsection 21.3.2 – Stem.
2. See Subsection 21.5.1 and 21.5.2 – Reproduction and draw figures.
3. See Subsection 21.4.1 and Fig. 21.4 Point for reference.
4. See Subsection 21.4.2.
5. Refer to Subsection 21.5.1.
6. Refer to Section 21.6 – Pollination and Fertilization.
7. Refer to Fig. 21.20.

GLOSSARY

Brachyblast	:	Same as dwarf shoots or foliar spurs; borne on long shoots
Cataphyll	:	Scaly leaves that are formed on a dwarf shoot, are spirally arranged
Dwarf shoot	:	Branches of limited growth (short shoots), bears opposite 2 prophylls and spirally arranged cataphylls.
Long shoot	:	Branches of unlimited growth, which bear an apical bud enclosed in a bud scale; arises from a lateral bud in the axial of a scale leaf.
Mycorrhiza	:	Symbiotic relationship of fungus with the root-(Root-fungi); (associated with dwarf root of pines).
Multiseriate ray	:	A ray in the secondary vascular tissue, originating from a ray initials; more than 2 cell wide.
Ovuliferous scale	:	A woody/hard megasporophyll bearing ovule.
Prophyll	:	Two oppositely formed scaly leaves on a dwarf shoot.
Spur-shoot	:	dwarf shoots that arise in the axil of scale leaves.
Sulphur-shower	:	'Yellow' shower consisting of pollen grains produced in abundance in a forest.
Uniseriate ray	:	A ray in the secondary vascular tissue, originating from ray initials; only one cell wide.

UNIT 22

GYMNOSPERMS: ECONOMIC IMPORTANCE

Structure

22.1 INTRODUCTION

The gymnosperms are important groups of plants that inhabit mostly the temperate areas and the higher elevations in the tropics. The conifers comprise a major component of the forest flora in the northern and southern temperate belts. The timber or lumber industry plays a vital role in the economy of the countries situated in these geographical regions viz; USA, Canada and Northern Europe.

The gymnosperms in general and the conifers in particular are the source of numerous products used in our day-to-day life. The trees are used to provide timber for building and construction work. They are also a source of numerous products such as resin, rosin, copal, sandarac, fatty oils and essential oils. The newsprint industry owes a lot to the paper obtained from coniferous wood. Seeds of some gymnosperms are edible and plant parts of some other may be eaten raw or cooked. Certain gymnosperms have been known to possess therapeutic properties and now these are being exploited commercially.

Last but not the least; it is this very group of plants that is the source of the "Christmas Tree". Used by landscape architects and the horticulturists the gymnosperms are an excellent source of evergreen plants. In this unit we will describe the economic importance of gymnosperms.

Objectives

After studying this unit, you should be able to:

- ❖ enumerate the uses of gymnosperms;
- ❖ list important species used as timber or for other non timber purposes;
- ❖ present a resume of the economically important Indian species; and
- ❖ mention some of the recent developments regarding utilization of gymnosperms for their therapeutic value.

22.2 WOOD TIMBER, NON-TIMBER AND PAPER PULP

The wood of gymnosperms is used by man in a variety of ways, almost all over the world. They are of enormous economic importance and some of the species, which grow quickly are used as common firewood. We will describe these uses in following sections:

- Timbers and its Products
- Non-Timber Products
- Pulp and Paper

22.2.1 Timber and its Products

The term 'timber' refers to trees or wood suitable for building purposes. 'Lumber' is another term that refers to timber but this term is used mainly in North America. The gymnosperms, especially conifers, are an important source of timber all over the world. Large tracts of forests in the temperate belts of America, Europe and Australia are comprised of evergreen conifers.

The common yew, *Taxus baccata*, offers the heaviest wood among softwoods.

The wood of *Thuja plicata* is one of the most durable ones due to the presence of antibiotics. Hollowed out trunks have been used as canoes.

The conifer wood lacks both vessels and xylem fibres, hence it is non-porous and soft. It consists of tracheids, xylem parenchyma and xylem rays. As it lacks fibres it has a higher content of cellulose compared to angiospermous woods and, therefore, it has a softer texture. The coniferous wood is generally straight-grained; light coloured and light-weight. There is very little difference between heartwood and sapwood. It finds use where great strength and durability are not required. It is valued for furniture making and interior decoration. We shall now discuss some important sources of timber.

Taxodium is one gymnosperm that does well in swampy and wet areas. It is useful at places where resistance to decay is more important than strength.

Pine wood is softwood which is put to a variety of uses all over the world. *Pinus sylvestris* (Scots pine). *P. caribaea*, *P. palustris*, *P. contorta* and *P. densiflora*, are some of the commercially important timber trees in America and Europe. The wood is used in construction and carpentary work. Other sources of pine wood are *P. halepensis* (Mediterranean); *P. nigra*, *P. pinaster* and *P. ponderosa* (North Europe); and *P. monticola*, *P. strobes*, *P. lambertiana* and *P. radiata* (North America).

Pinus roxburghii ("chir"), is one of the most widely used commercial timber of India. It yields a resinous, non-durable and light wood which finds its use mainly in packing cases, construction work, low priced furniture, poles, railway sleepers, truck and bus chassis. *P. wallichiana* ("kail" or blue pine) is comparatively hard and durable, and put to use similar to that of "chir".

The wood of spruce (*Picea* sp.) is light weight, and straight grained but it is not very durable. The timber has a natural lustre which makes it attractive for plywood and indoor finishing. It is also used for making match boxes. In Christmas time this tree is sold for decoration. The maximum utilization of this wood is for making pulp and artificial fabric pulp. Some of the important species are *Picea abies*, *P. engelmanni*, *P. glauca*, *P. mariana*, *P. rubens*, *P. sitchensis* and *P. smithiana*. Spruce wood shows spiral thickening on the inner wall of tracheids. These apparently are responsible for giving the wood a resonance that makes it ideal for use as soundboards for violins, pianos and organ pipes.

Larch trees (*Larix* sp.) yield moderately hard and durable wood that can be used even in contact with the ground such as pit props in mines and boat building. Posts of larches are known to last for 20 years or more and are a source of one of the toughest of all conifer woods.

There are about 40 species of fir (*Abies*) which are widely used in construction work, plastic and paper industries and as Christmas trees, *Abies alba*. *A. balsamea* and *A. concolor* form an important timber source in Europe and North America. A. *pindrow* occurs in India but its wood is not very strong or long lasting.

Douglas fir (*Pseudostuga menziesii*) is not a true fir. It grows into giant trees that are second only to the redwoods in size. It is probably the most desired timber tree in the world today. The wood, which is strong and relatively free of knots (because of rapid growth with less branching than most other conifers), is made into heavy plywoods an large beams. It takes paint and polish well.

Coast redwood (*Sequoia sempervirens*) is also prized for its wood, which has certain substances that inhibit the growth of fungi and bacteria. The wood is soft, light in weight, but strong and splits easily. It is a source of excellent timber, but as the species is facing extinction, it is protected in reserves and national parks. It is used for some type of construction, furniture, posts and several other purposes.

The common yew (*Taxus baccata*) yields one of the heaviest softwoods. The wood is used in making bows for archery, candle stands and curios. As it is very durable, oily and decorative (because of irregular growth rings) it is used in furniture, flooring, panelling, etc.

Cedrus deodora, the "deodar" (India) and *C. atlantica* (Algeria and Morocco) are valuable timber trees. The cedar wood is durable, oily and much in demand as the seasoned wood is resistant to insect attack due to the presence of oil. However, it is not suitable for ply wood because of large knots.

Fig. 22.1 : Forest of *Cedrus deodara.*

Red cedar wood (*Thuja plicata*) is used for pencils as well as for cedar chests, closet lining, fence posts and cigar boxes. The wood is durable due to the presence of certain ingredients that impart weather resistant properties, thus preventing decay. The wood of Eastern white cedar (*Thuja occidentalis*) is pliable, and several native American tribes used it for making canoes. The white cedar is an attractive tree and is grown as Christmas tree in Indian plains.

The balsam fir (*A. balsamea*) produces on its bark blisters containing a clear resin which is known as Canada balsam.

Agathis australis (kauri pine) is the chief timber tree of New Zealand. It is the most important conifer of the Southern Hemisphere. *Araucaria* species are important sources of timber in Brazil and Australia.

The wood of *Taxus* has tertiary spiral thickenings on its tracheids which impart elasticity to the wood.

22.2.2 Non-Timber Products

Besides yielding timber, the wood of conifers is put to a variety of uses which we are going to describe.

Resins

Resins are plant exudates that make the wood resistant to decay. They are insoluble in water but dissolve in organic solvents.

The wood of a large number of conifers shows the presence of resin ducts which yield oleoresin on tapping. An **oleoresin** (pine gum, pine pitch or turpentine) is a mixture of rosin and essential oil. On distillation of turpentine (i.e. crude resin), a brittle resin is left behind called **rosin** or **gum rosin**. Rosin is also obtained by solvent extraction of old stumps. This is called **wood rosin**. Rosin is used in making varnishes, inks, etc.

Box 22.1: Turpentine collection

Turpentine oozes out from the resin canals after vascular cambium layer has been exposed by a cut, and at the same time the development of new ducts above the cut is stimulated. In the species used commercially the ducts are exceedingly large, and there is a heavy production of the oleoresin. Chipping, and re-exposing of the vascular cambium, has to be performed periodically; otherwise the oxidation and crystallization of the resin would clog the old ducts.

Amber occurs as lumps of translucent material with a yellow tint. Some lumps weigh up to 45 kg.

Fig. 22.2: Fossil resin called amber.

Copal and **Sandarac** are hard resins which contain very little essential oil. Copal is obtained from living trees as well as fossil state. The most important is **Kauri gum** or **Kauri copal** from *Agathis australis*. It is used for the preparation of lacquers, varnishes and enamels. **Manila copal** is obtained from *Agathis alba, Tetraclinis* sp. and *Callitris* sp. produce Sandarac.

Amber is also a fossil resin secreted by the extinct pine, *Pinus succinifera*. Fossil amber (Fig. 22.2) sometimes shows the presence of remains of plants and animals trapped in the resin. It has been reported that the human blood, when kept in an amber container, does not coagulate.

Canada Balsam (Fig. 22.3) is the resin obtained from *Abies balsamea*. Its refractive index is near that of glass and it does not crystallize. It is used as a mounting medium for microscopic histological preparations and a cement for lenses in optical work.

Fig. 22.3: Canada balsam.

Box 22.2: Resins

The term resin is a generally used to describe the brittle, glassy, thickened exudates of certain plants. Resins are plant exudates which make the wood resistant to decay. Conifers are amongst the major resin sources of the world. Resins are water insoluble, but dissolve easily in organic solvents. Resins are put to a variety of uses; the superior grade is used in the sizing of paper, as a constituent of varnishes, enamels, plasters, medicines and ointments; the inferior grades go in the making of oil cloth, grease, insecticides, adhesives, plastic, disinfectants, shoe polish, etc. The huge kauri pines (*Agathis*) of New Zealand, which belong to a different family from that of true pines, are the source of a mixture of resin which are used in high-quality colorless varnishes. This was also the resin originally used in the manufacture of linoleum.

In India the tapping of pine trees (*Pinus roxburghii* and *P. wallichiana*) is generally done from March to November. Tapping is done in two ways; (i) light continuous tapping and (ii) heavy tapping. A rectangular piece of galvanized iron is hammered in, to form a “lip” and a nail is driven about 2 cm below the lip on which the collecting vessel is hung. A channel is made just above the lip and this facilitates collection of the exudates. Every year the channel is increased at its upper end. After 5 years a new face is made on the same tree trunk and the process continues till the complete girth is used. In heavy tapping numerous faces are tapped simultaneously. This is done on trees that are old and earmarked for felling in future.

Tannins: Tannins are extracted from the bark of some of the tree species of gymnosperms (*Picea, Larix, Sequoia, Tsuga, and Araucaria*). Tannins are used in the leather and petroleum industry for dyeing, tanning purposes and in medicine. However, tannins from these sources have as yet not been exploited commercially. The bark of larch and spruce are also used for tanning of leathers.

Miscellaneous Uses: The roots of white spruce are pliable and the split from the roots were used for basket and canoe making by native Americans.

22.2.3 Pulp and Paper

Pulp from conifer wood is used world-wide for the manufacture of paper. The newsprint industry is almost entirely dependent on this source. Superior quality writing and printing paper is manufactured from the wood of conifers such as *Picea*, *Abies*, *Tsuga*, *Larix* and *Pseudotsuga*. The chief source for pulp and paper making in North America is white spruce (*Picea glauca*).

Major portion of wood pulp is derived from coniferous wood especially *Picea*, *Abies* and *Pinus*. Several products such as rayon, transparent paper and photographic films etc. are also manufactured from wood pulp.

In India, *Picea smithiana*, *Abies pindrow* and *Pinus roxburghii* provide excellent quality pulp. The wood of *Cryoptomeria japonica* yields kraft paper.

Conifers are preferred throughout the world as a source of pulp because of greater average length of their tracheids and large percentage of long tracheids per given volume of wood. The best source is *Picea* which produces wood pulp that is light coloured with low resin content.

SAQ 1

a) Match the species given in column B with the uses given in column A.

Column A	Column B
i) Non-porous and soft wood	a. *Picea* sp.
ii) Widely used as commercial timber of India.	b. *Abies* sp.
iii) Wood used in manufacture of sound boards of violins, pianos, etc.	c. *Pinus roxburghii.*
iv) One of the toughest of all conifer woods	d. Conifer wood.
v) Mostly used for paper industries or as ornamental plant.	e. *Larix* sp.

b) Fill in the blanks:

i) An oleoresin is a mixture of ....and..................

ii) Kauri copal is obtained from.............

iii) ....and.......................are hard resins which contain very little essential oil.

iv) ....a resin, which is used as a medium for mounting microscopic objects.

c) What is resin? Discuss its uses.

d) Write a note on uses of conifers in paper manufacturing.

22.3 FOOD, MEDICINAL AND AESTHETIC VALUES

Besides timber and products derived from it, the gymnosperms are also useful to mankind in many other ways. Some of them are discussed here under the following heads:

1) Food
2) Medicinal and Allied Uses
3) Aesthetic Value

22.3.1 Food

The cycads are used as food in many parts of the world. They are eaten as a source of starch which is obtained either from the stem pith or the seed kernels.

Box 22.3 : Sago production

The *Cycas* plants which are nearly seven years old and have not fruited are best suited for stem starch purposes. The plants are cut just before the flush of new leaves and the outermost dry annularly furrowed stem along with the fronds are removed. Only the innermost cylindrical axis is used which after drying is made into flour. The starch is converted into spherical granules, called "sago". These granules are passed through sieves to obtain several grades such as 'bullet sago', 'pearl sago', etc.

The starch (popularly known as "sago") is obtained from the stem of *Cycas circinalis*, *C. rumphii*, *C. revoluta*, *Zamia* and *Macrozamia*. The pith of *Encephalartos* stem is used for making "kaffir bread" in Africa. Cycads have a toxic principle (cycasin) which is inactivated by heating. Seeds of *Cycas* and *Macrozamia* are eaten in India and Australia respectively by the tribals.

Roasted seeds of *Araucaria*, *Ginkgo* and *Torreya* are consumed in Australia, Chile and Japan. Pine seeds have been used for a long time as a food item. In India, too, *Pinus gerardiana* (Chilgoza pine) seeds have been marketed by traders who obtain most of the supply from Afghanistan. The tree grows in the higher altitudes of the Western Himalayas (Himachal Pradesh). In Europe and North America also, edible seeds of pines (*P. pinea*, *P. cembra*, *P. pumila*, *P. edulis*, *P. parryana*, *P. monophylla*) are sold as nuts for use in soups, desserts and in the manufacture of candies and confectionary.

Inner soft parts such as phloem and cambium of many conifers have been used as emergency food since time immemorial. The phloem contains sugar that makes it taste sweet. Some N. American tribes eat the material raw. Some dry it and ground it into flour, while some others boil it and store it as dried strips for use in winter.

The fleshy red aril surrounding the seeds of *Taxus* is sweet and consumed by animals. But the seeds themselves and other parts of the plant are poisonous.

The *Ginkgo* seeds possess fleshy seed coat which has a foul odour but the kernels (starchy 'endosperm' in seeds) are edible. In China and Japan these are widely used either boiled or roasted.

22.3.2 Medicinal Allied Uses

One of the best known medicinally important gymnosperms is *Ephedra*. The alkaloid ephedrine is extracted from the green branches of *Ephedra gerardina*, *E. equisetina* and *E. sinica*. Ephedrine is an important ingredient of cough mixtures and nasal drops. It dilates the bronchial tube and also contracts the mucous membrane. Presently all pharmaceutical industry requirements of ephedrine are met from the commercially synthesized alkaloid. Local requirements in indigenous medicine are still fulfilled by using plant extracts.

Taxus (Yew) is used for curing a number of ailments. Leaves of *T. baccata* are used in asthma, bronchitis, epilepsy and indigestion. The plant contains a toxic principle taxine which is an active heart poison. Another important drug presently being marketed is taxol which is obtained from *Taxus brevifolia*. It has been effectively used as an anti-cancer drug (especially against ovarian, breast and colon cancer). As a large number of yew trees are being felled to obtain this drug, efforts are now on to produce the chemical taxol through tissue culture. The alternative possibility of chemical synthesis is also being investigated.

Box 22.4: Cancer and Taxol

> In 1989, at John Hopkins Oncology Centre, N.Y. Washington, researchers have reported that ovarian cancers that had not responded to traditional therapies (including, in some case, surgery) had a decrease of 50% or more in the size of their tumors, and one women's tumor disappeared altogether after treatment with taxol, a drug obtained from the bark of the Pacific yew tree (*Taxus* sp.). Pacific yew trees are small and do not occur in extensive strands. They grow very slowly and take nearly 70 years to attain their full size.

Seeds of *Ginkgo biloba* are used in the cosmetics industry in China and Japan. Unripe seeds are collected and the pulp of the seed coat is utilized.

The leaf extract of *Ginkgo biloba* is useful in the treatment of cerebral insufficiency and vertigo. Ginkgolide compounds also antagonise platelet activating factor (PAF) in vertebrate systems.

Cycas seeds are used as an emetic and a cure for boils and sores. *C.rumphii* pollen is believed to be narcotic. The powdered stem of *C. pectinata* is used as hair wash for diseased hair roots. *Zamia* seeds yield a poisonous substance that acts as a cure for gout and pains. The peculiar odour of *Cycas* male cones drives away bugs and sometimes even rats from fields or stored grains.

Fig. 22.4: Essential oil.

Essential oils extracted from conifers (Fig. 22.4) are used to some extent in perfumery, or in the preparation of insect repellents, deodorants and certain medicines for skin ailments. The oil from female cones of *Juniperus communis* is used to flavor liquors (gin and other alcoholic beverages). In India, *Cedrus deodara* oil is used in perfumery and soaps. It also serves as immersion oil for microscopic work.

SAQ 2

a) State whether the following statements are true or false; write **T** for true and **F** for false in the given brackets.

i) Pearl sago is obtained from the fruits of *Cycas revoluta*. [ ]

ii) The seeds of nearly all the pines are edible. [ ]

iii) Aril, seeds and other parts of the *Taxus* plant are sweet and edible. [ ]

iv) In India chilgoza seeds are obtained from *Pinus gerardiana*. [ ]

v) The stem starch commonly known as sago is obtained from *Cycas circinalis*, *C rumphii* and *C. revoluta*. [ ]

b) Fill in the blanks:

i) The alkaloid………………………..is extracted from……………………………

ii) The drugs…………………………..is obtained from *Taxus brevifolia*.

iii) …………………….compounds also antagonise platelet deactivating factor (PAF) in vertebrates.

iv) ………………………..oil is used in perfumery and soaps.

c) Write a short note on Taxol.

22.3.3 Aesthetic Value

The scenic beauty of hill stations can be attributed in large measure to the presence of conifers on the mountain slopes. Their evergreen habit, symmetric growth and tall appearance are a treat to the eyes. Planted as garden or as avenue trees or even as green belts to screen off the sunshine, they are the pride of horticulturists and garden lovers. Pines, cedars, firs, spruces, junipers and hemlock are common planting material in the temperate climate. Gymnosperms also offer a good source of planting material for developing "Bonsai" plants. This art of dwarfing plants and maintaining them as showpieces originated in Japan; junipers and pines are favourites for this purpose.

Ginkgo biloba (maidenhair tree) is a gift and relic of the past. The plants are extensively cultivated in numerous gardens and arboreta of the world as botanical curios.

Cupressus funebris is generally planted around tombs and religious buildings; *Taxus* is an ornamental and an excellent plant for topiary work. Other conifers commonly grown in gardens are *Biota*, *Thuja*, *Juniperus*, *Araucaria* and *Pinus*.

At the time of Christmas, saplings and branches of *Picea abies* are commonly used in Europe for decoration. In India, it is *Cedrus* and *Thuja* which fulfil this role. In warmer areas (i.e. tropical and sub-tropical) cycads are used as outdoor plants. Their captivating graceful appearance adds to the beauty of gardens in these areas; they are also grown in green houses in the temperate regions.

The fossil resin amber is used for beads, ornaments or for carving making figurines and cigar holders. Portions of amber containing remains of plants and insects are artistically modeled into pendants and show pieces.

22.4 SUMMARY

- The gymnosperms are put to a variety of uses. They provide timber, resins, paper and board, edible seeds and some are even the source of medicines.
- The Coniferales are an important source of timber all over the world, yielding wood that is put to a variety of use all over the world.
- In India *Pinus roxburghii* (Chir) is most widely used as a commercial timber.
- The spruce (*Picea*) is used for making sound boards of musical instruments.
- Coast redwood is also prized because its wood is resistant to bacteria and fungi.
- Resin from pines is the source of turpentine and rosin. Turpentine oil is used as a solvent and rosin is used for making varnishes, ink, etc.
- The major portion of wood pulp for paper production comes from conifers such as *Picea*, *Abies* and *Larix*.
- The stem starch known as “sago” is obtained from *Cycas*.
- Some species of gymnosperms are medicinally important such as *Ephedra* from which ephedrine is extracted. Another important drug taxol is obtained from *Taxus brevifolia* which is effective against ovarian cancer.
- The evergreen habit, symmetric growth, and tall appearance make gymnosperms aesthetically important. *Cupressus*, *Juniperus*, *Pinus*, *Taxus*, *Ginkgo*, *Thuja* and *Aracucaria* are commonly grown in gardens.

22.5 TERMINAL QUESTIONS

1. Enumerate the uses of gymnosperms.
2. What is resin and what are its sources?
3. Write a short note on cancer taxol.

4. Give the names of the major conifers that are a source of timber in India.
5. Why is the newsprint industry largely dependent on the conifer wood?
6. Write a short note on the aesthetic value of gymnosperms.
7. If money is not a constraint and you wish to make a dream landscape, what type of gymnosperms you would choose and why?

22.6 ANSWERS

Self-Assessment Questions

1. a) i) *Pinus roxburghii*
   ii) Conifer wood
   iii) *Picea* sp.
   iv) *Larix* sp.
   v) *Abies* sp.
   b) i) rosin, essential oil
   ii) *Agathia australis*
   iii) Copal and Sandarac
   iv) Canada Balsam
   c) See Subsection 22.2.2; Box 22.3.
   d) See Subsection 22.2.3.
2. a) i) F
   ii) T
   iii) F
   iv) T
   v) T
   b) i) *Ephedrine*; *E. gerardiana*
   ii) Taxol
   iii) Ginkolide
   iv) *Cedrus deodara*
   c) Refer to Subsection 22.3.2; Box 22.4.

Terminal Questions

1. Make a list of uses of gymnosperms and write few lines on each.
2. Please refer to Subsection 22.2.2 and Box 22.3.
3. Please refer to the Subsection 22.3.2 and Box 22.4.
4. See Subsection 22.2.1 – Timber and its Products.
5. See Subsection 22.2.3 – Pulp and Paper.

6. See Subsection 22.3.3 – Aesthetic Value.

7. You should make a list of the gymnosperms you will like to plant, and then make a rough sketch keeping in mind the following points (1) climate (2) arrangement the gymnosperms according to their (a) height, (b) leaf structure and (c) branching.

The answer will differ from person to person.

GLOSSARY

Amber : A fossilized resin. Exudate from extinct Pine, *Pinus succinifera*

Essential Oil : Derivatives of turpentine or benzene evaporate quickly when in contact with air.

Lumber : Wood that has been prepared to some extent for future use.

Plywood : Thin boards made up of an add number of 3 or more very thin sheets of veneers glued together under pressure with thickness varying between 3-25 mm.

Resin : Sticky, viscous water insoluble liquids, somewhat opaque, produced in specialized ducts.

Rosin : Exudates of plants used for preparing paints and varnishes, polishes, waxes, soaps, oil cloth, linoleum, sealing-wax, rubber, floor-coverings etc.

Tannin : Amorphous, dark-coloured organic compounds, forming colloidal suspension in water, present in the cell-sap of vacuole and bitter in taste (astringent).

Timber : Large sizes of lumber to be used for heavy construction purposes such as beam, girders, posts etc.

Varnish : Resin dissolved in organic solvents forms varnish.

Wood : Accumulated adaxial product of secondary growth by vascular cambium forming core of tree trunks and branches.

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