e.g. *Selaginella*.

D. Characteristic features of Pteridophyta :

1. The plant body represents the sporophyte. In the life history of pteridophytes, both the sporophytic and gametophytic generations are *independent of each other*. Although in Pteridophyta, sporophytes are *nutritionally independent of the gametophyte* still they are dependent on gametophyte *for a short embryonic period.*

2. Plant bodies are provided with well developed *true roots* (exceptions : fossil Pteridophyta and *Psilotum*), stems and leaves. Stems and roots have apical growth. Roots are provided with permanent growing point and can grow in length indefinitely.

3. Reduction of photosynthetic tissue i.e., chlorophyll bearing cells remain mainly within the leaves—hence photosynthesis is also restricted to leaves which are provided with epidermis having stomata and chlorophyll bearing cells.

4. Sporophytes show well marked tissue differentiation—roots, stems and leaves are traversed by *vascular* i.e., *conducting tissues such* as xylem and phloem—hence pteridophytes are also known as *vascular cryptogams.*

5. The sporophytes are also known as asexual or spore-producing generations. In Pteridophyta this generation may be either *homosporous* i.e. bearing one kind of spores which on germination give rise to gametophytes bearing both male and female sex organs (i.e. *monoecious* or *homothallic*), or *heterosporous* where spores are of two kinds—*viz*, smaller *microspores* and larger *macro-* or *megaspores.* Microspores on germination produce male gametophytes while macro- or megaspores on germination give rise to female gametophytes—hence heterosporous pteridophytes always produce *dioecious* or *heterothallic* gametophytes.

6. Spores are produced within sporangia—in homosporous types, sporangia are of one kind as spores are alike, but in heterosporous types sporangia are of two kinds viz. *microsporangia* (microspore containing sacs) and *macro-* or *megasporangia* (macro- or megaspore containing sacs). Sporangia bearing leaves are called *sporophylls*—in heterosporous pteridophytes sporophylls are also of two types viz., *microsporophylls* (microsporangia bearing leaves) and *macro-* or *megasporophylls* (megasporangia bearing leaves). Sporophylls in many cases do not differ from the mature foliage leaves and are loosely arranged (some species of *Lycopodium*, ordinary ferns like *Polypodium* etc.) ; in other cases sporophylls are specialised and localised to form a compact structure known as *strobilus* (plural : *strobili*) or *cone.*

7. Stem and roots of the plant body i.e., sporophyte are provided with *stele*—a central vascular cylinder of conducting system.

For different types of steles in pteridophytes and their evolution refer *Plant Anatomy* portion, Chapter 5, article 5.9, page 277.

E. Life cycle—In the life history of the pteridophytes there is a *typical heteromorphic alternation of sporophytic and gametophytic generations*—these two generations alternate with each other in a regular succession i.e., sporophyte to gametophyte and gametophyte to sporophyte. The sporophytic or asexual generation is diploid, which results from the union of two haploid gametes (i.e.,, antherozoid and ovum)—the starting point of this generation is the zygote or oospore ($2n$). The gametophytic or sexual generation is haploid (n) and which results from the formation of haploid spores (the starting point) produced by the sporophyte—in this type of alternation, chromosome number is doubled at the time of gametic union and becomes halved at the time of spore formation showing thereby a cytological alternation of diploid and haploid generations.

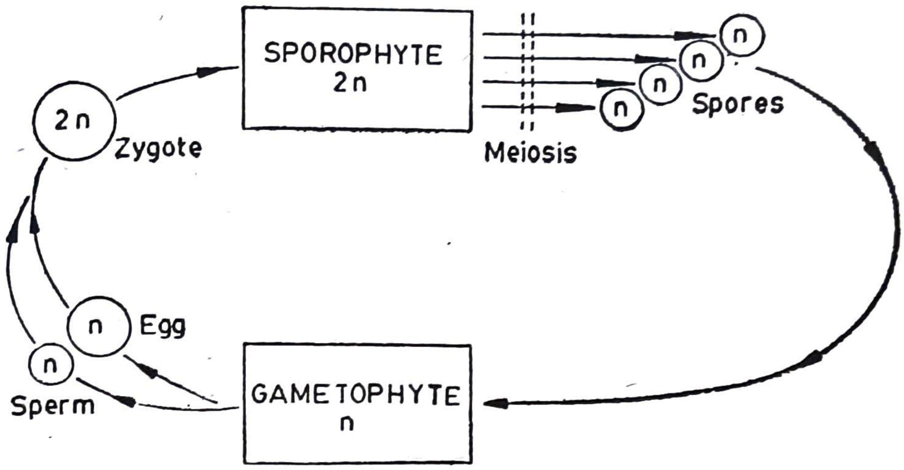

Fig 1.1—Life cycle of a homosporous pteridophyte.

Among pteridophytes the sporophyte is the dominant generation, as it very soon becomes independent of the gametophyte and grows to a much greater size along with greater degree of morphological and anatomical complexity. On the basis of size differences of the spores produced by sporophytes, pteridophytes may be homosporous and heterosporous. In homosporous, spores are of same sizes; each spore on germination produces monoecious gametophyte (prothallus) bearing both antheridia and oogonia—hence the life cycle (Fig. 1.1) of a homosporous pteridophyte is basically same like that of bryophytes. On the other hand spores produced by heterosporous pteridophytes are of different sizes such as larger *megaspores* giving rise to female gametophyte bearing only archegonia and smaller *microspores* giving rise to male gamatophyte bearing antheridia only. Therefore the

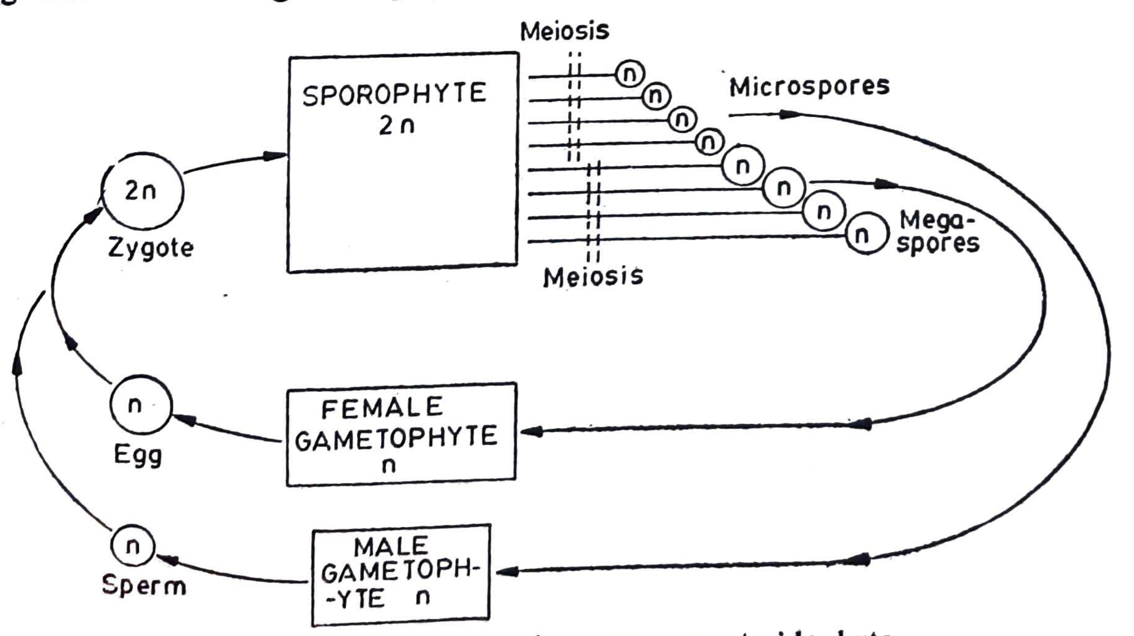

Fig. 1.2—Life cycle of a heterosporous pteridophyte.

life cycle of heterosporous pteridophytes (Fig.1.2) differ markedly from that of homosporous pteridophytes. It is to be noted, that such size difference of spore is well marked wherever the gametophyte is retained within the spore.

Sometimes cytological alternation of generation is hampered due to the formation of the gametophyte directly from the sporophyte without the production of spores (*apospory*) and also sporophyte directly from the vegetative cells of the gametophyte without gametic union (*apogamy*); sometimes egg cell may develop apogamously into a sporophyte—this phenomenon is known as *parthenogenesis*.

F. Classification :

According to Smith (1955) Pteridophyta *i.e.* pteridophytes have been classified as follows :

Division I. **Psilophyta**—Sporophyte is rootless, stem consists of branches only or both branches and leaves. Sporangia are borne singly at the tips of branches.

CLASS I. PSILOPHYTINAE—

Order I. *Psilophytales*, it contains 4 families. All genera are fossils, known from Lower and Upper Devonian.

Order 2. *Psilotales*, it contains single family Psilotaceae, e.g., *Psilotum*.

Division II. **Lepidophyta**—Sporophyte is differentiated into root, stem and leaves. Leaves are spirally arranged. Sporangia are borne on the adaxial region of leaves near the base.

CLASS I. LYCOPODINAE—

Order I. *Lycopodiales*, it contains 2 families *viz*., 1. Protolepidodendraceae (includes fossil genera, e.g. *Protolepidodendron*) and 2. Lycopodiaceae (includes living genera e.g. *Lycopodium*, *Phylloglossum* etc.).

Order 2. *Selaginellales*, it contains 2 families *viz*. 1. Selaginellaceae (contains only one living genus *Selaginella*) and 2. Miadesmiaceae (containing only fossil genus *Miadesmia*).

Order 3. *Lepidodendrales*, it contains 4 families *viz*. 1. Lepidodendraceae (*Lepidodendron*), 2. Lepidocarpaceae (*Lepidocarpon*). 3. Bothrodendraceae (*Bothrodendron*) and 4. Sigillariaceae (*Sigillaria*)—all are extinct i.e. fossils, known from Upper Devonian.

Order 4. *Isoetales*, it contains 2 families *viz*., 1. Pleuromeiaceae (contains fossil member e.g., *Pleuromeia*) and 2. Isoetaceae (e.g., *Isoetes*).

Division III. **Calamophyta**—Sporophyte is differentiated into root, stem and leaves; leaves are arranged in whorls. Sporangia are borne on sporangiophores.

CLASS I. EQUISETINAE—

Order I. *Hyeniales*, consisting of single family Hyeniaceae, e.g. *Hyenia*, *Calamophyton* (fossils).

Order 2. *Sphenophyllales*, it contains single family Sphenophyllaceae only, e.g. *Sphenophyllum* (fossil).

Order 3. *Equisetales*, containing 2 families *viz*., 1. Calamitaceae and 2. Equisetaceae e.g., *Equisetites* (fossil) and *Equisetum* (living).

Division IV. **Pterophyta**—Sporophyte is differentiated into root, stem and leaves, leaves are spirally arranged. Sporangia are borne on the margin of adaxial face of the leaf.

Class 1. FILICINAE—

Subclass I. Primofilicales—Sporangia are borne singly at the apex of a leaf. Jacket of sporangia is more than one-cell layer thick. Known in fossil condition from Paleozoic.

Order 1. *Protopteridales*—It includes two families *viz.*, (1) Protopteridaceae (*Protopteridium* and *Aneurophyton*) and (2) Cladoxylaceae (*Cladoxylon*) —all are fossils.

Order 2. *Coenopteridales*—It includes three families *viz.*, (1) Zygopteridaceae (*Zygopteris*), (2) Botryopteridaceae (*Botryopteris*) and (3) Anachoropteridaceae (*Anachoropteris* and *Gyropteris*).

Order 3. *Archaeopteridales*—contains one family Archaeopteridaceae, e.g. *Archaeopteris* (Fossil).

Subclass II. Eusporangiatae—Sporangia are borne on an outgrowth known as spike, sporangia in sori, formed at the abaxial surface of leaf, spores many in a sporangium ; jacket of sporangium is more than one-cell layer thick ; known from Carboniferous to present-day.

Order 1. *Ophioglossales*, contains single family Ophioglossaceae, e.g. *Ophioglossum*.

Order 2. *Marattiales*, contains single family Marattiaceae, e.g. *Marattia*.

Subclass III. Leptosporangiatae—Sporangaia are in sori and are borne marginally or abaxially on leaf blade. Spores are few in a sporangium ; jacket of sporangium is one-cell in thickness.

Order 1. *Filicales*—This order consists of 10 families, beginning from Osmundaceae and ending in Parkeriaceae ; examples are *Osmunda*, *Schizaea*, *Gleichenia*, *Matonia*, *Hymenophyllum*, *Dryopteris*, *Polypodium*, *Pteris*, etc.

Order 2. *Marsileales*—Single family Marsileaceae, e.g. *Marsilea*.

Order 3. *Salviniales*—Single family Salviniaçeae, e.g. *Salvinia*, *Azolla*.

Eames (1936), Tippo (1942) and others placed all the vasculsr plants (Pteridophyta and Spermatophyta) in a single-division '*Tracheophyta*' cognate with Thallophyta and Bryophyta. They segregated Tracheophyta into four sub-divisions e.g., **Psilopsida** (Psilophytales and Psilotales), **Lycopsida** (Lycopodiales, Selaginellales, Lepidodendrales, Pleuromeiales and Isoetales), **Sphenopsida**-(Hyeniales, Sphenophyllales and Equisitales) and **Pteropsida** (Filicineae, Gymnospermae and Angiospermae). Bold (1957) does not agree the term Pteridophyta or Tracheophyta as a division, rather he classified all the vascular cryptogams into four divisions viz., **Psilophyta** (=Psilopsida), **Microphyllophyta** (=Lycopsida), **Arthrophyta** (=Sphenopsida) and **Pterophyta** (=Filicinae)—he has abandoned the term Pteropsida of Eames and Tippo. Pichi-Sermoli (1958), however has retained in his classification the Pteridophyta as a division and which includes six classes *viz.*, 1. **Lycopsida**, 2 **Sphenopsida**, 3. **Noeggerathiopsida**, 4. **Psilotopsida**, 5. **Psilophytopsida** and 6. **Filicopsida**. Zimmermann (1959) in *Die Phylogenie der Pflanzenfamilien* (Aufl. 2) has divided pteridophytes i.e. vascular cryptogams in five divisions such as **Psilophyta**, **Lycophyta**, **Sphenophyta**, **Noeggerathiophyta** and **Pterophyta**. Parihar (1962) has followed a system of classification in which the pteridophytes are grouped into four divisions viz. **Psilophyta** (containing 2 classes, e.g. Psilophytopsida and Psilotopsida), **Lycophyta** (classes Eligulopsida and Ligulopsida), **Arthrophyta** (classes Calamopsida and Sphenophyllopsida) and **Filicophyta** (classes Leptosporangiopsida, Protoleptosporangiopsida, Eusporangiopsida and Primofilicopsida).

Reimers' classification of the Pteridophyta as published in the 1954 edition of Engler's *Syllabus der Pflanzenfamilien*—

Division : PTERIDOPHYTES

A. Sub-division : **Psilophytopsida**

Order *Psilophytales*

Families : Rhyniaceae, Zosterophyllaceae, Psylophytaceae, Asteroxylaceae.

B. Sub-division : **Psilotopsida**
Order *Psilotales*
Families : Psilotaceae, Tmesipteridaceae.

C. Sub-division : **Lycopsida**
Order 1. *Protolepidodendrales*
Families : Drepanophycaceae, Protolepidodendraceae.
Order 2. *Lycopodiales*
Family : Lycopodiaceae
Order 3. *Lepidodendrales*
Families : Lepidodendraceae, Bothrodendraceae, Sigillariaceae, Pleuromeiaceae.
Order 4. *Isoetales*
Family : Isoetaceae
Order 5. *Selaginellales*
Family : Selaginellaceae

D. Sub-division : **Sphenopsida**
Order 1. *Hyeniales*
Families : Protohyeniaceae, Hyeniaceae.
Order 2. *Sphenophyllales*
Families : Sphenophyllaceae, Cheirostrobaceae.
Order 3. *Calamitales*
Families : Asterocalamitaceae, Calamitaceae.
Order 4. *Equisetales*
Family : Equisetaceae

E. Sub-division : **Pteropsida**
a. Class PRIMOFILICES
Order 1 *Cladoxylales*
Families : Cladoxylaceae, Pseudosporochnaceae.
Order 2 *Coenopteridales*
Families : Zygopteridaceae, Stauropteridaceae, Botryopteridaceae.
b. Class EUSPORANGIATAE
Order 1 *Marattiales*
Families : Asterothecaceae, Angiopteridaceae, Marattiaceae, Danaeaceae, Christenseniaceae.
Order 2 *Ophioglossales*
Family : Ophioglossaceae
c. Class OSMUNDIDAE
Order *Osmundales*
Family : Osmundaceae
d. Class LEPTOSPORANGIATAE
Order 1 *Filicales*
Families : Schizaceae, Gleicheniaceae, Hymenophyllaceae, Dicksoniaceae, Matoniaceae, Dipteridaceae, Cyatheaceae, Dennstaedtiaceae, Adiantaceae, Polypodiaceae.
Order 2 *Marsileales*
Families : Pilulariaceae, Marsileaceae.
Order 3 *Salviniales*
Families : Salviniaceae, Azollaceae.

G. Origin of Pteridophyta—Regarding the phylogenetic origin of Pteridophyta, there are two theories such as (*a*) *algal origin* and (*b*) *bryophytic origin*, the former postulates direct origin from Algae, the latter is based on the consideration that bryophytes gave rise to pteridophytes and both are related to each other.

Some supporters of direct algal origin of pteridophytes consider that similarities existing to some extent between certain sections of Algae and Pteridophyta are due to parallel evolution but not due to phylogenetic connection or link between them. Other supporters of algal origin believe that the origin was from the brown algae, as this group of algae has similar motile male gametes resembling those of many pteridophytes. Fritsch (1945) has suggested that the origin of pteridophytes from chaetophoraceous type of filamentous green algae (Chlorophyta) where the vegetative body was of an erect parenchymatous type and like pteridophytes there was an alternation of two generations. Scott (1900), Eames (1936) and others do not advocate the origin of pteridophytes from any particular section of algæ whereas Church (1919), Arnold (1947) and others postulate that the origin of pteridophytes took place from some complex algae inhabiting tidal levels of sea shore and gradually transmigrating from sea—such evolution was presumed either from Phaeophyta (brown algae) or from Chlorophyta (green algae).

Bryophytic origin of pteridophytes is supported by many workers like Bower (1935), Lignier (1903), Zimmermann (1930, '38), Campbell (1895, '99, 1924) and others. Bryophytes and pteridophytes, in many respects have common features, so it is not at all improbable that there might be phylogenetic connection and relationship between them. Bryophytic relationship of pteridophytes is based on the following common morphological and biological similarities existing between the two groups—

(*a*) General similarity in the vegetative gametophytic structure of thallose bryophytes (*Riccia, Marchantia, Anthoceros* etc.) and pteridophytes (i.e. prothallus of ferns, *Equisetum* etc.).

(*b*) Similarity in the mature structure and development of sex organs, particularly those of archegonia of both bryophytes and pteridophytes.

(*c*) Encasing of the embryo in the venter of the archegonium and partial parasitism of the young or mature sporophyte upon the gametophyte in both bryophytes and pteridophytes.

(*d*) Presence of heteromorphic life cycle in which there is an alternation of two vegetatively unlike generations.

Bower, Lignier and Zimmermann believed that there is phylogenetic connection between bryophytes and pteridophytes, the latter arose from very primitive archegoniatae type of hypothetical terrestrial plant in two divergent evolutionary lines. Campbell advocated that pteridophytes had direct origin from anthocerotean type of bryophyte. Campbell's idea of direct origin of pteridophytes from anthocerotean type i.e., from *Anthoceros* is based on the following facts :—

(*a*) The indefinite growth of the sporophyte together with highly developed photosynthetic tissue of *Anthoceros* makes the sporophyte the nearest approach to the entirely independent sporophyte of pteridophytes (ferns).

(*b*) The sporophyte of *Anthoceros* is capable of independent existence by virtue of bulbous foot—if it is allowed to grow on earth, it can live and can produce leaves and roots even showing thereby the independent existence of growth and life.

(*c*) The rootless, leafless and dichotomously branched shoot of Psilophyta (a primitive group of pteridophytes) bears strong testimony to anthocerotean origin of Pteridophyta.

(*d*) If the meristematic region of an anthocerotean type of sporophyte was shifted from base to apex then the initiation of dichotomous branching by the meristem and the confinement of sporangia and spore formation in the branch apices would have been possible—such sporophytes of certain Psilophytales and of *Anthoceros* resemble closely. *Anthoceros*, therefore, may show the beginning of an approach to such condition—so sporophytes have been found in which there is a restriction of spore formation to the distal end and in which columella is differentiated into conducting tissue in the lower portion.

H. Economic importance :

Lycopodium obscurum, commonly called Christmas greens, are used as garland during Christmas festival and for the purpose of decoration. Generally species of *Lycopodium* is widely used in homoeopathic system of medicine. From the spores of *Lycopodium inundatum* 50% fixed oils are obtained—such oils are used as cover for pills, this oil is also used in the manufacture of fire works. The spores are also used during theatrical performance for poducing stage lightening, under the name of Vegetable Brimstone". The spore dusts of *Lycopodium clavatum* and other species are used in pharmacy as water repellent. Dusting spore-powder on the soft skin gives protection. Spore dusts are also used in the preparation of suppositories. The beautiful species of *Lycopodium volubile* is very commonly used for table decoration as it keeps well after collection. Extracts of *Lycopodium* plant in the past was used as a stimulant for kidney.

Selaginella plant also used during Christmas festival as garland and for various type of table decoration for its good conservancy. This plant is greatly regarded with wonder and pleasure for their feathery moss-like and lush-green foliage. *S. willdenovii* and *S. caesia* are important for their metallic and different tinge other than the principal colour, specially bronze and blusih colours. *S. serpens* is famous for the periodic changes in the colour of its leaves, which are bright green in the morning, but slowly become paler during the day and towards night again they regain their beautiful green colour. Hence various species of *Selaginella* are grown as ornamentals. *S. lepidophylla* and *S. pilifera* are sold as curiosities, under the name "resurrection plants." *S. botryoides* yields a medicine which is used in curing liver diseases.

The underground modified stem (corm) of *Isoetes*, is used as food by ducks and other aquatic animals.

The genus *Equisetum* is of much economically important. The stems of most species are used for polishing wood, floor, furniture etc. and to clean utensils (alloy dishes). Many species of *Equisetum* acts as harmful weeds in poorly drained soils. The complete plant of *Equisetum arvense* has been recognised by the German Pharmacopoeia under the name of "*Herba Equiseti*", which is used in promoting the discharge of urine—the ashes of this plant are used to relieve acidity and dyspepsia. This species also contains silica in therapeutically active form, for which it has got haemostatic and haemopoietic properties. *E. debile* yield a medicine which relieves gonorrhoea.

Different types of ferns enhances the beauty of the garden and glass houses and some are also used in the preparation of bouquets and in keeping in the button holes of coats. In the tropical regions, tree ferns are used for the building of houses.

The stalks and leaves of the plants of *Marsilea*, *Dryopteris*, *Pteris* etc. are used as herbage-vegetables, specially during food scarcity. From the rhizome of *Dryopteris* medicines are produced. The starchy paste of the sporocarps of *Marsilea drummondii* is prepared into cakes, commoly called "nardoo" by the natives of Australia.

Generally all types of Pteridophyta take part in the formation of coal.