Equisetum

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Classification

Division: Equisetophyta
Class: Sphenopsida
Order: Equisetales
Family: Equisetaceae
Genus: Equisetum
(The only extant member of this division)

Subgenera: Hauke reconized two subgenera on the basis of distribution and position of stomata in epidermis and striations

1. Equisetum
2. Hippochaete

Christenhusz *et al.* (2019) recongnized a third subgenus

3. Paramochatae

Common names: Horsetail and Scouring rush
Referred as Living fossil as it shows combination of pritmitive and advanced features and has long fossils history.

Distribution, Habit and Habitat

Distribution near-cosmopolitan, being absent only from Antarctica, though they are not known to be native to Australia, New Zealand nor the islands of the Pacific. They are most common in northern North America (Canada and the northernmost United States), where the genus is represented by nine species (*E. arvense*, *E. fluviatile*, *E. hyemale*, *E. laevigatum*, *E. palustre*, *E. pratense*, *E. scirpoides*, *E. sylvaticum'*, and *E. variegatum*).
Only four (*E. bogotense*, *E. giganteum*, *E. myriochaetum*, and *E. ramosissimum*) of the fifteen species are known to be native to south of the Equator.

Some species prefer damp and shady places (e.g. *E. pratense*), while others grow in marshy places, ponds or along the sandy river banks (e.g. *E. palustre*). E. arvense is found in diverse habitats, such as open grasslands, along roadsides and railway tracks. Some common Indian species of the genus are *E. arvense, E. debile, E. diffusum, E. ramosissimum* and *E. elongatum.* Of these, *E. debile* is found in plains along the river banks, while *E. arvense* is common in the western Himalayan ranges.

Species of *Equisetum* are used as indicators for minerals in the soil. Some species accumulate gold from the auriferous soil. There is a deposition of silica on the outer walls of the epidermal cells, due to which the plants become rough (just like sand paper) in texture and are used as abrasive. Silica also provides a protective covering to these plants against predators and pathogens. Some species of *Equisetum* are also used in ayurvedic medicines as diuretic.

The *Equisetum* species are perennial plants, herbaceous and dying back in winter as most temperate species, or evergreen as most tropical species and the temperate species *E. hyemale* (roughhorsetail), *E. ramosissimum* (branched horsetail), *E. scirpoides* (dwarf horsetail) and *E. variegatum* (variegated horsetail). They typically grow 20 cm–1.5 m (8 in–5 ft) tall, though the "giant horsetails" are recorded to grow as high as 2.5 m (8 ft) (*E. telmateia*, northern giant horsetail), 5 m (16 ft) (*E. giganteum*, southern giant horsetail) or 8 m (26 ft) (*E. myriochaetum*, Mexican giant horsetail), and allegedly even more.

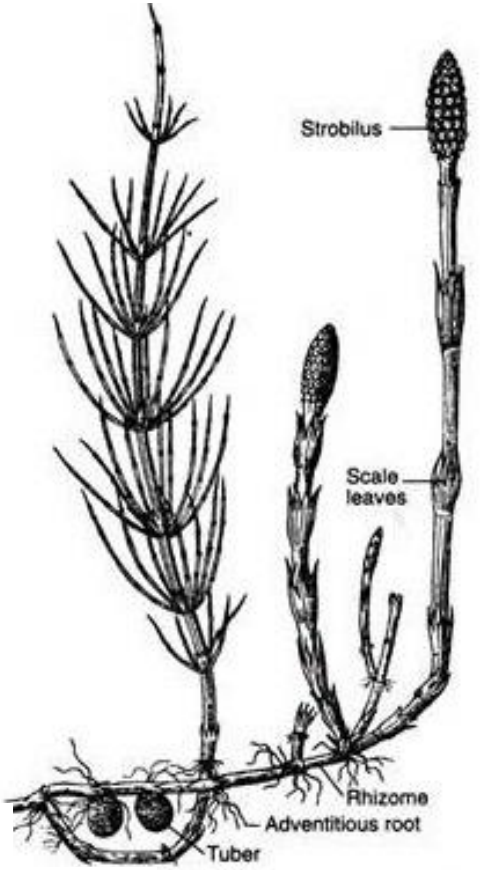
Ecological Adaptation

Xerophytic features : 1. Reduced non-photosynthetic scaly leaves, 2. Absence of stomata in leaves, 3. Photosynthetic nature of stem,4. Presence of sunken stomata in stem, 5. Presence of Silica impregnated epidermis. 6.Presence of sclerenchyma in stem against ridges and furrows.

Hydrophytic features: 1. Presence of hollow canal systems like, vallecular canal in cortex against furrow, carinal canal in vascular bundle against ridge and hollow pith in internodes. 2. Reduced xylem.

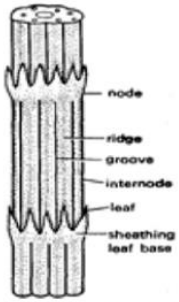
External Morphology

Sporophytic plant



Equisetum arvense sporophyte

Strobilus



***Equisetum*: A part of aerial stem.**

Leaf sheath

Stem:

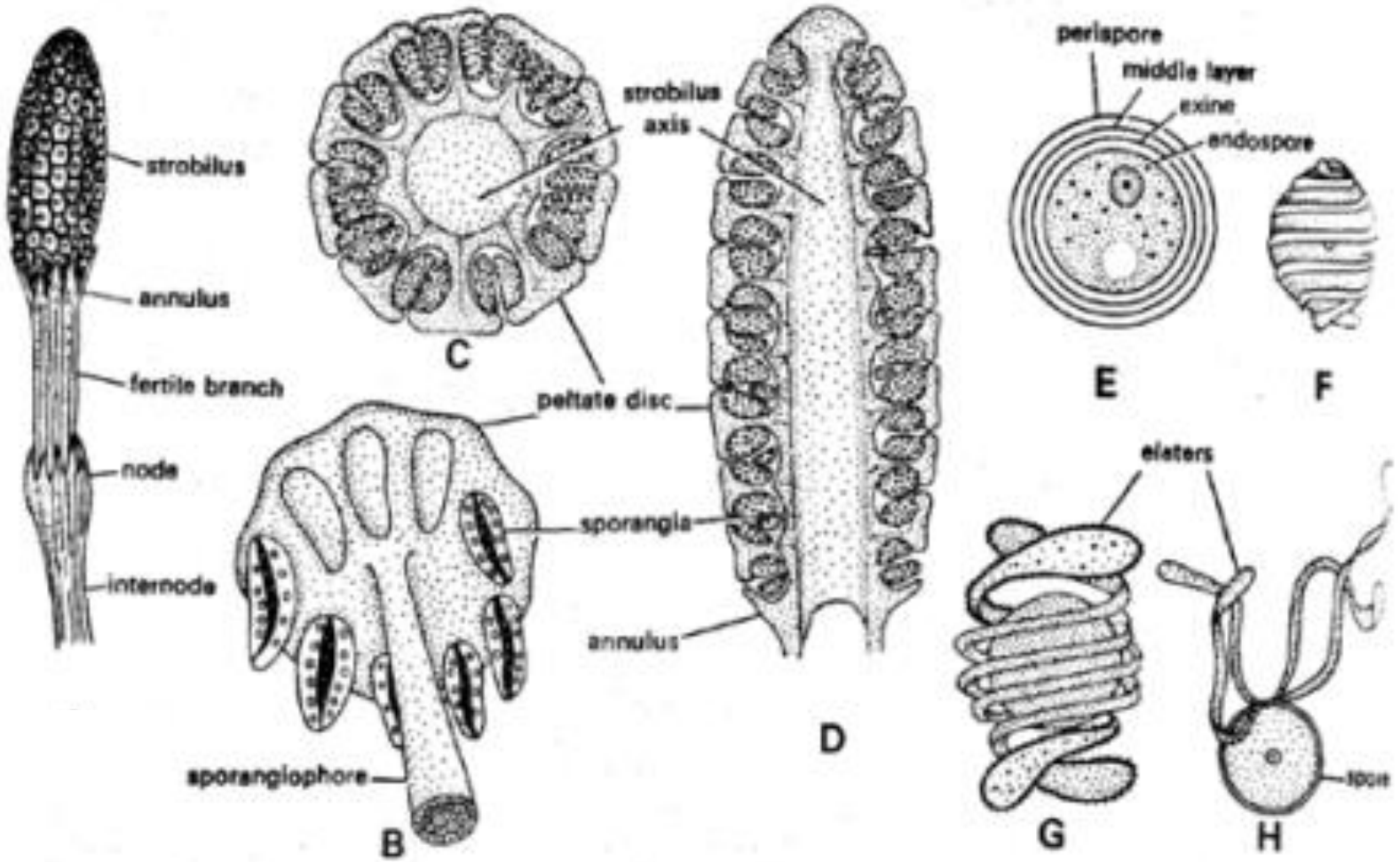
The stem of *Equisetum* is articulated and has two parts: perennial, underground, much-branched rhizome and an erect, usually annual aerial shoot. The branching is monopodial, shoots are differentiated into nodes and internodes.In majority of the species, all the shoots are alike and chlorophyllous and some of them bear strobili at their apices (e.g., *E. ramosissimum, E. debile*). Sometimes shoot shows dimorphism (two types of shoots i.e., vegetative and fertile) e.g., *E. arvense.* Some shoots are profusely branched, green (chlorophyllous) and purely vegetative. The others are fertile, unbranched, brownish in colour (achlorophyllous) and have terminal strobili. The underground rhizome and the aerial axis appear to be articulated or jointed due to the presence of distinct nodes and internodes. Externally, the internodes have longitudinal ridges and furrows and, internally, they are hollow, tube-like structures. The ridges of the successive internodes alternate with each other and the leaves are normally of the same number as the ridges on the stem.

Root:

The primary root is ephemeral. The slender adventitious roots arise endogenously at the nodes of the stems.

Leaves:

The leaves of Equisetum are small, simple, scale-like and isophyllous; they are attached at each node, united at least for a part of the length and thus form a sheath around the stem. The sheath has free and pointed teeth-like tips. The number of leaves per node varies according to the species. The species with narrow stems have few leaves (e.g., 2-3 leaves in *E. scirpoides*) and those with thick stem have many leaves (e.g., up to 40 leaves in *E. schaffneri*). The number of leaves at a node corresponds to the number of ridges on the internode below. The leaves do not perform any photosynthetic function and their main function is to provide protection to young buds at the node.

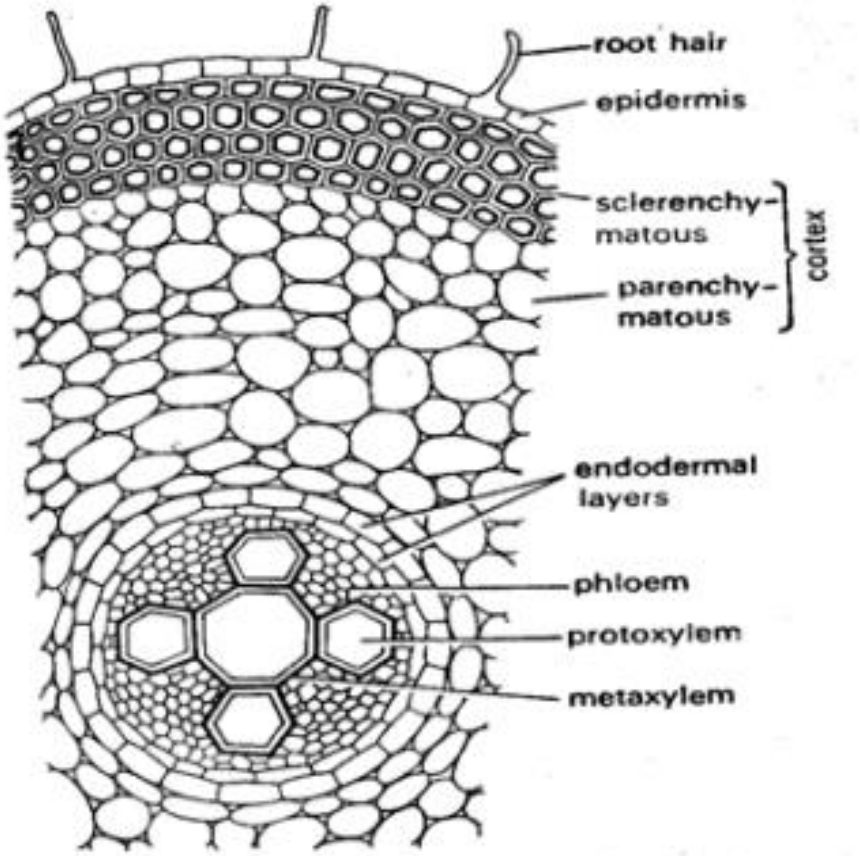


***Equisetum*: Structure of strobilus, A, A fertile shoot; B, A sporangiophore with sporangia; C, Transverse section of strobilus; D, Longitudinal section of strobilus; E, Transverse section of spore showing various wall layers; F-H, Spores with elaters**

Strobili are terminal in position on the chlorophyllous vegetative shoot However, they may be borne terminally on a strictly non- chlorophyllous axis (e.g., *E. arvense*).The strobilus is composed of an axis with whorls of sporangiophores Each sporangiophore is a stalked structure bearing a hexagonal peltate disc at its distal end. On the under surface of the sporangiophore disc 5-10 elongate, cylindrical hanging sporangia are borne near the periphery in a ring.The flattened peltate discs of the sporangiophores fit closely together which provide protection to the developing sporangia. The axis bears a ring-like outgrowth, the so-called annulus immediately below the whorls of sporangiophores which provide additional protection during early development.
Dehiscence through vertical slits.

Spores: Homospory present. All claims of heterospory prooved to be false. The spores of *Equisetum* are spherical, uninucleate, green and contain numerous chloroplasts. The spore wall is differentiated into four concentric layers, the outermost perispore, the second middle layer, the third exospore and the innermost endospore . The perispore, also known as epispore, splits into four strips or bands . Although these bands are separate from one another, they are attached to a common point on the spore. Initially, these bands are wrapped around the spherical spore but as the spore dries the bands are uncoiled. These bands are known as elaters and they have expanded spatulate ends.

Function of spores:The elaters are hygroscopic and respond to change in humidity. They probably help in the dehiscence of the sporangium by expanding and contracting. More often they seem to keep spore groups entangled. They also act as parachute and help spores to float in air and help in long distance dispersal. The monoecious gametophytes grow in cluster so that cross fertilization is facilitated.



T.S.Root

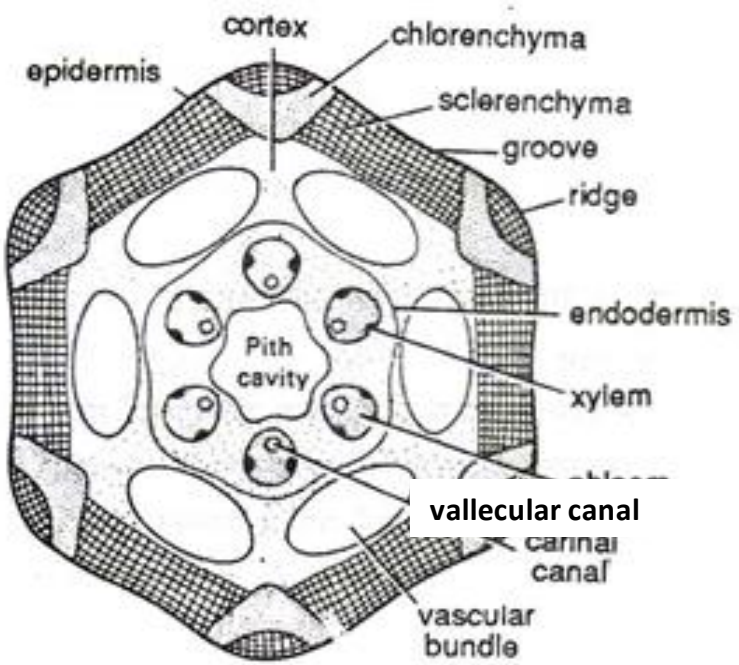
Root: A transverse section of the root shows epiblema, cortex, and stele. The single-layered epiblema forms the outer most protective covering of the root. Some cells of epiblema elongate to form root hairs. The epiblema is followed by a wide cortex, usually differentiated into an outer sclerenchymatous and an inner parenchymatous region. The latter has intercellular spaces. The sclerenchymatous outer cortex is also known as exodermis.

Two layered endodermis. The cells of the outer endodermal layer are larger and have casparian bands but those of the inner endodermis are smaller and without casparian bands.

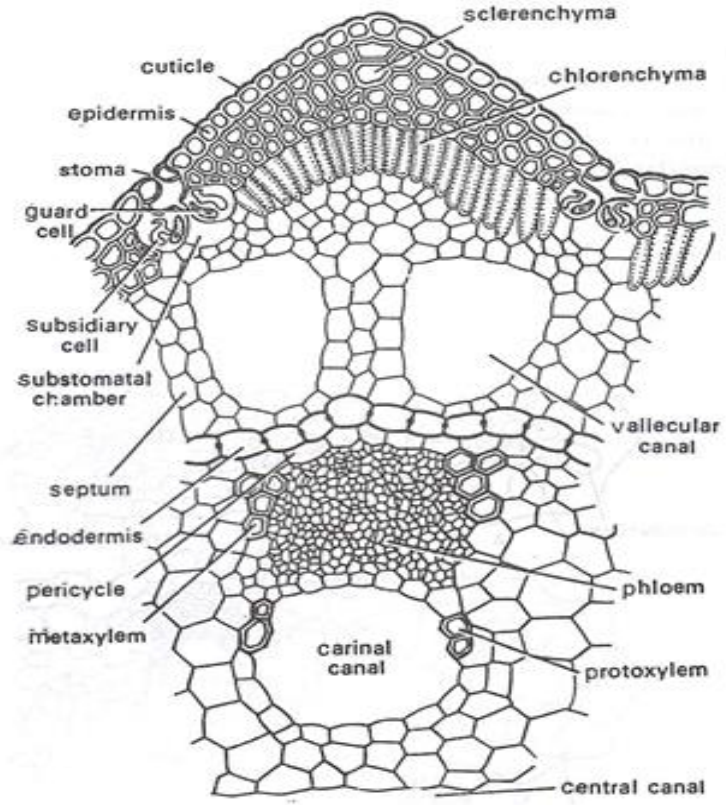
Pericycle is absent and lateral roots arise from the inner endodermis.

A protostele is present in the centre of the root with diarch to tetrarch xylem. The number of xylem strands usually increases with the diameter of the root. A large metaxylem tracheid is present in the centre of the stele and the protoxylem strands lie around it. The phloem is present in between the protoxylem strands.

T.S. through internode of aerial stem



Equisetum. T. S. internode of aerial sterile shoot (diagrammatic).



Equisetum. T.S. internode of aerial shoot (a part).

Aerial shoot: The anatomy of the stem of Equisetum is interesting as it shows a combination of hydrophytic and xerophytic characters. The nodes and internodes have different internal structures. Internode: A transverse section of the internode is wavy in outline due to the presence of ridges and grooves. It has a distinct epidermis, a well developed cortex, a stele with a ring of vascular bundles and a large central pith cavity. The epidermis is composed of a single layer of cells, with a heavy incrustation of silica on their outer and radial walls. Silica provides mechanical strength to the shoot. The epidermis is interrupted by stomata, which are usually confined to the groovesThe stomata are usually sunken, but in species like E. pratense and E. palustre they are at the level of the epidermis. The cortex is differentiated into an outer and an inner region. The outer cortex consists of sclerenchymatous and chlorenchymatous cells. The sclerenchyma lies just below the epidermis and provides mechanical strength to the shoot. It is many layered below the ridges but in the region of the grooves it is only 1-2 layered. It has large schizolysigenous canals, known as vallecular canals, below the furrows. These canals extend throughout the length of the internode and form distinct aerating system. The cortex is delimited from the stele by an endodermis, which varies in its position in different species.

The endodermis is followed by a single layer of parenchymatous pericycle. Stele eustelic where vascular bundles are arranged in a ring around the large pith. The vascular bundles lie opposite to the ridges, in positions alternate to the vallecular canals. Thus, the number of vascular bundles corresponds with the number of ridges. The vascular bundles are conjoint, collateral and endarch. The xylem of a bundle is in the form of two lateral and a median group of tracheids. In a very young vascular bundle, the protoxylem is represented by tracheids with annular or spiral thickenings. But in the mature bundle, the protoxylem elements disintegrate to form a conspicuous protoxylem lacuna, called carinal canal. Some protoxylem elements, however, can be seen along the periphery of the carinal canal. The metaxylem tracheids have scalariform, reticulate or pitted thickenings.

The phloem lies outside the xylem and in radial alignment with the carinal canal. It is composed of phloem parenchyma and sieve tubes with sieve areas on radial walls. The carinal canals are filled with water and help in conduction of water. Thus they are different from the vallecular canals which contain air only. The central part of the internode of the aerial shoot is occupied by a large pith cavity.

T.S. through node of aerial stem: The internal structure of node differs from that of the internode in the following features.

1. The pith is not hollow at the node, but instead a solid diaphragm, called nodal diaphragm, is present.
2. 2. Vallecular canals are usually not present in the node.
3. 3. The vascular bundles fuse together and form a vascular cylinder around the nodal diaphragm.
4. 4. Carinal canals are absent in the nodal region.
5. 5. Leaf and branch traces arise from the vascular cylinder of the node .

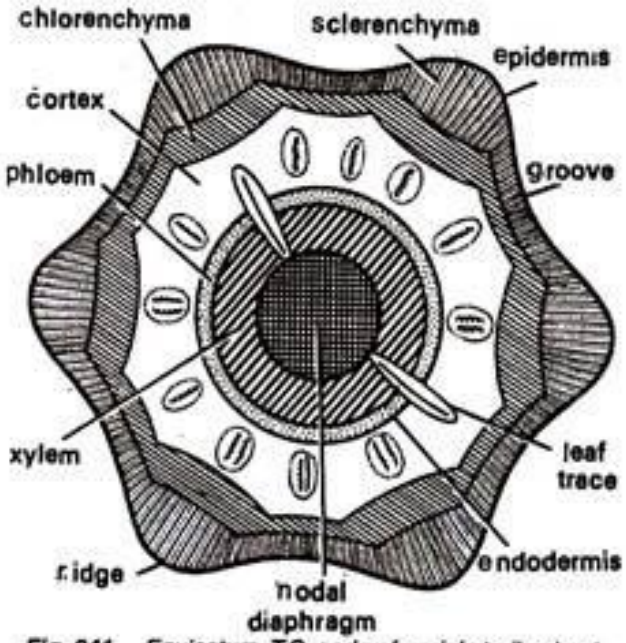
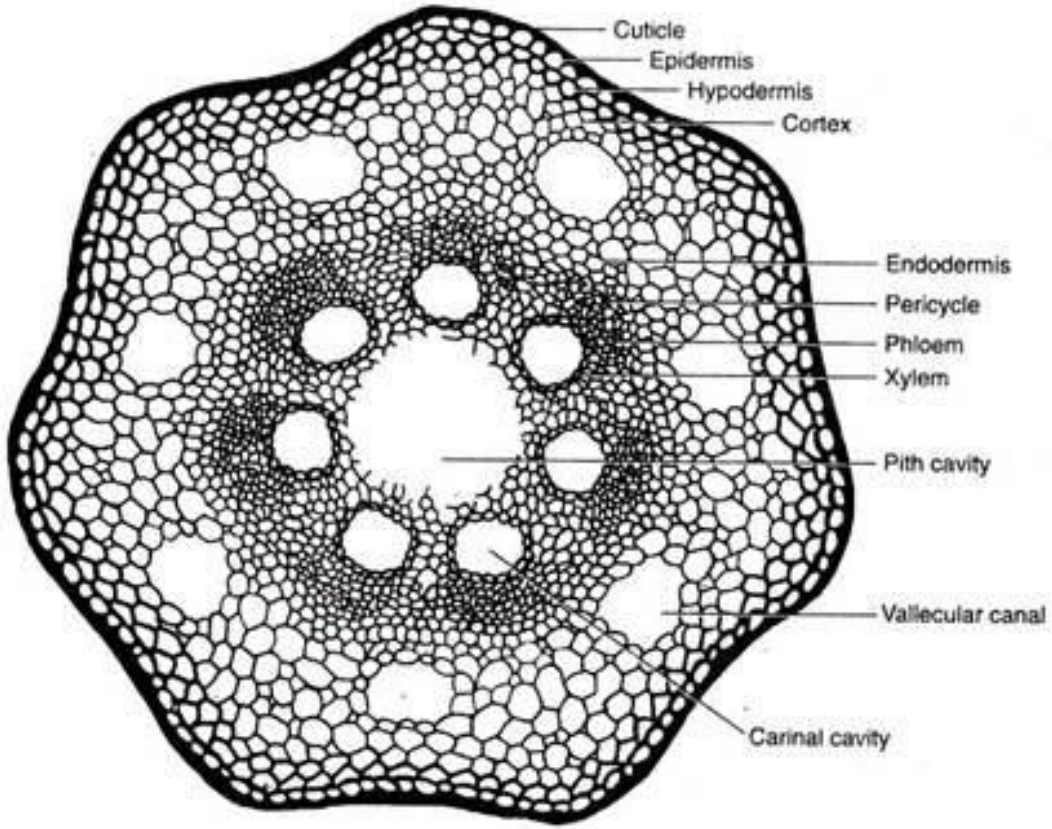


Fig. 241. Equisetum. T.S. node of aerial sterile shoot (diagrammatic).

T.S. Internode of Rhizome:

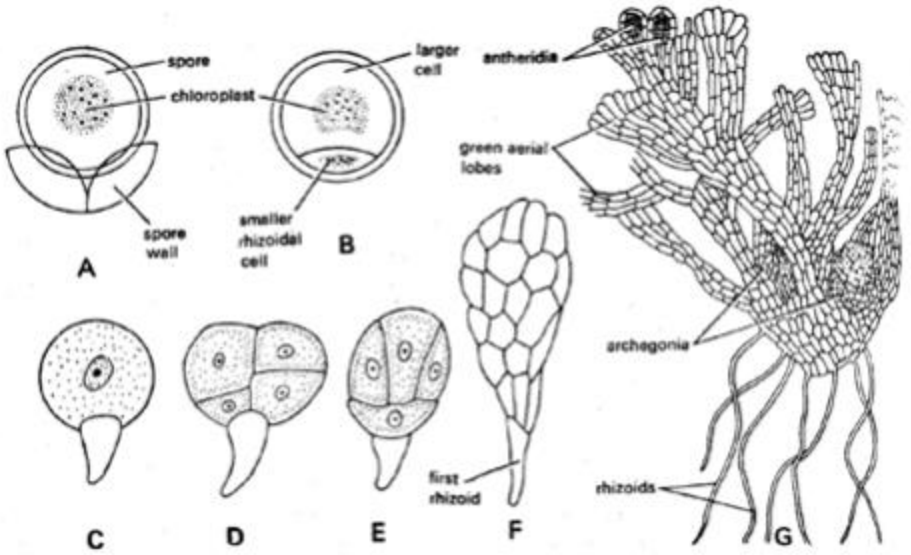
It also resembles in structure with the aerial stertile shoot except a few following dissimilarities:

1. Ridges and grooves are not so much well-marked as in sterile shoot.
2. Absence of stomata.
3. Absence of chlorenchymatous region.
4. Sclerenchyma is poorly developed.
5. Hollow pith cavity is not well-developed and sometimes it becomes solid.

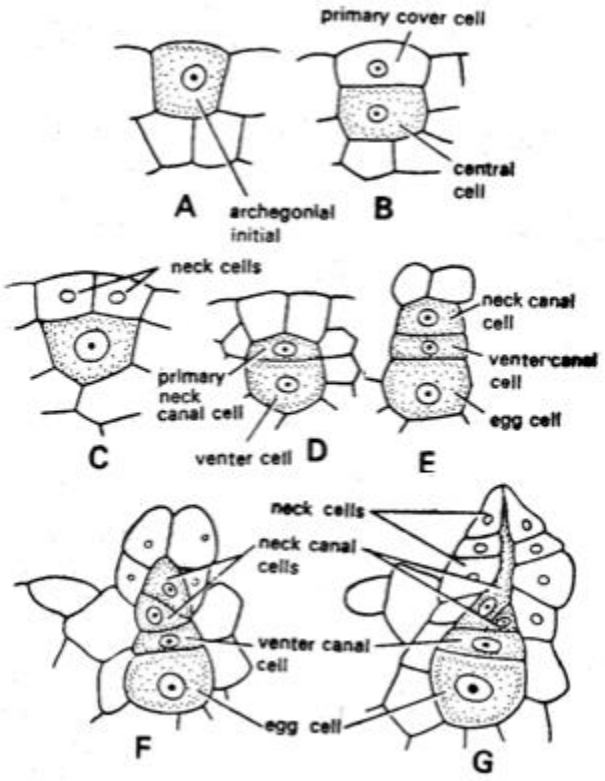


Equisetum: T.S. of stem (rhizome)

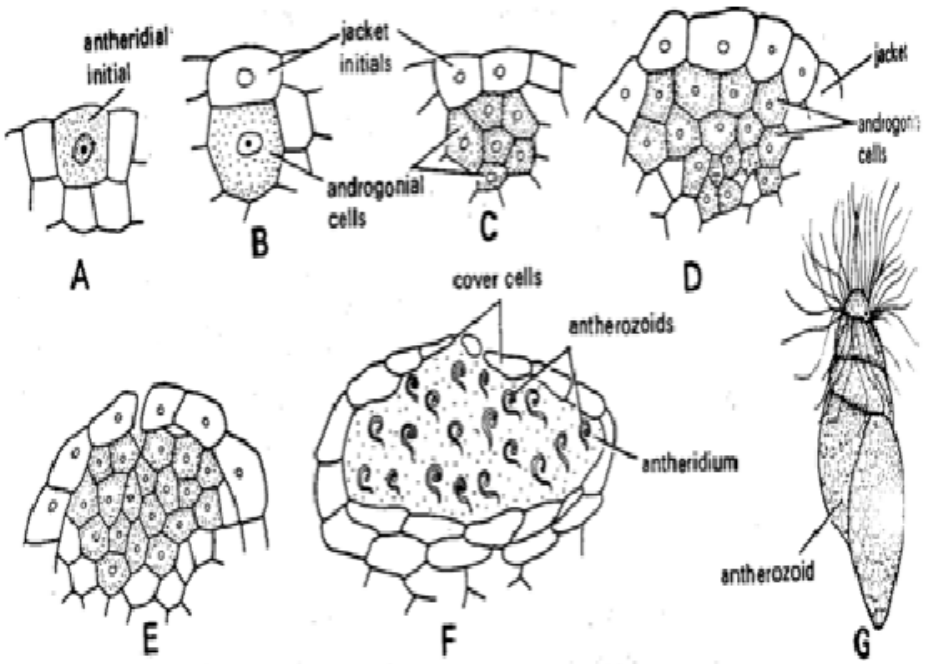
Development of gametophytic prothallus



The spores of Equisetum germinate shortly after shedding. They are short-lived and remain viable for 1-48 hours after shedding. Such a short duration of viability of Equisetum spores is perhaps due to their high rate of respiration. The spores germinate on a suitable substratum. They swell by absorbing water and shed the outer coat. The first division of the spore is asymmetrical, producing a rhizoidal cell and a larger cell . The former develops into the first rhizoid, whereas the latter eventually gives rise to prothallus. The shape and size of prothallus depends on prevailing conditions; if a number of spores germinate within a limited space, the prothalli formed are usually filamentous, whereas some germinating spores usually form relatively thick and cushion-shaped prothalli.

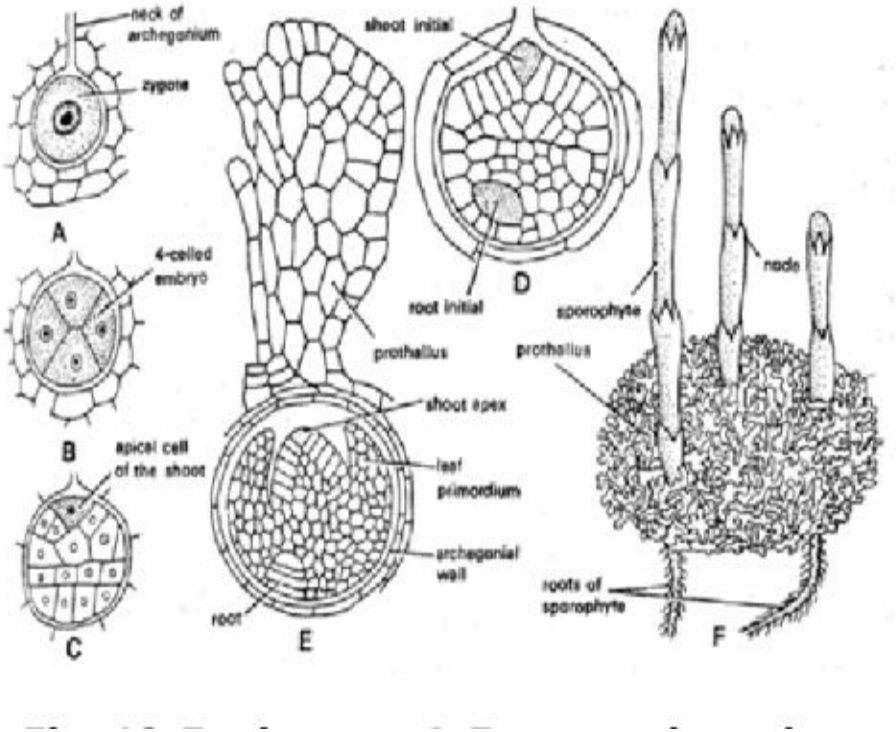


Diagrams showing developmental stages of archegonium of Equisetum sp.



Equisetum: Development of antheridium; AE, successive stages in the development of antheridium; F, mature antheridium; G, a multiflagelate antherozoid.

Embryogeny



Fertilization occurs by zoidogamy and chemotaxs. Zygotes divides by series of mitotic divisions to produce exoscopic embryo.

Reasons for calling *Equisetum* as Living Fossil

Combination of primitive and advanced features along with old fossil history

Primitive features: 1. Photosynthetic stem, 2. Occurrence of sporangia on sporangiophores, 3. Occurrence of reduced functionless leaves, 4. Occurrence of homospory, 5. Ocurrence of monoecious gametophyte, 5. Occurrence of reduced xylem, 6. Occurrence of zoidogamy and chemotaxis

Advanced features: 1. Occurrence of eustele in stem, 2. Occurrence of endarch xylem in stem, 3.Occurrence of multiflagellate antherozoids.

Antiquity: More than 100 million years (app 136 my)