3.2 *SELAGINELLA*

Selaginella, commonly known as 'small club moss' or "spike moss", belongs to the family Selaginellaceae, order Selaginellales, class Lycopodinae, division Lepidophyta and the group Pteridophyta.

Habitat—The genus *Selaginella* has about 700 species and is world-wide in distribution. Although some species of *Selaginella* occur in temperate regions, but the vast majority occur in the rain forests of tropical countries and grow on the ground in damp, shaded and humid conditions. Some species also occur in arid regions of the world. Temperate species are found to grow on damp shady sides of the hills.

About 58 species of *Selaginella* have reported by Alston (1945) from India ; of these, common species are *Selaginella rupestris*, *S. chrysocaulos*, *S. pallidissima*, *S. jacquemonth*, *S. megaphylla*, *S. pentagona*, etc. ; *S. kraussiana* is a native of Africa, this species is now naturalized in India and grown in green houses as ornamentals.

Habit—*Selaginella* plants i.e. sporophytes are generally perennial or rarely annual prostrate herbs, creeping on soil surface or over logs and stones (*S. kraussiana*). The species also show some variations in habit viz. some species are sub-erect (*S. trachyphylla*), others are erect (*S. erythropus*) or climbers (*S. alligans*). The size of the sporophyte varies greatly from a few centimetres to several metres.

A. **Structure of the Sporophyte** (plant body)

1. EXTERNAL MORPHOLOGY—

(*a*) The *stem* is long, slender, usually dorsiventral and prostrate with short erect branches ; in some species the stem is erect. The stem may be

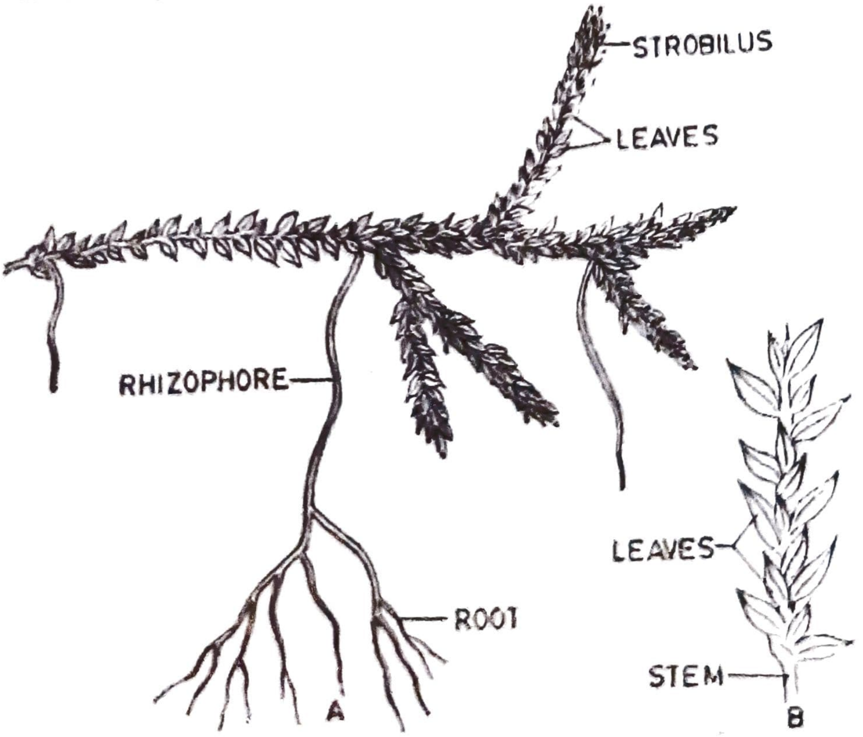


Fig. 3.10—*Selaginella kraussiana*. A—Portion of the plant (sporophyte) with strobili. B—A portion of stem showing leaf arrangement.

unbranched or dichotomously *branched*. In *S. kraussiana*, a typical species, the main stem is repeatedly branched, the branching is *dichotomous* at first, then becomes *lateral*. The growth of the stem in most species takes place by the activity of a single well-defined apical cell situated at the growing apex. From each ramification of the stem, colourless, leafless, elongated and cylindrical appendages known as *rhizophores* develop. The rhizophores grow downwardly into the soil and give rise to a small tuft of adventitious roots at their free ends.

Morphological nature of the rhizophore—There are three views about the morphological nature of the rhizophore, such as—(1) rhizophores are regarded as *capless roots* (Van Tieghem and Harvey-Gibson 1902 ; Uphof, 1920) as they are like root positively geotropic, leafless and have the same anatomical structure as that of a root ; (2) rhizophores are regarded as *leafless shoots* (Pfeffer, 1871 ; Bruchmann, 1909 ; Worsdell, 1910) because rhizophores like the stems are exogenous in origin and develop from 'angle meristems' occurring in pairs, one above and one below at the junction of two branches. In some species, only one of these is active and the other remains dormant—the active one grows into a smooth glossy forking structure without leaves ; its branches are without root caps, but root-caps appear whenever branches reach the soil and all subsequent branches then look like typical roots. This is the normal behaviour, but the behaviour of angle meristems depends upon the influence of auxin concentrations, because rhizophores give rise to leafy shoros only after damage to the adjacent branches. Therefore rhizophore is neither a stem nor a root, but exhibits some of the characters of both (Sporne, 1966) ; (3) Goebel (1905) and Bower (1908, 1935) hold that rhizophores are neither roots nor shoots but organs '*sul generis*'.

(*b*) *Leaves*—Stem and branches bear numerous small (a few milimetres long at most), lanceolate, ovate to filiform leaves which are arranged in *spirals, decussate* pairs or *in four longitudinal rows*. Leaves are always *ligulate*, i.e. all the leaves in all species possess a small, membranous, tongue-like projection inserted in a pit on the adaxial (upper) surface near the base. Leaves are generally thin and delicate in texture. Leaves are provided with unbranched mid-vein (microphyllous leaf). In some species (*S. pygmaea, L, uliginosa*) leaves are all alike and arranged spirally on the stem. But in others e.g. *S. kraussiana, S. lepidophylla* etc. leaves are usually of two types i.e. leaves are dimorphic, and they are arranged in four longitudinal rows on the dorsi-

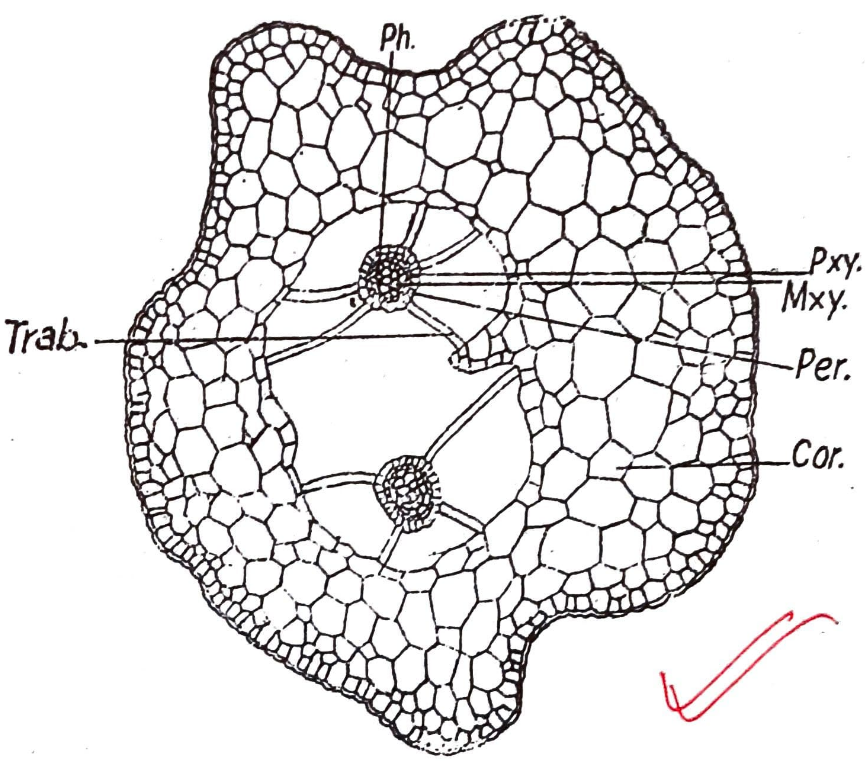


Fig. 3.11—*Selaginella kraussina* stem in transverse section. Cor.—Cortex. Per.—Pericycle. Trab.—Trabeculae. Ph.—Phloem. Pxy.—Protoxylem, Mxy.—Metaxylem.

ventral stems. There are two rows of small leaves (microphyllous) and opposite to them lie two rows of large leaves (megaphyllous). The leaves occur in pairs and the two leaves of each pair are unequal in size, the smaller leaf of each pair is inserted on the upper surface of the stem and the large leaf is inserted on the lower surface of the stem.

(*c*) *Roots*—First root i.e. primary root is short-lived, later delicate

[1] Latin words which mean "organ of its own kind" or "a unique/peculiar structure constituting a class alone".

adventitious roots arise from the underside of the stem and from the tips of rhizophores also. Roots are delicate and branching of the root is dichotomous in alternate planes.

2. INTERNAL MORPHOLOGY—

(a) The *stem* in cross-section shows :

(i) a superficial epidermis, one-cell in thickness and it consists of parenchymatous cells. *Stomata are absent* in epidermis ;

(ii) a thick cortex, composed either entirely of thin-walled, green, parenchymatous cells without interceullar spaces, or of partly sclerenchymatous cells forming a hypodermis and parenchymatous cells. *True endodermis* is *absent*, instead *endodermal cells are modified into* radially elongated cells known as *trabeculae* by means of which stele or steles are attached to the cortex ;

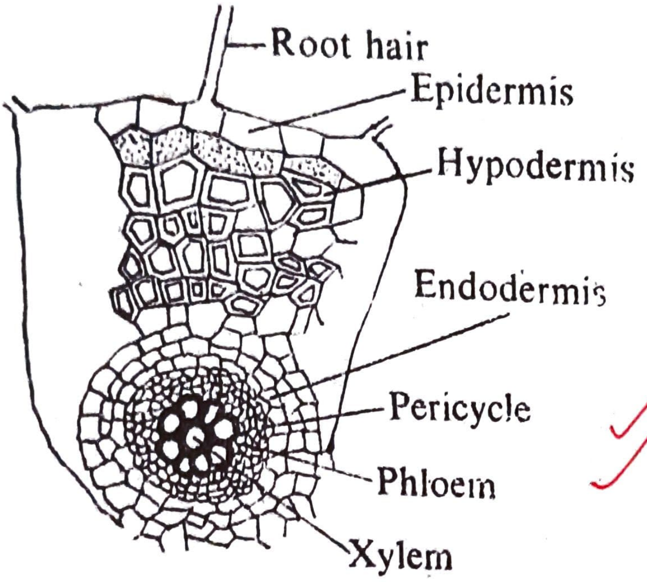


Fig. 3.12—*Selaginella rubella* root in transverse section.

(iii) the stelar organisation varies in different species. The stele is protostelic in nature with *exarch* xylem, the number of which ranges from one (monostelic) to several i.e., 2, 3, 4 etc. (polystelic) ; each stele is externally limited by a layer of pericycle.

(b) The *root* in cross-section shows one-cell layer thick epidermis, cortex and stele ; the cortex is like that of stem but is provided with an endodermis. The stele is protostele, which is *monarch* and exarch.

(c) The *leaf* in cross-section (Fig. 3.13) shows a distinct upper and lower epidermis—each is one-cell in thickness, an undifferentiated mesophyll and a central vascular bundle. The mesophyll tissue is composed of more or less elongated and similar cells with intercellular spaces. Vascular bundle is concentric, phloem surrounds the xylem.

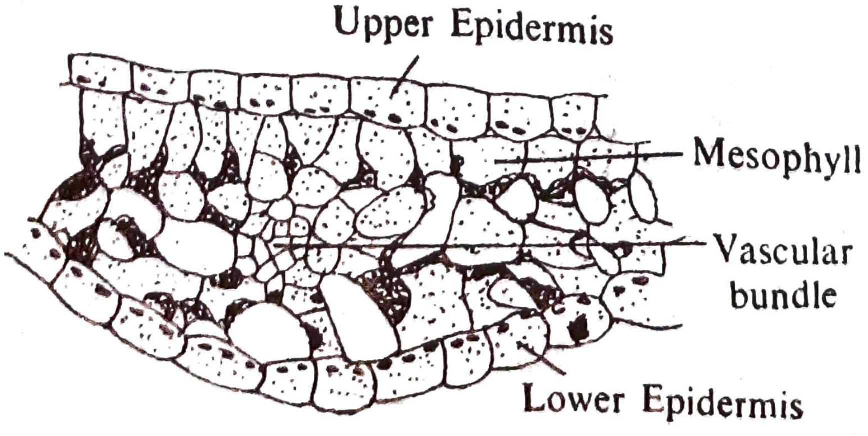


Fig. 3.13—*Selaginella kraussiana* leaf in cross-section.

3. VEGETATIVE REPRODUCTION—Vegetative reproduction takes place by the following methods.

(1) *Surface tubers* and *underground tubers* are developed at the ends of ordinary vegetative branches and at the ends of filamentous modified underground branches respectively—they germinate and produce new plants.

(2) Vegetative reproduction also takes place by bulbils, by fragmentation, by rooting at the frond-tips etc.

4. REPRODUCTIVE STRUCTURES—Reproductive structure are strobili *i.e.* cones.

Structure of Strobilus—The cone i.e. strobilus varies in size from 5 mm to 6-7 cm. They are cylindrical or *quadrangular* and are borne at the apices of main stem or on lateral branches. Strobili are usually erect, rarely pendent or horizontal. Each strobilus is usually tapering towards the apex and consists of an axis upon which, in most species, *two types of sporophylls* viz., *megasporophylls* (or *macrosporophylls*) and *microsporophylls* are always arranged spirally, but the spiral arrangement is so condensed that sporophylls appear to lie opposite to each other and in 4 distinct vertical rows. In *Selaginella* as a whole the megasporophylls occur at the base of the cone and the microsporophylls above. In some species, the strobili i.e. cones are made up mainly of microsporophylls with one megasporophyll at the base (Fig. 3.14); in others the stobili consist largely of megasporophylls with one or two microsporophylls occasionally. In *S. oregana* the strobilus bears only microsporophylls on one side and only megasporophylls on other side. There are some species in which a strobilus has only megasporophylls or only microsporophylls (Mitchell, 1910). Sporophylls also *ligulate*. Each microsporophyll bears a single stalked *microsporangium* in its axil attached either nearly upon the adaxial (upper) surface of the sporophyll or on the surface of the axis just above the axil of the sporophyll. Similarly, each *mega-* i.e. *macrosporophyll* bears a single stalked *mega-* i.e. *macrosporangium* in its axil attached either nearly upon the adaxial surface of the sporophyll or on the axis just above the axil of the sporophyll. The two kinds of sporangia (micro- and mega) vary greatly in size, and the megasporangia are larger while the microsporangia are smaller; they are either *reniform*, *obovoid* or *rarely flattened*. Both types of sporangia are provided with a jacket (wall) of sterile cells, *two cell-layers in* thickness; within the jacket lies sporogenous tissue, which is surrounded externally by a *prominent* layer of nutritive tissue called the *tapetum*. Within the microsporangium sporogenous tissue later on differentiates into microspore mother cells, all of which, except a very few, by reduction

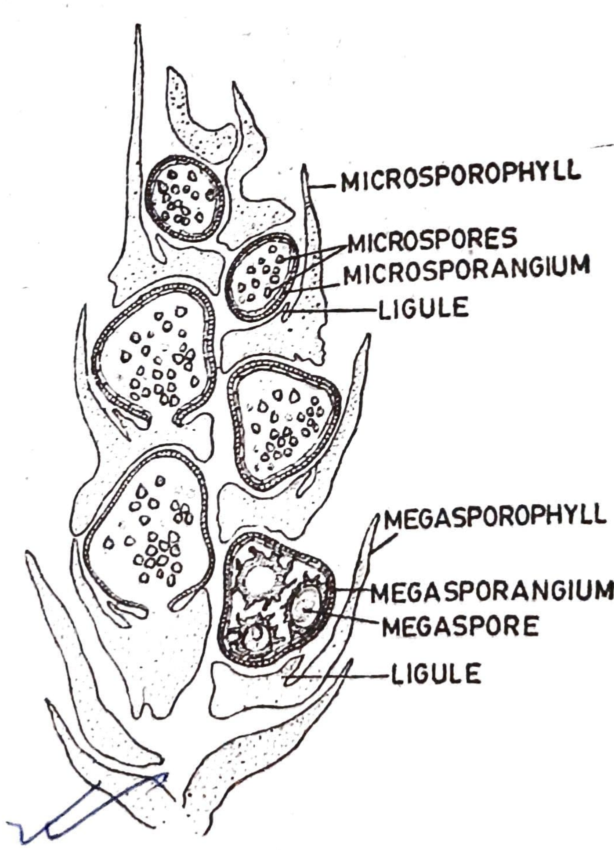


Fig. 3.14—*Selaginella* sp. Strobilus in logitudinal section.

division give rise to spore-tetrads—thus each microsporangium contains *numerous microspores.* Sporogenous tissue of each megasporangium also differentiates into megaspore mother cells but all of them *except one* degenerate; the surviving megaspore mother cell by reduction division gives rise to *four megaspores.* In some cases, of these four megaspores, only one or two survive, others degenerate. *Selaginella* is *heterosporous* due to the production of two kinds of spores viz, smaller microspores and larger megaspores within their respective sporangia. As soon as spores are developed, gametophytic *i.e.* haploid generation begins.

5. DEHISCENCE OF SPORANGIA—In *Selaginella,* dehiscence of both kinds of sporangia takes place by *vertical splitting of the upper part of the sporangial jacket into two valves* which gap apart—this is due to differential hygroscopic changes in the apical and lateral parts of the sporangium wall. After this, spores containing immature gametophytes are liberated to the exterior.

B. Structure of Gametophytes

As *Selaginella* is heterosporous, it produces *two kinds of gametophytes* viz., *microgametophyte* i.e. *male gametophyte* from microspore and *megagametophyte* from mega- or macrospore—thus gametophytes are *dioecious* (*heterothallic*).

1. MALE GAMETOPHYTE—Microspore is the first cell of the male gametophyte. Each microspore is small, *spherico-tetrahedral* and provided

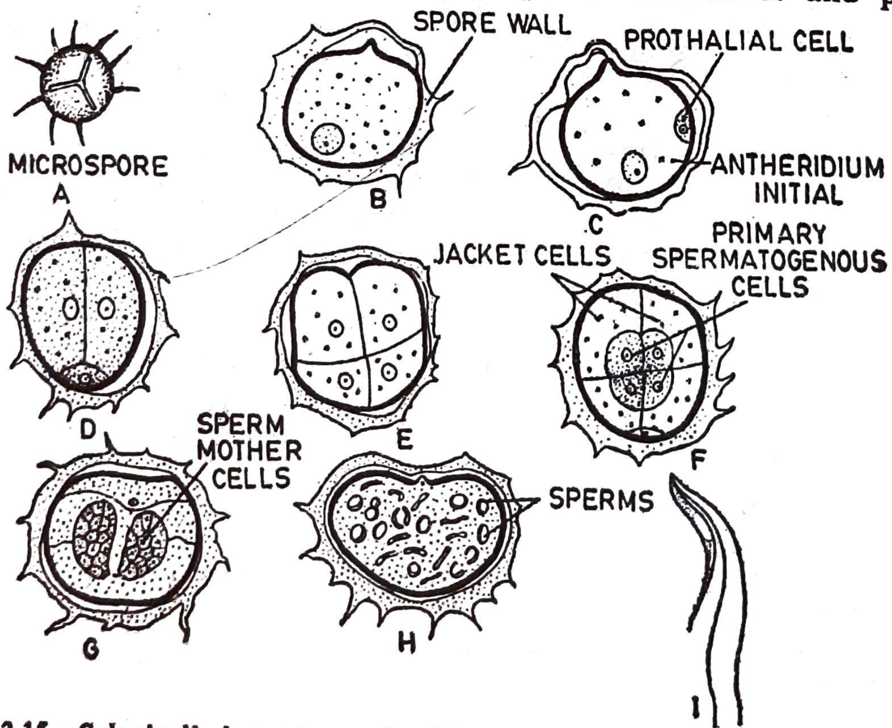


Fig. 3.15—*Selaginella kraussiana.* A—Microspore (entire). B—Microspore in l.s. C-H—Different stages of the development of the male i.e. microgametophyte. I—Single sperm.

with two coats viz., outer *thick ornamental* exine (exospore) and an inner delicate intine (endospore).

Germination of microspore takes place *within the microsporangium.* In the microspore the first cell division forms a small lense-shaped cell called the *prothallial cell* at one side and a larger cell called the *antheridium initial.* The prothallial cell divides no further but the antheridium initial divides and redivides forming a 12-*celled* structure, the so-called *antheridium.* Now the male gametophyte consists of 13 cells (12 cells derived from the division of antheridium initial and 1 prothallial cell). Of these thirteen cells, the central four cells constitute the *primary spermatogenous cells*, the eight cells surrounding the primary spermatogenous cells constitute the *sterile jacket cells* and one remains as prothallial cell. The primary spermatogenous cells divide several times forming 128 or 156 *sperm mother cells* i.e. *androcytes*. Each sperm mother cell is then metamorphosed into a biflagellate sperm. The sterile jacket cells break down and sperms float free in the cavity of spore wall. Finally sperms are liberated in the surrounding film of water by the rupture of the spore wall.

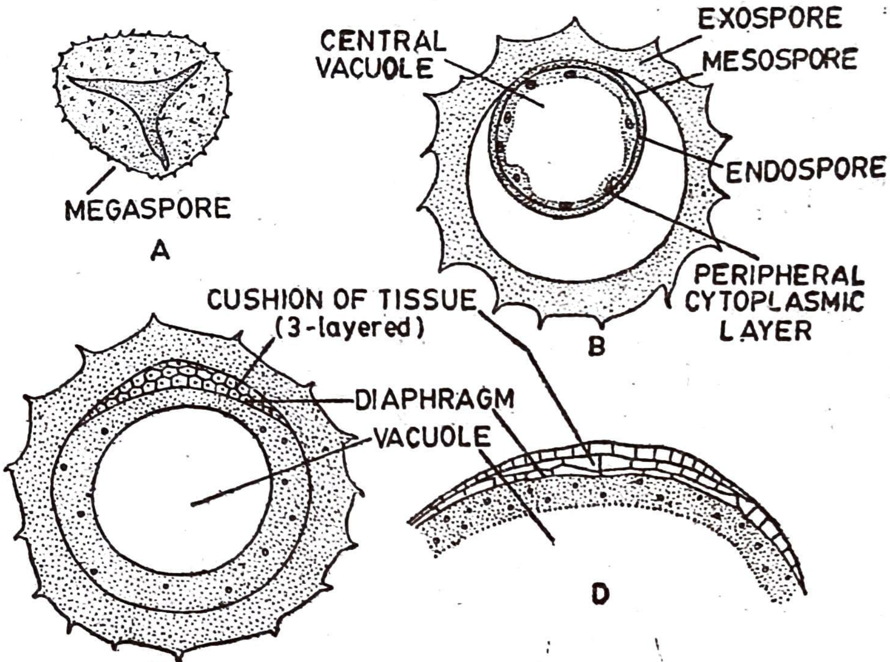


Fig. 3.16—*Selaginella kraussiana*. A—Single megaspore. B-D—Stages of the development of female i.e. megagametophyte.

From above structure, it is evident that the male gametophyte of *Selaginella* is of a *much reduced* type ; the gametophyte is never set free[1] and is *dependent on the parent sporophyte for nutrition.*

2. Female gametophyte—Megaspore or macrospore is the first cell of the female gametophyte. Megaspores are *larger* and *tetrahedral* in shape with prominent tri-radiate ridge, the spore wall consists of outer sculptured thick exine (exospore) and inner thin intine (endospore).

The female gametophyte also begins to germinate while the megaspore is still within the megasporangium ; sometimes the entire development takes place within the megasporangium, in some cases partly within the megasporangium and partly when it is shed. The germinating megaspore first enlarges in size and now consists of *three wall layers*[2] and a thin layer of peripheral cytoplasm enclosing a nucleus. Its nucleus divides into two, but this is not followed by cell division—then the two nuclei, by free nuclear divisions, divide continuously until the peripheral cytoplasmic layer contains many free, flattened nuclei surrounding a larger central vacuole (Fig 3 16, B). As the nuclei increase in number, the cytoplasmic layer becomes thicker and the vacuole becomes smaller, and ultimately the vacuolar region is filled up with cytoplasm. Now wall formation begins about the nuclei in the apical region (near the tri-radiate ridge)—as a result a cushion of tissue is formed there which gradually extends inwards filling the megaspore completely before

[1] In some cases development of male gametophyte takes place *partly within the microsporangium* and *partly when it is set free.*

[2] Outer exospore, middle mesospore and inner endospore.

fertilization. In some species, wall formation stops temporarily after the cushion of tissue has become 3 to 10 layers thick from the periphery and inner walls of the lower-most cells become thickened forming a *diaphragm* which separates the cellular portion (i.e. cushion) from the non-cellular

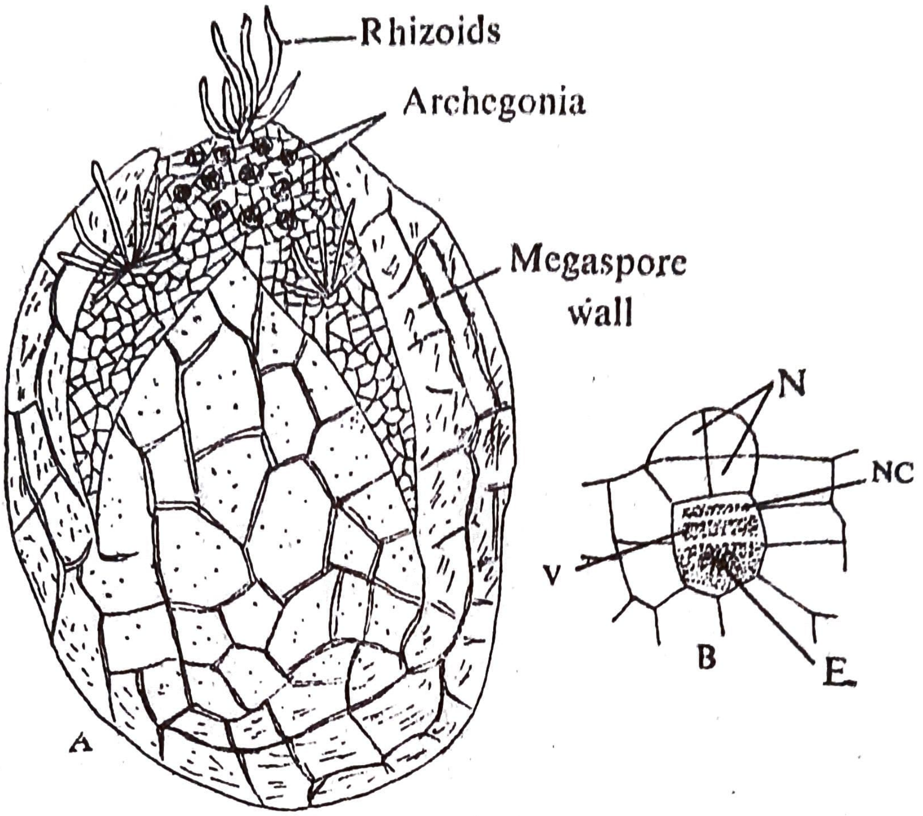


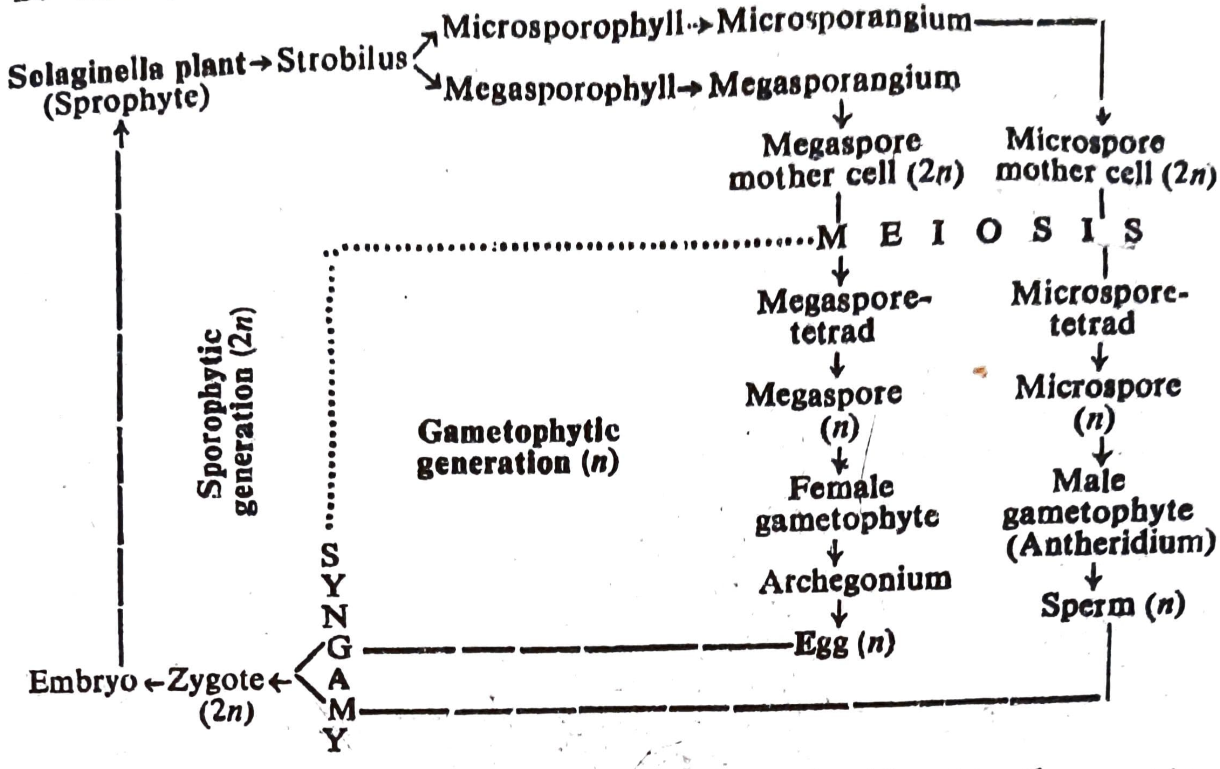
Fig. 3.17—A-Entire mature female gametophyte of *Selaginella kraussiana*. B—An archegonium. N—Neck. C—Neck canal cell. V—Ventral canal cell. E—Egg.

portion. Later, the lower region i.e. non-cellular portion is also divided into cells, but those cells are larger than the cells of the cushion and they contain abundant food matter. Shortly after the formation of apical tissue, the spore wall cracks along the triradiate-ridge and the apical cushion of tissue becomes exposed ; this tissue of the gametophyte may become green and rhizoids may develop (Fig. 3.17, A) from the gametophytes after they have fallen on the soil.

Most of the superficial cells of the apical tissue are potential archegonium initials, and several of these develop into archegonia. Archegonia, varying from *few to many*, are developed in the centre of the cushion ; they are small and *sunken* in the surrounding tissue of the gametophyte. Each archegonium consists of a neck composed of two tiers of four cells each, *one neck canal cell*, a ventral canal cell and an egg (Fig. 3.17, B).

C. **Fertilization**—It may take place while the female gametophyte is still within the megasporangium or after the megasporangium has fallen to the ground. The sperms after liberation swim to the archegonia in dew or in rain water and one of them ultimately fertilize the egg or ovum, as a result a zygote i.e. oospore (2n) develops. With the formation of oospore, diploid *i.e.* sporophytic generation begins.

D. Life cycle (in word diagram)



E. The young Sporophyte i. e. Embryo—After fertilization the zygote or oospore secretes a protective wall and develops into an embryo which gives rise to adult *Selaginella* plant in course of time.

Order **Lepidodendrales**—Members of this order are extinct. The sporophytes of the members of Lepidodendrales were tree-like (arboreal) in size and habit, and with secondary growth in both root and stem. Roots were borne on rhizophores—this rhizophore bearing root system was first considered as a separate genus *Stigmaria*, hence this structure has been designated uptil now as "stigmarian root system." Stigmarian root system consists of *four* horizontal branches (rhizophore in nature like that of *Selaginella*) radiating from the base of the erect trunk of the sporophyte. Leaves were deciduous, microphyllous, ligulate. All the members of this order were heterosporous ; sporophylls were borne in strobili.

According to Smith (1938, '55), Lepidodendrales contains *four* families viz. (1) Lepidodendraceae, includes type genus *Lepidodendron*, (2) Lepidocarpaceae includes type genus *Lepidocarpon*, (3) Bothrodendraceae includes type genus *Bothrodendron* and (4) Sigillariaceae includes type genus *Sigillaria*.

It is evident from the known fossil records that the Lepidodendrales appeared in the Upper Devonian and became extinct during the Permian of Paleozoic age.