PTERIDOPHYTES

General Account

The term **cryptogams** is combination of two Greek words *kruptos*=hidden and *gamos*=marriage, and refers to group of plants in which seed formation is absent. It includes *algae, fungi, bryophyte* and *pteridophyte* groups of plants. The first three are without vascular tissue whereas the *pteridophytes* have a well developed vascular system, therefore these are called **vascular cryptogams**.

Pteridophytes (Gr. *pteron*=feather, refers to feather-like pinnate fronds) have certain characters not found either in bryophytes or in seed plants. They differ from them in having both the gametophytes and sporophyte independent plants at maturity. On the basis of vegetative structure of the sporophyte, the manner sporangia are borne and the structure of the sporangia, the pteridophytes can commonly be differentiated as **psilophytes, lycopods, horsetails** and **ferns**.

The pteriodphytes have a long fossil history and can be traced back to the Silurian (about 400 million years ago). They flourished well from Devonian to Pensylvanian periods of the late Paleozoic which is usually regarded as the age of pteridophytes. Tree ferns, giant horsetails and arborescent lycopods dominated the landscape during this era. The plant bodies of earliest known pteridophytes were rootless and leafless (in certain cases small leaves without veins were present on the branches). The sporangia were borne singly at the tips of branches. The sporangia resemble those of bryophytes. These are commonly termed as **psilophytes**.

Psilotum and *Tmesipteris* are two living pteridophytes which have retained these old primitive characteristics. The present day lycopods (*Lycopodium, Isoetes, Selaginella*) and sphenopsids (*Equisetum*) are true copies of their ancient ancestors that reached 120 feet in some cases (*Lepidodendron, Calamites*).

GENERAL ACCOUNT OF PTERIDOPHYTES

Habitat

The pteridophytes grow in a variety of habitats. *Most pteridophytes are terrestrial plants and thrive well in abundant moisture and shade while some flourish in open, dry, xeric conditions. A few are aquatic while still others are epiphytic.*

The Plant Body

The dominant phase is a **sporophyte** that possesses a well developed vascular system. It consists of a shoot system made up of stems, leaves and roots. Some primitive pteridophytes were rootless, leafless and free-living sporophytes. These consisted of a dichotomously branched axis (**psilophytes** — *Rhynia*) bearing rhizoids on the underground part of the axis which acted as absorbing structures. The modern survivors of psilophytes *Psilotum* and *Tmesipteris* are also rootless. The roots originated during later phases of growth.

The Stem

The shoots are characterized by presence of **apical meristems** at their tips which are responsible for branching and organ formation.

The shoots exhibit two types of branching:

1. **Dichotomous Branching:** The root or shoot apex divides into two sister apices, each developing into a branch of equal size, for example in *Psilotum*.
2. **Monopodial Branching:** In this type, the branches develop laterally some distance behind the main shoot apex from axillary buds. It is dominant type of branching in seed plants and found in few vascular cryptogams.

In *Lycopodium* and *Selaginella*, the dichotomous division takes place in the same plane successively to form a flat system of short forked branches. This is known as **determinate branch system** and demonstrate a transition to monopodial branching. In *Equisetum* the branches develop in whorls. Each branch originates from a bud and alternates with a leaf in a whorl at node. In ferns (*Marselia*) the determinate branching system differentiated into a frond. The fern frond and short shoot of *Selaginella* are closely like in many aspects.

The Leaf

The leaves originate as **primordia** (sing. primordium) by means of localized division and cell extension at nodes on the flanks of the shoot apex. Thus, the leaf is a major appendage on the stem. The most primitive fossil pteridophyte *Rhynia* was leafless, however *Psilophyton* axis possesses few small, spine-like emergences, but these too are restricted to certain parts of the axis and without vascular traces. The axis of living genus *Psilotum* also bear small appendages without vascular supply. In *Lycopodium* and *Selaginella* these appendages are small but leaf-like, but in *Isoetes* the appendages have attained a considerable length.

Two morphologically different types of leaves are found in pteridophytes. These are:

i. **Microphyll:** It is a small leaf with simple vascular system. A single leaf trace diverges from the edge of the stele and extends as an unbranched midvein from the base to the apex of the leaf. The microphylls occur in all *lycopods* and *Equisetum*.

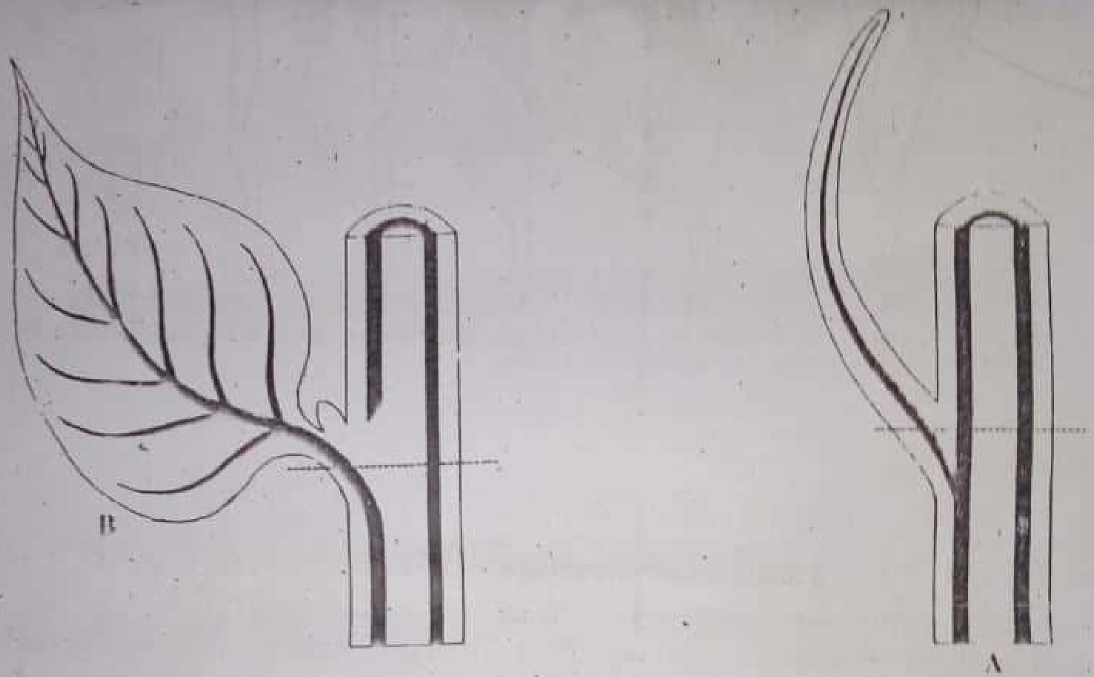
ii. **Megaphyll:** It is large leaf characterized by presence of two or more veins. The leaf traces are accompanied with leaf gaps. The venation is open dichotomous (the veinlets are dichotomously branched and terminate freely). The megaphylls are characteristic leaves of *ferns*.

Ligule

In certain genera of *lycopsids*, for example *Selaginella* and *Isoetes* small scale-like outgrowth called **ligule** is present near the adaxial base of each **microphyll**. A ligule initiates from a single or row of surface cells and a mature ligule comprises of a base or foot region which is sunken in the tissue of microphyll and consists of a layer of cells continuous with the epidermis of the leaf, and **glossopodium**, which consists of group of large wedge-shaped cells.

The ligule is considered to be a secretory organ which exudes water and mucilage that protect the young leaves and sporangia from desiccation. Transfusion tissue consisting of tracheid-like cells is present between ligule sheath and the adjacent vein of the microphyll.

On the basis of presence or absence of ligule, the *lycopsids* are arranged into two series: the **ligulates**, in which the ligule is present; and **eligulates** in which ligules are absent.



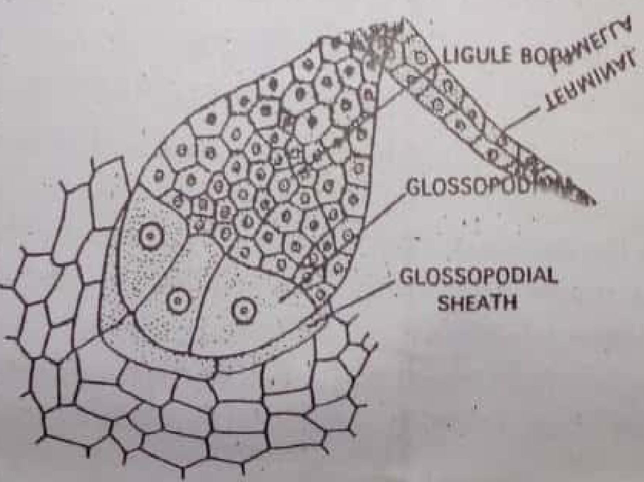
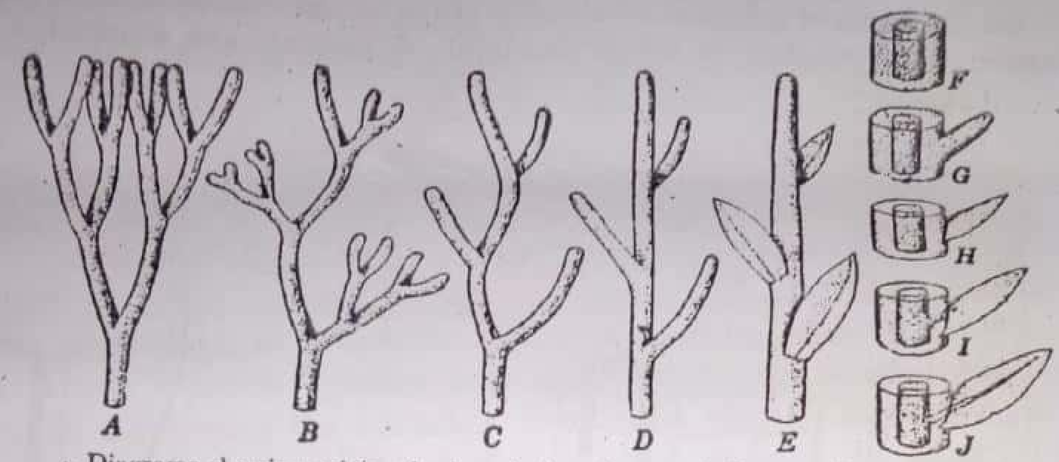


Fig. 1.1: A. *Microphyllous and megaphyllous leaves*; B. *Ligule*;

Origin of Leaf

According to **Bower** the **microphylls** originated as **enations** or superficial lateral outgrowths from the naked axes as in *Psilophyton* in which the enation was a small scale or spine-like outgrowth without leaf trace. In *Asteroxylon* the enation was provided with a rudimentary leaf trace which terminated at the base of the appendage. Additional support of enation theory of the microphyll is found in the shoots of *Psilotum* and *Tmesipteris* where the young axis is naked and the appendages are without vein in *Psilotum* whereas a single mid-vein is present in *Tmesipteris*. This theory of origin of leaf is called **enation theory**.



. Diagrams showing origin of microphyllous leaves. *A–E*, according to the telome theory. *F–J*, according to the enation theory.

Fig. 1.2: *Enation concept of origin of leaf.*

On the other hand, **Zimmermann** (1954) was of the view that microphylls and scale-like appendages arose as a result of reduction from lateral dichotomously branched system of axes or telomes. This theory of origin of leaves is called **telome theory**. This theory is less widely accepted as for as the origin of microphyll is concerned, however it is widely accepted regarding the origin of megaphylls of *ferns*.

According to Zimmermann the development of a megaphyll took place by three successive phenomena namely overtopping, planation and webbing.

i. **Overtopping:** Beginning with a leafless and dichotomously branched plant such as *Rhynia*, unequal dichotomous branches resulted in the overtopping of the weaker branch by its more aggressive sister branch; this process was repeated at each point of a major dichotomy and resulted in the initial distinction between the axis and leaves.

ii. **Planation:** The lateral branches at first branched dichotomously in more than one plane but later restricted themselves to a single plane. This is planation.

iii. **Webbing:** The final step consisted in the fusion or webbing of the separate telomes of an overtopped lateral branch into a flat, primitive lamina characterized by presence of a simple open dichotomous venation. Later the fusions between the veinlets produced reticulate venation.

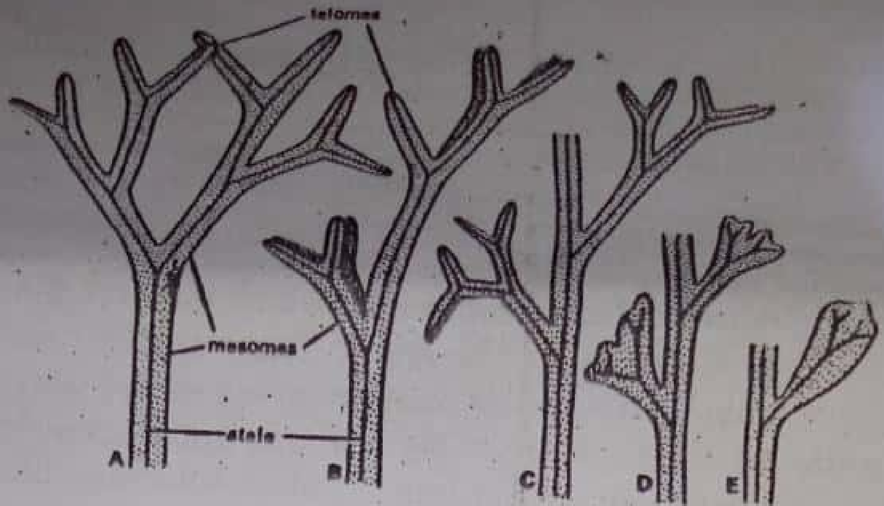


Fig. 1.3: Zimmermann's concept of origin of leaf.

Root System

The roots of most of the pteridophyte groups are adventitious structures and only in *Isoetes* a definite root system is present. The basal part of the axis bear roots. It has been observed anatomically that these are not true roots rather **rhizomorphs**. In *Selginella* the rhizomorphs are present but these are lateral structures and do not have indeterminate growth.

Vascular Tissue System

The sporophyte of pteridophytes is characterized by the evolution of two general types of conducting tissue, the **xylem** and *phloem*, not found in the cryptogams, i. e., *algae* and *bryophytes*. The origin of vascular tissue is unknown, however it is believed to be evolved from columella of *Anthoceros* sporophyte. The vascular tissue is present in the form of vascular bundles, a bundle comprising of xylem and phloem tissues. The vascular elements develop from a core of or column of meristematic tissue called **vascular cambium.**

Xylem

The fundamental xylary element is **tracheid:** an elongate dead cell consisting only of a thick lignified cell wall at maturity with end walls showing a taper usually. The walls of tracheids contain transversely elongate or circular thin areas called pits which help in conduction of water. **Vessel** is a vertical series of water-conducting elements, called **vessel members**. These have perforations in their end walls. Their diameter is same as those of tracheids unlike the vessels of higher vascular plants. **Parenchyma cells** are also present in the xylem. In some cases these are present between the phloem and tracheids whereas in others, such as *Lycopodium* these intermingle with xylary elements.

The portion of the xylem consisting of tracheids which elongates after after the disappearance of their protoplasts is called **protoxylem**. It is the first-matured portion of the xylem. The portion of the xylem matured after the elongation has ceased is called **metaxylem**. The tracheids of metaxylem are unable to elongate after they are mature. The tracheids of protoxylem are smaller in diameter than those of the metaxylem.

Phloem

The phloem of pteridophytes is composed of sieve tubes, a series of elongate living cells, known as **sieve tube members**, in which the protoplast is connected to one another through perforations in the walls. These perforations are not present throughout the walls but restricted to certain areas called **sieve areas**, usually present at end walls. In old sieve tubes perforations are blocked by development of callus pads (callus is a carbohydrate) turning the sieve tube non-functional. The other component of the phloem is phloem parenchyma.

Sometimes a distinction is made between the **protophloem** and **metaphloem**, but, unlike the xylem, there is no prominent morphological difference between the first-formed and later-fomed phloem.

Reproduction

The sporophyte reproduces by formation of spores, therefore the mode of reproduction is asexual.

Asexual Reproduction

The asexual reproductive units, the **spores** are produced in **sporangia**.

Sporangia

The sporangia differ in position, form, size, structure and method of development in different groups of pteridophytes. This characteristics is used for classification of vascular cryptogams.

The sporangia originated from stem and this fact is supported by position of sporangia in fossil pteridophytes *Horneophyton* and *Rhynia* and living pteridophytes *Psilotum*, *Tmesipteris* and *Equisetum*. In *Equisetum*, the sporangia occur in circular groups attached to the under surface of peltate **sporangiophore**. A sporangiophore is regarded as highly modified fertile branch. In *ferns* the sporangia are related to leaves. A leaf or leaf-like structure which bears one or more sporangia is called a **sporophyll**. In *Selaginella* and most *Lycopodium spp* the sporophylls aggregate into a compact cone-like structure called **strobilus**.

Structure of a Sporangium

A mature sporangium is stalked and consists of one or many spores enclosed by a one to many-layered protective wall. Certain cells of the sporangium wall are unevenly thickened and form a an incomplete ring called **annulus** or **stomium**. It helps in dehiscence and dispersal of spores. In most cases the wall layer adjacent to spore mother cells is nutritive in function and known as **tapetum**.

On the basis of development two principal types of sporangia are recognized:

1. **Eusporangiate Sporangia:** The sporangium that arise from a group of superficial initial cells and the sporangium wall is many-layered **eupsorangiate**

sporangium, for example in *Lycopodium*, *Selaginella* and *Equisetum*.

ii. **Leptosporangiate Sporangia:** The sporangium that arises from a single superficial initial and its wall consists of a single layer of cells is called **leptosporangiate sporangium**. This type of sporangium is found in *leptosporangiate ferns*.

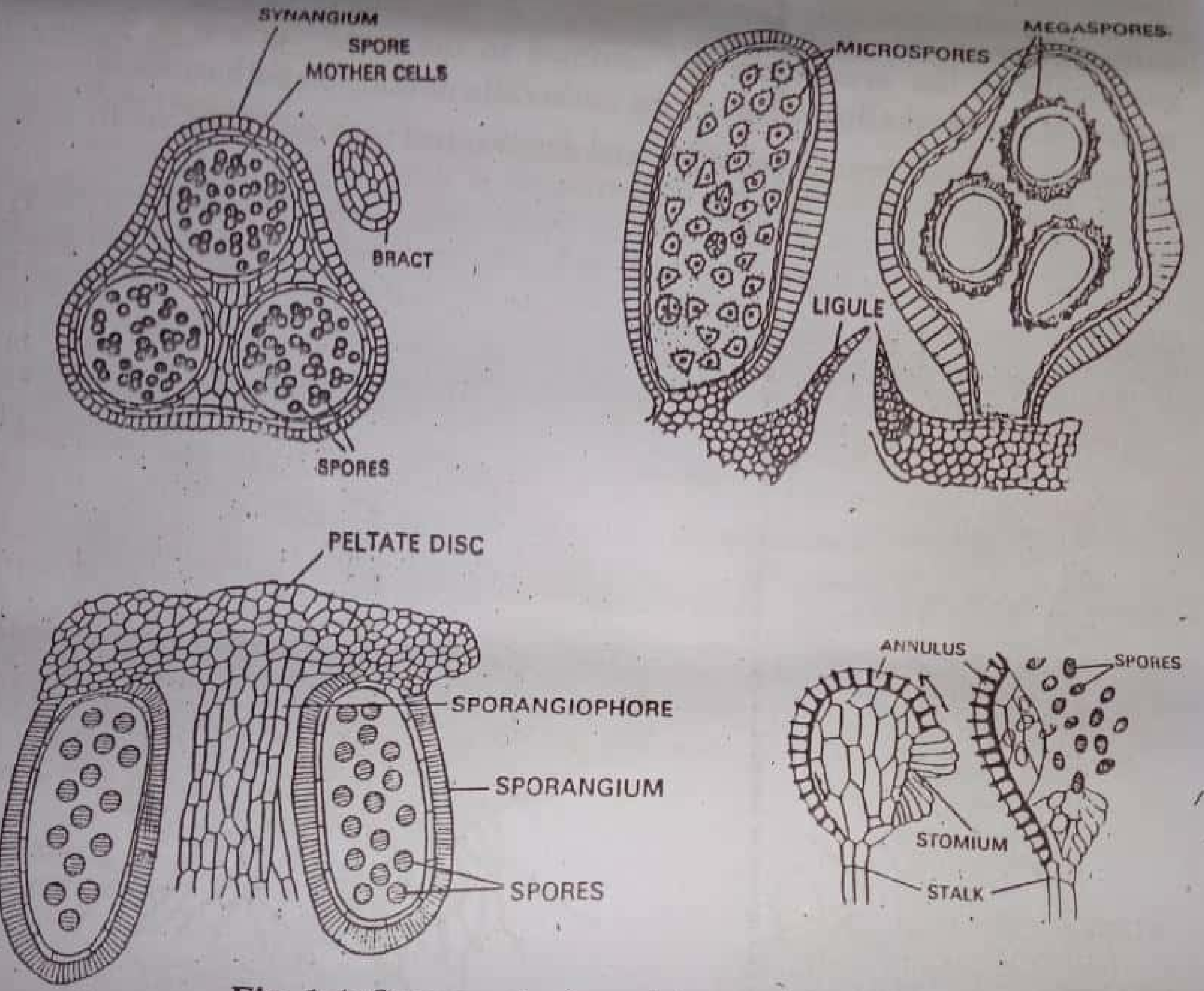


Fig. 1.4: *Sporangia found in pteridophytes.*

Heterospory

The presence of morphologically and physiologically different types of spores is usually referred to as **heterospory**. Heterospory is found in almost all groups of pteridophytes, however it is not pronounced among giant horsetails but in lycopods (*Selaginella*) and ferns (*Marselia*) it is conspicuous and **megaspores** are many times larger than the **microspores**.

Sexual Reproduction

The spores on germination give rise to haploid monoecious or dioecious gametophytes. The gametophytes reproduce sexually.

Gametophyte

The sex organs develop on separate, independent but much reduced plants, the **gametophytes**. The gametophytes in vascular cryptogams are extremely reduced, photosynthetic and simple in structure. These are generally called **prothalli** (sing. prothallus). Two types of prothalli are present among pteridophytes:

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i. **Cylindrical Type:** The gametophyte is upright and cylindrical, for example in *Psilotum, Lycopodium*, etc. In these gametophytes the gametangia are intermingled and occur all over the surface of the gametophyte as in *Psilotum* and *Tmesipteris*. In *Lycopodium* the sex organs are present in clusters on the upper surface of the gametophyte.

ii. **Dorsiventral Type:** The gametophytes in which dorsal and ventral surfaces can be recognized, for example in *Equisetum* and *ferns*. In these gametophytes the archegonia are confined to the lower surface of prominent midrib of the prothallus, whereas the antheridia develop on both surfaces.

The cylindrical type is primitive and dorsiventral type evolved from it.

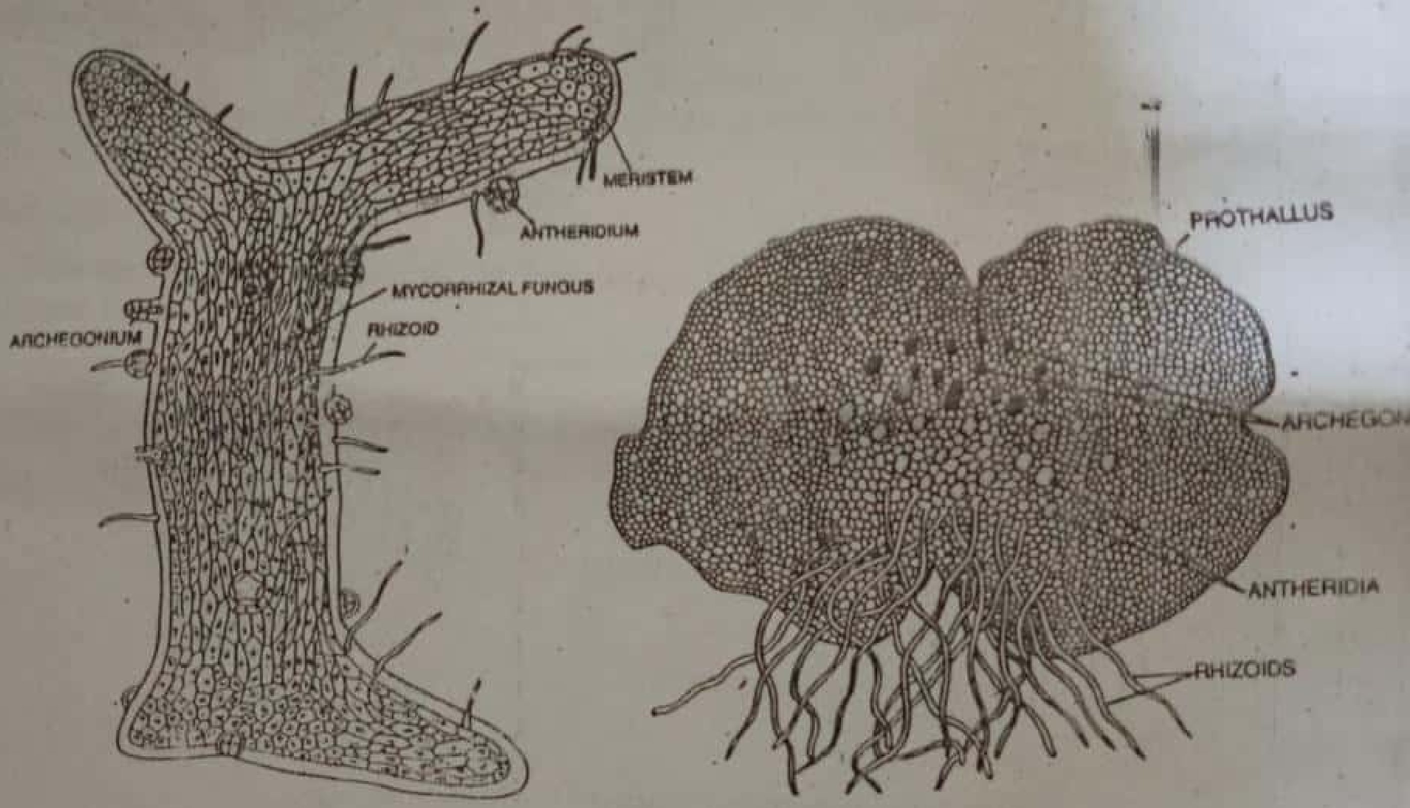

Fig. 1.5: ***Gametophytes found in pteridophytes.***

The gametophytes may be:

i. **Exosporic,** when these are free-living and not enclosed by the spore wall. Exosporic type of gametophytes represent original and primitive condition. Exosporic gametophytes are **monoecious**, i. e., they produce both types of sex organs.

ii. **Endosporic**, when entire or most part of the gametophyte is enclosed in spore wall. Endosporic gametophytes are present in heterosporous species usually. Endosporic gametophytes are strictly **dioecious**.

The **male gametophyte** (microgametophyte) in heterosporous species is an extremely reduced structure, for example in *Selaginella* and *Isoetes*. It consists of a single vegetative **prothalial cell** and one **antheridium**.

The **female gametophyte** (megagametophyte) is massive and contains food-storing tissue. The sex organs are usually embedded in the vegetative tissue of the prothallus, especially the basal part of archegonium containing egg is always within the prothallus tissue.

In higher leptosporangiate ferns (*Adiantum*) the female gametophyte is in the form a heart-shaped cushion, the sex organs are restricted to lower surface of with archegonia develop in tissue behind the notch and antheridia near the basal end of the prothallus.

Sex Organs

The sexual reproduction is by pairing of morphologically different gametes. The male gametes are motile, flagellated and usually termed **male sperms**, whereas the female gametes are passive and non-motile called the **eggs**. The gametes are produced in separate sex organs, the **gametangia**:

i. **Antheridium:** The male gametangium commonly known as **antheridium** produces male sperms. The number of sperms vary from species to species. Each antheridium consists of a **jacket** of sterile cells enclosing the **spermatocytes**. The sperms are biflagellate, however in *Isoetes* multiflagellate sperms are present.

ii. **Archegonium:** The female gametangium is archegonium. A typical mature **archegonium** consists of a **neck** which project above the surface of the gametophyte, and basal sunken portion, the **venter**. The neck contains an axial row of cells, the neck canal cells and the venter contains an **egg** and a **ventral canal cell**. The venter is surrounded by a sterile layer of cells forming jacket. The neck usually comprise of four vertically arranged rows of cells.

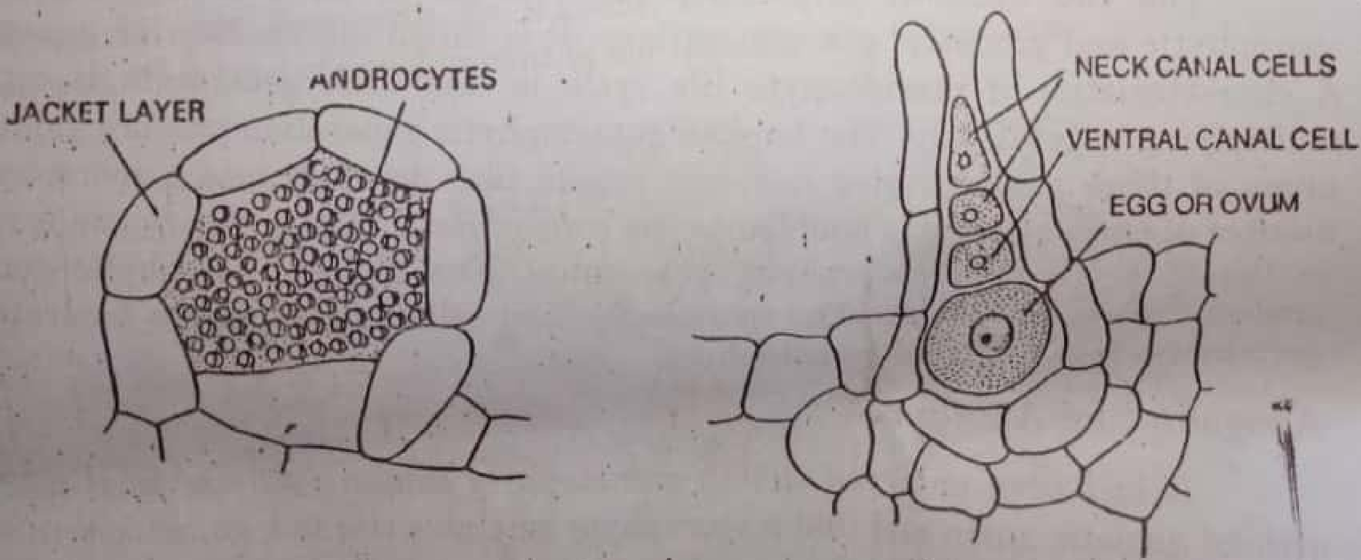

Fig. 1.6: *Sex organs in pteridophytes.*

Embryogeny —— Development of Embryo

Embryogeny refers to the successive steps in the growth and differentiation of a zygote into a young sporophyte. During earlier phase of development the embryo is protected by venter and adjacent gametophytic tissue. Divisions in specific planes in zygote result in an **apical pole** and the base of the embryo. Subsequent enlargement and organ development result in formation of a shoot apex with one or more leaf **primordia**, a **root**, a well-defined **foot** and in many genera a **suspensor**.

The **foot** serves as a haustorial organ which attaches the embryo to the nutritive tissue. In majority of plants the apex of young embryo faces inwardly toward the gametophytic tissue and away from the neck of the archegonium. The apical pole is the portion from the first or primary shoot takes its origin. The first leaves are designated as **cotyledons**. The cotyledonary leaves may be very small or rudimentary as in *Lycopodium* or large and photosynthetic as in *Isoetes* and many leptosporangiate ferns. The base of the embryo is represented by **suspensor**, e. g., in *Lycopodium* and *Selaginella*. The suspensor is absent in *Isoetes*. The suspensor is a temporary organ which forces the embryo into the nutritive tissue of the gametophyte. The embryo of most plants acquires a **root**, however in *Psiltoum* and *Tmesipteris* the root is absent.

In some embryos such as those of *Selaginella*, *Isoetes*, *Equisetum* and *leptosporangiate ferns* a conspicuous foot is present which anchors and convey nutrients to the embryo from the gametophyte. In *Psiltoum* entire lower half of the embryo develops into a haustorial structure which sends lobed and irregular processes deep into the tissue of the gametophyte.

Alternation of Generations

The life cycle of a pteridophyte consists of an alternate succession of sporophytic and gametophytic generations. It is called **alternation of generations.** A characteristics of pteridophyte life cycle is that each generation is capable of multiplying vegetatively. The haploid gametophytic generation produce gametes and union of these gametes give rise to a zygote that develops into a sporophyte. The number of chromosomes is doubled at the time of fertilization. The zygote is regarded as the first cell of a sporophytic generation. The diploid sporophytic generation produces spores by meiosis. The spore is the first cell of gametophyte generation as it germinates into a haploid gametophyte.

Apogamy and Apospory

It had been observed that a gametophyte might give rise to a sporophyte without gametic union and that a sporophyte may give rise to a gametophyte without a production of spores. The former phenomenon was named apogamy and the latter as apospory. These phenomena are now known to be widespread among ferns and a fern plant may be both apogamous and aposporous. Apospory is also noticed in *Selaginella*.

Apospory

A gametophyte may develop by apospory from leaf of sporophyte along the margins or apex of the blade or from a sporangia in a sorus. Such gametophyte commonly termed as **aposporous gametophyte**. Th...

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sporophytic characters, for example tracheids are present in the gametophytic tissue at the back of apical notch. These gametophytes develop antheridia and archegonia in normal way and produce diploid gametes. The sporophyte resulting from the union of these diploid gametes is tetraploid (4n).

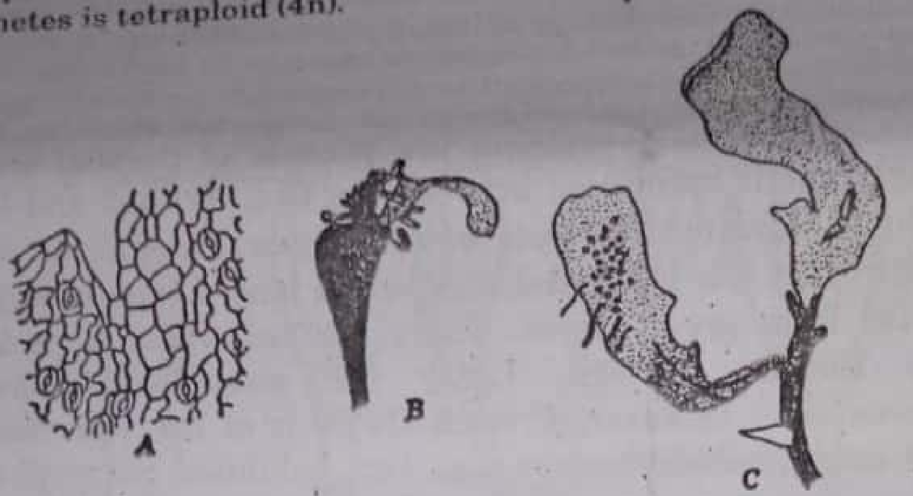

Fig. 1.7: ***Aposporous development of gametophytes from leaf apex of a sporophyte.***

Apogamy

A sporophyte resulting from apogamy, called apogamous sporophyte, may develop from a single vegetative cell of the gametophyte or from the cell of an archegonium. In some cases, e. g., in *Marselia* the apogamous sporophyte may develop from the egg. Such a development of sporophyte is called *parthenogenesis*. In others it may develop from a group of meristematic cells usually present on the ventral side of the gametophyte and posterior to the apical notch. A very special type of development of aposporous sporophyte has been observed in fern, *Lastrea pseudo-mas var Polydactyla Wills*, where a nucleus from a gametic cell migrate into an adjoining cell and fuse with its nucleus. This cell then develops into a diploid sporophyte. This type of development is not found in any other fern.

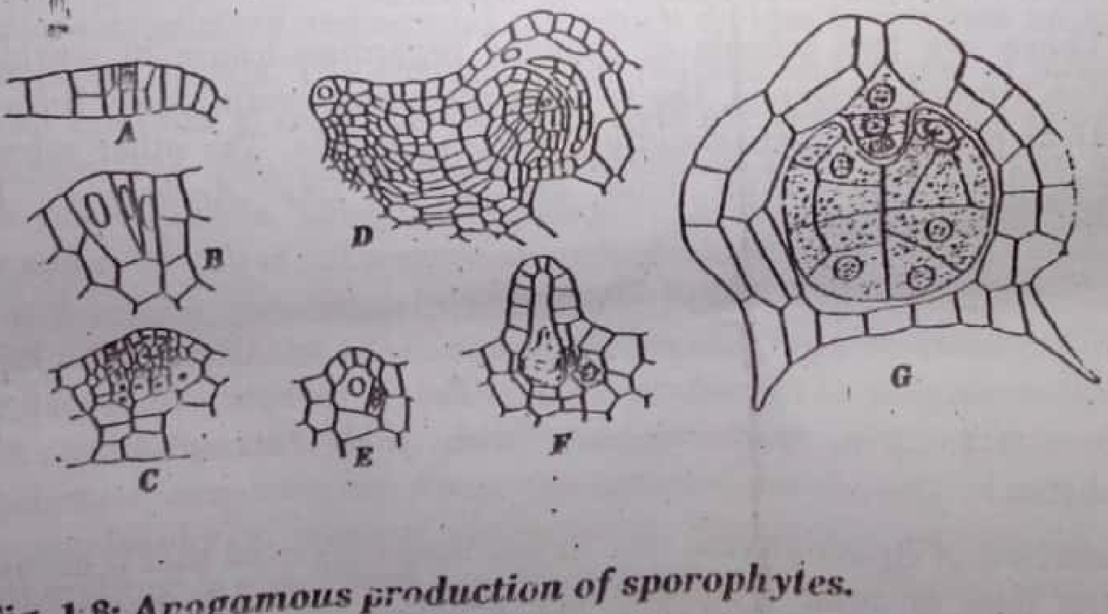

Fig. 1.8: ***Apogamous production of sporophytes.***