STELAR SYSTEM IN PTERIDOPHYTES

The conducting system of pteridophytes consists of *xylem* and *phloem* and associated parenchyma cells, all of which are organised into a *stele* (L. *stela,* rod or column) that is generally separated from the outer cortex by a layer of *endodermis*. At one time, the *vascular bundle* was considered the fundamental unit in the vascular system of the pteridophytes. Later, the concept of the stele as the fundamental unit of vascular system became the basis of stelar theory, put forward by van Tieghem and Douliot (1886). It postulated that the primary structure of the stem and root were fundamentally similar because each consisted of a central core, the *stele*, enclosed within the *cortex*. The term '*stele*' was interpreted as including the vascular tissues and the so-called *conjunctive tissues* associated with them, the *pith* (if present), and *pericycle*. The idea of the stelar theory was widely accepted by many scientists and proved to be useful in the comparative anatomical and phylogenetic studies of the varied types of vascular cylinders that occur in stems and roots of all vascular plants.

In recent years, some scientists have suggested that the stelar theory should be thoroughly rediscussed in the light of some modern studies. For example, an endodermis, although common in the stems and roots of most lower vascular plants, seldom occurs in the stems of seed plants. Furthermore, in Filicophyta, the vascular connection between the leaf and stem is more complex than any other groups of pteridophytes. In the lower vascular plants, *e.g.*, *Lycopodium* and *Selaginella,* most of the portion of the primary vascular system of the stem is cauline and is not related in its development to the vascular system of the leaves, for the leaf traces are very small and superficially connected to the vascular cylinder of the stem. But in ferns, the stelar anatomy of the stem is largely affected by the large leaf traces and leaf gaps. Wardlaw (1946), Wetmore and Wardlaw (1951) consider the stele of the stem in Filicophyta as a composite structure, consisting of both cauline (stem) and foliar (leaf) vascular components.

Different types of steles found in the pteridophytes and evolutionary relationship among them.

On the basis of the kind of stelar organisation that occur in different pteridophytes, an evolutionary sequence can be recognised among different groups of them.

The following two types of stele occur in pteridophytes.

1. **Protostele.** Protostele is the simplest, and considered to be the most primitive type of stele. It consists of a solid core of *xylem* surrounded by a cylinder of *phloem*, enclosing *no pith*. Protosteles are considered primitive because of their occurrence in certain earliest of the land plants which appeared about 400 million years ago. All other types of steles have evolved from it in the course of evolutionary specialisation. Protosteles are most common in psilophytes and lycophytes, but they occur also in the juenile stems of ferns. Such a stele

primitive psilophytes like *Horneophyton* and *Rhynia*, and is found in a number of living genera, e.g. *Lycopodium cernuum* and *Selaginella kraussiana*.

(ii) ***Actinostele.*** In a number of pteridophytes, the central xylem core of a protostele is not smooth but is thrown into radiating ribs with the protoxylems at the extremities and phloem alternating with its rays, when seen in a cross section. Such a type of protostele is termed an *actinostele* (Fig. 36.11, B). It is found in *Psilotum triquetrum*, and *Lycopodium serratum*.

(iii) ***Plectostele***. In the stems of some species of *Lycopodium*, e.g., *L. clavatum* and *L. volubile*, when seen in a cross section, the xylem occurs in the forms of small parallel bands alternating with the phloem plates. This specialised form of protostele is usually termed a *plectostele* (Fig. 36.11, C).

(iv) ***Mixed-protostele.*** In *Lycopodium cernuum*, the xylem when seen in a cross section, appears in the form of irregular groups that are embedded in the ground mass of phloem. This type of protostele is called the *mixed-protostele* (Fig. 36.11, D).

2. **Siphonostele.** A kind of stele in which there is present a pith in the central region is called a *siphonostele* or *medullated protostele*. This type of stele is thought to have been evolved from a protostele by a degradation or reduction of tracheary elements into parenchyma, and represents a stage in evolutionary advance. In siphonostele, the vascular tissues are arranged in the form of a hollow cylinder, with a distinct pith in the centre. The siphonostele and its variations are found frequently in the ferns.

Origin of Siphonostele. There is a general acceptance that the siphonostele has evolved from a protostele. Two theories have been proposed accounting the phylogenetic origin of the pith: intrastelar theory and extrastelar theory.

Intrastelar theory, which is supported by Boodle (1901), Gwynne-Vaughan (1908), Bower (1911), Petry (1914), and others, holds that pith originates by metamorphosis of the inner vascular elements into parenchyma. Support for this theory is furnished by a number of plants like *Botrychium lunaria* and *Osmunda regalis*, in which the central region of the protostele consists of both tracheids and parenchyma cells.

According to the ***extrastelar theory***, which was put forth by Jeffrey (1897, 1902, 1917), the pith is extra stelar in origin. The theory holds that the pith originated as a result of the invasion of cortical tissues into the stele through the leaf gaps and branch gaps, in the course of phylogenetic development of the vascular plants. According to this theory, the pith is cortical in nature.

Types of Siphonostele. According to the distributional patterns of the xylem and phloem, the siphonostele has been classified into following two types:

(i) ectophloic siphonostele

(ii) amphiphloic siphonostele

In the *ectophloic siphonostele*, the phloem occurs only on the outer surfaces of the xylem cylinder (Fig. 36.11, E). It is found in *Equisetum* and some ferns like *Osmunda* and *Schizaea*.

In the *amphiphloic siphonostele*, the phloem may be both external and internal (Fig. 36.11, F). An amphiphloic siphonostele is also known as a *solenostele*. It is found in the ferns like *Adiantum* and *Marsilea*.

In its simplest form, the siphonostele has no leaf gaps, *e.g.*, some species of *Selaginella*. A siphonostele, which has no leaf gap is termed as *cladosiphonic siphonostele*.

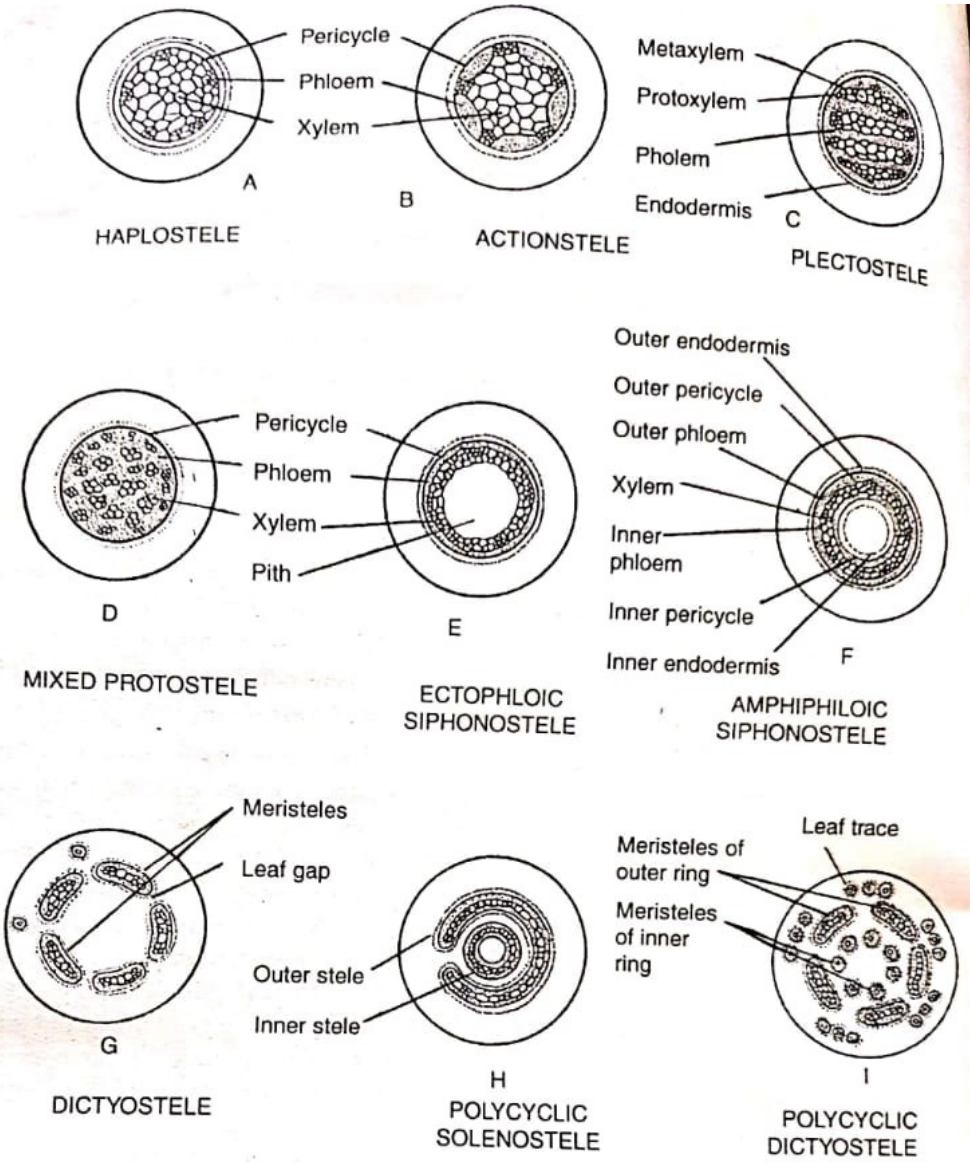

Fig. 36.11. Diagrammatic views of various types of steles found in pteridophytes. A to D—types of Protostele. A—Haplostele, B—Actinostele, C—Plectostele, and D— Mixed-protostele. E to I—types of Siphonostele. E—Eetophloic siphonostele, F— Amphiphloic siphonostele, G—Dictyostele, H—Polycyclic solenostele, and I—Polycyclic dictyostele.

occurred in such primitive psilophytes as *Horneophyton* and *Rhynia*, and may be found in *Selaginella, Lycopodium, Gleichenia* and *Lygodium* among present day forms.

Variations of the protostele include, the haplostele, actinostele, plectostele, and mixed-protostele.

(i) ***Haplostele.*** A protostele with central solid and smooth core of xylem surrounded by phloem is known as *haplostele* (Fig. 36.11, A). This particular type of protostele has been regarded as the most primitive among the different types. It occurred in