Leaf: In *Cycas,* two distinct types of leaves are present, namely the foliage leaves and scale leaves

In all the species, the foliage leaves are large, pinnately compound (paripinnate) and are arranged in a close spiral succession, alternating with each other. The young leaves show **circinate vernation**.

The leaves of *Cycas circinata, C. revoluta* and *. media* are covered with hair, in young stage Each leaf, measuring 0.6-1.8 metres long, has around 80-100 leafet pairs. Some of the lower pinnae (leaflets) may become tough and leathery in texture, exhibiting their **xerophytic nature.**

The pinnae are linear, narrow and have margins curved downwards and inwards The leaflets inrolled in bud condition and are closely set on the rachis of the leaf). The leaf on maturity has a stout and woody rachis which is biconvex in outline. The pytxis is cirainate type. Each leaflet has **a single midrib.** The new leaves are formed every year or every second year. In the interval, usually the succession maintained by production of numerous brown scale leaves which gradually become woody

. Bulbils are found in the crevises of these scales These scale leaves are far more numerous than the foliage leaves, persistent and protective in function. Scale leaves cover the shoot apex and also protect the young foliage leaves

Scale leaves:

These are small, dry, brown,
triangular structures with a thick covering of brown hairs or rameta.
These leaves alternate with green foliage leaves. These leaves prote
apex and reproductive stru

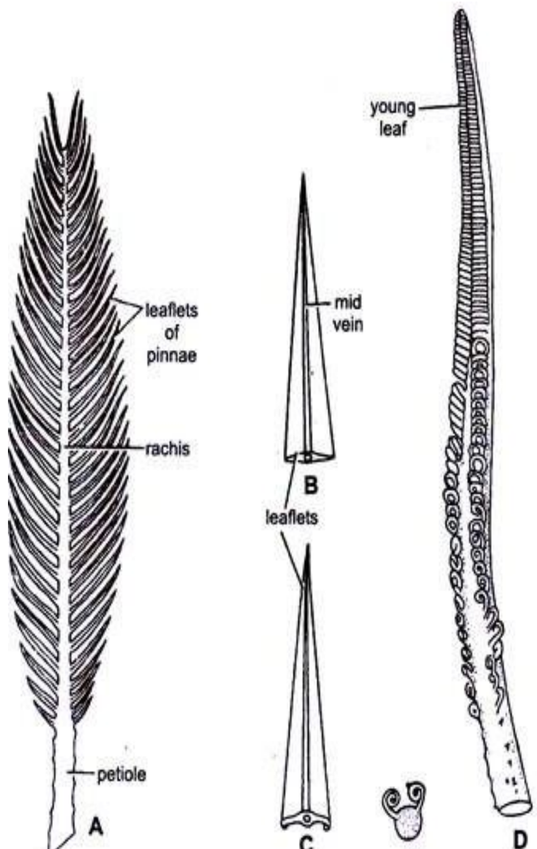


Fig. 6. (A-E) *Cycas*. (A) External features of a normal foliage leaf; B) Flat leaflet of *C. rumphii*, (C) Revolute leaflet of *C. revoluta*, (D, E) Young foliage leaf showing circinate vernation of leaflets.

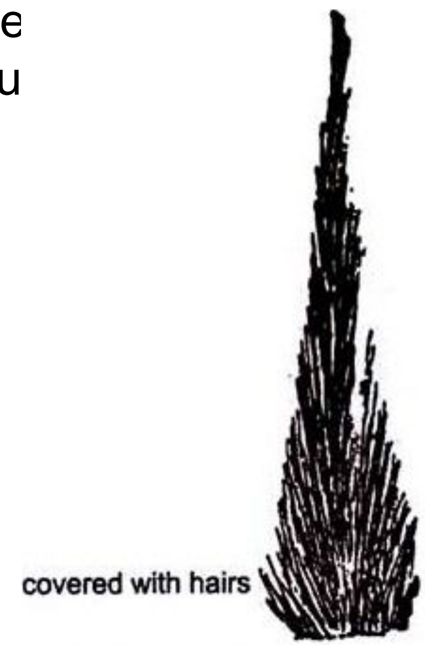


Fig. 3. *Cycas*. A scale leaf

Primitive Characters of Cycas

- Presence of circinate vernation in young leaves.
- Xylem lacks vessel and phloem lacks companion cells.
- Archegonium is present.
- Sperms are **flagellate** and **motile**.
- Microsporangia form **sori**.
- Megasporophyll is covered by brown hair called rementa

Xerophytic Adaptation of the Cycas leaf

- Tough and **leathery** texture.
- Strongly cutinized thick walled epidermis.
- Highly thickened hypodermis on both sides of the leaflet.
- **Sunken stomata** restricted only to the lower surface.
- Unbranched midrib.
- Occurrence of primary and secondary transfusion tissue.

The leaf of *Cycas*, as mentioned above is large and compound The leaflets are tough, thick and leathery. A vertical section of the leaflet in the region of midrib shows the following tissues :

1. Cuticle. The upper surface of the leaf is covered with a thick cuticle. It serves to check excessive transpiration.

2. Epidermis. It forms the outermost cellular layer on both the surfaces of the leaflet. It is protective in function and consists of a single layer of thick-walled parenchymatous cells. The upper epidermis is continuous but the lower is punctured here and there with pits or stomata. The stomata, which are confined only to the lower epidermis, are sunken and lodged at the bottom of these pits with overarching rims fig 9.9.

3. Hypodermis. It forms a single layer of thickened cells on both sides immediately below the epidermis. The cells of the upper hypodermis are hignly thickened. It checks excessive transpiration and serves as a heat screen preventing over heating.

4. Mesophyll Tissue. It lies on both sides, between the upper and lower epidermis. It is differentiated into a well developed **palisade layer** on its upper side immediately below the upper hypodermis. It functions as the main photosynthetic tissue. Its elongated coloumnar cells contain abundant chloroplasts. The lower part of the mesophyll which lies within the lower hypodermis consists of loosely arranged parenchymatous cells with scanty inter-cellular spaces between them. The cells contain chloroplasts. It is called the **spongy mesophyll** It functions, as aerating and supplementary assimilatory tissue.

- **. Vascular bundle:**
- A single large vascular bundle is present in the mid rib region of the leaflet. It is surrounded by a single layer of sclerenchymatous cells, known as bundle sheath. The vascular bundle is conjoint, collateral, open and diploxylic. Xylem is present towards the dorsal surface and phloem is present towards the ventral surface.
- Xylem and phloem are separated by a non-functional strip of cambium. Centrifugal xylem is represented by two small groups on either side of the protoxylem. The remaining space of the vascular bundle is filled with thin walled parenchymatous cells.

Transfusion tissue:

Groups of tracheidal cells, separated by some parenchymatous cells, or directly in **contact with the centripetal xylem**, the bundle sheath are present in the leaflet. It is called primary transfusion tissue. The cells of this tissue are short and wide with are reticulate or bordered pitted walls.

A zone is present on either side of the midrib between the palisade and spongy layers. It is three layered and is composed of elongated colourless cells. These cells run paralled to the leaf surface from the midrib to the margin. This zone is called accessory transfusion tissue or secondary transfusion tissue or hydrostereom or radial parenchyma.

On either side of the leaflet it is connected with the primary transfusion conducting channel otissue present around centripetal xylem of the vascular bundle. Primary and secondary transfusion tissue help in the lateral conduction of water. The presence of transfusion tissue is to compensate for the unbranched condition of the midrib and it probably serves as a later f water.

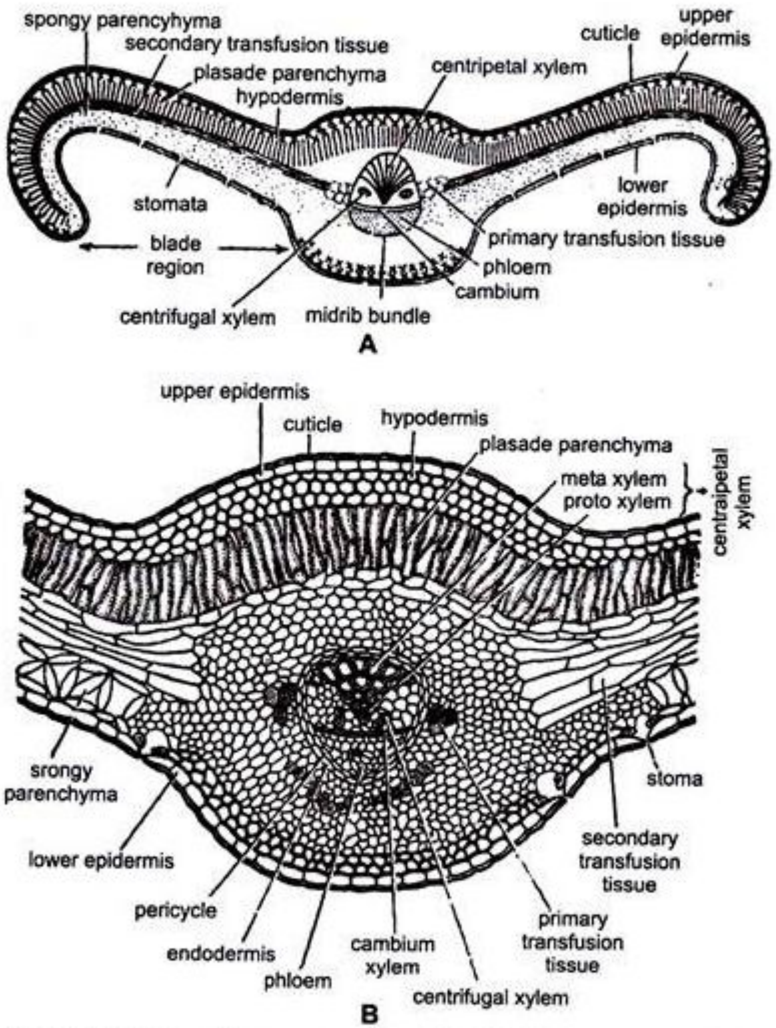
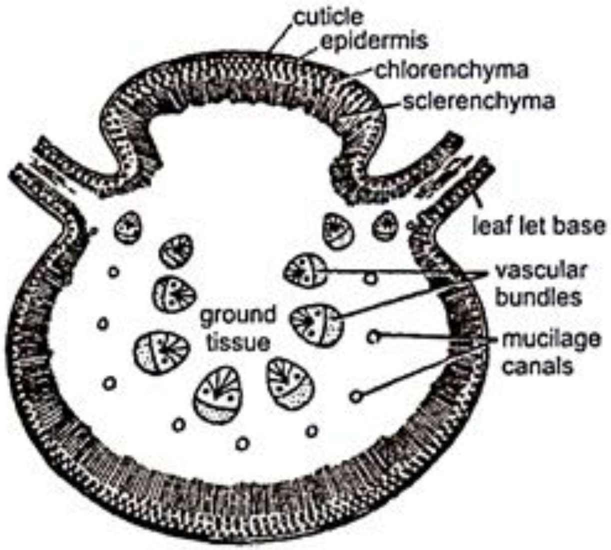
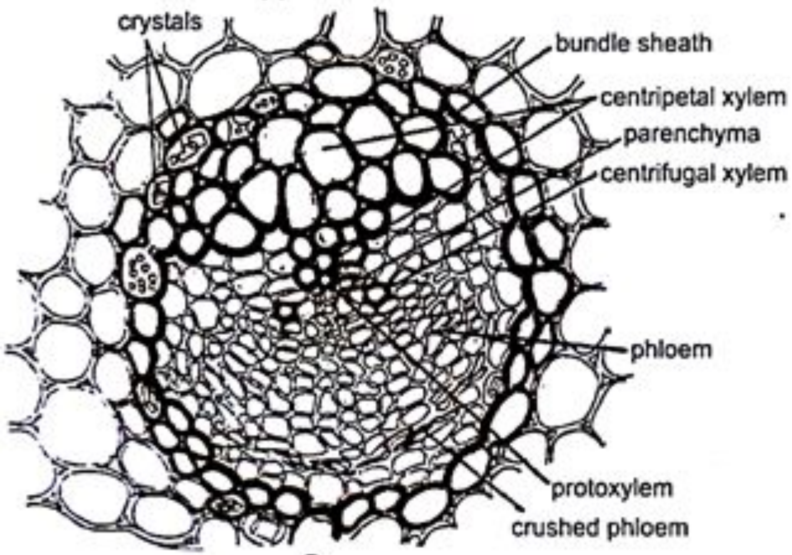


Fig. 16 (A–C). *Cycas.* **Transverse section of leaflet (A) diagrammatic; (B) A**

- **5. Rachis:**
- A transverse section of the rachis is somewhat rhomboidal in outline, but a little higher up it is shield shaped. Its internal structure can be differentiated into epidermis, cortex and Vascular bundles.
- **a. Epidermis:**
- It is the outermost covering. It is made up of compactly arranged thick walled cells. It is single layered, covered with thick cuticle and has stomata.
- **Hypodermis:**
- Epidermis is followed by hypodermis. It is differentiated into outer 2-3- layers of chlorenchyma (Chlorophyll containing thin walled cells) and inner 4-6 layers of sclerenchyma (thick walled, lignified cells; Fig. 14A, B).
- **Ground tissue:**
- Below the sclerenchyma is present a large tissue made up of thin walled parenchymatous cells. It is called ground tissue. In this region are present many mucilaginous canals and vascular bundles.

- b. **Vascular bundles:**
- Vascular bundles are arranged in the shape of inverted Greek letter 'omega' [Ω; Fig. 14 A], Each vascular bundle is conjoint, collateral, endarch, open and diploxylic i. e., consists of centripetal and centrifugal Xylem and is surrounded by bundle sheath.
- Xylem is present towards the inner side and consists of tracheids and xylem parenchyma. Vessels are absent. Phloem is present towards the outer side of the vascular bundle. It consists of sieve tubes and phloem parenchyma. Companion cells are absent, Cambium is present in between the xylem and phloem.
- In rachis the vascular bundles are endarch at the base (centrifugal xylem is well developed, protoxylem faces towards the centre showing endarch condition, centripetal xylem is not developed), mesarch in the middle (centripetal and centrifugal xylem are present showing diploxylic condition) and exarch at the apex (centripetal xylem is well developed, triangular and exarch, centrifugal xylem is much reduced and in the form of two patches lying one on each side of the protoxylem elements of centripetal xylem) due to twisting of the rachis (Fig. 15 A-C).





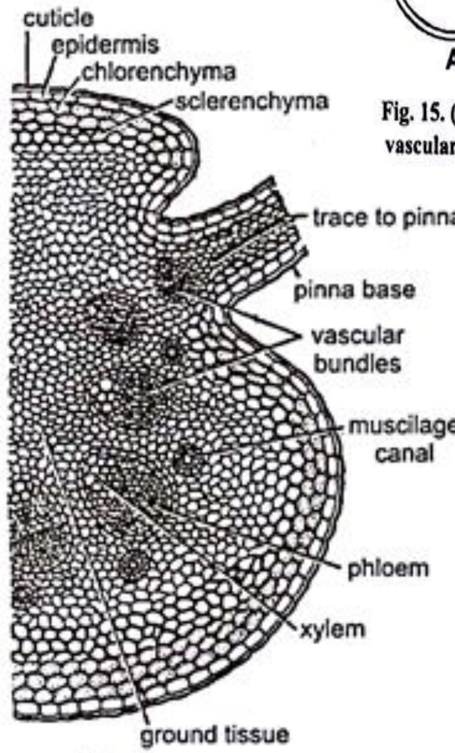


Fig.14 (A–C) ***Cyas Rachis.*** **(A) T.S. rachis (diagrammatic); B. T. S rachis (a part cellular); C. A vascular bundle of *Cycas revoluta* with both centripetal and centrifugal Xylem.**

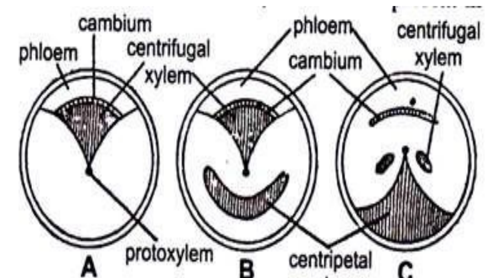


Fig. 15. (A–C) ***Cyas.*** **Diagrammatic representation of vascular bundles at different levels. (A) At the base; (B) In the middle; (C) At the apex.**

Coralloid root:

- . Develops from the normal roots
- Apogeotropic
- . Dichotomously branched and appears like coral
- Gets infected with algae,
- . Cortex is wider in comparison
- . Due to presence of the algal zone in the cortex, it is differentiated into outer cortex and inner cortex
- . Main function is nitrogen fixation

secondary growth of stem

The normal intrastelar secondary growth is observed in early stages due to the bifacial activity of cambium.

This primary cambium ring is short-lived, thus remains functional for a short time.

The secondary xylem thus produced centripetally shows tracheids with 4-5 rows of bordered pits and scaiariform thickenings and one row of thin-walled cells in between (

The three types of vascular rays are produced :

(i) uniseriate rays, (ii) multiseriate rays, and (iii) foliar multiseriate rays. The phloem is well-developed which may exceed the volume of xylem. The sieve elements contain numerous sieve areas on their radial wall.

The companion cells are absent, instead some phioem parenchyma termed **albuminous cells** — are formed, closely associated with sieve cells. The stem does not produce any annual ring.

A peculiarity of *Cycas* stem is that the young stem is **monoxylic** becomes **polyxylic** at maturity due to the formation **of accessory cambium rings in the cortex The second cambium ring forms the secondary** xylem towards the inner side and secondary phloen towards the outer side. The second cambium ring remains functional for a short time and thereafter its activity ceases. In a similar fashion, successive cambium rings initiate in the cortical region. The first two vascular rings are thicker and. the subsequent rings are narrower than these two rings, gradually diminishing towards the periphery. Usually 3-4 rings of wood are produced in *Cycas* .

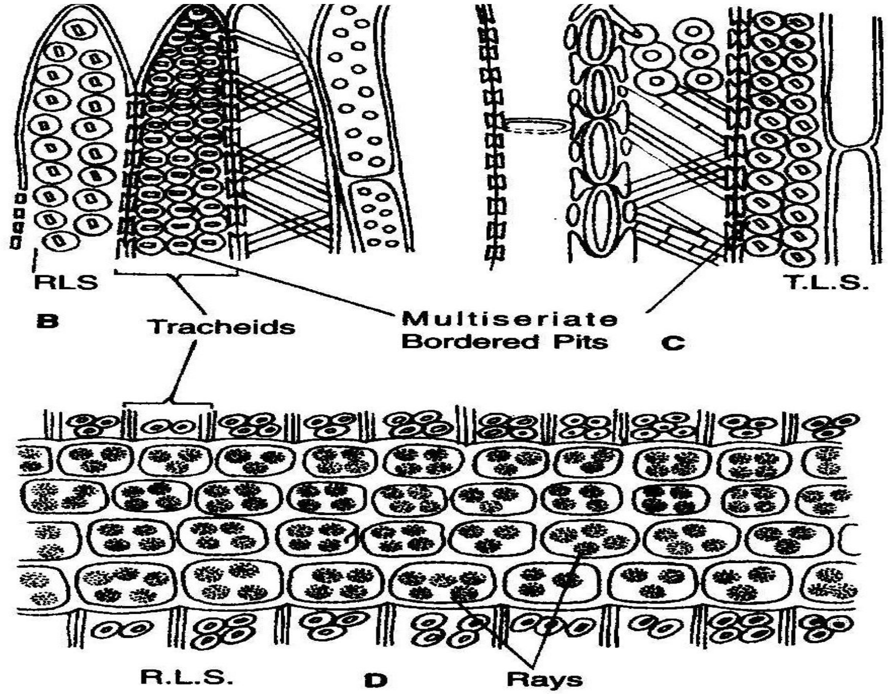


Fig. 9.7 (B-D) L.S. Cycas old stem showing bordered pits.

The anatomy of the stem of *Cycas* presents certain interesting features. They are, the large pith and cortex traversed by numerous mucilage canals, thousands of girdle bundles in the cortex, scanty wood region, short lived primary cambium with well developed broad medullary rays, and several rings of secondary vascular tissue formed by successive rings of cambium formed independently in the cortex or pericycle regions **The wood formed is known as *manoxylic***

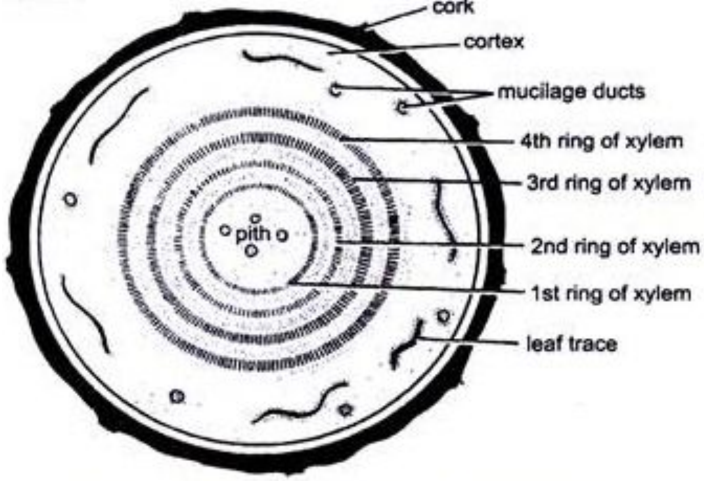


Fig. 13. *Cycas*. T. S of old stem (diagrammatic)

- **The extrastelar secondary growth** has also been observed in the stem of *Cycas* which forms the **periderm.** With the formation of the secondary vascular tissues, the outer tissues of the stem are subjected to tangential pressure. Eventually they rupture, but before this take places a special protective tissue the corky periderm is formed outside the cortex by the activity of a special cambium which arises in the outer cortex immediately below the epidermis. This cambium is a secondary meristem. It is called the **phellogen** or **cork cambium.** By repeated division of the phellogen cells a tissue is formed to the exterior. It is the **cork.** It forms the stem surface in the lower part of the very old stem replacing the outer armour of leaf bases.

- **Reproduction of Cycas**
  All living species of *Cycas* are dioecious as the male and the female structures occur on separate plants
- The **microsporophylls** are aggregated into large compact male strobili or cones.
- The **megasporophylls** are loosely arranged. They do not form a true cone

Figure 5. *Cycas nayagarhensis* R. Singh, P. Radha and J.S. Khuraijam sp.nov.
A. Robust habit, **B-C**. Male cone. **D**. Magnified portion of male showing sterile apex.
E. Microsporophyll with forked sterile apex. **F-I**. Microsporophylls (F. upper surface,
G. lower surface, H. lateral view, and I. lower view showing lateral spines). Scale bar: 1 cm

. **Male Strobilus** The male are borne singly and terminally on the main stem The apical growth of the stem is continued by the formation of the axillary bud at the base of the cone. It becomes the new stem apex. As it grows the male cone is displaced to one side

the male plant of *Cycas* is a **sympodium**

The male cone is the largest among the plant kingdom. It is woody in texture, compact, long, spindle-shaped and blunt-ended object , 40—50 cm in length It consists of a central woody axis bearing microsporophylls (stamens) in a close and compact spiral. They develop in acropetalous succession

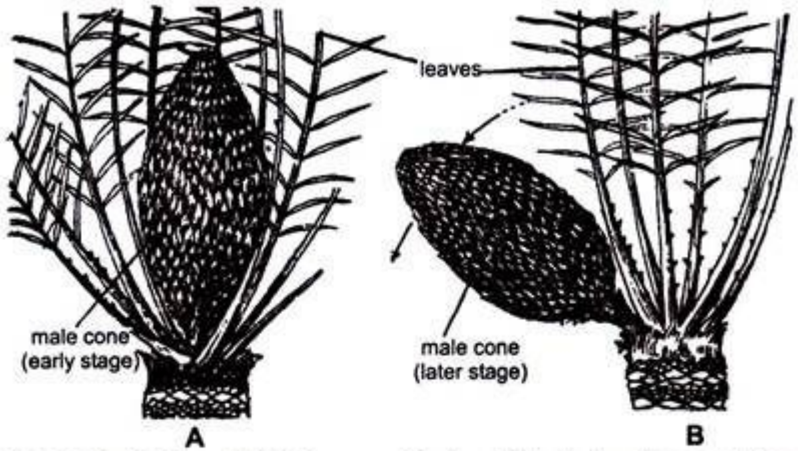
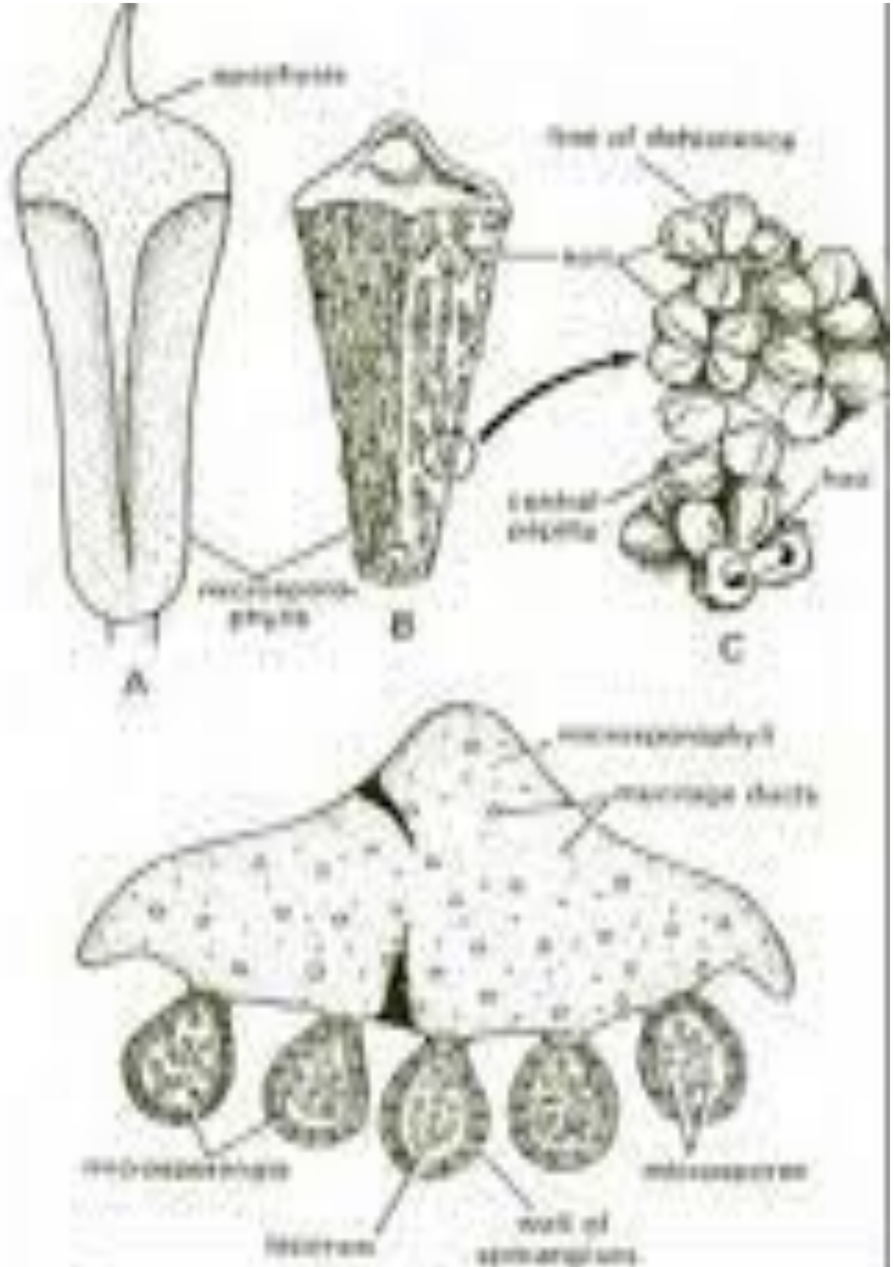


Fig. 18 (A, B). *Cycas*. (A) Male cone at the top, (B) Apical meristem pushing the cone on one site.

- Male plant of cycas produces every year a single male cone) at its apex. In the formation of the male cone the apical meristem is used up, and therefore, the growth of the steam checked for some time some time but later an apical meristem is formed at the base of the cone, which pushes that on one side so that the growth of the stem is resumed again.
- Such growth of the stem is called sympodial

- **Microsporophyll**
  A single microsporophyll is nearly triangular flattened woody structure it differentiated into a proximal wedge shaped fertile part & a distal sterile part known as apophysis . It bears several hundred microsporangia (700 in C circnales,1100 in C.media) (pollen sacs) on its lower or abaxial surface (The microsporangia are arranged in clusters of three to Six.
  Microsporangia -microsporangia are born in groups of 3-5 forming **sori .** The microsporangia in a sorus arise from a common central papilla or protuberance Each mature microsporangium is an oval body attached by a short stalk at one end It produces a large number of **microspores** (pollen grains). The large output of microspores is commensurate with **the primitive nature of *Cycas*.**

Fig. Microsporophyll
A. Entire, cone B. longitudinal section



- **Development of Microsporangium:**
- The development of microsporangium is of eusporangiate type i. e., develops from a group of cells called microsporangial initials (Fig. 21A). These cells are hypodermal in origin and divide by periclinal walls into upper primary wall cells and lower primary sporogenous cells.
- Primary wall cells divide and redivide to form three to six layered wall below the epidermis. Simultaneously primary sporogenous cells also divide and redivide irregularly to form a mass of cells known as sporogenous tissue.
- At this time from the peripheral cells of the sporogenous tissue or the inner most wall layer differentiates into a single celled, nourishing layer known as tapetum (Fig. 21C, D). The outermost layer of the sporangial wall forms the epidermis or exothecium.
- The rest of the sporogenous tissue increases in size and functions as spore mother cells. These are the ultimate cells of sporophytic phase. Each spore mother divides cell by reduction division to form four haploid microspores (Fig. 21D-F).

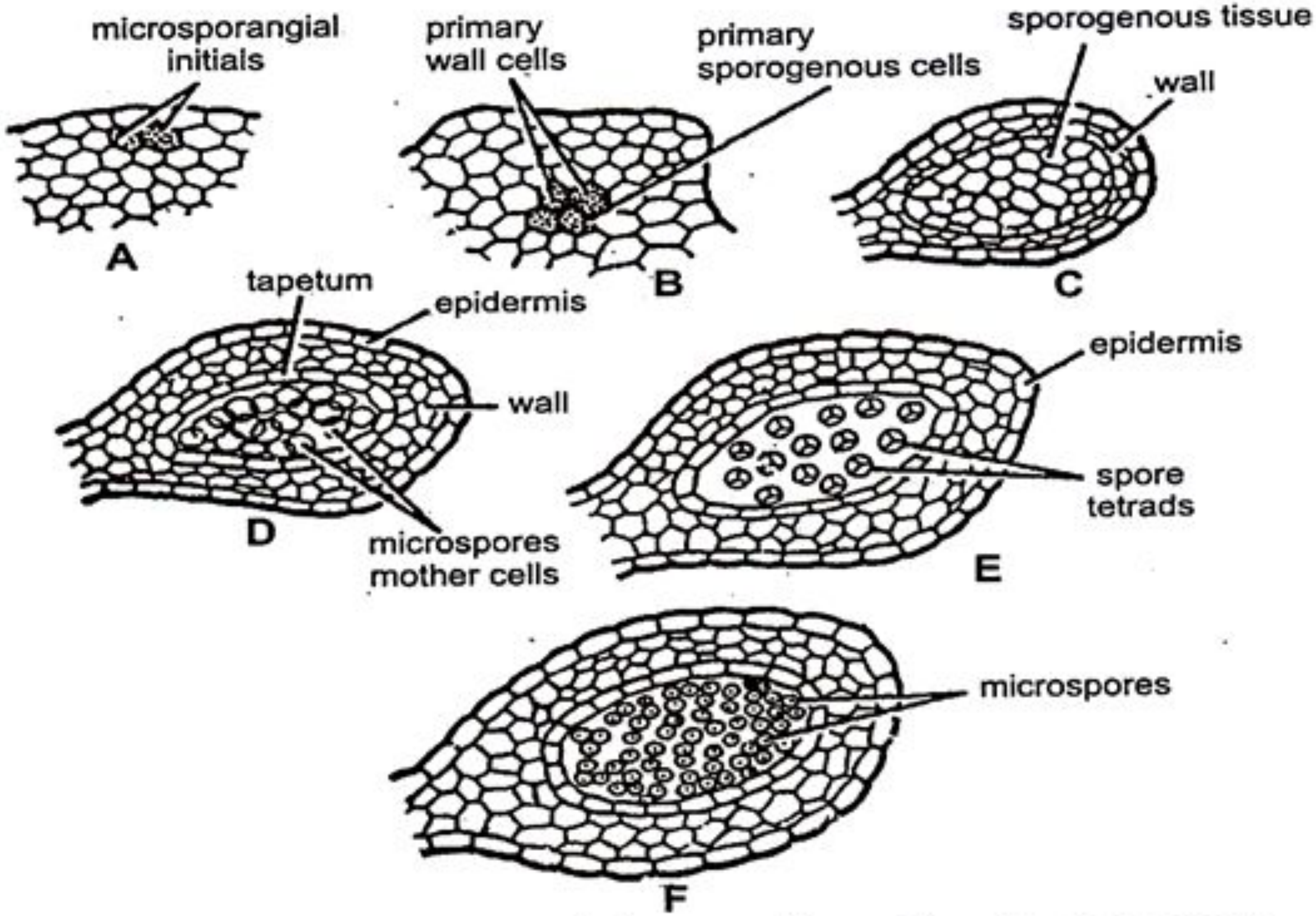
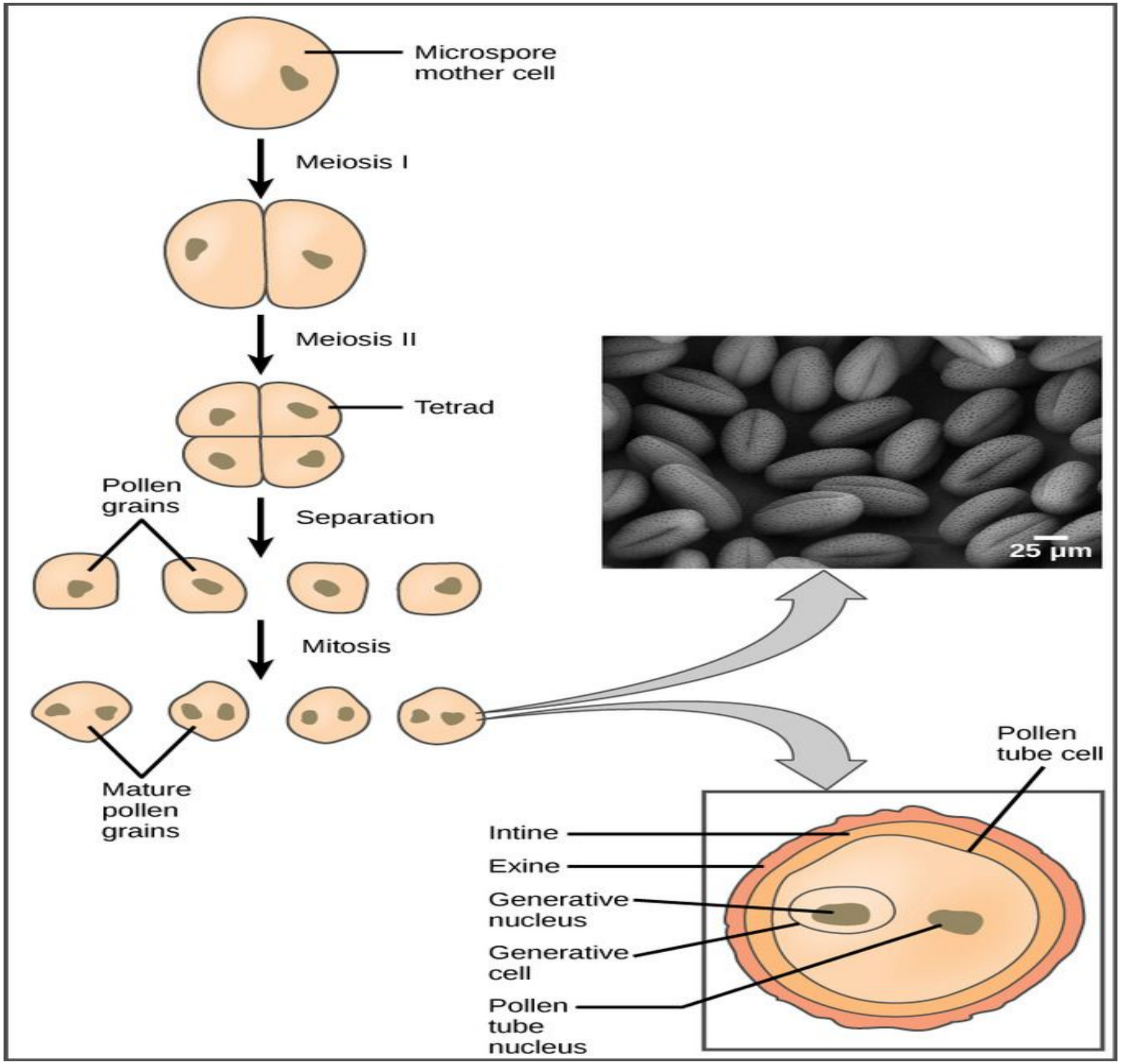


Fig. 21 (A–F) *Cycas* : Development of microsporangium and formation of microspores


Microspore
mother cell
Meiosis I
Meiosis II
Tetrad
Pollen
grains
Separation
Mitosis
Mature
pollen
grains
25 µm
Pollen
tube cell
Intine
Exine
Generative
nucleus
Generative
cell
Pollen
tube
nucleus

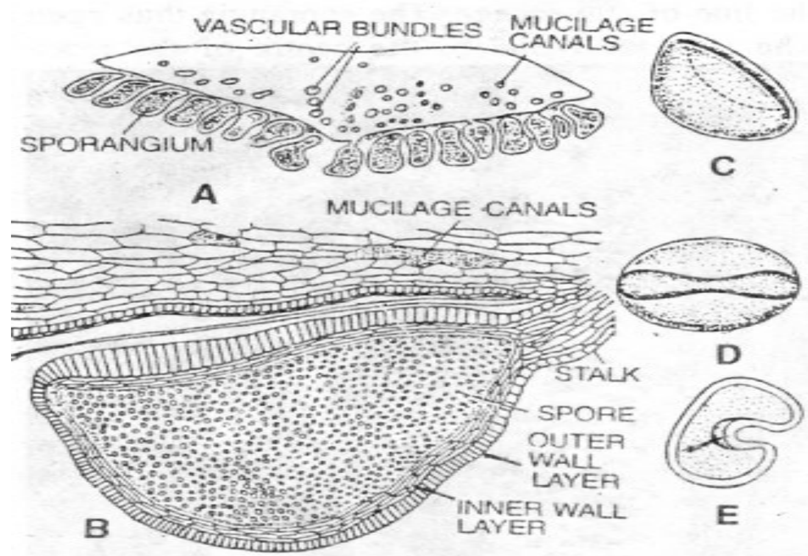


Fig. 9.18 A. T. S. microsporophyll showing sporangia on its abaxial side. B. Enlarged view of portion of A showing highly magnified and longitudinally cut mature microsporangium. C—E. Mature microspores after being shed (After woodehouse).

- **Dehiscence of the Sporangium**
- It is longitudinal. When the microspores reach maturity, the male cone elongates considerably and rapidly. The scales separate from one another so that the sporangia are exposed. The sporangia lose water and with the loss of water from its cells the exothecium shrinks. As a result the wall splits open on the abaxial side along the elongated cells marking
- **Each** spore is thickened at the opposite **poles. The** spore wall is differentiated into **two** coats. The outer is called the **exine** and the inner **intine**

- **Female Reproductive Organs:**
- Female reproductive organs are megasporophylls. Each female plant every year produces numerous megasporophylls in acropetal succession above each crown of foliage and scaly leaves. There is no female cone formation. The number of the megasporophylls is much more than the number of the foliage leaves on the stem.
- During the formation of the megasporophylls the apical meristem is not used up like that of male cone and therefore, the growth of the stem continues, and thus in female plant growth is monopodial.
- **Structure of Megasporophyll:**
- Each megasporophyll (carpel) is regarded as a modified leaf. It is about 12.7 cm to 25.4 cm long and can be divided into 3 parts: upper leafy portion, middle ovule bearing portion and lower stalk. Ovules are formed on the lateral side of the middle portion. The upper portion is pinnate and each pinna is tapering to a point.
- Two lateral rows of ovules are present on the lateral side of the middle portion. In Cycas there is a great variation regarding the pinnate character of megasporophyll and the number of ovules per sporophyll as a result of which in various species of Cycas gradual reduction in megasporophylls can be traced.
- The megasporophylls of C. revolula (Fig. 22A) are pinnate whereas those of C. circinalis C. rumphii and C. beddomei (fig 22 B-D) are ovate lanceolate structures. In C. pectinata and C. siamensis they are orbicular or rhomboidal structures (Fig. 22B, F).
- The laminar portion is well developed in C. revoluta, C.pectinata and C. siamensis but reduced in C. circinalis, C. beddomei and C. rumphii (fig. 22). The margin of lamina is serrate or dentate in C.circinalis, C.beddomei and C. rumphii. The number of ovules differ in different species of Cycas. It is 1-6. pairs in C.revoluta, C. Circinalis and only one pair in C. norambyana. Megasporophylls are covered by yellow or brown hairs.

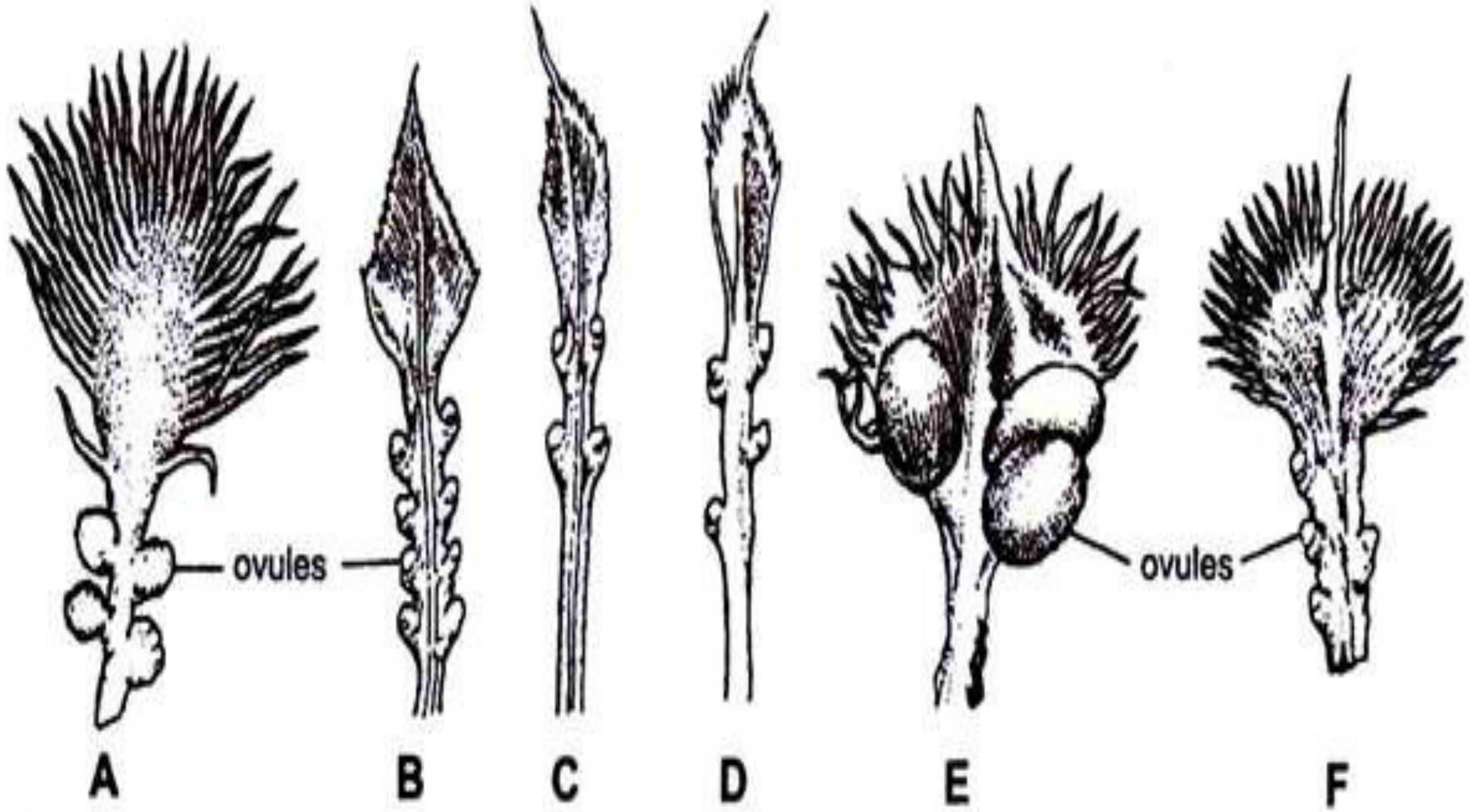


Fig. 22 (A – F). Megasporophylls of *Cycas* (A) C. *revoluta*; (B) *C. circinalis;* (C) *C. rumphii,* (D) *C. beddomei.* (E) *C. pectinata;* (F) *C. siamensis.*

- **Structure of ovule (megasporangium):**
- The ovules are sessile and are borne laterally on the stalk. The ovules of Cycas are largest in plant kingdom (7 cm long in C. thoursaii, 6 cm long x 4 cm diameter in C. circinalis) and can be seen by naked eye. The ovule is green when young and is covered by hairs. At maturity its colour changes to orange and hair also fall off.
- The ovules are orthotropus (short and straight) and unitegmic (with one integument).
- **The integument is very thick and consists of three distinct layers:**
- (i) Outer, green or orange fleshy layer called outer sarcotesta
- (ii) Middle, yellow stony layer called sclerotesta and
- (iii) Inner fleshy layer or inner sarcotesta.
- The parenchymatous tissue inside the integument is called nucellus. The integument encloses all the nuclellus except at one point. This point or opening is called micropyle. Just below the micropyle, the cells of the nucellus form the nucellar beak.
- Some of the cells of the nucellar beak dissolves and forms a cavity like structure called pollen chamber. Just below the pollen chamber is present an archegonial chamber. Micropyle leads into the pollen chamber. Just below the floor of the archegonial chamber 3-6 archegonia are present towards the micropylar end.
- The ovule is supplied by three vasular traces (Fig. 23). The central vascular trace enters the chalazal end of the nucellus. The inner and outer vascular traces divide into two each, one branch supplies the outer fleshy layer and the inner fleshy layer. Thus, the outer and inner fleshy layers receive the vascular supply but the middle stony layers get no vascular supply (Fig. 23).

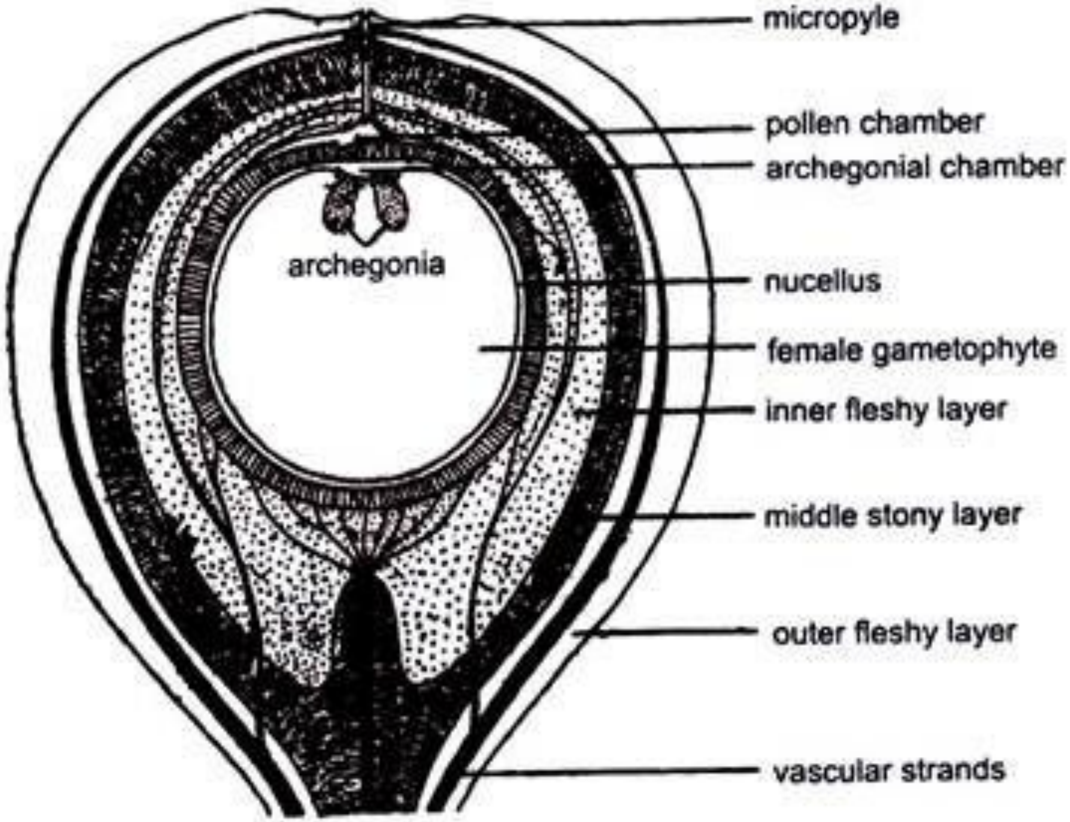


Fig. 23. ***Cycas.*** **Longitudinal section of ovule showing its internal structure.**

- **Development of Ovule:**
- When megasporophyll is young; in its middle portion 4-6 ovules arise as a hypodermal mass of meristematic cells on the lateral side. These meristematic cells divide and redivide to form a mass of parenchymatous cells known as nucellus.
- Soon the neighbouring cells at the base are also activated and they grew upwards forming the integument which surrounds the nucellus on all sides except at the top where a small opening is left which is known as micropyle In the beginning the nucellus and integument are free but afterwards due to intercalary growth both of them fuse except in the region of micropyle.

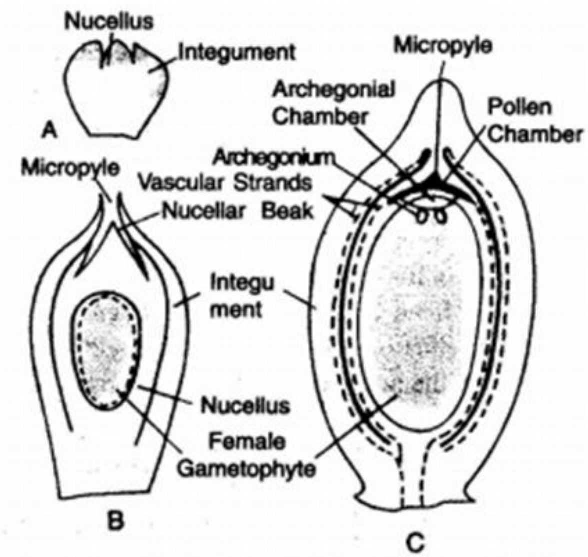


Fig. 9.24. (A-C) Stages in the development of the ovule *Cycas*

Development of the female gametophyte

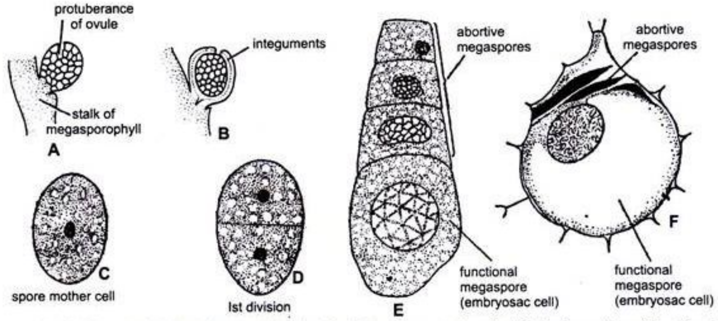
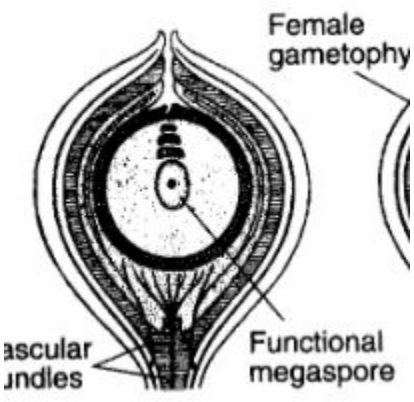


Fig. 24. Cycas (A–F). Development of ovule; (A, B) Development of ovule; (C–F). Formation of functional megaspore.

The development of the female gametophyte of *Cycas* is **monosporic**
as only one of the megaspores takes part in its development.
The process may be considered under the following heads :
(i) Formation of megaspores; *(ii)* **development of female prothalli or gametophytes; and *(iii)* the development of archegonia**



Formation of megaspores

1. All the cells of the nucellus are at first alike. By the time it is fully developed an **archesporial cell** becomes distinguishable deep down within the tissue by its large size and dense contents
2. . It functions as the **megaspore mother cell** and it undergoes two divisions to form a linear tetrad, of four cells
3. . the lowest cell develops further.and upper three cells of the row abort. It is the first cell of the female gametophyte.
4. This functional megaspore develops into the female gametophy which surrounded by spongy nucellus tissue..

2) Development of Female Gametophyte:

The functional megospore (also called embryo sac cell or first cell of female gametophyte) is haploid and it starts its development in situ i. e., within the nucellus (Fig 26 A). It absorbs the surrounding cells of the nucellus and enlarges considerably. Its nucleus divides by free nuclear divisions and as a result a large number of nuclei are formed. A vacuole develops in the centre.

It pushes the free nuclei and cytoplasm of the megaspores towards its periphery. (Fig. 26 B) Now the wall formation starts from periphery to the centre (centripetal wall formation). It results in the formation of a cellular tissue called endosperm or female prothallus or megagametophyte (Fig. 26 C). The endosperm in Cycas is a haploid tissue formed before the fertilization. Endosperm is nutritive in function. Simultaneously, a tiny space develops on the upper side of the ovule between nucellus and the female gametophyte due to degeneration of certain nucellar cells. This is called archegonial chamber2)2)

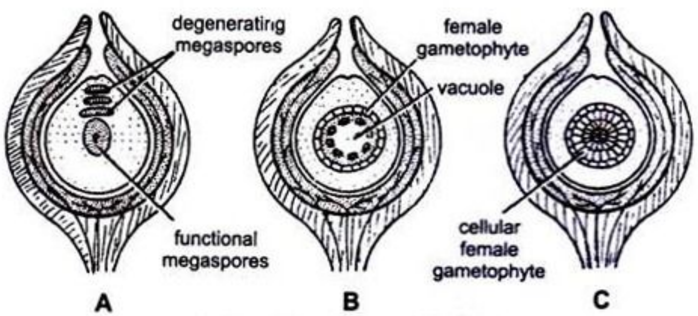


Fig. 26 (A – C). *Cycas*. Development of female gametophyte

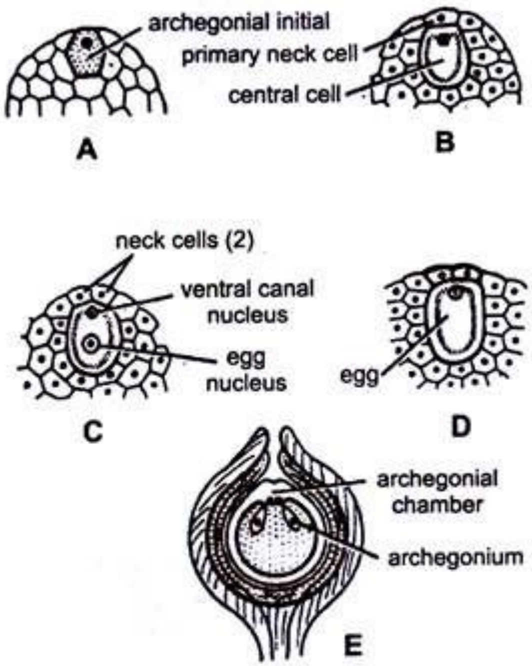


Fig. 27 (A – E) *Cycas*. Development of archegonium

- **3)Development of archegonium:**
- The archegonia develop from the gemetophytic cells lining the archegonial chamber towards the micropylar end. Any cell enlarges in size and functions as archegonial initial (Fig. 27A). It divides transversely into an upper primary neck cell and a lower central cell (Fig. 27 B). The primary neck cell divides by a longitudinal division to form two neck cells. These cells form the neck of the archegonium.
- The central cell enlarges its size and its nucleus divides to form a ventral canal nucleus and an egg nucleus (Fig.27 C). No wall is formed between the venter canal nucleus and egg nucleus. Therefore, there is no neck canal cell. Later on venter canal nucleus disorganises. The egg of the Cycas is largest in all living plants measuring 5 mm in diameter.

- **4)Structure of Archegonium:**
- The mature archegonium consists of a neck of two neck cells. The archegonial neck opens in the archegonial chamber. There is no neck canal cell. There is no venter either. The egg and the venter canal

  nucleus remain surrounded by the cells of the endosperm. These cells act as archegonium jacket.