family Cycadaceae contains the genus *Cycas* only, family Stangeriaceae also contains one genus *Stangeria* and the family Stangeriaceae also contains one genus *Stangeria* and the family Zamiaceae includes the remaining 8 genera.

A. *CYCAS*

Cycas belongs to the family Cycadaceae, order Cycadales, and division Cycadophyta of Gymnospermae.

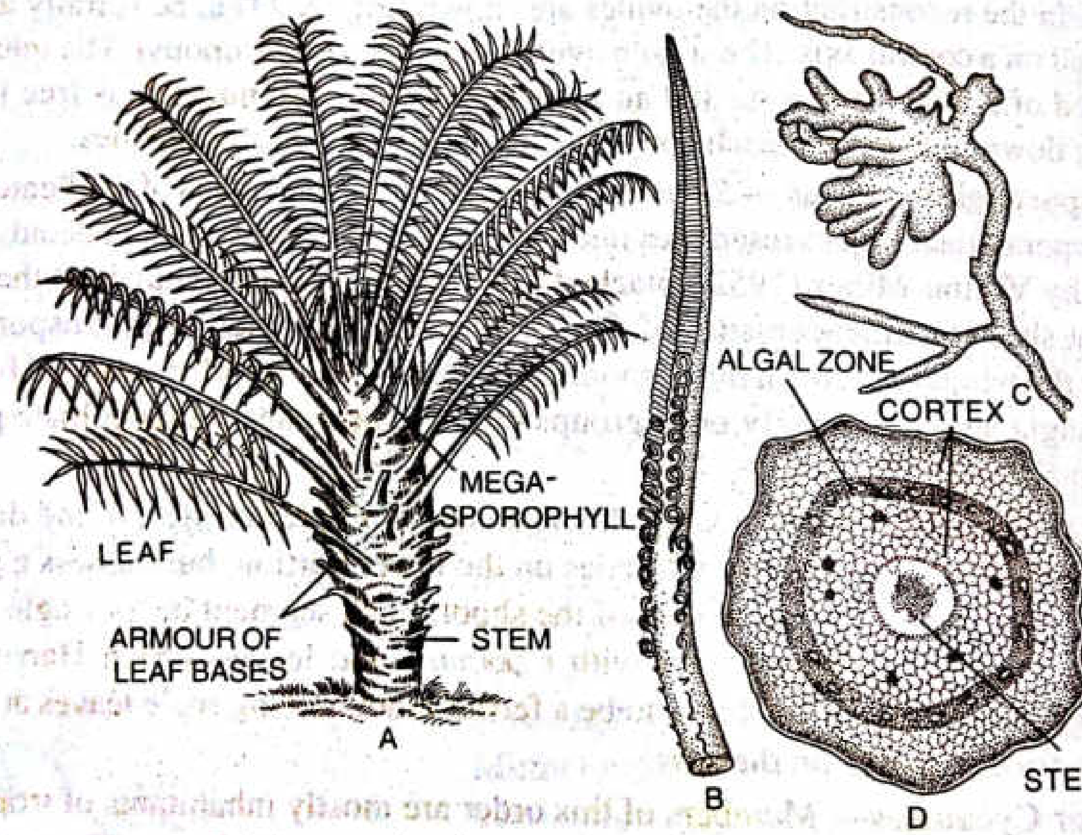

Fig. 2.24— *Cycas* sp. A—Female plant. B—Young leaf showing circinate vernations of leaflets. C—Coralloid roots. D—T.s. of coralloid root showing algal zone.

Distribution : The genus *Cycas* with at least 15 or 20 (Johnson 1959)[1] species is widely distributed, but the genus is predominantly represented in the Eastern hemisphere. Its species are distributed abundantly in Australia, Madagascar, East Africa, India, South China and South Japan.

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[1] Johnson, L.A.S. 1959. The families of Cycads and the Zamiaceae of Australia, *Proc. Linn. Soc.* N.S.W. 84 : 64-117. Also refer J.C. Willis' *Dictionary of Flowering Plants & Ferns* (1966)

In India 4 species of *Cycas* are found to occur—these species with their distribution are as follows :—

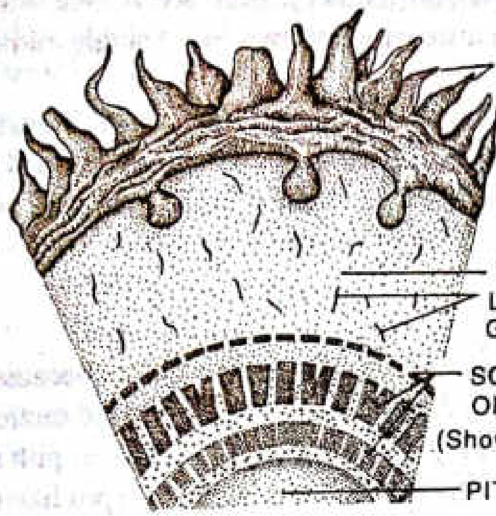


Fig. 2.25—*Cycas* sp. T.s. of the stem showing large pith, extensive cortex and scanty zone of wood (diagrammatic)

(1) *Cycas circinalis* L. (Orissa, Andhra and Tamil Nadu extending to Sri Lanka). Plant is about 4.5 m tall. Leaves are unipinnate 1.5 to 3.0 m long, with 80 to 100 pairs of leaflets.

(2) *Cycas pectinata* Griff. [Eastern Nepal, Champaran District of Bihar, Sikkim, Assam (Khasia hills), Bangladesh (Chittagong), Arakan]. Stem is thick, columnar, trunk about 1.4 to 3.0 m high. Leaves 1.5 to 2.0 m long.

(3) *Cycas rumphii* Miq. (Andaman & Nicobar Islands, Sri Lanka). Very tall plant, upto 6.0 m high. Leaves 1 to 2 m long, with 50 to 60 pairs of leaflets.

(4) *Cycas beddomei* Dyer. (Andhra Pradesh, Tamil Nadu). Plants are low shrubs, the stem is upto 40 cm in height. Leaves 0.9 m long.

Besides above mentioned Indian species, other species of *Cycas* are (*a*) *Cycas revoluta*—This species grows in China and Japan; in India this species is grown as an ornamental garden plant; (*b*) *Cycas siamensis* is a Burmese species, also found in Siam and Indochina. This species, according to Burkill (1953), is nothing but a variation of C. *pectinata*.

According to B.M. Raizada and K.C. Sahni (1960), *Cycas* is represented in India by above mentioned six species.

Structure of the Sporophyte

1. External Morphology—*Cycas* is a small arboreal tree, looking like palm trees or a tree-fern. Therefore *Cycas* is also called "palm-fern".

(*a*) **Root**—*Cycas* plants possess a normal tap root sytem in the beginning. This tap root system is short-lived and later on is replaced by a number of adventitious roots. The adventitious roots develop a few negatively geotropic lateral roots which come out of the soil surface, these roots are profusely and dichotomously branched. These roots get infected by bacteria; the growth of bacteria is very soon followed by the entry of some members of blue-green algae, possibly *Anabaena cycadacearum*, within the root cortex—as a result, the infected roots become distorted producing a mass of exposed tubercles which look like a coral or knob. Hence such type of root is known as *coralloid root* (Fig.2.24, C) or corallorhiza.

(*b*) **Stem**— The stem is stout, columnar, erect, unbranched and covered by armour of persistent leaf bases. They bear at the apex, a crown of large foliage leaves. The stem bears large adventitious buds carried with scales at the base often called bulbils, which helps in vegetative propagation.

(*c*) **Leaves**—Leaves are dimorphic i.e. (i) brown scale leaves and (ii) large green pinnately compound foliage leaves; foliage leaves are arranged spirally at the top of the stem forming a crown. The foliage leaves are simple pinnate, very large which may be 0.9m to 2.7m long. Each pinnate leaf bears on its rachis several (50 to 100 pairs according to species) closely set leaflets. Leaflets are tough and leathery, they are sessile with a narrow base and decurrent margins; each leaflet is entire which shows only a single midvein (midrib) without lateral veins and veinlets.

Early in the development the leaflets of *Cycas* exhibit circinate vernation i.e. immature leaves coiled inwardly. As the leaf matures, it becomes coriaceous i.e. leathery and the margins of the leaflets often become revolute i.e. rolled downword. Alternating with these large foliage leaves, are clusters of small, dry and brown scale leaves which are also roughly felted.

2. **Internal Morphology**—

Stem—In transverse section, the stem of *Cycas* assumes an irregular outline because of the presence of numerous armoured leaf bases (Fig.2.25). It shows in transverse section a relatively massive pith, extensive cortex and a scanty zone of wood in between pith and cortex. The vascular cylinder i.e. stele is an endarch siphonostele (eustelic type) like that of a dicotyledonous angiosperm.

The vascular bundles are conjoint, collateral and open; primary xylem in endarch; in seedling stage the xylem is mesarch. The vascular bundles are arranged in a ring around a massive central pith, pith is composed of parenchyma cells which contain starch and secretory ducts. Cortex is composed of thin-walled parenchyma cells. Presence of *leaf trace girdles* in the cortex is another important feature in *Cycas*. A leaf trace often arising from the stelar cylinder generally does not enter into the nearest leaf directly, but the leaf trace forms a 'girdle' or semi-circle round the stem before entering the next leaf situated a little above. As those traces go round the stem, so they are called '*girdling traces*' or '*indirect traces*'. Usually a number of leaf traces enter each rachis of a leaf. Both the cortex and pith contain numerous mucilage canals which are interconnected through leaf gaps. Medullary rays occur in between the vascular bundles.

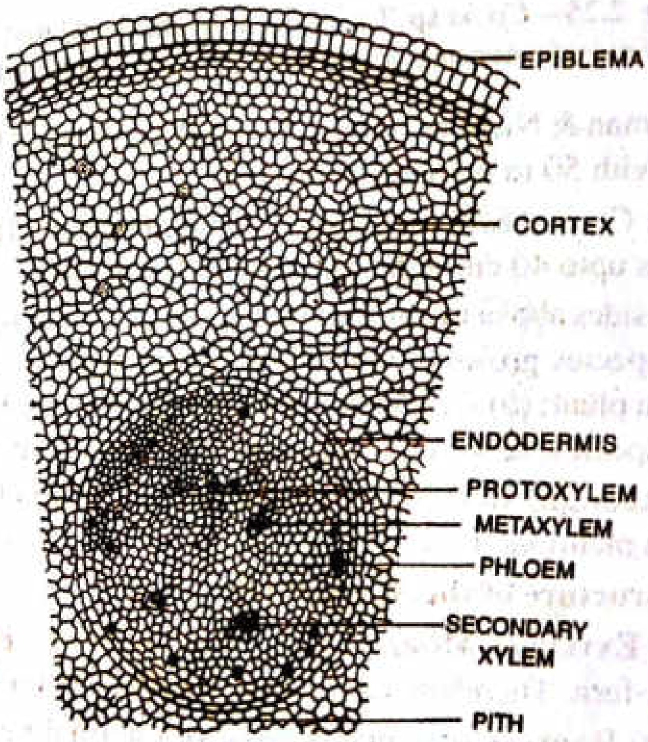


Fig. 2.26—*Cycas* sp. Root in transverse section showing formation of secondary xylem.

Secondary increase in thickness in stem takes place but generally little amount of secondary wood is formed. The mode of secondary growth is anomalous.

In the comparatively older stem, there may be the formation of such 10-12 alternate rings of wood and bast. In addition to the rings of bundles, there may be developed accessory bundles both in pith and cortex, resulting in the complicated arrangement of tissues in older stem. Periderm formation in the cortex also takes place.

The primary cambium ring is short-lived; it ceases its function very soon and a second i.e. a new cambium is developed outside in the cortex. This cambium gives rise to a second ring of secondary xylem and phloem towards inside and outside respectively. This process is repeated resulting in the formation of alternate rings of wood and bast. The secondary cortical bundles are concentric. The secondary xylem is monoxylic with some very broad rays.

Root—The root anatomy of *Cycas* is almost same as that of a dicotyledonous angiospermic plant (Fig. 2.26). In young stage, the root in transverse section shows an outermost thin layer called the epiblema, a multilayered parenchymatous cortex containing mucilage canals and a central vascular cylinder i.e. stele. Cortex is internally limited by a single-layered endodermis with Casparian strips. Pericycle is multilayered. Stele is tetrarch generally. Vascular bundles are radial; xylem is exarch. Secondary growth generally takes place early, but secondary wood formation is irregular. Coralloid roots have one or rarely more than one-layered thick algal zone in the cortex (Fig.2.24, D).

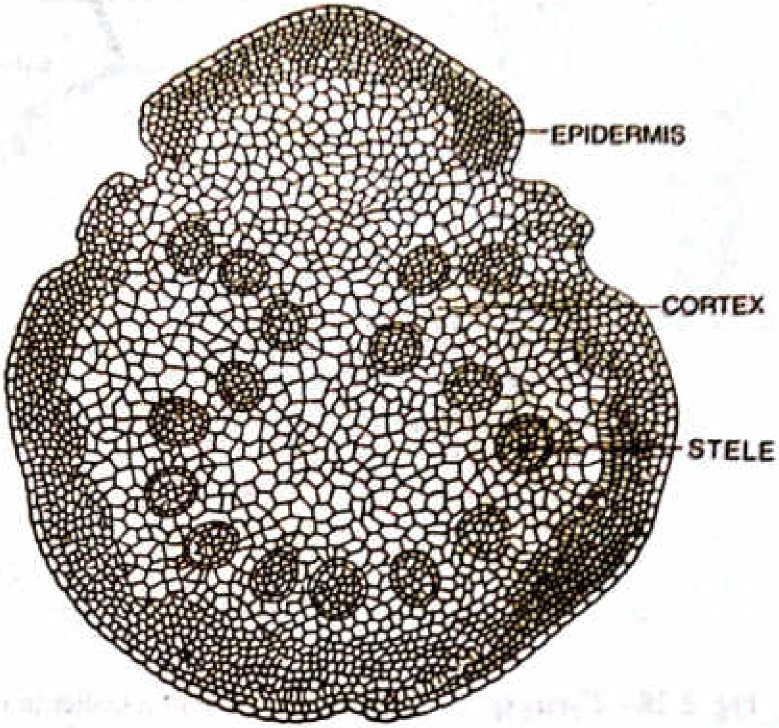


Fig. 2.27—*Cycas* sp. Petiole of a large compound leaf in transverse section.

Petiole—The petiole of the leaf in transverse section shows a large number of collateral bundles, often showing an inverted omega-shaped arrangement. Xylem is situated on the upper side and the phloem below (Fig.2.27).

Leaflet—The anatomy of a leaflet is interesting as it reveals xerophytic structure. The transverse section (Fig.2.28, B) of a leaflet shows two cuticularised epidermal layers, one is upper and the other lower. The upper epidermis forms a continuous layer composed of oval or tubular cells. Beneath the upper epidermis, one or two layers of sclerenchymatous cells forming hypodermis are present. Beneath the hypodermis a row of palisade tissue consisting of elongated columnar cells full of chloroplasts is present. Below the palisade tissue, scanty spongy parenchyma cells containing chloroplasts may or may not occur. Above the lower epidermis there lies spongy parenchyma tissue consisting of loosely arranged oval cells full of chloroplasts. Sunken stomata (haplocheilic) are present only in the lower epidermis. Lower epidermis may have palisade cells. Most important feature of a *Cycas* leaflet is the presence of *transfusion tissue* in between upper palisade and lower spongy layers. Transfusion tissue is arranged parallel to the epidermal layers. Transfusion tissue is composed of several layers of transversely elongated, thin-walled, colourless, short and wide cells; this tissue probably serves for lateral conduction.

There is only vascular bundle corresponding to the median vein (midrib) of the leaflet.

The vascular bundle is encircled by a sclerenchymatous sheath ... directed towards the upper surface; phloem lies towards the lower surface.

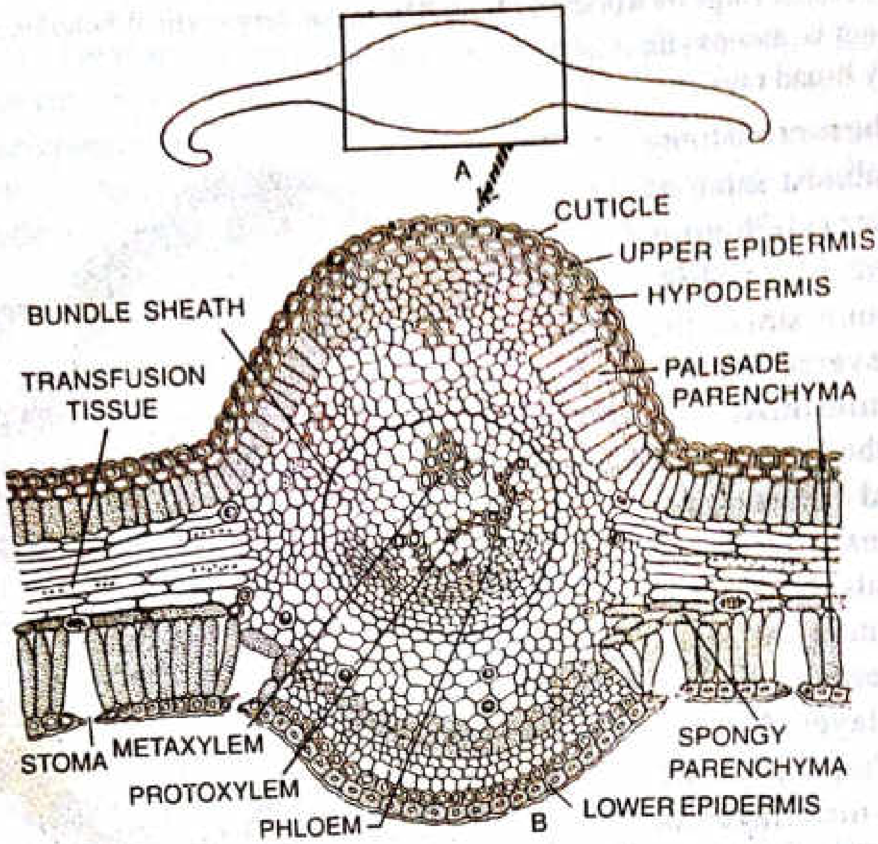


Fig. 2.28—*Cycas* sp. A—Outline structure of a leaflet in t.s. B—T.s. of a leaflet showing midrib and portions of lamina.

Xerophytic adaptations of *Cycas* leaf :

The xerophytic adaptive features of Cycas leaves are :

(*a*) Tough, leathery texture of the leaf (*b*) Strongly cutinized thick walled epidermal layer (*c*) Greatly thickened hypodermis on both upper and lower epidermis (*d*) Presence of sunken stomata on the lower epidermis (*e*) Presence of primary and secondary transfusion tissues.

3. Reproduction—

Vegetative reproduction takes place by the help of adventitious buds or bulbils, which commonly arise on the trunk.

Cycas plants are dioecious as the male and female flowers (reproductive structures) occur on different plants. Flowers are unisexual and simple; male flowers are represented by microsporophylls (stamens) and female by megasporophylls (carpels). Only the microsporophylls are arranged in clusters forming compact cones i.e. strobili. *The megasporophylls are loosely arranged and therefore no compact cone formation occurs.*

(*a*) *Male cone* i.e., *Male strobilus* :— Male cone is a compact structure, cylindrical or ovoid in form and woody in texture. Each cone is very large and upto 50 cm in length. The cone develops singly or a few at the growing apex of the stem but it becomes lateral in position by the growth of a lateral bud.

Each cone consists of a central axis on which numerous microsporophylls are compactly and spirally arranged in acropetal succession. Each microsporophyll measuring about 3-5 cm long and 12-13 mm wide, is flattened and wedge-shaped woody structure. The basal narrow part is sterile while the flat distal portion is fertile. Beyond the fertile part of the microsporophyll, there is an upper expanded sterile part, often called *apophysis* (Fig. 2.29,B). On the under surface (i.e., abaxial surface) of the fertile portion numerous microsporangia (pollen sacs or one-lobed anthers) are borne in groups, i.e. in sori. Each sorus contains 3-6 microsporangia. The development of microsporangia is of *eusporangiate* type. Microsporangia are intermingled with hairs. Each microsporangium is almost sessile, unilocular, oval, sac-like. structure. Microsporangium is provided with a multilayered jacket i.e. wall and a tapetum enclosing numerous microspore mother cells which by reduction division forms numerous microspores i.e. pollen grains. Microspores are simple in structure and without wings. On maturity each microsporangium dehisces by a longitudinal slit at its anterior end to release the microspores. When microspores are ready for shedding, the axis of the male cone elongates and microsporophylls get separated from one another.

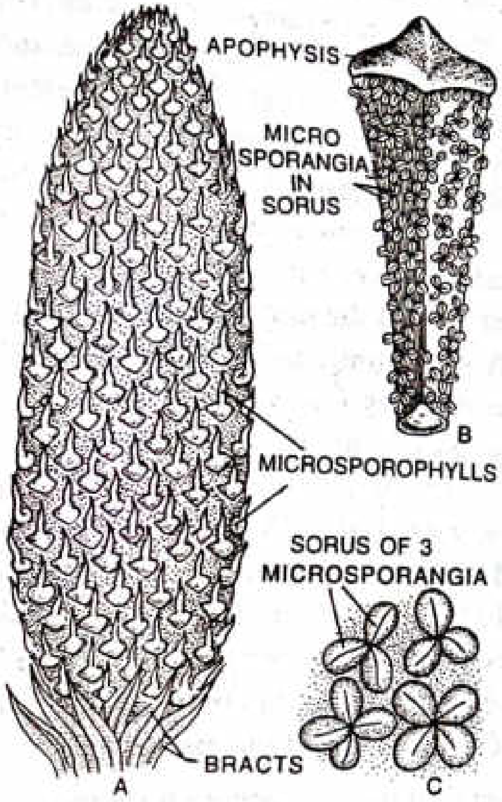


Fig. 2.29—*Cycas* sp. A—Male cone. B—A microsporophyll. C—Microsporangia arranged in sori.

(*b*) *Female cone*[1]— Female cones *are not true cones* because megasporophylls do not form any compact ovulate strobilus. Megasporophylls appear like a rosette structure; they are loosely arranged in acropetal succession (i.e. spirally) at the tip of the female plant, leaving the apical growing point free for further growth.

Each megasporophyll (Fig.2.30) is a leaf-like pinnate structure, 15 to 20 cm in length, brown in colour and is covered with hairs.

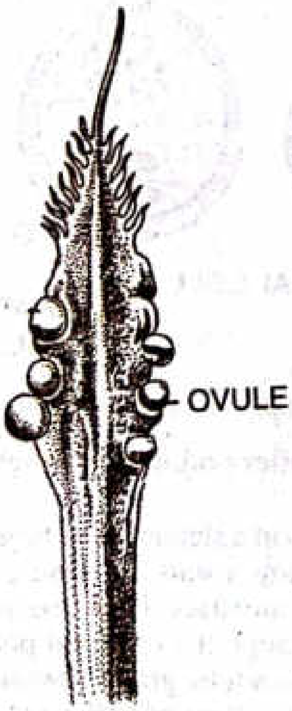


Fig. 2.30—*Cycas* sp. A megasporphyll.

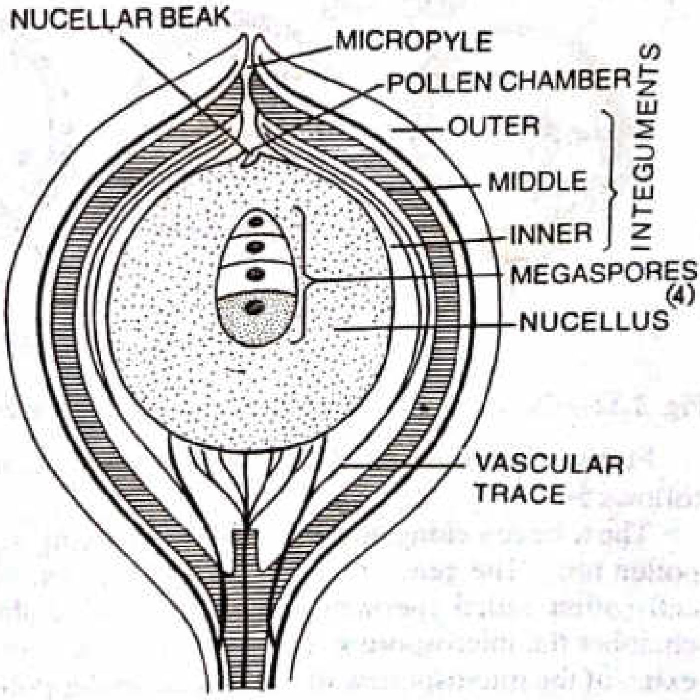


Fig. 2.31—*Cycas* sp. Longitudinal section of an ovule (enlarged)

[1] For the convenience of students and readers, this heading is retained.

The upper part of each megasporophyll is pinnately dissected into several segments which may be considered as leaflets of a pinna. Each megasporophyll bears 1-5 pairs of big lateral ovules (megasporangia) on the rachis.

Each megasporangium i.e. ovule (Fig.2.31) is orthotropous and becomes very large, measuring about 6 cm in length. A mature ovule consists of a massive nucellus surrounded by a thick integument. The integument is three-layered, e.g. (*a*) outer fleshy layer, (*b*) middle stony layer and (*c*) inner fleshy layer, often called *sarcotesta, sclerotesta* and *endotesta* respectively. The well-developed nucellus of the megasporangium remains fused with the integument except at the micropylar end where it forms a beak-like structure called *nucellar beak*. The pollen chamber lies within this nucellar beak. Vascular supply is noted both in the integuments and nucellus.

A single megaspore mother cell is differentiated within the nucellus tissue, which by meiosis gives rise to a linear-tetrad of four megaspores (Fig.2.31). Out of the four megaspores, only the lowermost one (i.e. the megaspore facing towards the chalazal end) is the functional megaspore, while the rest three facing towards the micropylar end degenerate (Fig. 2.33, A).

The Gametophytes

1. Male Gametophyte— Microspore is the first cell of the male gametophyte. Each microspore is boat-shaped and bilaterally symmetrical, and is provided with an outer thick exine and an inner thin intine. Starch grains are present within the pollen grains (Fig. 2.32, A). Germination of the microspore begins within the microsporangium.

At first the microspore nucleus cuts off a small persistent cell called *prothallial cell* at one end, leaving a larger antheridial cell at the other end. Antheridial cell next divides into a smaller generative cell in contact with the prothallial cell and a large tube cell (Fig.2.32, B-D). At this three-celled stage, pollination takes place.

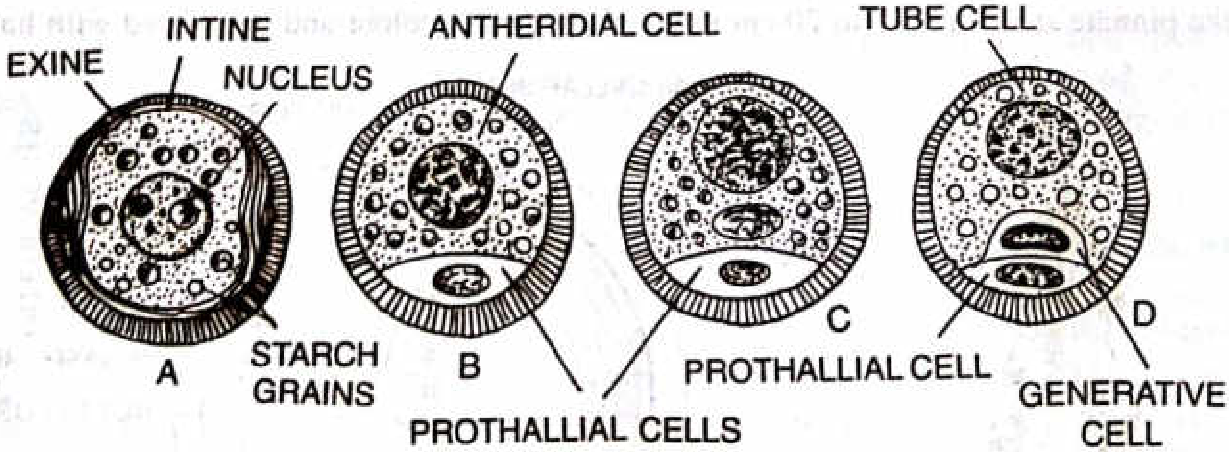


Fig. 2.32—*Cycas* sp. A—Microspore. B-D—Early stages in the development of male gametophyte.

Further development of the male gametophyte takes place after pollination which is as follows :—

The tube cell elongates (Fig.2.34, B) breaking the exine to form a slender long branched pollen tube. The generative cell becomes larger, and divides into a stalk cell and a body cell (often called spermatogenous cell). With absorption of moisture from the pollen chamber the microspore swells. The tube cell stretches out through the ruptured point of exine of the microspore wall forming a slender pollen tube. Pollen tube grows downwards through the nucellus digesting and breaking down the tissues of the floor of pollen chamber serving as a nutritive haustorium unlike pollen tube of angiosperms which serves as agent

[1] For the convenience of students and readers this heading is retained.

of fertilization. The stalk cell is functionless while the body cell by another division gives rise to two large, spirally coiled, multiciliate spermatozoids (Fig.2.34, C). Before the division of the body cell into two sperms, the body cell increases in size and two blepharoplasts make their appearance at the two poles of the nucleus (Fig.2.34, B). Body cell next divides to form two sperms, to each of which a blepharoplast gets attached, forming a large spirally arranged band on which numerous flagella arise.

2. **Female Gametophyte**—The female gametophyte is monosporic i.e., out of the four megaspores, only one becomes the functional megaspore (Fig.2.33, A).

Development of the female gametophyte takes place entirely within the

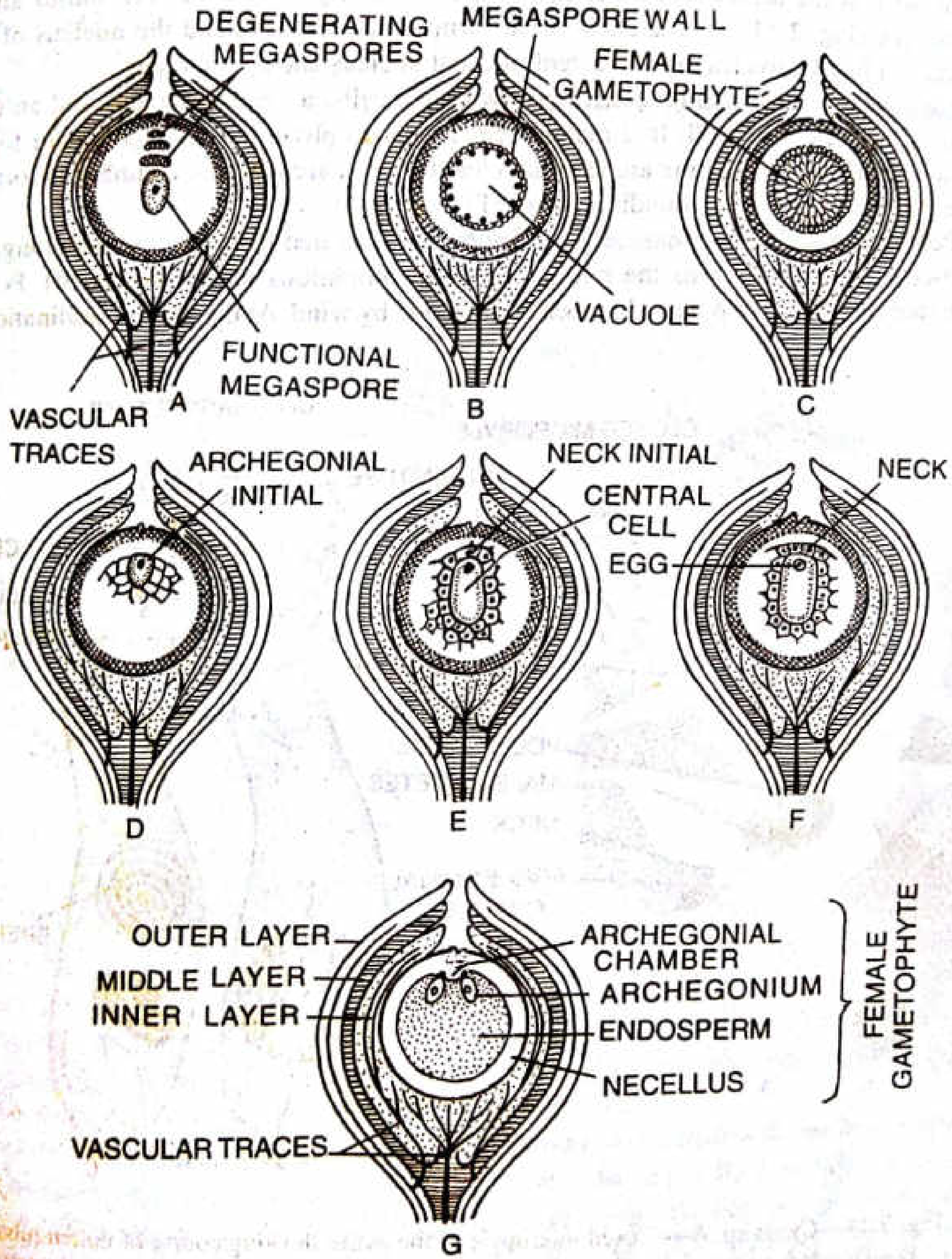


Fig. 2.33—*Cycas* sp. A—Functional megaspore stage. B-G—Different stages in the development of female gametophyte within the ovule.

megasporangium. The megaspore is surrounded by a tough membrane which later enlarges, its nucleus divides and redivides freely forming numerous free nuclei which are distributed in the cytoplasm of the megaspore; next a vacuole appears in the centre and thereby the free nuclei are distributed in the peripheral cytoplasm (Fig.2.33, B). Cell wall formation between the free nuclei takes place from the periphery extending towards the centre until the megaspore-vacuole is filled up by a cellular tissue. As a result, a solid mass of gametophytic tissue called *endosperm tissue* is formed, which is haploid. (Fig. 2.33, C).

The gametophytic tissue shows two regions viz., (a) region of larger cells near the chalaza and (b) the region of smaller cells towards the micropylar end. Towards the micropylar end, several (2-8) archegonia are developed from the cells of the gametophytic tissue. At first the archegonial initial divides transversely to form a *neck initial* and a *central cell* (Fig. 2.33, E). The neck initial forms two neck cells and the nucleus of the central cell finally divides to form a central canal nucleus and egg nucleus.

Each mature archegonium consists of two neck cells, a ventral nucleus and an egg. There is no neck canal cell. In a mature female gametophyte the archegonia are found below a depression called the archegonial chamber, this archegonial chamber is formed by the upgrowth of the surrounding tissue. (Fig. 2.33, G).

Pollination— Pollen grains i.e. microspores are liberated from the microsporangia at the 3-celled stage. In *Cycas* the pollination is anemophilous (wind pollinated). Pollen grains are carried to the pollen chamber of the ovule by wind. At the time of pollination, a

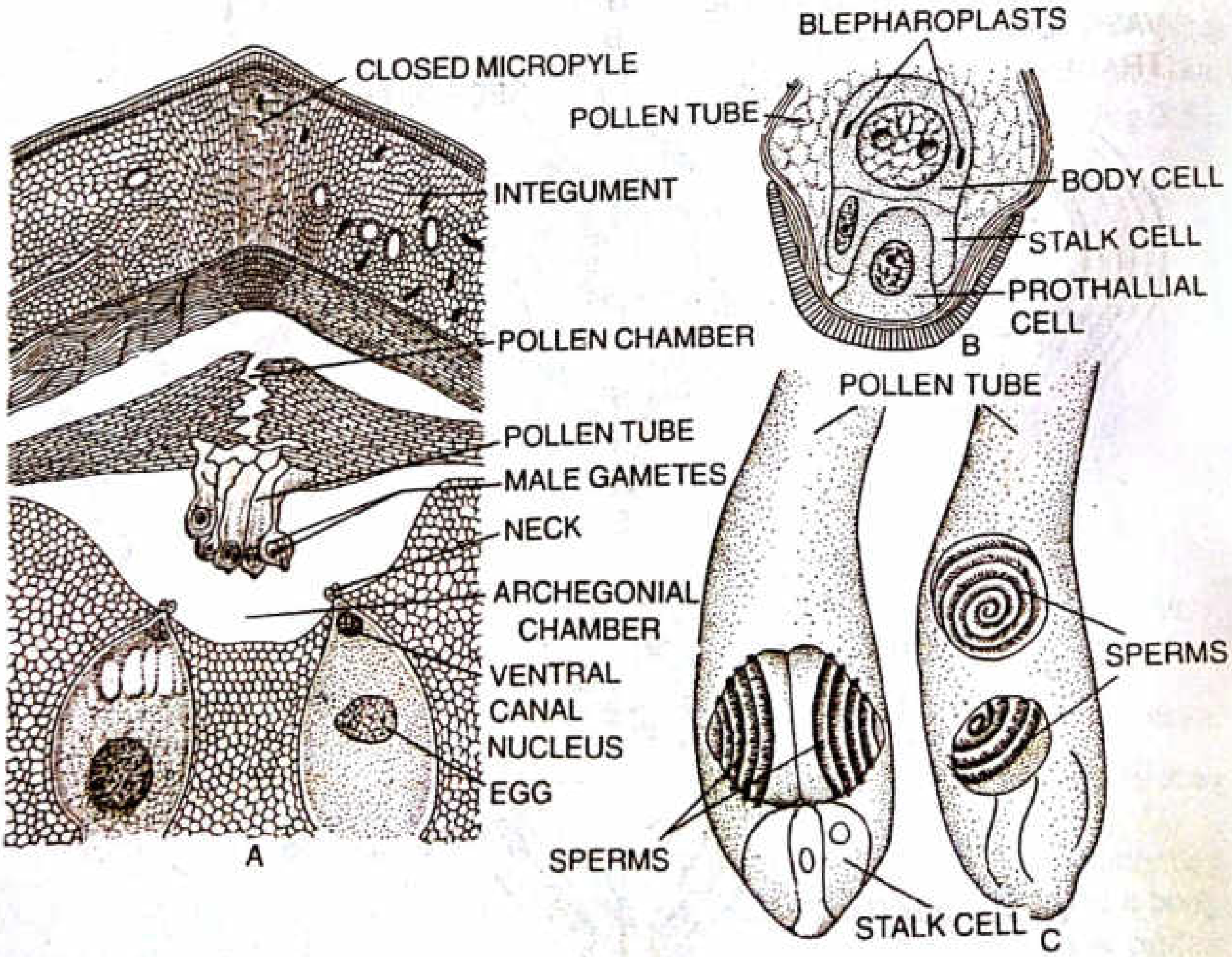


Fig. 2.34—*Cycas* sp. A—Closed micropyle of the ovule showing course of pollen tubes. B—Developing base of pollen tube showing prothallial cell, stalk cell and body cell with two blepharoplasts. C—Formation of sperms (left) and their separation from each other (right side) at the time of fertilization.

drop of mucilage called pollination drop, oozes out at the micropylar end of the ovule. The pollen grains which are floating in the air are caught in this drop. As the drop dries up, the pollen grains are drawn into the pollen chamber, then due to further drying up of the pollination drop, the pollen chamber is closed.

At the time of pollination, pollen grains are directly deposited on the nucellus of the female gametophyte.

Fertilization—Pollen tube grows towards the archegonium of the female gametophyte. There, the end of the pollen tube bursts and discharges its contents into the archegonial chamber. Then motile male cells i.e., sperms swim towards the neck of the archegonium and make their way down to the egg cell. One of the sperms fuses with the egg nucleus *i.e.* oosphere, as a result diploid oospore *i.e. zygote* (2*n*) develops.

Embryo and Seed— After fertilization the zygote enlarges and its nucleus divides by free nuclear divisions into numerous free nuclei (64 to 256 nuclei) which are distributed in the cytoplasm. Simultaneously a vacuole appears in the centre and thus all the nuclei get

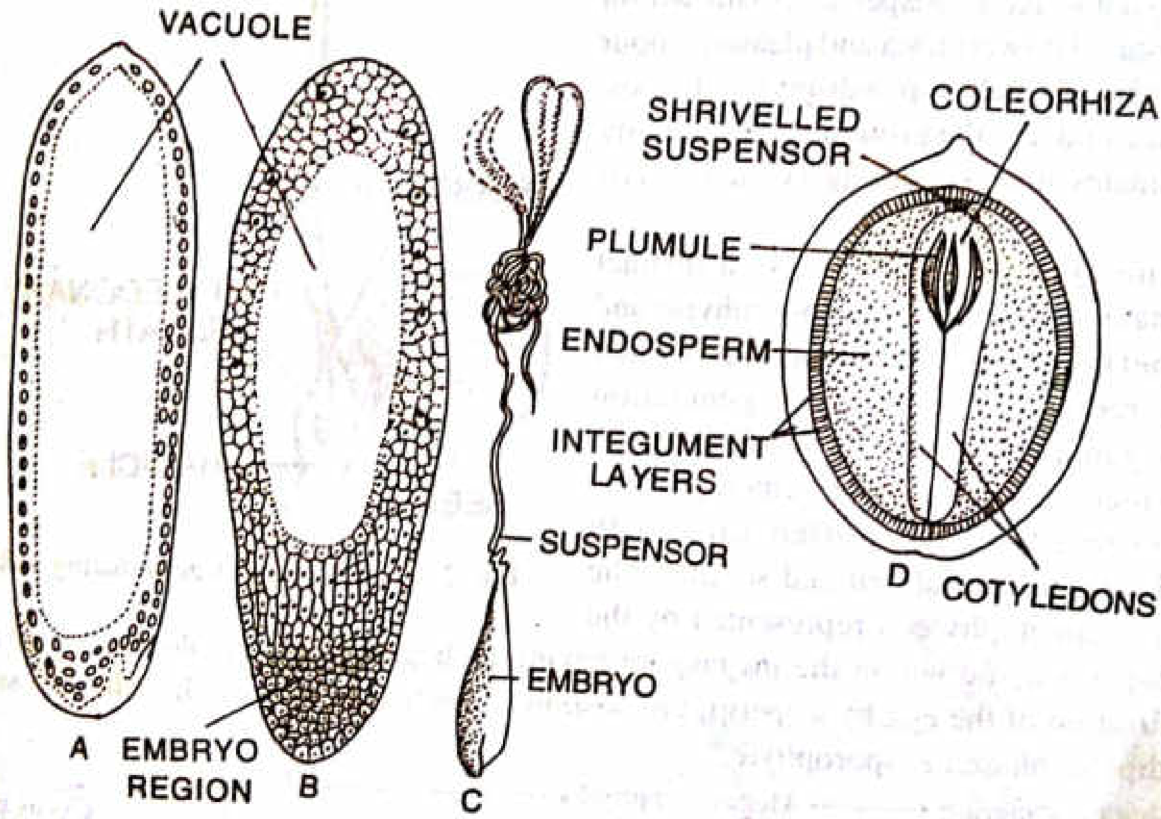


Fig. 2.35—*Cycas* sp. A—Early stage of proembryo. B—Later stage of proembryo showing the formation of embryo region. C—Embryo with long suspensor. D—L.s. of a seed.

pushed to the periphery (Fig.2.35, A). There are more nuclei at the lower i.e. chalazal end than at the micropylar end. In *Cycas*, the embryo is formed from a cellular part of this chalazal end, hence this structure is termed a *proembryo* but not an embryo. Now wall formation begins at the base of this proembryo (Fig. 2.35, B) which gradually extends upto the periphery until the entire structure becomes cellular.

The basal cells of the proembryo are smaller and more numerous with dense cytoplasm; from this basal region the embryo proper is formed. The upper cells of this embryonic region begin to elongate vigorously forming a long, spirally coiled structure called *suspensor.* The embryo with two prominent cytyledons develops from the tip cells through a series of divisions.

Due to the development of a long suspensor, the embryo is pushed out of the zygote-membrane deep into the endosperm from which the embryo derives nutrition. The embryo within the ovule gradually enlarge greatly. The nucellus is completely used up and the thick integument becomes differentiated into a three-layered testa (seed coat) viz. outer fleshy, middle stony and inner fleshy layers.

At the basal end of the embryo a cylindrical stem apex develops; the two cotyledons in the form of minute outgrowths arise laterally. Root in the form of radicle develops quite late. The mature embryo is straight and the hypocotyl is very short.

The mature seed of *Cycas* is fleshy, red or orange-brown in colour. The seed is enclosed by a thick seed coat (Fig.2.35, D) formed from the integument. The straight embryo and the endosperm remain within the testa. The sweet testa and pleasant odour attract birds which help in dispersal of seeds. The seed falls to the ground and eventually germinates into a seedling (young *Cycas* plant).

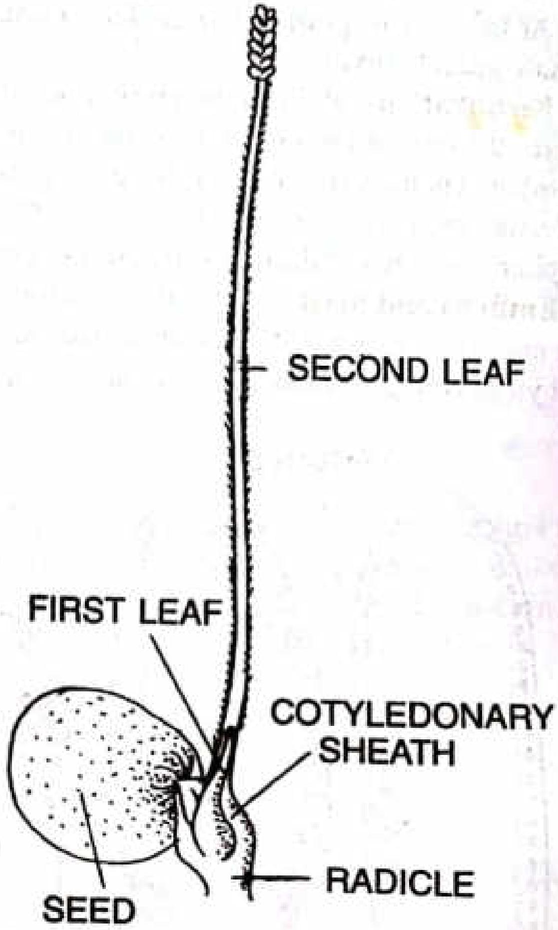
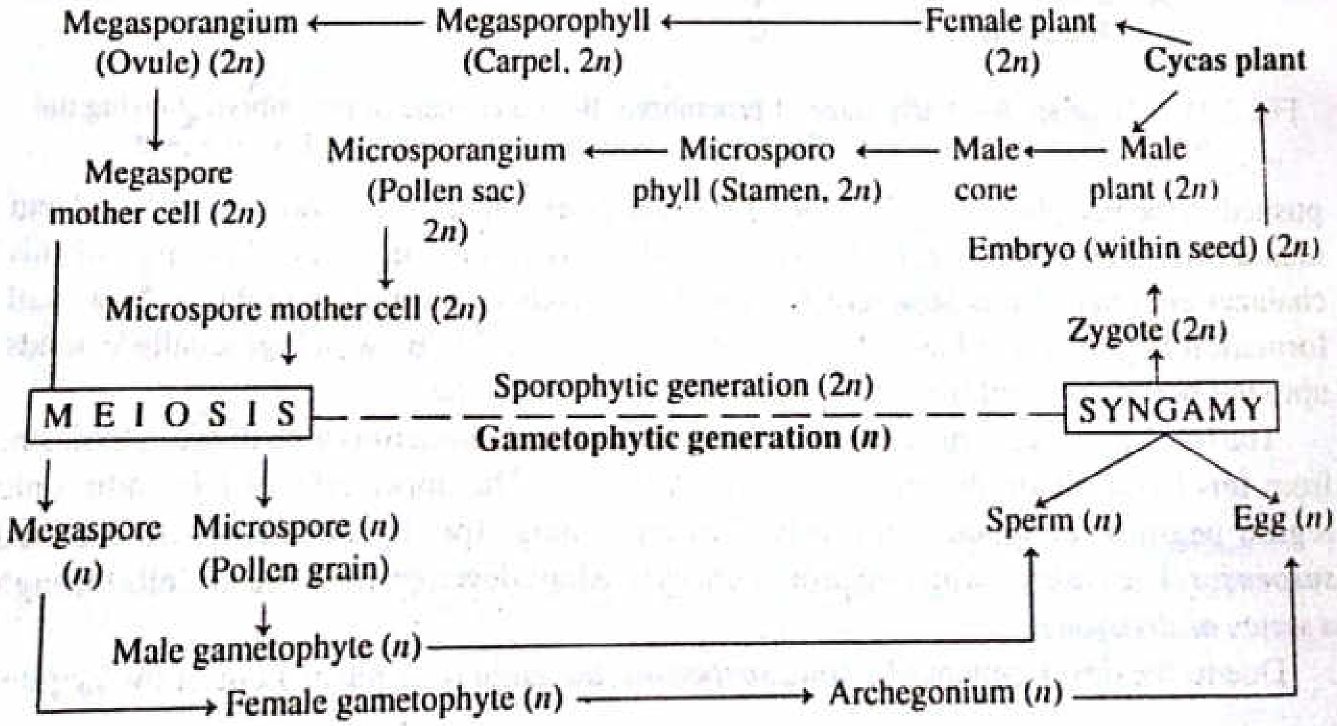


Fig. 2.36—*Cycas* sp. A germinating seed.

Life cycle — *Cycas* shows a distinct alternation of diploid i.e. sporophytic and haploid i.e. gametophyte generations. Plant body represents sporophytic generation while gametophytes (male and female) are very much reduced. Male gametophyte is represented by the pollen tube with persistent prothallial cell and sperms. The female gametophyte is represented by the endosperm tissue within the megaspore having archegonia, the female sex organ. After fertilization of the egg by a sperm, the oospore (zygote) results, which is the first step in the diploid phase *i.e.* sporophyte.



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Fern characters of *Cycas* :—

The *Cycas* resembles fern in the following characters :

(*a*) Circinate vernation of leaflets of pinnate compound leaves.

(*b*) Motile sperms with a large number of cilia. The sperms can swim comfortably in case of ferns, in *Cycas* they swim only within the pollen tube.

(*c*) On the abaxial (lower) surface of the microsporophylls, microsporangia are borne in sori like tree fern.

(*d*) Presence of archegonia in the female gametophyte.

(*e*) Stem shows the presence of persistent leaf traces.

(*f*) Stems with prominent pith and cortex, and primary wood consisting of tracheids and xylem parenchyma.

(*g*) Absence of true vessels and companion cells.

(*h*) Ovules borne laterally on leaf-like megasporophylls.

Economic importance :— Leaves of *Cycas* are used in making mats. The young succulent shoot and seeds are cooked as vegetables by the people of Assam, Malaya, Indonesia etc. In Japan a type of starch is prepared from the trunk of the *Cycas* plant, this starch is sold in the market as 'Sago'. Sago can also be obtained from the seeds which contain about 31% starch. In Malabar, the flour of seeds, known as 'Indum podi' is used in the preparation of cakes and porridges. Besides, various species of *Cycas* are planted in gardens for their ornamental value.

Order Cycadeoidales (= BENNETTITALES)

The Cycadeoidales became exinct by the end of the Cretaceous, leaving fossil record. Cycadeoids had fronds almost similar to those of Cycads. But in the Cycadeoids, syndetocheilic stomata were present which is not found in Cycads. The stem of Cycadeoids and Cycads are also alike. The stems of some plants are slender and highly branched, while others have trunk-like stems with few branches which are clothed with spirally arranged persistent leaf bases.

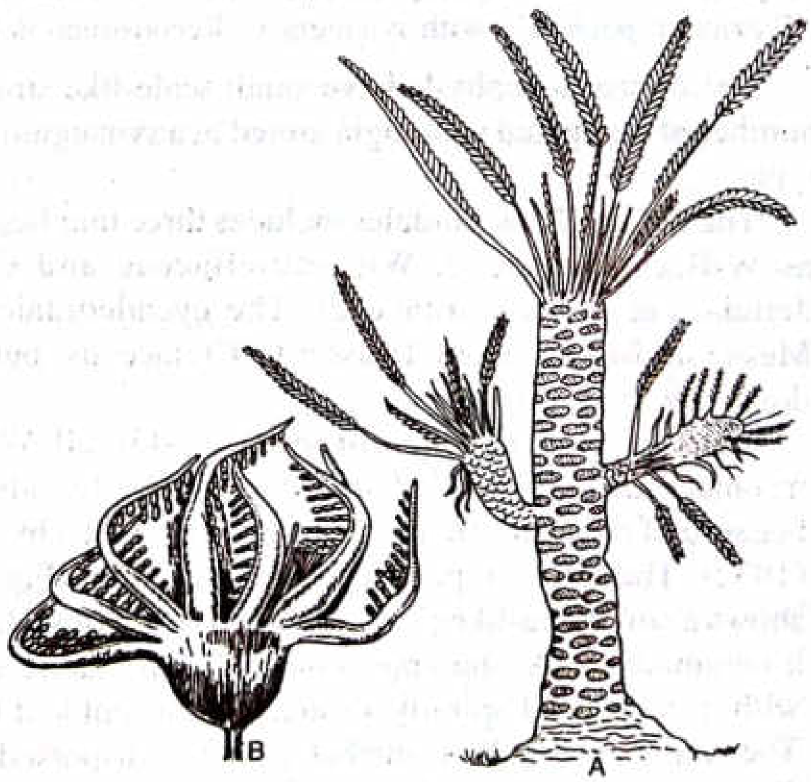

Fig. 2.37—A. Diagrammatic representation of *Williamsonia sewardiana* Sahni B. Male flower of *Williamsonia spectabilis*.

Where the anatomy of the stem is known, there is large pith surrounded by a cylinder of well developed wood — the secondary xylem, usually is compact. Some have scalariform pitting on the walls by secondary tracheids, others have multiseriate bordered pits on their radial walls. The primary xylem is endarch. Leaf traces, when observed, arise from the primary xylem and pass directly through the secondary xylem into the cortex where they branch into several traces that