HOFMEISTER (1862) was the first to give an account of the gametophyte of *Botrychium lunaria*, young sporophytes of which were collected by his friend Irmish. He described the gametophyte as being oval in shape, about a millimetre in length, of light brown colour externally and yellowish white in section. Antheridia were found on the upper surface and archegonia situated below. Root-hairs were sparingly interspersed among the sex-organs. Antherozoids resembled those of other Filicinese. Attempts to germinate spores under observation were unsuccessful. No young embryos were obtained, nor was it possible to study the development of the sex-organs. As a result of the inferior position of the archegonia the young sporophyte appeared on the lower surface of the prothallus and the growing shoot was forced to make a half turn to assume its natural geotropic position.

The next contribution to our knowledge is due to the discovery of the gametophyte of *Botrychium virginianum* by Campbell (1895) at Grosse Isle, Michigan. The prothallia were, like those of *B. lunaria* reported by Hofmeister, but unfortunately too old for the study of the development of the sex-organs and embryo. They are described as being flattened, tuberous with folded upper margins, covered with root-hairs and bearing reproductive organs on the superior surface. No young embryos were found but only advanced young sporophytes bearing only the first or a subsequent leaf.

Jeffrey (1898) has given a detailed description of the gametophyte of *Botrychium virginianum* collected in the province of Quebec and also near Toronto. According to him the gametophytes are subterranean symbiotic, non-chlorophyllous and their whole surface beset with rhizoids which are generally multicellular. Reproductive organs are found exclusively on the superior surface, the antheridia being on the crest of the ridge and the archegonia on its flanks. The archegonia and antheridia are of the eusporangiate filicineous type. Embryo formation is like that of *Isoetes echinospora*. Root and shoot arise from the epibasal cell while the whole of the hypobasal cell gives rise to the foot. The cotyledon is derived secondarily from the shoot meristem.
Campbell (1920) stated that the genus *Botrychium* comprises of about 35 species of almost world-wide distribution. Up to the present our knowledge of the life-history of these ferns has been confined almost exclusively to two species, namely *Botrychium lunaria* (L) SW and *B. virginianum*. Campbell (1921) has worked out the gametophyte and embryo of *Botrychium obliquum* MUHL from the collections which Dr. Lyon generously turned over to him. The gametophyte and sex-organs of this species do not differ externally from those of the other species of *Botrychium*. However, the embryo differs from *B. lunaria* and *B. virginianum*. It has a well-developed cotyledon, the origin of the root is endogenous and the bipolar arrangement of cotyledon and root is clearly seen. There is a suspensor which is not found in the other species.

Campbell (1922) also described the gametophyte and embryo of *Botrychium simplex* Hitchcock, the smallest species of the genus. The material was collected in Minnesota by Dr. Lyon. The gametophyte, sex-organs and embryo resemble those of *B. lunaria*.

Bierhorst's (1958) observations on the gametophytes of *Botrychium virginianum* and *B. dissectum* present data to disprove the two generalisations that the gametophytes of *Botrychium* are rare and difficult to find and that there is no variation among the gametophytes of a given species. He made six collections of gametophytes of *Botrychium virginianum* in several localities in Ontario, Minnesota, Ohio and Virginia. From a study of the apical meristem the hypothesis of a rotating apical cell position is presented. The antheridial ridge is interpreted as a series of determinate, upright branches which may be separate or fused.

From the above account it is clear that all the previous work on *Botrychium* has been done on North American material where it is easily accessible.

In Asia, particularly in India, though *Botrychium* has been reported as available in several places by Beddome (1873) the author's experience has been different.

According to Nishida (1956) the discovery of the gametophytes of *Botrychium virginianum* var. *lanuginosum* by Rao (1939) has been for a long time the only record for Asia. He gave an account of the gametophyte of *B. virginianum* and its endogenous fungus collected at two localities in Japan for the first time. Nozu (1954) gave a brief account of the gametophyte and sporophyte of *B. japonicum* Urd. He designated that part of the stele where strands run close together as 'phyllomophore' and doubted Lyon's view of the presence of suspensor in *B. obliquum*. 
In 1937 the author collected a large number of young plants of *Botrychiurn* some still being attached to the gametophytes. These plants were growing on a moss-covered humus soil by the side of a perennial stream at Kodaikanal, South India. The ground was sloping towards the stream and was protected above from the sun by the arching branches of trees. Young plants were detected first by their characteristic cotyledons or the greenish yellow first leaves projecting out of the humus soil. When young plants were gently pulled out from the soil they came out with the tuberous gametophytes still attached (Text-Figs. 1–8). An intensive search was made on the spot for young gametophytes with success. More than a hundred gametophytes of all ages were collected (Text-Figs. 9–24). A preliminary study of these has been reported in 1939. Further collections were made on subsequent occasions in different localities along the same stream and elsewhere in that area. Great difficulty was experienced in getting the young sporophytes out of the humus soil which required careful observation under a binocular microscope in the field. The small size, colour and resemblance of the gametophytes to the eggs of small worms added to the difficulty in detecting them.

**THE GAMETOPIIYTE**

A very young gametophyte is generally a flat dorsiventral body. It is about 1 mm. long and is rare to secure a gametophyte of this stage in the field. Sex-organs are not found at this stage. It has a broad basal and somewhat narrow apical end. The apical portion is made up of clear meristematic cells while the basal end consists of cells with endophytic fungus. Brown unicellular rhizoids are found all over the body. This flat body of the gametophyte by the growth of the meristematic cells loses its flat nature soon and becomes a symbiotic, tuberous, irregular or pear-shaped body densely covered with dark brown rhizoids. From the apical region lobes are produced which in some cases project out of the rhizoidal covering. Adult prothalli grow about 6 to 10 cm. deep in the soil, hence the spores must have been washed down with the percolating rain-water and settled at different depths. Sex-organs are produced on the apical regions and on the lobes formed by it (Text-Figs. 27, 28; Plate III, Fig. 57; Plate VI, Figs. 68 and 69). Antheridia are produced first and hence they are carried forward or upward by these lobes. The younger antheridia are at the base and older ones at the top. After some time the formation of the antheridia appears to cease and archegonia develop from the same meristematic base, consequently one generally finds mature antheridia and developing archegonia on the same lobe. When young antheridia are found on a lobe archegonia are not generally present; on the

* Since confirmed as *B. lanuginosum.*
other hand, empty antheridia and older stages of archegonia are commonly seen on the same prothallus (Text-Fig. 27). Hence it is very difficult to get all stages of sex-organs in the same gametophyte. Further according to Bower (1926) the above form and the relative position of antheridia and archegonia are best suited biologically in exposing an upward face to the rain soaking into the soil and thus helping the transfer of the sperms from the higher level to the archegonia below.

The regions, the fungal and non-fungal, can clearly be distinguished in a median longitudinal section of the gametophyte. In the non-fungal apical region the meristematic cells are situated and the sex-organs are produced. The basal region is infected with an endophytic fungus (Text-Figs. 27, 31 and Plate III, Fig. 57). The outer cells are free from the fungus.
TEXT-FIGS. 9-24
The fungus is found in the form of clumps in some cells of the gametophyte. The hyphae can be seen clearly entering the tissue through the rhizoids.

Some gametophytes develop small globular bodies with slender attachment. They look like lobes or branches of the main body and are easily detached. Their body is made up of parenchymatous cells filled with reserve material. Their function is under investigation.

**Development of the Sex-Organs**

*Antheridium.*—The antheridium arises from a cell of the meristematic region. The antheridium mother cell can easily be made out from its neighbours by its conspicuous nucleus and dense protoplasm. By a periclinal division this cell divides into an outer and an inner cell. The outer or the primary cover cell divides again periclinaly resulting in two cells which by further anticlinal divisions give rise to a number of cells constituting the two-layered wall of the antheridium (Text-Figs. 33-39). The inner cell by repeated anticlinal and periclinal divisions ultimately gives rise to a large number of spermatocytes or spermatid mother cells. At the region of the opening of the antheridium one of the cells of the inner layer forms the opercular cell which initiates the dehiscence of the antheridium and then disintegrates. Antheridia are completely embedded in the gametophytic tissue (Plate IV, Figs. 58-61).

A study of the antheridium containing fully developed sperms and also the ripe sperms just emerging from the antheridium clearly shows that the major portion of the body of the sperm is occupied by the nucleus of the sperm mother cell. The sperm has a head and a band-like tapering anterior end bearing a number of cilia. It is coiled into one and a half or two turns. The free swimming sperm in stained preparations shows a relatively elongated nucleus which does not reach the anterior end. It is pointed bluntly at the posterior end.

During the metamorphosis of the sperm mother cell into a sperm, the sperm mother cell loses its angular shape (Text-Figs. 40-44). It becomes rounded and the cytoplasm of the cell also seems to contract. In a mature sperm mother cell the cytoplasm is found only in the region more or less within the coils of the sperm. The blepharoplast which makes its appearance earlier appears at one stage like a thick curved line situated at one side of the sperm mother cell. The blepharoplast later elongates and becomes attached to the spiralising nucleus at one end. From its position we can infer that the blepharoplast or "Border Brim" gives rise to the numerous cilia. The sperm output is very large.
TEXT-FIGS. 25-32
Archegonium.—The archegonium is embedded in the tissue of the gametophyte with only the tip of the neck projecting. The development of the archegonium is of the fern type with slight variations. A single superficial cell of the prothallus forms the archegonial initial (Text-Figs. 45–52). The archegonial initial divides periclinally giving rise to a bigger inner cell and a smaller cover cell. The cover cell by an anticlinal division produces two cells which by further divisions form the neck of the archegonium. The venter is massive. The neck is broad, and is made up of four to six tiers of four cells each. The inner cell divides periclinally giving rise to the central cell and the primary neck canal cell. The primary neck canal cell moves into the narrow neck canal, while the central cell remains in the venter region. The primary neck canal nucleus divides into two nuclei which move up in the neck canal with no wall formation between them. The central cell divides to form a ventral canal cell and the egg. The ventral canal cell will generally be at the entrance to the neck canal and soon disintegrates along with the neck canal cells. According to Campbell (1911) the ventral canal cell is very inconspicuous and often impossible to detect. Jeffrey (1898) gives a figure with a very evident ventral canal cell the nucleus of which is much smaller than that of the egg or the neck canal cell. Campbell (1911) also found what seemed to be a ventral canal cell in the archegonium shortly before it opened but this was not absolutely certain. Bruchmann (1906) was also unable to find a ventral canal cell in B. lunaria which closely resembles that of B. virginianum nor did he see the division of the nucleus of the neck canal cell. The ventral canal cell and the egg could be seen very clearly with the curved partition wall between them in Plate V, Fig. 64 A–B while the two neck canal nuclei can be seen in the neck higher up in Plate III, Fig. 64 B. Thus the presence of a ventral canal cell can be established clearly. The egg gradually becomes bigger and occupies practically the whole cavity of the spacious venter. The cover cells of the neck break down and the canal now communicates with the exterior though filled with a viscous fluid. The archegonium is ready to receive the sperm at this stage.

Fertilization.—Though the gametophyte is situated deep in the soil the opening of the antheridium and the transfer of the sperms to the archegonium are facilitated by the dense covering of the rhizoids which hold in their mesh enough water for the dehiscence of the antheridium as well as for the movement of sperms to the archegonium. The relative position of the sex-organs on the gametophyte is also favourable for the migration of the sperms. The sperms are attracted by the viscous fluid formed in the neck canal of the archegonium. After passing through the neck of the archegonium the sperm comes in contact with the egg which is very big with its conspicuous nucleus.
and rich protoplasm. The sperm enters the egg with its head first. The cilia are left behind and only the head containing the nucleus of the sperm enters the egg and fuses with the nucleus (Plate V, Figs. 62 and 63). The fertilised egg does not divide immediately but undergoes a period of rest. It is on account of this variation in time between fertilisation and first division of the zygote that we do not see embryos in the preparations containing ripe archegonia and even fertilised eggs. Embryos appear still at a later stage.

**Embryo.**—The first division of the zygote is transverse resulting in the formation of an epibasal and a hypobasal cell. The hypobasal cell divides vertically forming two cells which by another division give rise to four cells. The epibasal cell also divides to form cells, however the divisions are slow and do not follow the pattern of the hypobasal cell. Further there is no regularity in the divisions with the result a mass of cells is formed (Text-Figs. 26, 29 and Plate V, Fig. 65). The venter of the archegonium is finally ruptured and the embryonal cells come in direct contact with those of the gametophyte tissue. The growth of the embryo is very slow and in some species several years pass before the first leaf appears above the ground. Slow development appears to be characteristic through all the stages of the plant growth (Eames, 1936).
The first organ of the sporophyte to be differentiated is the root. A group of cells at one pole becomes prominent with conspicuous nuclei. The polarity can be noticed early as the embryo grows and elongates along the future root-leaf axis. One of the cells of the group becomes the apical cell of the root. The apical cell is of pyramidal shape with three cutting faces. It gives rise to a number of cells by repeated divisions and maintains its sub-terminal position by cutting off more cells along the three pyramidal surfaces and only a few along the curved outer surface (Plate VII, Fig. 71). The first root thus differentiated comes out of the gametophytic tissue and generally establishes itself in the soil. Meanwhile the other pole of the leaf-root axis, i.e., leaf pole, organises a leaf. This first leaf has an apical cell and due to its activity the leaf grows, elongates into a cylindrical structure and ultimately outgrows the gametophyte (Text-Figs. 53–56, and Plate VII, Figs. 72–74). The cylindrical leaf has a groove running on one side which becomes the future adaxial side. As the groove widens the cylindrical leaf also broadens out. The cells of the leaf are elongated and three zones are distinguished inside. The three regions are the peripheral, the middle and the central with the vascular trace (Plate VI, Figs. 66 and 67). This leaf appears to be non-functional. After some time the portion of the leaf that protrudes from the gametophyte dries up while the one which is enclosed by it remains robust, and healthy. An abscis layer develops at the junction of the two parts lead-
ing to the separation of the terminal end. This is the first leaf which ends its life as a scale-leaf.

There is a foot generally seen with the embryo and the young sporophyte embedded in the gametophytic tissue. The foot is derived from the remaining cells of the embryonal mass after the differentiation of the first root and the leaf has taken place (Text-Figs. 30, 31, 32; Plate VI, Figs. 68 and 69). It has to be stressed here that the root-leaf axis is not perfectly straight but slightly bent at the junction of leaf and root. This bend becomes sharp in some cases and can be noticed clearly. The foot formed by the division of the cells remains at a side of the axis and thus helps the root and the leaf to emerge from the gametophyte. The foot is purely an appendage of the embryo and it appears to lose its function as the developing sporophyte takes over the function of acquiring nutrition from the gametophyte. One noteworthy feature of those cells of the embryo and the young sporophyte which come in direct contact with the gametophytic cells is that they become glandular in appearance, i.e., cells become large with rich protoplasm, conspicuous nuclei and sometimes elongated like root-hairs. These cells seem to help in the digestion and absorption of nutrition from the gametophytic cells on which they are evidently parasitic (Plate VI, Figs. 66 and 67 at R). Sporophytes with two or even three leaves exhibit the above mode of nutrition or rather temporary parasitism.

The vascular elements appear both in the leaf and the root immediately after the apical cells begin their activities. They are found just behind the apical cells and their differentiation goes on along the centre of the root-leaf axis. They are uniseriate at the polar ends and biseriate in the middle of the young embryo. Their forerunner, i.e., the procambial cells joining the two poles can be noticed very clearly with partially differentiated vascular elements. The vascular trace of the young sporophyte is not straight in its course but forms a sharp bend at the junction of the root and the leaf. This has been foreshadowed by the course of the procambial elements (Text-Fig. 25). Root trace is diarch or monarch while that of the leaf is collateral. Lateral roots arise endogenously on the main roots occasionally.

At the time the first leaf shows signs of decay the second root takes its origin at or just below the junction of the first leaf and root. It is endogenous and an apical cell is initiated early which directs the further growth and elongation. The vascular trace which starts developing behind the apical cell continues to extend until it finally joins the vascular strand of the leaf-root axis at the bend mentioned above. All the roots that are organised and
developed remain functioning for a number of years (Plate VII, Figs. and 73-74).

Just above the origin of the second root the primordium of the second leaf develops and is ensheathed by the remnant base of the first leaf. As this second leaf grows and elongates a vascular trace is differentiated in the usual way which ultimately comes to be attached to the main vascular strand at the sharp bend. The second leaf also is scaly and temporary. Thus the main vascular strand appears to be composed of only the leaf and root traces joining at the bend and forming the "Dictyostele" of the mature sporophyte (Campbell, 1921 a).

The stem appears late in the ontogeny of the sporophyte. The stem primordium is initiated very near the second leaf primordium and is situated in a notch. An apical cell is organised which is terminal in position (Plate VII, Fig. 71). Further growth and elongation of the stem is very slow. Leaves are produced in regular order at the rate of one leaf per year. The third, fourth and in some cases even the fifth leaf do not come to the surface of the soil and hence remain scaly and non-functional. It is the sixth leaf that becomes functional as the photosynthetic organ with open dichotomous venation while the seventh or eighth leaf bears the sporangia and hence becomes a reproductive leaf. With the formation of every leaf whether it is scaly, functional or non-functional, reproductive or sterile, a root is invariably formed (Text-Figs. 1-8 and 20-24). A normal leaf functions only for a year though it takes about four to five years from its inception to unfolding, and it withers at the end leaving a scar on the short stock. Hence the stem proper of Botrychium is short and always remains so since the older posterior portions die from behind. The above observations on the leaf and root of B. lanuginosum are supported by Eames (1936), Smith (1938) and Campbell (1911) as applied to the species they have investigated.

**SUMMARY**

The life-history of Botrychium lanuginosum has been worked out for the first time in Asia. The work is mostly on the gametophyte, embryo and young sporophyte. Gametophytes were discovered for the first time in 1937 in India.

A very young gametophyte is a colourless dorsiventral body covered with white unicellular rhizoids, growing by an apical meristem.

The dorsiventral young gametophyte grows and becomes a tuberous body and assumes varying shapes with lobes and ridges. Its colour changes
from white to brown and develops a dense covering and dark brown unicellular rhizoids. It is subterranean, containing a symbiotic fungus.

Two regions are clearly demarcated as seen in the longitudinal section of a gametophyte—the upper meristematic zone bearing sex-organs and the lower fungal infected zone.

Sex-organs are produced on the mature gametophytes—antheridia first followed by archegonia. They are raised on ridges or lobes.

Antheridia are embedded in the gametophytic tissue with the opercular cell at the surface. A large number of sperm mother cells are ultimately formed. Each one of them is transformed into a sperm. During this process the blepharoplast plays an important role. Sperms are coiled, the tapering anterior ends bear a number of cilia.

Archegonia are of the fern type. They are embedded in the tissue, leaving only the tip of the neck. Development is of the filicineous type. The venter is massive with a broad slightly bent neck. Ventral canal cell is clearly seen. Neck canal nuclei have no wall between them.

During fertilisation, the head of the sperm comes in contact with the egg and fuses with it. The cilia are left behind. The oospore begins segmentation after a period of rest.

The division of the fertilised egg is horizontal to the long axis of the archegonium. The hypobasal cell by further orderly divisions gives rise to a large number of cells out of which the first root and the first leaf are organised. The epibasal cell divides to form a mass of cells which organises a foot.

Procambial strand appears early connecting the leaf-root poles of the embryo. Vascular trace replaces the procambial strand and runs as a continuous strand with a bend at the junction of the leaf and the root.

Subsequent roots and leaves are formed in a regular sequence and their vascular traces extend to meet at the bend the earlier traces to form the central strand, i.e., the mature dictyostele.

The stem primordium appears late in the organisation, its growth is slow and the stem proper remains short.

The sporophyte remains attached to the gametophyte for several years and appears to take nutrition from the gametophyte. To this end cells of the leaf and root that come in intimate contact with those of the gametophyte are suitably modified for the purpose,
ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Professor P. Maheshwari of Delhi University for very readily giving him facilities to take the photomicrographs that appear in this paper except Plate V, Fig. 64 A and B. He also wishes to express his thanks to his erstwhile colleague in the University of Mysore, Dr. K. M. Safeeulla, for his invaluable help in going through the manuscript and preparing the same for the press. His thanks are due to the Director, Royal Botanic Gardens, Kew, London, for kindly fixing the specific name of the Botrychium under investigation.

REFERENCES

Beddome, R. H. .. Ferns of Southern India, 1873, 22.
Bower, F. O. .. The Ferns (Filicales), 1926, 2, Cambridge.
Nozu, Y. .. "Gametophyte and young sporophyte of Botrychium japonicum,” Ibid., 1954, 4, 430–34.
EXPLANATION OF TEXT-FIGURES

N.B.—The magnification noted against each text-figure should be reduced to half.

Text-Figs. 1-8. Figs. 1-4. Young plants of *B. lanuginosum* still being attached to the gametophytes. Fig. 1. The leaf shows the distinct dichotomy. Fig. 2. The first functional leaf is three-lobed. Note the presence of the previous scaly leaf. Fig. 3. Same as above with three roots. Fig. 4. The leaf is deeply three-lobed. In addition to the four roots a number of special wart-like bodies are found attached at the base of the root stock. All Figs. × 3. Figs. 5-8. Somewhat older sporophytes. Fig. 5. The three-lobed leaf showing dichotomous venation, × 2. Fig. 6. The leaf is deeply lobed, × 2. Fig. 7. Still older plant having the functional leaf, × 1½. Fig. 8. The first reproductive leaf, bearing a poorly developed spike with few sporangia, × 1½.

Text-Figs. 9-24. Figs. 9-19. The various shapes which may be assumed by the gametophyte in its development. Figs. 10 and 11. The scar left by the first scaly leaf. Figs. 13 and 16. The fungal region of the gametophyte covered over by rhizoids. Figs. 12, 15 and 18. The globular bodies developing on the tuberous gametophytes with slender attachment. They are easily detached and scattered. Their function is under investigation. All Figs., × 8. Figs. 20-24. The young sporling at various stages of development. Fig. 20. The scar left by the first leaf or the cotyledon is found surrounding the base of the second leaf primordium. Fig. 21. Young sporophyte with five roots and perhaps with equal number of leaf scars surrounding the primordium of the current leaf. Fig. 22. First scaly leaf with the curved tip emerging from the gametophytic tissue. Fig. 23. First scaly leaf with the second leaf primordium at its base. Fig. 24. First scaly leaf and the second scaly leaf with the recurved tip. All Figs., × 8.

Text-Figs. 25-32. Fig. 25. Young sporophyte attached to the gametophyte G at the left. The initiation of the first root and the second leaf with the overarching first leaf are shown. The leaf-root axis along with procambial cells are seen. Fig. 26. Young embryo still within the gametophytic tissue. Apical cell of the first root is organised. Remnants of the archegonial neck are seen at the left. Fig. 27. Complete longitudinal section of the gametophyte showing the two regions. The upper non-fungal region bears a number of sex-organs. Rhizoids are borne all over the surface. Fig. 28. Transverse section of the non-fungal region of a gametophyte showing the distribution of the sex-organs. Fig. 29. Young embryo within the gametophyte. Cotyledon at C and below it the apical cell of the second leaf are shown along with the remnants of the archegonial neck cells at the arrow. Fig. 30. Longitudinal section of the gametophyte at the left with the young sporophyte in which the apical cells of the first root are organised. The sporophyte also shows the thick-walled outer cells and the elongated glandular cells at the junction of the gametophytic cells. Fig. 31. Longitudinal section of a gametophyte showing the line of demarcation between the fungal and the non-fungal regions. A few big cells of the fungal region with the endophytic fungus are shown. Upper region is composed of small-sized cells bearing the sex-organs. Rhizoids are borne all over the surface. Fig. 32. Longitudinal section of a gametophyte bearing a developing sporophyte and a number of mature sex-organs. The sporophyte has already organised an apical cell of the root and leaf, the root-leaf axis with the vascular elements and the haustorial layer of cells. The gametophyte bears antheridia above and archegonia below the lobe, while the young sporophyte is to a side of the lobe. All Figs., × 80.

Text-Figs. 33-52. Figs. 33-36. Stages in the development of an antheridium from a single cell, × 400. Fig. 37. Antheridium showing the two-layered wall and the spermatogenous tissue, × 400. Fig. 38. Antheridium showing the sperm mother cells. Note the opercular cell × 400. Fig. 39. Ripe antheridium with sperms. Opercular cell has disintegrated. The sperms are free to move out, × 400. Figs. 40-44. Stages in the metamorphosis of sperm mother cell.
Life-History of Botrychium lanuginosum Wall. ex Hook. et Grev.

into a sperm, × 1,200. Fig. 40. Spermatogenous cell. Fig. 41. Sperm mother cell, Fig. 42. Note the curved band at the right blepharoplast. Fig. 43. Sperm with the cytoplasm in the curve. Fig. 44. Ripe sperm. Figs. 45-47. Stages in the development of the archegonium. Fig. 47. Fully developed archegonium with an egg, a ventral canal cell and two neck canal nuclei forming the axial row. Figs. 48-49. Stages in the fertilization of the egg. Fig. 48. The head of the sperm is just entering the egg cytoplasm. Fig. 49. The sperm has entered the egg, its tail being outside the egg nucleus. Fig. 50. Archegonia with egg ready for fertilization. Fig. 51. Fertilized egg or oospore. Fig. 52. The oospore has divided into epibasal and hypobasal cells and the latter has again divided to form two cells. Three-celled embryo, All Figs., × 400.

TEXT-FIGS. 53-56. Longitudinal section of the young sporophytes reconstructed out of a series of micro-sections to show relative positions of parts. R₁ = first root; L₁ = first leaf; L₁-R₁ forms leaf-root axis with the bend. R₂ = second root. R₃ = third root. L₄ = second leaf, L₅ = third leaf. Dotted portions = gametophyte. Clear portions = Sporophyte. The gametophyte is split by the growing sporophyte. Fig. 53. The first and second leaves have not emerged out of the gametophyte, × 31. Fig. 54. The first leaf has come out of the gametophyte with bent tip, × 22. Fig. 55. Same as Fig. 54, × 24. Fig. 56. Formation of three leaves and two roots seen in a portion of the sporophyte still attached to the gametophyte, × 29.

EXPLANATION OF PLATES

PLATE III

Fig. 57. Longitudinal section of a gametophyte showing the fungal region A; the reproductive region B; meristematic region C; archegonia D; antheridia with sperms E. Note the rhizoids all over the surface, × 75.

PLATE IV

Fig. 58. Developmental stages of the antheridium from spermatogenous cells to sperms. Note the meristematic tissue in the notch above (right-hand upper corner), × 160

Fig. 59. Two antheridia enlarged to show the spermatogenous cell in one and sperms in the other, × 340.

Fig. 60. Portion of an antheridium to show the ripe sperms, × 700.

Fig. 61. Transverse section of a lobe of the gametophyte with reproductive organs. A full developed archegonium at A and an antheridium with sperm at B can be seen, × 130.

PLATE V

Fig. 62. The venter of an archegonium showing the egg with its large nucleus and the head of the sperm lying just above it, its tail perhaps still in the ventral canal region, × 490

Fig. 63. Archegonia with egg in the venter with which a sperm has fused. The tail end of the sperm is visible, × 490.

Fig. 64A. In the archegonium on the left, the partition wall between the egg cell and the ventral canal cell can be seen clearly. This partition wall is slightly curved. Egg nucleus also is evident. In the right side archegonium the egg and the V.C. cell cytoplasm are separate though the partition wall is seen. By the side of this archegonium the initial of another archegonium can be seen, × 200.
Fig. 64 B. Enlarged view of another archegonium showing the two neck canal nuclei close together at a, the ventral canal cell with its nucleus at b and the egg cell at c, × 350.

Fig. 65. Young embryo consisting of mass of cells without any differentiation, × 300.

PLATE VI

Figs. 66 and 67. Transverse section at different levels of the gametophytes to show relative positions of the emerging root leaf, etc. G = gametophyte tissue, R = first root, L₁ = first leaf, L₂ = second leaf, L₃ = third leaf. Note the epidermal cells of the root enlarging and acting as absorbing organ at R₁, × 53.

Figs. 68 and 69. Two gametophytes bearing young sporophytes. Old reproductive organs are also seen. Note the absorbing cells at A in Fig. 69 at the junction of the tissues of gametophyte and sporophyte. Root at R and cotyledon at C, × 38.

PLATE VII

Fig. 70. Apical cell of the stem, arched over by the tissue of the second leaf. Note its terminal position, × 290.

Fig. 71. Apical cell of the root. Note its sub-terminal position and pyramidal shape, × 290.

Figs. 72–74. Longitudinal section of young seedlings to show the relative position of the different parts. G = gametophyte, L₁ = first leaf, R₁ = first root, B = the bend.

Fig. 72. The first leaf runs up from the bend to the tip of the section while the first root runs down to the end. The second leaf has taken its origin on the right side of the bend. The leaf is ensheathed by the gametophytic tissue, × 12.

Fig. 73. Seedling younger than the previous one. The first leaf is ensheathed by the gametophytic tissue, × 15.

Fig. 74. Seedling still attached to the gametophyte shows first root, second root, second leaf and first leaf with the bend. First leaf is withering away beyond the gametophytic tissue where an abscis layer is formed, × 20.
FIG. 57
Figs. 59–61