COURSE NAME-BIOLOGY AND DIVERSITY OF ALGAE, BRYOPHYTA AND PTERIDOPHYTA
(Paper Code: BOT 502)

UNIT–16 : GENERAL CHARACTERS AND CLASSIFICATION OF PTERIDOPHYTES

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CONTENT

- INTRODUCTION
- GENERAL CHARACTERISTICS
- HABITAT
- CLASSIFICATION
- REPRODUCTION
- ALTERNATION OF GENERATION
- ECONOMIC IMPORTANCE

INTRODUCTION

The word Pteridophyta has Greek origin. Pteron means a “feather” and Phyton means plants. The plants of this group have feather like fronds (ferns). The group of pteridophyta included into Cryptogams with algae, fungi and Bryophytes. The algae, fungi and bryophytes are called lower cryptogames while the Pteidophytes are called higher cryptogams. Pteridophytes also called Vascular cryptogames, because only pteridophytes have well developed conducting system among cryptogams. Due to this reason they are the first true land plants. All cryptogams reproduce by means of spores and do not produce seeds. The Peridophytes are assemblage of flowerless, seedless, spore bearing vascular plants, that have successfully invaded the land.
Pteridophytes have a long fossil history on our planet. They are known from as far back as 380 million years. Fossils of pteridophytes have been obtained from rock strata belonging to Silurian and Devonian periods of the Palaeozoic era. So the Palaeozoic era sometimes also called the “The age of pteridophyta”. The fossil Pteridophytes were herbaceous as well as arborescent. The tree ferns, giant horse tails and arborescent lycopods dominated the swampy landscapes of the ancient age. The present day lycopods are the mere relicts the Lepidodendron like fossil arborescent lycopods. Only present day ferns have nearby stature of their ancestors. Psilotum and Tmesipteris are two surviving remains of psilopsids, conserve the primitive features of the first land plants.

GENERAL CHARACTERITICS

1-The main independent plant body is sporophyte, with vascular system. It develops from the diploid zygote.
2-The pteridophytes grow mostly in cool, moist and shady places, but some are aquatic (*Marsilea*, *Salvinia*, *Azolla etc*.) and few are xerophytic (*Selaginella rupestris*, *S. respanda*, even some species of *Marsilia*, *M. rajasthanensis*, *Marsilia condenseta* etc.).
3-Plants are differentiated into true roots, shoots and leaves. Some primitive members lack true roots and well developed leaves (e.g; In members of Psilophytales and Psilotales).
4-Except few woody tree ferns all living pteritophytes are herbaceous.
5-They may be dorsiventral or radial in symmetry with branched stems.
6-The leaves of ptridophyte may be scale like leaf (e.g. *Equisetum*), small sessile leaves (e,g. *Lycopodium and Selaginella*) and large, petiolate compound leaves occurs in true ferns.
7-The stem bears leaves which may be small microphyllous type in which the leaves are quite small in relation to the stem (e.g. *Lycopodium*, *Selaginella*, *Euisetum*), or megaphyllous type, in which the leaves are large in relation to the stem (e.g. ferns).

8-In fern, the young leaves show circinate vernation (curved inwards).
9-Primary embryonic roots are short lived and replaced by adventitious roots.
10-The pteridophyte reproduced by haploid spores which are produced within a specialized structure called sporangia.
11-Plants may be homosporous (all spores are same in shape and size) and heterosporous (spores are two different shape and size) smaller called microspore and larger called megaspore.
12-In some pteridophytes the sporangia developed on stems, axis between leaf and stem, on leaves (mostly ventral surface of leaves). On the stem sporangia may be terminal e.g. *Rhynia*, lateral in *Lycopodium*, on the surface of leaves (Sporophyll) in Ferns. The sporangia are borne on ventral side of specialized leaf called Sporophyll.
13-In true ferns the sporangia are located on the lower surface of the leaf as clusters called sori (sorus).
14-The haploid spore is a unit of gametophyte. On germination it develops gametophytic prothallus.
15-The Gametophytic plant is called prothallus since it more or less looks like the thallus of a primitive bryophyte.

16-Prothallus bears sex organs archegonia and antheridia. As a result of fertilization the zygote or oospore is formed.
17-The homosporous species are monoecious (Antheridia and archegonia borne on same thallus).
18-Heterosporous types are mostly dioecious (Antheridia and archegonia borne on separate male and female prothallus respectively).
19-Microspore gives rise to male prothallus which produces the male sex organs antheridium.
20-Megaspore gives rise to female prothallus which produces the female sex organs Archegonium.
21-The sex organs are embedded or projected in the prothallus.
22-The male gametes are called antherizoids and produce inside the antherdium.
23-Antherozoids are unicellular, spirally coiled and flagellate.
24-The archegonia are differentiated into upper neck and lower venter.
25-The achegonial neck is projected or the venter is embedded.in the prothallus.
26-Water medium is essential for fertilization.
27-The egg and atherozoids fuse, to form diploid zygote.
28-The Zygote develops into new sporophytic plant body.
29-Clear alternation of generation takes place in the life cycle of Pteridophytes.

HABITAT

Pteridophytes are first land vascular plants so, they are mostly terrestrial in nature, grow in cool and shady places. Some pteridophytes are inhabit in xerophytic, semi-aquatic and aquatic condition.

(a) Terrestrial Pteridophyte

Members of Psilophyta or ferns grow in terrestrial habitat. Some pteridopytes are Lithophytic on horizontal rocky patches. The fossil pteridophytes were terrestrial in nature. Most species of Lycopods growing in such habitat are *Lycopodium clavatum, L.cernuum*, *L. reflexum*, *Selaginella chrysocoulus*, *S. kraussiana*, *Isoetes coramandelina*, etc.

Some pteridopytes are epiphytic. *Psilotum nudum*, *L. phlegmaria*, *S. oragana* and few ferns grow as epiphytes. The tall and well stratified trees in the forests provide a suitable habitat for the growth of epiphytic Pteridophytes. However, a few other ferns prefer open tree trunks and branches. These epiphytes share a common niche along with orchids and ferns. Species like *Drynaria quercifolia* grow in pure colonies on exposed rather dry tree trunks, covering entire tree trunks at times.

(b) Aquatic pteridophytes

Some pteridophytes grow in aquatic and semi-aquatic habitats. *Isoetes panchananii* and *I. englemanni* are semi-aquatic. Some members of ferns are commonly called water ferns. The examples of water ferns are *Marsilea, Salvinia*, *Azolla*, *Regnellidium etc*.

(C) Xerophytic pteridophytes

Some species of *Selaginella* and *Marsilea* are xerophytic in nature. The examples are *S. repanda, S. lepidophylla, M. rajasthanensis, M. condensata.*

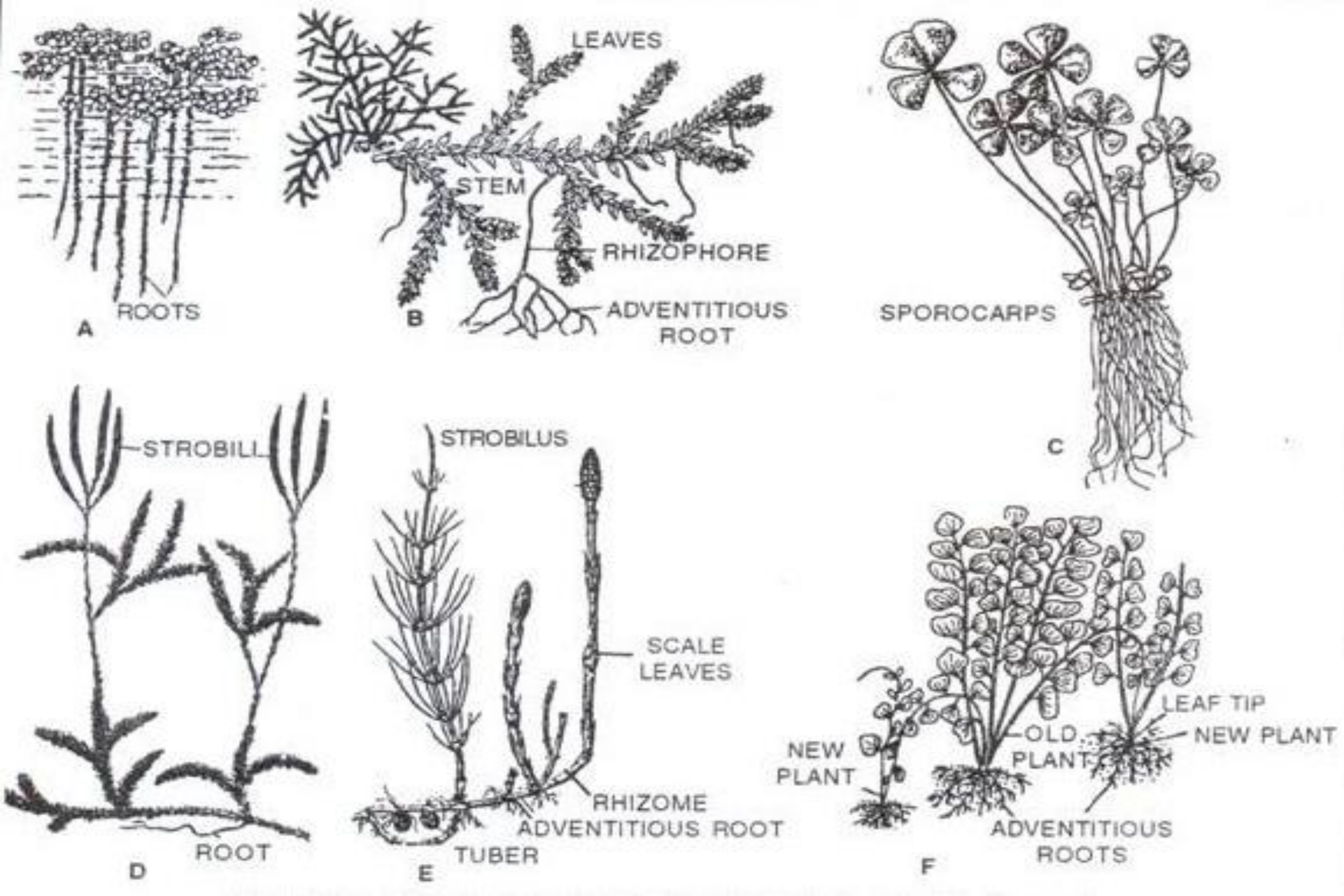


Fig. Different types of pteridophytes : A . ***Azolla*****, B.** ***Selaginella*****, C.** ***Marsilea*****, D.** ***Lycopodium*****, E.** ***Equisetum*** **, F.** ***Adiantum***

CLASSIFICATION

On the basis of presence and absence of seeds the vascular plants classified by primitive taxonomists into two divisions, **Pteridophyta** and **Spermatophyta.** The division pteridophyta includes primitive vascular plants which bear no seeds. Later some fern like seed bearing fossil plants (Cycadofilicales) were discovered into 1903. The discovery eliminated the distinction between the two divisions **Pteridophyta** and **Spematophyta.** Sinnott (1935) therefore introduce a new term **"Tracheophyta"** for a division which includes all the vascular plants. Eames (1936) on the basis of some characters of plants and position of sporangia the division Tracheophyta divided into four groups, Psilopsida, Lycopsida, Sphenopsida and Pteropsida. Zimmermann (1930) and Arnold (1947) considered these groups as divisions and Tippo (1942) considered as subphyla.

Classification proposed by Reimers (1954) and Followed by Sporne (1996)
The classification of pteridophytes proposed by Reimers in the 1954 edition of Engler's *syllabus der pflanzenfamilien.*

1. PSILOPHYTOPSIDA

Psilophytales — e.g. *Rhynia*, **Asteroxylon**

2. PSILOTOPSIDA

Psilotales — e.g. *Psilotum*

3. LYCOPSIDA

a) Protolepidodendrales
b) Lycopodiales — e.g. *Lycopodium*, *Phylloglossum*
c) Lepidodendrales — e.g. *Lepidodendron**, *Lepidocarpon**
d) Selaginellales — e.g. *Selaginella*
e) Isoetales — e.g. *Isoetes*

4. SPHENOPSIDA

a) Hyeniales
b) Sphenophyllales — e.g. *Sphenophyllum**
c) Calamitales — e.g. *Calamites**, *Calamostachys**
d) Equisetales — e.g. *Equisetum*

5. PTEROPSIDA

(A) Primofilices
a) Cladoxylales
b) Coenopteridales — e.g. *Botryopteris**, *Zygopteris**
(B) Eusporangiatae
(a) Ophioglossales, — e.g. *Ophioglossum*
(b) Marattiales, — e.g. *Angiopteris*
(C) Osmundidae
Osmundales — e.g. *Osmunda*
(D) Leptosporangiatae
(a) Filicales — e.g. *Hymenophyllum*, *Adiantum*
(b) Marsileales — e.g. *Marsilea*
(c) Salviniales — e.g. *Salvinia*, *Azolla*

(Asterisk mark indicates the fossil members).

Classification proposed by Cronquist et al.(1966) and followed by Parihar (1977)

Cronquist, Takhtajan and Zimmerman (1966) classified the pteridophytes into five divisions. The classification has also been followed by Parihar (1977). The outline of classification is following:

1-Division :- Rhyniophyta
    Class :- Rhyniatae
    Order :-Rhyniales

2-Division :- Psilotophyta
    Class :- Psilotatae
    Order :-Psilotales

3-Division :- Lycopodiophyta
    Class :- Lycopodiatae
    Orders :-Asteroxylales, Drepenophycales, Protolepidodendrales and Lycopodiales.

4-Division :- Equisetophyta
    Class: Sphenophyllatae
    Order :-Sphenophyllales and Pseudoborniales
    Class :- Equisetatae
    Order :- Calamitales and Equisetales

5-Division :-Polypodiophyta
    Class:- Polypodiatae (the class divides sub classes.)
    Sub-classes :- Prototeridiidae, Archaeteridiidae, Ophioglossiidae, Noeggerothiidae, Marrattidae, Polypodiidae, Marsilleidae, Salviniidae)

These sub-classes are further divided into orders.

Accordingly ICBN amendment the four major groups of pteridophyta are-

1-Class Psilopsida

2-Class Lycopsida

3-Class Sphenopsida

4-Class Pteropsida

REPRODUCTION

Reproduction through spores is main mode of reproduction in Pteridophytes. Although vegetative reproduction is also common in pteridophyte.

1-Vegetative reproduction

The sporophyte of many pteridophytes reproduce vegetatively by following means:-

(a) By the formation of gemmae or bulbils

Vegetative reproduction is carried out by bulbils (bulblets) or gemmae which are leafy side branches with wide base and develop new sporophytes. The gemmae fall on ground and grow into a new young plant. Ex. *Psilotum*, *Lycopodium phlegmaria*, *L. selago* etc. Certain species of *Selaginela* propagate by bulbils.

(b) Fragmentation

Death and decay of older region of stem leads the formation of new branches. The individual branch develops into new plant. It is common method of vegetative reproduction in certain species of *Lycopodium, Slaginella, Dryopteris, Pteris, Adiantum* etc.

(c) Formation of Tubers

The tubers originate from the paranchymetous regions of shoot and root. The tubers are formed at surface of the ground, called surface tubers and if they are developed underground hence called underground tubers. They consist of a group of cells with stored food materials. They have capacity to germinate into new plants. In some species of *Marsilea* irregular tuberous bodies are formed in the stem. *Lycopodium renulosum* few species of *Selaginella* and *Equisetum* develop such tubers.

(d) Formation of Adventitious Buds

Such buds have been induced on isolated bulbil leaves. Decapitation of stem near its apex also induces the formation of such buds. Certain species of *Lycopodium*, *Selaginella*, also developed such buds. Few species of *Asplenium*, *Diplazium* and *Ophioglossum* develop adventitious buds. In *Dryopteris* adventitious buds arise in the axil of leaves and are detached from the plant and form new plants. In some cases (*Asplenium esculentum and platycerium*) the root apex develops directly into a leafy bud. The leafy bud can grow into a new plant.

2-Asexual Reproduction

Reproduction through spores is main mode of reproduction in Pteridophytes. Pteridophytes reproduce asexually by haploid spores, which are formed in sporangia. The sporangia developed either on the ventral surface or in the axils of the leaves. The Sporangia bearing leaves are called sporophylls. However in Psilophytales the sporangia were cauline. The sporangia were terminal on the fine aerial branches, in fossil Pteridophyte, *Rhynia*. In *Equisetum* and *Selaginella* these sporopylls present in the form of compact structures called strobili or cones (Fig.2 & 3). In genera, such as, *Azolla*, *Marsilea* and *Salvinia* the sporangia are present in specialized bodies called Sporocarps. The sporangia in higher ferns are present in the form of well organized groups called sori (singular sorus) (Fig.4).

Fig.1 Synangia of *Psilotum*

Fig. 2 Cone of *Equisetum*

Fig. 3. Strobilus or cone of *Lycopodium*

Fig. 4 Sori of fern

On the basis of development of sporangia, Goebel (1881) classified sporangia into two types, i.e. **Eusporangiate** and **Leptosporangiate**. The sporangium develops from a group of initial cells called eusporangium and the development called eusporangiate development. When the sporangium develops from a single initial cell called leptospoangium and the developmental pattern called leptosporangiate development.

Sporophyte

The spore producing body of Pteridophyta is called **Sporophyte**. The Sporophytic generation is dominant and conspicuous in the life cycle of Pteridophytes. The life cycle of typical Pteridophyte consists of a regular alternation of sporophytic (asexual) and gametophytic (sexual) generations.

In bryophytes the gametophytic phage is dominant in life cycle, and the sporophyte is dependent on gametophyte. By contrast, in Gymnosperms and Angiosperms the gametophytic generation is reduced and is dependent on the sporophyte. Pteridophytes with an **intermediate position**, are characterized by free living gametophytic and sporophytic generations. Nevertheless the sporophyte is a dominant generation; it soon becomes independent of the gametophyte and attain a much greater size.

Pteridophytes are characterized by two basic kinds of life-cycles, **homosporous** and **heterosporous**. The heterosporous pteridophytes form two kinds of spores, the larger **megaspores** and smaller **microspores**, from which develop two kinds of gametophytes (female and male gametophytes), respectively.

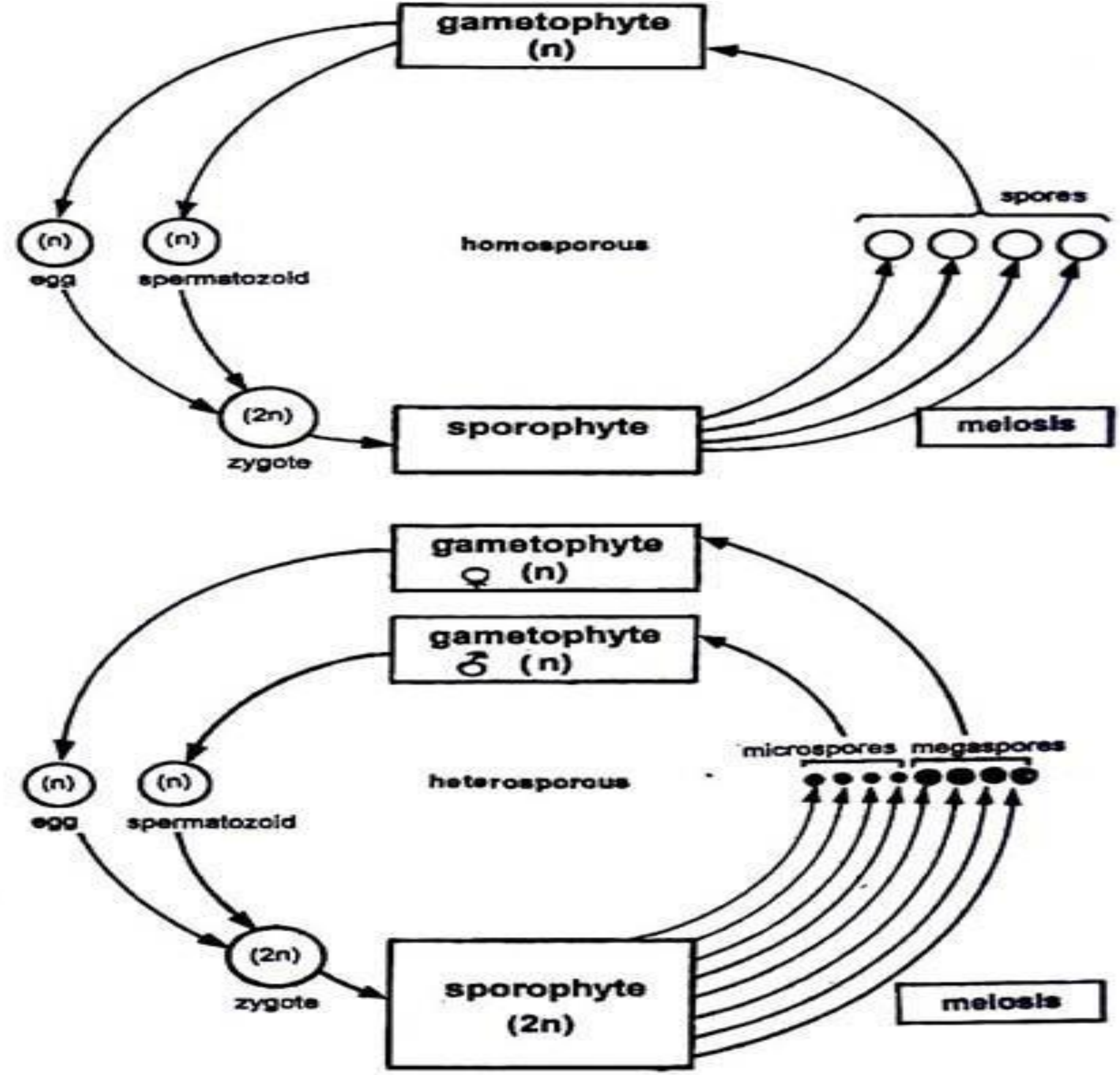
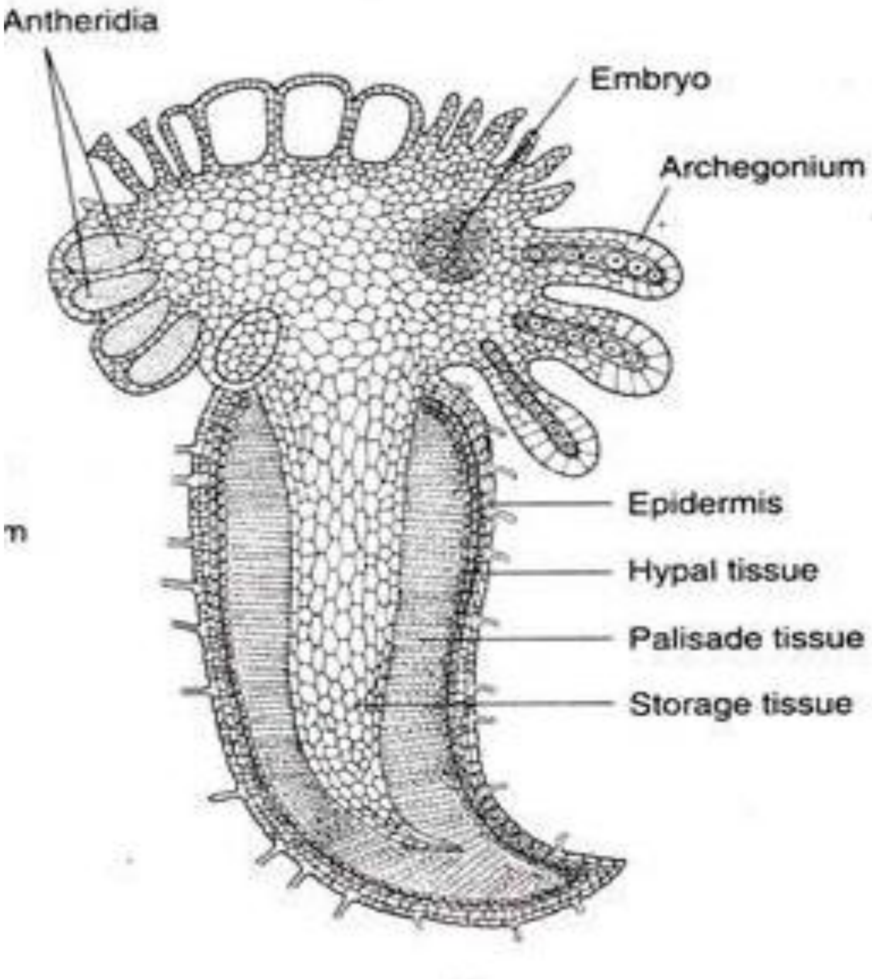


Fig. Life cycles of Homosporous and Heterosporous Pteridophytes

The homosporous pteridophytes form only one kind of spore from which a hermaphroditic (monoecious) gametophyte usually develops. Thus the heterosporous pteridophytes are obligatorily heterothallic, while the homosporous are usually homothallic. Some examples of heterosporus pteridophytes are *Selaginella*, *Isoetes*, *Masilea*, *Salvinia*, *Azolla*, *Regnellidium* etc. The homosporous life-cycle is found in the *Psilotum*, *Tmesipteris*, *Lycopodium*, *Equisetum*, and the homosporous Filicopsids.

Sexual reproductive phage : Gametophyte

The gametophyte is the **sexual phase** in the life cycle of a plant .T**he haploid spore is a unit of gametophyte**. The spores are haploid and form after reduction division in the sporogenous cells of the sporangium. The spore germinates into a **porothallus** (fig.3). Generally the prothalli are green, simple, somewhat branched and aerial structures. But in some genera such as *Lycopodium*, they are subterranean, branched, colourless and saprophytic structure (fig.1).. The two sex organs **antheridia** and **archegonia** develop on the prothallus. Generally the prothalli of homosporous pteridophytes are monoecious. But the prothalli of heterosporous pteridophytes usually are dioecious.



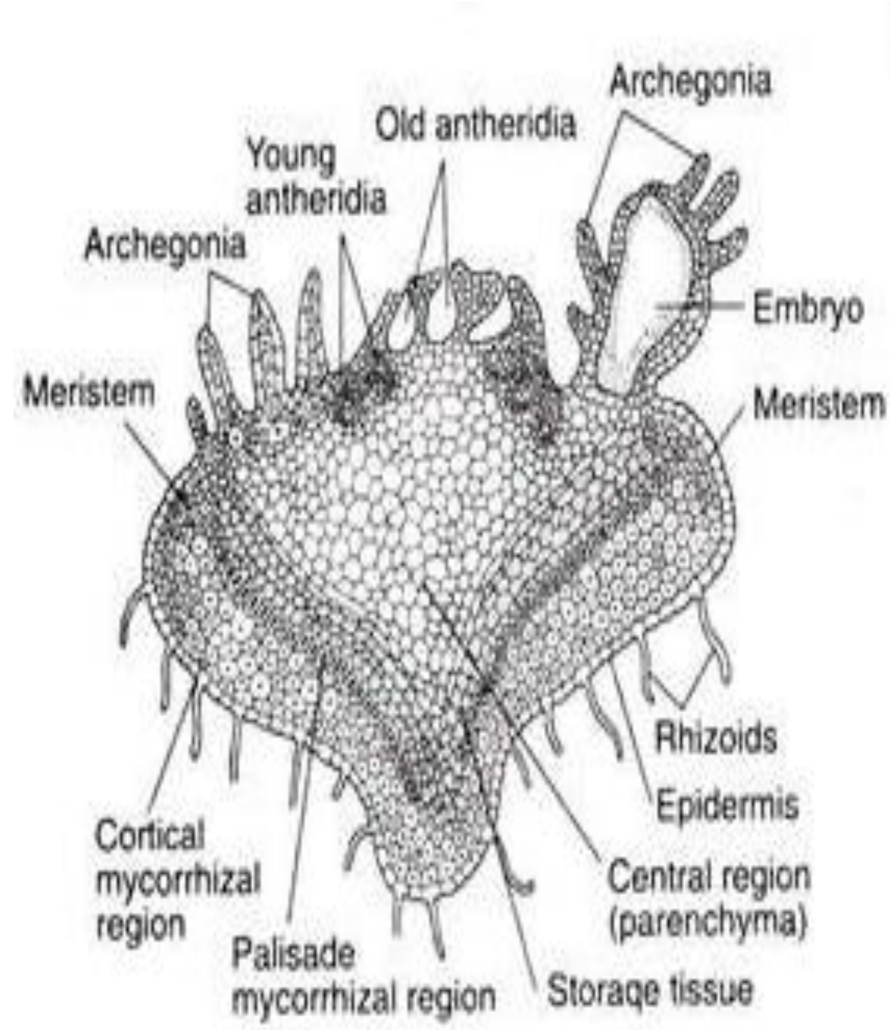


Fig.1 Prothallus of *Lycopodium clavatum* **Fig.2 Prothallus of *Lycopodium complanatum***

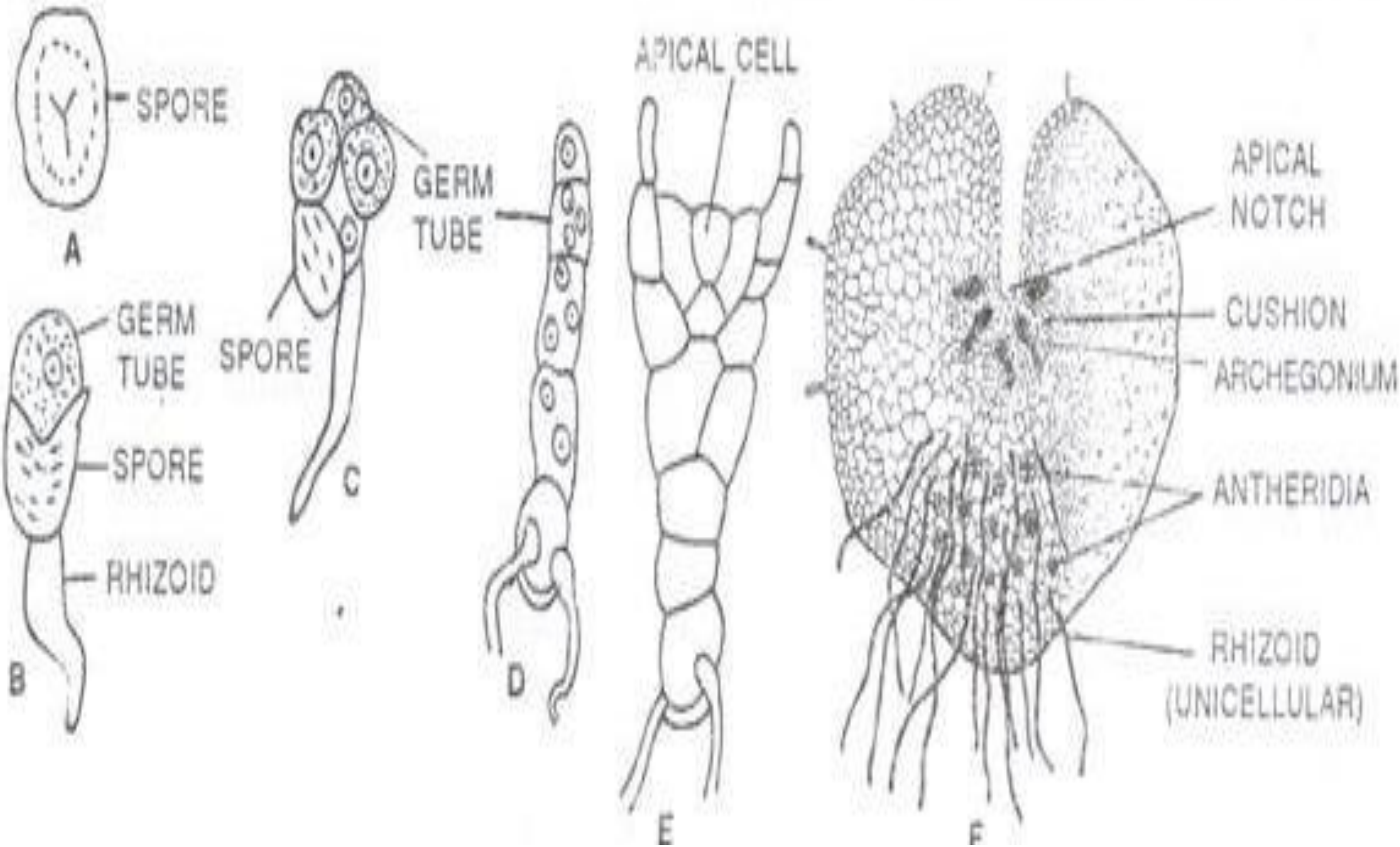


Fig.3 (A-F) Germination of spore and development the of Prothallus in *Dryopteris*

Mostly the antheridia and archegonia embedded in the prothallus. The antheridium is always surrounded by a jacket layer. The antheridia produce **antherozoids.** The antherozoids are unicellular, uninucleate and biciliate structure in *Lycopodium*, *Selaginella* etc. but they are multiciliate in *Psilotum*, *Tmesipteris*, *Isoetes*, *Equisetum* and ferns. The **archegonium** consist a projecting **neck** and the lower embedded portion **venter**. The neck has neck canal cells and the venter has venter canal cell and egg cell.

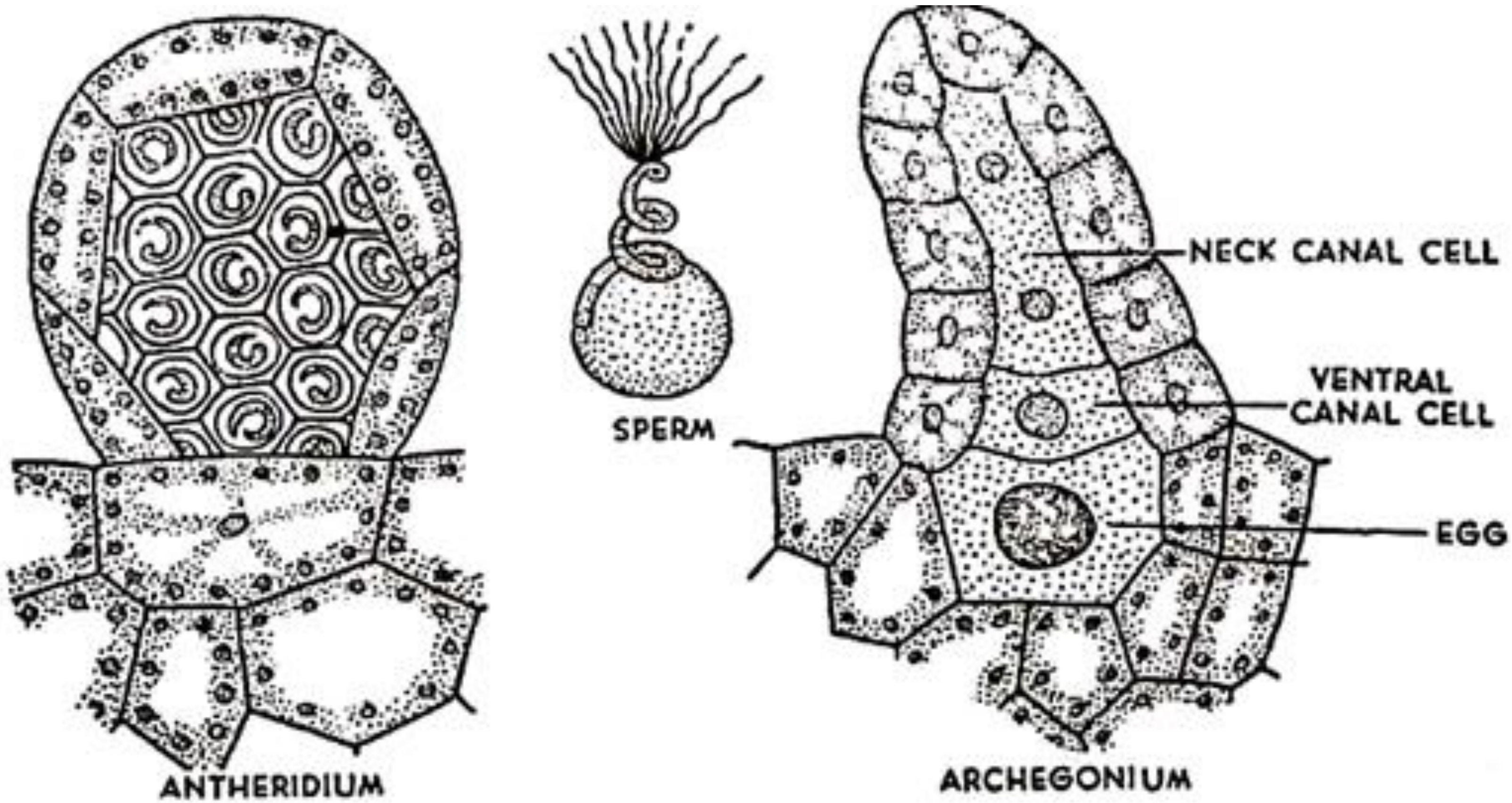


Fig.-Antheridum and archegonium of fern

Fertilization and Zygote formation

The fertilization takes place with the help of water. When a film of water flow between prothallus and substratum, the cap cells of antheridia pushed open to release antherozoids. Antherozoids are attracted chemotactically towards the archegonium, The antherozoids swim towards archegonia in response to malic acid released from mucilaginous mass (chemotactic). Many antherozoids swim down the neck of archegonium, only one of them fuses with egg to form a diploid zygote. Usually, cross-fertilization occurs due to protandrous nature of prothalli (i.e. antheridia mature before archegonia). The fertilization takes place and results into the formation of **diploid zygote**. **The zygote is the first cell of sporophyte** and develops into a well-developed sporophyte.

Embryo development

The zygote develops into an embryo. The first division of Zygote is generally (if not always) transverse . After a usual transverse division of zygote, a two celled structure is formed. Transverse division followed by a vertical division and thus developed a quadrant. The successive divisions finally develop a young sporophyte.

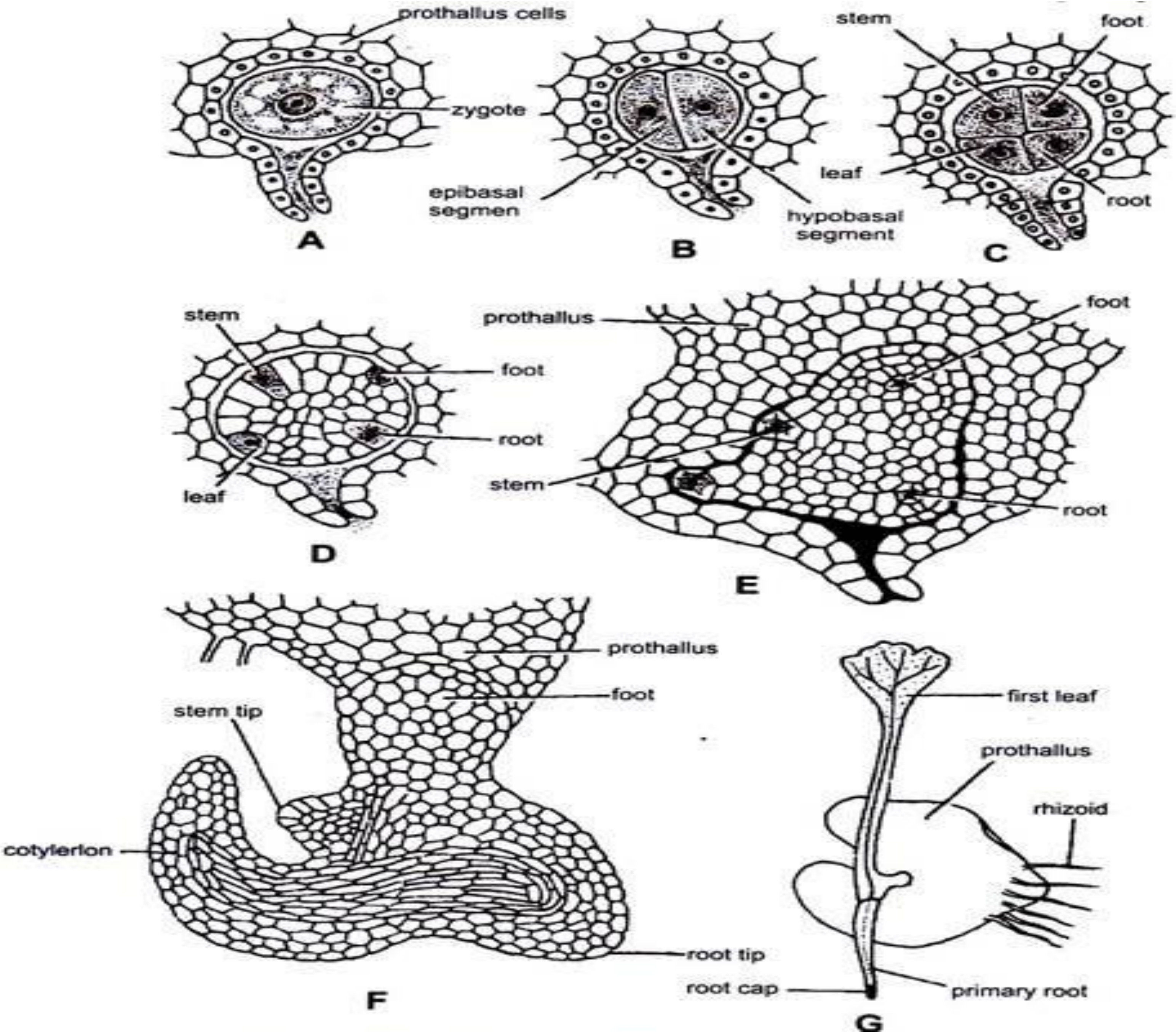


Fig. (A-G) Successive stages of development of embryo in fern

Alternation of Generation

Pteridophytes show a **true alternation of generations**. Here, the dominant sporophyte produces spores through meiosis. The gametophyte generation forms gametes by mitosis. **Alternation of generations** (also known as **metagenesis**) is the type of life cycle that occurs in pteridophytes and other plants. They have distinct sexual haploid and asexual diploid stages. In these groups, a multicellular gametophyte, which is haploid with *n* chromosomes, alternates with a multicellular sporophyte, which is diploid with 2*n* chromosomes, made up of *n* pairs.

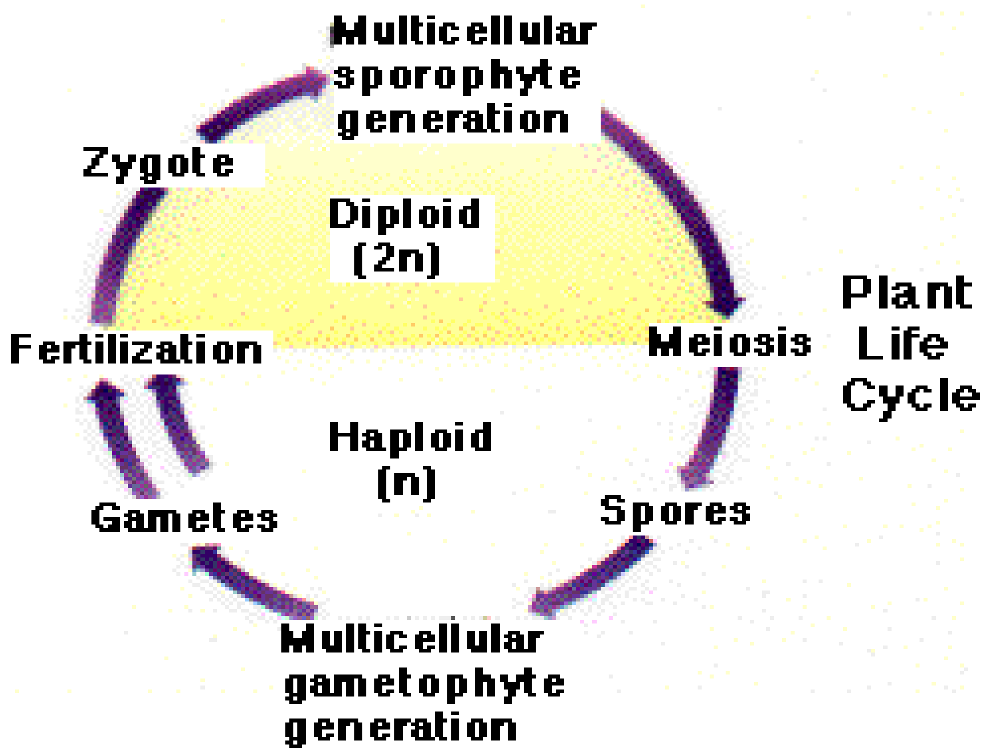


Fig. Alternation of generation in pteridophytes

A mature sporophyte produces spores by meiosis, a process which reduces the number of chromosomes to half, from 2*n* to *n*. The haploid spores germinate and grow into a haploid gametophyte. At maturity, the gametophyte produces gametes by mitosis, which does not alter the number of chromosomes. Two gametes (originating from different organisms of the same species or from the same organism) fuse to produce a zygote, which develops into a diploid sporophyte. The sporophyte and gametophyte stages take place continue one by one in life cycle. This is called alternation of generation. This alternation of generations is a **survival strategy** in which a plant alternates between different reproductive techniques.

Abnormalities in the Life cycle

The normal life cycle of the vascular plant has two alternating generations. Both haploid and diploid generation alternate regularly in the life cycle of the Pteridophytes. The regular alternation of chromosome numbers is sometimes impaired by the occurrence of two common phenomena called apospory and apogamy.

(a) Apogamy

Development of sporophyte directly from the gametophyte without any sexual fusion or syngamy. The sporophyte has same haploid chromosome numbers as in gametophyte. It was first discovered by Farlow (1874) in *Pteris cretica*. It is a common and widespread phenomenon in ferns. The natural apogamy reported in a number of ferns including *Pteris*, *Pteridim*, *Dryopteris*, *Adiantum*, *Osmunda*, *Todea*, *Athyrium*, *Asplenium* etc.

(b) Apospory

The development of gametophytes from the vegetative parts or cells of the sporophyte, without of any meiotic division and formation of spores. Such types of gametophytes are diploid and this phenomenon of their formation is called apospory. The phenomenon of apospory was first discovered by Druery (1884) in Athyrium filix-foemina. Since then apospory has been reported in many pteridophytes including *Pteridium aquilinum*, *Asplenium dimorphum*, *Osmunda regalis*, *Todea* etc.

ECONOMIC IMPORTANCE OF PTERIDOPHYTES

Besides being a lower plant, pteridophytes are economically very important. About 170 species of Pteridophytes have been found to be used as food, flavor, dyes, medicines, biofertilisers, oil, fibers and biogas production (Manickam and Irudayraj 1992).

(1) Food

Like other plants, pteridophytes con-stitute a good source of food and fodder. Sporocarps of *Marsilea*, a water fern, yield starch that is cooked and eaten by certain tribal. Young circinately coiled leaf tips of *Diplazium esculentum*, *Diplazium maximum* and some other ferns are eaten as vegetable. Marselia is used as a substitute for clover to feed animals. In Canada the crozires of Matteuccia struphiopteris are served as common spring vegetables. They are also stored and frozen for later use.

(2) Biological fertilizer

Azolla (a water fern) has a symbiotic association with nitrogen fixing cyanobacterium *Anabaena azollae*. Azolla is a very small pteridophyte and has small microscopic leaves. Each leaf has a small cavity at its base. Inside this cavity the filaments of nitrogen fixing blue green alga *Anabaena azollae*. Due to this, azolla has the ability of to fix atmospheric nitrogen and thus increases the fertility of the soil. It is inoculated to paddy fields to function as biofertilizer.

(3) Medicines

Many pteridopytic plants are used for treating several human diseases. An anthelmintic drug is obtained from rhizomes of *Dryopteris* (Male Shield Fern). Fronds and rhizome of *Adiantum* caudatum used for wound healing. The leaf and root decoction of commonly occurring *Adiantum lunulatum* syn. *Adiantum philippense* has been found to be very effective in the treatment of chest complaints.

Leaves of *Marsilea minuta* and leaves of *Pteris quadrifolia* used as cough and bronchitis and fresh leaves of *Ophioglossum reticulatum* used in menstrual disorders. Tender leaves of *Tectaria cicularia* used for wound healings, eczemza and scabies.

(4) Ornamentals

Some species of *Lycopdium* and *Selaginella* are used as ornamentals in big gardens and green houses because of their variously coloured, feathery moss like leaves. Ferns are grown as ornamental plants for their delicate and graceful leaves. Some such examples are *Adiantum, Marattia, Pteris, Salvinia, Osmunda regalis, Lycopodium obscurum* ect.

(5) Soil Binding

By their growth pteridophytes bind the soil even along hill slopes. The soil is protected from erosion.

(7) **Ecological Indicators**

Pteridophytes are also used as a indicator plants. *Equisetum* accumulates minerals, especially gold, in their stem, so it is the ecological indicator of gold in the soil. Similarly, *Asplenium adulterinum* is an indicator of nickel and *Actinopteris australis* is a cobalt indicator plant.