ARULMIGU PALANI ANDAVAR ARTS COLLEGE FOR WOMEN, PALANI

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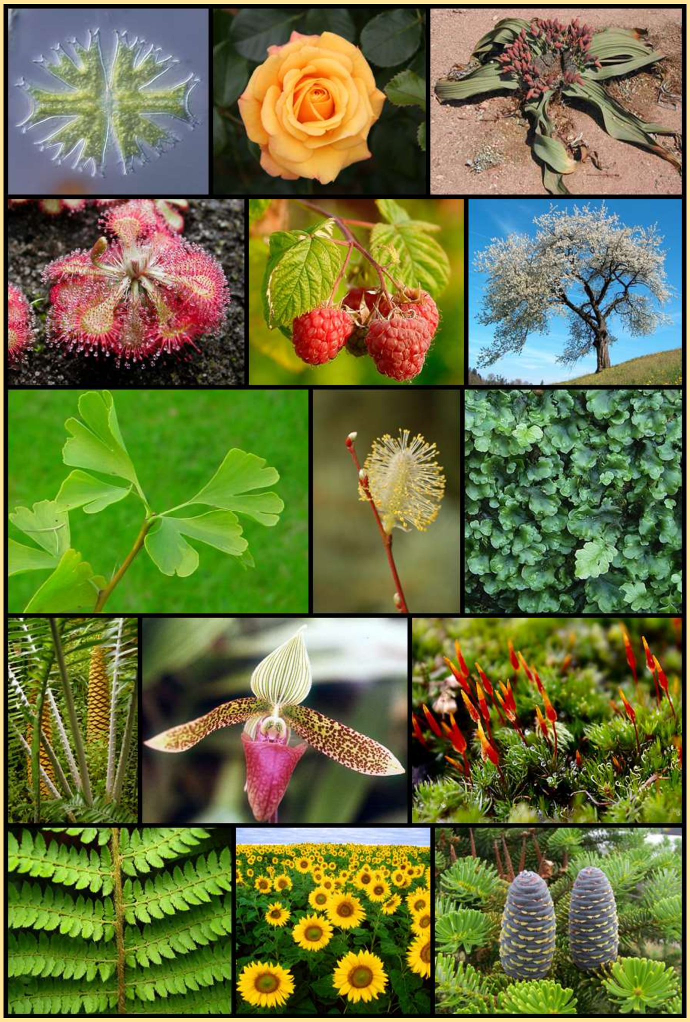


LEARNING RESOURCES

PLANT DIVERSITY

ALGAE

GENERAL CHARACTERS OF ALGAE:

Pacific general characteristics of algae are common to plants as well as animals.Algal cells are eukaryotic. For instance, algae can photosynthesize like plants, and they possess specialized structures and cell- organelles, like centrioles and flagella, found only in animals. The algal cell walls consist of mannans, cellulose and Galatians. Listed below are some of the general characteristics of algae.

- Algae are photosynthetic organisms
- Algae can be either unicellular or multicellular organisms
- Algae lack a well-defined body, so, structures like roots, stems or leaves are absent
- Algae are found where there is adequate moisture.
- Reproduction in algae occurs in both asexual and sexual forms. Asexual reproduction occurs by sporeformation.
- Algae are free-living, although some can form a symbiotic relationship with other organisms.

Types of Algae

There are many types of algae. However, these are some of the more prominent types

Red Algae

Also called Rhodophyta, it is a distinctive species found in marine as well as freshwater ecosystems. The pigments phycocyanin and phycoerythrin are responsible for the characteristic red colouration of the algae. Other pigments that provide green colouration (such as chlorophyll a) are present. However, they lack chlorophyll b or beta-carotene.

Green Algae

It is a large, informal grouping of algae having the primary photosynthetic pigments chlorophyll a and b, along with auxiliary pigments such as xanthophylls and beta carotene.

Higher organisms use green algae to conduct photosynthesis for them. Other species of green algae have a symbiotic relationship with other organisms.

Members are unicellular, multicellular, colonial and flagellates. Prominent examples of green algae include *Spirogyra, Ulothrix, Volvox,* etc.

Blue-Green Algae

In the past, blue-green algae were one of the most well-known types of algae. However, since blue-green algae are prokaryotes, they are not currently included under algae (because all algae are classified as eukaryotic organisms).

Also called cyanobacteria, these organisms live in moist or aquatic environments just like other algae. These include dams, rivers, reservoirs, creeks, lakes and oceans. This class of bacteria obtains energy through the process of photosynthesis. Ecologically, some species of blue-green algae are significant to the environment as it fixes the nitrogen in the soil. Hence, these are also called nitrogen-fixing bacteria. E.g. Nostoc, Anabaena, etc.

ECONOMIC IMPORTANCE OF ALGAE

Algae are entities that are spread throughout the world. They greatly vary in their shapes, sizes and colours. Algae can exist without anyone else, or they can develop on the surfaces of different life forms, in the dirt or on rocks. These creatures are significant in light of the fact that they make a big deal about Earth's oxygen, which people and different creatures need to relax. Some of these organisms look like plants, such as seaweed.

Their size varies greatly, and they grow in many different habitats. Microscopic algae in lakes and oceans called phytoplankton, float or swim. Phytoplankton is so small that one thousand individuals can fit on a pin's head.

Algae pertain to a broad variety of marine eukaryotic organisms that are all involved in the photosynthesis process. Such aquatic plants are distinguished by their lack of flowers, formal roots, leaves, or even stems, ranging from unicellular microalgae to giant kelp. The organic material can be utilized in fish farming as a source of food, as a fodder, and also as a fertilizer. It likewise assumes a key job in recovering alkalines, can be utilized as dirt restricting specialist and utilized in various business products.

Uses of Algae

Algae can be used as food, fodder and also as a binding agent. They are also used as thickening agents in food, biodiesel fuel, bacterial growth medium, etc.

Food

Most societies around the globe think about green growth as a basic wellspring of sustenance. Residents living in European nations like Scotland, Ireland, France, Germany, Sweden, and Norway just as individuals living in South and North America, and Asian countries like Japan and China are utilizing green growth as a key fixing in various nearby dishes. Such dinners may remember green growth for a serving of mixed greens, following meat in a singed pot, as oats beating, or even as a fluid concentrate in a nutritious smoothie.

Green growth contains various gainful components including sugars, fats, proteins and nutrients A, B, C and E. Green growth isn't just viewed as a minimal effort wellspring of protein by numerous buyers around the globe, it additionally contains various significant minerals, for example, potassium, iron, magnesium, manganese, calcium, and zinc. An assortment of dairy items, for example, milk, frozen yoghurt, cheddar, whipped fixings, just as sugar, icing, organic product squeeze, and even plate of mixed greens dressings, are regularly found in green growth.

Specifically, dark-coloured green growth is utilized to balance out, expand, and emulsify different nourishment items, while red green growth is utilized in the arrangement of different semi-strong items as huge as meds, beauty care products, and in the preparation of a wide scope of nourishments. For instance, to sustain domesticated animals

Fodder

Algae are utilised as a feed for a diverse set of farm animals, especially seaweed. For example, cows and chickens, Rhodymenia palmate or alleged "Sheep's weed" is utilized. Green growth is utilized as a grain in different nations, including the northern European nations of Denmark, Sweden, and Norway, just as in Taiwan, Australia, New Zealand and South and North America.

Reclaiming alkaline

Fields that once generated large quantities of agricultural yields in several countries, like India too, for instance, can no more be used to procure the same yield as a result of high alkalinity levels of the soil. To eventually grow crops in these lands, often referred to as “usar” lands, it is necessary to lower pH level and increase the soil’s ability to hold onto water. The blue-green algae can be used to accomplish this cycle.

ECOLOGICAL IMPORTANCE OF ALGAE

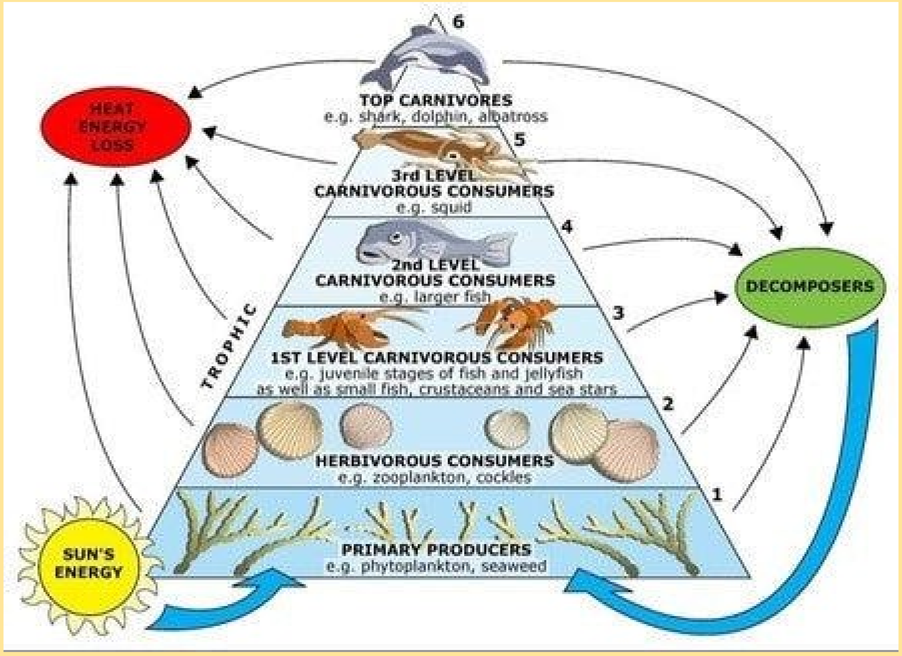
Microscopic algae are arguably the source of more than half of the world's oxygen though photosynthesis. They turn carbon dioxide into biomass and release oxygen. Ecologically, algae are at the base of the food chain. They are the beginning of the transfer of solar energy to biomass that transfers up trophic levels to the top predators. Phytoplankton, are largely responsible for this primary production. Phytoplankton are mostly single-celled type of algae, that are in turn eaten by small animals called zooplankton (mostly crustaceans such as copepods) that drift near the surface of the sea. The zooplankton are in turn fed upon by larger zooplankton, small fish, and filterfeeding whales (think krill). Energy transfer happens and larger fish eat the smaller ones. At the top of the open-water food web may be fish-eating birds, seals, whales, very large fish such as sharks or bluefin tuna, and humans.

The larger algae provide a habitat habitat for fish and other invertebrate animals. A great example of this is Macrocystis, which is a keystone species in a giant kelp forest.

As algae die, they are consumed by organisms called decomposers (mostly fungi and bacteria). The decomposers feed on decaying plants and consume the high-energy molecules essentially remineralizing the biomass into lower-energy molecules that are used by other organisms in the food web

1. **Source of Food:** Algae has the best position as a producer within the food chain, which means they are present in a wide range of food chains. Life in the ocean is primarily dependent on algae because many species eat algae, which is the primary source of life in the ocean. As a result, algae is extremely important and plays a critical role in the survival of ocean life. Ecologists have demonstrated that the consumption of algae increases the lifespan of many ocean living organisms such as fish and tadpoles. Algae are high in fiber, particularly glucan, which is essential for the human body. Many researchers have also revealed that algae have very high nutritional values, and thus it is consumed by many people who live in coastal communities. Algae is also high in vitamin A, K, Selenium, and Magnesium, and is one of the best natural

sources of Iodine. Algae is beneficial to the thyroid gland because it contains iodine, which other foods do not. As a result, as a source of food, algae is extremely important to the environment.



2. Source of Oxygen: The production of oxygen is the most important role that algae play in the environment. The presence of Chlorophyll is what distinguishes land plants from algae. This chlorophyll contributes to the formation of organic food molecules by utilizing solar and carbon dioxide energy. This process is critical for algae survival, and oxygen is released later. Algae produces more than 30% of the oxygen that land animals consume. The main reason for the world's high level of oxygen production is the abundance of algae in the oceans. According to recent estimates, the oceans produce 50 -80 percent of the oxygen, with most of it coming from oceanic plankton, which includes plants and algae with the ability to photosynthesize. Algae may die due to mineral depletion, which may result in the death of living organisms in the oceans. As a result, algae are extremely important to the environment as a source of oxygen.

3. Indicator of Pollution: Algae plays an important role in providing information about water body pollution. There are numerous factors that cause algae to aid us in determining whether water bodies are contaminated. One of the factors is that algae reproduce quickly, and we can examine the offspring to see if there is a difference in the rate of reproduction of algae. Many Algae have already been used as environmental indicators. The main challenge for scientists is that algae have a very short life span, making it difficult to study pollution indicators. Algae can also provide information about what types of pollutants are affecting water bodies, as different pollutants have different effects on water bodies. Chemicals also play an important role in extending the life of algae. Farm chemicals, for example, contain a high concentration of phosphorous and nitrogen, which aid algae growth. As a result, as a source of pollution indicator, algae is crucial to the environment.

4. Indicator of Climate Change: According to the Environmental Protection Agency, carbon dioxide accounts for 76% of greenhouse gas emissions. As the algae grows, carbon dioxide is removed from the atmosphere by converting it to oxygen via the Photosynthesis process. Many studies have also shown that algae in the environment absorb a large amount of carbon dioxide, reducing the gas buildup. As a result, algae are critical to the environment as a source of climatic change indicators.

5. Provision of Habitat: Algae promotes the growth and spread of aquatic life by providing habitat for a variety of species. Forests with an abundance of brown sea wood are examples of large species of algae that provide habitat for a variety of organisms. Kelp Forests are the name given to these types of forests. Although algae overgrowth can disrupt the ocean's ecosystem, the spread of algae in both fresh and saltwater supports a diverse population of fish. As a result, algae is critical to the environment as a habitat.

6. Source of Fodder: Several types of livestock animals are fed on algae, particularly seaweed. For instance, Rhodymenia palmata, sometimes known as "Sheep's weed," is a product of algae that is used to feed animals like chickens and calves. Numerous nations, including those in northern Europe, including Sweden, Denmark, and Norway, as well as in Scotland, China, New Zealand, and all of North and South America, are widely known for using algae as animal feed.

7. Pisciculture: Pisciculture, commonly referred to as fish farming, is the business of breeding and raising fish. Algae are used throughout the entire production process in fish farming, commonly known as pisciculture. According to scientists, different fish species like to eat different kinds of algae, with blue-green and green algae, as well as microalgae, serving as the most popular sources of food for fish. The primary sources of healthful vitamins that the fish consume are floating plankton and zooplankton. Algae are also employed in fish farming as a different type of method to naturally remove carbon dioxide from the air while also supplying the water with oxygen, making the marine environment more hospitable for fish.

8. Used to Make Fertilizer: The two most prevalent types of algae utilized in the production of fertilizer are giant red algae and brown algae. Particularly, only regions close to the water use the two forms of algae (red and brown). Concentrated seaweed extract is largely used in the production of liquid fertilizer. The primary reason this sort of fertilizer is so popular is the organism's extraordinary capacity to restore nitrogen levels that are already present in the soil. For instance, blue-green algae is often harvested and spread over agricultural fields in India where rice is grown.

Despite its many ecological benefits, algae can also be extremely harmful: Algal blooms are the overgrowth of algae in water. These Algal blooms are extremely dangerous and can kill animals and even humans due to the toxins they release. Algal blooms also cause dead zones in the water and increase the cost of drinking water treatment. The main cause of algal blooms is sunlight and slow-moving water. Human nutrient pollution exacerbates the problem. Many different types of phytoplankton are also to blame for the harmful blooms. However, three major phytoplankton species cause illness in both animals and humans. Cyanobacteria, also known as blue-green algae, Dinoflagellates, also known as microalgae or red tide, and Diatoms are the three types.

Conclusion:

Algae contain a high concentration of nutrients and can be used to make fertilizer. The minerals found in algae are also very beneficial to plastic and can thus be used to create flame-resistant plastics and artificial fibers. Algae can also be used to create medicines. Gelidium algae, for example, are used to treat kidney and lung diseases. As a result, algae are not only ecologically significant but also economically significant.

LIFE CYCLE OF ALGAE

Four main patterns of lifecycle in the algae are:

1. Hypotonic Life Cycle: The plant body is a gametophyte. The gametophytic plant produces haploid gametes. The gametes fuse to form a zygote, which is diploid. Thus, diploid represents the sporophytic phase (diploid phase) of their lifecycle. This lifecycle is also known as the monogenic lifecycle and is found to be active in a majority of classes.

2. Diplontic Life Cycle: The plant body is a sporophyte. The sex organs produce gamete by meiosis, and they represent the gametophytic stage. The gametes soon unite and fertilize to form a zygote. The zygote does not undergo any meiosis. The zygote is only responsible for giving rise to new sporophytic plant bodies.

3. Diplohaplontic Life Cycle: In this type, both the diploid and haploid phases are equally present and prominent, expressed by two distinct vegetative individuals. There is a difference in both only in terms of chromosome numbers and functions. The diploid (sporophytic stage) reproduces by the asexual process, while the haploid (gametophytic stage) reproduces by the sexual method. This kind of life cycle has two types: isomorphic (homologous) and heteromorphic (heterologous).

4. Triphasic Life Cycle: In this type, there is a succession of three distinct generations. This type of lifecycle has two types: Haplobiontic and diplobiotonic type.

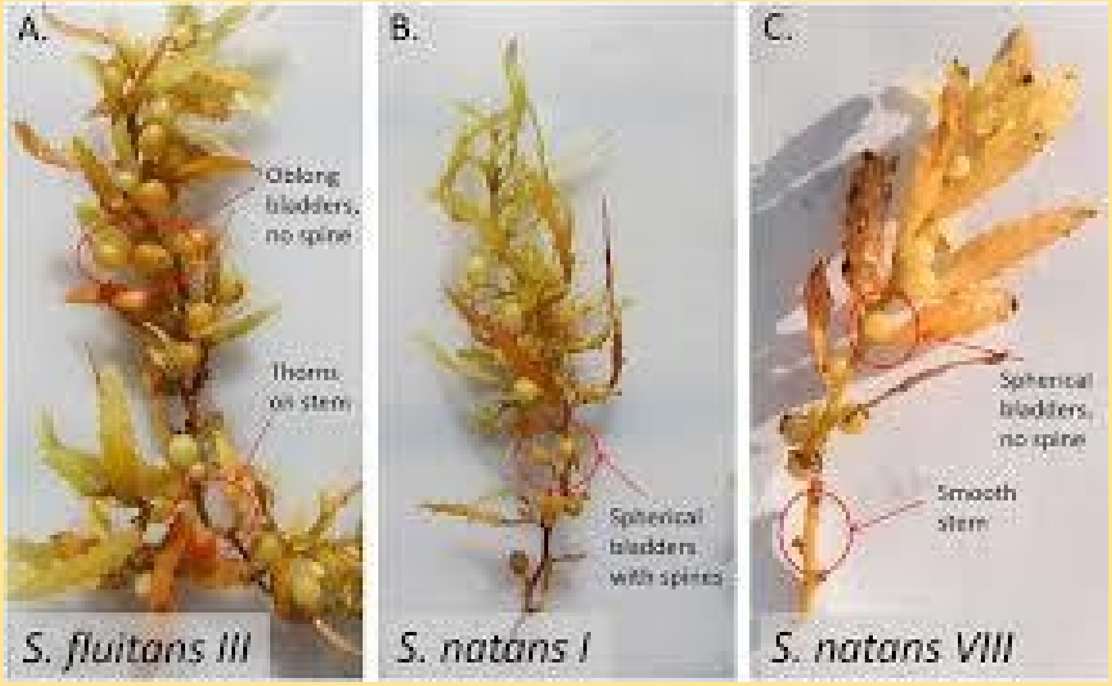
LIFE CYCLE OF SARGASSUM

(A) Vegetative Reproduction in Sargassum:

Sargassum multiplies profusely by vegetative fragmentation. The thallus breaks into fragments due to mechanical injury or death and decay of older parts. The species like S. hystrix and S. natans growing in Sargasso sea are completely sterile as they do not form any reproductive structures. In these species the fragmentation is the only method of multiplication.

(B) Sexual Reproduction in Sargassum:

Sexual reproduction in Sargassum is oogamous. The male sex organs are called antheridia and the female oogonia. The sex organs develop in special flask shaped cavity called conceptacle. These conceptacles are



Present is specially modified laterals called receptacles (Fig. 6 A-C). The male and female sex organs develop in separate conceptacles.

The conceptacles bearing antheridia are called male conceptacles and those bearing oogonia are called female conceptacles.

In homothallic or monoecious species the male conceptacle and female conceptacles are produced on same receptacle, but antheridia and oogonia are not produced in same conceptacles. In dioecious plants the male and female conceptacles are produced on separate male and female plants. Sargassum species are mostly monoecious.

Development of Conceptacles:

The conceptacle develops from a single superficial cell on the receptacular branch. This cell called conceptacle initial is flask shaped and differs from the adjacent cells due to its larger size and prominent nucleus (Fig. 6A). The initial cell divides slower than other cells. As a result it gets lower in position than adjacent cells.

The initial cell divides by transverse division; the two cells formed are separated by a curved septum. The lower cell is called basal cell and the upper is called tongue cell (Fig. 6 B, C).

The tongue cell divides transversely to make small filament which later disintegrates. The basal cell undergoes many vertical divisions to make fertile layer of the conceptacles. The cells of fertile layer later form antheridia and oogonia (Fig. 6 D-G).

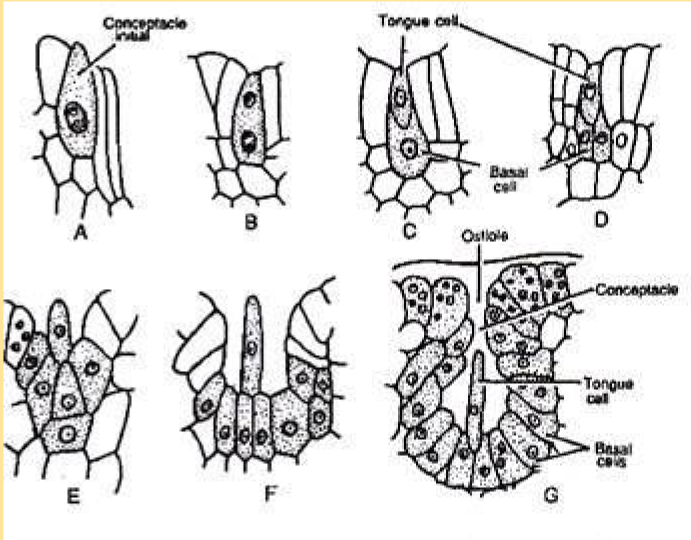


Fig. 6. (A–C). ***Sargassum*****. Developmentof conceptacle**

In fertile conceptacles the cells of basal layers do not spread in upper part, this forms narrow opening called ostiole.

Development of Antheridium:

Any cell of the fertile layer can function as antheridial initial. This cell is dense cytoplasmic and develops a papilla like outgrowth. It divides by transverse division to make lower stalk cell and upper antheridial cell (Fig. 7 A-B). The antheridial cell rounds off to make antheridium.

The stalk cell elongates and pushes the antheridium to one side. The growing stalk cell divides again to make basal cell and the antheridial cell. This process repeated many times and results in formation of many antheridia and a sterile paraphysis (Fig. 71).

The antheridia are oval structures with two layered cell walls. The outer wall is called exochite and the inner is called endochite (Fig. 7 G). At young stage the antheridia are inside conceptacles and on maturity the antheridia are detached from stalk and come out of ostiole.

The antheridium has one diploid nucleus which divides first by meiotic division and later by mitotic divisions. This results in formation of 32-64 haploid nuclei. The protoplast of antheridium also divides in equal number of segments. Each protoplast segment with haploid nucleus develops into an antherozoid (Fig. 7 H). The antherozoid is pear shaped structure with two lateral flagella.

The oogonial cell enlarges and makes spherical oogonium. The oogonia wall has three layers—the outer exochite, middle mesochite and the inner endochite. On maturity of the oogonium the exochite ruptures, the mesochite forms the gelatinous stalk and the oogonial nuclei- and protoplast remains surrounded by endochite.

The diploid oogonial nucleus undergoes meiotic and mitotic divisions to form 8 nuclei. The seven of these eight nuclei degenerate and only one remains functional. This nucleus with protoplasm forms single ovum or oosphere (Fig. 8 C-H).

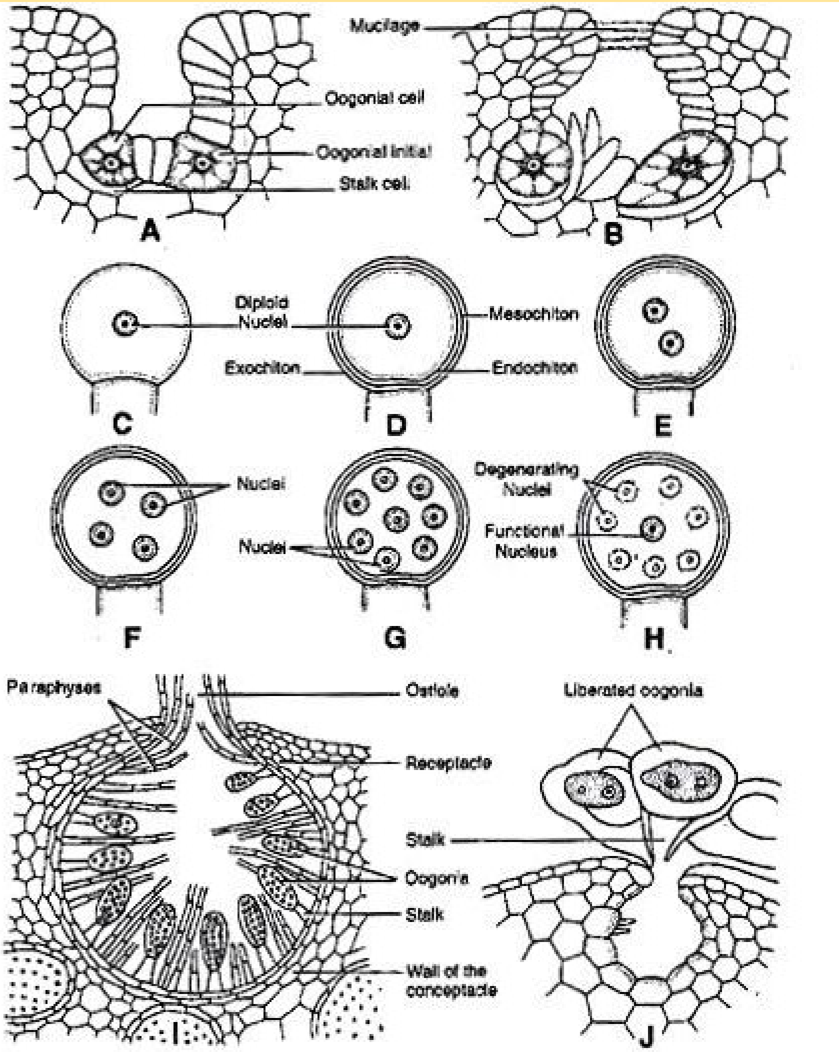


Fig. 8. (A–F). *Sargassum*. Development of oogonium. (A–H) Stages in the development of oogonium, (I) V.S. of receptacle through female conceptacle, (J) liberated oogonia.

The cells of female conceptacle which do not form oogonia develop into long hair like paraphyses.

Fertilization:

The antherozoids are released in water and the oogonia remain attached to the conceptacle base by mucilaginous stalk. The oogonia protrude out of the ostiole (Fig. 8 J). A large number of antherozoids surround the oogonium and attach to oogonial wall with the help of anterior flagellum (Fig. 9 A). Only one antherozoid penetrates the oogonial wall. The male and female nuclei fuse to form a diploid zygote (Fig. 9 B).

Germination of Zygote:

The zygote germinates immediately after fertilization when the oogonium still remains attached to the wall of conceptacle by a mucilaginous stalk. After some time the zygote is liberated by gelatinization of the oogonial wall. After liberation the zygote gets attached to any substratum in sea water. The zygote first divides by transverse division to make a lower cell and upper cell (Fig. 9 C-F).

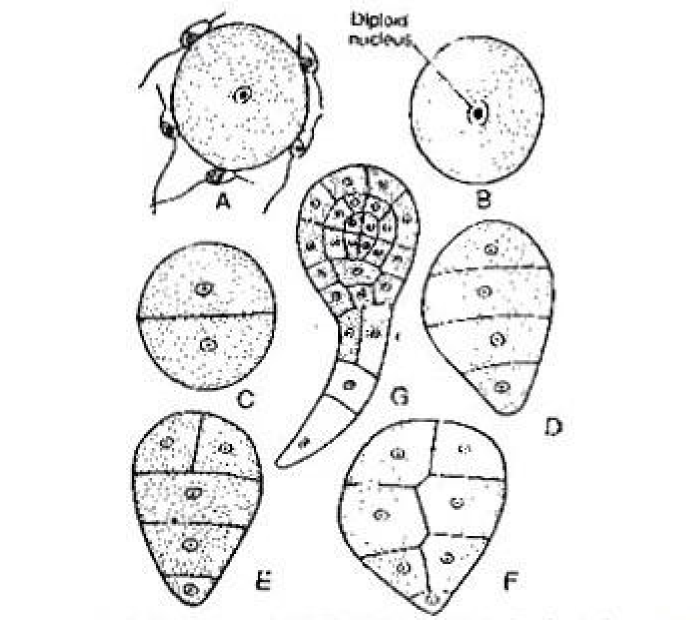


Fig. 9. (A–F). *Sargassum*. Fertilization and germination of zygote.

The lower cell forms the rhizoids. The upper cell first divides by transverse division and later by anticlinal and periclinal divisions. It results in the differentiation of three layers—the meristoderm, cortex and medulla. The divisions of upper cell result in formation of a diploid, sporophytic Sargassum plant.

The life cycle of Sargassum is diplontic type and there is no alternation of generation. The thallus is diploid sporophytic. It forms diploid antheridia and oogonia. The reduction division in antheridia and oogonia forms haploid antherozoid and oognial nuclecus. The gametes only are haploid structure in the life cycle. After fertilization a diploid zygote is formed which divides to make a diploid sporophytic thallus (Fig. 10, 11).

LIFE CYCLE OF OEDOGONIUM

Oedogonium is a genus of filamentous, free-living green algae. It was first discovered in the fresh waters of Poland in 1860 by W. Hilse and later named by German scientist K. E. Hirn. The morphology of *Oedogonium* is unique, with an interior and exterior that function very differently from one another and change throughout its life cycle. These protists reside in freshwater ecosystems in both hemispheres and are both benthic and planktonic in nature. As they form algal patches on the water's

surface, they interact closely with a multitude of other algae. These filamentous cells' life cycles include both sexual and asexual reproduction, depending on the life cycle stage. Although quite common, *Oedogonium* is difficult to identify since key ID factors are only present during reproduction, which is an uncommon life stage among this genus. *Oedogonium* has been found to be important in the fixation of heavy metals in freshwater ecosystems.

Oedogonium resides in freshwater ecosystems and prefers stagnant waters, such as small ponds, pools, roadside ditches, marshes, lakes, and reservoirs. It grows over a large pH range (7.3-9.6) and presents a wide tolerance to variation in nutrient type and amount in water. Cells exist either fastened to substrate at the bottom of the water system or free-floating within. When free-floating they form polyalgal patches (mats) on the water's surface to establish a relatively static habitat. Mats are created by interweaving multiple different algal filaments that are suspended in a gelatinous matrix. This matrix is a result of secretions by free floating thalli. Benthic cells are most often juvenile filaments and once matured they tend to let go, float to the top and form the mats. *Oedogonium* filaments typically appear during the warmer months, appearing at the end of June (north of the equator), and throughout July and August are found prevalent in polyalgal mats. Mats formed by *Oedogonium* are multi-species, associated with *Spirogyra*, *Rhizoclonium*, and *Cladophora*. Together these species use holdfast cells to grip one another in order to photosynthesize. These mats/patches are also known as algal blooms.

LIFE CYCLE

Asexual reproduction:

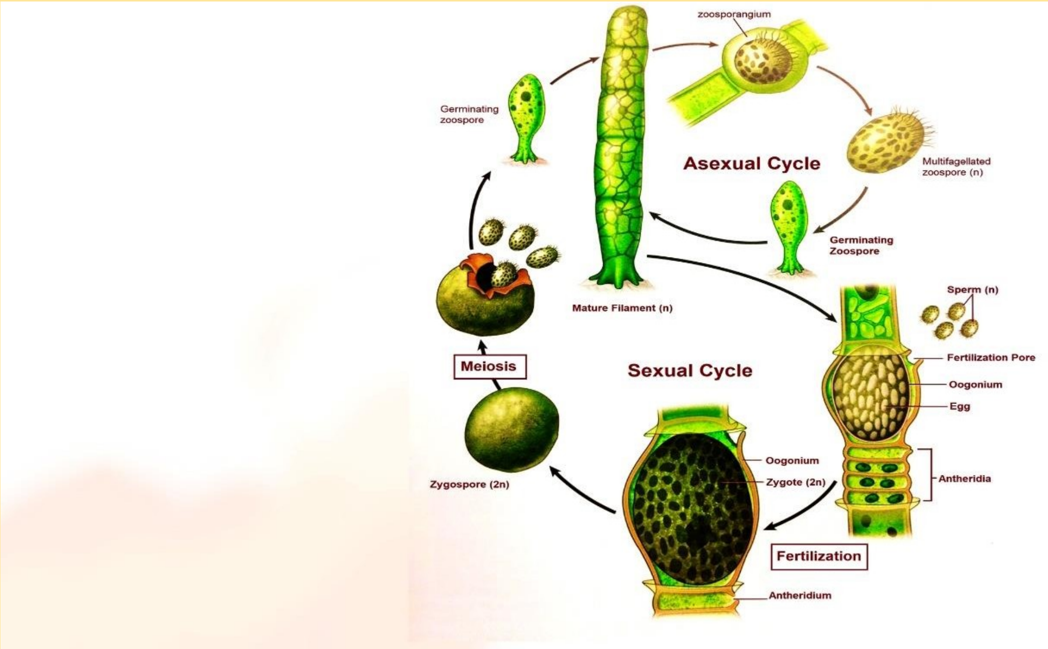
Oedogonium can reproduce asexually by fragmentation of the filaments, germination of aplanospores and akinetes, and through zoospores. In fragmentation, the filament splits apart and each fragment reproduces to form a fully functioning thallus. Splitting can occur more than once at the same position of the filament, explaining why some cells have more than one cap. The splitting of fragmentation may or may not be intentional – it could occur due to natural damage by the environment or predators.

Asexual reproduction via zoospore is also very common and occurs in vegetative (benthic) cells. Vegetative cells produce zoosporangia – the enclosure in which spores are formed – which give rise to the zoospores. Each zoospore has a small hyaline anterior region, and at the base of this region is a ring of flagella (~150). Once emerged from the zoosporangium, a zoospore is still enveloped by a fragile vesicle, from which it is soon discharged. Following dispersal, the zoospore experiences a short period of motility in which it searches for a substrate. When attached to a substrate, the ring of flagella is lost, and the zoospore begins dividing to form a new filament.

Germination of aplanospores and akinetes is uncommon but possible. An aplanospore is non- motile and formed within a vegetative cell, the wall of which is distinct from that of the parent cell. Under certain unfavourable conditions, aplanospores will secrete thick walls around them and store abundant food reserves. An akinete spore is large, non-motile, and thick walled, the wall of which is fused to that of the parent cell. Akinetes thick cell walls are enriched in food materials. Both aplanospores and akinetes are able to withstand unfavourable habitual conditions (cold, winter months or nutrient poor waters) and within these conditions remain dormant. With the onset of favourable conditions (such as warm winter months), they can germinate to form a new individual.

As these processes are all forms of asexual reproduction, they do not produce genetic diversity in the offspring. Therefore, asexual reproduced *Oedogonium* are more vulnerable to changing environments.

Sexual reproduction



Sexual reproduction in *Oedogonium* is oogamous; and can be monoecious or dioecious. Species may either be macrandrous (lacking dwarf males) or nannandrous (possessing dwarf males). Dwarf males are small, short, antheridium-producing filaments attached near the oogonia (female sex organ). These dwarf males are derived by repeated cell division of multiflagellate androspores. When an oogonial mother cell divides it forms a swollen oogonium bound by a supporting cell. Oogonial cells may exist in a series along the filament, and so division may also occur in a series; resulting in each oogonium containing a single egg. Production of an egg causes swelling of the cell wall, responsible for the name given by Hirn in 1900– oedos (swelling) and gonos (seed/offspring). Antheridia are short and disk-shaped, containing 1 to 2 multi-flagellated sperm cells. Motile male gametes will exit the antheridia and are chemotactically attracted to oogonia. A single sperm cell will pass through a pore opening in the oogonial cell wall, allowing fertilization. Zygotes (oospores) are initially green but will gradually become an orange-red colour and develop a thick multilayered cell wall with species specific surface adornments. Meiosis occurs in the zygote prior to germination, producing four multi-flagellated cells after germination. Once freed from the oogonium, each daughter cell is only motile for a short period of time. All four cells may eventually attach to a substrate and then divide repeatedly to form new *Oedogonium* filament.

The life cycle of *Oedogonium* is haplontic. The egg from the oogonia and the sperm from the antheridia fuse and form a zygote which is diploid (2n). The zygote then undergoes meiosis and reproduces asexually to form the filamentous green alga which is haploid (1n)

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BRYOPHYTES

The term Bryophyta came from the word 'Bryon' which means moss and python means plants. Bryophyte includes embryophytes like mosses, hornworts, and liverworts. These are the plants that grow in shady and damp areas and are small in size. They lack vascular tissues. They reproduce through spores instead of producing flowers and seeds. Despite the fact that most bryophytes lack complex tissue organization, they exhibit a wide range of forms and ecology. They are found all over the world and are relatively small in comparison to most seed-bearing plants. The study of bryophytes is called Bryology.

General Characteristics of Bryophytes:

- Plants occur in damp and shaded areas.
- The plant body is thallus-like, i.e. prostrate or erect.
- It is attached to the substratum by rhizoids, which are unicellular or multicellular.
- They have a root-like, stem-like, and leaf-like structure and lack true vegetative structure.
- Plants lack the vascular system (xylem, phloem).
- The dominant part of the plant body is the gametophyte which is a haploid.
- The thalloid gametophyte is divided into rhizoids, axis, and leaves.
- The gametophyte bears multicellular sex organs and is photosynthetic.
- The antheridium produces antherozoids, which are flagellated.
- The shape of an archegonium is a sort of a flask and produces one egg.
- The antherozoids fuse with an egg to make a zygote.
- The zygote develops into a multicellular sporophyte.
- The sporophyte is semi-parasitic and dependent on the gametophyte for its nutrition.
- Cells of sporophyte undergo meiosis to form haploid gametes which form a gametophyte.
- The juvenile gametophyte is known as protonema.
- The sporophyte is differentiated into foot seta and capsule.

Classification of Bryophytes:

According to the newest classification, Bryophyta is split into three classes:

A. Hepaticopsida (Liverworts)

B. Anthocerotopsida (Hornworts)

C. Bryopsida (Mosses)

A. Hepaticopsida (Liverworts):

The name hepaticopsida comes from the word "hepatic" which means liver. Liverworts come under this class. Liverworts are a type of bryophyte that belongs to this group. It has around 900 species. The most basic bryophytes are liverworts. They prefer moist rocks and wet soil to live in. Because they dwell near water, their chances of drying are much reduced.

A gametophyte is a type of plant. It can be thalloid (flat) or ribbon-like (ribbon-like), and is generally dichotomously branched. Marchantia, for example, is linked to the soil by rhizoids. Other species, such as Porella, tend to grow erect and are deceptively leafy, that is, differentiated into a fake stem and leaves. The gametophyte provides nutrition and protection to the sporophyte. The sex organs form towards the terminals of the branches on the upper surface of the thallus. As in Marchantia, they sometimes form distinct branches on gametophytes called antheridiophores and archegoniophores.

Hepaticopsida is Further Divided into 4 Orders:

1. Marchantiales (e.g. Riccia, Marchantia)
2. Sphaerocarpales (e.g. Sphaerocarpos)
3. Calobryales (e.g. Calobryum)
4. Jungermanniales (e.g. Pellia)

The Main Characteristics of the Class Hepaticopsida are:

- The gametophyte plant is either thalloid or foliose.
- Thalloid forms are dorsiventral, lobed, and dichotomously branched.
- Rhizoids are unicellular, branched, and septate.
- Sex organs are borne dorsally embedded in gametophytic tissues.
- The sporophyte is a compilation of only capsule (in Riccia) or foot, seta, and capsule (in Marchantia).
- The columella is absent in the capsule.

- Sporogenous tissues develop from endothecium.

Reproduction:

- **Asexual Reproduction:**

  It takes place by the formation of gemmae or by the process of fragmentation. Gemmae are produced inside gemma cups. Gemmae are green and multicellular and are also are asexual in nature. The gemma cup develops into a newly born plant after detaching from the parent plant.

- **Sexual Reproduction:**

  Sexual reproduction: Antheridium (male organ) and archegonium (female organ) could also be present on equivalent thalli or different thalli. They produce sperm and egg respectively. After fertilisation zygote is formed. The zygote develops into a diploid sporophyte, a couple of cells of the sporophyte undergo meiosis to make haploid spores. These spores become haploid gametophytes, which are free-living and photosynthetic.

B. Anthocerotopsida (Hornworts):

There are around 300 species present during this class. They are commonly known as hornworts. It has only one order i.e. Anthocerotales. Examples: Anthoceros, Megaceros, Notothylas. This group of bryophytes is slightly more advanced than Bryopsida and Hepaticopsida in several ways. From a broad perspective, the gametophyte is very lobed and uneven. The sporophyte is not reliant on the gametophyte for sustenance or protection, except during the early stages of development. In the gametophytic tissue, antheridia and archegonia are somewhat submerged.

The Main Features are:

- The gametophytic body is flat, dorsiventral, simple thalloid, and has no internal differentiation.
- Rhizoids are smooth-walled.
- Each cell has one chloroplast with a pyrenoid.
- Sex organs are present dorsally embedded in the thallus.
- Sporogenous tissues develop from amphithecium.
- Pseudoelaters are present in the capsule.
- The columella is present within the capsule, which originates from the endothecium.

Reproduction:

- **Asexual Reproduction:**

  Vegetative propagation takes place by the process of fragmentation of thallus and by tubers, which are formed under unfavourable conditions.

- **Sexual Reproduction:**

  They reproduce sexually with the help of waterborne sperm that travels from antheridium to archegonium. A fertilized egg develops into a sporophyte. The Sporophyte splits lengthwise to release spores which become a gametophyte.

C. Bryopsida (Mosses):

It's an important class of Bryophyta with around 1400 species. They are commonly called mosses. Most mosses, like liverworts, like wet environments. They grow equally well in relatively dry environments, unlike other bryophytes. Mosses, on the other hand, need water to reproduce, hence they usually grow into cushions or mats. Examples: Funaria, Polytrichum, Sphagnum.

Bryopsida is Further Divided Into 5 Classes:

1. BryalesAndriales
2. Sphagnales
3. Polytrichales
4. Buxbaumiales

The Main Features are:

- The gametophyte is divided into protonema and foliose gametophore.
- Foliose is formed of the stem as an axis and leaves without a midrib.
- Rhizoids are multicellular with oblique septa.
- Sex organs are borne apically on the stem.
- Elaters are absent.
- The sporophyte is differentiated into foot, seta and capsule.
- Sporogenous tissues develop from endothecium.
- The columella is present.

- Separation of the lid is the result of the Dehiscence of the capsule.

Reproduction:

- **Asexual Reproduction:**

  Asexual reproduction takes place by budding and fragmentation of the secondary protonema.

- **Sexual Reproduction:**

  Antheridia and archegonia are present at the apical part of leafy shoots. After fertilization sporophyte is produced, which is more differentiated than liverworts. The gametophyte develops from the spores.

Examples of Bryophytes

Bryophytes consist of around 20,000 plant species. Bryophytes are divided into liverworts, mosses, and hornworts. Some common examples are:

Liverworts: Marchantia, Riccia, Pellia, Porella, Sphaerocarpos, Calobryum.

Mosses: Funaria, Polytrichum, Sphagnum.

Hornworts: Anthoceros, Notothylas, Megaceros.

Ecological Importance of Bryophytes:

Bryophytes have great ecological importance. Mosses and lichens are the first organisms to colonize rocks.

- They decompose the rock making it suitable for the expansion of the higher plants. Soil formation takes place by the acidic secretion that causes the death and decay of mosses.
- Bryophytes grow densely and act as soil binders.
- Mosses play an important role in bog succession. The thick mat formed of mosses forms a suitable substratum for the germination of hydrophilic seeds due to the presence of water and humus. In the meanwhile, the dead and decayed mosses and hydrophilic plants form a solid soil for mesophytic development.
- They prevent erosion of soil by reducing the impact of falling rain.
- They reduce the quantity of run-off water because of their water holding capacity.
- They help in recycling the nutrients.
- They act as a rock builder. These plants decompose bicarbonate ions resulting in the precipitation of insoluble calcium carbonate. The mineral deposit continues to increase and therefore extends over several hundred square feet.

Economic Importance of Bryophytes:

Medicinal Uses:

- Sphagnum is employed in dressing as it has high absorptive power and a few antiseptic properties for filling absorptive bandages in replacement of cotton for the treatment of boils and discharging wounds
- Marchantia has been employed to cure pulmonary tuberculosis and affliction of liver
- The decoction of dried sphagnum is used in the treatment of acute haemorrhage and eye infections
- Peat-tar is antiseptic and used as a preservative. Polytrichum species has been shown to dissolve stone in the kidney and gallbladder
- Antibiotic substances are often extracted from certain bryophytes having antibiotic properties

In Research:

Mosses and liverworts are used in research in the field of genetics. The mechanism of sex determination within the plant is discovered in liverworts

Packing Material:

Dried mosses make superb packing for fragile goods like glassware, bulbs. For trans-shipment of living material like cuttings and seedlings as they need water retention capacity.

Food:

Some mosses provide food for herbaceous mammals, birds, and other mammals.

As Indicator Plants:

Some bryophytes grow during a specialized area and may be used as an indicator for acidity and basicity of the soil. For E.g. Polytrichum indicated the acidity of the soil, Tortella species grow well within the soil rich in lime or other bases and occur as calcicoles.

In seedbeds:

Because of its water retention capacity, it is used in seedbeds, greenhouses, nurseries to root cuttings. Sphagnum is additionally wont to maintain the high soil acidity required by certain plants.

Peat Formation:

Sphagnum is additionally referred to as sphagnum. Peat is formed by slowing down the decaying process. The gradual compression and carbonization of partially decomposed vegetative matter in bogs produce a dark-coloured substance called Peat.

It is used as fuel, lower layers of peat from coal, peat is also used in the production of ethyl alcohol, ammonium sulfate, ammonia, dye, paraffin, tannins, etc. It improves soil texture in horticulture.

Formation of Stone:

The travertine rock deposits are extensively used as a building stone.

The life cycle of Bryophytes:

The independent gametophyte generation, which generates the sex organs, sperm, and eggs, and the dependent sporophyte generation, which produces the spores, alternate generation in bryophytes. The bryophyte sporophyte, unlike vascular plants, usually lacks a sophisticated circulatory system and develops only one spore-producing organ (sporangium) rather than numerous. Furthermore, the bryophyte's gametophyte generation is usually perennial and photosynthetically independent of the sporophyte, which has a close relationship with the gametophytic tissue, particularly at the sporophyte's base or foot. The gametophyte, on the other hand, is dependent on the sporophyte in most vascular plants. The gametophyte is the long-lived and visible generation in bryophytes, while the sporophyte is the long-lived and visible generation in vascular plants. On the gametophore of bryophytes, structures resembling stems, roots, and leaves are seen, whereas these structures are found on the sporophytes of vascular plants. The sporophyte produces spores, which eventually grow into gametophytes.

The haploid gametophyte and the diploid sporophyte have alternate generations in the bryophyte life cycle. During the gametophyte stage, the specialized sex organs, the antheridia (male) and archegonia (female) produce haploid gametes (male and female) (female). Flagellated sperm swim through the water or are carried by insects. When two haploid gametes (sperm and egg) combine to form a diploid zygote, a diploid zygote is created. Bryophyte zygote develops inside archegonia and becomes a diploid sporophyte, as mentioned above. Mature sporophytes stay connected to the gametophyte and produce haploid spores in the sporangium through meiosis. These spores disseminate and become new gametophytes in the presence of favorable environmental circumstances.

LIFE CYCLE OF MARCHANTIA

External Features of Gametophyte:

The plant body is gametophytic, thalloid, flat, prostrate, plagiotropic, 2-10 cm. long and dichotomously branched

Dorsal surface:

Dorsal surface is dark green. It has a conspicuous midrib and a number of polygonal areas called areolae. The midrib is marked on the dorsal surface by a shallow groove and on the ventral surface by a low ridge. Each polygonal area re-presents the underlying air chamber.

The boundaries of these areas represent the walls that separate each air chamber from the next. Each air chamber has a central pore. The midrib ends in a depression at the apical region forming an apical notch in which growing point is situated (Fig. 28 B).

Dorsal surface also bears the vegetative and sexual reproductive structures. The vegetative reproductive structures are gemma cup and develop along the midrib. These are crescent shaped with spiny or fimbriate margins and are about one eighth of a inch in diameter

Ventral surface:

The ventral surface of the thallus bears scales and rhizoids along the midrib. Scales are violet coloured, multicellular, one cell thick and arranged in 2-4 rows (Fig. 1 C). Scales are of two types:

(i) Simple or ligulate

(ii) Appendiculate.

Appendiculate (Fig- 1 C, D) scales form the inner row of the scales close with midrib. Ligulate scales form the outer or marginal row and are smaller than the appendiculate scales (Fig. 1 C, E).

Rhizoids are unicellular, branched and develop as prolongation of the lower epidermal cells. They are of two types:

(i) Smooth-walled rhizoids,

(ii) Tuberculate rhizoids.

In smooth-walled rhizoids both the inner and outer wall layers are fully stretched while in tuberculate rhizoids appear like circular dots in surface view (Fig. 1 F). The inner wall layer modifies into peg like in growth which projects into the cell lumen (Fig. 1 H). The main functions of the rhizoids are to anchor the thallus on the substratum and to absorb water and mineral nutrients from the soil.

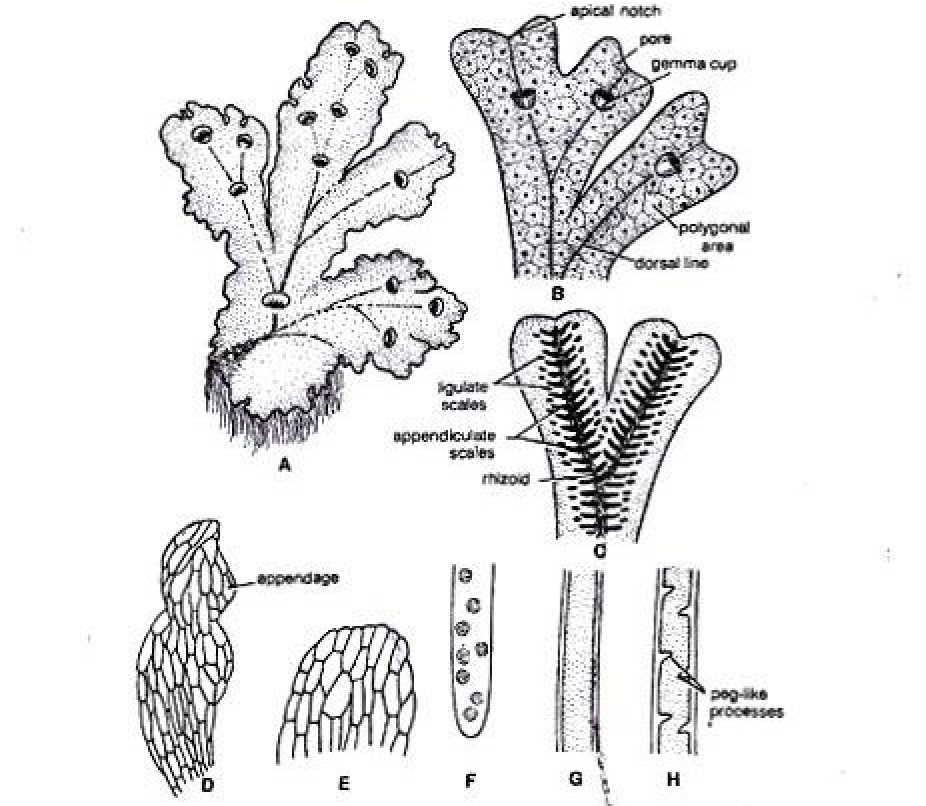

Fig. 1. (A–H). *Marchantia*. Thallus structure (A) Vegetative thallus, (B) Dorsal surface, (C) Ventral surface, (D) Appendiculate scale, (E) Ligulate scale, (F) Tuberculated rhizoid (surface view), (G) Smooth-walled rhizoid, (H) Tuberculated rhizoid showing internal view.

Reproduction in Marchantia:

Marchantia reproduces by vegetative and sexual methods.

(i) Vegetative Reproduction:

1. **By Gemmae:**

Gemmae are produced in the gemma cups which are found on the dorsal surface of the thallus (Fig. 3 A). Gemma cups are crescent shaped, 3 m.m. in diameter with smooth, spiny or fimbriate margins (Fig. 3 B).

V. S. passing through the gemma cup shows that it is well differentiated into two regions:

The structure of both the zones is similar to that of the thallus. Mature gemmae are found to be attached at the base of the gemma cup by a single celled stalk.

Intermingled with gemmae are many mucilage hairs. Each gemma is autotrophic, multicellular, bilaterally symmetrical, thick in the centre and thin at the apex. It consists parenchymatous cells, oil cells and rhizoidal cells. It is notched on two sides in which lies the growing point (Fig. 3 C).

Marchantia

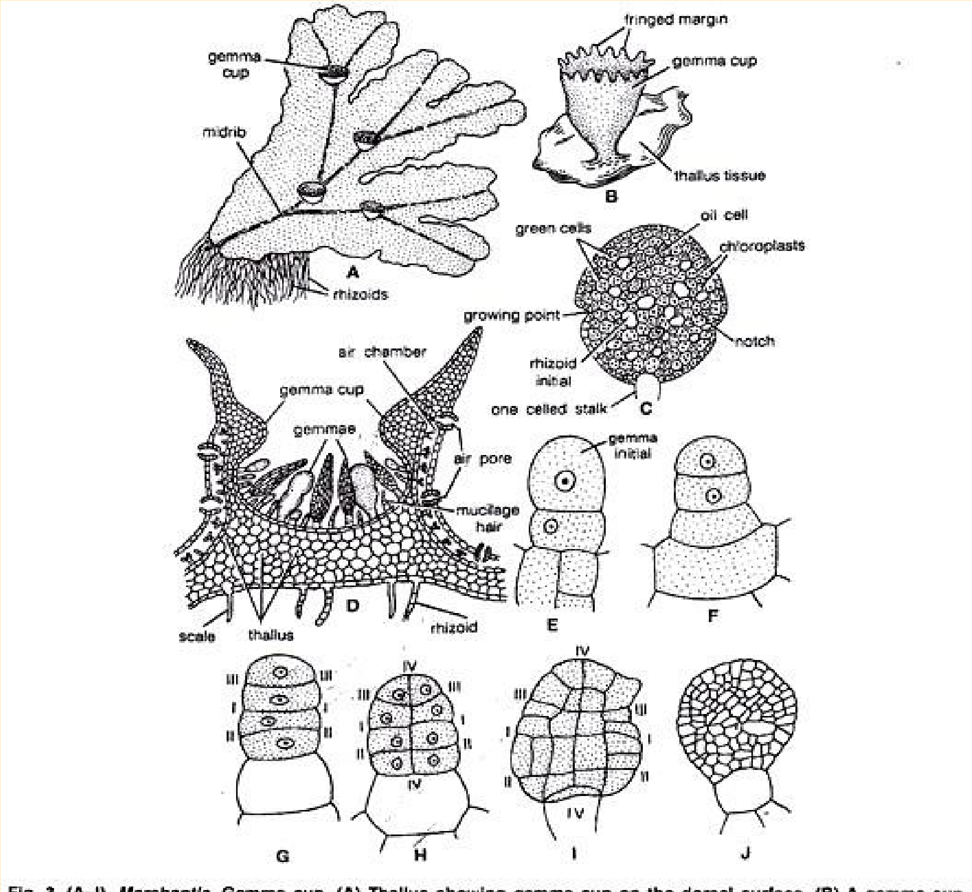

Fig. 3. (A-J). *Marchantia*. Gemma cup. (A) Thallus showing gemma cup on the dorsal surface. (B) A gemma cup, (C) Gemma, (D) Gemma cup in a vertical section, (E-J). Different stages in the development of Gemma.

By Adventitious Branches:

The adventitious branches develop from any part of the thallus or the ventral surface of the thallus or rarely from the stalk and disc of the archegoniophore in species like M. palmata (Kashyap, 1919). On being detached, these branches develop into new thalli (Fig. 4 D).

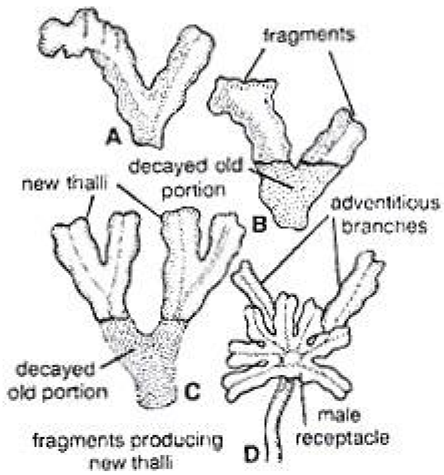

Fig. 4. (A-D). ***Marchantia.*** **Vegetative reproduction. (A-C). Fragmentation, (D) Adventitious branches arising between the lobes from the lower surface of the male disc.**

(ii) Sexual Reproduction:

Sexual reproduction in Marchantia is oogamous. All species are dioecious. Male reproductive bodies are known as antheridia and female as archegonia. Antheridia and archegonia are produced an special, erect modified lateral branches of thallus called antheridiophore and archegoniophore arpocephalum) respectively (Fig. 5 A, B).

Further growth of the thallus is checked because growing point of the thallus is utilised in the formation of these branches. In some thalli of M. palmatci and L. polymorpha abnormal receptacle bearing both anheridia and archegonia have also been reported, such bisexual receptacles are called as androgynous receptacles.

Internal structure of Antheridiophore or Archcgoniophore:

Its transverse section shows that can be differentiated into two sides: ventral side and dorsal side. Ventral side has two longitudinal tows with scales and rhizoids. These grooves, run longitudinally through the entire length of the stalk. Dorsal side shows an internal differentiation of air chambers. (Fig. 5 C).

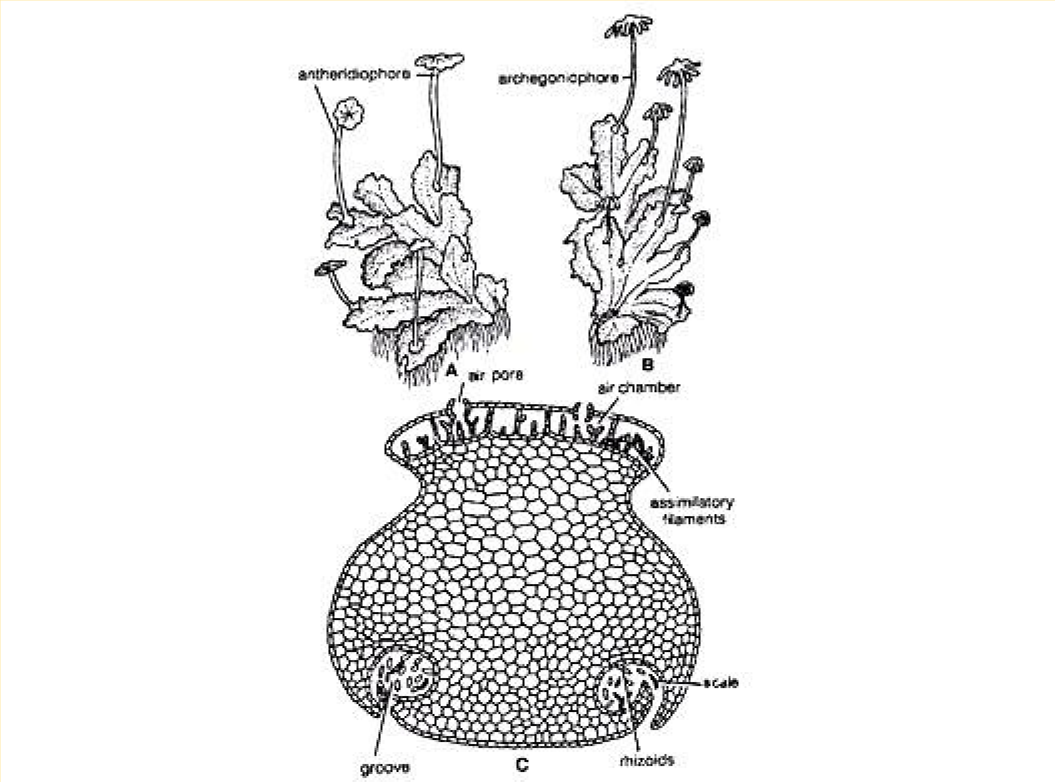

Fig. 5. (A-C). *Marchantia*. Gametophores. (A) Thallus bearing antheridiophores, (B) Female thallus bearing archegoniophores, (C) Transverse section of gametophore.

Antheridiophore:

It consists of 1-3 centimetre long stalk and a lobed disc at the apex (Fig. 32). The disc is usually eight lobed but in M. geminata it is four lobed. The lobed disc is a result of created dichotomies.

L.S. through disc of Antheridiophore:

The disc consists of air chambers alternating with heridial cavities. Air chambers are more or less triangular and open on upper surface by n pore Called ostiole. Antheridia arise in acropetal succession i.e., the older near the center and youngest at the margins. (fig. 6 A).

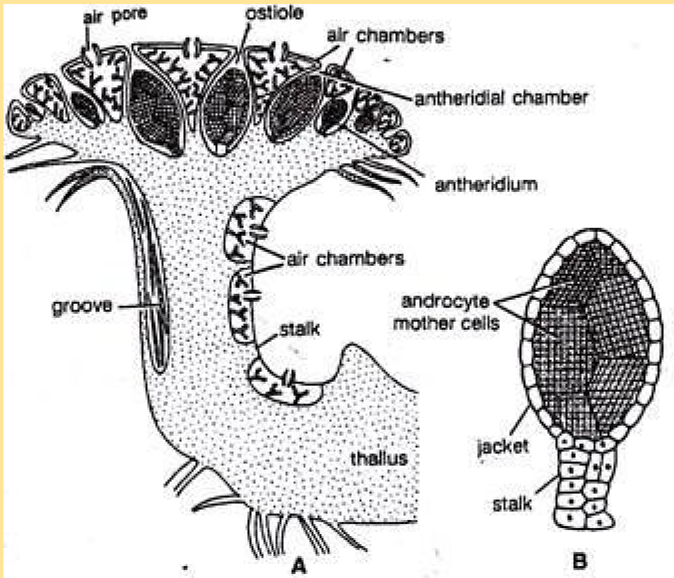

Fig. 6. (A-B). *Marchantia* Antheridia. (A) Vertical or longitudinal section passing through disc of antheridiophore, (B) a mature antheridium antheridium.

Mature Antheridium:

A mature antheridium is globular in shape and can be differentiated into two parts stalk and body. Stalk is short multicellular and attaches the body to the base of the antheridial chamber. A single layered sterile jacket encloses the mass of androcyte mother cells which metamorphosis into antherozoids (Fig. 6 B, 7 G). The antherozoid is a minute rod like biflagellate structure (Fig. 8 H).

Development of Antheridium:

The development of the antheridium starts by a single superficial cell which is situated on the dorsal surface of the disc, 2-3 cells behind the growing point. This cell is called antheridial initial (Fig. 7 A). The antheridial initial increases in size and divides by a transverse division to form an outer upper cell and a lower basal cell (Fig. 7 B).

Basal cell remains embedded in the tissue of the thallus, undergoes a little further development and forms the embedded portion Of the antheridial stalk. Outer cell divides to form a filament of four cells. Upper two cells of the four celled filament are known as primary antheridial cells and lower two cells are known as primary stalk cells (Fig. 7 C).

Primary stalk cells from the stalk of the antheridium. Primary antheridial cells divide by two successive vertical divisions at right angle to each other to form two tiers of four cells each (Fig. 7 D). A periclinal division is laid down in both the tiers of four cells and there is formation of eight outer sterile jacket initials and eight inner primary androgonial cells (Fig. 7 E).

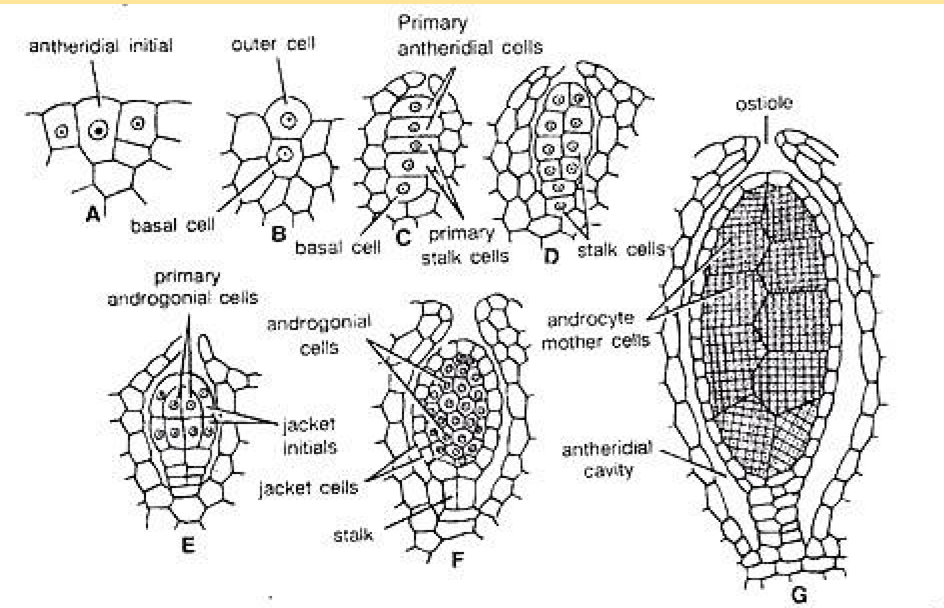

Fig. 7. (A-H). *Marchantia*. Development of antheridium (A-F). Successive stages in the development of antheridium, (G). A mature antheridium.

Jacket initials divide by several anticlinal divisions to form a single layer of sterile antheridial jacket. Primary androgonial cells divide by several repeated transverse and vertical divisions resulting in the formation of large number of small androgonial cells (Fig. 7 F).

The last generation of the androgonial cells is known as androcyte mother cells (Fig. 7 G). Each androcyte mother cells divides by a diagonal mitotic division to form two triangular cells called androcytes. Each androcyte cell metamorphosis into an antheozoid .

Mature Archegonium:
A mature archegonium is a flask shaped structure. It remains attached to the archegonial disc by a short stalk. It consists upper elongated slender neck and basal globular portion called venter. The neck consists of six vertical rows enclosing eight neck canal cells and large egg. Four cover cells are present at the top of the neck.

Fertilization in Marchantia:
Marchantia is dioecious. Fertilization takes place when male and female thalli grow near each other. Water is essential for fertilization. The neck of the archegonium is directed upwards on the dorsal surface of the disc of the archegoniophore (Fig. 9 A).

In the mature archegonium the venter canal cell and neck canal cells disintegrate and form a mucilaginous mass. It absorbs water, swells up and comes out of the archegonial mouth by pushing the cover cells apart. This mucilaginous mass consists of chemical substances.

The antherozoids are splashed by rain drops. They may fall on the nearby female receptacle or swim the whole way by female receptacle. It is only possible if both the male and female receptacles are surrounded by water.

Many antherozoids enter the archegonial neck by chemotactic response and reach up to egg. This mechanism of fertilization is called splash cup mechanism. One of the antherozoids penetrates the egg and fertilization is effected. The fusion of both male and female nuclei results in the formation of diploid zygote or oospore. Fertilization ends the gametophytic phase.

Development of Sporogonium:

After fertilization the diploid zygote or oospore enlarges and it completely fills the cavity of the archegonium. It first divides by transverse division (at right angle to the archegonium axis) to form an outer epibasal cell and inner hypo basal cell (Fig. 12 A, B).

The second division is at right angle to the first and results in the formation of four cells. This represents the quadrant stage (Fig. 12 C). The epibasal cell forms the capsule and hypo basal cells form the foot and seta.

Since the capsule is developed from the epibasal cell and forms the apex of the sporogonium, the type of embryogeny is known as exoscopic. The next division is also vertical and it results in formation of eight celled stage or octant stage.

Now the divisions are irregular and globular embryo is formed (Fig. 12 D). The lower cells divide to form a massive and bulbous foot. The cells of the seta divide in one plane to form vertical rows of cells.

In upper region of capsule (when the young sporogonium is about a dozen or more cells in circumference) periclinal division occurs and it differentiates it into outer single layered amphithecium and multilayered endothecium (Fig. 12 E, F).

The cells of the endothecium divide only by anticlinal divisions to form a single layered sterile jacket or capsule wall. The endothecium forms the archesporium. Its cells divide and re-divide to form a mass of sporogenous cells (sporocytes). Half of the sporogenous cells become narrow and elongate to form the elater mother cells. (Fig. 12 G, I).

In M. polymorpha sporogenous cells divide by five successive divisions to form thirty-two spore mother cells while in M. domingensis sporogenous cells divide only by three to four divisions to form eight or sixteen spore mother cells. The elater mother cells elongate considerably to form long, slender diploid cells called elaters.

Elaters are pointed at both the ends and have two spiral bands or thickenings on the surface of the wall. These are hygroscopic in nature and help in dispersal of spores (Fig. 12 K). The spore mother cell is diploid and divides meiotically to form four haploid spores which remain arranged tetrahedrally for quite some time (Fig. 12 J). The spores later become free and remain enclosed by the capsule wall along elaters. (Fig. 12 H).

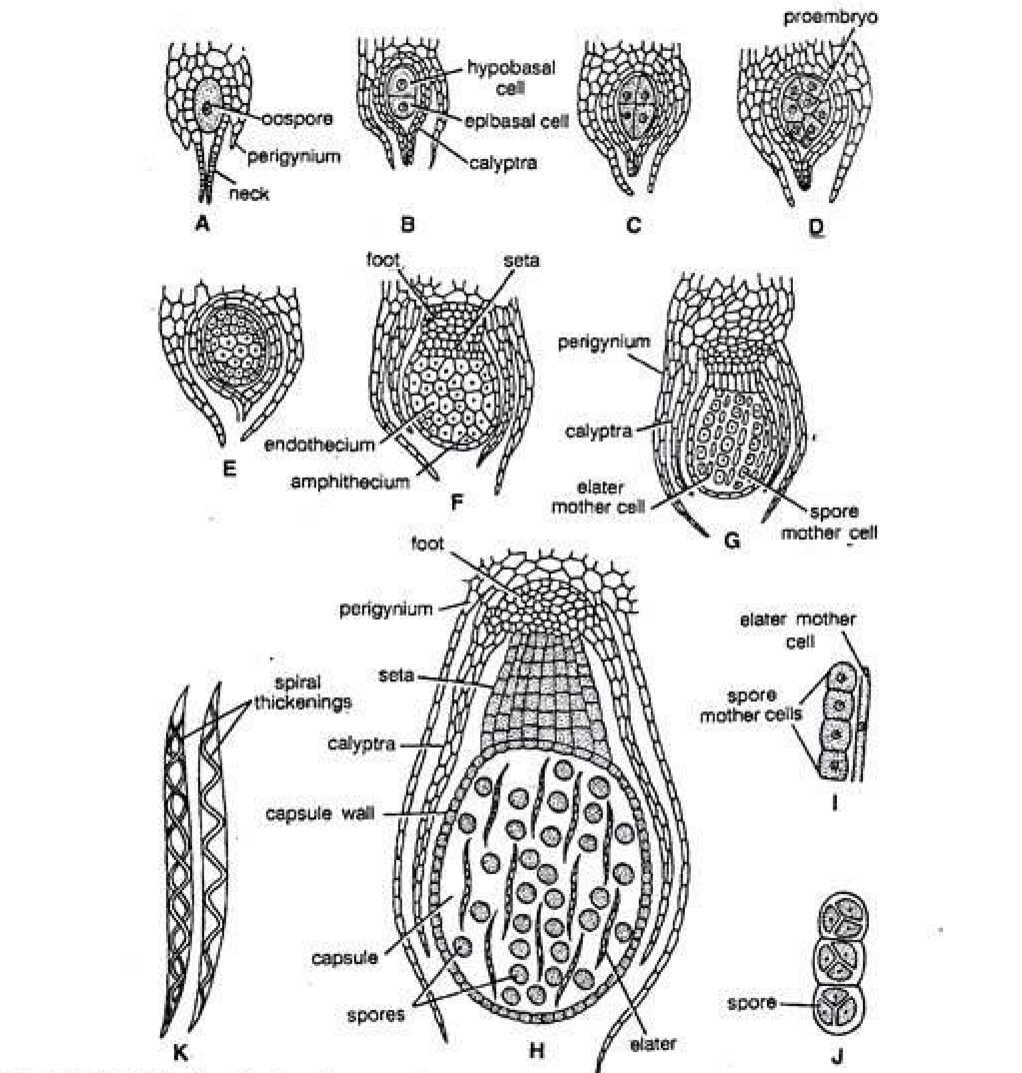

Fig. 12. (A-J). *Marchantia*. Development of sporophyt. (A-J). Successive stages in the development of sporoginium, (H). L.S. of mature sporogonium, (J) Spores tetred, (K) Two elaters.

The quadrant type of development of sporogonium is quite common in many species of Marchantia (e.g., M. polymorpha) but in a few species zygote divides by two transverse divisions to form the 3-celled filamentous embryo. In it the hypo basal cell forms the foot, the middle seta and the epibasal cell develops into capsule. However, it is the rare type of embryo development in M. chenopoda.

Alternation of Generation in Marchantia:

The life cycle of Marchantia shows regular alternation of two morphologically distinct phases. One of the generations is Haplophase and the other is diplophase.

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FUNGI

CHARACTERISTICS OF FUNGI

Following are the important characteristics of fungi:

1. Fungi are eukaryotic, non-vascular, non-motile and heterotrophic organisms.
2. They may be unicellular or filamentous.
3. They reproduce by means of spores.
4. Fungi exhibit the phenomenon of alternation of generation.
5. Fungi lack chlorophyll and hence cannot perform photosynthesis.
6. Fungi store their food in the form of starch.
7. Biosynthesis of chitin occurs in fungi.
8. The nuclei of the fungi are very small.
9. The fungi have no embryonic stage. They develop from the spores.
10. The mode of reproduction is sexual or asexual.
11. Some fungi are parasitic and can infect the host.
12. Fungi produce a chemical called pheromone which leads to sexual reproduction in fungi.
13. Examples include mushrooms, moulds and yeast.

Classification of Fungi:

Kingdom Fungi are classified based on different modes. The different classification of fungi is as follows:

Based on Mode of nutrition

On the basis of nutrition, kingdom fungi can be classified into 3 groups.

1. **Saprophytic** – The fungi obtain their nutrition by feeding on dead organic substances. Examples: *Rhizopus, Penicillium* and *Aspergillus*.
2. **Parasitic** – The fungi obtain their nutrition by living on other living organisms (plants or animals) and absorb nutrients from their host. Examples: *Taphrina* and *Puccinia*.
3. **Symbiotic** – These fungi live by having an interdependent relationship with other species in which both are mutually benefited. Examples: Lichens and mycorrhiza. Lichens are the symbiotic association between algae and fungi. Here both algae and fungi are mutually benefited as fungi provide shelter for algae and in reverse algae synthesis carbohydrates for fungi. Mycorrhiza is the symbiotic association present between fungi and plants. Fungi improve nutrient uptake by plants, whereas, plants provides organic molecules like sugar to the fungus.

Based on Spore Formation

Kingdom Fungi are classified into the following based on the formation of spores:

1. **Zygomycetes** – These are formed by the fusion of two different cells. The sexual spores are known as zygospores, while the asexual spores are known as sporangiospores. The hyphae are without the septa. Example – *Mucor*.
2. **Ascomycetes** – They are also called sac fungi. They can be coprophilous, decomposers, parasitic or saprophytic. The sexual spores are called ascospores. Asexual reproduction occurs by conidiospores. Example – *Saccharomyces.*
3. **Basidiomycetes** – Mushrooms are the most commonly found basidiomycetes and mostly live as parasites. Sexual reproduction occurs by basidiospores. Asexual reproduction occurs by conidia, budding or fragmentation. Example- *Agaricus.*
4. **Deuteromycetes** – They are otherwise called imperfect fungi as they do not follow the regular reproduction cycle as the other fungi. They do not reproduce sexually. Asexual reproduction occurs by conidia. Example – *Trichoderma*.

LIFE CYCLE OF SACCHAROMYCES

Cell Structure of Saccharomyces:

The genus Saccharomyces (Gr. Saccharon, sugar; mykes, fungus) consists of about 41 species. 5. cerevisiae, commonly known as Brewer yeast or Backer's yeast is used widely in wine and baking industry.

It produces two types of enzymes: an extracellular invertase and an intracellular zymase. The invertase hydrolyses canesugar to dextrose or invert sugar and zymase breaks invert sugar into ethyl alcohol and carbon dioxide.

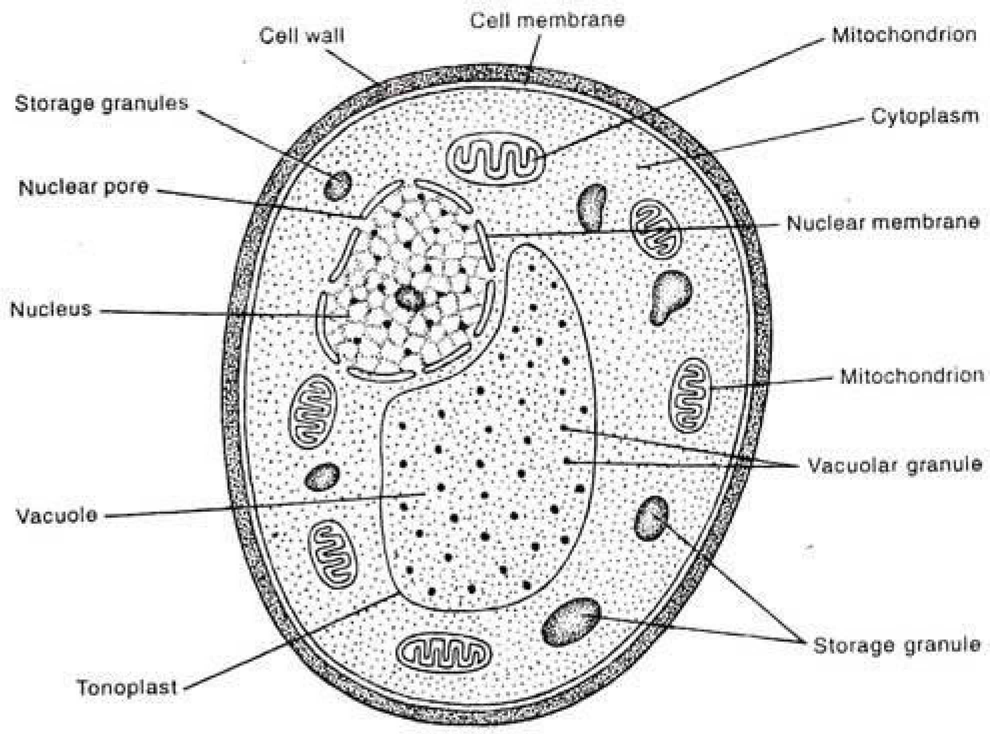


Fig. 4.34 : Cell structure of *Saccharomyces cerevisiae* under electron microscope

Vegetative Body of Saccharomyces:

The thalloid plant body is unicellular, but during rapid multiplication by budding the cells may remain attached in chain forming pseudo- mycelium (Fig. 4.38). The cells may be globose, elliptical, oval to even rectangular in shape and measure about 5-6 x 6-8 µm.

Electron microscopic studies (Fig. 4.34, 4.35) and chemical analysis of Saccharomyces cerevisiae show that the cells are surrounded by a distinct cell wall with three layers. The outermost layer mainly consists of protein-mannan and some chitin; the middle layer mainly of glucan and the innermost layer consists of proteinglucan.

Some phosphate and lipids are also present, while cellulose is absent in the cell wall. Inner to the cell watl is the cell membrane (plasmalemma), i.e., an usual unit membrane having series of shallow, elongated pits or invaginations (Fig. 4.35).

In the centre, the cell having a large central vacuole, limited by a single membrane, the tonoplast, which contains a watery substance, granules of polymetaphosphate and lipid.

Reproduction in Saccharomyces:
Saccharomyces reproduces by vegetative, asexual and sexual means.

A. Vegetative Reproduction:
Vegetative reproduction takes place by fission and budding.

(a) Fission:
It takes place during favourable condition. In this process, single vegetative cell forms two daughter cells of equal size (Fig. 4.36). During fission, a constriction appears in the middle of the cell and simultaneously nucleus undergoes mitotic division.

Both the steps progress simultaneously. After nuclear migration, one at each side, partition wall forms almost in the half way of the mother cell and, as such, two daughter cells are formed.

(b) Budding:
Budding also takes place during favourable condition. The protoplasm of vegetative cell swells up at one side in the form of a bud (Fig. 4.37). The nucleus undergoes mitotic division. Out of two nuclei formed by mitosis, one goes to the bud and other one remains in the mother. Bud enlarges and eventually cuts off from the mother by partition wall.

The size of the bud is always smaller than the mother cell. After maturation, these bud separate from the mother and leave a convex scar on the surface, called bud scar. Similar scar with concave surface remains on the wall of the bud, called birth scar.

Sometimes due to rapid division, large number of buds develop without being detached from one another and persist in the form of branched or unbranched chain, called pseudo-mycelium (Fig. 4.38). Finally the cells get detached and grow individually.

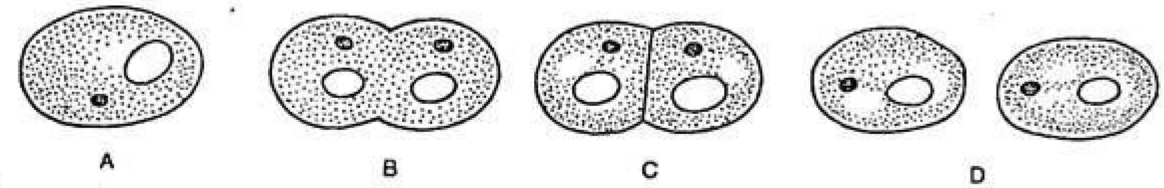


Fig. 4.36 : *Saccharomyces cerevisiae* : A-D. Stages of fission

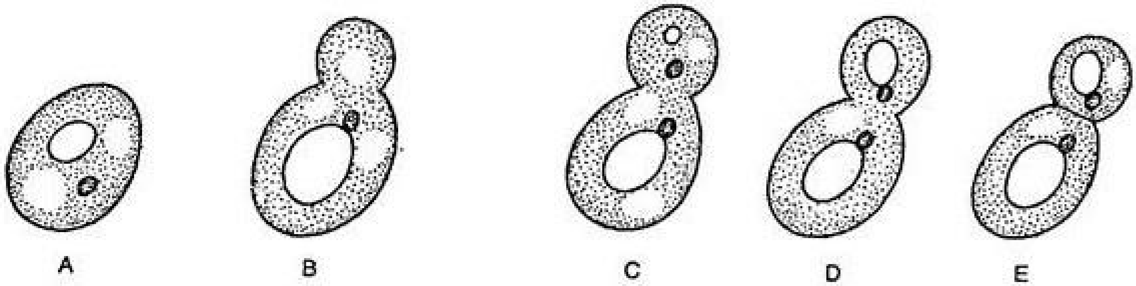


Fig. 4.37 : *Saccharomyces cerevisiae* : A-D. Stages of budding

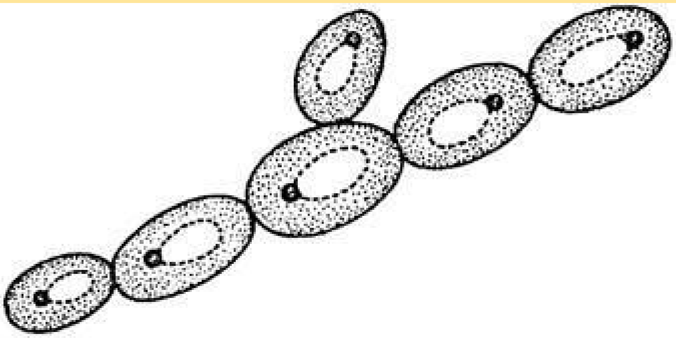


Fig. 4.38 : Pseudomycelium of *S. cerevisiae*

B. Asexual Reproduction:

It takes place during unfavourable condition by the formation of thick walled spore, called endospore (Fig. 4.39). During this process nucleus divides mitotically and forms four nuclei. The protoplast divides into four units, each with one nucleus and forms four endospores. During favourable condition, endospore germinates by budding and buds grow individually.

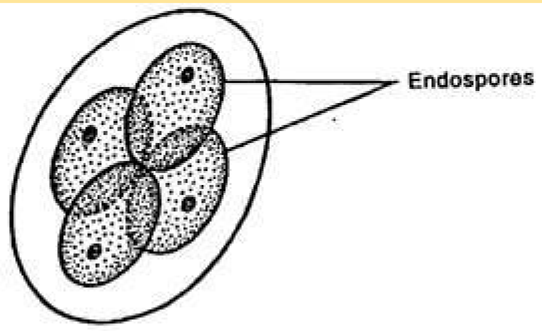


Fig. 4.39 : *Schizosaccharomyces pombe* : Endospores (four) in a cell

C. Sexual Reproduction:

Sexual reproduction takes place during unfavourable condition. In this process, two vegetative cells or ascospores behave as gametangia (Fig. 4.40). Two such cells come very close and develop beak-like outgrowth towards each other. Both the outgrowths come in contact and the intervening walls between them dissolve.

The nuclei of both the gametangia come to the fused outgrowth (conjugation tube) and they fuse therein to form a diploid zygote. The zygote behaves as an ascus. The diploid nucleus of zygote undergoes meiotic division forming 4 or 8 (with additional mitosis) ascospores. The ascospores are liberated by breaking the ascus wall and behave as somatic cell.

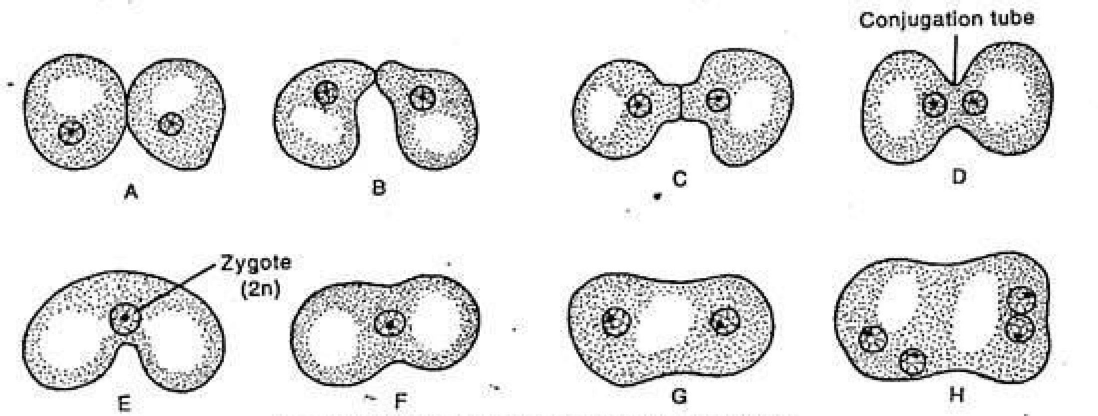


Fig. 4.40 : Different stages (A-H) of sexual reproduction

Life Cycle Patterns of Saccharomyces:

Three patterns of life cycle are found in yeast:

Haplobiontic, diplobiontic and haplodiplobiontic:

1. Haplobiontic Type:

This type of life cycle is characterised by more elaborate haploid phase than the diploid phase, found in Schizosaccharomyces octosporus (Fig. 4.41 A). The diploid phase is restricted only in the zygote. The vegetative cells are haploid and behave as gametangia.

Two such gametangia fuse together and form a diploid cell. The diploid cell behaves as an ascus whose nucleus divides first meiotically, then mitotically; results in the formation of eight ascospores. After maturation, the ascospores liberate by bursting the ascus wall. The ascospores then behave as vegetative cell and continue multiplication through budding.

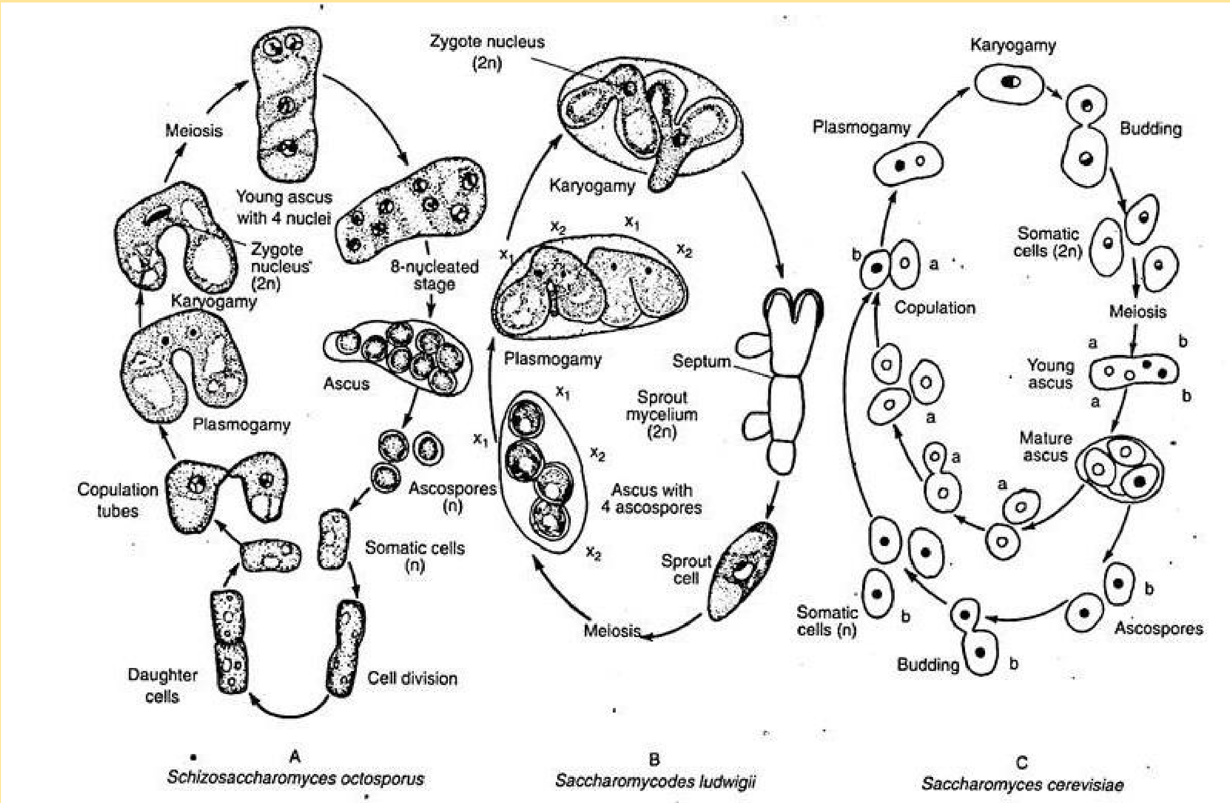


Fig. 4.41: Life cycles of three types of yeasts : A. Haplobiontic (*Schizosaccharomyces octosporus*). B. Diplobiontic (*Saccharomycodes ludwigii*), C. Haplo-diplobiontic (*Saccharomyces cerevisiae*).

2. Diplobiontic Type:

This type of life cycle is characterised by more elaborate diploid phase than the haploid phase, found in Saccharomycodes ludwigii (Fig. 4.41 B). The haploid phase is restricted only in ascospore, with short duration. The ascospores behave as gametangia and, without liberating from ascus, they unite in pair. The paired gametangia after fusion produce diploid zygote.

The zygote then germinates by producing germ tube which comes out through the ascus wall. The germ tube becomes multicellular from which diploid sprouts develop by budding. After detachment from the mother, the diploid sprouts function as asci and produce four ascospores by reduction division.

3. Haplo-Diplobiontic Type:

This type of life cycle is represented by haploid and diploid phases, of more or less equal duration, found in Saccharomyces cerevisiae (Fig. 4.41 C). The haploid cells of opposite mating type normally multiply by budding. Two such cells of opposite mating behave as gametangia and undergo fusion. The fused gametangia develop a diploid zygote.

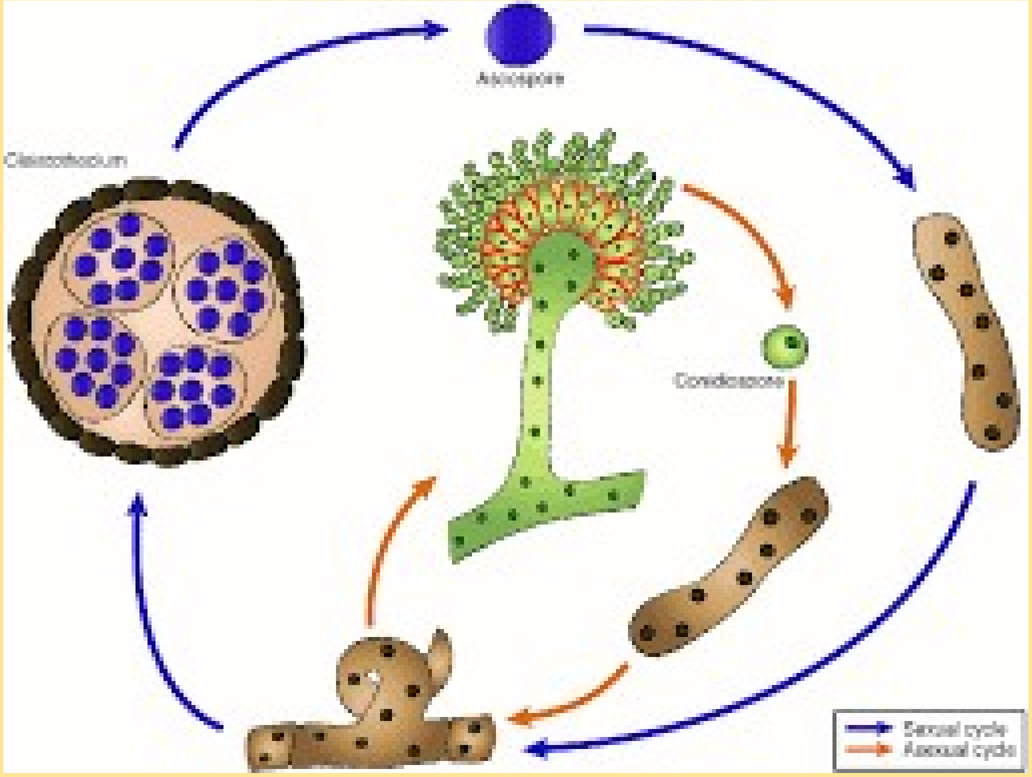
The diploid zygote like the haploid cells undergoes budding and forms many diploid cells. With the scarcity of food, the diploid cell behaves as an ascus and by reduction division it forms four haploid ascospores. After liberating from the mother wall, the ascospores undergo budding and form many haploid somatic cells.

LIFE CYCLE OF ASPERGILLUS

Aspergillus can reproduce sexually or asexually, like all species in the phylum Ascomycota. Most of the time, they reproduce asexually, while others, like *Aspergillus Niger*, are known to reproduce sexually.

Because of the high oxygen tension, *Aspergillus* species frequently develop as moulds on the surface of a substrate. They are highly aerobic and can be found in practically all oxygen-rich situations. *Aspergillus* species can grow in or on various plants and trees and are frequently found in starchy foods (like potatoes and bread). Aspergillus species, such as *A. niger* and *A. fumigatus*, rapidly colonise structures, preferring warm, wet, or humid regions like restrooms and the area around window frames.

The most widespread aspergillus species is *A. niger*. They undergo vegetative, sexual or asexual reproduction.



- Conidial spores are produced by *Aspergillus niger* during asexual reproduction.
- The life cycle begins with the dispersal of the conidia onto a substrate with an optimum temperature of at least 25 to 40 °C.
- Conidia then develop into vegetative cells by germination.
- The cells transform into hyphal mycelium and branches dichotomously to form aerial hyphae.
- The aerial hyphae develop into conidiophores, which enlarge at the apex to produce the conidiophore's vesicle.
- The primary sterigmata, called the phialides, develop from the vesicles.
- The secondary sterigmata are formed by the sterigmata, which begin to produce conidial spores.
- On top of the phialides, the spores are organised in columns (multiple rows).

A haploid phase and a diploid phase alternate in the life cycle of a sexually reproducing fungi. Nuclear fusion signals the end of the haploid phase and the start of the diploid phase, which is when the zygote is formed. Meiosis (reduced division) begins the haploid stage, producing the gametes, and restores the haploid amount of chromosomes.

LICHEN

What is Lichen? – Lichen Definition

lichen is not a single organism but a symbiosis among different organisms like fungus and a cyanobacterium or algae. Cyanobacteria are also referred to as blue-green algae despite the fact of being distinct from algae.

The fungal part is called mycobiont and non-fungal part is called photobiont that contains chlorophyll. Many lichen partners include one photobiont and one mycobiont which is not universal and there are lichens with more than one photobiont partner.

The fungal partner is viewed to be composed of filamentous cells and every filament is known as hypha. These hyphae may branch but maintain a constant distance and grow by extension. There are a few lichens with filamentous structure among the photobionts while others consist of chains of more or fewer cells.

The species of Ascomycetes or Basidiomycetes are the most common fungi in lichens. The common algal partners are either green algae Chlorophyta or Cyanophyceae family of blue-green bacteria. Normally, fungal partners cannot live without its phycobiont, but algae are often capable of living independently in water or moist soil. The largest lichen can make a thallus up to 3ft long, although most of them are smaller than a few centimetres. They are colourful, ranging from yellow to greens and black hues.

Mostly, lichens grow slowly. The one in which the phycobiont is a blue-green bacterium has the ability to convert nitrogen gas into ammonia. Some can reach the age of many centuries, mainly the one living in stressful environments such as arctic tundra or alpine.

Types of lichens

The growth form in which the lichens are leafy or bush-like are termed macrolichens. The other forms are called microlichens.

Lichens exist in one of the below-mentioned growth forms.

- **Crustose** grow across the substrate.
- **Foliose** are flat, leaf-like sheets of tissues and not bound closely.
- **Squamulose** are closely clustered and lit flattened pebble units.
- **Fruticose** are freely available in standing branching tubes.
- **Gelatinous** or jelly-like appearance
- **Leprose** are lichens with powdery appearance.

Likewise, lichens can also be seen in various colours like yellow, orange, red, brown, etc. These colours are due to the presence of special pigment called usnic acid. In the absence of this pigment, they are generally olive gray or green.

Internal Structure

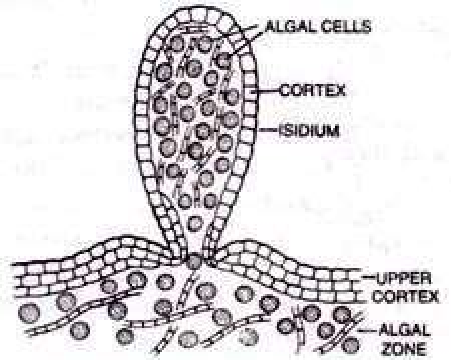


Fig. 2.55. Part of V.S. lichen showing an isidium and algal zone.

As per the diversity of basic growth, lichens have an identical internal morphology. The filaments of the fungal partner form the bulk of lichen’s body, and the layers in the lichen are defined by the relative density of these filaments.

The filaments are packed closely at the outer surface to form cortex that helps in contact with their surroundings.

The algal partner cells are not distributed below the cortex as the fungal filaments are scattered. The medulla is below the algal layer which is a loosely woven layer of fungal filaments. There is another layer beneath the medulla in foliose lichens and is in direct contact with the underlying substrate in squamulose and crustose lichens.

STRUCTURE OF LICHENS

In shape, the lichens are of three types:

i) Crustose:

Crust-like closely appressed to the substratum and attached to it at several places, e.g., Graphis, Lecanora, Rhizocarpon, Haematoma.

(ii) Foliose:

The body of the lichen is flat, broad, lobed and leaf-like which is attached to the substratum at one or a few places, e.g., Parmelia, Peltigera. Foliose lichen Cora (= Dictyonema) pavonia resembles bracket fungi in appearance.

(iii) Fruticose:

The lichen is branched like a bush and attached to the substratum by means of disc, e.g., Cladonia, Usnea, Evernia. The bulk of lichen body is formed by fungal partner or mycobiont. It includes the surface, medulla (or interior) and rhizines (attaching devices). The algal partner or phycobiont constitutes hardly 5% of the lichen body. It is generally restricted to a narrow zone (algal zone) below the surface.

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PLANT PATHOLOGY

Plant pathology is a science that studies plant diseases and attempts to improve the chances for survival of plants when they are faced with unfavorable environmental conditions and parasitic microorganisms that cause disease.

Red rot

Disease symptoms

The spindle leaves (3rd & 14th)) display drying. At a later stage, stalks become discoloured and hollow.

- Acervuli (black fruiting bodies) develop on rind and nodes. After splitting open the diseased stalk, a sour smell emanates.
- The internal tissues are reddened with intermingled transverse white spots.

Survival and spread

- In rainy season, the disease spreads so fast that whole crop dries and not a single milleable cane is obtained

Favourable conditions

- Primary transmission through soil and diseased setts, while the secondary transmission through air, rain splash and soil.

Wilt

Disease symptoms

- Externally gradual yellowing and drying of foliage, shrinkage/withering of canes.
- Internally light to dark purplish or brown discolouration of ground tissue, pithiness and boat shaped cavities in the middle of the internodes

Survival and spread

- The wilt pathogens are transmitted through soil, seed pieces, wind, rain and irrigation water.

Favourable conditions

- The disease symptoms appear during the monsoon and post monsoon periods, affected plants are present either singly or in small groups

Grassy shoot

Disease symptoms

- The disease is characterized by proliferation of vegetative buds from the base of the cane giving rise to crowded bunch of tillers bearing narrow leaves.
- The tillers bear pale yellow to completely chlorotic leaves.

- Cane formation rarely takes place in affected clumps and if formed the canes are thin with short internodes.

Survival and spread

- The grassy shoot disease is primarily transmitted through the diseased seed material (setts) and perpetuated through ratooning.
- The MLO is readily transmitted by sap inoculation and in the field it is transmitted through infected setts and perpetuated through crop ratooning.
- The aphids are the vectors for this disease
- This disease is also transmitted by a) mechanically by cutting knife, b) Insects (aphids, black hopper) and c) Dodder (root parasite).

Smut

Disease symptoms

- Production of whip like structure of 25 – 150 cm. from the growing point of the canes.
- Whip covered by translucent silvery membrane enclosing mass of black powdery spores.
- Initial thin canes with elongated internodes later become reduced in length.
- Profuse sprouting of lateral buds with narrow, erect leaves especially in ratoon crop

Survival and spread

- Sugarcane smut is disseminated via teliospores that are produced in the smut whip. These teliospores located either in the soil or on the plant, germinate in the presence of water.
- The primary transmission of the disease is through diseased seed pieces, while the secondary transmission is through windblown spores.
- In addition, spores or sporidia, present in or on the soil surface, are also carried to different fields through rain or irrigation water.

Favourable conditions

- Hot dry weather is suitable for the completion of disease cycle however; pathogen requires wet conditions for development of teliospores.

Leaf scald disease

Disease symptoms

- The disease can be latent, it can develop unseen for some time and when symptoms fi rst appear, the plant is already seriously infected.
- The first sign of the disease is the development of "pencil lines" of white with yellow borders following the veins on the leaf that lead to necrosis (death) of tissue.
- The term "scald" for the disease comes from areas of the leaf that loose their color and become a pale green (chlorotic) as they fail to produce chloroplasts.

Survival and spread

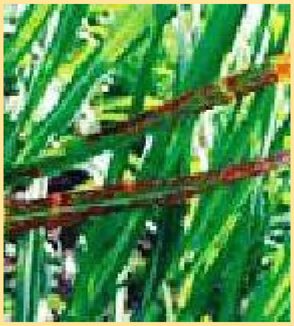
- Pathogen survives in cane stubble and on agricultural implements and this is an important mechanism of spreading the disease.
- It can also survive on grasses, including elephant grass and may be transmitted from them to sugarcane.

Favourable conditions

- Periods of stress such as drought, waterlogging, and low temperature are reported to increase disease severity.

Red striped disease

Disease symptoms



- Red stripe is characterized by the appearance on the leaves of chlorotic lesions carrying dark red stripes 0.5-1.0 mm in breadth and several mm in length, either distributed all over the blade, or concentrated in the middle
- Several of them may coalesce to cover large areas of the leaf blade, and to cause wilting and drying of the leaves.
- Whitish flakes occur on the lower surface of the leaf, corresponding to the red lesions on the upper surface.
- These flakes are the dry bacterial ooze. When young shoots are affected, shoot or top rot may result. The growing points of the shoot are yellow and later reddish with dark brown stripes on the shoots.
- If the affected plants are cut by splitting the shoot downwards, dark red discolouration of the tissues may be seen.
- In the affected canes cavities may form in the pith region, and the vascular bundles are distinct because of the dark red discolouration.

Survival and spread

- The disease spreads in the field by wind and rain, and by cutting, as the basal stem from which the sets are taken is mostly free from the bacterial infection.

Favourable conditions

- Moist humid conditions favour the development of disease.

Mosaic disease

Disease symptoms

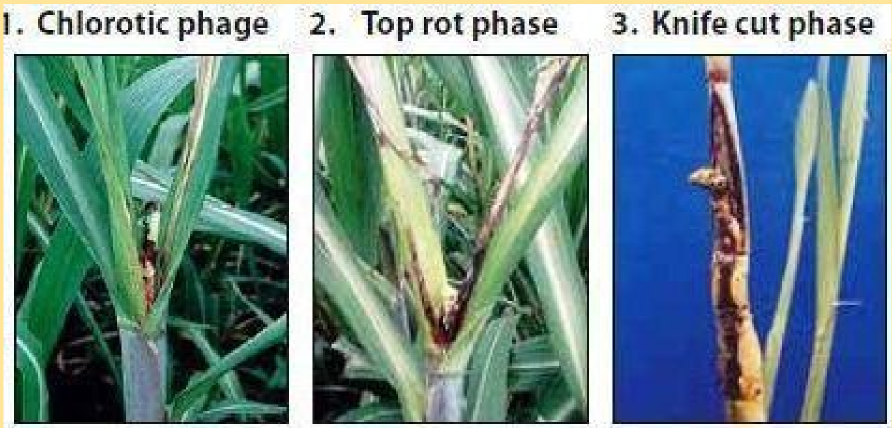
- Young leaves of the crown held against the light source display chlorotic and normal green area imparting mosaic pattern.
- The chlorotic area may show reddening or necrosis.
- Leaf sheath may also display such symptoms.

Transmission

- Primarily transmitted through the diseased seed material and perpetuated through ratooning. This disease is also transmitted mechanically by cutting knife.

Pokkahboeng

Disease symptoms



- The general symptoms of Pokkahboeng are mainly of three types;
- Chlorotic Phase: The earliest symptom of Pokkahboeng is a chlorotic condition towards the base of the young leaves and occasionally on the other parts of the leaf blades.

- Frequently, a pronounced wrinkling, twisting and shortening of the leaves accompanied the malformation or distortion of the young leaves. The base of the affected leaves is seen often narrower than that of the normal leaves..
- Acute Phase or Top-Rot Phase: The most advanced and serious stage of Pokkahboeng is a top rot phase. The young spindles are killed and the entire top dies.
- Leaf infection sometimes continued to downward and penetrates in the stalk by way of a growing point. In advanced stage of infection, the entire base of the spindle and even growing point showed a malformation of leaves, pronounced wrinkling, twisting and rotting of spindle leaves. Red specks and stripes also developed.
- Knife-cut Phase (associate with top rot phase): The symptoms of knife-cut stage are observed in association with the acute phase of the disease characterized by one or two or even more transverse cuts in the rind of the stalk /stem in such a uniform manner as if, the tissues are removed with a sharp knife, This is an exaggerated stage of a typical ladder lesion of a Pokkahboeng disease.

Survival and spread

- This is an air-borne disease and primarily transmitted through the air-currents and secondary transmission is through the infected setts, irrigation water, splashed rains and soil.

Favourable conditions

- 20-30°C temperature and the average relative humidity higher than 70 to 80% with a cloudy weather, drizzling rains favors the growth of pathogen.

Rust

Disease symptoms

- The earliest symptoms of common rust on the leaves are small, elongated yellowish spots which are visible on both the surfaces.
- These spots increase in size, mainly in length, and turn red-brown to brown in color. A narrow, pale yellow-green halo develops around the lesions.
- When the common rust is severe, numerous lesions occur on individual leaves giving them an overall brown or rusty appearance. These lesions coalesce to from large, irregular necrotic areas is usually result in premature death of the leaf. In such cases, the number of live leaves per plant can be seriously reduced.

Survival and spread

- The rust pathogen is transmitted by wind and water splash of the urediospores.

Favourable conditions

- High humidity and warm temperature favours the development of diseases.

Sugarcane yellow leaf disease

Disease symptoms

- Symptoms of SCYLD are a yellowing of the leaf midrib on the underside of the leaf. The yellowing first appears on leaves 3 to 6 counting down from the top expanding spindle leaf.
- Initial symptoms of yellow leaf, with a yellowing of the lower surface of the leaf midrib of leaves 3 to 6 counting from the top expanding spindle leaf.
- Yellowing is most prevalent and noticeable in mature cane from October until the end of harvest in March.
- The yellowing expands out from the leaf midrib into the leaf blade as the season progresses until a general yellowing of the leaves can be observed from a distance.

Transmission

- The virus is transmitted by aphids, Melanaphis sacchari and Rhopalosiphum maidis, in a semi-persistent manner. The virus is also spread by planting infected seed cane.

Favourable conditions

- Dry weather conditions during October to until the end of harvest in March.

CITRUS CANKER

Citrus canker is a citrus disease caused by the bacterium *Xanthomonas citri* subsp. *citri* (synonym *X. axonopodis* pv. *citri*). While not harmful to humans, canker significantly affects the vitality of citrus trees, causing leaves and fruit to drop prematurely. A fruit infected with canker is safe to eat, but has reduced marketability as fresh fruit.

The bacteria that cause citrus canker enter leaves through stomata, or through wounds caused by weather damage or insects, such as the citrus leaf miner (*Phyllocnistis citrella*). Young leaves are the most susceptible. Symptoms generally appear within 14 days of exposure to the canker bacteria. The bacteria remain viable in old lesions and on plant surfaces for several months.Canker lesions ooze bacterial cells, which can be dispersed by wind and rain. Infection may spread further by heavy rain and wind events such as hurricanes. People can move the disease by moving contaminated equipment and tools, tree clippings, untreated infected fruit, and infected plants. The disease thrives in areas with high rainfall and high temperatures. Citrus species, such as grapefruit, lime and lemon, are most susceptible to citrus canker.

DISEASE: Citrus canker

PATHOGEN: *Xanthomonas axonopodis* **pv.** *citri* **and** *Xanthomonas axonopodis* **pv.** *Aurantifolii*

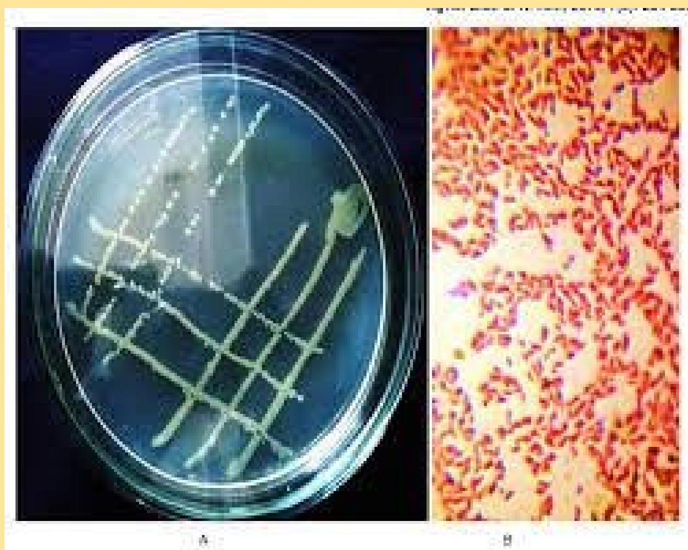
HOSTS: Numerous species, cultivars, and hybrids of citrus and citrus relatives including orange, grapefruit, pummelo, mandarin, lemon, lime, tangerine, tangelo, sour orange, rough lemon, calamondin, trifoliate orange, and kumquat.

Symptoms

Citrus canker can be a serious disease where rainfall and warm temperatures are frequent during periods of shoot emergence and early fruit development. This is especially the case where tropical storms are prevalent. Citrus canker is mostly a leaf-spotting and fruit rind-blemishing disease, but when conditions are highly favorable for infection, infections cause defoliation, shoot dieback, and fruit drop.

Leaf Lesions: Citrus canker lesions start as pinpoint spots and attain a maximum size of 2 to 10 mm diameter. The eventual size of the lesions depends mainly on the age of the host tissue at the time of infection and on the citrus cultivar. Lesions become visible about 7 to 10 days after infection on the underside of leaves and soon thereafter on the upper surface. The young lesions are raised or 'pustular' on both surfaces of the leaf, but particularly on the lower leaf surface . The pustules eventually become corky and crateriform with a raised margin and sunken center. A characteristic symptom of the disease on leaves is the yellow halo that surrounds lesions . A more reliable diagnostic symptom of citrus canker is the water-soaked margin that develops around the necrotic tissue , which is easily detected with transmitted light.

Causal Organism:



Xanthomonas citri

The bacterium *Xanthomonas axonopodis* pv. *citri* is a rod-shaped, gram-negative, and has a single polar flagellum. Colonies on laboratory media are usually yellow due to ‘xanthomonadin’ pigment production. When glucose or other sugars are added to the culture medium, colonies become very mucoid due to the production of an exopolysaccaride slime. A semi-selective medium can be prepared by adding an antibiotic, kasugamycin, which inhibits many contaminants but not xanthomonads. The maximum and optimum temperature ranges for growth are to 39°C (95 to 102°F) and 28 to 30°C (82 to 86°F), respectively.

Disease Cycle

Bacteria propagate in lesions in leaves, stems, and fruit. When there is free moisture on the lesions, the bacteria ooze out and can be dispersed to infect new growth. Wind-driven rain is the main dispersal agent and wind ≥ 8 m/s (18 mph) aids in the penetration of bacteria through the stomatal pores (Drawing of the disease cycle) or wounds made by thorns , insects (leafminer) , and blowing sand. Pruning causes severe wounding and can lead to infection. Multiplication of bacteria occurs mostly while the lesions are still expanding and numbers of bacteria produced per lesion is related to general host susceptibility.

Disease Management: In countries where the disease is well established and severe, only the more resistant types of citrus, such as Valencia oranges and mandarins may be profitable. In regions where canker is endemic, certain cultural practices are used to reduce the severity of the disease. It is imperative to avoid working in infected orchards when the trees are wet from dew or rain. The reduction of wind is another primary concern. Wind speeds are reduced by deployment of windbreaks on the perimeter of the orchard or between the rows. Reduction of wind speed lowers the probability of direct penetration of stomates by bacteria as well as entry of wind-induced injuries on foliage and fruit.

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PTERIDOPHYTES

Introduction:

Before the flowering plants, the landscape was dominated with plants that looked like ferns for hundreds of millions of years. Pteridophytes show many characteristics of their ancestors. Unlike most other members of the PlantKingdom, pteridophytes don’t reproduce through seeds, they reproduce through spores instead.

Pteridophyta Classification

Pteridophyta is classified into four main classes:

Psilopsida

- They are the most primitive.
- The stem is photosynthetic and dichotomously branched.
- Rhizoids are present.
- Leaves are mostly absent.
- The sporophyte is homosporous synangium.
- Examples- *Psilotum and Tmesipteris.*

Lycopsida

- They are commonly known as club moss.
- Well-differentiated plant body with adventitious root, stem, rhizophores and leaves.
- The sporophyte is homosporous or heterosporous.
- Examples- *Selaginella, Lycopodium.*

Sphenopsida

- Commonly known as horsetail.
- Well-differentiated plant body with roots arising from nodes of the underground rhizome, stem and scaly leaves.
- Homosporous, sporangia are borne on strobili.
- Examples- *Equisetum.*

Pteropsida

- Commonly known as a fern.
- Well-differentiated plant body with roots, stem and leaves.
- The sporophyte is homosporous or heterosporous.
- Antherozoids are multiflagellate.
- Examples- *Pteris, Dryopteris, Adiantum*

Pteridophyta Characteristics

1. Pteridophytes are considered as the first plants to be evolved on land:

It is speculated that life began in the oceans, and through millions of years of evolution, life slowly adapted on to dry land. And among the first of the plants to truly live on land were the Pteridophytes.

2. They are cryptogams, seedless and vascular:

Pteridophytes are seedless, and they reproduce through spores. They contain vascular tissues but lack xylem vessels and phloem companion cells.

3. The plant body has true roots, stem and leaves:

They have well-differentiated plant body into root, stem and leaves.

4. Spores develop in sporangia:

The sporangium is the structures in which spores are formed. They are usually homosporous (meaning: one type of spore is produced) and are also heterosporous, (meaning: two kinds of spores are produced.)

Read More: Sporulation

5. Sporangia are produced in groups on sporophylls:

Leaves that bear the sporangia are termed as sporophylls. The tip of the leaves tends to curl inwards to protect the vulnerable growing parts.

6. Sex organs are multicellular:

The male sex organs are called antheridia, while the female sex organs are called archegonia.

7. They show true alternation of generations:

The sporophyte generation and the gametophyte generation are observed in Pteridophytes. The diploid sporophyte is the main plant body.

Life Cycle of Pteridophyta

Pteridophytes show alternation of generations. Their life cycle is similar to seed-bearing plants, however, the pteridophytes differ from mosses and seed plants as both haploid gametophyte and diploid sporophyte generations are independent and free-living. The sexuality of pteridophytic gametophytes can be classified as follows:

1. **Dioicous:** the individual gametophyte is either a male producing antheridia and sperm or a female producing archegonia and egg cells.
2. **Monoicous**: every individual gametophyte may produce both antheridia and archegonia and it can function both as a male as well as a female.
3. **Protandrous**: the antheridia matures before the archegonia.
4. **Protogynous**: the archegonia matures before the antheridia.

Pteridophyta Examples

Following are the important examples of Pteridophyta:

- Whisk Fern
- *Dicksonia*
- *Selaginella*

- *Lycopodium*
- *Equisetum*
- *Pteris*
- *Dryopteris*
- *Adiantum*
- Man fern
- Silver fern

Conclusion

Pteridophyta is one of the older groups of plants present in the Plant kingdom. They have evolved much earlier than the angiosperms. They are one of the very first “true” plants to adapt to life on land.

Primary characteristics of Pteridophytes are as follows: They are seedless, vascular plants that show true alternation of generations. Furthermore, the sporophyte has true roots, stems and leaves. They reproduce by spores, which are developed in sporangia. They may be homosporous or heterosporous.

STELAR EVOLUTION IN PTERIDOPHYTES

A stele is the central cylinder or core of vascular tissue in higher plants and Pteridophytes. It consists of the xylem, phloem, pericycle, medullary rays, and pith if present.

The term stele has been derived from a Greek word meaning rod or column. Van Tieghem and Douliot (1886) introduced this term and put forward the stelar theory. The theory suggests that the cortex and the stele are the two fundamental parts of a shoot system. Both these components (stele and cortex) are separated by endodermis.

Types of Stele

Tieghem and Duoliot recognized only three types of steles. They also thought that the monostelic shoot was rare in comparison to polystelic shoots.

But now it is an established fact that most shoots are monostelic and polystelic condition rarely occurs. The stele of the stem remains connected with that of the leaf by a vascular connection known as the leaf supply.

There are several types of stele found in pteridophytes which are:

1. Protostele
2. Siphonostele
3. Solenostele
4. Dictyostele
5. Polycyclic stele
6. Eustele
7. Polystele

1. Protostele

Jeffrey (1898), for the first time, pointed out the stelar theory from the point of view of the phylogeny. According to him, the primitive type of stele is protostele.

In protostele, the vascular tissue is a solid mass and the central core of the xylem is completely surrounded by the strand of phloem. This is the most primitive and simplest type of stele.

- Pith is absent in protostele i.e. it is non-medullated.
- The majority of the pteridophytes show protostelic conditions in their rhizome, stem, or roots.

There are five forms of protostele

1. Haplostele
2. Actinostele
3. Plectostele
4. Mixed Protostele
5. Mixed Protostele with pith

(a) Haplostele

This is the most primitive type of protostele. Here the central solid smooth core of the xylem remains surrounded by uniform layers of phloem (e.g., in Selaginella spp., Gleichenia, Lycopodium).

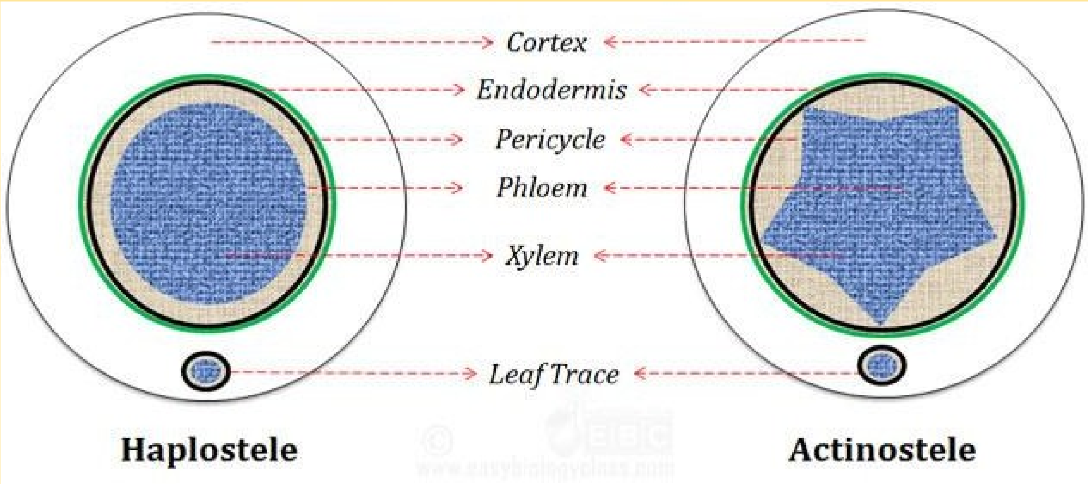
- Named by Brebner in 1902.
- Usually present in fossil genera like Rhynia and Horneophyton.

(b) Actinostele

This is the modification of the haplostele and is somewhat more advanced in having the central xylem core with radiating ribs or arms (e.g., in *Psilotum* spp., *Asteroxylon*, *Lycopodium serratum*).

- Xylem is star-shaped or stellate, hence the name.
- The phloem is not present in a continuous manner.
- Phloem occurs as separate patches between the arms of the xylem.

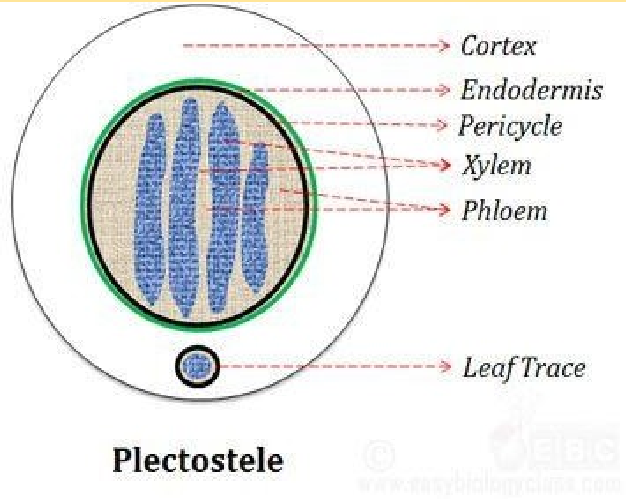
- Named by Brebner in 1902.



(c) Plectostele

This is the most advanced type of protostele. Here the central core of the xylem is divided into a number of plates arranged parallel to each other. The phloem alternates the xylem (e.g., in *Lycopodium clavatum*).

- Named by Zimmerman in 1930.



(d) Mixed protostele

Xylem is divided into several units or groups. Each xylem unit is scattered and arranged inside the groundmass of the phloem. Example: *Lycopodium cernuum*.

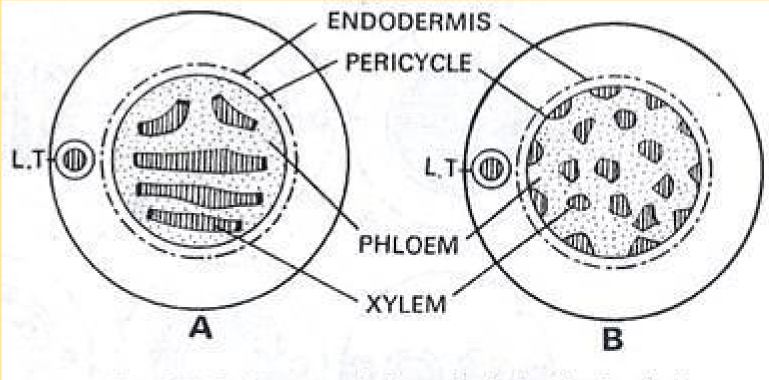


Fig. 32.3. Stelar system in ferns. A, plectostele; B, mixed

(e) Mixed protostele with pith
Here the xylem elements (i.e., tracheids) are mixed with the small patches of parenchymatous cells of the pith. This type is found in primitive fossils and living ferns. They are treated to be the transitional types in between true protosteles on the one hand and siphonosteles on the other (e.g., in *Hymenophyllum demissum*, *Lepidodendron selaginoides,* etc.).

2. Siphonostele

This is the modification of the protostele. A stele in which the protostele is medullated or with a pith at the center is known as siphonostele. Such stele contains a tubular vascular region and a parenchymatous central region i.e the central core of the pith is surrounded by the xylem.

- It is more advanced than protostele.

Origin of siphonostele:
There are different views among scientists regarding the origin of siphonostele. But they all agreed that the siphonostele originated from protostele by the formation of a pith in the center. Here, the centrally placed xylem core is replaced with a parenchymatous pith.

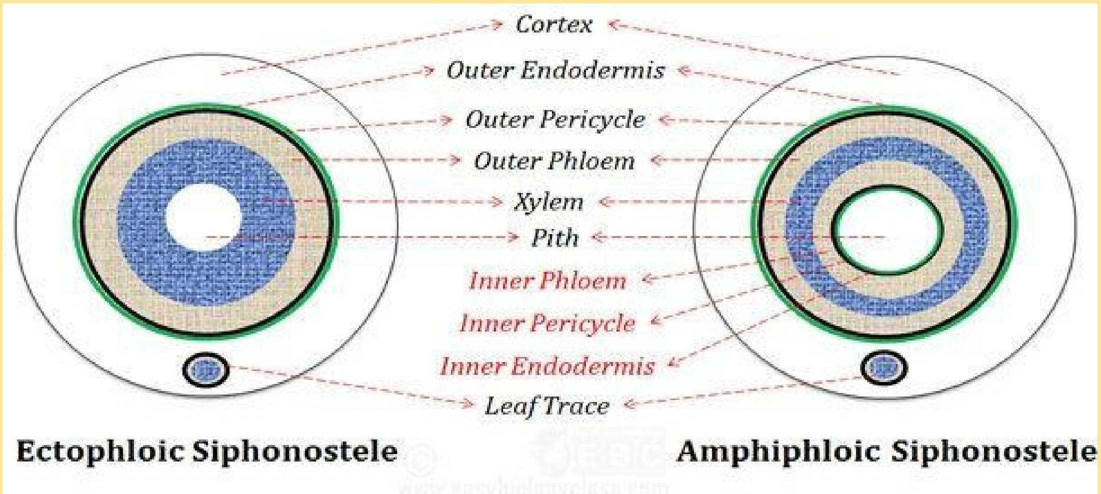
Different stages of changing protostele to siphonostele can be observed in the T.S. at different levels in Gleichenia, Osmunda, and Anemia.

Siphonostele may be of the following types:

(a) Ectophloic
In this type of siphonostele, the pith is surrounded by a concentric xylem cylinder, and next to the xylem the concentric phloem cylinder.

(b) Amphiphloic

In this type of siphonostele, the pith is surrounded by vascular tissue. The concentric inner phloem cylinder surrounds the central pith. Next to the inner phloem is the concentric xylem cylinder which is immediately surrounded by the outer phloem cylinder (e.g., in Marsilea rhizome).

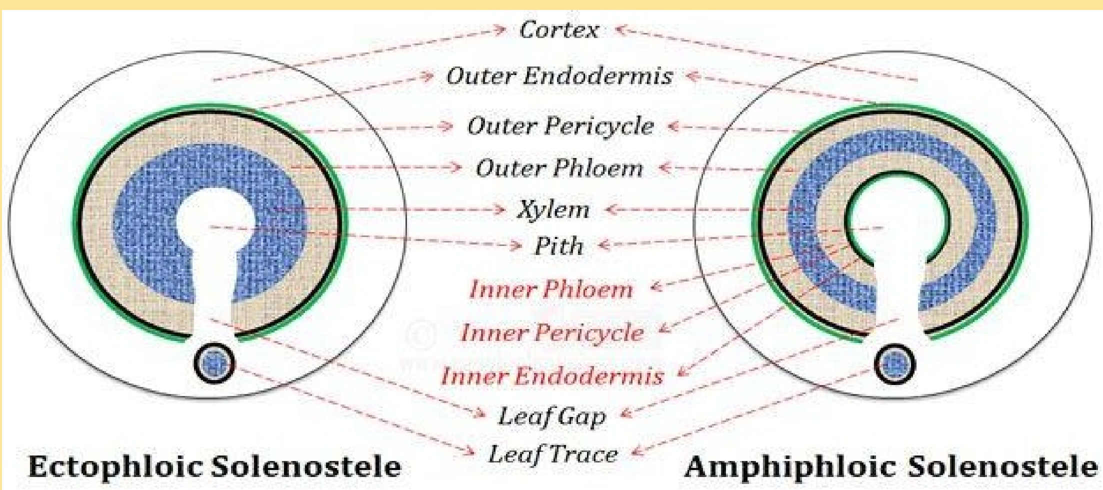


Solenostele

In solenostele, a pith is found with one leaf gap. It may be ectophloic or amphiphloic solenostele.

(a) Ectophloic: Xylem is surrounded only on the outer side by the phloem. E.g. in Osmunda.

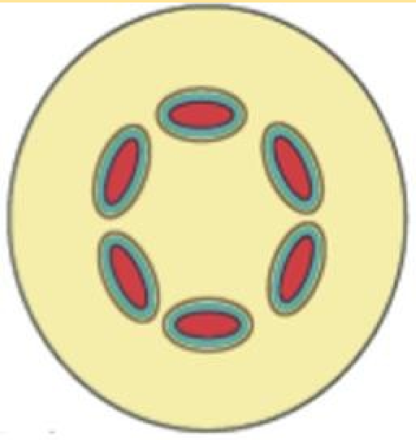
(b) Amphiphloic: In the center, a pith is found. Xylem is surrounded on both sides by phloem. E.g. Marsilea rhizome.



4. Dictyostele

Solenostele which is broken into a network of separate vascular strands is called dictyostele. This breaking up of the stelar core is due to the presence of a large number of leaf gaps.

Each such separate vascular strand is called a meristele. Each meristele is of protostelic type. The dictyostele with many meristeles looks like a cylindrical meshwork.



Examples: Pteris, *Adiantum capillus-veneris*.

5. Polycyclic Stele

This type of stelar organization is the most complex one among all vascular cryptogams (pteridophytes). Such types of steles is always siphonostelic in structure.

A typical polycyclic stele possesses two or more concentric rings of vascular tissue. This may be a solenostele or a dictyostele. Two concentric rings of vascular tissue are found in *Pteridium aquilinum* and three in *Matonia pectinata*.

(a) Polycyclic solenostele

(b) Polycyclic dictyostele

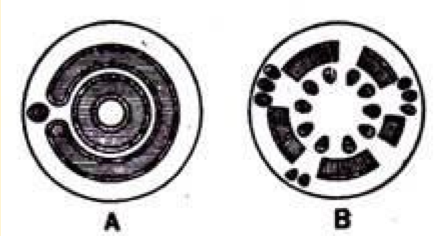


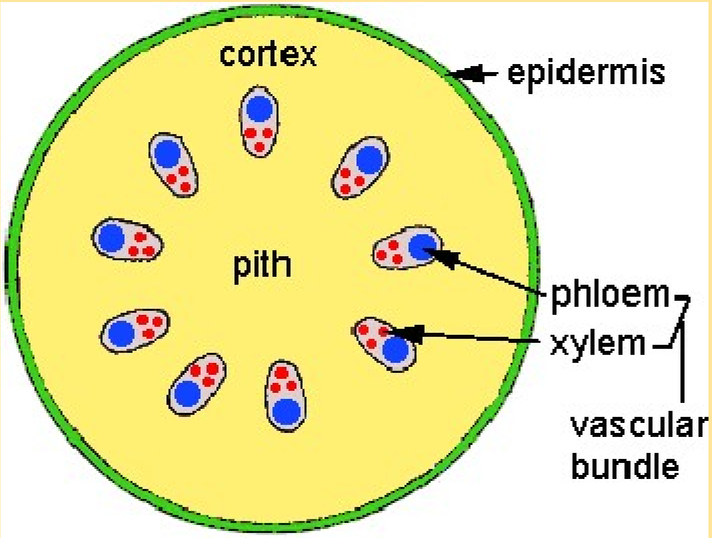
FIG. 581. Polycyclic stele—types (diagrammatic. sectional views). A. Polycyclic solenestele. B. Polycyclic dictyostele.

6. Eustele

According to Brebner (1902), there is one more modification of the siphonostele known as eustele. Here the vascular system consists of a ring of collateral or collateral vascular bundles situated on the periphery of the pith. An example of this type is the internode of Equisetum.

- It is the modification of the ectophloic siphonostele.

- Splitting takes place because of the overlapping leaf gaps.



7. Polystele

More than one stele in the axis of pteridophytes is presently known as a playstyle. It is a type that must have derived from protostele because each such stele shows protostelic condition. In Selaginella kraussiana generally, two steles are present. But in *Selaginella laevigata* as many as 16 steles are present.

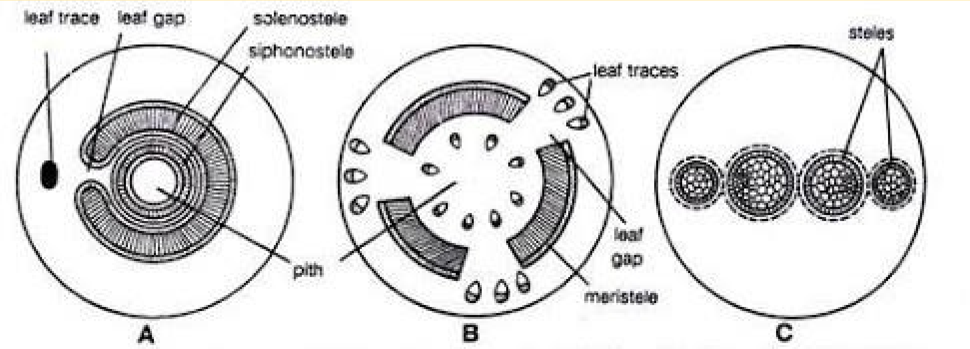


Fig. 6 (A–C). Stelar System : A. Polycyclic solenostele, B. Polycyclic dictyostele, C. Polystele

Other modifications of siphonostele

1. **Cladosiphonostele**: No leaf gaps present. It is the simplest type of siphonostele. And found in several species of Selaginella.
2. **Phyllosiphonic siphonostele**: Siphonostele that remains perforated by smaller or larger leaf gaps caused by leaf traces. Members of Filicophyta.

LIFE CYCLE OF LYCOPODIUM

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.

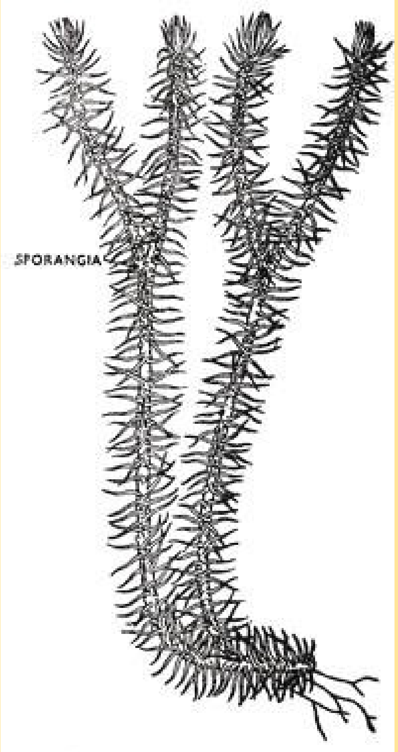


Fig. 537. *Lycopodium selago* (after Bower).

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.

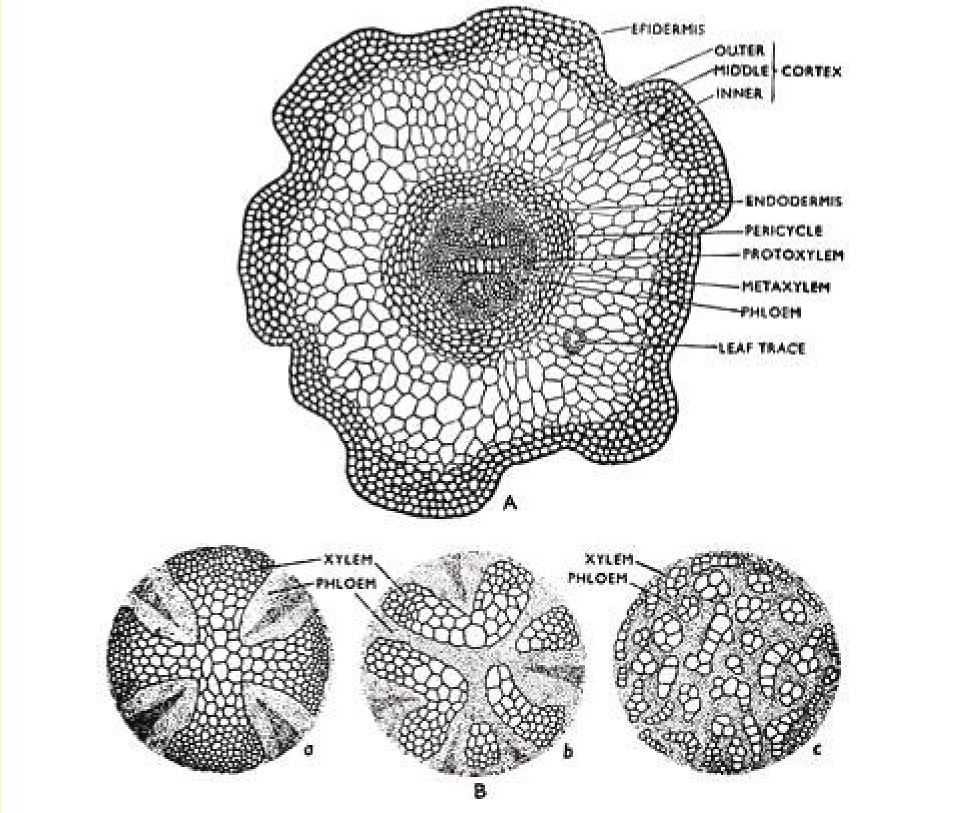


Fig. 539. A. T.s. of *Lycopodium clavatum* stem. B. T.s. of stelar regions of stems of (*a*) *L. serratum*, (*b*) *L. annotinum* and (*c*) *L. cernuum*.

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 patches.

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.

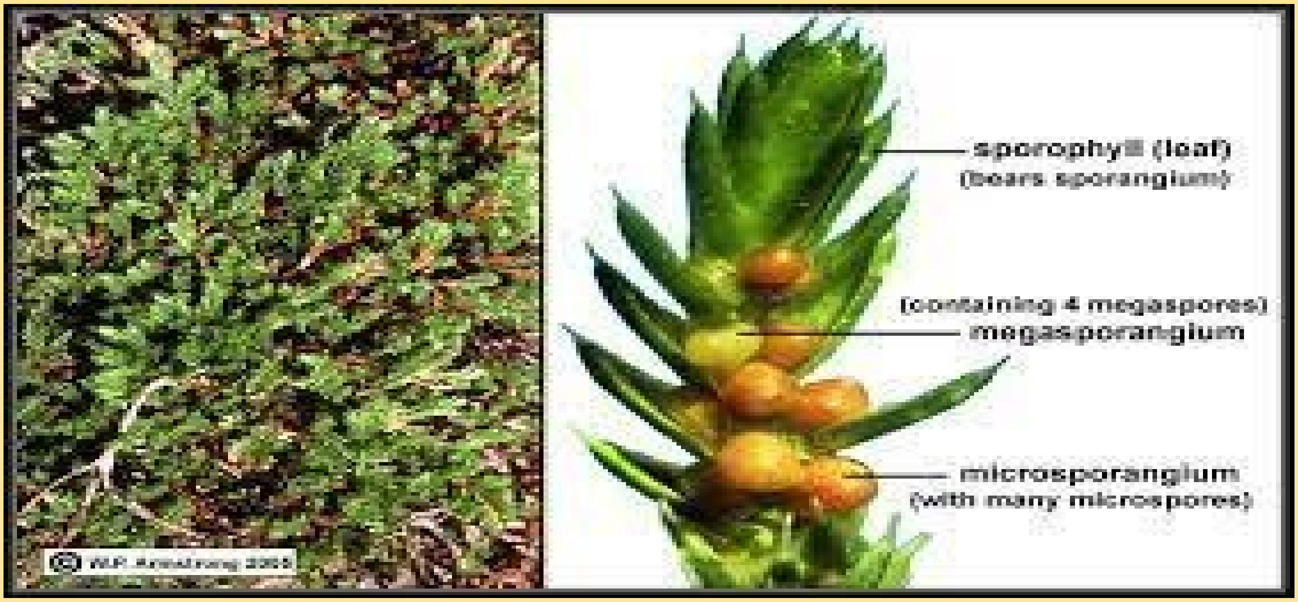
The reproductive shoots arise as erect branches from the horizontal stem late in the season (Fig. 538A). The lower part of the reproductive shoot is comparatively sparsely leaved and the tip branches dichotomously into two or more spike-like strobili (sporangiferous spikes) compactly covered by sporophylls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



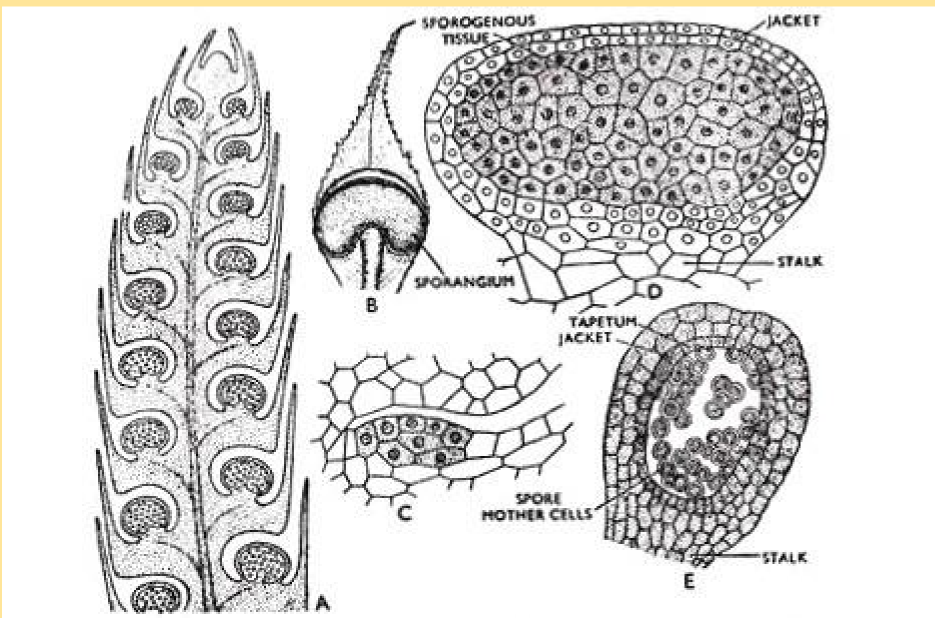


Fig. 540. *Lycopodium clavatum*. A. Median l.s. of strobilus. B. A sporophyll. C. Leaf base showing sporangial initials (shaded). D. Nearly mature sporangium before spore mother cells are formed. E. Mature sporangium.

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.

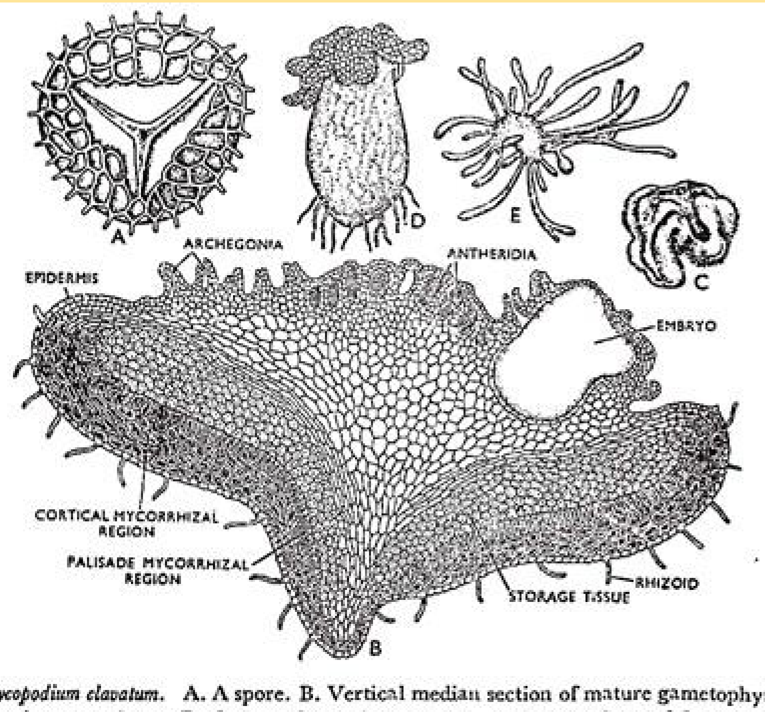


Fig. 541. *Lycopodium clavatum*. A. A spore. B. Vertical median section of mature gametophyte. C. An old convoluted gametophyte. D. Gametophyte of *L. cernuum*. E. Gametophyte of *L. phlegmaria*. (B–D after Bruchmann; E after Treub). L.

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.

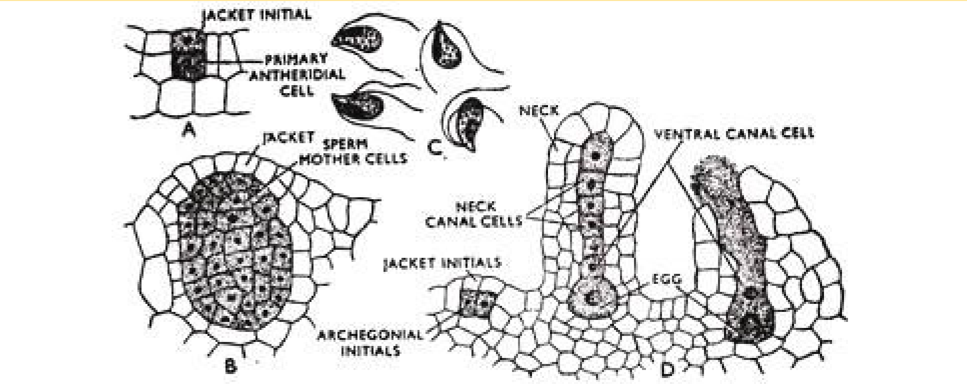


Fig. 542. *Lycopodium clavatum*. A. Early stage of antheridium formation. B. Mature antheridium C. Sperms. D. Part of gametophyte showing stages of development of archegonia.

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

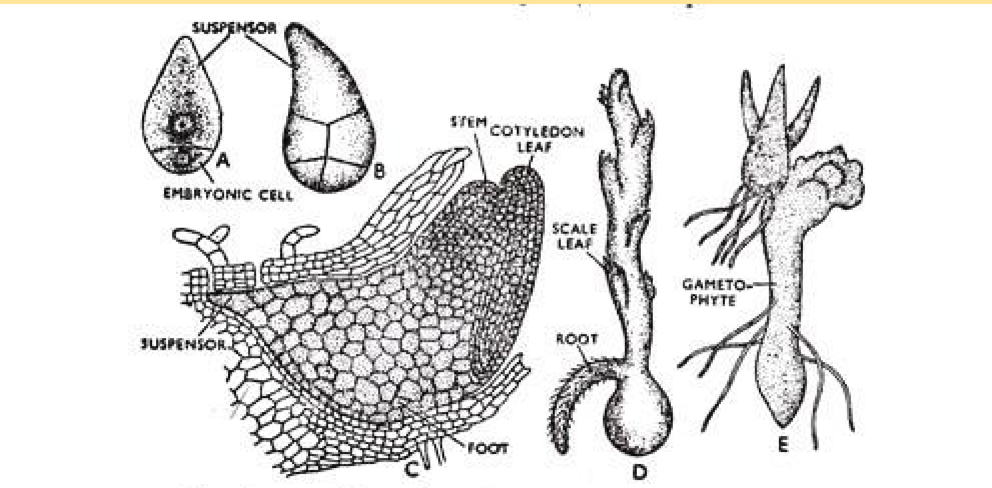


Fig. 543. Stages of development of *Lycopodium* embryo. A. 2-celled stage. B–C. Subsequent stages. D. New sporophyte. E. Protocorm of *L. cernuum*.

independentplant (Fig. 543D).

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.

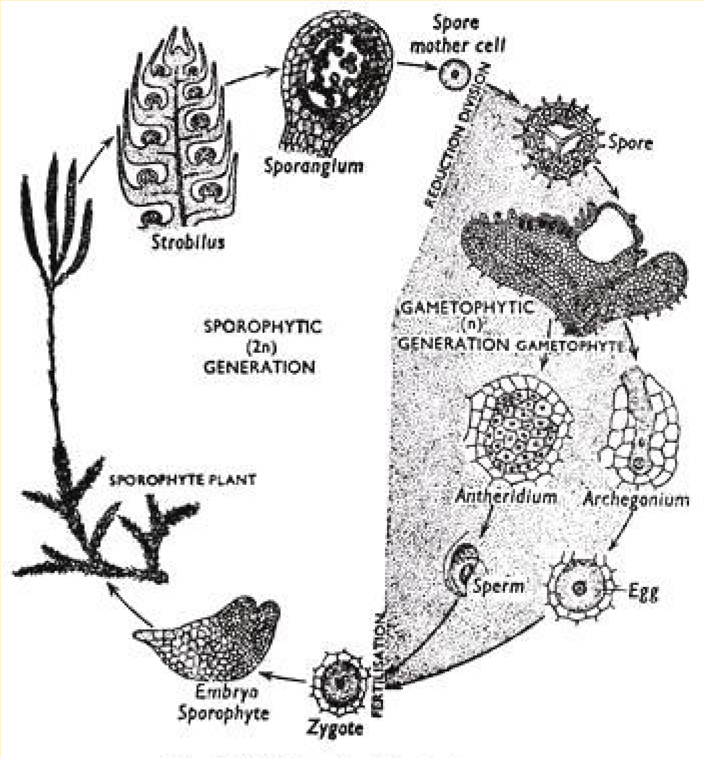


Fig. 544. Life cycle of *Lycopodium*.

Figure 544 shows diagrammatically the life cycle of Lycopodium.

LIFE CYCLE OF MARSILEA

Habit and Habitat of Marsilea:

Marsilea is commonly known as "pepper wort" or "water fern" (although it is a fern but hardly resembles a true fern). It is represented by about 53 species which are cosmopolitan in distribution but abundantly found in tropical countries like Africa and Australia. About 9 species have been reported from India.

Either the species are hydrophytic or amphibious i.e., they grow rooted in mud or marshes and shallow pools or are completely submerged or partially or entirely out of water in wet habitats. M. hirsuta is an Australian xerophytic species. M. hirsuta and M. quadrifolia are two most common Indian species usually found growing in marshy places, wet soil or near muddy margins of ponds and are commonly found in U.P., Punjab, Bihar, Delhi etc.

External Features of Marsilea:

The mature sporophyte is an herbaceous plant. Its underground rhizome spreads in a diameter of 25 meter or more. The plant body is distinctly differentiated into rhizome, leaves and roots (Fig. 1 A).

1. Rhizome:

All the species possess a rhizome which creeps on or just beneath the soil surface. It is slender, dichotomously branched with distinct nodes and internodes and is capable of indefinite growth in all directions as a result of which it occupies an area of 25 metre or more in diameter.

In aquatic species the internodes are long while in sub-terrestrial species they are short. Usually from the upper side at nodes, the leaves are given out while from their lower side, the roots.

2. Leaves:

They are borne alternately on upper side of rhizome at nodes, in two rows. Young leaves show circinate vernation (like ferns) (Fig. 1 A). In some species young leaves are covered with multicellular hairs. The leaves are compound, with basal petiole and terminal lamina.

In submerged plants the petiole is a long and flexible structure and the lamina floats over the surface of water but in muddy or marshy plants the petiole of the leaf is short and rigid with short lamina spreading in the air.

The lamina consists of 4 leaflets (pinnae) which are present at the apex of petiole. The 4 leaflets arise as a result of 3 dichotomies of the lamina in close succession to each other i.e., 2 leaflets arise slightly higher than other two (Fig. 1B).

Puri and Garg (1953) suggested that the leaf consists of single pinna consisting of 4 pinnules. Pinnae have got a dichotomously branched vein system with cross connections (Fig. 1C). The veinlets at the margin are connected with loops thus forming a reticulum. The shape of pinna varies from obovate to obcuneate and margin also varies from entire to crenate or crenate to lobed.

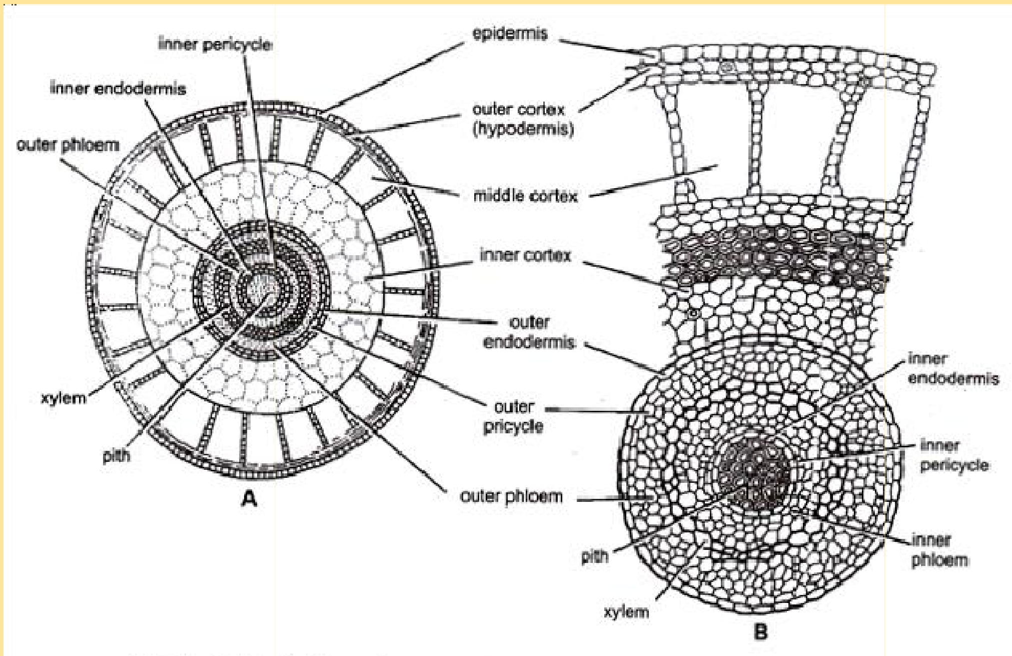


Fig. 2. A, B. *Marsilea.* Internal structure of rhizome. A. Diagrammatic, B. A part cellular.

3. Roots:
The roots are adventitious, arising from the underside of the node of rhizome, either singly or in groups. In certain cases the roots are given out even from the internodes (M. aegyptiaca).

Internal Structure of Marsilea:

1. T. S. Rhizome (stem):
A T. S. of the young rhizome shows a protostelic structure i.e., pith is absent and xylem is completely surrounded by phloem but in the old stem pith is developed in the centre and the stele is amphiphloic siphonostelic type.

It is the outermost limiting layer of single celled thick parenchymatous cells. The stomata are absent.

(ii) Cortex:
It is differentiated into three regions – the outer cortex, the middle cortex and the inner cortex.
(a) Outer cortex:
It is present just below the epidermis (also called hypodermis). It is parenchymatous and may be one to several cells thick. Some of its cells contain tannin.

(b) Middle cortex:
It is also called aerenchyma. It lies below the hypodermis. It consists of large air spaces (chambers) separated by one cell thick parenchymatous septa. In the xerophytic species e.g., aegyptiaca the air chambers are obliterated.

(c) Inner cortex:
It is a solid tissue of several cells thickness. The outer layers are thick walled (sclerenchymatous) while the inner layer of cells is thin walled (parenchymatous) and compactly arranged. Some of these cells are filled with starch or tannin.

(iii) Stele:
Stele is amphiphloicsiphonostele i.e., in the centre there is a pith which may be either parenchymatous (aquatic species) or sclerenchymatous (terrestrial muddy species). Xylem is present in the form of a complete ring which is surrounded on both sides by a complete ring of inner and outer phloem, pericycle and endodermis.

In this way the continuation of different tissues in the form of complete ring in stele is as follows—outer endodermis, outer pericycle, outer phloem, xylem, inner phloem, inner pericycle and inner endodermis. The protoxylem may be well defined exarch (M.vestita) or mesarch (M.aegyptiaca) or ill defined (M.quadrifolia).

A T. S. of the nodal region shows an amphiphloicsolenostelic condition and is provided with one leaf gap.

2. T. S. of Petiole:
A T. S. of the petiole is somewhat circular in outline and is differentiated into epidermis, cortex and stele.

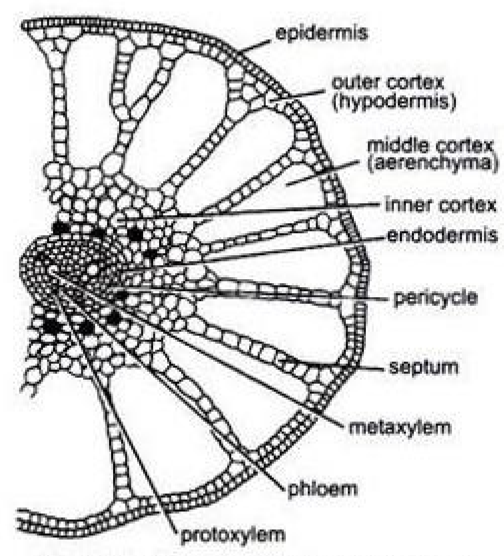


Fig. 3. ***Marsilea quadrifolia.*** **T.S. of petiole**

(i) Epidermis:
It is the outermost layer of single cell thickness. The cells are parenchymatous and slightly elongated.

(ii) Cortex:
It is differentiated into three regions: The outer cortex, the middle cortex and the inner cortex.

(a) Outer cortex:
It is present just below the epidermis, (also called hypodermis). It is made of thin walled cells (parenchymatous).

(b) Middle cortex:
It lies below the hypodermis and called aerenchyma. It consists a ring of air chambers. The air chambers are separated by single layered partitions of thin-walled parenchymatous cells.

(c) Inner cortex:
It is a solid tissue of several cells thickness. The cell layers are parenchymatous and contain starch and tannin filled cells. In M.minuta few sclerenchymatous layers are also present just inner to middle cotex.

(iii) Stele:
It is somewhat triangular in outline and is of protostelic type i.e. pith is absent. Xylem is "V" shaped with 2 distinct arms. Each arm is provided with metaxylem elements in the centre and protoxylem is situated at both the margins i. e., protoxylem is exarch.

The xylem is surrounded on all sides by phloem. Phloem is externally surrounded by a single layer of parenchymatouspericycle which, in turn, is bounded by a single layered endodermis.

3. Transverse Section of Leaflet:
A. T. S. of the leaflet shows epidermis, mesophyll and vascular bundles.

(i) Epidermis:
It is the outermost surrounding layer and is only one cell in thickness. It is differentiated into upper and lower epidermis. In floating leaflets the stomata are present on the upper epidermis but in case of plants growing in mud or moist soil where the leaves are aerial, the stomata are present both on upper as well as lower epidermis.

(ii) Mesophyll:
It occupies a wide space between upper and lower epidermis. It is usually differentiated into an upper palisade tissue and lower spongy parenchyma. The palisade tissue is made up of elongated cells provided with chloroplast. The spongy tissue is made up of loosely arranged parenchymatous cells with large air spaces separated by single layered septa. In submerged species, however, the mesophyll is not differentiated into palisade and spongy parenchyma.

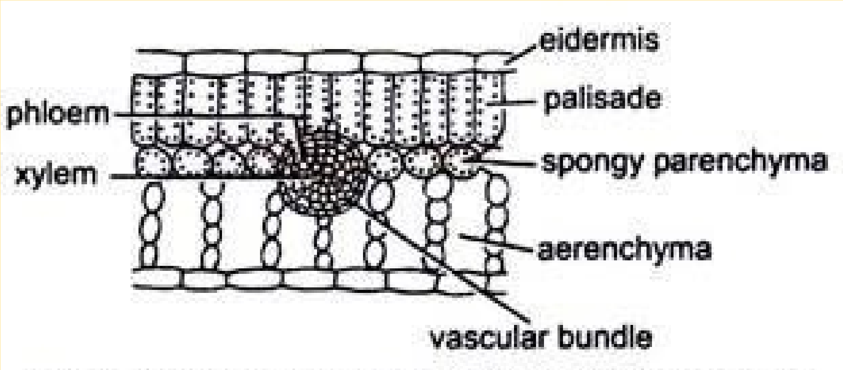


Fig. 4. ***Marsilea quadrifolia.*** **V.S. of leaflet or pinna**

(iii) Vascular bundles:
In between the mesophyll tissue are present several vascular bundles. Each vascular bundle is concentric and amphicribal type i. e., made up of a centrally situated xylem, surrounded on all sides by phloem. The phloem is enclosed by a single layered thick endodermis.

4. T. S. Root:
A T. S. of root is somewhat circular in outline and can be differentiated into epidermis or piliferous layer, cortex and stele (Fig. 5A, B).

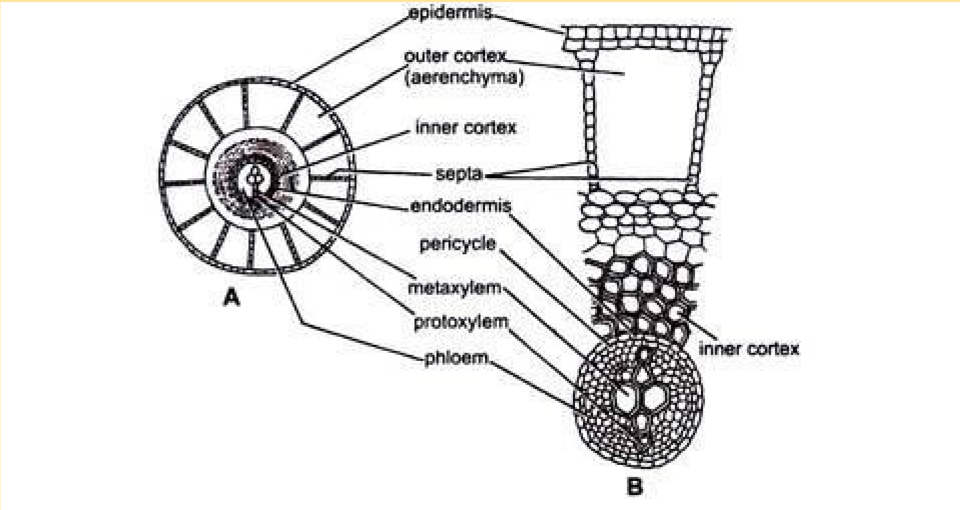


Fig. 5. (A, B) ***Marsilea quadrifolia.*** **Internal structure of root. A. Diagrammatic, B. A part cellular.**

(i) Epidermis:
It is the outermost, parenchymatous, single layered covering.

(ii) Cortex:
It can be differentiated into two parts: outer cortex and inner cortex. The outer cortex consists of large air chambers arranged in the form of a ring (parenchymatous). These chambers are separated from each other by

longitudinal septa. The inner cortex is differentiated into outer parenchymatous and inner sclerenchymatous regions. The inner cortex is delimited by single layered thick endodermis.

(iii) Stele:
It is of protostelic type and occupies the central position. It is devoid of pith. Xylem is situated in the centre which is diarch and exarch. It is surrounded by phloem. The phloem is bounded externally by a single layer of pericycle.

Reproduction in Marsilea:

Marsilea reproduces by two methods:
(i) Vegetative reproduction

(ii) Sexual reproduction.

Vegetative reproduction:
It takes place by means of tubers which are produced in dry conditions from the rhizome. First a branch is given out from the rhizome, which later on swells up due to the accumulation of food material. The structure is termed as tuber and is capable of tiding over the unfavourable conditions. On the return of favourable conditions it germinates to produce a new sporophytic plant, e.g. ,M. hirsuta, M. quadrifolia.

(ii) Sexual Reproduction:

1. Sporophytic Phase:
Spore producing organs:
Marsilea is heterosporous i. e., it produce two types of spores—microspores and megaspores. These spores are produced in microsporangia and megasporangia, respectively. These sporangia are borne in special type of spore producing organ called sporocarp. The sporocarp are born laterally on the short and lateral branches of the (called the peduncles or pedials) petiole of leaf either near the base or a little higher up.

They arise solitary or in clusters. The peduncle is usually unbranched but it may be branched also. Number of sporocarp differs in different species and varies from 1 to 20 or more. In M. vestitasporocarparises single, in M. quadrifolia the peduncle is dichotomously branched bearing 2-4 sporocarps, in M. polycarpa several sporocarps arise in a linear row. The attachment of the pedicel sporocarp varies in different species.

Mainly it is of three types (Gupta 1962):
(i) Pedicel of the solitary sporocarp is directly attached to the base of the petiole (e.g., M. coromendelica Fig. 6A) or pedicels of many sporocarps are attached on the petiole in a linear sequence on the same side (e.g.,M. polycarpa; Fig. 6B).

(ii) Pedicels first become united themselves with one another and then are attached to the petiole by a common stalk e.g., M. quadrifolia; (Fig. 6C).

(iii) Pedicels are free or slightly united and attached to the petiole by a single point (e.g.,M. minuta; Fig. 6D).

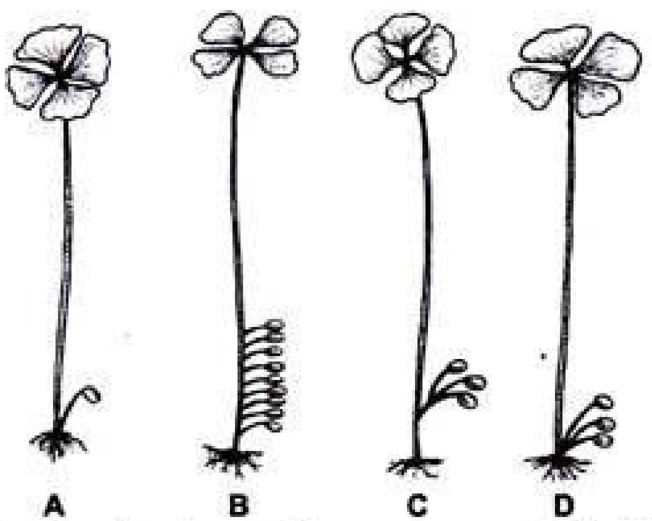


Fig. 6 (A-D) *Marsileas.* Attachement of sporocarps on petiole in different species. A. *M. coromendelica*, B. *M. polycarpa*, C. *M. quadrifolia*, D. *M. minuta.*

External Morphology of Sporocarp:

Each sporocarp is an oval or bean shaped biconvex, flattened structure. It is green and soft when it is young but at maturity it becomes very hard and brown in colour. It is made up of a short stalk like structure known as peduncle and the body.

The point of attachment of peduncle with the body is called raphe (Fig. 7A). Slightly above the raphe in a median plane are present 1 or 2 protuberances called tubercles. They are unequal in size and lower one is stouter than the upper one. In some cases the tubercles are absent e.g.,M. polycarpa.

Internal Structure of Mature Sporocarp:

The sporocarp is a bivalved structure. It can be split open in the dorsiventral plane into two halves (valves).

If we split open the sporocarp, we can see the following structures:

Wall of sporocarp:

It is very hard, thick and highly resistant to mechanical injury. It can be differentiated into three zones—outer epidermis, middle hypodermis and inner parenchymatous zone. Epidermis is single layered made up of broad and columnar cells. Its continuity is broken by the presence of sunken stomata (Fig. 7C).

Some of the epidermal cells develop into multicellular hairs (Fig. 7D). Hypodermis consists of two layers of radially elongated palisade like cells. Both the layers are without intercellular spaces and have chloroplast in their cells. Next to hypodermal layers is the parenchymatous zone (Fig. 7B). In mature sporocarp the cells of this zone gelatinise and form a gelatinous ring which helps in the dehiscence of the sporocarp.

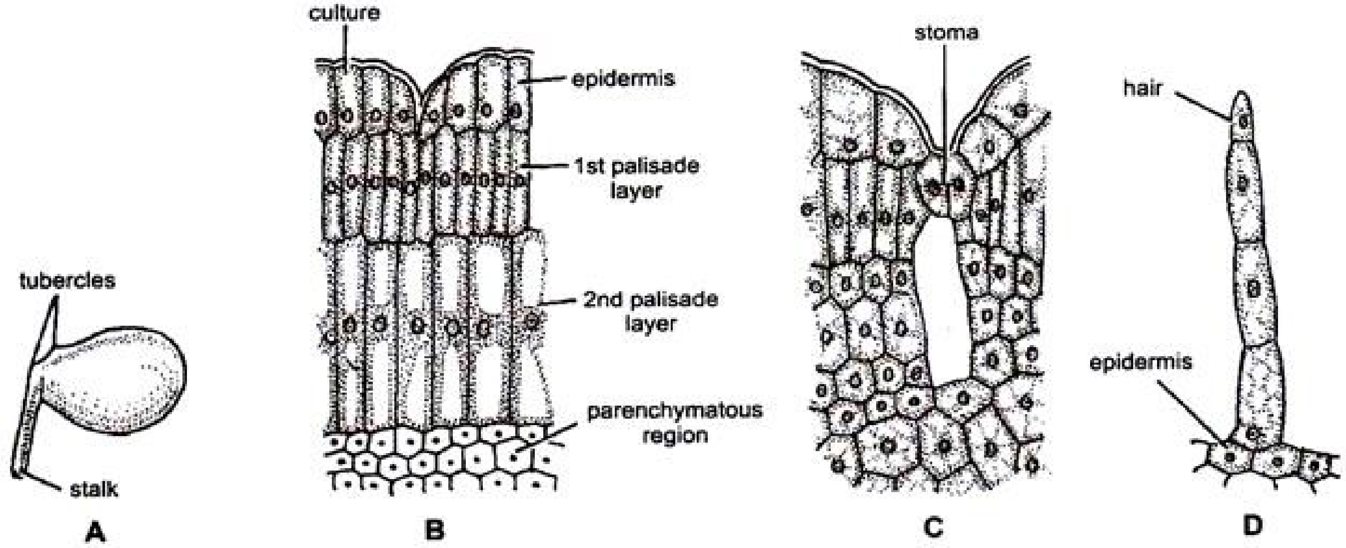


Fig. 7. (A-D). ***Marsilea.*** **Structure of sporocarp. A. sporocarp, B. Wall structure of sporocarp in T.S., C. sunken stoma in the wall of sporocarp, D. A multicellular hair.**

Cavity of sporocarp:

The alternating rows of sori (sing, sorus, a group of sporangia is called sorus), one along each side lies transversely-dorsiventrally to the long axis of the sporocarp. The sori on either side alternate with each other. The number of sori inside the sporocarp varies from species to species. It may be from two (e.g., M. aegyptiaca) to twenty (e.g.,M. vestita). Each sorus bears both microsporangia and megasporangia.

Their number also varies from species to species. In M. minuta a sorus has 4-8 megasporangia and 8-13 microsporangia. In M. aegyptiaca each sorus has 5-16 megasporangia and 9-19 microsporangia.

In M. minuta, M. vestita, M. rajasthanensis, sometimes megasporangia are absent in sorus. Each sorus arises on a ridge like placenta or receptacle formed on the sporocarp wall. Each sorus is surrounded by a thin, membranous two layered true indusium. The indusia of adjacent sori are partially fused.

Vascular supply of the sporocarp:

It is supplied by a main dorsal vein which runs along the narrow side facing the peduncle. From the dorsal vein, lateral branches are given alternatively right and left, at right angle to the dorsal vein which supplies laterally (Fig. 8). These lateral veins at their middle divide dichotomously. In the region here lateral vein forks, arises a placental bundle which too branches dichotomously. The first and the last lateral veins do not possess placental bundles.

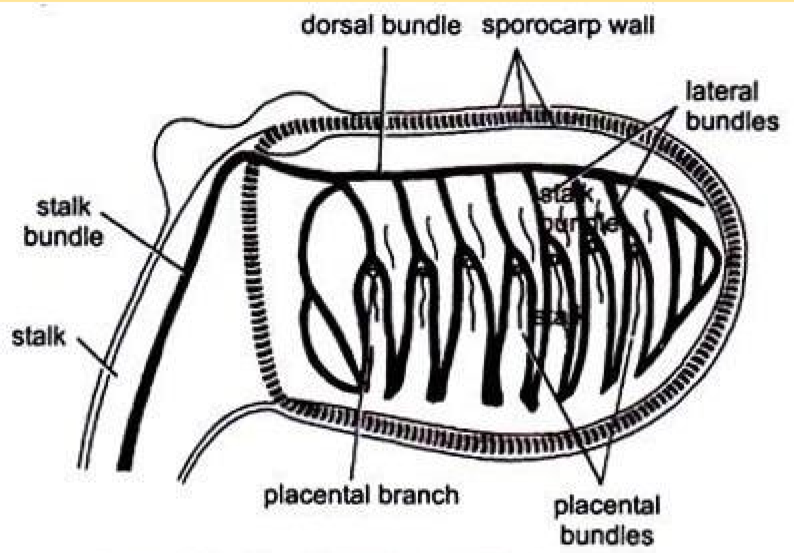


Fig. 8. *Marsilea.* Vascular supply of sporocarp.

Structure of Microsporangium:
It is somewhat oval structure with a long stalk and is present laterally on the receptacle. It is smaller in size. It has a single layered jacket followed by two layers of tapetal cells. In the centre is present a cavity filled with microspore mother cells (Fig. 14H).

At maturity the tapetal cells disintegrate and each microspore mother cell divides reductionally forming 4 haploid microspores (Fig. 141). The microspores are usually 32-64 in number and are liberated by the disintegration of the microsporangial wall (Fig. 14J).

Development of Microsporangium:
It takes place from a superficial cell situated laterally on the receptacle. This cell is called as sporangial initial. It divides transversely into an outer and inner cell (Fig. 14 B, C). The outer cell later on gives rise to the whole of the sporangium i. e., stalk, wall, tapetum and microspores. It divides by three successive diagonal divisions to form a tetrahedral apical cell (Fig. 14D) with three cutting faces.

This apical cell cuts off two cells from its each face which helps in the formation of stalk. Now a periclinal wall is formed towards the outer face of the apical cells forming an outer smaller primary jacket cell and an inner archesporial cell (Fig. 14J). The primary jacket cell divides only anticlinally to form a single layered jacket.

The archesporial cell again divides periclinally to form an outer primary tapetal cell and inner primary sporogenous cell (Fig. 14F, G). The primary tapetal cells divide periclinally as well as anticlinally to form a two layered tapetum. The primary sporogenous cell divides to form 8-16 microspores mother cells (Fig. 14H). Now each microspore mother cell divides reductionally to form a tetrad of spores as a result of which 32-64 microspores are produced (Fig. 14J).

Structure of Megasporangium:

It is a spherical structure with a short stalk and is present on the top of the receptacle (Fig. 14A). It is bigger in size than the microsporangium (Fig. 14A). Its structure is similar to microsporangium except that only one megaspore is present per megasporangium at maturity. The megaspore is liberated by the disintegration of the megasporangial wall.

Development of megasporangium:

The development of megasporangium is exactly in the same way as that of microsporangium except that out of the total number of megaspores formed, all degenerate leaving except one which behaves as a functional megaspore (x). It increases in size.

Dehiscence of Sporocarp and Liberation of Spores:

The decaying of the wall of the sporocarp takes place due to bacterial action and thus the sporangia and spores are liberated. The sporocarp bursts open only in water in valvecular manner along the ventral side and apex. The gelatinuous ring absorbs water and extends greatly through the open margins of the sporocarp thus dragging out sori along with it.

It straightens and behaves as sporophore. The gelatinous ring bears two alternating rows of sori. The delicate mucilage wall of the sporangia (micro-or mega) opens in water and the spores (micro-or mega are liberated which germinate soon (Fig. 15 A, E).

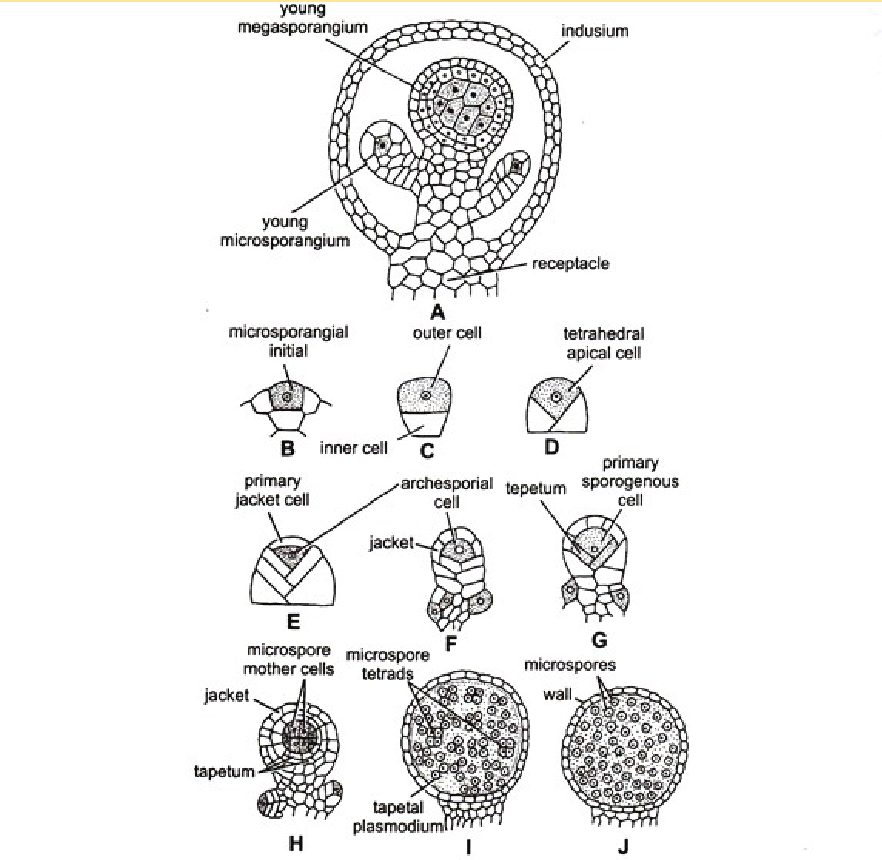


Fig. 14. (A-F). ***Marsilea.*** **A-H. Successive stages in the development of microsporangium and megasorangium, I. Microsporangium with spore tetrad. J. A mature micrposporangium with microspores.**

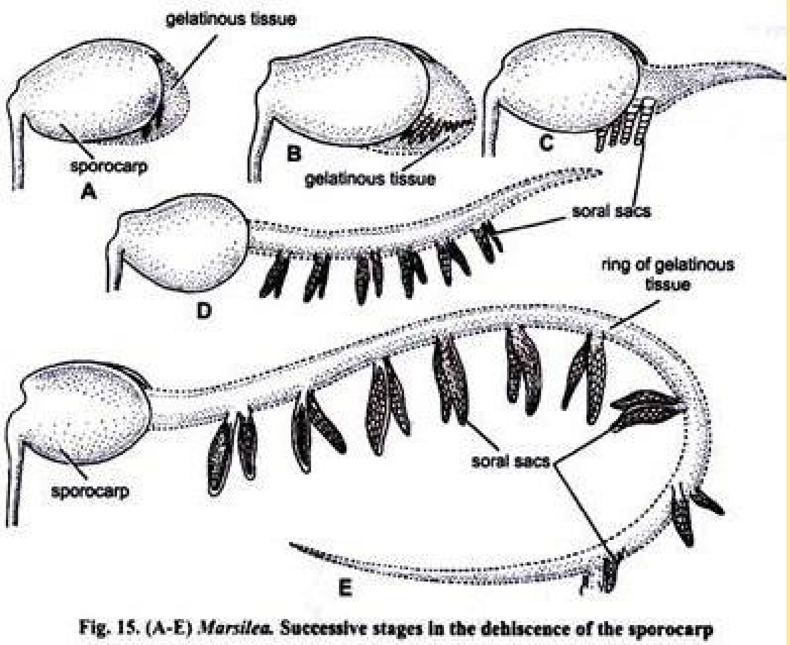


Fig. 15. (A-E) ***Marsilea.*** **Successive stages in the dehiscence of the sporocarp**

Development of embryo:

Oospore is the initial stage of sporophytic generation. The first division of the oospore is in a vertical plane (parallel to the long axis of archegonium) to form 2 unequal cells. The bigger one is known as epibasal cell and the smaller one as hypobasal cell (Fig. 18 A, B). This is followed by a second transverse division to form 4 cells (quadrant stage) (Fig. 18C).

The epibasal half gives rise to shoot and leaf whereas the hypobasal half gives rise to root and foot. The cell of epibasal half near the neck gives rise to cotyledon and other away from the neck, to the stem.

In the same way the cell of the hypobasal half near the neck gives rise to root and other away from the neck, to the foot. Simultaneously, the tissue surrounding the archegonium divides to form a 2 or 3 celled thick calyptra which protects the embryo in young stage. The embryo later on gives rise to an adult plant.

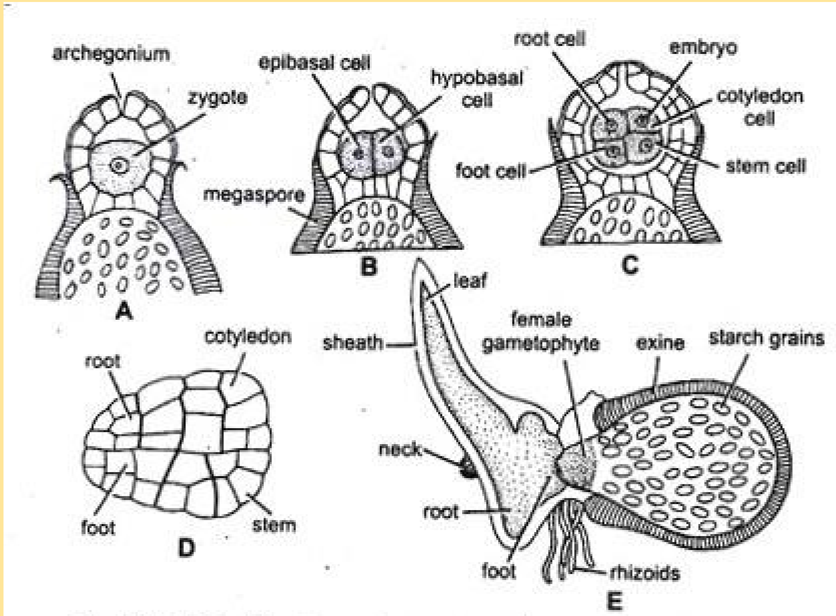


Fig. 18. A-E. Marsilea. Successive stages in the development of embryo.

Life Cycle Patterns of Marsilea:

Mature plant of Marsilea is diploid. Marsilea is a heterosporous fern because it produces 2 different types of spores i. e., microspores and megaspores. Micro- and megaspore mother cells are produced inside micro- and megasporangium respectively which represents the late stage of sporophytic generation. After reduction division microspores and megaspores are produced which represent the initial stage of gamestophytic generation.

Microspore gives rise to make gametophyte which, in turn, produces archegonium and egg. Both antherozoid and egg fuse to from a diploid oospore (2x).The oospore is the initial states of sporophytic generation. Hence, in the way the sporpytic andgametophytic generation alternate with each other although the sporophytic phase is dominant over gametophytic phase (fig 19,20).

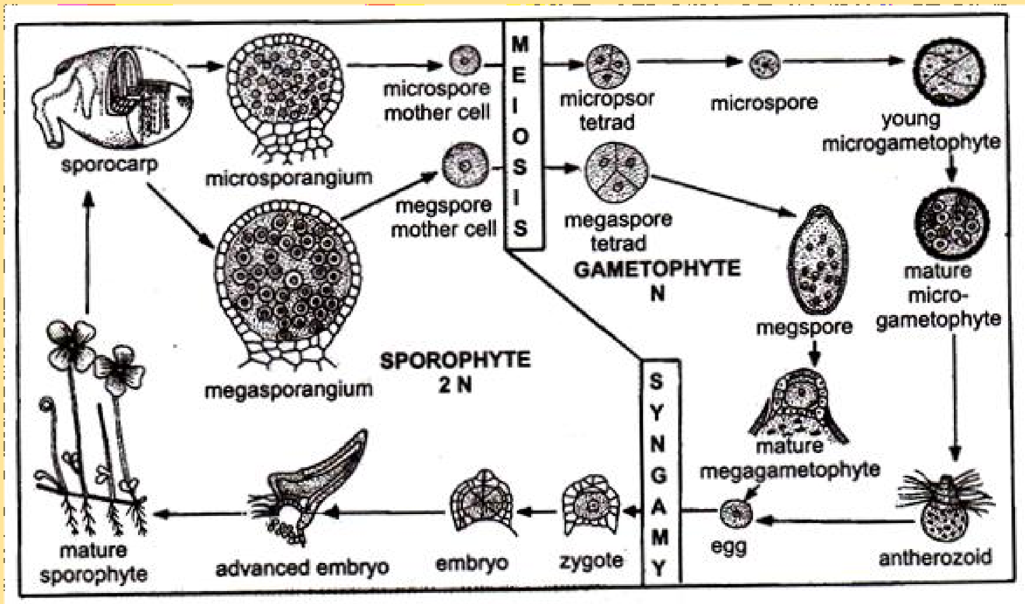


Fig. 19. *Marsilea.* Diagrammatic life cycle.

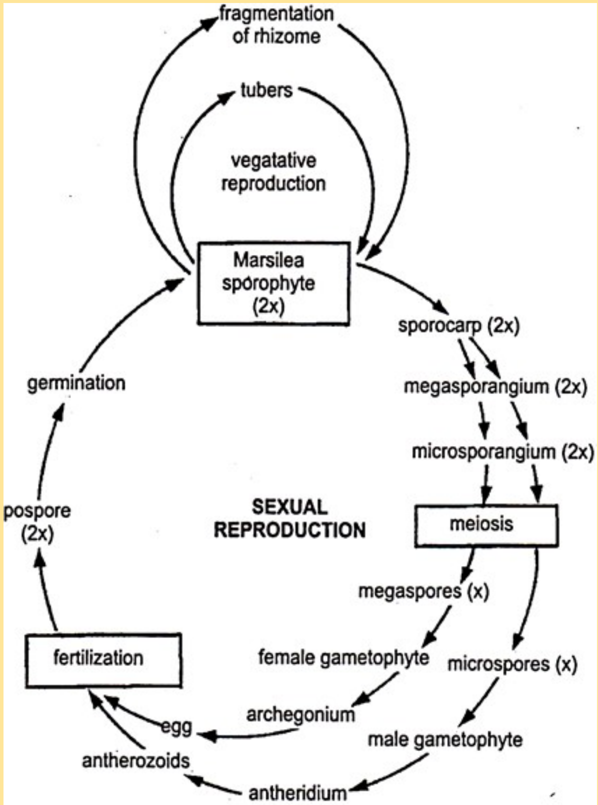


Fig. 20. *Marsilea.* Schematic life cycle.

GENERAL CHARACTERS OF GYMNOSPERMS

Definition

"Gymnosperms are a group of plants that produce seeds not enclosed within the ovary or fruit."

What are Gymnosperms?

The word "Gymnosperm" comes from the Greek words "gymnos"(naked) and "sperma"(seed), hence known as "Naked seeds." Gymnosperms are the seed-producing plants, but unlike angiosperms, they produce seeds without fruits. These plants develop on the surface of scales or leaves, or at the end of stalks forming a cone-like structure.

Gymnosperms belong to kingdom 'Plantae' and sub-kingdom 'Embryophyta'. The fossil evidence suggested that they originated during the Paleozoic era, about 390 million years ago.

Basically, gymnosperms are plants in which the ovules are not enclosed within the ovary wall, unlike the angiosperms. It remains exposed before and after fertilisation and before developing into a seed. The stem of gymnosperms can be branched or unbranched. The thick cuticle, needle-like leaves, and sunken stomata reduce the rate of water loss in these plants.

The family of gymnosperms consist of conifers, the cycads, the gnetophytes and the species of Gynkgophyta division and Ginkgo biloba.

Let us have an overview of the characteristics, examples, classification and examples of gymnosperms.

Characteristics of Gymnosperms

Following are the important characteristics of gymnosperms:

1. They do not produce flowers.
2. Seeds are not formed inside a fruit. They are naked.
3. They are found in colder regions where snowfall occurs.
4. They develop needle-like leaves.
5. They are perennial or woody, forming trees or bushes.
6. They are not differentiated into ovary, style and stigma.
7. Since stigma is absent, they are pollinated directly by the wind.
8. The male gametophytes produce two gametes, but only one of them is functional.
9. They form cones with reproductive structures.
10. The seeds contain endosperm that stores food for the growth and development of the plant.

11. These plants have vascular tissues which help in the transportation of nutrients and water.
12. Xylem does not have vessels and the phloem has no companion cells and sieve tubes.

Classification of Gymnosperms

Gymnosperms are classified into four types as given below –

Cycadophyta

Cycads are dioecious (meaning: individual plants are either all male or female). Cycads are seed-bearing plants where the majority of the members are now extinct. They had flourished during the Jurassic and late Triassic era. Nowadays, the plants are considered as relics from the past.

These plants usually have large compound leaves, thick trunks and small leaflets which are attached to a single central stem. They range in height anywhere between a few centimetres to several meters.

Cycads are usually found in the tropics and subtropics. Some members have adapted to dry arid conditions and some also have adapted to oxygen-poor swampy environments.

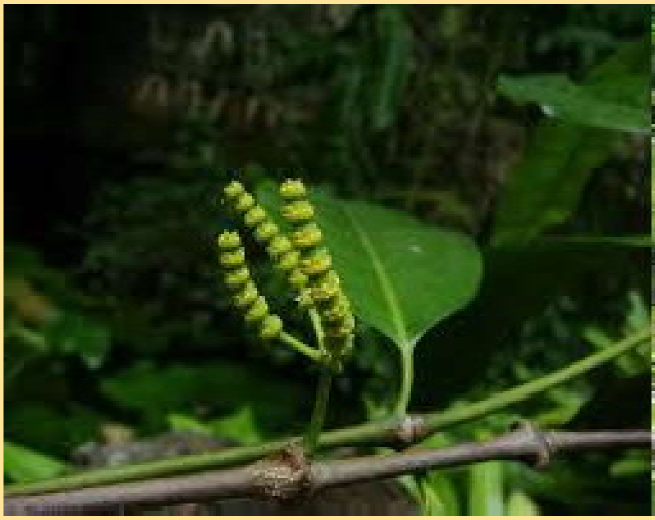
Ginkgophyta

Another class of Gymnosperms, Ginkgophyta, has only one living species. All other members of this class are now extinct.

The Ginkgo trees are characterised by their large size and their fan-like leaves. Also, Ginkgo trees have a large number of applications ranging from medicine to cooking. Ginkgo leaves are ingested as a remedy formemory-related disorders like Alzheimer's.

Ginkgo trees are also very resistant to pollution, and they are resilient against diseases and insect infestations. In fact, they are so resilient that after the nuclear bombs fell on Hiroshima, six Ginkgo trees were the only living things to survive within a kilometre or two of the blast radius.

Gnetophyta



Just like any other member of gymnosperms, Gnetophytes are also relics from the past. Today, only three members of this genus exist.

Gnetophytes usually consist of tropical plants, trees, and shrubs. They are characterised by flowery leaves that have a soft coating. This coating reveals an ancestral connection with the angiosperms.

Gnetophytes differ from other members of this class as they possess vessel elements in their xylem.

Coniferophyta

pinus

Cupressus

These are the most commonly known species among the gymnosperm family. They are evergreen; hence they do not shed their leaves in the winter. These are mainly characterised by male and female cones which form needle-like structures.

Coniferous trees are usually found in temperate zones where the average temperature is 10 °C. Giant sequoia, pines, cedar and redwood are examples of Conifers.

Gymnosperms Examples

Following are some of the examples of gymnosperms:

- Cycas
- Pinus
- Araucaria
- Thuja
- Cedrus
- Picea
- Abies
- Juniperus
- Larix

Gymnosperms Life Cycle

The life cycle of gymnosperms is both haploid and diploid, i.e., they reproduce through the alternation of generations. They have a sporophyte - dominant cycle.

The gametophyte phase is relatively short. The reproductive organs are usually cones.

Male Cones– These have microsporophylls that contain microsporangia. Microsporangium produces haploid microspores. A few microspores develop into male gametes called pollen grains, and the rest degenerate.

Female Cones– The megasporophylls cluster together to form female cones. They possess ovules containing megasporangium. It produces haploid megaspores and a megaspore mother cell.

The pollen reaches the egg through wind or any other pollinating agent, and the pollen grain releases a sperm. The nuclei of male and female gametophytes fuse together to form a zygote. This is known as fertilisation.

The seed appears as scales which can be seen on the cones of the gymnosperm.

PINUS

Pinus (Genus) – Description

The *Pinus* are resinous evergreen trees. They are mostly described based on their cones, needle and barks.

- **Pinus Needle –** The adult pine leaves are called needles. The foliages are bundled together in clusters known as fascicles.
- **Cone –** Cones are seed-bearing structures seen in gymnosperms. Usually, the female pine cones are larger compared to the male pine cones. They are encircled with many scales. Typically, the scales at the tip and base of the cone are sterile (no seeds).
- The seeds are winged structures that can be dispersed through the wind.
- The white pines (*Strobus*) have leaves in clusters of five. Their wood is generally soft and white with less prominent annual rings. They are called soft pines or haploxylon. E.g., *P. gerardiana.*

- The yellow pines (*Pinus*) have thick and fissured bark. Their wood is harder and yellower, with more prominent annual rings. They are called hard pines or diploxylon. E.g., *P. roxburghii.*
- The lacebark pines (*Ducampinus*) are an ancient group of pines with diverse morphology. This third subgenus is no longer considered valid.

Distribution of Conifers

The humid temperate northern part is dominated by the Pinaceae and other conifers, and the southern part has more ferns and conifers other than the Pinaceae. Some varieties of *Pinus* have also been introduced in the temperate parts of the southern hemisphere.

Some Examples of Pinus Species

- *Pinus brutia*
- *P. densata*
- *P. henryi*
- *P. roxburghii*
- *P. greggii*
- *P. radiata*
- *P. gerardiana*
- *P. rigida*

Life Cycle of Pinus

Pinus are gymnosperms that produce seeds in cones. Their ovules are not enclosed by any ovary wall and thus remain exposed before as well as after fertilisation.

Seed plants have a diplohaplontic life cycle that has two phases. The first dominant is the sporophyte phase, and the second is a brief gametophyte phase. Pines are monoecious; thus have female and male strobili are present on the same tree.

Male Strobili

- A male strobilus has many microsporophylls. Each of them has two microsporangium sacs.
- Each sac has tapetal pollen mother cells. These cells undergo meiosis to form 4 haploid microspores in the tetrad.
- The microspore coated with a pollen wall divides into a male gametophyte. Each male gametophyte produces two sperms for fertilisation.

Female Strobili

- Likewise, the female strobilus has many scales that produce megasporangia or ovules. Each ovule includes a megaspore mother cell that undergoes meiosis to produce 4 haploid cells.
- One of the four haploid cells grows into a female gametophyte that develops one or more archegonia. Each archegonium houses a single egg cell.

Fertilisation – The mature sperm cells reach down the pollen tube and fertilise the egg. After fertilisation, the integuments close to form a seed coat. The development of the embryo happens within the seed. Under favourable conditions, the seed germinates into a full sporophyte plant and continues the life cycle.

GNETUM

External Morphology:
Gnetum shows a typical tap root system which is profusely branched. The mature roots show normal secondary growth.

Internal Structure:
Internally, the root of Gnetum resembles the root of angiosperm. The root is differentiated into the outermost layer, epidermis, multilayered cortex and diarch vascular cylinder. The cortex consists of polygonal or oval-shaped parenchymatous cells containing starch grains. The thick-walled fibre cells are often present in the cortex. A single-layered endodermis encircles a multilayered pericycle.

The primary vascular cylinder is diarch, radial and exarch. The secondary growth in roots is of normal type. The arcs of cambium form below the phloem groups and above the xylem groups which join together to form a cambium ring. The secondary xylem consists of tracheids possessing uniseriate bordered pits with conspicuous Bars of Sanio. The vessels are also present.

The pits on the vessels are bordered or simple, small and multiseriate with or without inconspicuous Bars of Sanio. The xylem ray is composed of thin-walled parenchymatous cells containing starch grains. The phloem consists of sieve cells and parenchyma. The periderm is formed due to the extrastelar secondary growth.

2. Stem of Gnetum:

External Morphology:

Almost all the species of Gnetum, except the tree type like G. gnemon, exhibits two types of branches viz. dwarf shoots or branches of limited growth and long shoots or branches of unlimited growth. In climbing and scandent species of Gnetum, the stem is articulated with prominent joints.

The joint consists of two parts: one just above the node and the other below the node and these two are separated by an annular groove. In arboreal species such as G. gnemon, the stem exhibits uniform type of branching.

Internal Structure:

Internally, a Gnetum stem is similar to that of a dicot. In T.S. the stem exhibits more or less circular outline (Fig. 1.71 A). The following regions are discernible from outside inward: the heavily cutinised single-layered epidermis with sunken stomata, a several- layered (12-16 layers) thick cortex which is differentiated into an outer chlorenchymatous, a middle parenchymatous and an inner sclerenchymatous region.

The cells of the inner regions are referred to as spicular cells (Fig. 1.71C). Many fibrous cells are often present which have branched or unbranched pit canals. The cortex is followed by endodermis and pericycle layers which are not distinct. Next to pericycle, there is an endarch siphonostele.

Secondary Growth in Thickness:

In tree species like G. gnemon, the secondary growth is of normal type. The fascicular cambium joins with interfascicular cambium to form a complete cambium ring that cuts off a continuous cylinder of secondary xylem towards the inside and secondary phloem towards the outside. The secondary xylem is produced much more than the secondary phloem.

In climbing species (G. ula, G. africanum), the anomalous secondary growth is noted. Initially, the stem shows normal secondary growth. Later, several successive cambium rings are formed in the cortex.

Thus, several extra- stellar rings of xylem and phloem are formed which are separated into wedge-shaped bundles because of medullary rays (Fig. 1.71D). Some of these accessory rings remain incomplete and, as a result, the vascular bundles become eccentric with regard to pith (Fig. 1.71 E). The periderm is also formed by the activity of phellogen during the third or fourth year of growth of the stem.

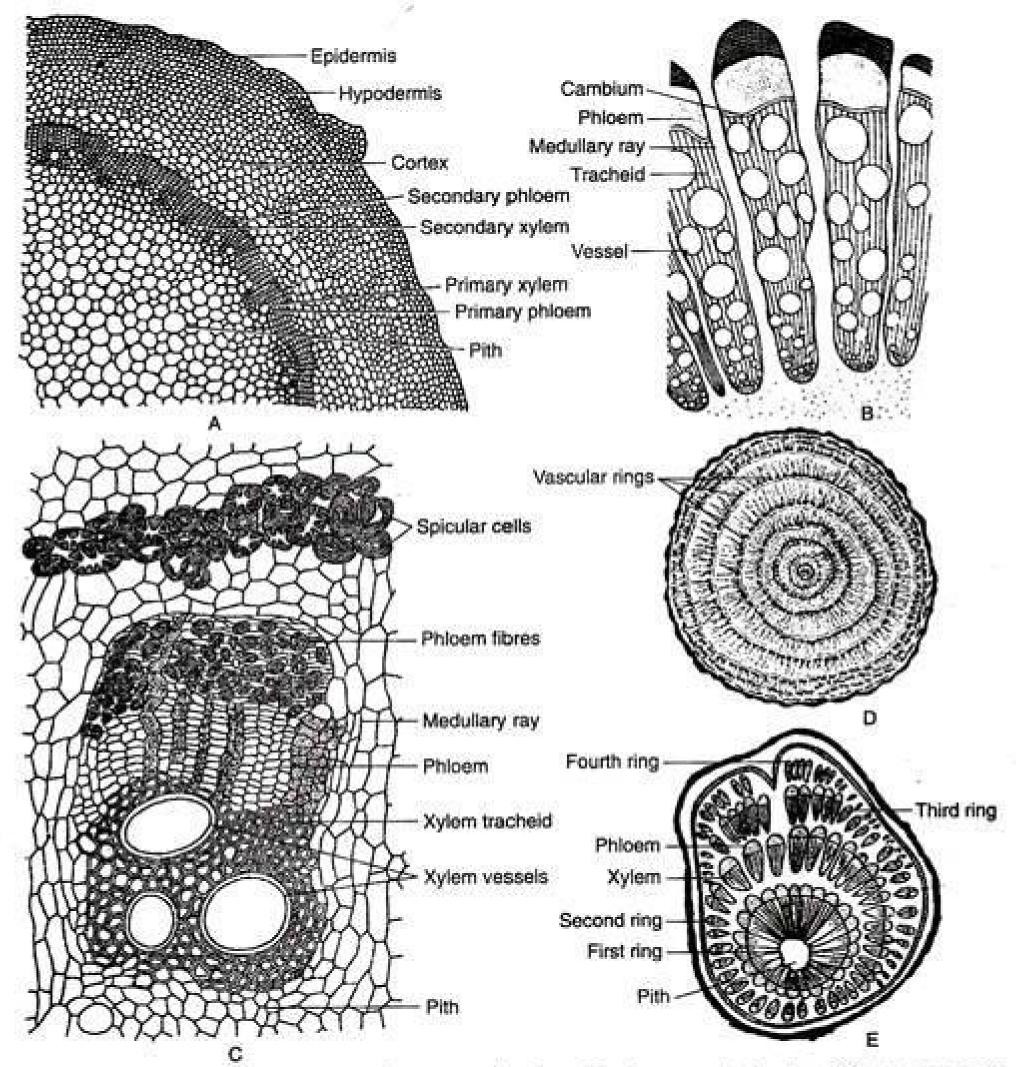


Fig. 1.71 : *Gnetum ula* : A. T.S. of stem, B. Same, a part is enlarged to show vascular bundles, C. Same, one vascular bundle is enlarged, D. T.S. of a mature stem showing polycyclic vascular rings, E. T.S. of a mature stem showing eccentric secondary growth

Reproduction:

Gnetum reproduces sexually. Gnetum is dioecious and both the male and female strobili (= inflorescence) are compound. The inflorescence is either axillary or terminal in position which occurs singly or in groups. The inflorescence is composed of a stout long axis with two opposite decussate, connate bracts at the base and a series of cup-like bracts called cupules or collars that are superposed one above the other (Fig. 1.73, 1.74A).

The strobilus becomes compact at young stage because of the suppression of internodes. Thus, the collars of a young strobilus appear to be continuous (Fig. 1.73). At maturity, the axis becomes elongated and the collars get separated. There are many rings of flowers in the axil of collars. The collars are developed in acropetal succession and the flowers are initiated as mounds of meristematic cells from the lower surface of a collar.

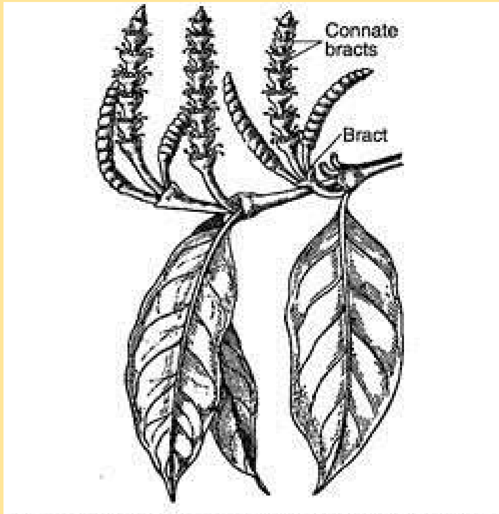


Fig. 1.73 : *Gnetum gnemon* : A twing bearing male inflorescences

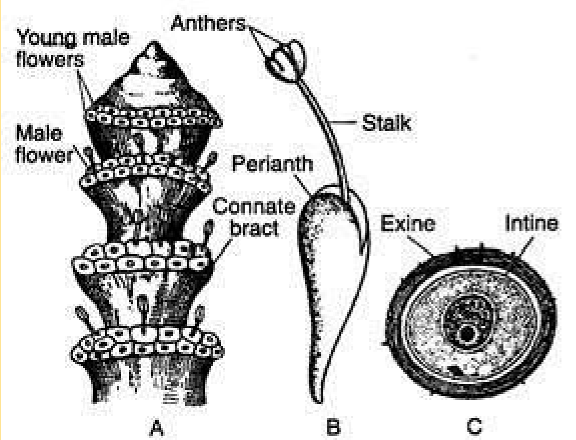


Fig. 1.74 : *Gnetum gnemon* : A. A part of a male inflorescence, B. A male flower, C. A pollen grain

Male Strobilus:

The male strobilus is compound and has a long slender axis bearing 10-25 whorl of bracts (collars) (Fig. 1.73). About 12-25 male flowers are arranged in three to six rings above each collar (Fig. 1.74A). A single ring of 7-15 imperfect female flowers or abortive ovules is present just above the male flowers.

Male Flower:

A male flower consists of two unilocular anthers on a stalk (antherophore) enclosed in a small sheathing perianth (Fig. 1.74B). The stalk of the anther elongates rapidly at maturity pushing the anther beyond the collars through a slit in the perianth.

Female Strobilus:

The female strobilus is very much similar to that of the male strobilus in the young stage. Like male strobilus, the female strobilus consists of an axis bearing several whorl of collars arranged one above the other (Fig. 1.75A). A ring of 4-10 ovules (female flowers) is present above each collar (Fig. 1.75B). The male flowers are not found in the female strobilus. The upper few collars are devoid of ovules and are thus sterile (Fig. 1.75B).

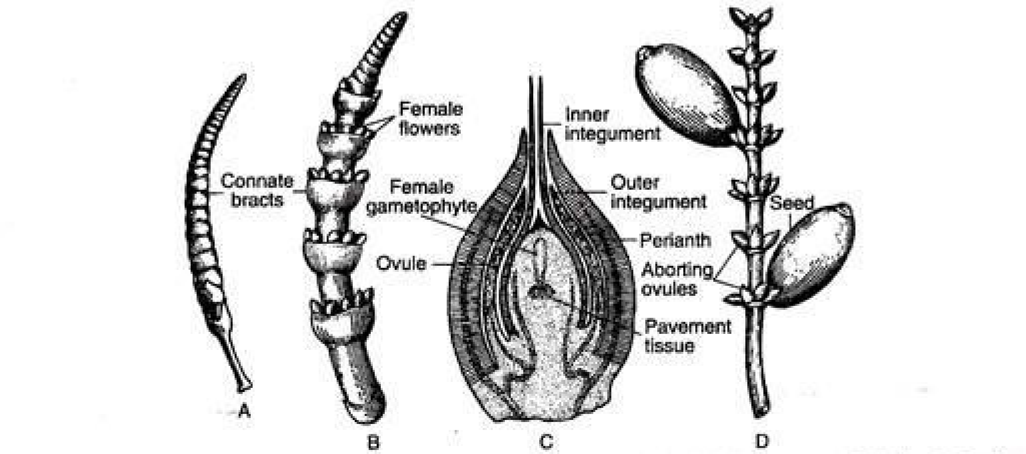


Fig. 1.75 : *Gnetum ula* : A. An young female inflorescence, B. A mature female inflorescence, C. Median L.S. of a female flower, D. A female inflorescence bearing two mature seeds

Ovule:

A single ovule represents a female flower. The ovule is stalked in G. ula, but may be sub- sessile or even sessile. The ovules are orthotropous, crassinucellate (with massive nucellar tissue) and are protected by three envelopes (Fig. 1.75C). The outer envelop which becomes thickened and succulent at maturity is considered to be the perianth corresponding to the perianth of male flower.

The middle and the inner envelopes are actually the integuments. Numerous laticiferous ducts and sclerides are present in the perianth with some epidermal stomata. The middle envelop is called the outer integument which is anatomically similar to the outer envelop. The inner envelop, i.e., the inner integument, elongates far beyond the apical cleft of the perianth and forms a long micropylar tube (Fig. 1.75C).

Anatomically, the inner integument is different from the other two envelopes, because neither sclerides nor stomata develop in the inner integument. The inner integument is free from the nucellus except at the chalazal end.

Two sets of vascular bundles are formed (Fig. 1.75C), of which the outer set passes to the perianth and the inner set again divides and one of its branches passes to the outer integument and the other to the inner integument. All the three envelopes of ovules develop in acropetal manner. A shallow pollen chamber is present at the tip of the nucellus.

Megasporogenesis:

Two to four hypodermal cells in the nucellar tissue at the micropylar end is differentiated into primary parietal cells towards outside and the primary sporogenous cells towards inside. The primary parietal cells together with nucellar epidermal cells divide repeatedly to produce a massive nucellus.

The primary sporogenous cells divide to form 8-20 sporogenous cells which are linearly arranged. The sporogenous cells function as megaspore mother cells which undergo meiotic division. Since no walls are laid down after meiotic division of megaspore mother cells, all the four nuclei remain within the mother cell to form a tetranucleate coenomegaspore. Thus, the female gametophyte of Gnetum is tetrasporic.

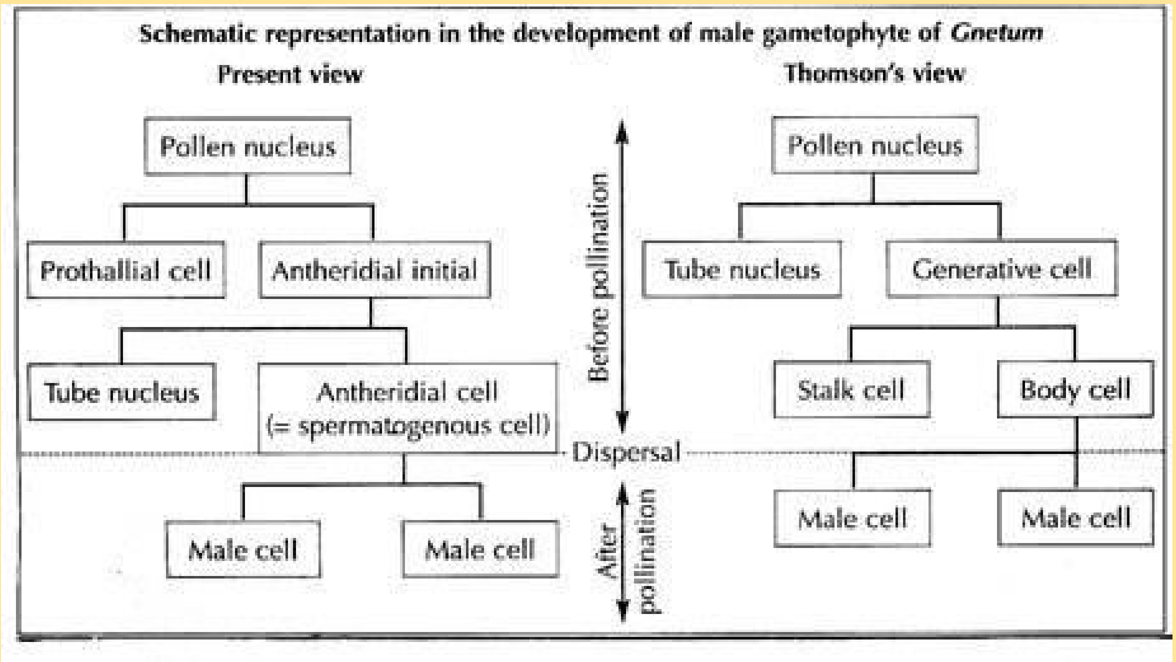
3. Gametophyte of Gnetum:

The spore is the first phase of gametophyte generation. The microspore or pollen grain represents the male gametophyte, while the tetranucleate coenomegaspore represents the first phase of female gametophyte which develops into a female gametophyte.

Development of Male Gametophyte before Pollination:

The pollen grain is inapeturate and spherical, bounded by the two concentric wall layers: the outer thick, spiny exine and the inner thin intine (Fig. 1.74C). The pollen nucleus divides mitotically to produce a small lens-shaped prothallial cell and a large antheridiai initial (Fig. 1.76B). The prothallial cell does not divide further and eventually degenerates.

The antheridiai initial divides to form an antheridiai cell and a tube nucleus (Fig. 1.76C). The antheridiai cell directly functions as spermatogenous cell. The pollen grains are released from the microsporangium at this 3-celled stage (one prothallial cell, an antheridiai or spermatogenous cell and a tube nucleus).



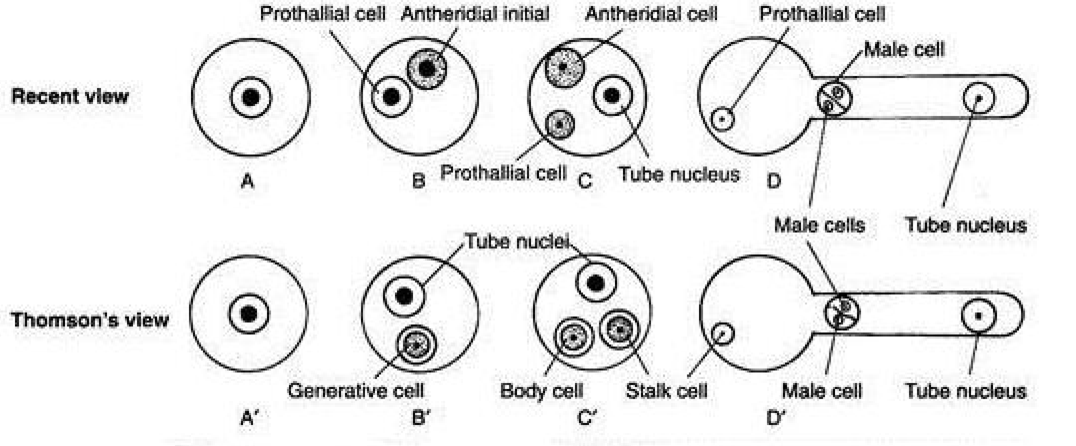


Fig 1.76 : Genetum: The development of male gametophyte : A-D. Recent view, A'-D'. Thomson's View

According to Thomson (1961), the prothallial cell is not formed in Gnetum. He proposed that the pollen nucleus cuts off a tube nucleus and a generative cell (Fig. 1.76B'). The generative cell again divides forming a stalk cell and a body cell (Fig. 1.76C'). Thus, the pollen grains are released at this 3-celled stage (tube nucleus, stalk cell and body cell).

Development of Male Gametophyte after Pollination:

The exine is cast off during pollen germination. The tube cell of the pollen comes out in the form of a pollen tube which traverses the nucellar tissue through intercellular spaces. The prothalial cell remains within the pollen grain and eventually disorganises.

The spermatogenous cell moves into the pollen tube and subsequently it divides to form two equal (e.g., G. ula, G. gnemon) or unequal (e.g., C. africanum) male cells just prior to fertilisation (Fig. 1.76D). The male cells are actually the male gametes which are non-motile. However, according to Thomson (1961) the stalk cell remains within the microspore and eventually degenerates. The body cell moves into the tube where it divides to form two male cells (Fig. 1.76D').

Development of Female Gametophyte:

At the initial stage, before the gametophyte formation, the nucellar cells immediately below the megaspore mother cell divide to form a tissue. The cells of this tissue are arranged in radiating rows. This tissue is termed as 'pavement tissue' which eventually gets absorbed and seems to be nutritive in function.

There is a free nuclear division in the coenomegaspore, as a result a large number of free nuclei are formed (Fig. 1.77A). The number of nuclei thus formed varies in different species, viz. 256 in G. gnemon, 512 in G. africanum and 1500 in G. ula. At this stage, a large central vacuole appears and the free nuclei lie in a thin film of cytoplasm around the vacuole towards the periphery (Fig. 1.77B). Later, the nuclei in the peripheral cytoplasm divide repeatedly.

At this stage, the upper part of the gametophyte surrounding a vacuole widens, while the lower part of the gametophyte shows accumulation of cytoplasm. Thus, the gametophyte becomes an inverted flask-shaped structure (Fig. 1.77C). The wall formation starts very slowly from the chalazal end towards the micropylar end. Thus, the nuclei remain free at the microphylar end even at the time of fertilisation.

The important characteristic in the female gametophyte of Gnetum is the absence of archegonia. One to three nuclei of the gametophyte in the micropylar end enlarge several times and accumulate dense cytoplasm around them. These large and densely cytoplasmic cells are the eggs (Fig. 1.77B). It is important to note that all the eggs do not mature simultaneously.

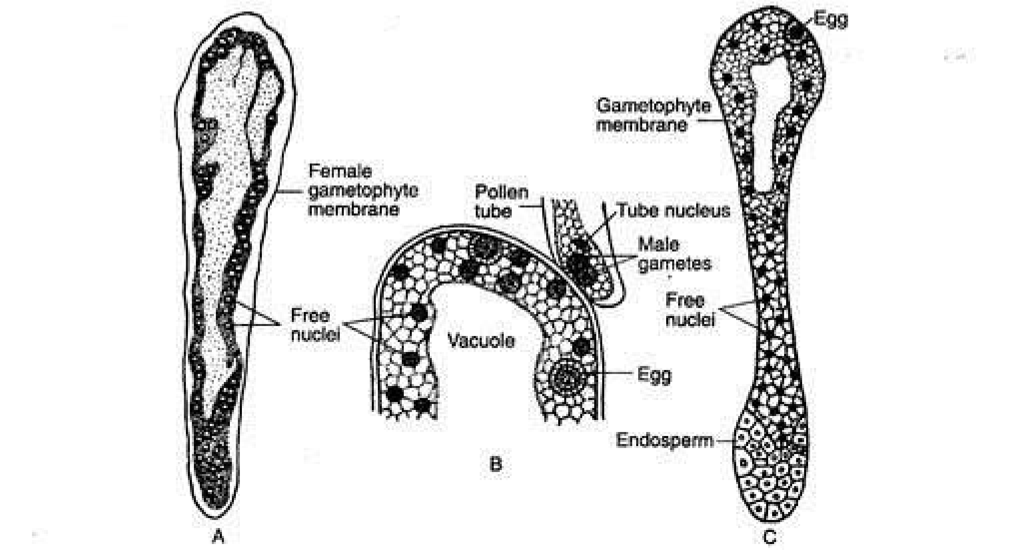


Fig. 1.77 : *Gnetum ula* : A. A female gametophyte in free nuclear stage, B. Top of the female gametophyte showing eggs, C. Female gametophyte showing first part of endosperm at base

Pollination:

Gnetum is wind-pollinated. The pollen grains are dispersed from the anther and remain suspended in the air for some time. At the free nuclear stage of the female gametophyte, the nucellar beak in the ovule disorganises forming a viscous sugary liquid which comes out through the microphyle in the form of a pollination drop. The pollen grains are caught in the pollination drop.

Due to the drying off of the fluid, the pollen grains are sucked into the micropylar canal and are finally collected in the pollen chamber. The mouth of the micropyle is then sealed from the outer environment due to the development of flage (a circular rim or an umbrella-shaped structure develops from the inner integument) and micropylar closing tissue (a tissue develops by the proliferation of the inner epidermis of integument at the level of flage).

Fertilisation:

The pollen tube enters the female gametophyte and the male gametes move ahead of tube nucleus (Fig. 1.77B). The pollen tube ruptures to discharge the male gametes into the egg cell.

The cell sheath of male cell is left outside the egg cell. Usually one of the male nuclei fuses with the egg nucleus and thus a zygote is formed. Sometimes, two male gametes may fuse two different eggs if those eggs are in the vicinity of the pollen tube.

Endosperm:

In gymnosperms, endosperms are cellular and haploid and are formed before fertilisation. However, in Gnetum the development of endosperms starts before fertilisation very slowly from lower part of the gametophyte which eventually proceeds upward. After fertilisation, the wall formation starts in such a way that the cytoplasm divides into many multinucleate compartments (Fig. 1.78A). Later, the nuclei in each cell fuse to form a single polyploid nucleus (Fig. 1.78B).

In this stage, the lower part of the gametophyte becomes cellular, while the upper part remains free nuclear even after fertilisation (Fig. 1.77C). Thus, the development of endosperm takes place even after fertilisation. There is a great variation in the development of endosperm in Gnetum.

In some cases, the wall formation starts either from the upper part or from the middle part of the gametophyte instead of the lower part and the whole gametophyte may become cellular. Though some portions of the endosperms are formed after fertilisation, the characteristic triploid endosperm through double fertilisation is, however, absent in Gnetum.

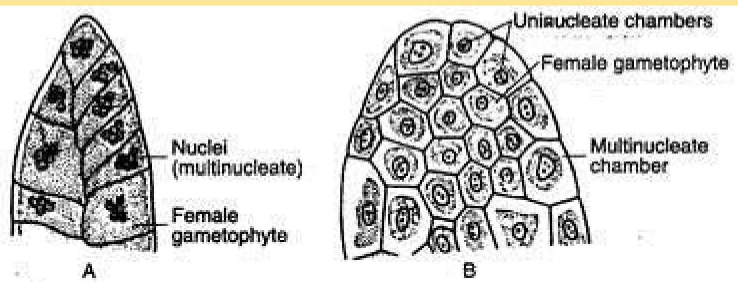


Fig. 1.78 : *Gnetum ula*. Development of endosperm : A. A portion of female gametophyte showing multinucleate endosperm, B. Uninucleate and multinucleate chambers

Embryogeny:

In all angiosperms (except, Paeonia), the division of zygote is accompanied by wall- formation; while in all gymnosperms (except Sequoia, Welwitschia), there is a free nuclear phase in the zygote during the development of embryo. However, Gnetum occupies an intermediate stage between gymnosperms and angiosperms with regard to embryo development by having both the free-nuclear divisions as well as cell divisions.

There is a great variation in the early development of the embryo in different species of Gnetum.

In C. gnemon, the zygote develops 1-3 small tubular outgrowths. Only one of the pro-tuberances receives the nucleus and survives, while the remaining protuberances die out (Fig. 1.79A).

The surviving tubular outgrowth becomes much elongated and branched and develops in various directions invading the intercellular spaces of the endosperm. These tubes are called primary suspensor tubes or proembryonal tubes (Fig. 1.79B).

All the primary suspensor tubes remain coiled around each other. At the tip of the primary suspensor tube, a small cell is cut off which eventually divides by a transverse wall, followed by a longitudinal wall resulting into four cells.

This is further followed by irregular divisions to form a group of cells. Now, further divisions take place in some of these cells which eventually elongate to form secondary suspensor. The rest of the cells at the tip form an embryonal mass (Fig. 1.79C, D).

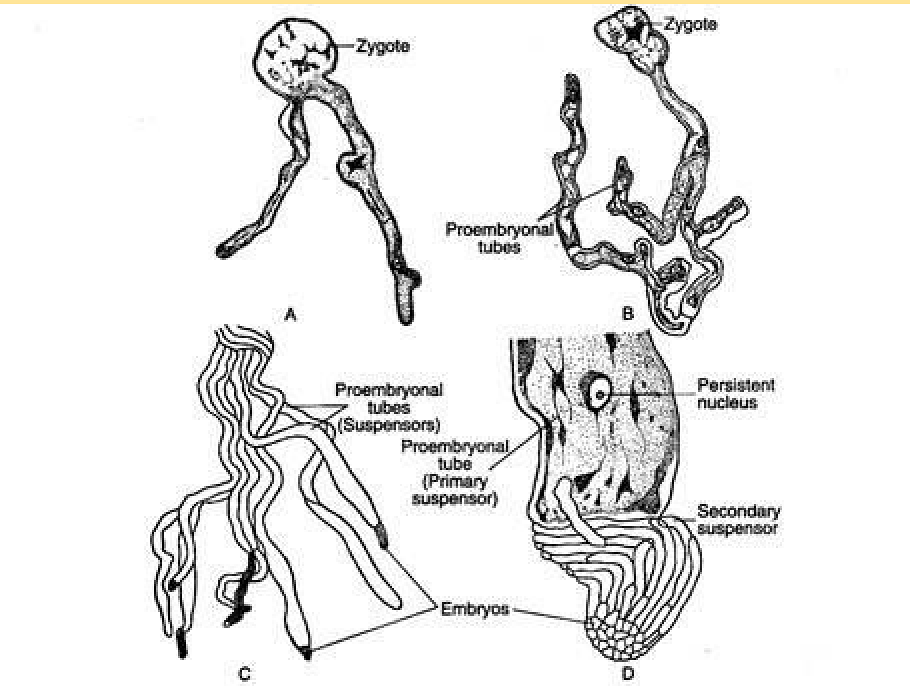


Fig. 1.79 : A. Germination of *Gnetum gnemon* zygote, B. Branching of *G. gnemon* suspensor tube to form several proembryonal tubes, C. Interwined primary suspensor or proembryonal tubes and embryo initials in young seed of *G. ula*, D. Tip of proembryonal tube with growing embryo in *G. ula*

In G. ula, the early development of the embryo up to the primary suspensor cells is almost similar to that of G. gnemon. The nucleus of the primary suspensor cell (Fig. 1.80A) divides to form two unequal nuclei, of which the smaller nucleus is cut-off by a thin wall. This cell is called peculiar cell which forms the embryo (Fig. 1.80B).

The peculiar cell divides twice forming a four-celled stage (Fig. 1.80C, D) which further divides transversely resulting into a 8-celled embryo (Fig. 1.80E). The embryonal mass increases in size by the further irregular divisions (Fig. 1.80F). Some cells of the embryonal mass adjacent to the primary suspensor elongate to form the secondary suspensor.

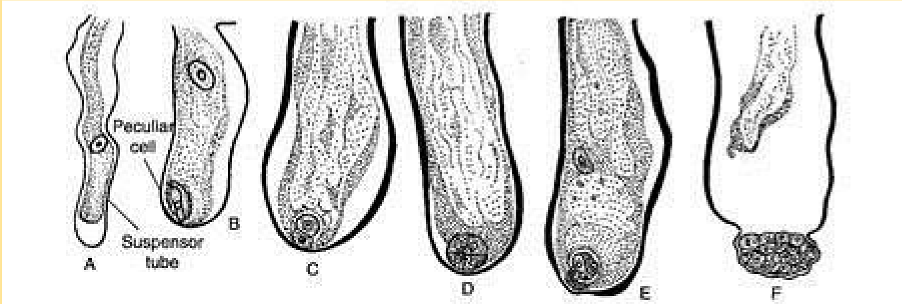


Fig. 1.80 : *Gnetum ula* : A. Tip of primary suspensor tube, B. Formation of peculiar cell, C–E. Peculiar cell dividing to form two (C), four (D) and eight (E) cells, F. Mass of cells formed by the peculiar cell

Irrespective of the pattern of formation of embryonal mass and secondary suspensor, the cell of the embryonal mass in Gnetum are small and compact with dense cytoplasm forming the embryo-proper. The cells of the secondary suspensor are thin-walled, uninucleate and highly vacuolated. Both the primary as well as secondary suspensors push the embryo deep inside the endosperm for the nourishment of the embryo.

At the tip of the embryonal cells, a stem tip with two lateral cotyledons is differentiated (Fig. 1.81 B). A root tip with a root cap also develops at the opposite end of the stem tip. Simultaneously, a hump-like structure called feeder is developed in-between the stem and root tips (Fig. 1.81B). Thus, a mature embryo is composed of a stem tip, two cotyledons, a large feeder and a root tip covered with root cap.

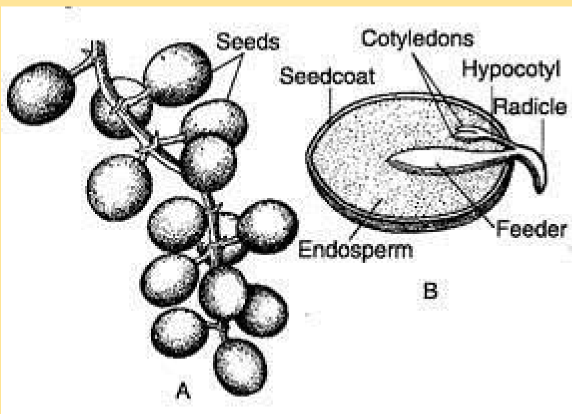


Fig. 1.81 : *Gnetum gnemon* : A. A twig containing seeds, B. Median L.S. of seed about to germinate

In Gnetum, polyembryony takes place in various ways. Each of the primary suspensor tube may develop an embryo, thus a large number of embryos are formed from a single zygote (Fig. 1.79C).

Sometimes additional embryos may develop due to the proliferation of the proembryonal mass present at the tip of the secondary suspensor. Sometimes, the primary suspensor tube branches giving rise to several primary suspensor tubes, each of which may develop an embryo at its tip.

Seeds:

Gnetum seeds are oval in shape (Fig. 1.81 A) and green to brown-red in colour. The seeds remain covered with a three-layered envelop, of which outer is fleshy, middle is stony and inner is pepary. The nucellus is used up and the embryo is embedded within the endosperm. Gnetum shows one-year reproductive cycle where pollination, fertilisation and development of embryo take place in one year.

The germination of seed is epigeal. The seeds of G. ula germinate after one year's of res-ting phase.

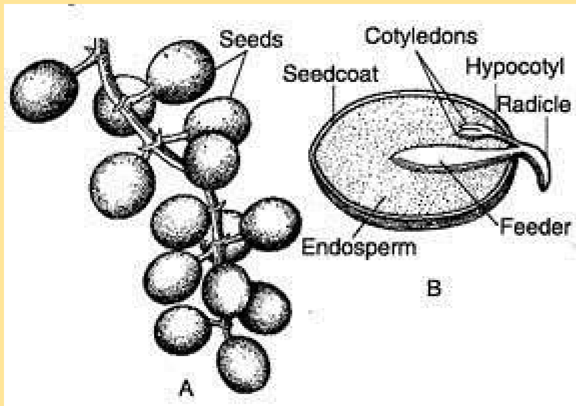


Fig. 1.81 : *Gnetum gnemon* : A. A twig containing seeds, B. Median L.S. of seed about to germinate

Figure 1.82 shows the life cycle of Gnetum.

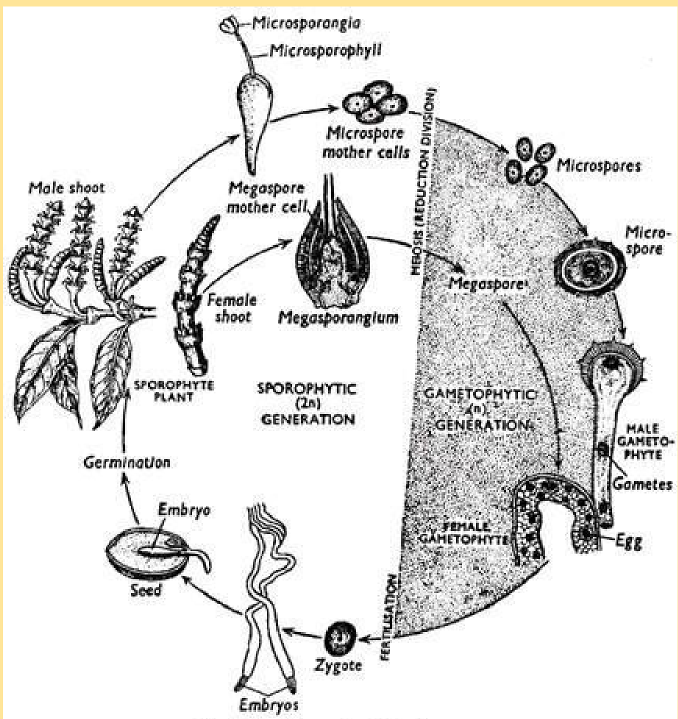


Fig. 1.82 : Life cycle of *Gnetum*

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PALEOBOTANY

The study of ancient plants is called **paleobotany**. The term "paleo" means ancient and "botany" means the science of plant life. **Plant fossils** that are found in sedimentary rocks are used for paleobotany. These fossils can be either compressions or impressions of plants on wooden or on rock surfaces that preserved the original plant in the form of a rock-like material. This branch of science helps in the identification of plants and uses a plant or its remains to study the evolution of that plant and its past environments. A scientist who studies paleobotany is known as a **paleobotanist**. The father of paleobotany is a French scientist named Adolphe-Theodore Brongniart.

WILLIAMSONIA

Occurrence of Williamsonia:
Williamsonia belongs to family Williamsoniaceae of Bennettitales. It has been reported from Upper Triassic period but was more abundant in Jurassic. This was earlier discovered under the name Zamia gigas by Williamson (1870) but has now been named as Williamsonia.

Professor Birbal Sahni (1932) described Other reported species from Rajmahal Hills are Williamsonia indica, W. microps and W. santalensis. Bucklandia indica, described from Rajmahal Hills, is now considered to be the stem of Williamsonia sewardiana.

External Features of Williamsonia:
Williamsonia (Fig. 6.13) resembled Cycas in appearance, and its best known species is W. sewardiana. A reconstruction of this species was published by Sahni (1932). The leaves of W. sewardiana were like that of Ptilophyllum. The plant had an upright, branched and stout stem covered by persistent leaf bases.

A terminal crown of pinnately compound leaves was present. For the stem genus Bucklandia, Sharma (1991) opined that features of leaf bases such as their shape, size and arrangement pattern are of taxonomic significance.

W. sewardiana from Rajmahal Hills of Bihar (India). Professor AC. Seward, a well-known palaeobotanist, described W.scotti. Gupta (1943) discovered Williamsonia sahnii from Rajmahal Hills and named if after Professor Birbal Sahni.

He observed that leaves in Williamsoniaceae show syndetocheilic stomata with rachis possessing collateral endarch vascular bundles arranged in a double U-manner. A distinct constriction was present at the base of lateral shoots as shown in Fig. 6.13.

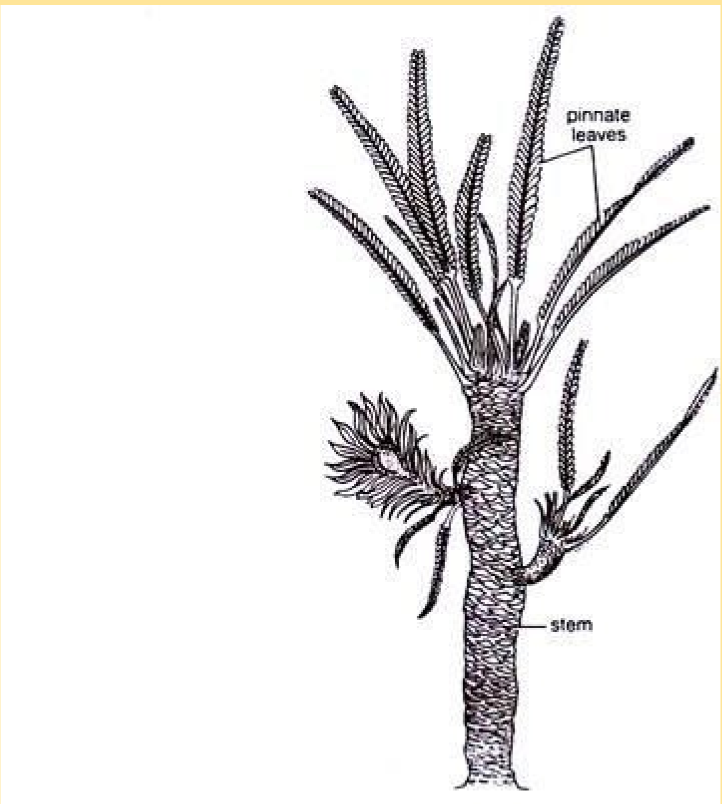

Fig. 6.13. *Williamsonia sewardiana* (after Sahni)

Reproduction in Williamsonia:

The fructifications of Williamsonia were large and attained a diameter of about 12 cm. They were borne on a peduncle. Many spirally arranged bracts were present around the base of the floral axis. In W. gigas the cones were present among the crown of leaf bases while in W. sewardiana they were present on the short lateral branches. Williamsonia plants were unisexual.

Female Flower:

The female 'cones' of Williamsonia gigas and W. sewardiana have been investigated in detail. Instead of 'strobili' or 'cones', Sporne (1965) has proposed to use the term "flower" in Williamsonia. The structure of female flower of W. gigas is illustrated in Figs. 6.14, 6.15. The conical receptacle was surrounded by many perianth-like bracts. The ovules were stalked.

The apex of the receptacle was naked and sterile. The nucellus was surrounded by a single vascularize integument, which was fused with the nucellus. The nucellus had a well-marked beak and a pollen chamber. In young ovules the micropylar canal was long and narrow.

In mature ovules, the canal widened because of the formation of nucellar plug and disappearance of interlocking cells. In the apical part of endosperm, Sharma (1979) observed 2 or more archegonia.

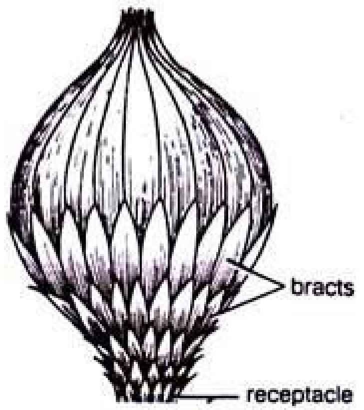

Fig. 6.14. *Williamsonia gigas.* A female flower bud. (after Williamson).

Fig. 6.15. *Williamsonia gigas.* L.S. female flower. (after Williamson).

Male Flower:

Out of several known male flowers of Bennettitales some have been described to belong to Williamsonia. Male fructifications have never been found in actual connection with the plant, and are sometimes referred to the genus Weltrichia.

Fig. 6.18. *Williamsonia spectabilis*, showing upper side of one lobe of pollen-bearing organs. (after Nathorst).

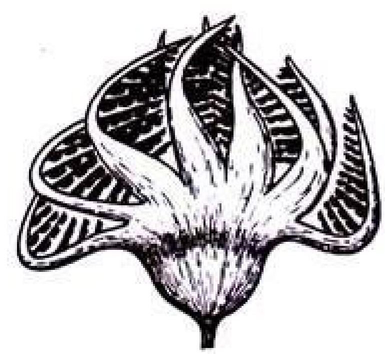

Fig. 6.17. *Williamsonia spectabilis*. Pollen-bearing organs. (after Thomas).

Male flowers consisted of a whorl of microsporophyll's, which were united to form a more or less cuplike structure. In majority of the investigated species (e.g. Williamsonia whitbiensis) the sporophylls were unbranched (Fig. 6.16) but in some species (e.g. W.spectabilis) they were also pinnately branched (Figs. 6.17, 6.18).

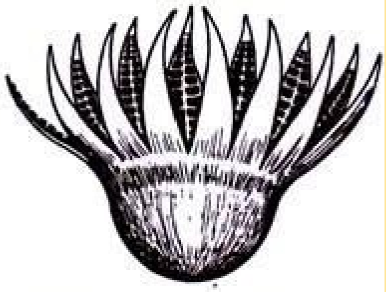

Fig. 6.16. *Williamsonia whitbiensis.* Pollen-bearing organs. (after Nathorst).

Sitholey and Bose (1953) discovered Williamsonia santalensis from Upper Gondwana (India), and observed that microsporophyll's in the species were bifid. One of the branches of microsporophyll was fertile while the other was sterile. The fertile part had finger-like structures called synangia Each synangium had two rows of chambers enclosing microsporangia. Sharma (1977,1983, 1991) has confirmed the synangiate nature.

The entire male flower attained a length of about 20 cm., while a single microsporophyll was about 10 cm long. The fertile branch of the bifid sporophvll possessed many purse-like capsules, in each of which there were present many monocolpate pollen grains.

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