18BZO14A-U3

The life cycle of lycopodium, explained with the help of suitable diagrams.

Lycopodium is a large genus with about 180 species having world-wide distribution in tropical to temperate regions. They are herbaceous, terrestrial plants or erect to pendent epiphytes. The stems are densely covered with microphylls and are protostelic. The genus is homosporous with the sporangia on the adaxial faces of the sporophylls.

This large genus Lycopodium shows a great diversity in forms.

Urostachya shows erect (e.g., L. selago) or pendent (e.g., L. phlegmaria) plants which are never creeping. They may be un-branched or dichotomously branched. The adventitious roots come out only through the base of the stem and are not to be found along the surface of the stem. Even if any root develops on the upper stem, it traverses through the cortex and emerges only at the base.

The sporophylls are green and usually of the same size as the vegetative leaves. In L. selago (Fig. 537) there are sterile (vegetative leaves) and fertile (sporophylls) patches on the stem. In most species of this subgenus there are no organised strobili. In some species (e.g., L. phlegmaria), however, the sporophylls, though green, are shorter and localised at the tips forming distinct dichotomously branched strobili.

In Rhopalostachya, on the other hand, the stem is prostrate with adventitious roots developing on the under surface of the prostrate stem. The branching, though dichotomous at first, becomes monopodial later. The sporophylls are smaller, paler in colour, usually with dentate margins although the vegetative leaves are smooth-margined and form distinct strobili.

The chromosome numbers of the Urostachya are much higher (2n=up to 528 as against up to 68 in the Rhopalostachya).

Because of this variation, some modern Pteridologists are not satisfied by merely breaking the genus into two subgenera but they suggest several genera—even families.

Pichi-Sermolli (1959) supports breaking up into four genera: Huperzia, Lycopodium, Lepidotis and Diphasium— the first one. of Urostachya and the other three out of Rhopalostachya. The four genera are also supported by Love and Love (1958) from the cytological point of view.

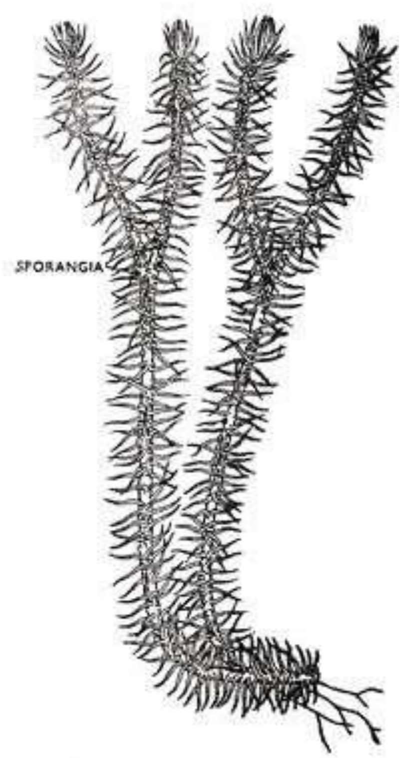

Fig. 537. *Lycopodium selago* (after Bower).

Sporophyte:

Lycopodium clavatum (Fig. 538A) is a temperate to sub- tropical, terrestrial species very common on the Indian hills, specially the Himalayas. The sporophyte has a weak, prostrate stem trailing along the surface and rooted down with adventitious roots growing anywhere on the lower surface.

The branching is dichotomous becoming monopodial by the strong development of aerial branches here and there. The stem is closely covered spirally by small, simple (microphyllous), sessile, lanceolate leaves (Fig. 538B) with mildly serrate margins and single median veins.

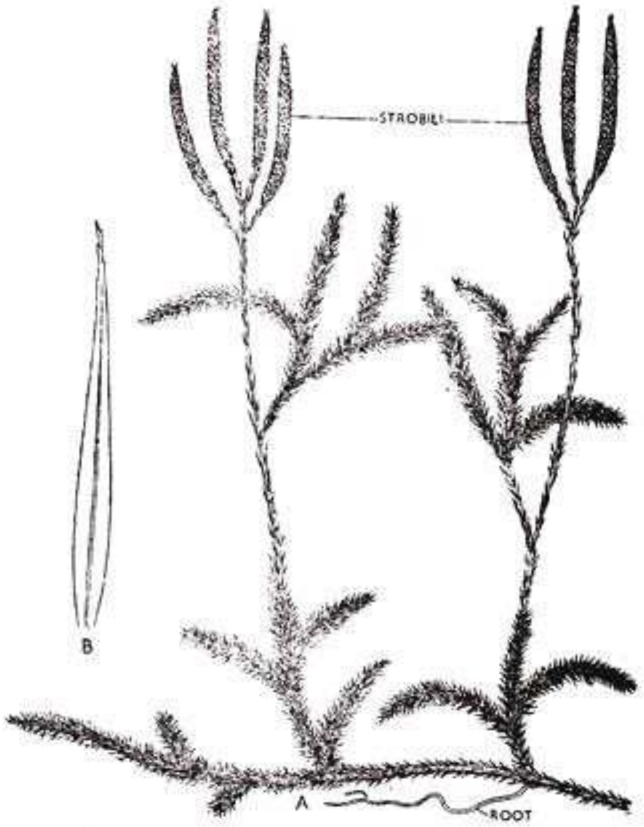

Fig. 538. *Lycopodium clavatum.* A. Habit of sporophyte with strobili. B. A vegetative leaf.

Lycopodium plants may grow almost perennially by the dying out of older parts and the growth of the branches. Gemma-like reproductive buds are also known in several species.

The stem of Lycopodium is protostelic without any cambium. It grows at the tip by several apical cells. A. t.s. of the stem of L. clavatum (Fig. 539A), which may be cylindrical or somewhat fluted, shows an epidermis of one layer of thick-walled cells broken here and there by stomata.

Below it there is a thick cortex traversed by leaf trace bundles. The outer layers of the cortex are sclerenchymatous while the cortex below is parenchymatous. In mature specimens the innermost region of the cortex also has thickened cell walls.

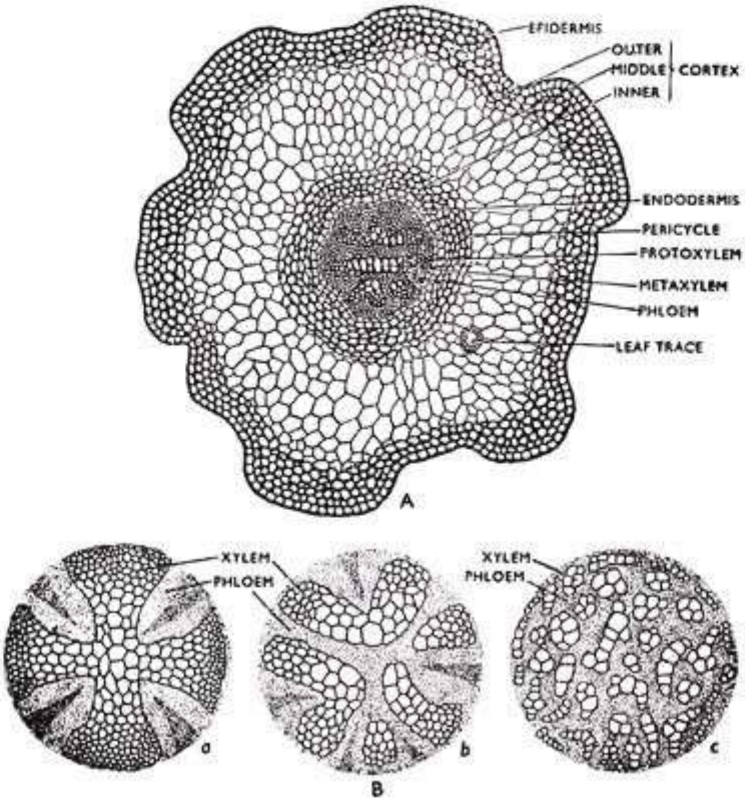

Fig. 539. A. T.s. of *Lycopodium clavatum* stem. B. T.s. of stelar regions of stems of (*a*) *L. serratum*, (*b*) *L. annotinum* and (*c*) *L. cernuum*.

The cortex is bounded on the inside by a layer of endodermis with the usual thickened radial walls (casparian strips). Internal to the endodermis is a pericycle of one or more layers of parenchymatous cells. The- stele in this case is protostelic of the plectostele type. The xylem elements are arranged in more or less parallel plates with the phloem between these patche

The xylem is formed only of tracheides and is exarch with the protoxylem (smaller spiral and annular tracheides) at the ends of the plates and the metaxylem (large scalariform tracheides) forming the general mass. The phloem shows sieve cells and parenchyma. The sieve cells are elongated with tapering ends and with sieve plates on the lateral walls. Leaf traces do not cause leaf gaps in the stele.

In other species of Lycopodium the stelar structure shows great variation. In L. serratum (Fig. 539a) the stele is actinostelic (star-shaped xylem). In L. annotimum (Fig. 539b) the stelar structure is broken up. The breaking up is the maximum in L. cernuum (Fig. 539c) where the stele is a meshwork of innumerable xylem patches with surrounding phloem tissue.

This type is termed as a mixed protostele. These types of stelar structure may be considered as showing the course of stelar evolution —the actinostele being the most primitive and the mixed protostele the most modern. The plectostele is placed before the mixed protostele. The stelar structures are so characteristic that Lycopodium species may be identified from anatomy alone.

The anatomy of the leaf is very simple with a surrounding one-layer epidermis broken by stomata, a uniform parenchymatous mesophyll with numerous air spaces and chloroplastids, and a median concentric vascular bundle

The slender roots show simpler structures with usually monarch steles.

The reproductive shoots arise as erect branches from the horizontal stem late in the season (Fig. 538A). The lower part of the reproductive shoot is comparatively sparsely leaved and the tip branches dichotomously into two or more spike-like strobili (sporangiferous spikes) compactly covered by sporophylls (Fig. 540A).

The sporophylls are of one type only (homosporous). The sporophylls (Fig. 540B) are differentiated from the vegetative leaves by the wider bases and more serrations in the margins.

The sporangia are comparatively large, reniform of subglobose, orange to light-yellow in colour and with short stalks when mature. These develop on the adaxial (ventral) face of the sporophyll a little above the axil. In other species the sporangium is known to develop from the axil or even from the stem just above the axil.

The sporangium is a massive structure developing from a group of initial cells (Fig. 540C). This is known as the eusporangiate mode of sporangium development. In the nearly mature sporangium (Fig. 540D & E) there is a stalk, a. jacket (2 or more layers thick), a massive sporogenous tissue and a nutritive tapetum formed partly by the inner layer of the jacket and partly by some outer sporogenous cells.

The sporogenous cells soon become spore mother cells (Fig. 540E) which become rounded, separate from one another and undergo reduction division to form the spore tetrads. The mature sporangium splits along a vertical line of weakness (stomium) and the spores are released.

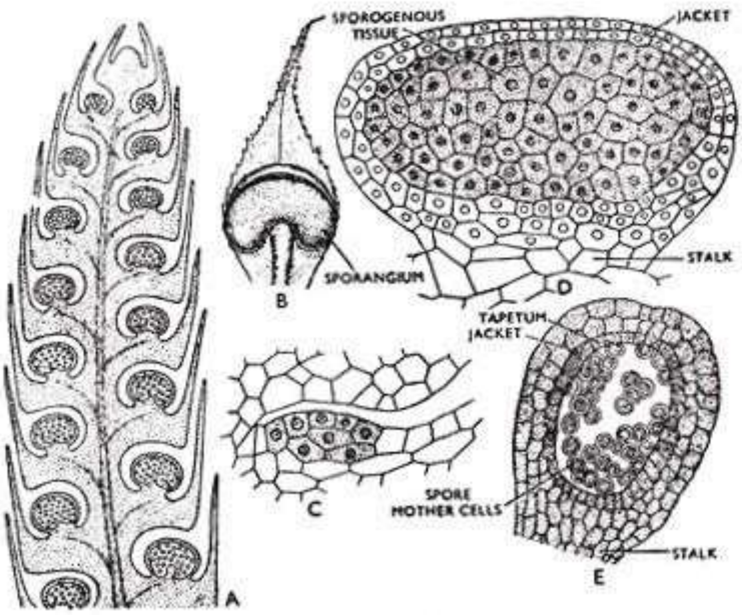

Fig. 540. *Lycopodium clavatum*. A. Median l.s. of strobilus. B. A sporophyll. C. Leaf base showing sporangial initials (shaded). D. Nearly mature sporangium before spore mother cells are formed. E. Mature sporangium.

Gametophyte:

The spore is tetrahedral with the usual intine and a sculptured exine showing a triradiate ridge (Fig. 541 A). A few chloroplastids are usually present.

The spore of L. clavatum remains viable for a long time and may germinate only after a year or more. The exine splits at the triradiate fissures and a tissue, developing very slowly (taking another year or more), comes out forming a top-shaped (Fig. 541B), underground, non-green, tuberous gametophyte or prothallus.

With age this gametophyte loses its shape and becomes much convoluted (Fig. 541G). The gametophyte ceases to grow if it does not become infected by a fungus at an early stage of development.

A vertical t.s. of the mature gametophyte (Fig. 541B) shows an outer epidermis with some rhizoids; an outer cortex filled by mycorrhizal fungi; an inner cortex with an outer parenchymatous and an inner palisade zone; and a central parenchymatous storage tissue where the outermost cells are elongated. The top of this top-shaped gametophyte is lobed and the antheridia, the archegonia and the growing embryos are located on these lobes. This type of gametophyte is noted in many creeping species.

A second type of gametophyte is represented by L. cernuum (Fig. 541D). In these the spore germinates without passing through any resting stage. The gametophyte is usually smaller, annual, partly aerial and partly underground. The lobed crown with antheridia and archegonia becomes green.

A still third type of gametophyte is found among the epiphytic species like L. phlegmaria (Fig. 541E). The prothalli are saprophytic, growing on trunks below a coating of humus. Here a central, small, tuberous body develops a number of colourless, slender, cylindrical arms on whose surfaces the antheridia and the archegonia develop.

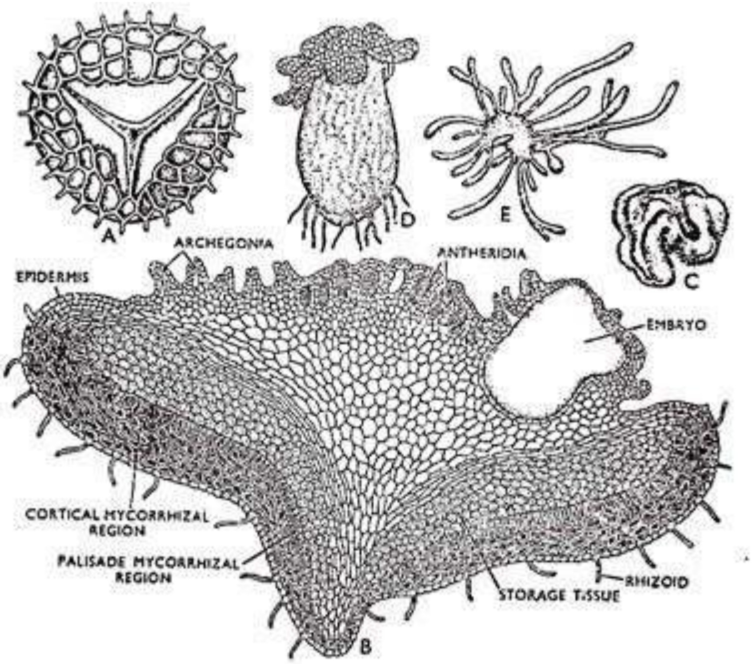

Fig. 541. *Lycopodium clavatum.* A. A spore. B. Vertical median section of mature gametophyte. C. An old convoluted gametophyte. D. Gametophyte of *L. cernuum*. E. Gametophyte of *L. phlegmaria*. (B–D after Bruchmann; E after Treub).

L. selago shows gametophytes of both the first and the second types according as it grows on the surface or below the soil level.

All gametophytes are monoecious. In the development of an antheridium, an epidermal cell divides transversely forming an upper jacket initial and a lower primary antheridial initial (Fig. 542A). The jacket initial ultimately forms a jacket layer one cell in thickness with a triangular cell at the top centre.

The lower cell forms a mass of tissue which ultimately become very small cubical sperm mother cells (Fig. 542B). Each sperm mother cell gives rise to a biflagellate (rarely triflagellate) sperm (Fig. 542C) resembling rather the Bryophytes. The antheridia are almost wholly sunken in the gametophytic tissue. The sperms are liberated by the breaking down of the triangular cell at top.

The archegonium (Fig. 542D) also develops similarly from a superficial archegonial initial cell. The first division gives rise to an upper primary cover cell and a lower central cell. The central cell divides to form a lower primary ventral cell and an upper primary canal cell.

The primary canal cell divides transversely to form usually four (1 to 3 in L. cernuum, 7 in L. selago, up to 16 in L. complanatum) canal cells while the ventral cell forms the egg often after cutting off a ventral canal cell. The primary cover cell develops the neck 3 to 4 cells high. In the mature archegonium the neck portion protrudes out while the venter remains sunken.

Fertilisation takes place in the usual way. The neck canal cells and the ventral canal cell (if any) disintegrate and come out exuding citric acid and citrates which probably chemically attract the sperms one of which fertilises the egg developing the zygote.

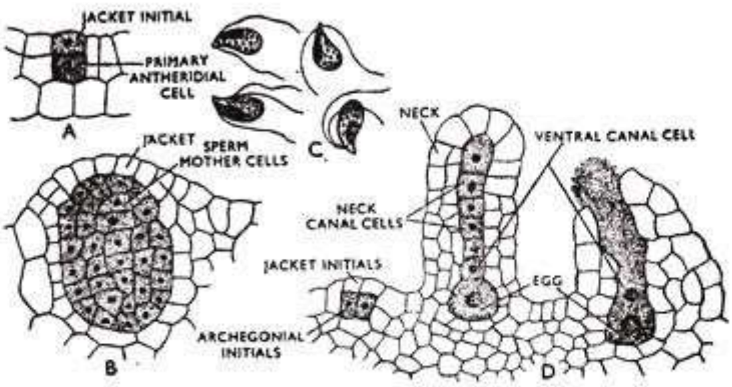

Fig. 542. *Lycopodium clavatum*. A. Early stage of antheridium formation. B. Mature antheridium C. Sperms. D. Part of gametophyte showing stages of development of archegonia.

New Sporophyte:

The zygote divides transversely to form an upper suspensor and a lower embryonic cell (Fig. 543A). The embryonic cell divides into eight cells in two tiers of which the upper 4 near the suspensor gives rise to the foot (for absorption of food material from the gametophyte) and the lower 4 to the stem on one side and a cotyledonary leaf (Fig. 543 B & C) on the other side.

As the embryo grows it rises erect above the gametophyte, the first root developing from the point where the cotyledon and the foot joins. The first leaves are scaly. The new sporophyte soon gets established as an independent plant (Fig. 543D).

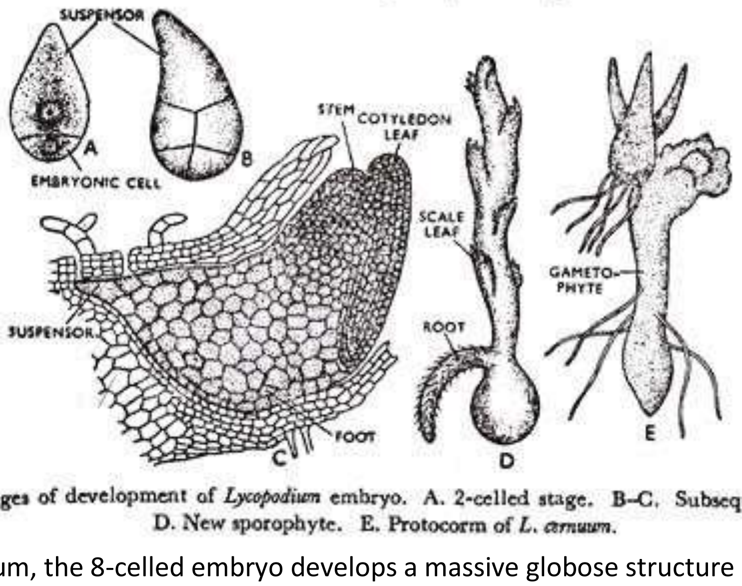

Fig. 543. Stages of development of *Lycopodium* embryo. A. 2-celled stage. B–C. Subsequent stages. D. New sporophyte. E. Protocorm of *L. cernuum*.

In L. cernuum, the 8-celled embryo develops a massive globose structure called the protocorm which becomes green and develops rhizoids below. The structure develops a few erect, conical outgrowths functioning as leaves (Fig. 543E). The protocorm remains in this condition for some time and then the apical meristem bursts into a normal shoot.

A mycorrhizal fungus grows inside this structure. This intermediate protocorm structure has been considered to be of some evolutionary significance by some (Protocorm Theory) while others consider it as a mere passing phase. Treub considered this as an undifferentiated primitive stage of sporophyte which was present in all Pteridophytes but has been lost in most of them.

Phylloglossum (described below) shows a permanent protocorm while this occurs occasionally in Ophioglossum. Goebel, Bower, etc., however, consider the protocorm merely as an occasional adaptation to; meet the strain of sporophytic development under special conditions. The Protocorm Theory is now only of historical importance.

Figure 544 shows diagrammatically the life cycle of Lycopodium.

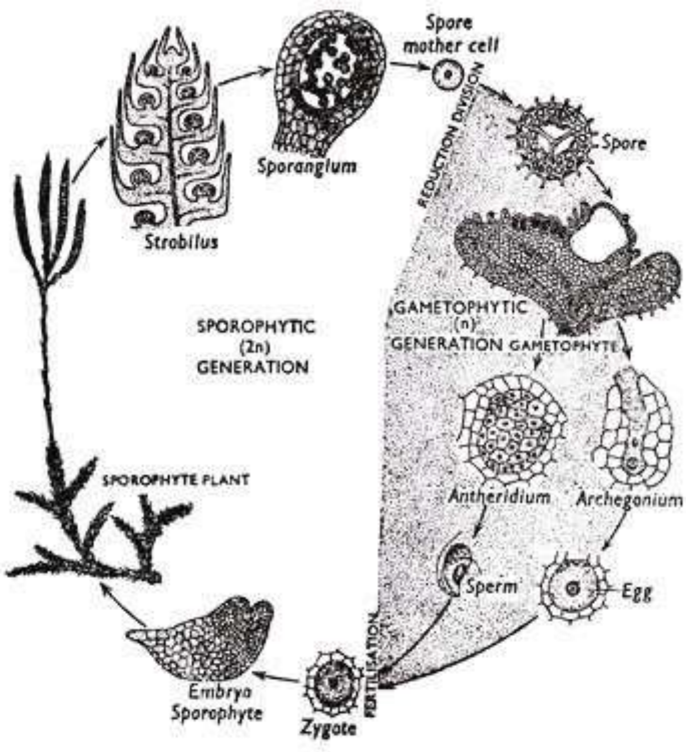

Fig. 544. Life cycle of *Lycopodium*.

Genus Phylloglossum:

This is a peculiar plant represented by a single species Phylloglossum drummondii found only in Australia, Tasmania and New Zealand. It is a small plant with a fleshy, tuberous, perennial stem and a few stiff, awl-shaped leaves (Fig. 545) reminding the protocorm stage of Lycopodium cernuum. A compact sporangiferous spike is developed on a stalk at the tip of the stem.

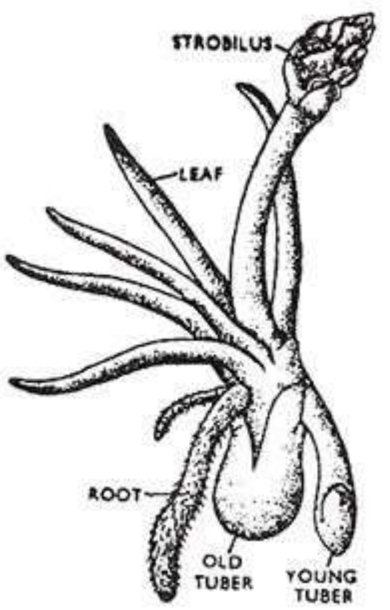

Fig. 545. *Phylloglossum drummondii* (after Bertrand).

1. Occurrence and Distribution of Adiantum 2. Sporophyte of Adiantum 3. Gametophyte

Occurrence and Distribution of Adiantum:

Adiantum is popularly called 'Maiden hair fem' because of the shiny black rachis of the leaves. It is one of the most widely distributed genera (Other genera are Cheilanthes, Pellaea, Ceratopieris and Anogramma) of the family growing luxuriantly in both tropical and sub topical regions of the world. It grows ubiquitously wherever nature offers a moist, shaded locality. There are nearly 200 species.

Nayar (1961) has investigated the morphology of 24 Indian species of Adiantum. Some of the common Indian species are – A. capillus-veneris, A.pedatum, A. incisum, A. caudatum, A. venustum, A. lunulatum, A. edgowrthii etc. Species of Adiantum are commonly cultivated in green houses because of their attractive foliage.

Sporophyte of Adiantum:

Morphology of the plant: The sporophytic plant body consists of an underground rhizome from which are produced leaves and roots. The rhizome is covered with chaffy scales (Paleae). It may be erect (A. caudatum), semi erect (A. pet- datum), or creeping (A.capillusveneris).

Studies of Nicholas (1985) in Adiantum trapeziforme indicate that the erect rhizome of the young sporophyte quickly transforms itself into creeping. The rhizome may be hard or soft and brown in colour.

The chaffy scales that cover the rhizome are of various shapes and sizes. Nayar (1961) has made a detailed study of these scales in 24 species of Adiantum. From the undersurface of the rhizome arise a number of adventitious roots. The roots are stiff and black in colour. Occasionally they may be branched.

The leaves are produced in acropetalous succession on the creeping rhizome. They show circinate vernation typical of ferns. The rachis of the leaf is hard, wiry, shiny and black or dark brown in colour thus giving the name maiden hair fern. The rachis has a medium dorsal groove, and is covered with paleae at the basal region. In addition to this, glandular hairs may also be present.

The leaves may be unipinnate (Axaudatum) or bi or tri-pinnate as in , A. capillus – veneris (Fig. 149). The pinnae are stalked and have a dichotomous venation. The rachis may terminate in a pinna or may bear a bud. In A capillus veneris the rachis divides pinnately and the ultimate branches bear pinnae in an alternate fashion.

There is no distinction between fertile and sterile leaves in Adiantum. The whole leaf may be sporangiferous or only certain pinnae may bear sporangia. The soral organisation is very evident. Sori are borne on the ventral surface of the pinnae.

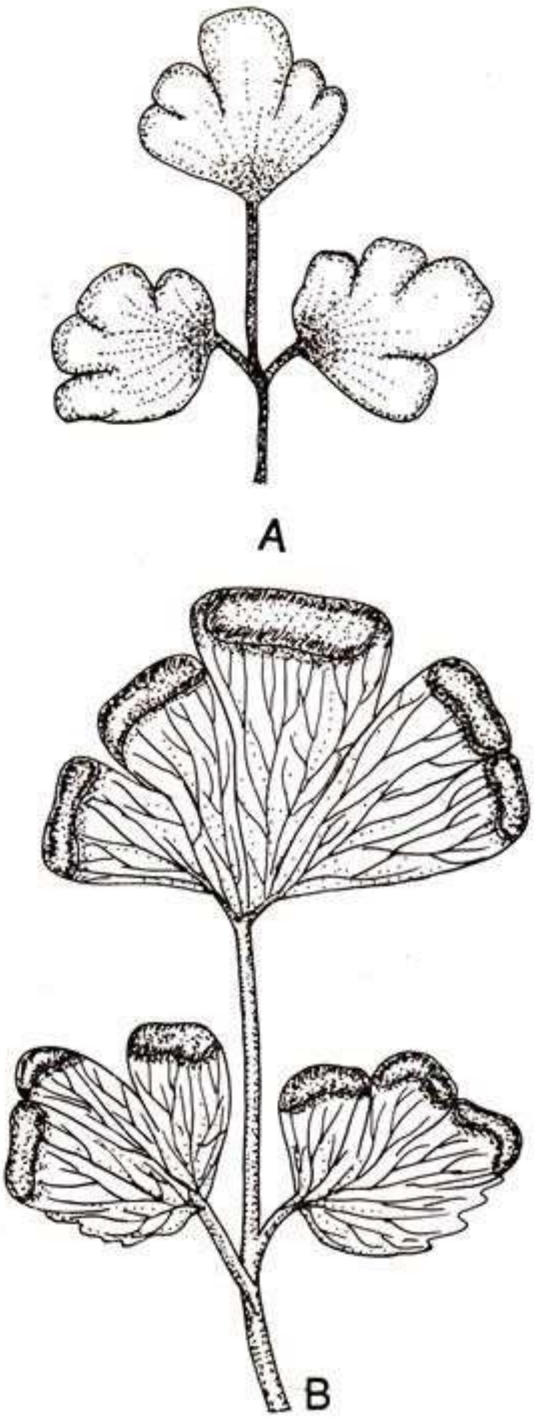

Fig. 149. *Adiantum* : Sterile (A) and Fertile (B) Leaflets of *A. capillus veneris*

Apical Organization:

In a study of apical organisation of rhizome, leaf and root in Adiantum capillus veneris, Bir and Randhawa (1984) have reported the occurrence of a single apical cell, which is later replaced by a group of cells.

Internal Structure:

1. Rhizome:

A transection reveals the usual three zones epidermis, cortex and stele (Fig. 150). The outline of the section would be wavy. Epidermis is single layered and the cells may be thin walled or thick walled. There is a cuticle external to the epidermis.

Cortex lies internal to the epidermis. It may be wholly parenchymatous (A. rubellum), (Fig. 150) or it may have sclerenchyma and parenchyma. In A. pectinatum, scattered masses of sclerenchyma are found embedded in the parenchymatous ground tissue. In A. caudatum, sclerenchyma constitutes the hypodermal region.

The central vascular cylinder exhibits great variety. In A. capillus veneris, it is a dictyostele consisting of a ring of meristeles. In the young condition the stele may be a solenostele. In A. rubellum the stele is a typical amphiphloic solenostele, with characteristic features such as outer endodermis, outer pericycle, outer phloem, xylem, inner phloem, inner pericycle and inner endodermis lining the parenchymatous pith.

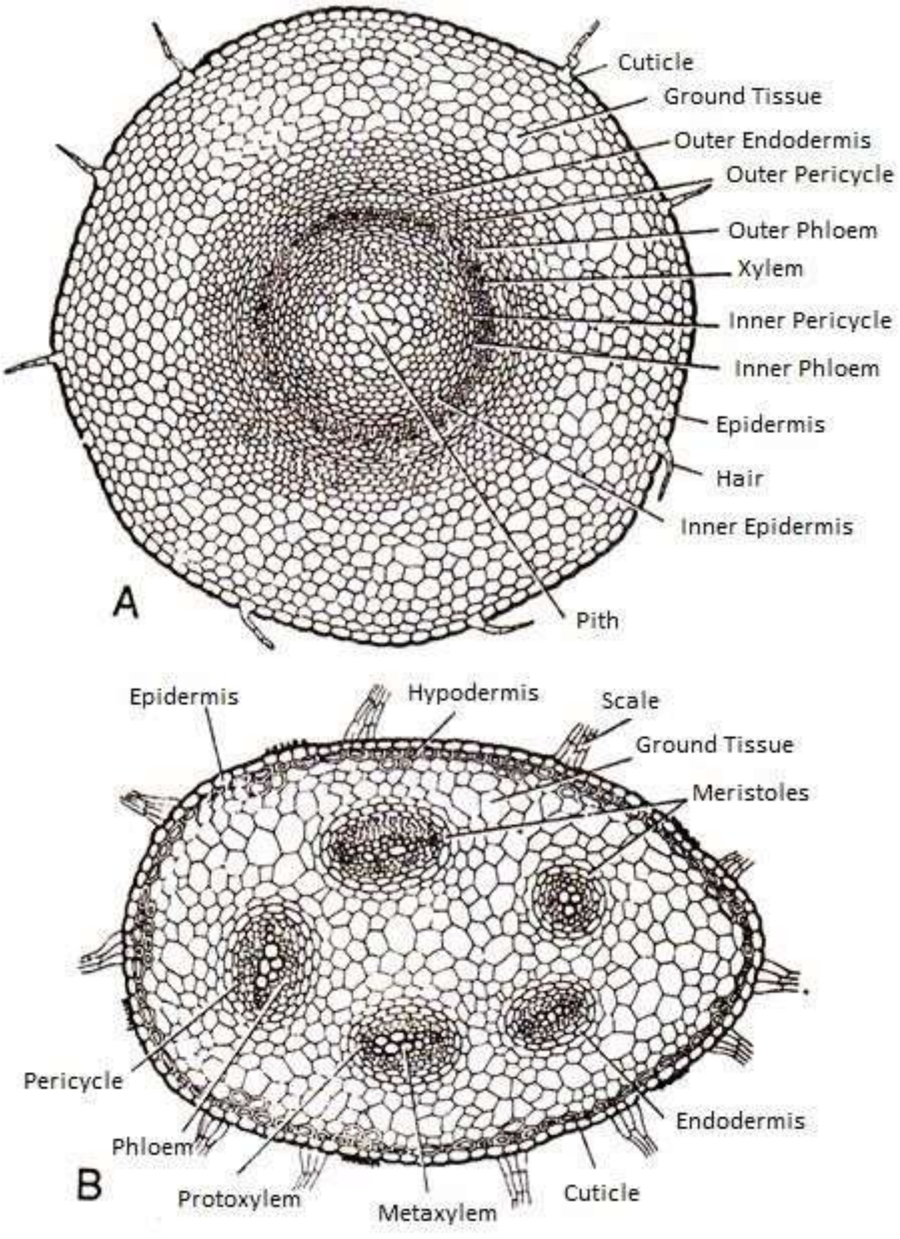

Fig. 150. *Adiantum* : Anatomy of Rhizome
A. Amphiphloic Siphonostele in *A. rubellum*, B. Dictyostele in *A. capillus veneris*

2. Leaf:

The petiole shows an epidermis, parenchymatous cortex and the vascular trace. Srivastava (1979) has studied the foliar epidermis of Adiantum. There is a thick walled hypodermis next to the epidermis. The number of leaf traces entering the leaf, varies.

It is single in A. caudatum and others and double in A. capillus – veneris. Even when there are two leaf traces, both of them unite further up resulting in a single bundle. The xylem is concave at the base but triradiate higher up with three protoxylem groups. Xylem is exarch.

In A. bausei there is a patch of included parenchyma in the xylem. Khare and Shankar (1986) studied the vascular organisation of the petiole in Adiantum caudatum, A.edgeworthii, A.pedatum, A.phillippense, A.pubescens and A.trapeziforme and have reported two types of vascular supply to the leaf.

In A.phillipense, A.caudatum and A.edgeworthii there is always a single vascular trace from the rhizome which remains unaltered in the petiole, while in the other three species two distinct traces originate from the rhizome.

These two merge into one after entering the petiole. In a comparative anatomical study of the stipe of Adiantum, Bidin and Walker (1985) have reported eight different types of xylem configurations. According to them this is of systematic value.

The lamina shows the two epidermal layers upper and lower the mesophyll is generally undifferentiated. It is highly reduced in A. capillus – veneris, A pedatum, etc., having only two layers of cells. In A. pedatum, in some regions the mesophyll is totally absent and at such places the two epidermal layers are closely appressed to each other.

The mesophyll (when present) as well as the epidermal layers are chlorophyllous. The epidermal layers are chlorophyllous. The epidermal cells over the veins are thick walled. The stomata are scattered throughout the surface of the leaf. Paleae or ramenta may be borne even on the epidermis of the lamina. The vein may or may not have a bundle sheath. The vascular tissues show the characteristic X\P arrangement.

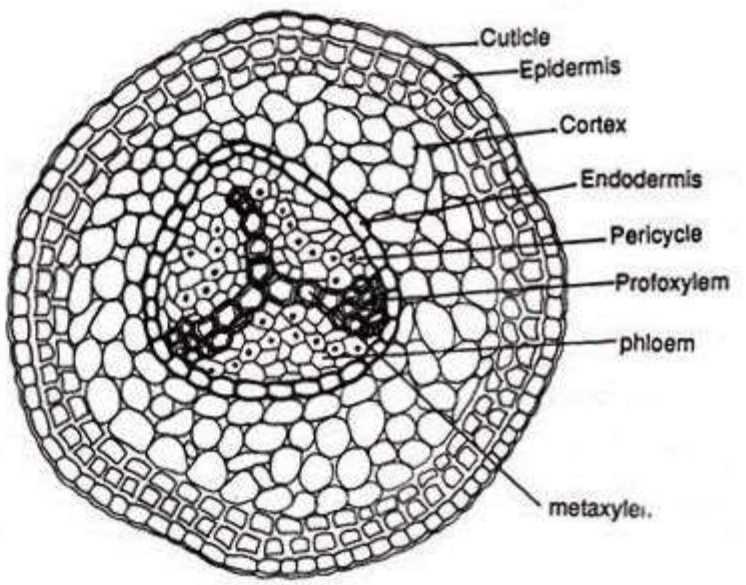

Fig. 151. *Adiantum* : T.S. of Petiole

3. Root:

A transection shows a very prominent piliferous layer, a two zoned cortex and the central protostele (Fig. 152). The piliferous layer has brown coloured cell walls. Cortex has an outer parenchymatous zone and an inner sclerotic zone.

Surrounding the stele is a conspicuous endodermis with prominent casparian thickenings. The xylem is exarch and diarch, phloem completely surrounds the xylem. External to phloem is a single layered pericycle.

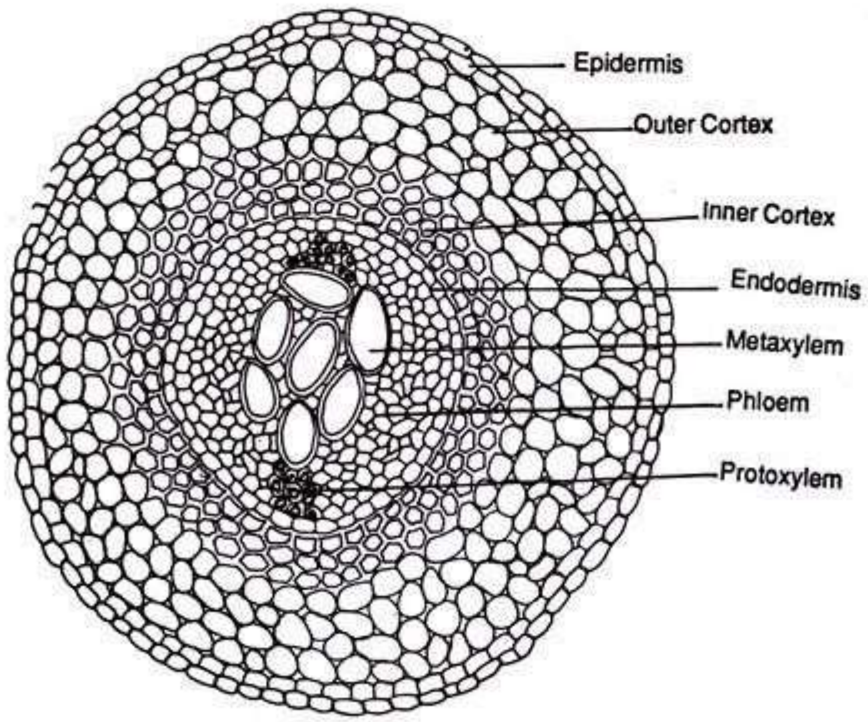

Fig. 152. *Adiantum* : T.S. of Root

Reproduction:

Vegetative propagation is brought about by buds produced at the leaf tips. The buds enter the ground when the leaf bends and touches the soil. There they develop into a new individual. This, in turn may repeat the process leading to the walking Habit. Walking habit is seen in A caudatum.

Spore Producing Organs:

As has already been said there is no distinction into fertile and sterile leaves. The son are born at the distal end of the pinnae. But the sori are not exactly marginal. They are borne a little behind the tip of the veins.

The sorus bearing margin of the leaf incurls and forms the false inducium. In some cases sporangia may develop at the distal ends of the veins (A. phillippense). In the sori paraphyses may be present in between the sporangia as in A. rubellum, A. tenerum, etc. The sorus is of the mixed type.

Development and Structure of the Sporangium:

The development is similar to what is seen in Pteris. A mature sporangiuim has a stalk made up of three rows of cells. The stalk terminates in a globose or biconvex capsule. The wall is single layered.

There is an obliquely vertical annulus (Fig.153) of 12-24 cells long. The annulus is separated from the stalk by two or three cells. The stomium also is separated from both the stalk, and the annulus. The rest of the sporangial wall is composed of a few large cells.

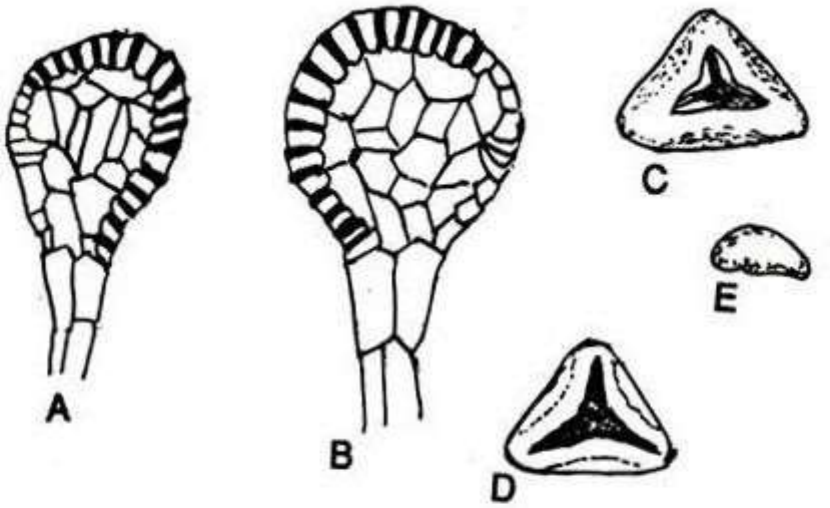

Fig. 153. *Adiantum* : Sporangia and Spores of *A. capillus veneris*
A-B. Sporangia, C-E. Spores

The sporangium dehisces transversely liberating the spores. All the spores are of the same type.

Gametophyte of Adiantum:

Structure and germination of the spores:

Spores are tetrahedral in shape. The wall is two layered. Exine is thick and smooth and has a brownish tinge. On falling upon a suitable substratum the spore germinates. The first sign of germination is the rupturing of exine and the protruding out of the germ tube.

The germ tube undergoes several transverse divisions to form a short filament. The lowest cell (Fig. 154a) forms a lateral rhizoid. The terminal cell becomes an apical cell with three cutting faces. By the division of the apical cell, a spatulate pro-thallus is formed first. (Fig. 154).

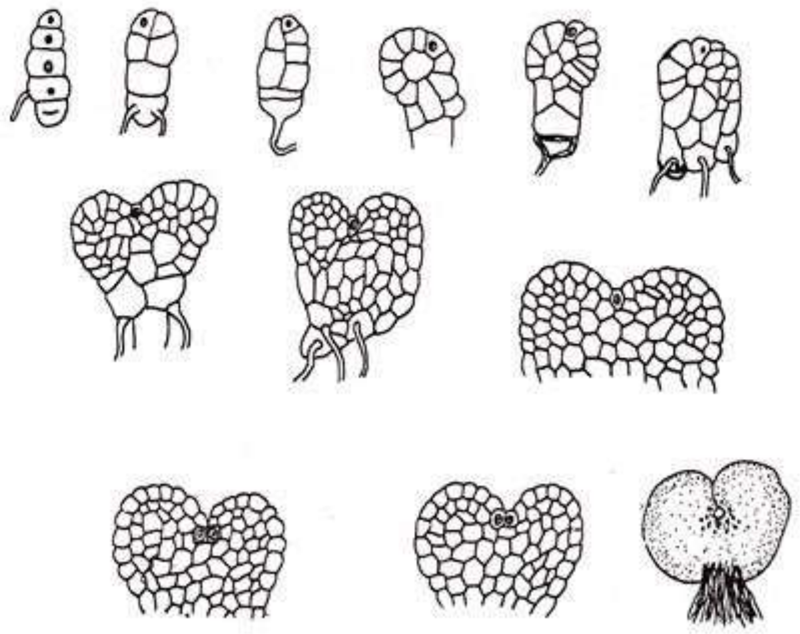

Fig. 154. *Adiantum* : Germination of Spore and Development of the Gametophyte
A-K. Developmental Stages, L. Mature Gametophyte

The mature pro-thallus is cordate, photosynthetic, dorsiventrally flattened and aerial. The growing point is situated in the apical notch (Fig.154e, 154f). All the cells in the pro-thallus are parenchymatous. The pro-thallus is one celled thick towards the margins but many celled thick towards the centre. In some species collenchyma may be found at the corners. Rhizoids are produced from the ventral surface.

Reproduction:

The prothalli are monoecious. Antheridia are found in between the rhizoids towards the ventral surface. Arehegonia are found near the growing point towards the ventral surface. Structure and development of sex organs is same as in Pteris.

Embryogeny:

The first division of the zygote is vertical (Fig. 155b). The epibasal half (next to the archegonial neck) forms the leaf and root while the hypo basal half forms the stem' apex and foot (Fig. 155c). Embryogeny is essentially similar to what is seen in Pteris.

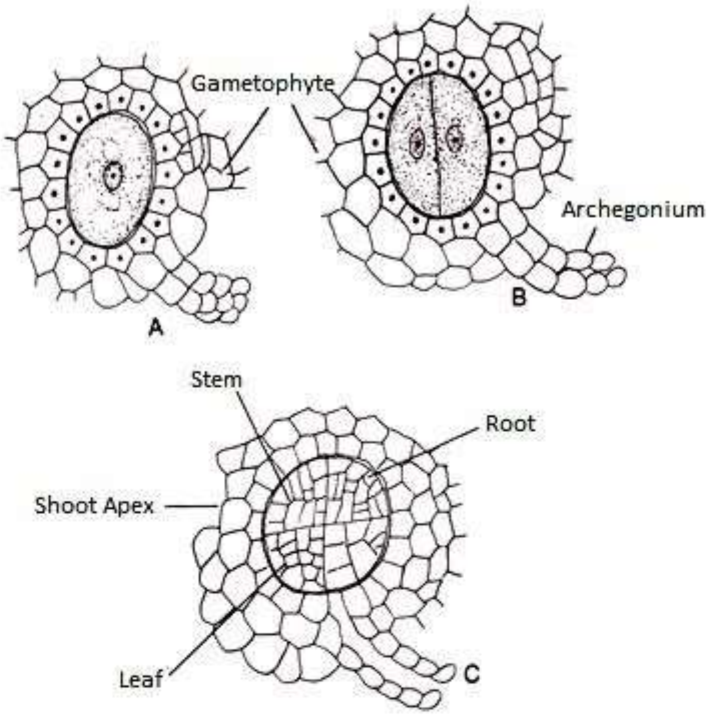

Fig. 155. Adiantum: Embryogeny in A. capillus veneris

Generally only one sporophyte is formed per pro-thallus. During embryogeny the root and juvenile leaves make their appearance first, with the stem differentiating late. The primary root penetrates the soil and establishes itself. Apogamy has been reported in A.philippense.

Cycas: Morphology and Reproduction| Cycadales

Some Indian Species:

1. Cycas beddomei Dyre:

A small shrub with a trunk of about 40 cm long. It is distributed in Andhra Pradesh, Madras, Calicut, etc. Leaves are large and reach up to 1 metre in length with quadrangular rachis. Leaflets are narrow and linear. Male cones are oblong to ovoid, bearing a short peduncle.

Megasporophylls are ovate, lanceolate with dentate margins. They are produced in November-December.

2. Cycas circinalis Linn:

Commonly called 'Jangli-madan-mast-ka-Phul' (Hindi) or 'Kamakshi' (Telugu), C. circinalis is commonly distributed in western part of Peninsular India, Western Ghat and Orissa Hills in India. It is often cultivated in Indian gardens.

It is an evergreen tree bearing leaves of 1.5 to 3 metres in length with about 100 pairs of leaflets. Leaflets are linear-lanceolate with flat margin and acuminate apex. Upper sterile part of megasporophyll is longer than broad with dentate margins. Male cones are cylindrical to ovoid with a short peduncle. Megasporophylls contain brown tomentose hairs.

3. Cycas pectinata Griff:

It is distributed in Sikkim, Assam, Manipur and Someshwar Hills of Bihar in India along with some other countries including Nepal and Bangladesh. Its trunk ranges from 1.5 to 2.5 metres in length.

Leaves attain a length of about 1.5 to 2 metres. Leaflets are narrow, linear, tapering into a minute spine and measure from 14 to 25 cm. in length. Male cone is cylindrical-ovoid. The upper part of the megasporophyll is as broad as long.

4. Cycas revoluta Thunb:

It grows in wild state in Japan, China and Taiwan and is widely cultivated in several parts of the world, including India. It is so named because of the revoluted margins of its leaflets It is a palm-like tree, the trunk of which reaches up to 2 metres in length. Male cones are cylindrical or ovoid-oblong. Megasporophylls are 10-25 cm in length and densely tomentose

5. Cycas Rumphii Miq:

It is an evergreen palm-like tree distributed in Andaman and Nicobar Islands of India along with Sri Lanka, Malaysia and Australia. Its trunk reaches up to 4 metres while the leaves attain a length of 1-2 metres with 50 to 100 or more pairs of leaflets. Male cone is shortly stalked and ellipsoidal to oblong in shape. Megasporophylls are ovate-lanceolate with many small teeth.

6. Cycas siamensis Miq:

It is found in Myanmar, Thailand, China and Laos. It is a palm like tree. The leaves reach about 1 metre in length. Leaflets are narrow, linear with mucronate or acuminate apex. Male cone is ovoid oblong.

Megasporophyll’s sterile blade is as broad as long with usually only 2 ovules. Burkill (1933) considered Cycas siamensis as a geographical form of C. pectinata. Pant and Nautial (1963) also consider the two species similar, mainly because of their epidermal and anatomical studies.

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2. General Morphology of Cycas:

Cycas is a palm-like, evergreen plant (Fig. 8.8). Prior to the anatomical studies of the stem of Cycas revoluta by Brongniart (1829), the Cycas was actually considered a palm. The plant body consists of a columnar aerial trunk with a crown of pinnately compound leaves as its top.

According of Eichler (1889), Coulter and Chamberlain (1910), Schuster (1932) and others, a tap root system persists in the adult plant, but according to Worsdell (1906) the tap roots are soon replaced by adventitious roots.

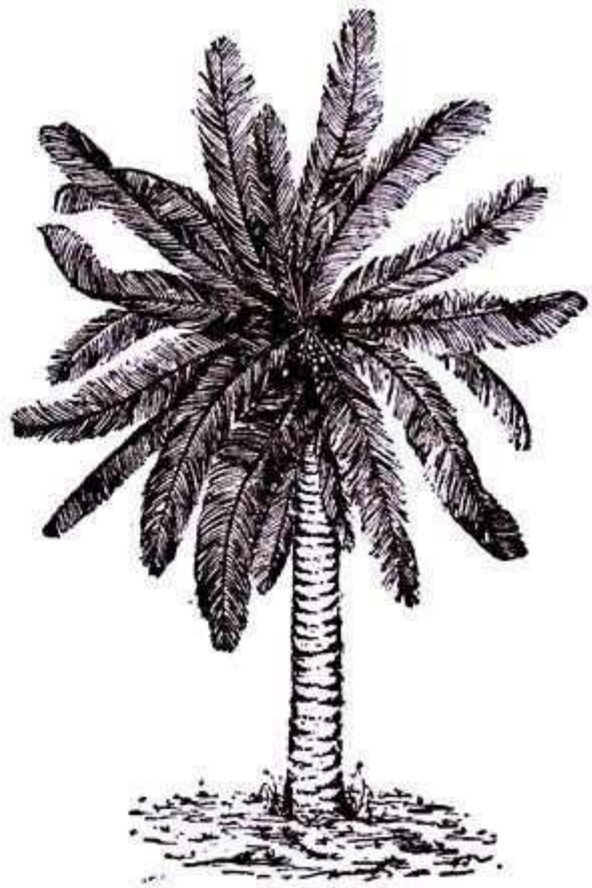


Fig. 8.8. *Cycas*, a mature plant.

Roots:

Roots in Cycas are of two types, i.e., normal tap roots forming a tap root system, and coralloid roots. Normal tap-roots are positively geotropic, grow deep into the soil and generally possess no root hairs. Their function is to fix the plant in the soil and to absorb water and other minerals.

From the normal roots develop some lateral branches near the ground surface. These lateral roots get infected with some bacteria, fungi and algae, and are called coralloid roots (Fig.
8.9). They grow- first horizontally in the soil and become swollen at their tips.

They divide repeatedly to form big bunches of greenish or brownish structures, which are coral like in appearance. They divide dichotomously, come out of the soil on the ground surface and are phototrophic in nature. Young plants bear more coralloid roots than the older ones.

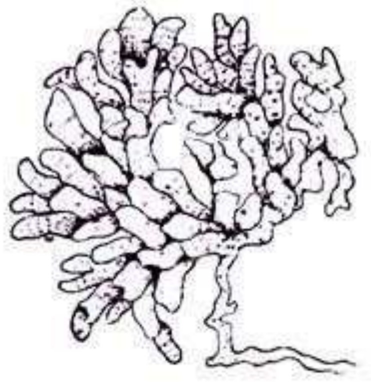


Fig. 8.9. *Cycas* A bunch of coralloid roots

Recently, Pant and Das (1990) reported non-coralloid aerial roots in Cycas circinalis, C. revoluta and C. rumphii. The charactenstic algal zone of coralloid roots is absent in these roots. These are positively geotropic, adventitious and develop from the lower sides of leaf bases or bulbils when they are still attached to the plant.

Stem:

The stem is thick, woody and usually un-branched. It is tuberous when young but columnar, erect and stout at maturity. Branching in stem (Fig. 8.10) is also not rare after the plants have reached a certain age. The aerial part of the trunk remains covered by a thick armour of large and small rhomboidai leaf bases.

These occur regularly in alternate bands (Fig. 8 .11). The larger leaf bases represent the bases of foliage leaves, while the smaller ones are the bases of scaly leaves in male plants and scales and megasporophylls in female plants. The age of the plant can be calculated by counting the number of crowns of leaves and megasporophylls which are produced every year.

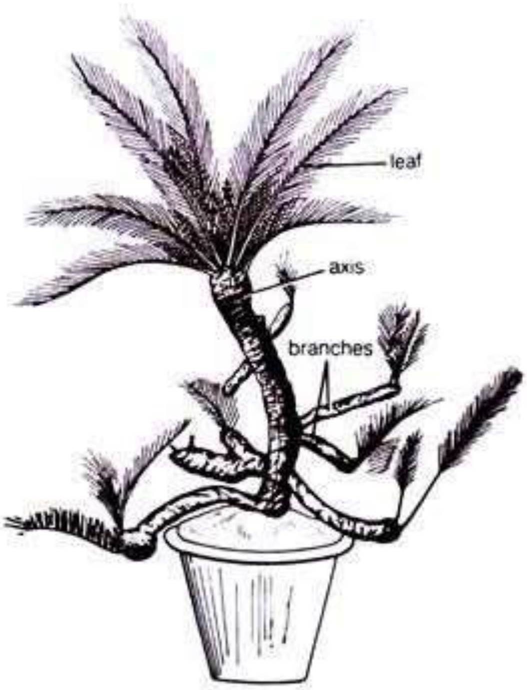


Fig. 8.10. *Cycas revoluta.* A plant with many diffuse branches

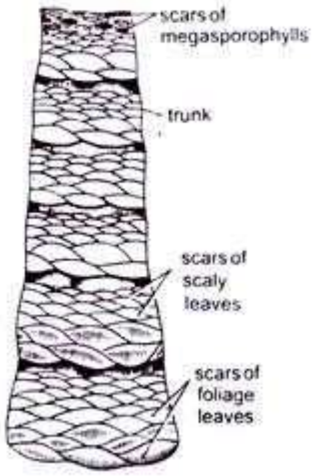


Fig. 8.11. *Cycas circinalis* Basal part of columnar trunk

Among all Cycas species, C. media is tallest, attaining a height up to 20 metres. Regarding the age of Cycas, the plants can survive for a long period. C. circinalis, if allowed to grow undisturbed, may attain an age of 100 years or even more.

Leaves:

Two types of leaves are present in Cycas. These are green, assimilatory ox foliage leaves, and scaly leaves or cataphylls.

1. Foliage Leaves or Assimilatory Fronds:

These are green, large, pinnately compound and stout leaves with a spiny petiole and large, strong rachis. They are produced at the apex of the stem in the form of crown. The rachis bears many leaflets.

With the help of a transversely expanded rhomboidai leaf base, a leaf remains attached with the stem Two rows of strong and stiff spines are present on the petiole. These spines gradually transform into two rows of pinnae towards the upper side of the leaf (Fig. 8.12).

Fig. 8.12. *Cycas*. A single foliage leaf

Pant (1953) reported many abnormalities in Cycas leaves. Author, along with two of his colleagues, also reported many abnormalities in the vegetative parts of an year-old plant of Cycas circinalis growing in the Botanical Garden of Meerut College, Meerut.

Cycas leaf is very large and may reach up to 3 metres in length in some species such as C. thouarsii. Two rows of pinnae on the leaves may be alternate or opposite. The number of pinnae varies in different species. As many as hundred pairs of pinnae may be present in a mature leaf.

Each pinna is sessile, elongated, ovate or lanceolate in shape with a spiny or acute apex. Pinnae are repeatedly and deeply dichotomized in C. micholitzii (Fig. 8.13). Each pinna or of leaflet contains a midrib without any lateral branching.

Forking of the midvein of the leaflet has been reported in C. circinalis by author in 1976. Margins of the leaflets are revolute in C. revoluta and C. beddomei, while in C. rumphii and C. circinalis they are flat.

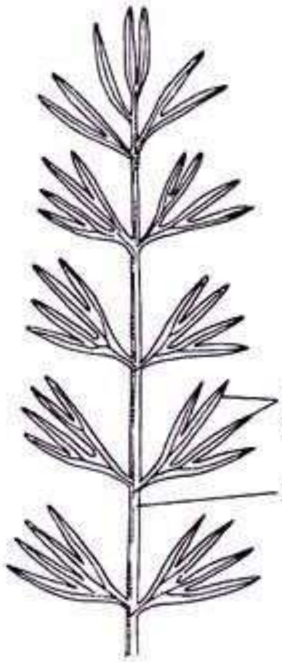


Fig. 8.13. *Cycas micholitzii.* A part of leaf showing forked pinnae. (after Seward, 1971).

According to Chamberlain (1935) the **"vernation is circinate in the midrib and pinnules of Cycas".** Leaves, when young, have circinately coiled pinnae like those of ferns (Fig. 8.14). Very young parts of Cycas are also covered by fern-like hairs or ramenta.

Fig. 8.14. *Cycas.* A young leaf showing circinate vernation.

2. Scaly Leaves or Cataphylls:

These are dry, brown-coloured, somewhat triangular leaves with their one end pointed. They are present at the apex of the stem and remain covered with several ramental hairs (Fig. 8.15).

Fig. 8.15. A scaly leaf of *Cycas*.

3. Anatomy of Vegetative Parts of Cycas:

(i) Normal Root (Young):

It is circular in outline and resembles structurally with dicotyledons (Fig. 8.16). Outermost layer is epiblema or exodermis, which surrounds the large parenchymatous cortex. Epiblema consists of tangentially elongated cells. From some of its cells arise root hairs.

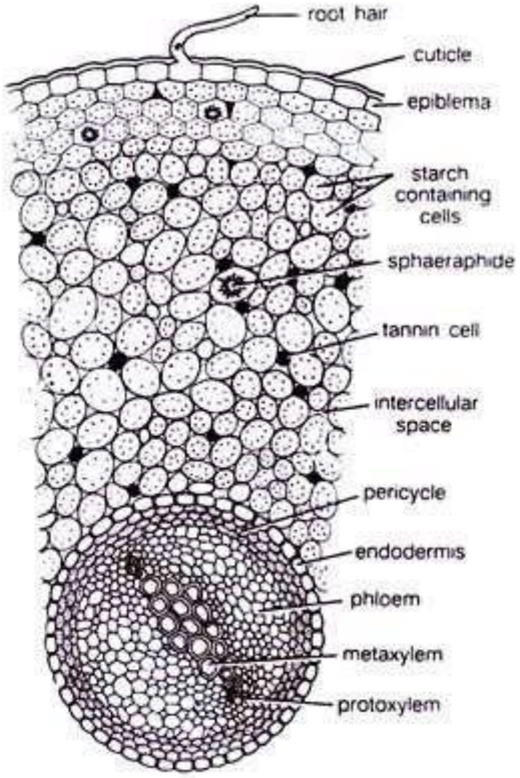


Fig. 8.16. *Cycas revoluta* T.S. normal root (Young)

In the wide zone of parenchymatous cortex there are present many intercellular spaces. Cells of the cortex remain filled with starch. Some tannin-filled cells, mucilage cells and sometimes sphaeraphides are also present in the cortex. The cortex is delimited by a single-layered endodermis. Casparian steps are present in the barrel-shaped cells of the endodermis.

Endodermis is followed by multilayered pericycle. Xylem and phloem bundles in the roots are radially arranged, i.e. present on different radii. The roots are usually diarch but sometimes the number of protoxylem strands range between 3 to 8.

The protoxylem consists of spiral tracheids while the metaxylem consists of scalariform tracheids. Vessels are absent. Phloem is present alternately with xylem groups and consists of sieve tubes and phloem parenchyma. Pith is generally absent.

(ii) Normal Root (old) Showing Secondary Growth:

The older roots (Fig. 8.17) undergo secondary growth. The cambium cuts secondary phloem towards the outer side and secondary xylem towards the inner side. After sometime the pericycle cells also become meristematic and form a complete cambial ring.

The secondary xylem consists of radial rows of tracheids separated by parenchymatous cells. The crushed primary phloem is present in the form of dark streaks outside the secondary phloem. The secondary xylem is manoxvlic and contains many multiseriate rays.

Periderm starts to develop in the cortex of old roots. Some of the cells of the outermost cortical region start to become meristematic and function as cork cambium. It cuts cork towards outer side and secondary cortex towards inner side. Cork cells are dead and remain filled with subenn. Cycas roots often show two layers of periderm (Fig. 8.17).

Epiblema is ruptured and there are no root hairs in the older roots.

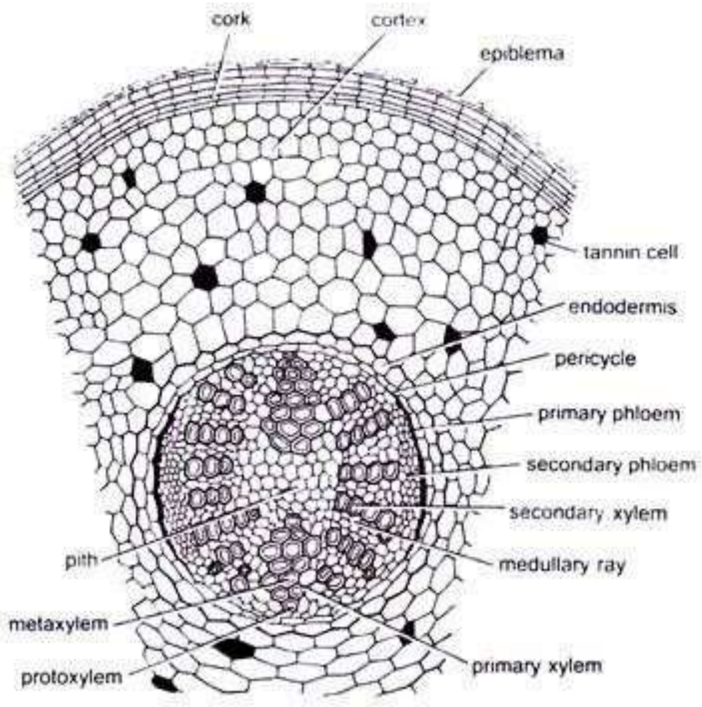


Fig. 8.17. *Cycas revoluta.* T.S. normal root (old).

(iii) Coralloid Root:

Anatomically, the coralloid roots (Fig. 8.18) resemble normal roots except some under mentioned differences:

1. The secondary vascular tissue in coralloid roots is either totally absent or poorlydeveloped.

2. The cortex is wider in comparison with the normal root.

3. Presence of a greenish algal-zone in the middle of the cortex. But according to Chaudhary and Akhtar (1931) the algal-zone is not of universal occurrence in the coralloid roots of Cycas. It may be absent in such coralloid roots which go very deep in the soil. According to these workers only those coralloid roots are negatively geotropic which are infected by algal members.

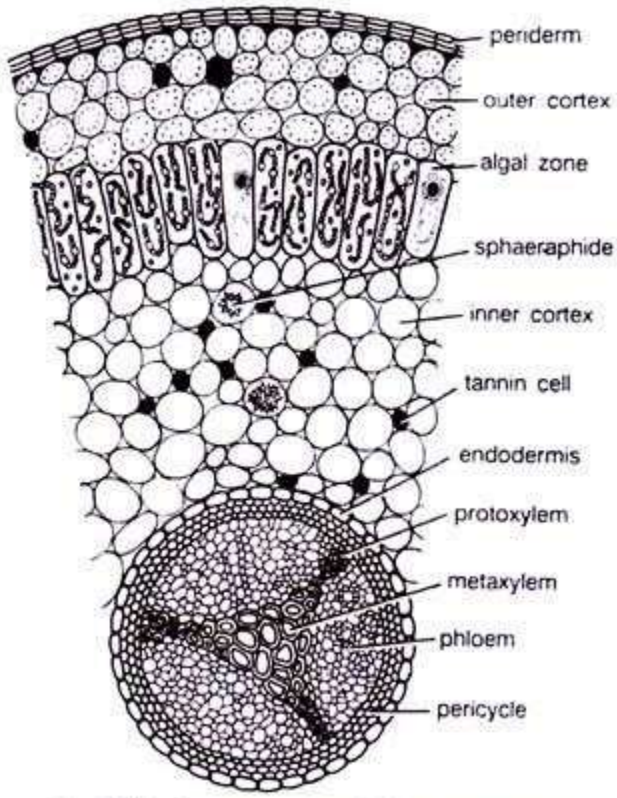


Fig. 8.18. *Cycas revoluta* T S. coralloid root

Algal-zone consists of radially elongated, large, thin-walled cells having large intercellular spaces occupied by algae. Life (1901) opined that these spaces are formed because of the retardation of growth of such cells which are already infected by fungi and bacteria.

Such infected cells cannot keep pace with the neighbouring cells, and a tension is produced which results in the formation of air spaces by breaking of certain cells. These spaces are further widened by the algal infection. But according to Chaudhary and Akhtar (1931) the alga is mainly responsible for the formation of these large intercellular spaces.

Following members have been reported from the algal zone of coralloid roots: Anabaena cycadae, Nostoc punctiforme, Oscillatoria, Azotobacter, Pseudomonas radicicola and even a few fungi. According to Kubitzki (1990) blue green algae or Cyanoba cteria (Anabaena, Nostoc and Calothrix) may rarely be present intracellularly (i.e. inside the cell) in the coralloid roots of Cycas. He opined that these algae fix nitrogen and promote the growth of host plant.

Due to the presence of blue-green algal members and some nitrogen-fixing bacteria, the function assigned to the coralloid roots is chiefly the nitrogen fixation. The presence and structure of endodermis, pericycle and vascular bundles in the coralloid roots are similar to that of normal roots. The xylem is exarch and triarch.

(iv) Stem:

Similar to root, the stem of Cycas also resembles internally with a dicotyledonous stem.

It shows the following anatomical features:

Epidermis is the outermost layer consisting of compactly arranged thick- walled cells. Presence of several persistent leaf bases makes the epidermis a discontinuous and ruptured layer. Cortex is large and consists of thin- walled, parenchymatous cells, filled densely with starch grains. It contains numerous mucilaginous canals and girdle traces.

Each mucilage canal is lined with many radially elongated epithelial or secretory cells (Fig. 8.19). Medullary rays connect the mucilage canals of the cortex with that of the pith Starch in the parenchymatous cells of the cortex is the source of **'sago'.** Endodermis and pericycle are not clearly demarcated.

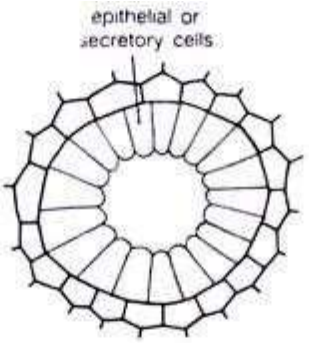


Fig. 8.19. *Cycas.* A mucilage canal

Numerous vascular bundles remain arranged in a ring. The stele is ectophloic siphonostele. Each vascular bundle is conjoint, collateral, open and endarch (Fig. 8.20). The xylem consists of tracheids and xylem parenchyma (Fig. 8.21).

Protoxylem contains tracheids with spiral thickenings while the metaxylem has scalariform thickenings with bordered pits. Vessels are absent. The phloem is located outside the xylem and consists of sieve tubes and phloem parenchyma. Companion cells are absent.

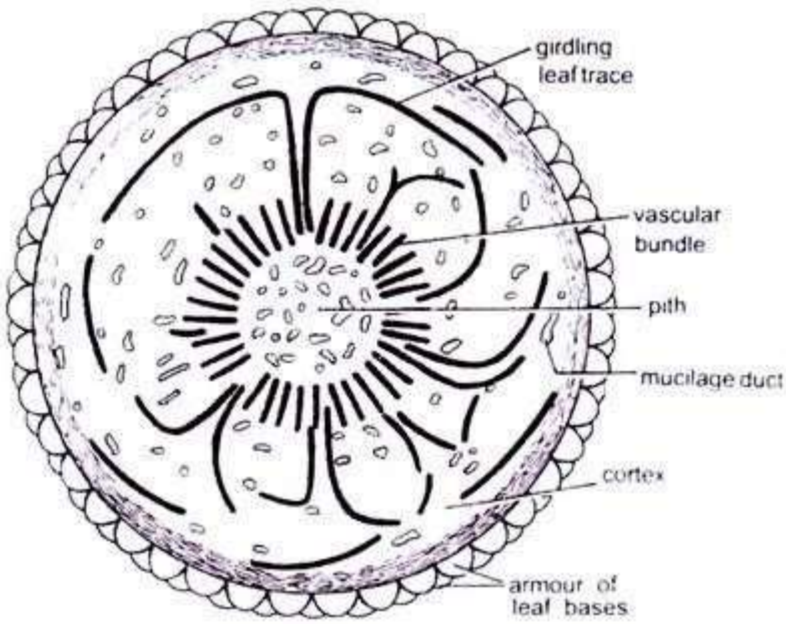


Fig. 8.20. *Cycas.* Diagrammatic representation of T S. young stem

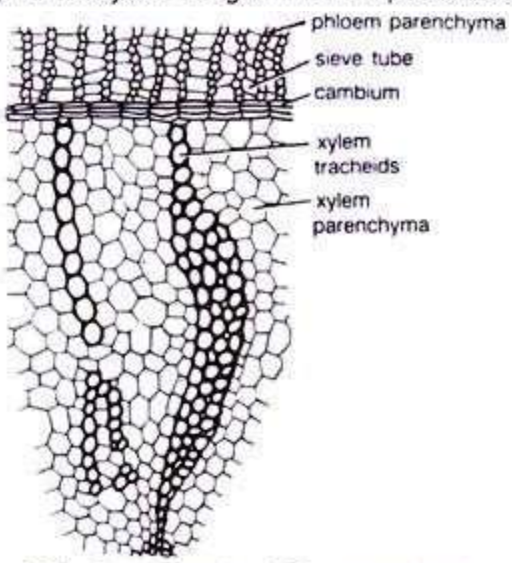


Fig. 8.21. *Cycas revoluta.* T S. stem showing only a part of vascular bundle

Between the xylem and phloem lies the primary cambium, which remains active only for a short period. It is soon replaced by another ring of secondary cambium somewhere in the cortex. These successive cambial rings form 2-14 different vascular rings showing polyxylic condition in the old stem (Fig. 8.22).

Several broad and well-developed medullary rays are present between the vascular bundles.

Pith is large, well-developed and parenchymatous. It contains many mucilaginous canals.

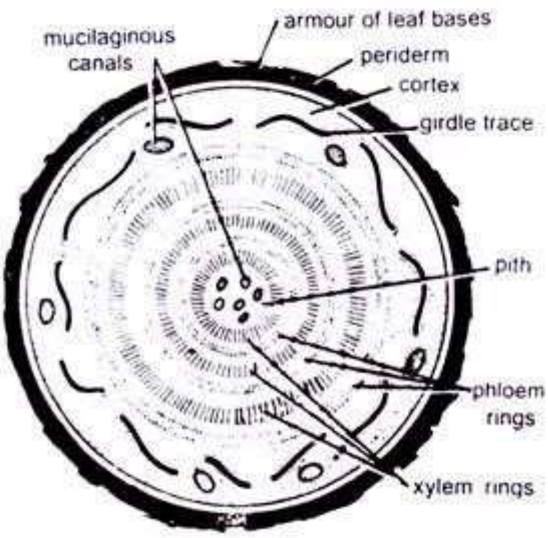


Fig. 8.22. *Cycas* T.S. old stem (diagrammatic)

(v) Leaf Traces:

The leaf traces remain scattered in the cortical region of the stem and constitute the vascular supply to the leaves from the main vascular cylinder. Normally, there are four leaf traces which form the vascular supply to the leaf. Two of these are direct traces, while the remaining two axe girdle traces (Fig. 8.23).

The direct traces originate from the vascular cylinder lying in front of the leaf base while the girdle traces develop from the vascular cylinder lying opposite to that of direct traces. They proceed together and curve soon in opposite directions, and by girdling round the vascular cylinder they enter in the leaf base.

In the cortical region the girdle traces also remain connected with other leaf traces. At the time of their entrance in the petiole, the leaf trace bundles subdivide and form many petiole bundles. Such type of unique girdle traces of Cycas, which also occur in Magnoliaceae. show a close relationship of Cycadales of Gymnosperms and Magnoliaceae of dicotyledons.

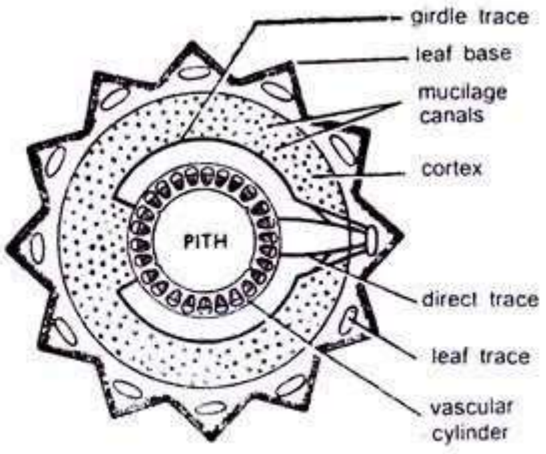


Fig. 8.23. *Cycas* T.S. stem (diagrammatic) showing distribution of leaf traces

(vi) Secondary Growth:

It is similar to that of dicotyledons. In the beginning, Cycas is monoxylic, i.e. contains a single ring of vascular bundles. But one or more concentric rings of vascular bundles appear outside the primary ring of bundles in the older stems showing polyxylic condition (Fig. 8.24)

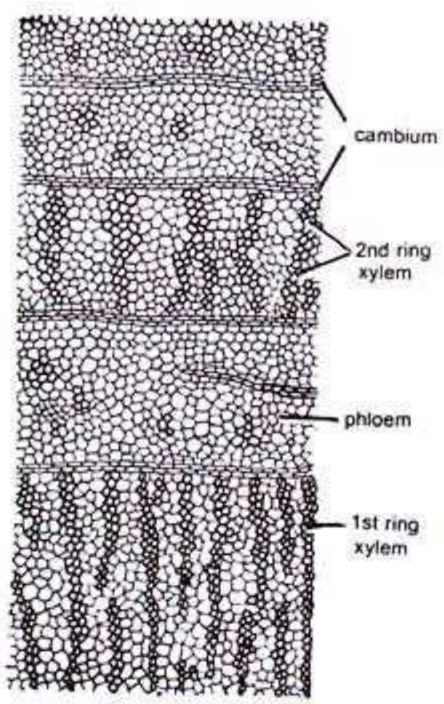


Fig. 8.24. *Cycas.* A part of T.S. stem showing secondary vascular tissues.

By the activity of inter-fascicular and intra-fascicular cambia, which unite to form a cambium ring, the secondary growth is initiated. This cambium ring cuts secondary phloem towards outer side and secondary xylem towards inner side. Well-developed medullary rays traverse through the so-formed secondary vascular tissue.
After a short while this cambium ring stops functioning and a second cambium ring develops either in the parenchymatous cortex or in the region of pericycle This cambium ring also behaves in the similar fashion.

In this fashion, as many as 14 rings of vascular tissue may develop in the stem of Cycas pectinata of about 20 cm diameter showing polyxylic condition. Seward (1917) reported 12 such rings in the stem of C. media of about 30 cm diameter, and Schuster (1932) reported 22 such rings in the stem of C. rumphii having a diameter of about 85 cm.

Cambial rings towards the periphery of the stem form lesser number of vascular bundles. The cork cambium develops on the outer region of the cortex and cuts cork towards outer side and secondary cortex towards inner side.

(vii) Rachis:

The outline of transverse section is rhomboidal in the basal region of the rachis, biconvex in the middle cambium and roughly cylindrical at the tip region or at the apex of the rachis. Two arms of the bases of leaflets are present on the rachis, one on each side (Fig. 8.25).

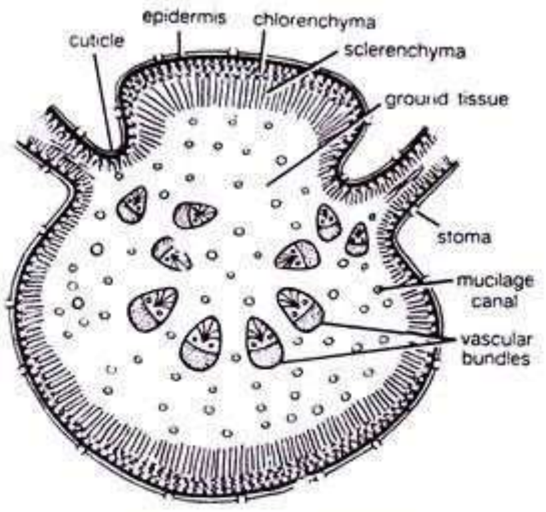


Fig. 8.25. *Cycas* T.S. rachis (diagrammatic).

In T.S. the rachis reveals the following structures from outside within:

Epidermis is the outermost layer of the rachis consisting of thick-walled cells. It is heavily circularized. On its upper as well as lower sides are present irregularly distributed sunken stomata. Hypodermis is present below the epidermis.

It is differentiated into outer 2-3 layers of chlorophyll-containing thin-walled cells of chlorenchyma and inner 4-6 layers of thick- walled lignified cells of sclerenchyma. Sclerenchyma is poorly-developed on the lateral sides. It is also seen intermixed with chlorenchyma.

Ground tissue is a large region consisting of thin- walled, parenchymatous cells. Many mucilaginous canals and vascular bundles are present in this region. The number and arrangement of mucilage canals have no definite relation with that of vascular bundles. Each mucilage canal is a double-layered structure consisting of an inner layer of epithelium cells surrounded by an outer layer.

Vascular bundles are arranged in the shape of an inverted Greek letter Omega (Ω) (Fig. 8.25). Towards the tip of the rachis the bundles are arranged in C-shaped manner and their number is comparatively less. Each vascular bundle remains surrounded by a bundle sheath (Fig.
8.26). It is conjoint, collateral and open.

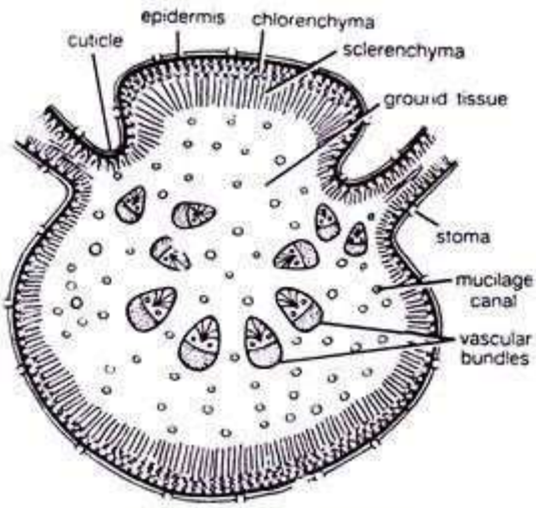


Fig. 8.25. *Cycas* T.S. rachis (diagrammatic).

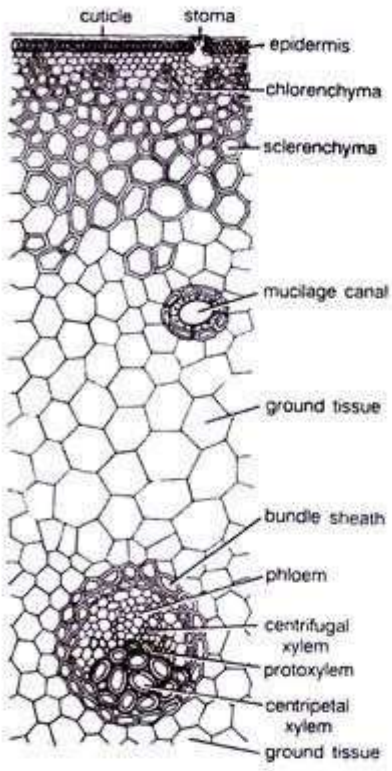


Fig. 8.26. *Cycas revoluta*. A part of T.S. of rachis.

The xylem in each vascular bundle is present towards inner side. It consists of tracheids and xylem parenchyma. Cambium separates the xylem from the phloem. Vessels are absent.

The vascular bundles are diploxylic, i.e. consists of two types of xylem viz. centripetal xylem and centrifugal xylem. Phloem, present towards the outer side of the vascular bundle, consists of sieve tubes and phloem parenchyma. Companion cells are absent.

The vascular bundles show different structure at different levels of rachis starting from the base up to the apex, especially with regard to their diploxylic nature.

Their brief description is under mentioned:

(a) Vascular Bundles At the Base of Rachis:

Only the centrifugal xylem is well-developed in the vascular bundles (Fig. 8.27A). Its protoxylem faces towards the centre showing endarch condition. Centripetal xylem is not developed.

(b) Vascular Bundles In the Middle of Rachis:

Both centripetal as well as centrifugal xylem are present showing diploxylic condition (Fig. 8.27B). Centripetal xylem is present just opposite to the protoxylem of the centrifugal xylem.

(c) Vascular Bundles At the Apex of Rachis:

Centripetal xylem is well-developed, triangular and exarch (Fig. 8.27C). Centrifugal xylem is much reduced and present in the form of two patches lying one on each side of the protoxylem elements of centripetal xylem. Centrifugal xylem is totally absent at the extreme tip of the rachis.

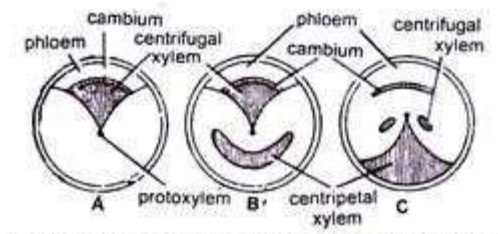


Fig. 8.27A-C. *Cycas.* Diagrammatic representation of vascular bundles of rachis at different levels. A, At the base; B, In the middle; C, At the apex.

(viii) Leaflet:

Cycas leaflets are large, tough, thick and leathery. In a vertical section the leaflet is differentiated into a swollen midrib portion and two lateral wings (Figs. 8.28, 8.29). In C. revoluta and C. beddomei the wings are curved downward or revoluted at the margins but in C. circinalis, C. rumphii, C. pectinata and C. siamensis the margins are flat.

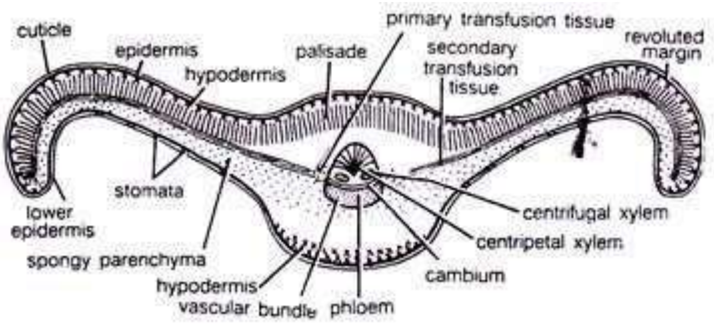


Fig. 8.28. *Cycas revoluta.* T.S. leaflet (diagrammatic)

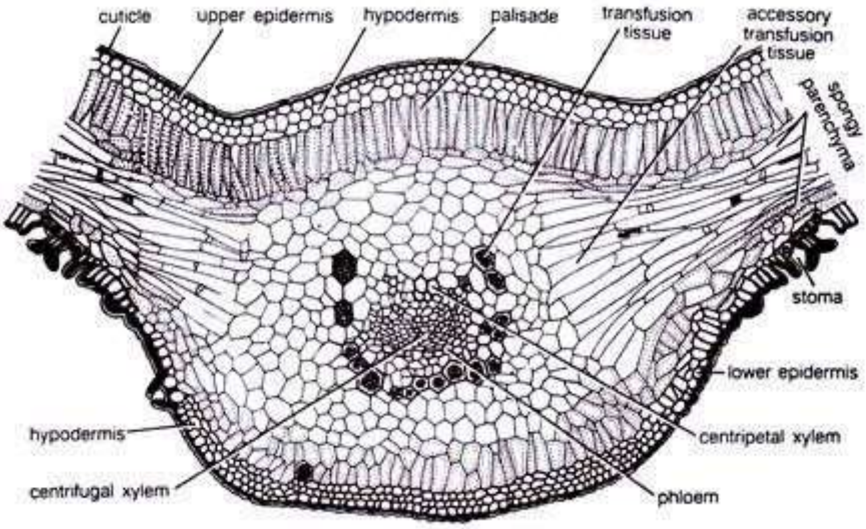


Fig. 8.29. *Cycas revoluta.* A part cellular of T.S. leaflet (modified after Pant, 1973)

Epidermis is the outermost layer consisting of thick-walled cells. It is surrounded by a thick layer of cuticle. Upper epidermis is a continuous layer while the continuity of the lower epidermis is broken by many sunken stomata. On all the sides of the epidermal cells occur simple pits almost in regular series.

According to Pant and Mehra (1964), the stomata are of haplocheilic type (perigenous) in Cycas circinalis, C. revoluta and C rumphii. Hypodermis is sclerenchymatous and present below the epidermis. It is absent below the lower epidermis but in the midrib region it is several-celled thick.

Mesophyll is well-developed and remains differentiated into palisade and spongy parenchyma. A continuous layer of palisade is present below the sclerenchymatous hypodermis. Its cells are radially elongated and filled with chloroplasts. The palisade may be a continuous layer over the midrib as in Cycas beddomei, C. media, C. pectinata and C. revoluta, or it may be a discontinuous layer as in C. circinalis and C. rumphii.

Spongy parenchyma is present only in the wings, directly above the lower epidermis. Its cells are oval, filled with chloroplasts, and loosely arranged having many air-filled intercellular spaces. Transfusion tissue consists of two small groups of short and wide tracheid-like cells with reticulate thickenings or bordered pits on their walls.

These cells have been named as transfusion tissue by Von Mohl (1871), and were first described by Frank (1864). Few layers of transversely elongated cells are present in both the wings just in between the palisade and spongy parenchyma.

This represents the accessory transfusion tissue or secondary transfusion tissue. The secondary' transfusion tissue has also been named as hydrostereom by Bernard (1904) or radial parenchyma by Pilger (1926). A great phylogenetic significance has been attributed to the transfusion tissue by Worsdell (1897).

Vascular bundle is one, and present in the midrib region of the leaflet. It is conjoint, collateral, open and diploxylic. The triangular centrifugal xylem is well-developed with endarch protoxylem. It is represented by two or sometimes more small groups on either side of the protoxylem.

Phloem is arc-shaped and remains separated by cambium. Phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent. The portion of the midrib in between the palisade layer and lower hypodermal region is filled with parenchymatous cells. Some of these cells contain calcium oxalate crystals.

[I] Vegetative Cycle:

This is a deviation of regular alternation of generations between sporophyte and gametophyte.

In this type of cycle, a sporophyte gives rise to a sporophyte of the same sex. Vegetative Cycle takes place with the formation of adventitious buds called bulbils in the basal part of stem (Fig. 9.2).

Bulbils are protected by scale leaves. During favourable period bulbils detach from the parent and grow into an independent sporophyte.

This cycle is more prevalent in Northern India where male plants of Cycas revolute are not found.

[II] Sexual cycle (Sexual reproduction):

The sexual life cycle of Cycas is diplohaplontic. It shows heterologous or heteromorphic type of alternation of generations because the sporophyte (2n) and gametophyte (n) generations exhibit morphological differences. In Cycas, the sporophyte (2n=22) is a complicated, independent and dominant generation whereas the gametophytes (n=ll) are inconspicuous and endosporic. The gametophytes of Cycas are of 2 types: male or microgametophyte and female or magagametophyte. Female gametophyte is retained whereas male gametophyte is transfer during pollination.

Reproductive organs:

After many years of vegetative growth sex organs develop on Cycas sporophytes in the form of cones or strobili. Cycas is dioecious i.e. male cone and female cone (lax) born on separate sporophytes. The male sporophyte is heterogametic having sex chromosomes-XY while the female sporophyte is homogametic having sex chromosomes-XX.

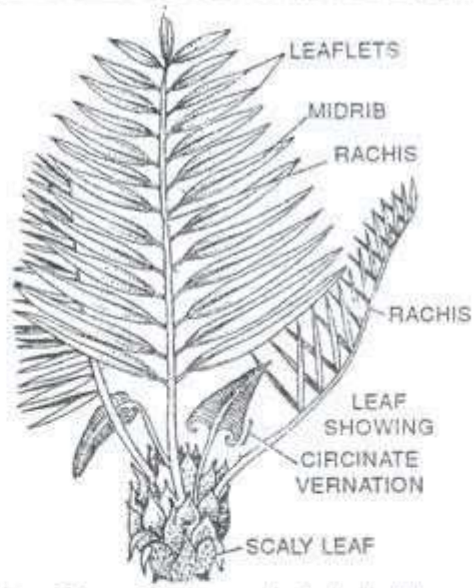


Figure 9.4 *Cycas* : A single bulbil.

Male Cone:

Male cone is ovoid or conical and grow up to 1.5 m. It has a central axis or cone axis surround by compactly and spirally arranged micro-sporophylls. Each microsporophyll has adaxial (upper) and abaxial (lower) surfaces. The adaxial surface is ridge like with sterile apophysis at the apex. The adaxial surface contains numerous microsporangia in group of 3-6 called sori. Each microsporangium filled with numerous haploid microspores or pollen grains (Fig. 9.5, 9.6 & 9.7).

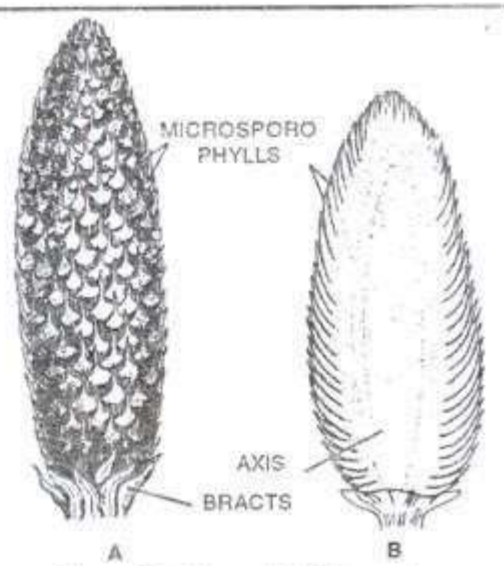


Figure 9.5 *Cycas* : **A.** Entire male cone, **B.** Male cone in L.S.

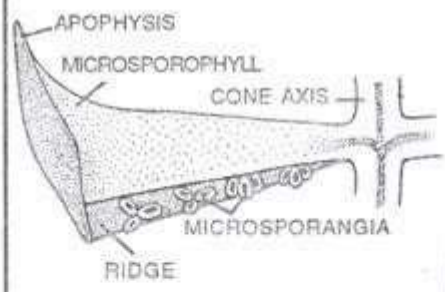


Figure 9.6 L.S. of a single microsporophyll along with cone axis.

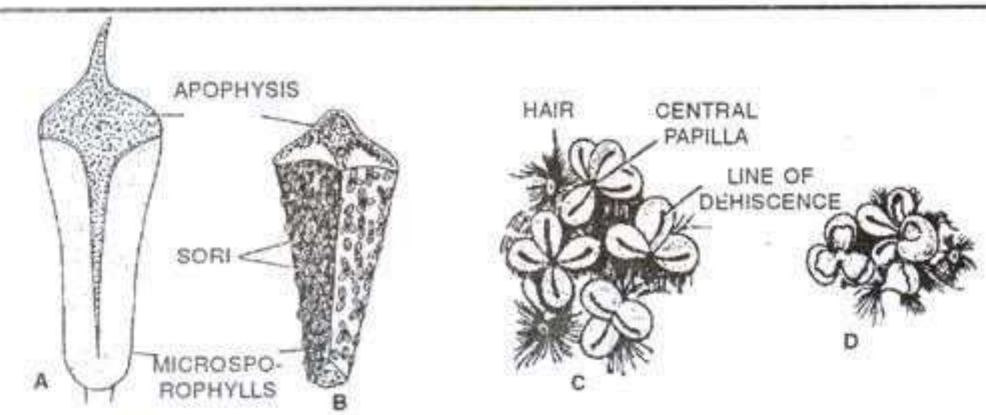


Figure 9.7 *Cycas* : Microsporophyll ; **A.** Adaxial (upper) surface, **B.** Abaxial (lower) surface, **C.** Undehisced microsporangia arranged in sori. **D.** Dehisced microsporangia.

Female Cone:

In Cycas true and compact female cone (ovulate strobilus) is absent, instead it is a lax where megasporophylls are loosely arranged at the stem apex that appears like a rosette. Each megasporophyll is a modified foliage leaf ranging from 15-30 cm. in length. It has a proximal petiole, middle ovule bearing part and upper pinnately dissected sterile region. The middle fertile part bears 2-12 sessile rounded ovules in two rows (Fig. 9.8 & 9.9).

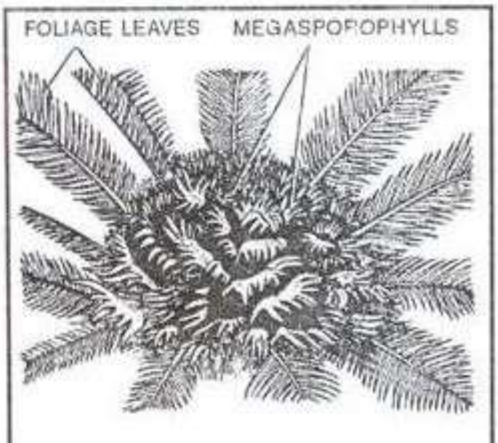


Figure 9.8 *Cycas* : Rosette of megasporophylls.

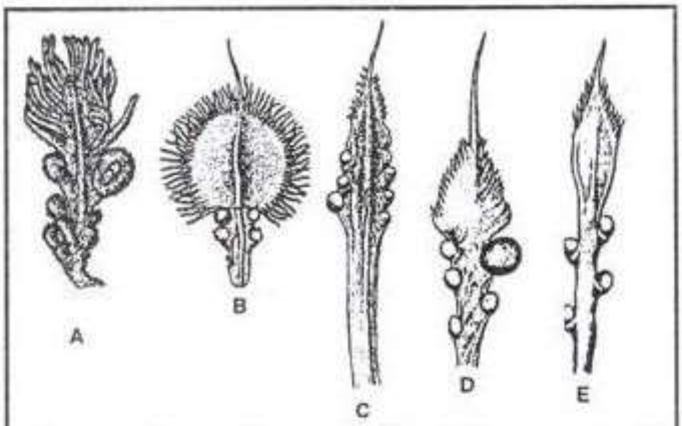


Figure 9.9 *Cycas* : Megasporophylls of different species. A. *C. revoluta*, B. *C. pectinata*, C. *C. circinalis*, D. *C. rumphii*, E. *C. beddomei*.

Ovules:

The ovules are orthotropous, unitegmic and sessile or shortly stalked. The Cycas ovule is largest in plant kingdom with 6-7 cm in diameter. In young stage ovules are green covered with brown hairs but after fertilization hairs are lost and appear orange to red in colour. The body of ovule is called nucellus (megasporangium), covered by a thick integument in all sides except an opening called micropyle. The apex of the nucellus has a pollen chamber and a nucellar beak. The integument consists of three distinct layers: outer and inner fleshy layers and middle stony layer.

(a) Development of female gametophyte (Endosperm):

Inside the nucellus, one cell differentiated into megaspore mother cell. It undergoes reduction division (meiosis) to form a linear tetrad of four haploid megaspores. Usually, the upper 3 megaspores towards micropyle degenerate while the lower most functional megaspore (embryo sac cell) undergoes free nuclear division followed by wall formation to form a cellular female gametophyte or endosperm.

Hence, the formation of female gametophyte is monosporic, i.e develops from a single megaspore. During formation of endosperm nucellus is utilized. It should be noted that in gymnosperms the endosperm develop before fertilization and is haploid (n) while in angiosperms it is triploid (3n) and formed after fertilization (Fig. 9.10).

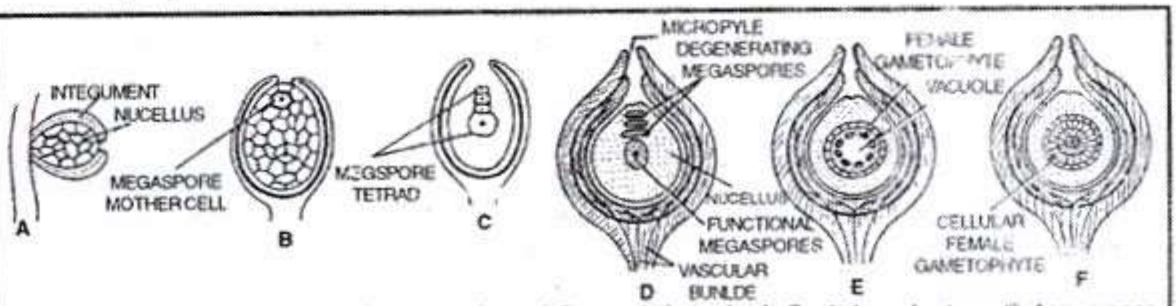
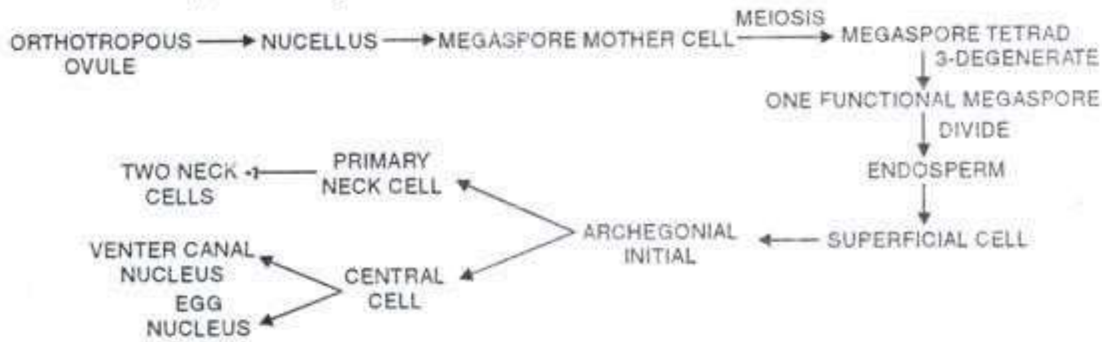


Figure 9.10 Development of female gametophyte of *Cycas* within ovule. **A.** Ovule in early stage, **B.** Appearance of megaspore mother cell, **C.** Megaspore mother cell divides reductionally to form four megaspores, **D.** Three megaspores degenerate, one remain functional, **E** to **J.** Development of female gametophyte and archegonia, **K.** Mature ovule.

Summary of development of Female Gametophyte



(b) Development of archegonium:

At the micropylar end of female gametophyte 2-8 archegonia develop. All the necks of archegonia open into an archegonial chamber formed by a depression in female gametophyte (Fig. 9.11). Each archegonium develops from single superficial cell called archegonial initial.

It gets enlarged and divides transversally into outer primary neck cell and inner central cell. The primary neck cell divides anticlinally to form two neck cells. The inner central cell enlarges and its nucleus divides into venter canal nucleus and egg nucleus. Soon the venter canal nucleus disorganizes. Thus, a mature archegonium has two neck cells and an egg. Neck canal cells are not formed. The egg cell in Cycas is largest in the plant kingdom (Fig. 9.11).

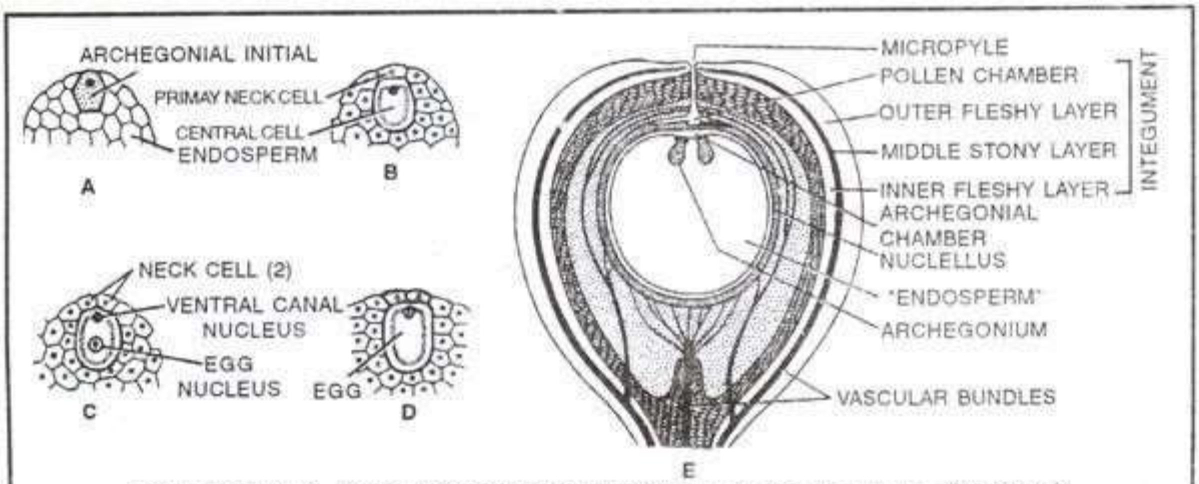


Figure 9.11 A-D. *Cycas*. Development of archegonium, E. V.S. of a mature *Cycas* ovule

(c) Development of Male gametophyte (Before pollination):

Microspore or pollen grain is the first cell of the gametophyte. The microspore germinates in situ i.e. while within the microsporangium. Each microspore divides asymmetrically into a 2cells: a smaller prothallial cell and a larger antheridialcell. The prothallial cell does not divide further while the antheridial cell divides into a smaller generative cell near the prothallial cell and a larger tube cell. Finally pollination takes place at 3-celled stage (a prothallial cell, a generative cell and a tube nucleus) (Fig. 9.12).

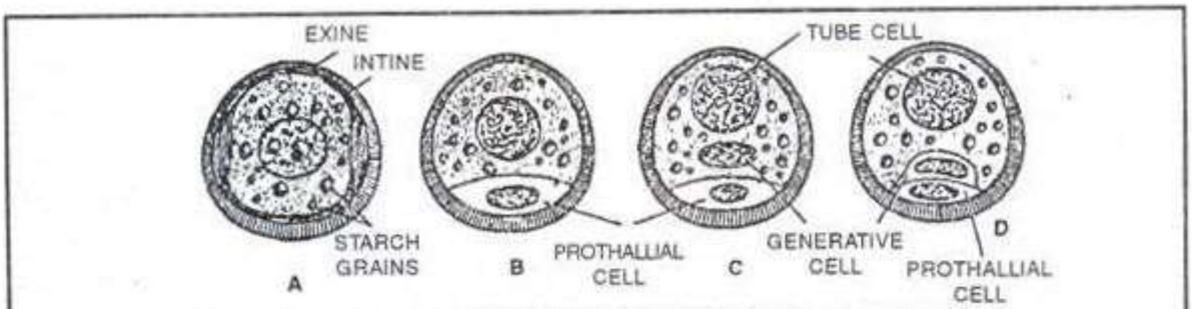


Figure 9.12 *Cycas*. A-C : Pre-pollination development of male gametophyte

Pollination:

In Cycas pollination is anemophilous (by wind). The 3-celled microspores liberate from mega-sporangia are blown away by wind. Finally microspores reach on ovules and get enlarged in the pollination drop (ooze) of micropyle. As the ooze dries up, the microspores are drawn into the pollen chamber.

(d) Development male Gametophyte (After pollination):

After a gap of about 4 months, post-pollination development of male gametophyte occurs. The exine ruptures and the intine grows out in form of apollen tube. The pollen tube acts as a haustorium, i.e. absorb food while penetrating through the nucellus and hang in the archegonial chamber. In the pollen tube, generative cell divides into a stalk cell and a body cell. Finally, the body cell divides into two male gametes or antherozoids. Thus, a fully developed male- gametophyte consists of a disorganized prothallial cell, stalk cell, tube nucleus and 2 male gametes (Fig 9.13)

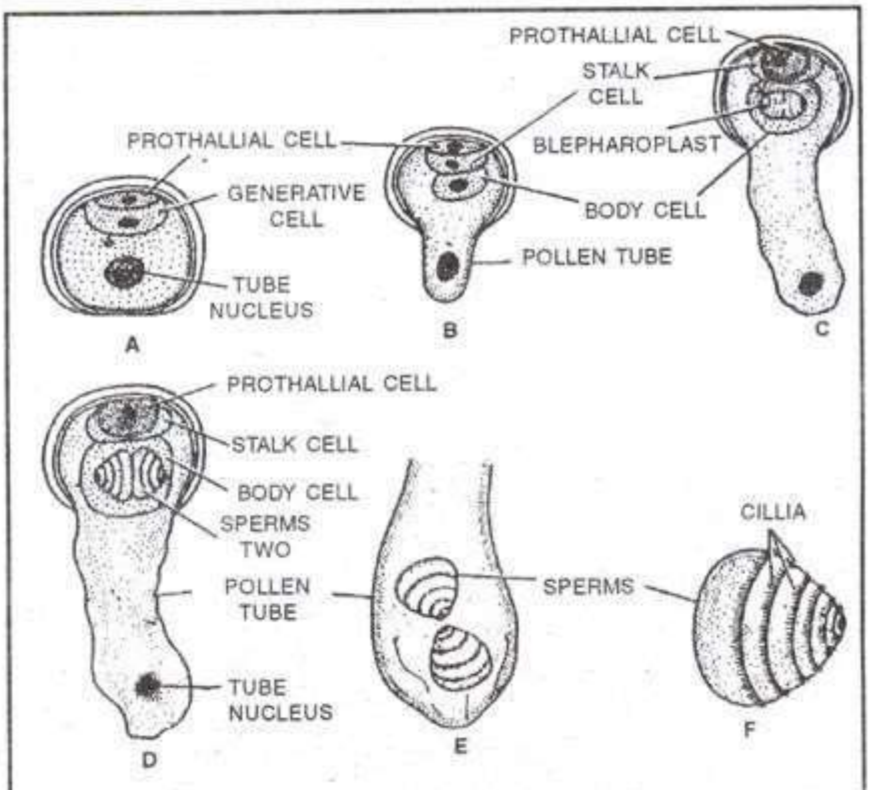


Figure 9.13 *Cycas*. A-F : Post-pollination development of male gametophyte

Each male gamete appears top-shaped with 5-6 spiral bands of cilia. The size of male gamete in Cycas varies from 180-210µm (largest, 400«m reported from Chigua, a cycad).

Fertilization:

In the archegonial chamber, the tip of pollen tube burst to discharge its contents. One of the sperms enters the archegonium. When moving toward s egg, the sperm lost cilia and cytoplasmic membrane. So the fusion of a male nucleus and egg nucleus occurs to form a zygote. (2n) It is noted that in Cycas fertilization exhibits both siphonogamy (i. e. formation of pollen tube) and zoidogamy (i.e. participation of ciliated male gametes).

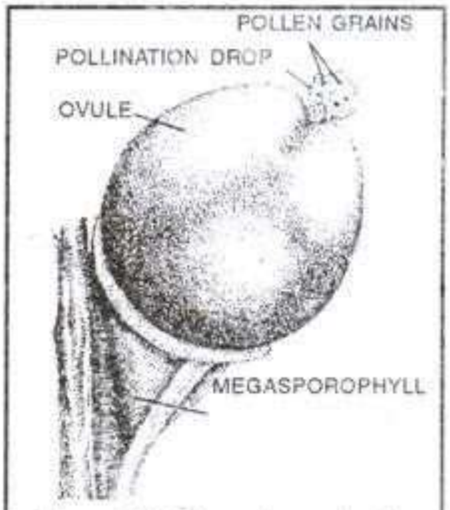


Figure 9.14 *Cycas*. An ovule with pollination drop and pollen grains

Embryogeny:

The zygote (2n) secretes cell wall and becomes the oospore. The zygote or oospore is the first cell of sporophyte generation. The oospore undergoes free nuclear division followed by wall formation to form a small cellular mass called pro-embryo. The pro-embryo differentiated into a basal embryonalzone, middle suspensor and upper haustorium. The haustorial region remains in contact with the free-nuclear region and soon disappear (Fig. 9.15).

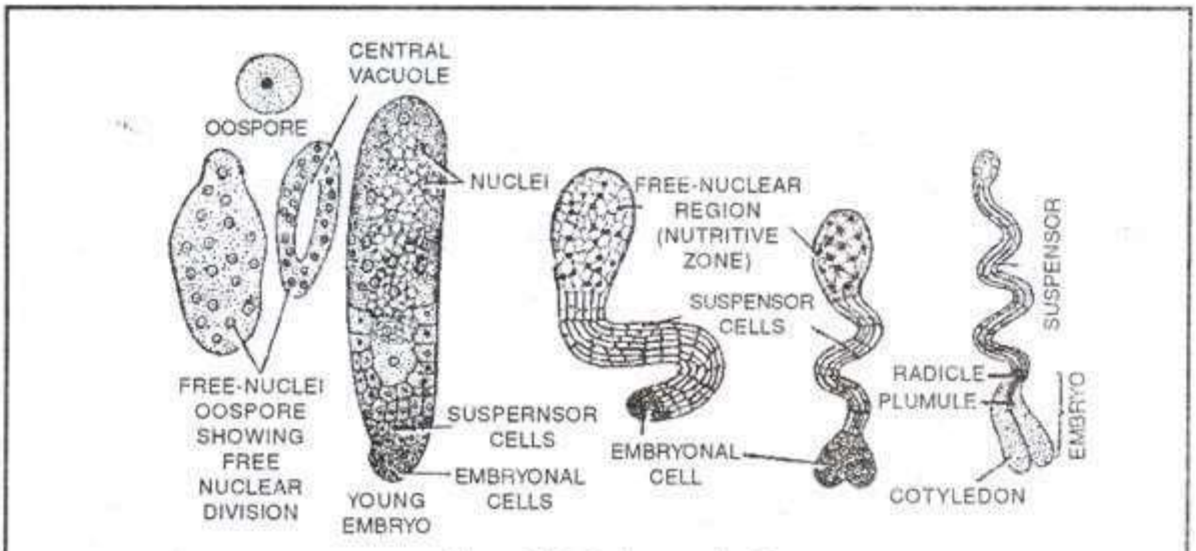
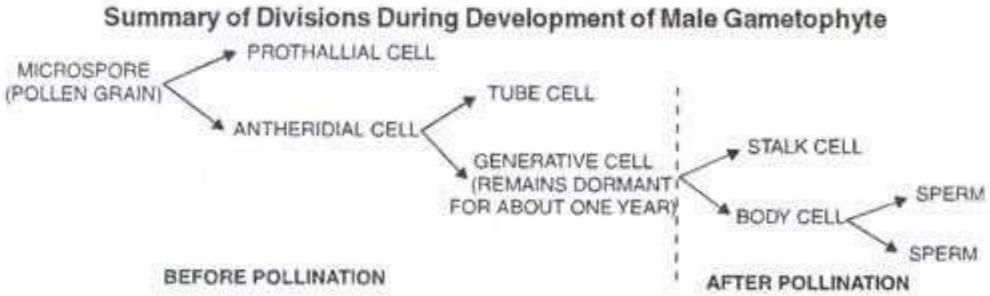


Figure 9.15 Embryogeny in *Cycas*

The cells of embryonal zone divide and re-divide to form embryo proper which is differentiated into two cotyledons, plumule and radicle. The suspensor becomes enlarged and coiled to push the embryo into the nutritive endosperm. The endosperm froms a pad like tissue called coleorhiza which protects the tip of radicle.



Since, a single Cycas ovule contains 2-8 archegonia; the same number of embryo develops. All degenerate except one embryo that reaches maturity.

Seed formation:

As a result of post-fertilization changes the entire ovule becomes a seed. Following changes take place in the process:

Ovule	→ Seed
1. Integuments.	
(*a*) Two outer layers of integument	
(*i*) Outer fleshy layer which becomes creamy orange or red coloured	Seed coat
(*ii*)	Middle stony layer
(*b*) Inner fleshy layer.	
2. Nucellus	Absorbed by developing gametophyte. Present in the form of a cap towards micropylar end. (absorbed by developing gametophyte at other places).
3. Female gametophyte (endosperm)	Function as food for developing embryo
4. Zygote	Embryo with radicle, plumule and two cotyledons.

Seed Germination:

The testa of Cycas seed emits pleasant odour and sweet in taste. This causes its dispersal by birds. The seed remain variable for a few months. Under favourable condition, the seed germinates into a sporophyte. The seed germination in Cycas is hypogeal i.e. the cotyledon remains underground enclosed in the endosperm and absorb food for the growing embryo. The plumule form leafy shoot and radicle elongates into a tap root (Fig. 9.16).

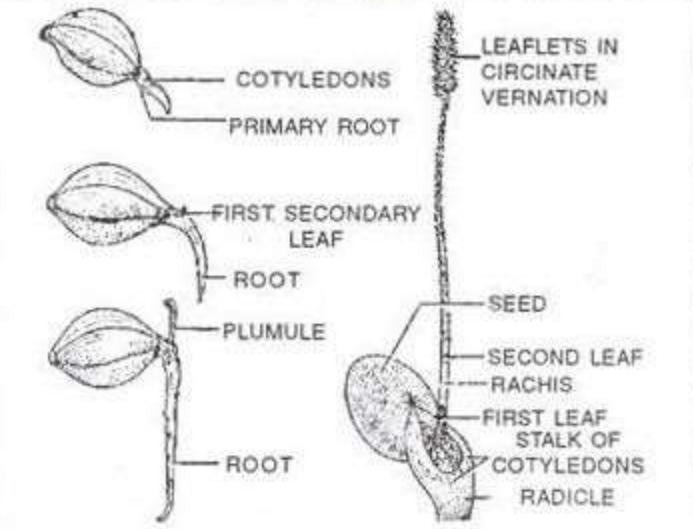


Figure 9.16 *Cycas* : Various stages of seed germination.

Three Generations Locked in Seed:

A seed contains three generations locked one within another.

The following three generations present in a Cycas Seed are:

1. Parent Sporophyte: Seed coat and nucellus.

2. Female Gametophyte: Endosperms

3. Future Sporophyte: Embryo (radicle, cotyledons and plumule).

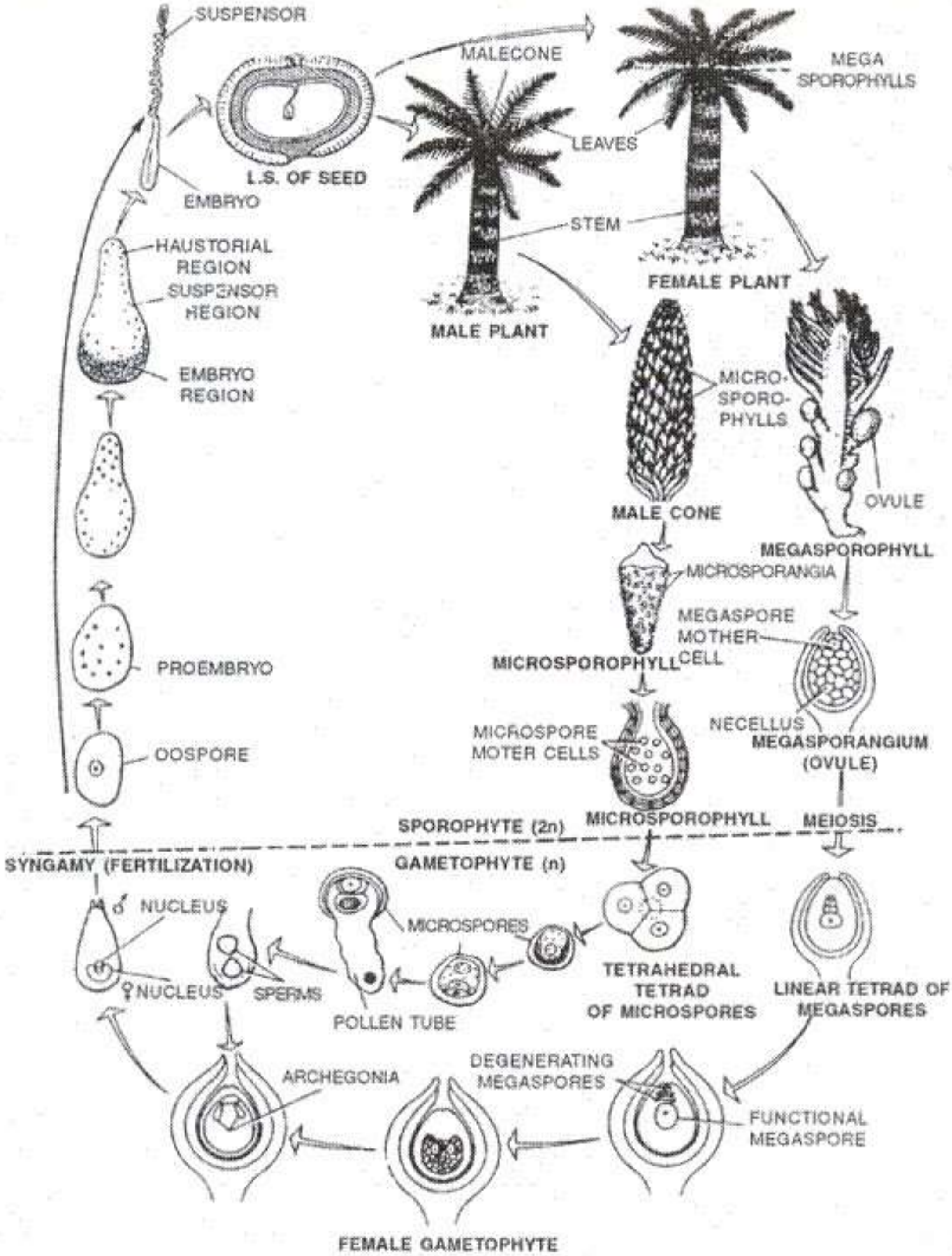


Figure 9.17 Diplontic life cycle of *Cycas*.