MEMOIRS
OF THE
TORREY BOTANICAL CLUB.

VOL. II. No. 3.

CONTRIBUTIONS TO THE KNOWLEDGE OF THE GERMINATION OF SOME NORTH AMERICAN PLANTS.

BY THEODOR HOLM.

(Plates V.–XIX.)

The present paper deals with the description of the germination and early stage of the growth and development of the rhizomes of some plants, mostly from North America. The greater part of the material upon which it is based was collected in the immediate vicinity of Washington. The foreign materials, as well as some of the rarer North American species, were obtained from the U. S. Botanical Garden, where they had been cultivated by Mr. G. W. Oliver, to whom the author is under especial obligations. The author is also greatly indebted to Prof. F. H. Knowlton, who has kindly looked over the manuscript and suggested several alterations in regard to the language, and recommended the use of some botanical terms.

RANUNCULACEÆ.

Anemone thalictroides.

This plant was first described by Linné, and referred to the genus *Anemone*, and later has been transferred from one genus to another by various authors. Michaux placed it under *Thalictrum*, and Asa Gray, accepting the suggestion of Michaux in regard to its systematic position, called it *Thalictrum anemonoides*, although with the additional subgeneric name of *Syndesmon* of Hoffmansegg.

The plant was then again placed under *Anemone* by Bentham and Hooker as representing the subgenus "*Syndesmon*," considered as identical with *Anemonella* of Spach. In the 6th edition of Gray's Manual, revised by Watson and

Coulter, we find it as a true genus *Anemonella*, separate from *Anemone* and *Thalictrum*.

The plant seems to show characters intermediate between those of *Anemone* and *Thalictrum*, having the flower and involucre of an *Anemone* and the foliage of a *Thalictrum*. It has umbellate peduncles like those of *Anemone narcissiflora* and others, while the ribbed achenia ally it to *Thalictrum;* but it does not seem, however, as though this divergence of characters were sufficient to entitle it to rank as a separate genus.

And when the genus *Anemonella*, in the synopsis of the genera in the revised edition of Gray's Manual, is characterized as having a larger number of achenia than *Thalictrum*, that is, "four to fifteen in *Anemonella*," and few in *Thalictrum*, it does not correspond to what is said in the generic diagnosis of *Thalictrum*, which is also described as having "four to fifteen achenes."

In regard to the structure of the roots our plant shows a certain peculiarity, which removes it at once from *Anemone* and *Thalictrum*. The roots are fusiform and tuberous, corresponding to the same kind of nutritive roots so well known in *Dahlia*, *Ficaria*, etc. The plant is perennial and the germination shows a few points of interest. A germinating plantlet has been figured on Plate V, Fig. 1, where we see the two long-petioled cotyledons, the blades of which are ovate and almost obtuse (Fig. 2). There is no distinct hypocotyl,* but the primary root, which seems to commence immediately under the cotyledons, is strongly developed and shows a certain ability of growth in thickness in this very early state. The end of the root is sometimes bifurcated and terminates suddenly in thin branches. The first leaf shows the general features of the final ones, but has merely a smaller number of divisions. A somewhat older state is shown in Fig. 3, where the primary root shows the characteristic tuberous form, while no secondary roots are yet developed. One of these is,

---

* "Hypocotyl" has been used instead of the older term "caulicle," in accordance with Darwin's usage (The Power of Movement in Plants, 1881, p. 5), signifying the hypocotyledonous portion of the stem.

however, to be seen in Fig. 4, and shows the bifurcation mentioned above. There is to be observed a difference in regard to the roots and the foliage, if we consider the older, full-grown and flowering specimen, the rhizome and roots of which are shown in Fig. 5. The primary root is either no longer present or is not to be distinguished from the equally developed secondary roots. It is most probable that it has disappeared during the gradual growth of the plant. Another thing is the presence of a slender, thin, not at all tuberous root (r*), which proceeds from the rhizome at the very base of the stem. This part is covered with several (usually six) scale-like leaves, so that our plant has two different kinds of roots as well as of leaves. The roots are tuberous or slender and the leaves underground and scale-like or above ground and ternately compound.

Thalictrum dioicum.

Two germinating plantlets have been figured in Plate V, Figs. 6 and 7, and show the presence of a distinct primary root (R), which already forms several lateral branches in this very early stage. The hypocotyl is frequently very short, and there is a wreath of rather long root-hairs at the base, where it passes into the root. The cotyledons, which are above ground, are long-petioled, with the blade varying from ovate and acute to broadly ovate and obtuse. The first leaf after the cotyledons has mostly the same form as the leaves that develop later. It is decompound, with the divisions cordate, obcordate or roundish. The primary root is not of long persistence, and is replaced by several secondary ones, developed from the base of the stem, which can be seen on an older plant (Fig. 8).

We have there a vertical stem, bearing several leaves, of which the lowest are from the previous year and faded. The internodes are very distinct, and at the two earliest, buds have developed, so that the complete rhizome is indicated as being vertical with ascending shoots. We see this final form of the rhizome in Fig. 9, drawn from a flowering specimen, which shows the relatively short under-

ground axis, upon which a large bud has been developed at the side of the base of the stem. This bud, so much larger than the other ones, of which four are visible in the figure, situated a little higher up on the stem, alternating like the leaves, in the axils of which they have been developed—this bud will produce in the following year a series of leaves and a flowering stem. The smaller buds will merely produce leafy shoots, of which one has been shown in the same figure, but it is to be supposed that they might be of a certain importance to the plant, if, for instance, the large bud should be injured, they might then replace it and get a further development, producing not only leaves but also flowering stems. The first leaves which are now developed upon these short, lateral shoots are merely scale-like.

Ranunculus abortivus.

Germinating plantlets of this species were exceedingly common during the month of April in shaded places in the woods, along the shore of the Potomac, in the vicinity of Washington. They occurred abundantly, together with older plants, and were easily distinguished from other species by the characteristic shape of their leaves. Fig. 10 in Plate V shows a germinating plantlet, in which the cotyledons are elliptical, obtuse, shortly petioled and united at their bases, forming a sheath around the plumule. There is a distinct, straight hypocotyl (C), and the primary root (R) is long, but rather thin and not branched. The same is observed in regard to the secondary roots, which seem to have been developed contemporarily, one at each side of the primary root. Only one leaf is developed at this stage, and its form accords entirely with that of the later ones, being reniform or sometimes almost cordate.

Another germinating plantlet, a little older, has been figured in Plate V, Fig. 11, merely differing from the last-mentioned in having an additional secondary root (r^2), which has come out behind the primary one. Otherwise there is no difference, but as soon as the second leaf appears a great change will be observed in regard to the growth of this very

young plant. The hypocotyl now begins to be bent towards the ground, and another root-system will be developed. We see then in Fig. 12 that the hypocotyl is no longer straight, and that it shows the beginning of a young root (r^3) at the base of the cotyledons, while the other roots still persist and even increase slightly in length. The first leaf has assumed its final shape and size, and another one (L^2) has commenced to unfold. If we follow the further development of the seedling we shall see, in Fig. 13, that there are now two distinct and different systems of roots, the first consisting of the primary and earliest developed secondary roots (r^1–r^2), the second consisting of two roots (r^3–r^4), the situation of which is below the cotyledons, or rather at the apex of the hypocotyl. The cotyledons are still green and attached to the stem, and four leaves have been developed. The primary root-system is now beginning to fade away, and is replaced by the second one, as may be observed in Fig. 14. Here the primary root has begun to die, the second ones next in the course of development have already faded, while the new set of roots is in rapid growth from the base of the young plant (r^1–r^5), being more or less thick, and some of them having several lateral branches. Three leaves (L^1–L^3) have finished their growth and a fourth one (L^4) has appeared. As soon as the plant has dropped the hypocotyl with the first system of roots it shows its final manner of growth, *i. e.*, several leaves crowded at the base of the flowering stem, and the roots fibrous.

This species should, according to A. Gray,* be biennial, but it is certainly perennial. For, if we consider the Fig. 15 on Plate VI, we shall see the rhizome and the base of an older plant, which is at least three years old. The plant does not flower during the first year, but forms only a number of leaves, while the following year the inflorescence appears. We see in Fig. 15 the persisting bases of the inflorescence (F^1) of a previous year (1889) and of some faded leaves, the plant then having attained an age of at least two years ; be-

* Asa Gray : Manual of Botany of the Northern United States, 6th Edition, revised by Watson and Coulter, 1890.

sides this we see the base of another flowering stem (F), which has been developed this year (1890), and finally a young shoot (S), which undoubtedly will produce a third inflorescence next year. This young shoot (S in the Fig.) corresponds to the young plant (Fig. 14), which is preparing to flower the following year, but with the difference that the last one (Fig. 14) contains the whole main axis, while the other one (S in Fig. 15) has been formed from a bud in the axil of one of the basal leaves of the older plant, and is then merely a lateral shoot on the main axis, now only represented by the very short rhizome.

Ranunculus recurvatus.

It was to be supposed that the germination of this species would be the same as described for the preceding one, *R. abortivus*, and it proves to be the case. There are, however, a few characters in which they differ, and these are easily discovered if we compare the drawing of *R. recurvatus* (Plate VI, Fig. 16) with that of *R. abortivus* (Fig. 12). The number of secondary roots from the base of the hypocotyl is larger in *R. abortivus* than in *R. recurvatus*, the cotyledons have rather longer petioles in *R. recurvatus*, and finally the young leaves are hirsute in *R. recurvatus*, whereas they are almost glabrous, or at least the blade is so, in *R. abortivus*. The margin of the leaves when young is crenate in *R. abortivus*, but in the other species it is serrate or sometimes even three to five-lobed. The full-grown plant of *R. recurvatus* shows, however, the same structure as do those of *R. abortivus* in regard to the short rhizome and the profuse development of fibrous secondary roots, while the primary root fades early, as does the hypocotyl.

Delphinium nudicaule.

The very peculiar germination of this plant has already been mentioned by several authors, and Bernhardi* has figured a similar case from a specimen of *D. fissum* W. K.

---

*Bernhardi: Ueber die merkwürdigsten Verschiedenheiten des entwick. Pflanzen-embryo. Linnaea, Vol. 7, 1832.

The principal difference from the usual manner of germinating consists in the presence of a cotyledonar sheath, formed by the petioles of the cotyledons, which are connate, forming a long tube, at the base of which is a small slit for the penetration of the plumule (Plate VI, Fig. 18 Sl). The cotyledons are long-petioled, with the blade ovate, slightly acute at the apex, and the two blades show also a tendency to grow together at their very base, leaving only a minute opening in the middle, representing the superior end of the tube. In one case (Fig. 17) there were developed three cotyledons, of which the blades were all equal in size and each of which showed the same nervation, so that it was certain that no division had taken place.

As to the primary root, this is relatively very large in the youngest state of the plant and shows early several lateral branches, which are densely covered with long root-hairs. Fig. 17 shows the first leaf coming out through the slit at the base of the tube. The cotyledons are persistent for a long time and do not fade away until four or even five leaves have been developed. The primary root is persistent as long as the plant lives, and increases gradually in thickness and ramification.

SARRACENIACEÆ.

Sarracenia purpurea.

Two germinating plantlets of this species were figured many years ago by Schnizlein,* and the figures show very exactly the part above ground: that is, the hypocotyl, the cotyledons and the first leaves. Further, in regard to the germination, Gray has described the cotyledons as being "short," which is, however, not correct according to the following observations, which have been made on numerous seedlings cultivated in the U. S. Botanical Garden.

A very early stage of the germination has been figured on Plate VII, Fig. 23, where we see the rather long, linear cotyledons, carrying the testa of the seed at their summit, the

---

* A. Schnizlein: Iconographia fam. nat. regni veget. 1843–46, Plate 185, Figs. 19 and 20. Asa Gray: Genera Flor. Boreali—Orientalis illustrata, vol. I, 1848, p. 108.

plumule, showing the first leaf (L^1), coming out at the very base of the cotyledons, and borne on a distinct, straight hypocotyl (C), at the base of which is a wreath of long root-hairs; we see further the primary root, which is relatively short and unbranched. The whole germinating plantlet, except the root and the lowest part of the hypocotyl with the wreath of root-hairs, is now above ground, the testa of the seed is soon dropped and the cotyledons now spread out, being perfectly flat, green and entirely different from the later, the pitcher-shaped leaves. Fig. 25 shows a somewhat later state, where the first leaf has attained its full size and final shape, not differing essentially from the typical leaf of this species. It is an interesting fact that there are no transition-forms between this, the first leaf (Fig. 27), and the later ones. The hypocotyl is straight for some time, and the primary root grows slowly in length and does not show any ramification until later. The leaves now begin to develop, forming a dense rosette near the surface of the ground; the cotyledons fade away, and, while the primary root has attained its final length, the secondary roots begin to grow at the upper part of the hypocotyl, just below the cotyledons. But before this stage, figured in Fig. 26, the plant has undergone some changes: the plumule, hitherto kept a little above the surface of the ground, has now gradually been moved downwards by the bending of the hypocotyl, a consequence of the zigzag direction of the primary root, which very soon disappears. By this mechanical movement the whole plant attains its final position in the soft mass of Sphagnum and is able to continue its growth and produce leaves and flowers.

PAPAVERACEÆ.

Sanguinaria Canadensis.

Germinating plantlets of this species were collected at the end of April in shaded places in the woods on the shore of the Potomac, where the plant occurs in great abundance. The seed germinates deep under ground, and the cotyledons never appear above the soil. They (Plate VII, Fig. 29) are oblong, obtuse, red and fleshy, and contain deep red juice like the

whole plant. The hypocotyl is relatively strongly developed, swells very soon after the appearance of the first leaf, and represents the first stage of the rhizome that is developed later. The primary root is slender, rather long, and shows several ramifications. It is the only root during the first stage of the germination, but very often after the appearance of the first leaf one or two secondary roots break out from the base of the hypocotyl. Figs. 28 and 30 show two germinating plantlets, and we see in these the somewhat swollen hypocotyl (C), the short-petioled, slightly curved cotyledons (Cot.), the slender primary root (R), and the development of one or even two secondary roots (r^1 and r^2). The first normal leaf is long-petioled, like those of the full-grown plant, but the blade is entire, not palmately lobed, as is the case in the later ones. The form of the young leaves is nearly kidney-shaped, the margin more or less crenate and the nervation palmate; they may, however, also show an almost heart-shaped form, but they are always palmately nerved. The first leaf next the cotyledons shows the principal character of the final leaf, and (as appears in Fig. 30) the next one shows the same. One or two leaves are then developed in the first year, and during the following winter the hypocotyl increases in thickness and forms a roundish tuber. It is interesting to follow the further development of the young plant, and we see early the next spring that a series of scale-like leaves precede the normal ones. Fig. 34 shows such a young plant, one year old, where l^1–l^4 indicate four scale-like leaves, which are alternately biseriate. They are very thin, almost membranaceous, carinate and uncolored. The fifth leaf, L^2, is broadly heart-shaped, with the margin crenate. In regard to the hypocotyl, this has, as mentioned above, become still more swollen than in the first year, and, while the primary root still persists, some secondary roots have developed, of which r^1 and r^2 surpass it in length and thickness. These secondary roots are developed at different heights from the hypocotyl, above each other, and it was observed that they mostly break out on the same side, in which manner the hitherto vertical young rhizome is gradually forced into a horizontal direc-

tion, as in the mature plant. It is, however, to be observed that the number of scale-like leaves is far from constant; there may be developed merely two or three, as shown in Fig. 33. The same course in regard to the development of scale-like leaves succeeded by normal ones is to be noted in the full-grown plant, as shown in Fig. 35, where six scale-like leaves precede the two normal ones and the flower. The shape of the full-grown leaf is palmately lobed, but it shows a great variation in regard to the number of lobes (three or nine) and also in regard to the depth of the sinuses. But it is a constant character, that, not only the normal leaves of the young specimens, but also the first or second ones, belonging to the lateral branches of the main subterranean stem, the large rhizome, are similar in shape, always heart or kidney-shaped, without lobation. I did not observe in any case that the normal leaves on the lateral branches were not preceded by scale-like ones, and Fig. 36, which represents a lateral shoot, shows the presence of seven scale-like leaves, after which come two normal ones, L^1 and L^2. The full-grown rhizome (Fig. 35) is rather long, cylindrical, and dies off gradually at its posterior end. Most of the roots are strong, sparingly branched above, and very long, especially those proceeding from the inferior part of the rhizome. In regard to the whole growth of the rhizome, this has been shown to be sympodial by Mr. Foerste in his interesting paper, "Notes on *Sanguinaria Canadensis*,"* where he has also mentioned the singular case of the occurrence of a two-flowered scape.

VIOLACEÆ.

Viola palmata, var. *cucullata*.

The germinating plantlet of this species (Plate VIII, Fig. 37) shows the long-petioled, ovate cotyledons, the distinct hypocotyl (C), the unbranched primary root (R) and the two secondary ones (r^1), which have been developed at the same time. There is a great difference between this early state and

* Bulletin of the Torrey Bot. Club, Vol. XIV, No. 4, 1887.

the final development of the plant, even if it is quite easy to trace the later transformations of some of the organs.

A few weeks after this first state, and while the cotyledons still persist, the hypocotyl commences to increase in thickness, as shown in Fig. 41, and the roots to form branches; the first leaf (L^1) has come out, is cordate and crenate, which is characteristic of this variety. By continuation of growth the hypocotyl has now been transformed to an obconical body (C in Fig. 40), which is crowned by the swollen bases of the two leaves (L^1 and L^2), while the root-system has undergone no change in regard to the further development of secondary roots. The cotyledons have dropped, leaving a semi-lunate scar at the upper part of the hypocotyl, which is shown in Fig. 38. Plate VIII.

The structure of the rhizome is now indicated, being fleshy and almost toothed, the teeth representing the swollen base of the successively dropping leaves. This may be seen in Fig. 39, which shows the rhizome of a plant one year old, where the primary root still persists, although it has partly faded. The secondary roots (r^1) are unchanged, and we see another pair of roots developing a little above them, between the scars of the cotyledons, and alternating with the older pair (r^1). Five teeth are visible in this figure and show their origin very distinctly, the base of the petiole. The rhizome of this specimen was vertical, but it gradually becomes almost horizontal, creeping under the surface of the ground. We have then a strongly developed rhizome before us, of which the leaves are not scale-like, but perfectly normal and densely covering the rhizome. The persistent bases of the petioles and stipules contain a large quantity of starch.

LEGUMINOSÆ.

Lespedeza violacea.

Fig. 43 on Plate IX shows a germinating plantlet of this species, where we see a long primary root, carrying a few tubercles, especially upon the lateral branches. The cotyledons are short-petioled, obovate and obtuse, and the hypocotyl is straight and very distinct. The first leaf is unifoliolate,

while the later developed ones are trifoliolate, but with the leaflets of the same shape as the first one. That the primary root is long persistent is to be seen in Fig. 44, which represents the rhizome of a flowering plant. The tubercles are also especially to be observed here on the lateral branches of the root, and we see further the short, ascending rhizome, merely consisting of the lowest part of the stem, from the base of which buds are developed, forming the prostrate, decumbent branches.

Lespedeza procumbens.

In regard to germination this species differs a little from the above-mentioned one in having the first leaves, next the cotyledons, opposite. They are unifoliolate, with the leaflets broadly cordate and pointed, while these in the final leaves are obcordate, with the apex retuse (Plate IX, Figs. 45, 46). The first two or three leaves next to these show the same shape, but are alternate. The whole germinating plantlet otherwise much resembles that of *L. violacea*, as regards the shape of the cotyledons, the development of the hypocotyl and the primary root. The rhizome of the full-grown plant (Fig. 46) agrees entirely with that of *L. violacea.*

Clitoria Mariana.

There are a few points of interest which may be mentioned in the germination of this plant. The hypocotyl is rather long, straight and pubescent, while the cotyledons, which are sessile, ovate and obtuse, are perfectly smooth. The first two leaves, next above the cotyledons, are opposite, ovate and acuminate, and the primary root is slender, with several thin branches, but destitute of any tubercles. There is quite a considerable difference between a germinating plantlet of this species (Plate IX, Fig. 47) and of that of *C. ternatea*, which has been figured by Lubbock.* In this species, the cotyledons are more obtuse, and the first leaf after them is already trifoliolate.

As to the full-grown plant of *C. Mariana*, the leaves are

---

* Sir John Lubbock: Phytobiological Observations, Journal of Linn. Society, Vol. XXII, 1887, p. 355.

trifoliolate, with the leaflets ovate and obtuse. There is a rather short rhizome (Plate X, Fig. 49) with a strongly developed and persistent primary root (R) upon which no tubercles were observed.

Cassia Chamaecrista

and *C. nictitans* L. show the same manner of germinating as represented on Plate X, Fig. 50, where a seedling of *C. Chamaecrista* has been figured. The only difference between these species during the germination period is that *C. Chamaecrista* is larger in all details. The cotyledons are above ground, sessile and roundish, borne on a hypocotyl which is not very long. The primary root is long and slender, and shows at this very early stage the small tubercles, which are so characteristic of most of the Leguminosæ. Lateral roots have been formed, but these are as yet rather short. The plumule has developed an erect stem, of which all the leaves, even the first one, show the same shape as the later ones, being pari-pinnate and minutely hairy along the margin of the leaflets.

ROSACEÆ.

Rubus hispidus.

Fig. 51 on Plate X shows a germinating plantlet of this species, and we see there the two short-petioled, ovate and obtuse cotyledons, borne on a distinct hypocotyl. The primary root (R) is slender and shows several lateral branches, while no secondary roots are as yet to be observed. The plumule has developed a glandular-hairy stem and carries a few nearly reniform leaves, which show the same glandular hairiness as does the stem. The leaves are serrate in this very early state, and no other form of leaf will develop even in the next year. Fig. 52 represents a plant two years old, and shows approximately the same shape of the leaves, with the exception that the blade is proportionally narrower and acuminate, a form which is very different from that of the leaflets of the final leaves. We further see in this figure the persistence of the primary root, and a very short rhizome, from which three secondary roots have been developed. St.[1] is the main stem, which is much longer than the second-

ary one, St.^{2}, which has been developed from the axil of the first leaf. The whole plant was glandular-hairy, like the germinating plantlet.

Potentilla Canadensis.

The cotyledons of this species are entirely under ground, short-petioled, with the blade ovate and rather fleshy. The hypocotyl is short and covered with minute glandular hairs, as are also the cotyledons, and the primary root is strongly developed, long, and branched at an early stage. This is to be seen in Plate X, Fig. 53, where we also see the rapid development of the plumule into an axis, which is runner-like, ascending with several leaves, of which the first one differs from the final one in being almost kidney-shaped, with the margin coarsely serrate; the other leaves are palmately trifoliolate.

When the plant has attained its full growth, a rhizome is to be observed, which is often tuberous and with the primary root still persisting (Fig. 54).

SAXIFRAGACEÆ.

Saxifraga Virginiensis.

The seed of this species germinates early in the month of March, and the germinating plantlet is especially characterized as having short-petioled and broadly ovate cotyledons, which are above ground, a distinct, erect hypocotyl, and a long, filiform primary root (Plate X, Fig. 55). When the leaves begin to unfold the hypocotyl bends downward to the ground after having developed two or three secondary roots that very soon surpass the primary one. The first leaves are broadly ovate or elliptic, sparingly hairy, with stellate hairs on the upper surface of the blade, and the petiole is slightly pubescent (Figs. 56 and 57). When the plant grows older, the primary root disappears entirely and is replaced by several secondary roots, and in Fig. 58 we see the beginning of the formation of the very short, vertical rhizome that is provided with a few roots and is represented by the superior part of the hypocotyl. Five leaves were developed

on this specimen (Fig. 58), of which the three oldest showed the same form as the ones mentioned above (Figs. 55–57), while the two younger were almost cuneate and bidentate, pubescent on both surfaces as well as on the petiole. The plant now continues its growth in this manner, developing a leafy rosette upon the apex of the short rhizome, and some buds will also develop in the axils of these leaves, so that the rhizome finally will carry a crown of leafy rosettes, some of which will contemporarily produce flowering stems in the following years.

DROSERACEÆ.

Dionaea muscipula.

The very first stage of germination, figured on Plate X, Fig. 60, shows the development of the primary root, which is densely covered with blackish hairs, especially at its upper part where it joins the hypocotyl. For some time the testa of the seed is carried by the apex of the cotyledons, but after it drops off the cotyledons spread a little (Fig. 61), and the plumule begins to form the first leaves. These, even the first one next to the cotyledons (Plate XI, Fig. 62), show the characteristic shape and peculiar function which has made the plant one of the most interesting in the world. The germinating plantlet can now be characterized as having narrow lanceolate cotyledons, a distinct hypocotyl and a relatively short, blackish-hairy primary root. While the leaves begin to develop in the form of a small rosette, the growing point is moved from its original place between the cotyledons to outside these, as has been shown in Fig. 63. At this point the first secondary root is developed just below the foremost part of the horizontal, now creeping axis, and it is already indicated how the plant will continue its growth. A distinct horizontal rhizome will be developed, which is very easily seen in the older plants, of which one is figured in Fig. 64, while Fig. 65 shows a longitudinal section of the same specimen. The fresh leaves form a rosette, as has been described by various authors, but it is by no means correct to call the

plant "acaulescent," as do for instance A. Gray,* and Bentham and Hooker.†

While Fig. 63 shows the plant at a very early stage, with a small rosette of green leaves and the beginning of a creeping rhizome, indicated by the position of some of the leaves outside the cotyledons, together with the development of a secondary root at some distance from these, Fig. 64 illustrates in the older specimen the true rhizome, creeping with rather thick, short and still unbranched roots, with the base of the leaves of the previous year still persisting. The internodes of the rhizome are, when young, exceedingly short, and it looks therefore as if the leaves formed a true rosette—that is, as if they were arranged alternately upon a short, erect axis with the blades spread out horizontally as, for instance, in *Drosera rotundifolia*, instead of upon a decumbent, creeping stem.

The bases of the leaves are, as mentioned above, persistent for a long time, whereas the faded blades disappear very soon, and it has been observed that a large quantity of starch is deposited here. The leaves of *Dionaea* have then a double function in being organized for the purpose of capturing and devouring insects, after which they serve as reservoirs, which contain quite considerable deposits of starch, as do the fleshy bulb-scales of many monocotyledonous plants.

UMBELLIFERÆ.

Thaspium barbinode.

The cotyledons are like those in most Umbelliferæ, that is, above ground, and long-petioled with a lanceolate blade. The hypocotyl is here either very short or, what seems to be the most common case, entirely wanting. The primary root is, on the contrary, strongly developed, thick and only sparingly branched. No secondary roots are developed during the first year and probably not in the second. Fig. 66 (Plate XI) shows a germinating plantlet, the plumule of which

---

* A. Gray: Gen. Ill. vol. I, p. 196.

† Bentham and Hooker : Genera plant.

has already developed two leaves that show in general features the shape of the final ones, but they have a smaller number of divisions than the later ones. We see in Fig. 67 an abnormal case, where three cotyledons have been developed, but the seedling does not differ in other respects from the above-mentioned description of this (Fig. 66). The young plant will continue its growth in that manner, the primary root will gradually attain the shape of a so-called tap-root (Fig. 68), while the proper rhizome will show merely a short, nearly subterranean axis, upon which leaves will develop until the inflorescence terminates the main axis, after which the plant will be renewed by the development of buds in the axils of the basal leaves. A full grown plant has several shoots upon the rhizome, at the base of the flowering stem, and beside the primary root a few secondary ones were observed which were almost the same size.

Thaspium aureum.

This species agrees in most respects with the one above described, the only difference being in the shape of the leaves. Fig. 69 in Plate XI shows a germinating plantlet, of which the cotyledons and the primary root show the same development as in *T. barbinode.* The first leaf, on the contrary, has not any separate division, but is almost entire or slightly five-lobed, with the margin sharply serrate.

Osmorrhiza longistylis.

The germinating plantlet (Plate XI, Fig. 70) has a strongly developed primary root, but the hypocotyl is rather inconsiderable. The cotyledons are long-petioled, with linear blades, and are entirely above ground. The first leaf shows relatively the shape of the final ones, with the exception that it is smaller and has only three divisions, the shape of which, however, accords in many respects with that of the later leaves. It is to be noted that the form of the divisions of these decompound leaves, "broadly ovate, with the margin serrate," is not the only one which occurs in this species. We shall see, at a later stage of development (Fig. 71), where the cotyledons have dropped and where the leaf (L^1) shows a somewhat

different form in regard to the divisions. These are more compound than those of the first-mentioned specimen, and the divisions are not ovate, but cuneate, with the margin sparingly dentate. Another circumstance is that, while the final leaves are densely pubescent, this leaf is almost glabrous. The specimen figured in Fig. 71 is one year old, the primary root has increased in length and thickness, and has developed several long, filiform lateral roots. A rhizome (Rh.) is already formed, and it consists of the short internodes of the first year, carrying the above-mentioned leaf (L^1) and two other ones of which the second shows the same shape as L^1, while the third one has the normal form, described above. It is therefore shown that the first leaves in the second year of the life of the plant are different in form from the later ones, a fact which seems to be constant.

We see, if we examine a full-grown plant, that the leaves show the same different aspect in regard to the size and shape of the divisions, and it is always the leaves that are the first to develop in the spring which have the smallest and almost cuneate divisions. In regard to the rhizome, this is vertical and rather short, carrying several small buds, which will develop leaves in the following years. The primary root persists, as it seems, as long as the plant lives, and several secondary roots are developed from the base of the rhizome, some of which are thick and similar to the primary root and contain a large deposit of starch, or they are thin, very strong and much branched like the common roots. It is to be noted, in regard to this plant, that it seems as if it had been hitherto overlooked, that it has dimorphous leaves, a character which ought to be mentioned in the diagnosis of the species.

Sanicula Marylandica.

The cotyledons are long-petioled, with an ovate-lanceolate blade, which is short-pointed (Plate XI, Fig. 72). The hypocotyl is straight, well developed, as is also the long and slender primary root, which is shown in Fig. 73. These are the features in general for the primary stage of development, but

the plant will gradually undergo rather considerable changes. The next stage will be (Fig. 74) where the leaves have commenced to come out, and this drawing was made from a plant two months older than the first one described (Fig. 73). We now see that the hypocotyl has been bent and is lying upon the ground. The primary root persists, but has now begun to fade away. Another root-system is formed at this time, consisting of two strong, secondary roots, which proceed from the bases of the cotyledons, which have fallen away. These roots are very long, sparingly branched and rapidly surpass the primary one in length and thickness. We therefore have an umbelliferous plant, where the roots at an early stage are all secondary, while commonly in this order, as it seems according to descriptions, the primary root persists for a long time or even during the whole life of the plant. The rhizome of the full-grown plant is very short, merely represented by an exceedingly short, vertical axis, upon which buds are at length developed, producing for several years leaves and flowering stems.

ARALIACEÆ.

Aralia spinosa.

The seeds of this tree did not germinate for about eighteen months after they had been sown, and the young plants all showed the peculiar fact, that the cotyledons were unequal in size and shape. The one had the common form of a cotyledon, being oblong and obtuse with the margin entire, while the other one was smaller and ovate, with the margin serrate. That is, however, the only thing which characterized the germinating plantlet of this species (Plate XI, Fig. 75). The primary root was not very strongly developed and showed only two lateral branches, the hypocotyl was rather long and the first leaf next the cotyledons showed approximately the same shape as the final ones, but had only three leaflets.

URTICACEÆ.

Pilea pumila.

The typical shape of the leaf of this species is broadly ovate, with a long point and a coarsely serrate margin, a form

which differs very much from that of the first two pairs of leaves of the germinating plantlet (Plate XII, Fig. 82). We see in this figure that the first pair of leaves, next the cotyledons, are ovate, but with the margin perfectly entire and the apex obtuse, while the next pair (Fig. 83) show a slight lobation, with a long middle-lobe, forming the transition to the serrate margin and the long point of the final leaves. The cotyledons are long-petioled, with the blade broadly oblong and the apex slightly retuse; the hypocotyl is straight and long, and the primary root, which is slender, shows several ramifications.

PALMÆ.

Sabal Palmetto.

The fruit of this genus, which belongs to the tribe *Corypheae*, is a black, monospermous, dry berry. The albumen is cartilagineous and the apex of the cotyledon is transformed to a conical spongy body, closely imbedded in and absorbing the albumen. When the germination begins, the thick, conical primary root penetrates the pericarp and carries the plumule along with it. The plumule is, however, not visible at the very early stage of germination, figured on Plate XIII, Fig. 84, but is enclosed by the base of the cotyledon, which is represented here by two clearly differentiated parts, the above-mentioned conical spongy apex, enclosed by the albumen, and the free cylindric base. A short time later —that is, after one or two weeks—the anterior part of the base of the cotyledon begins to show a small protuberance, which quite rapidly grows outward towards the surface of the ground, attains a length of one inch or even more, and becomes at last ruptured by the penetration of the plumule, and forms a cylindrical closed sheath around it. The first leaf alternates with the cotyledon, is whitish, scale-like and partly sheathing, and encloses the base of the next leaf, which is green and lanceolate in shape. As to the primary root, this dies off very soon, almost simultaneously with the appearance of the second leaf, and forms a thickish, conical body, entirely destitute of ramifications. Fig. 86 shows a young plant, where the fruit has disappeared, together with the en-

closed and the free part of the cotyledon, with exception of the still persisting sheath (Sh. in the figure), around the base of the leaves. The first leaf (l^1) is almost faded.

The second one (L^1) is rather large, lanceolate and shows the longitudinal foldings, which are so characteristic of the first leaves of most of the palms. A third leaf (L^2) has come out and is of the same shape as the second, and will be followed by several others, similar in form, before the normal, fan-shaped leaves appear. We see further in this same plant that two secondary roots have been developed a little above the primary one, and these are growing rapidly in length and have a great tendency to ramification.

Closely allied to this genus is *Nannorhops Ritchieana*, Griff., from Asia, of which some fruits were sown at the same time as those of *Ṣabal*. The germination accords nearly with that of *Ṣabal*, but there is, however, a difference in regard to the further development of the primary root. Plate XIII, Figs. 87–91, illustrate the germination of this plant, and in these figures is shown the gradual growth of the primary root. It grows much faster than the sheath of the cotyledon can be formed, and is not destitute of lateral branches, as was the case with *Ṣabal*. Fig. 90 shows a later stage of development, where the first two leaves have come out and are surrounded by the sheathing part of the cotyledon, as in *Ṣabal*, but the primary root has not yet faded away, but, on the contrary, it continues to grow. At a still later state, figured in Fig. 91, where in all three leaves have been developed (l^1, L^1 and L^2), it seems to have stopped its growth and commences to swell at the lower extremity, while the lateral branches continue their growth. The first secondary root is to be seen in this same state; it surpasses the primary one and has numerous ramifications. The fruit was still attached to the plantlet, but in the most essential details the germination did not show any great differences from that of *Ṣabal*.

Attalea excelsa.

The apex of the cotyledon has the same shape and position as described for *Ṣabal*, but the basal part seems to be rela-

tively longer in this plant. It does not appear that more than one of the seeds in each fruit germinates, at least not generally, but this happens occasionally, however, and was observed in one case where two germinating plantlets were developed from the same fruit. Fig. 92, in Plate XIII, shows an early state of the germination, and we see there the cylindrical, free part of the cotyledon, of which the extremity is somewhat swollen and contains the plumule, as in Fig. 93, which represents the same specimen, divided longitudinally. We see further a short-pointed, conical tip below the plumule, from where the primary root will come out. One month later the plumule appears, and the base of the cotyledon forms a sheath around it similar to the one described in *Sabal* and *Nannorhops*. The first leaf ($l.^1$ in Fig. 94) is whitish, almost tubular and alternates with the cotyledon. At the same time the primary root has further developed and shows several lateral branches, but no secondary roots have appeared. It is now to be pointed out that the primary root attains a very advanced development, not only in regard to length, but also as to its ramification. We have then two scale-like, sheathing or rather tubular leaves, preceding the green or first assimilating leaf, which, as shown on Fig. 95, is broadly lanceolate and folded, as is characteristic in the Palm Family. This figure (Fig. 95) has been drawn from a specimen seven months older than the one above described. The fruit has now become separated from the young plant, and there is left only the partly faded, fibrous base of the cotyledon. The first and second leaves (l^1 and l^2) are also beginning to fade, and no other root has been developed beyond the primary one, which continues its growth in length and with the lateral branches increasing in number.

CYCLANTHACEAE.

Carludovica palmata.

Belongs to the tribe "Carludoviceæ," of which the seed has a very copious albumen. The cotyledon is fusiform (Plate XIV, Fig. 96) and is entirely enclosed in the seed during the germination, excepting the foremost part, the very base

which encloses the plumule and later forms the sheath around it. The primary root (R) is the first part of the seedling which becomes visible, and grows rapidly out, although not attaining any considerable length. It is hairy above and entirely unbranched. Fig. 96 represents the germinating plantlet, where the above-mentioned parts are visible besides the two first leaves, the first of which alternates with the cotyledon and is broadly lanceolate, three-nerved and with a sheathing base. The next stage of the germination may be seen in Fig. 97, which shows the appearance of a third leaf, the continued growth of the root, and finally the formation of a very short, but distinct epicotyl between the cotyledon and the first leaf. No secondary roots have come out yet. A few weeks later the young leaves are further developed (Fig. 98), the second and third (L^2 and L^3) being ovate, pointed, five-nerved and with the base partly sheathing. The fourth leaf (L^4) has come out, and, in regard to the root system, we see that a secondary root (r^1) has been developed from the epicotyl, and only a little above the primary one, which has attained its full size, while the other one grows rapidly and has already surpassed it in length.

In a later stage (Fig. 99) the plant has dropped the cotyledon and thereby lost its character as a germinating plantlet. The primary root still persists and another secondary root (r^2) has been developed at the base of the first leaf (L^1) and opposite the first root (r^1), both of which are still unbranched.

This is the general course of the growth of this plant, it being exceedingly short-stemmed, with all the roots confined to the base of the stem, which is entirely under ground. The leaves gradually change their shape from ovate and sheathing to fan-like and long-petioled.

AMARYLLIDEÆ.

Agave univittata.

The seed germinates in the ground and the primary root is the first organ that develops. It is densely covered with root-hairs, especially at its upper part, and does not show any tendency to ramification for a considerable time. Fig. 100

shows an early state of the germination, and we see here the primary root (R), the hypocotyl (c) and the long, cylindrical cotyledon, bent and forming an acute angle, of which the apex is still enclosed in the seed. It will be so for a short time, after which it gradually lengthens, lifting the testa of the seed above ground, as shown in Fig. 101. When the testa of the seed drops the free summit of the cotyledon shows a somewhat faded aspect (Fig. 102), and at this time the plumule commences to appear through a slit (Sl), which has been visible for some time at the base of the cotyledon. The cotyledon is then green, and is of almost the same shape as the first leaves, except that the apex soon fades away.

The hypocotyl shows an axis at a very early stage of the development of the young plant, while the following internode is exceedingly short, until at last the long-stemmed inflorescence terminates the main axis.

Eucharis candida.

In this species when the seed germinates the primary root is the first to appear and grows out quite rapidly. The apex of the cotyledon is imbedded in the albumen and never becomes free, while the base forms an almost tubular body, enclosing the plumule, as shown on Plate XIV, Fig. 103. At a later stage (Fig. 104) the first leaf has come out and alternates with the cotyledon, is long-petioled, with the blade elliptic, tapering at both ends like the final leaves of this species, and we see further the development of the first secondary root. The primary root still persists and shows, like the secondary one, a distinct wrinkling in the upper part, the cause of which will be mentioned later. The base of the cotyledon has increased in thickness and shows an opening above, through which the first leaf has come through, and the whole base shows the beginning of the formation of the bulbous rhizome of the plant, the sheath of the cotyledon persisting for a long time and representing the first bulb-scale.

LILIACEÆ.

Smilax rotundifolia.

The material, which has been examined to illustrate the germination and the formation of the rhizome of this plant,

was collected in the large Smilax thickets which so commonly occur in open places in the woods along the shore of the Potomac, and in spite of the great similarity that exists between several of the woody species of Smilax when young, these plants showed a few characters which were sufficient to distinguish them as belonging to the species "*S. rotundifolia*."

In regard to the structure of the rhizome of the whole genus Smilax, it is remarkable to see how few observations have been made, and, with the exception of the two species, *S. Pseudo-china*, L. and *S. hispida*, Muhl., none of the other North American representatives have been examined with reference to their rhizomes. Another fact is, that there seems to be a certain kind of variation in the young foliage of this species, which it might not be superfluous to describe in connection with the germination and the structure of the rhizome.

Turning to the examination of our species *S. rotundifolia*, the seed germinates deep in the ground for a long time with the fruit attached, Plate XV (Fig. 105). There is a distinct, sheathing cotyledon, as shown in Fig. 106, where the upper part of the cotyledon has been removed from the albumen in which it was closely imbedded. Besides this enclosed part there is to be observed a free one, which is the base, and which forms a sheath around the plumule.

There is also a hypocotyl (c in Figs. 105–107) more or less developed, but never wanting, as it seems, according to the numerous seedlings which were examined. The primary root is rather slender, branched at an early stage, and persists for at least the first year. The plumule, after having penetrated the cotyledonar sheath, develops an ascending stem, the first one to three leaves of which are under ground, scale-like and partly sheathing. After these leaves the normal ones appear, and diverge more or less from the typical shape, which has been described as "ovate, or round-ovate, and slightly heart-shaped" for this species.

These are the general features of the germinating plantlet, and we shall now see how the rhizome commences to develop.

Several seedlings were collected in the stage figured in Fig. 108, which shows the base of the young plant, and we see that the fruit with the apex of the cotyledon has dropped, while a swelling has taken place at the base of the stem and inside the persisting sheath of the cotyledon. This is due to the presence of a conical bud, which has been formed in an earlier state (Fig. 107), but has now grown farther out, having attained quite a considerable size in the stage of growth figured in Fig. 109. The place of this bud is in the axil of the cotyledon, just at the back side of the main axis, as is shown in Fig. 107. This bud seems most frequently to develop into a tuber (Fig. 111), and it is to be pointed out that the apex of the bud will gradually bend downwards so that the axis of the tuber describes a horizontal direction. The first leaf upon this tuber turns its back towards the main axis, as does the first leaf upon each secondary branch in most monocotyledonous plants. This fact is especially to be seen in Fig. 110, where the bud has not formed a tuber, but has developed immediately an ascending branch, at the base of which we see the adorsed scale-like leaf, the "prophyllum," while the remaining sheath of the cotyledon is to be observed at Sh. and the main axis at A. In regard to the root-system, the secondary roots are growing out already in the first year (Figs. 108, 110, 111); they are thicker than the primary root, whitish and merely sparingly branched. They have been developed from the upper part of the hypocotyl, the first one regularly on the anterior face of the germinating plantlet, just below the slit of the cotyledonary sheath. In Fig. 111 we see the beginning of the formation of the rhizome and the slight difference due to the relative size between the young rhizome and that of an older plant, shown in Fig. 112. We see in this last figure the full-grown rhizome, which is relatively short, horizontal, tuberous and provided with several strong roots. The base of the ascending stems is more or less tuberous, covered with scale-like leaves and very often rooting at the nodes. The youngest part of this rhizome shows a comparatively large tuber with an ascending stem (1), which will eventually produce leaves and probably also

flowers the same year. The base of two other stems are to be seen at 2 and 3, indicating their rank in regard to their time of development, No. 3 being the older one, and these stems carried several leaves which had persisted over winter.

The three other basal parts (Nos. 4, 5 and 6) were the only remaining parts of old faded stems, and the probable age of the whole plant was at least six years. Only one stem had been developed each year in this specimen, but the period necessary for the formation of the tubers (say, for instance, the younger one, which was relatively longer than the other ones and was covered with about three scale-like leaves) is uncertain.

As regards the foliage of *S. rotundifolia*, as already remarked above, there seems as if there were quite a considerable variation even in the same specimen. The form, indicated as typical for this species, should be, according to De Candolle (l. c.), "limbi ovati vel ovales, basi subcordati, obtusi vel prope petiolum cuneati, apice (in eodem ramo) sæpius acute cuspidati vel acuminati, et interdum obtusi." The most characteristic feature of the leaf, when the question is to distinguish it from other species, for instance, *S. glauca*, with which the young specimens showed a great resemblance, is the minutely dentate margin. As regards this character it accords, however, with *S. hispida*, Muhl., but the leaves of this species show from seven to nine nerves, whereas there are not more than five to seven in *S. rotundifolia*. The consistency of the leaf is also different, as the leaves of *S. rotundifolia* are thick, almost coriaceous, in contrast to the leaves in *S. hispida*.

We will shortly consider the leaves of *S. rotundifolia*, figured on Plate XV, which have been taken from a full-grown plant, or from very young specimens, the ages of which were only one year.

The leaf in Fig. 121 shows the typical form, while the other one (Fig. 122), which has also been taken from an older plant, is more elongated and tapers gradually to the pointed apex. We find this form again in Fig. 113, which shows the youngest leaf of a one-year-old plant. In Fig. 114 we see

another leaf which belonged to the same branch of the above-mentioned plant, but was the oldest one, and the shape of which is approximately cordate. The broadly roundish cordate form is represented in the leaf in Fig. 119, which leaf was succeeded by the regularly heart-shaped one shown in Fig. 120. This, the roundish and more or less cordate form, seems to be the most common one in the young plants, but we might also find the more ovate and sharply pointed form, as, for instance, in the leaves (Figs. 116–118), all of which belonged to the same branch of a very young specimen, 116 being the youngest and 118 the oldest one. There is then quite a considerable variation in the foliage in this species, so that forms might occur more or less approaching those of the above-mentioned species, *S. glauca* and *S. hispida*. We have accordingly to take refuge in the structure of the leaf, and it seems that some characters are to be found here. The anatomical difference must now be looked for in the presence or absence of stomata and in the undulations of the cell-wall of the epidermis. The epidermis of *S. glauca*, taken from the superior face of the leaf, does not show stomata, while in the two other species stomata were present and not in small numbers. The number of the cells surrounding the stomata was nearly constantly two in *S. hispida* and four in *S. rotundifolia*. The relative size of the epidermis cells was also somewhat different, and, while the undulations were the same in *S. glauca* and *S. rotundifolia*, the cells of *S. glauca* were proportionally larger than those of *S. rotundifolia*. In *S. hispida* the cell-walls showed merely a very slight undulation, and the size of the cells was almost the same as in *S. glauca*. If we were to examine the epidermis from the inferior surface of the same leaves, we would find stomata present in great numbers, and equally so in all three species. The undulations of the cell-wall were slighter than those described for the upper surface, especially in *S. hispida*, in which the cells showed a rectangular or rhombic form.

Smilax glauca.

A germinating plantlet of this species, figured on Plate XV, Fig. 123, resembles very much that of *S. rotundifolia*,

described above, the only difference being that the margin of the final leaves of *S. glauca* is entire and never toothed, as in the other species. Otherwise the structure of the cotyledon, the primary root, the presence of a hypo- and epi-cotyl and the scale-like shape of the first three to five leaves agree entirely with what we have seen in *S. rotundifolia*. In regard to the development of the rhizome there seem, however, to be some slight differences, by which the underground parts of these two species, at least at a later stage, are to be easily distinguished.

The rhizome of *S. glauca*, figured in Figs. 124–126, is strongly tuberous and consists of a chain of tubers, due to the swelling of the short internodes of the subterranean stem, and in such a manner that each tuber represents from three to four internodes, the leaves of which are scale-like and very broad. From each tuber proceeds a stem, of which the lower leaves are scale-like and partly sheathing. The direction of the stems is ascending, and after having reached the surface of the ground the final leaves will replace the scale-like ones.

The whole rhizome shows a great similarity to that of *Polygonatum*, excepting that the stems exist for several years. Fig. 124 shows the rhizome of a younger specimen. Only two stems have been developed, of which *a* is of this year's growth, not having yet penetrated the ground, while the other one, *b*, in the figure, represents the base of a stem that is evidently three years old. The rhizome itself is horizontal with cylindrical internodes, whitish, and does not emit any large number of roots. They, the roots, are rather few and are especially developed from the inferior part of the tuber. The larger rhizome, Fig. 126, is from an older plant, and we see here three tubers and altogether three stems of different ages. The course, in regard to the whole development of the tubers and the stems, is, however, the same as shown above for the younger specimen (Fig. 124). It is to be observed very distinctly in the older specimen, that the stems are supported by the subterranean scale-like leaves of the tubers, and we see, for instance, in B a small wart-like body, which is a bud,

eventually developing into a stem, most probably in the following year.

There is no regularity in regard to the number of internodes by which the tubers are formed; it seems to vary from three to four. The form of the tubers is, on the contrary, very uniform, cylindrical, broadest at the middle, and tapering at both ends. They contain a large quantity of starch. Fig. 127 illustrates the underground part of a very old plant, and we there see that the true tuberous rhizome is wanting. The whole rhizome consists merely of a stolon, which has been separated from the primary rhizome, and of which the ascending branches proceed from small tubers, each representing one single internode. It denotes the fact that the lateral branch (br^2) has been developed from the axil of a scale-like leaf, without being preceded by any formation of tubers, while the main branches (Br^1 and Br^2) form tubers above each leaf, which support a lateral branch. Strong roots proceed from the inferior face of the tubers, while the stolons otherwise are mostly destitute of roots. It is especially the ability of forming these tubers that makes the stolons able to continue their life after having been separated from the main rhizome of the plant.

Hemerocallis fulva.

This plant is not properly indigenous to America. It is a native of Europe, but has been cultivated here for a long period and sometimes occurs escaped from cultivation. A germinating plantlet has been figured on Plate XVI, Fig. 128, where we see a rather strongly developed primary root (R) and one secondary root (r) which has grown out through the base of the sheath that is formed by the cotyledon. The cotyledon itself is partly enclosed in the seed, or at least its apex is, while the base is free and forms, as mentioned above, a sheath around the plumule, which has developed three leaves (L^1–L^3); the latter are linear and carinate. The plant shows the same general course of development in regard to its germination as do most of the monocotyledonous plants, but there is, however, quite an interesting fact, which must

be taken into consideration. This is the distinct wrinkling, which the primary root shows, and which may be observed also in the secondary root, when it has grown out to its full length, as shown in Fig. 129. This peculiar fact (the wrinkling of the roots) depends on their ability to contract, and, as explained by Irmisch, is for the purpose of keeping the plant as close to the ground as possible. The older state of the plant, figured in Fig. 129, shows also that the secondary root (r) has increased quite considerably in thickness, being almost fusiform, taking the function of a nutritive root, and contains a large quantity of starch, like the tuberous roots, of *Orchis*, *Dahlia* and several others.

Yucca gloriosa.

The seed of this species is compressed, almost triangular, with a corneous albumen. A longitudinal section of the seed (Plate XVI, Fig. 131) shows the fusiform apex of the cotyledon, lying diagonally in the albumen. When the seed commences to germinate the primary root is the first that appears; it is rather thick and attains a considerable length before the plumule becomes visible. Figs. 130 and 132 show this very first stage of the germination, and we observe there a slight bending downwards of the cotyledon, so that the seed is kept under ground during this, the first, stage of the germination. The lower part of the cotyledon shows very early an incipient swelling, which is caused by the growth of the plumule inside. Fig. 133 shows the plumule (P) coming out, but in other regards the germinating plantlet has not changed from what has been figured above. But after that time, when the first leaf has been developed (L^1 in Fig. 134), some very considerable changes have taken place. The primary root has grown rapidly out, and shows already some lateral branches, and the cotyledon has commenced to stretch itself upwards, so that the seed is entirely above ground, still being for some time carried by the apex of the cotyledon, the base of which shows the swelling, mentioned above, and has even increased in length. The first leaf alternates with the cotyledon, is broadly linear, pointed and five-nerved. In the next stage

of the germination, figured in Fig. 135, the second leaf has appeared, and contemporarily the primary root has attained a considerable length, with a few ramifications. The base of the cotyledon seems to have decreased in thickness, and will gradually fade away, leaving a somewhat fibrous sheath around the base of the young plant, as is shown in Fig. 136. This plant (Fig. 136) was about one month old, and we can see the continued growth of the primary root, that has acquired several lateral branches, but no secondary roots have been developed. The cotyledon has partly dropped, at least the upper part, while the lower is still persistent, forming a narrow sheath around the base of the young plant. No axis nor internode is visible, and the plant will not develop a longer stem, the leaves all being situated near the ground, forming a dense rosette. The development of the secondary roots is very late, and the primary root persists for about half a year. Fig. 137 shows a young plant, the age of which is eight months. We see in this figure four secondary roots (r–r), of which two are relatively more strongly developed than the other ones; the latter are rather thin, but provided with several lateral branches in contrast to the two others, the thicker ones. There is only a scar (R) left from the primary root, but the plant has not been changed in any other respect, except by the addition of leaves to the ones figured in Fig. 136.

ARACEÆ.

Peltandra undulata.

The fruit of this plant is a fleshy berry, of which the pericarp is very thin, notwithstanding that it is tough when fresh, dark colored and almost black (Plate XVII, Fig. 138). The enclosed seed (Plate XVII, Fig. 140, there being most frequently only one) is globular, surrounded by a tenacious jelly which, according to Baillon and Engler, is the transformed exterior integument of the ovule. The plumule is green and lies in a furrow formed by the large scutellum, the margins of which tightly enclose, but do not quite cover the plumule. When the fruits have matured in the fall, they drop into the water, and will be found floating for a certain time, while the

pericarp either opens by gradual decay or becomes ruptured by the jelly, which, after contact with the water, swells rapidly and forms a perfectly translucid, mucilaginous coat around the seed (Plate XVII, Fig. 139), very much like the shell of a univalve mollusk, and is only to be removed from the seed with great difficulty. The germination begins while the seed is still floating upon the water, and the first sign of the young plant is the plumule breaking out through the mucilaginous envelope and separating itself from the clasping margins of the cotyledon (Plate XVII, Fig. 141). In this very first state of germination there is to be seen not only the first leaf (L^1 in Fig. 141) surrounding the plumule, the position of which is alternating with the cotyledon, but also the primary root (R in Fig. 141), which has commenced to break out. Two pairs of other roots are visible on each side of the first root, but merely as round spots, which are lighter colored than the surrounding parts of the seed. The seed now begins to sink in the water, and, while the plumule continues its growth, the roots become more distinct, partly breaking through the still persisting mucilaginous coat. It will be seen by an examination of Plate XVII, Fig. 141, in which the same seed, seen from the side and from the front, has been figured, that the primary root is the farthest developed.

Next in order are the two pairs of roots, mentioned above. The coleorhiza is distinct, but entirely smooth, as the roots themselves, without any hairs. Above these roots and at the very base of the plumule one pair of round spots is to be observed, which, as will be shown later, represent a third pair of roots, but whose development is proportionally very slow.

In following the further development of the germinating plantlet, the next state is (Plate XVII, Fig. 144) the disappearance of the jelly by gradual solution, till it forms but a thin membrane around the seed, then soon decays and disappears entirely. The first leaf now comes out and shows its final form, it being bicarinate, sheathing and scale-like. The form of this first leaf next the scutellum is characteristic of most of the Araceæ with exalbuminous seeds, while in those

with albuminous seeds the first leaf mostly has the form and structure of the normal leaves, and has a distinct petiole and blade developed. This fact has been pointed out by Engler,* but it seems, as if it had been overlooked, that the seed of our plant is exalbuminous, as Engler describes it under the tribes Peltandreae as having "Semina albuminosa."

But, besides the development of the first leaf, we see also the second one (L^2 in Fig. 144), and further, that the primary root has been almost surpassed, in regard to growth, by the lowest pair of secondary roots (r^1). The primary root, of which the direction seems to be almost horizontal in contrast to the others, which usually grow immediately downward, has now attained its final length, while the secondary roots (r^1, r^2 and^3 in Fig. 145) are rapidly growing out. We see further, in Fig. 145, that, besides the above-mentioned two pairs of secondary roots (r^1 and r^2), another one has been developed (r^3) below the primary one. In this same state (Fig. 145) the leaf has come out (L^2) showing the shape of the first one (L^1), but is almost twice its length, and surrounds the base of the third one (L^3), which again assumes the same form. We now have on this germinating plantlet three leaves, all of which are approximately scale-like, or at least with the blade entirely wanting, and very different from the normal, arrow-shaped leaves. There is, however, between these two forms a sort of transition, since, as shown in Figs. 147 and 148 (L^2 and L^3 which are the first leaves after the scale-like ones), they have a blade, which is ovate-lanceolate and tapering at both ends. This kind of leaves, which precede the normal ones, may appear sooner or later, *i. e.*, either following immediately upon the first scale-like leaf (l^1 in Figs. 147 and 148) or being preceded by even three of that kind, as the specimen shows (Fig. 145). The further development of the roots is shown in the Figs. 147 and 148, and we see in all four pairs of secondary roots on both sides of the front part of the young plant, and two others, the one above, the

---

* A. Engler: Araceæ in Alph. and Cas. De Candolle's Monographiae Phanerog. Prodromi, vol. II., 1879.

other one below the primary root, which is now entirely faded. The roots do not show any sign of ramification, and they are but sparingly covered with root-hairs.

It is curious to see, that the pair of roots (r^4) that are already visible in that very early state, appearing there (Fig. 143) as two round spots, have now first been developed. The space of time, that has passed since the first stage of germination (Fig. 140) to the last one (Fig. 148), is about three months, and still the scutellum is attached to the plantlet, and is not changed in any considerable degree in size or in shape.

In regard to the rhizome of the full-grown plant of *Peltandra undulata*, this does not show any essential difference from that of the young plant, shown in Fig. 148. The stem is very short, sparingly branched with ascending shoots, covered with the sheaths of the leaves and emitting numerous whitish, rather thick roots, that are but sparingly branched at their ends.

Orontium aquaticum.

This genus belongs to the tribe "Symplocarpeæ," and the fruit contains only one seed, which is exalbuminous, provided with a mucilagineous jelly, similar to that of *Peltandra.* The embryo and the testa of the seed are light green, and the germination commences immediately after the maturity of the fruits, as soon as they have dropped. Several germinating plantlets were collected in the month of June in the stage of germination, shown on Plate XVIII, Fig. 150. The cotyledon is large, roundish, and very much like that of *Peltandra*, but does not show the furrow, that embraces the plumule as in *Peltandra*, but simply a shallow cavity of irregular form.

The first leaf, alternating with the cotyledon, is nearly linear, pointed and sheathing at the base, terete, not bicarinate. It is to be especially remarked, that the primary root does not come out before the first leaf has attained its full size, and the appearance of the whole root system seems to develop very slowly in this plant. We find the same condition, as mentioned in *Peltandra*, that is, that the shape of the

first leaf is entirely different from that of the normal ones, which are long petioled with a blade broadly oblong and tapering at both ends. All the first five leaves of this plant showed the same uniform shape, and there will usually be several more developed before the typical leaf appears. The primary root does not attain any considerable length, and very soon dies off, and is then replaced by the secondary roots, as figured in Plate XVIII, Fig. 152. This figure shows a germinating plantlet about one month old, in which the cotyledon is still attached, and where the first five leaves have developed, the first two (l^1 and L^1) having partly faded. Three roots have come out besides the primary one, but none of these show any ability either of rapid growth or of any form of ramification.

Anthurium Andraeanum.

This genus belongs to the tribe Anthurieæ in which the seeds are albuminous, and where the germination shows the same general course of development, as has been described by Engler, for this group, *i. e.*, the first leaf next the cotyledon, has the same shape and structure as the normal leaves, with only a few unimportant modifications. The bright yellow fruit (Fig. 153) is a berry, of which the pericarp is very thin, almost membranaceous, and contains merely one single seed, the testa of which is also very thin.

While the fruits were still attached to the spadix, several of them had already commenced to germinate, and showed the primary root penetrating the pericarp. The embryo is green. The cotyledon is fusiform, as shown on Plate XVIII, Fig. 156, where it has been detached from the albumen. The first state of germination (Plate XVIII, Fig. 155) shows the conical primary root, covered with root-hairs, and further developed than the small, wart-like plumule, which is still enclosed by the front of the cotyledon. The next state has been represented in Fig. 156, where the primary root has grown further in length, and the plumule is visible, having penetrated the front of the cotyledon, which forms a sheath around it. The first leaf (L^1 in Fig. 157) alternates

with the cotyledon and shows a distinct sheath and blade, the form of which is cordate, sometimes ovate or even roundish in other specimens, while the final and normal form of the leaf is oblong-cordate (Fig. 164).

If we were now to follow the further development of the germinating plantlet, we would see that the primary root continues its growth without showing any tendency to ramification, and further, in Fig. 160, that the first internode has been formed and directed vertically. In this same state two more leaves have come out (L^2 and L^3), and there is also seen the beginning of the development of the fourth one (L^4). Two secondary roots have appeared, the first one (r^1) just above the primary root and at the very base of the leaf (L^1), while the other one has been developed on the middle of the first internode and in alternation with the root (r^1). There was from the very young state (Fig. 157), to the last mentioned one (Fig. 160), a period of two months. A few days after the primary root had attained its final length, and the germinating plantlet (Fig. 161) had stretched itself and obtained one more internode besides one more leaf (L^5), while the secondary root (r^2) has not yet grown out in this specimen; but we see, on the other hand, that the primary root of this specimen has obtained a lateral branch, a case, however, which seems to be relatively rare in the specimens examined.

The further growth of the plant is already indicated, the stem being erect, consisting of several internodes of about the same length, and all provided with roots, one at each internode, and developed opposite the respective leaves. This is seen in Fig. 162, where a young plant has been drawn five months later than the last-mentioned one (Fig. 161). We see here that the seed is still attached, that the primary root still persists without fading, and that a number of secondary roots have been developed from the stem. The oldest of these secondary roots (r^1) has not attained any considerable length, and does not grow any more. The same seems to be the case in regard to r^2, while all the other ones (r^3–r^9) are growing quite rapidly, and all directed downwards to the ground, offering in that manner a good support to the ascend-

ing or almost erect young stem. The roots are all densely covered with root-hairs and unbranched. The leaves are now considerably larger than in the state last described, but the blade has not yet, however, assumed the normal shape, which has been figured on Plate XIX, Fig. 164. The plant continues its growth, as indicated (Fig. 162), and the whole stem is entirely above ground without any proper rhizome.

ALISMACEÆ.

Alisma Plantago, var. *Americana.*

The germination of the seed of this variety is the same as that of the typical form, which has been so exactly figured by Mirbel.*

The cotyledon is a relatively long, terete leaf, which carries the testa of the seed at its summit for some time, and is entirely above ground. A germinating plantlet is shown on Plate XIX, Fig. 166, where the plumule (P) has not yet come out, but is still to be found inside the base of the long cotyledon, that shows an incipient swelling at the place where the plumule has to penetrate. There is between the base of the cotyledon and the primary root a cylindrical body (C), which is the hypocotyl, and we further see a distinct roll at the transition from the stem to the root, which is densely covered with hairs, and which Mirbel has explained as a rudimentary coleorhiza. The primary root (R) is very short and is not further developed, and is replaced by secondary roots, of which the first one will come out at the base of the cotyledon, just below the plumule, while the other parts of the seedling, the hypocotyl, the rudimentary coleorhiza and the primary root disappear very early.

CONCLUDING REMARKS.

It is merely a matter of incident that has caused just the above-mentioned species to have been described from their

---

* Brisseau-Mirbel. Elémèns de Physiologie végétale et de Botanique, 1815, Pl. 61.

earliest stage as germinating plantlets until they have attained an older state, or even full-grown age. It was a collection of material that was in the hands of the author, and it was thought the opportunity ought not to be neglected to present these contributions to the knowledge of the germination of some of our native plants. And even if several other species might have shown facts of greater interest than those described here, we must recall the fact that the number of plants taken from our flora, that have been described from their germination, is exceedingly small. The whole series of germinating plantlets, presented above, show several characters, so that genera and species of the same family are to be distinguished from each other in their very earliest stage. We see for instance, *Anemone thalictroides* differing from most of the other species of this genus by its tuberous roots, which are already developed in the first year. The two species of *Ranunculus*, *R. abortivus* and *R. recurvatus* differ from each other by the shape of the cotyledons, short or long-petioled, and by the form of the first leaf. *Delphinium nudicaule* shows a relatively rare manner of germination in comparison with other species of that genus. The germinating plantlets of *Sarracenia* and *Dionæa* are so characteristic that they might easily be distinguished from any other plants, when merely the first leaf is visible. There is probably no genus of the Papaveraceæ which germinates in the same manner as shown for *Sanguinaria*, with the cotyledons deeply under ground, and with a tuberous hypocotyl. *Viola palmata*, var. *cucullata*, has some relatives in regard to the development of the young rhizome, but is, however, different from most of the other species of *Viola*. The two species of *Lespedeza* are easily distinguished from each other by the foliage alone during the germination. And even among the Umbelliferæ some characters are to be observed that enable us to distinguish them at that early stage. The two species of *Thaspium* differ in the shape of their first developed leaves ; *Osmorrhiza* is characterized at an early stage by its dimorphous leaves, and *Sanicula* by the early fading of the primary root, together with its relatively broad cotyledons. *Aralia*

further shows the peculiar fact, that the cotyledons are unequal as well as different in shape. In regard to the monocotyledonous plants we are also able to find among them some characteristic differences, the long, terete, leaf-like and free cotyledon of *Agave* in contrast to the short, conical cotyledon of *Yucca*, which is enclosed in the seed. The distinct epicotyl, observed in *Smilax*, *Anthurium*, etc., and the development of the bud in the axil of the cotyledon in the first genus. And if we consider the Araceæ, we shall find, for instance, as pointed out by Engler (l. c.), that the final leaves are most often preceded by scale-like ones in the species with exalbuminous seed, as shown in *Peltandra*, *Orontium* and *Aglaonema* (Fig. 165), in contrast with *Anthurium*, where the albuminous seed develops a plant of which the first leaf has a distinct blade, petiole and sheath.

These germinating plantlets show also, in several respects, that the earliest stage of the plant, or what we call "the germinating plantlet," gives a figure in a small scale of the full-grown plant. Turning to some of the more interesting facts described above, we shall take for instance the case of cotyledons with connate petioles as in *Delphinium nudicaule*. This peculiar fact was discovered several years ago, and is mentioned by Bernhardi in a paper entitled: Ueber die merkwurdigsten Verschiedenheiten des entwickelten Pflanzen Embryo und ihrem Werth für Systematik.* The author enumerates there several plants that he has found germinating in this manner, namely: "many," Umbelliferæ, for instance, *Ferulago sp.*, *Bunium luteum* and *Prangos ferulacea*, further "many," *Delphinieæ; D. fissum*, *D. ochroleucum* and partly *D. puniceum*, *Dodecatheon Meadia* of the Primulaceae and finally *Leontice Altaica* and *L. vesicaria* of the Berberideæ.

Another author who has observed the same fact is A. Winkler in his paper, "Ueber die Keimblætter der deutschen Dicotylen,† where he calls the attention to the same manner

---

* Linnaea, Vol. VII, 1832, page 561.

† Verhandlungen d. bot. Vereins d. Provinz. Brandenburg, Vol. XVI, 1874.

of germination in *Polygonum Bistorta*, and evidently, also, *P. viviparum*, further *Anemone alpina* and *A. narcissiflora*, while in some species of *Dentaria*, *Chærophyllum bulbosum*, *Eranthis hiemalis* and *Aconitum Anthora*, the plumule does not attain any further development the first year, but grows out during the next year after the cotyledons and the cotyledonar tube have faded away entirely. Asa Gray has also given some contributions in his paper: The germination of the genus *Megarrhiza*, Torr,* where he has described some germinating plantlets of *M. Californica*, and mentions the same case as characteristic of *Delphinium nudicaule*. Furthermore Dickson† has observed, that *Anemone coronaria* and *Podophyllum Emodi* germinate in the same manner, while Lubbock‡ has given some remarks upon *Polygonum polystachyum*, of which the germination differs a little from the above mentioned, as the plumule does not break through the base of the cotyledonar tube, but passes through it, so that the seedling has the appearance of possessing an erect hypocotyl with nearly sessile cotyledons. Figs. 79 and 80, on Plate XI, represent two germinating plantlets of *Rheum Moorcroftianum* which were cultivated in the U. S. Botanical Garden, and that showed the same fact mentioned above, that the petioles of the cotyledons form a long tube, and where the plumule becomes visible through a slit at the base of it. Several specimens were examined, and this seems to be the normal condition also of this plant. The tube was cylindrical, and a transverse section showed the presence of only four fibro-vascular bundles, while two groups of a collenchymatic tissue were to be observed in the place where the petioles had been united. Fig. 81 represents a section of half of the tube.

We have then seen that this manner of germination is the

---

* Silliman's Journal of Science, Vol. XIV, 1877.

---

† Dickson: On the Germination of *Podophyllum Emodi*. Transact. of Bot. Soc. of Edinburgh, Vol. XVI.

---

‡ Sir John Lubbock: Phytobiological Observations, Journal of Linn. Society, Vol. XXIV, No. 159, 1887.

normal one in several plants, especially in some Ranunculaceæ, Berberideæ, Umbelliferæ, and Polygonaceæ, while it may occasionally occur as an abnormal condition in some others, as for instance in *Ricinus*, where it has been observed by Magnus.*

If we now turn to the germination of *Ipomaea paniculata* (Plate XI, Fig. 76), we see that the plumule is there situated at the summit of a large root, and between two very long-petioled cotyledons, just as it has been observed, for example, in several Umbelliferæ. It is relatively the same case, as observed in *Delphinium nudicaule*, with the exception that the petioles are free, while the plumule, notwithstanding that it is protected in the same manner, is kept well underground and protected against severe cold and draught. This occurrence in some species of *Ipomoea* has been mentioned by Gray in his "Notulae exiguae,"† where he has described the same manner of germination in *I. leptophylla*, *I. pandurata* and *I. Jalapa*, all of which are large-rooted species. There was, however, one germinating plantlet of *I. paniculata* (Fig. 77) which showed four cotyledons, of which two were grown together with their petioles and blades, whereas the other pair were perfectly free. The plumule was situated close to the base of the furrow, formed by the connate petioles (Fig. 78), and this fact might lead to the conclusion, that the cotyledonar tube probably has existed or still exists also in this genus.

In contrast to these cases, where the plumule is kept underground, or at least close to its surface, we have seen, in most of the other dicotyledoneous seedlings examined, that a distinct hypocotyl has been developed. This might seem to be rather injurious to the plant, as the plumule does not receive any further protection, and the hypocotyl is ordinarily not strongly developed, is neither thick nor possesses any mechanical tissue. But it must then be remem-

---

* P. Magnus: Ueber zwei monstrose Keimpflanzen von *Ricinus*. Verhandl. d. Bot. Vereins d. Provinz Brandenburg. Vol. XVIII, p. 107.

---

† Botanical Gazette, Vol. V, p. 87, 1880.

bered that in some cases it is of great importance to the young plant that the plumule should be kept free from the surrounding plants, so as to be more exposed to the air and light. And we have seen, for instance, in the germinating plantlets of *Ranunculus abortivus*, *R. recurvatus*, *Sarracenia*, *Saxifraga* and *Sanicula*, how the hypocotyl gradually is forced to bend down to the ground, after the first leaves have developed. The plant attains the same protection as *Ipomæa* and *Delphinium*, only at a later stage, and it is well attached to the ground by the development of roots from the upper part of the hypocotyl in connection with the more or less persistent primary root and the earlier developed secondary ones. It is to be supposed that this manner of germinating, with the rooting hypocotyl and the primary root dying away, is far from rare among the perennial herbs with short, tufted rhizomes. Another manner in which the young plant can be kept near the surface of the ground is by the roots as mentioned under *Hemerocallis* and *Eucharis*, where the roots show a distinct wrinkling, depending on their ability to contract, and this fact is also observed in several other monocotyledonous plants, as well as among the Dicotyledoneæ.

In regard to the shape of the cotyledons there is quite a considerable difference, but the case of *Aralia spinosa* with unequal cotyledons seems to be very rare. A similar case has, however, been observed by Lubbock,* who has described the germination of *Petiveria octandra*. The cotyledons were different in size, and of a very different shape, one being oblong, tapering at both ends and entire, while the other one was subcordate and three-lobed.

If we consider the figures, illustrating the germination of the monocotyledonous plants (Plate XIII to Plate XIX), we shall see that the germination is very uniform, although it shows a few differences. The shape of the single cotyledon is different, depending on the seed being albuminous or exalbuminous. In the first case, it may be perfectly leaf-like, as *Agave* and *Alisma*, or the superior part of the blade may be

---

* Sir John Lubbock: Phytobiological Observations. Journal of Linn. Society, Vol. XXII, 1887, p. 371.

transformed into a spongious body, closely imbedded in the albumen, while the lower part is free, as for instance in the Palmae, *Smilax* and *Yucca ;* or the cotyledon can be entirely enclosed in the seed, showing a more or less shield-like, conical or fusiform shape, as, for example, in *Carludovica*, *Eucharis*, *Hemerocallis* and *Anthurium.* On the contrary, in plants with exalbuminous seeds, the cotyledon forms a more or less roundish body, as in *Peltandra*, *Orontium* and *Aglaonema.* The sheath, formed by the base of the cotyledon, and opens with a slit on the anterior face, has been observed in all the species with albuminous seeds, but not in the other ones, *Peltandra*, *Orontium* and *Aglaonema.* The first leaf next the cotyledon is mostly scale-like, and is, at least in the species described above, in constant alternation with the cotyledon, like the epiblast of the Gramineæ.

The presence of a hypocotyl has been observed in *Smilax* and *Agave*, and a distinct epicotyl was found in *Smilax*, *Carludovica* and *Anthurium.*

The primary root does not always fade away as soon as is usually described as characteristic of the Monocotyledoneæ, and we have seen several cases of a rather strong development, and of a considerably long duration in *Attalea*, *Yucca* and *Anthurium.*

U. S. National Museum, Washington. June, 1890.

EXPLANATION OF THE ABBREVIATIONS USED IN THE PLATES.

B,.....Bud.
Br.....Branch.
C.....Hypocotyl.
Cot....Cotyledon.
E.....Epicotyl.
F.....Flowering Stems.
Fr.....Fruit.
L.....Final Leaf.
l'.....Scale-like Leaf.
Pl.....Plumule.
pr....Prophyllum.
R ....Primary root.
r.....Secondary root.
S.....Shoot.
Sd....Seed.
Sh....Sheath.
Sl.....Slit.
St.....Stem.
T.....Tube.

EXPLANATION OF PLATES.

(Figures all drawn from nature by the Author.)

PLATE V.

Anemone thalictroides.

Fig. 1. A germinating plantlet, nat. size.
2. A cotyledon, 5 × nat. size.
3. A young plant, shortly after the cotyledons have dropped, nat. size.
4. A plant, one year old, nat. size.
5. The rhizome of the full-grown plant, nat. size.

Thalictrum dioicum.

Fig. 6. A germinating plantlet, nat. size.
7. A germinating plantlet, showing the distinct hypocotyl, nat. size.
8. The rhizome and the lower part of the stem of an older specimen, nat. size.
9. The rhizome of a full-grown plant, nat. size.

Ranunculus abortivus.

Fig. 10. A germinating plantlet, 3 × nat. size.
11. The same, a little older, 3 × nat. size.

PLATE VI.

Ranunculus abortivus (continued).

Fig. 12. A germinating plantlet, a little older than Figs. 10 and 11, 3 × nat. size.
13. An older stage of the same, 3 × nat. size.
14. A young plant, from which the cotyledons have dropped, and of which the hypocotyl and the primary root have commenced to fade away, 2 × nat. size.

Fig. 15. The rhizome of a full-grown plant with the leaves and the bases of two flowering stems, nat. size.

Ranunculus recurvatus.

Fig. 16. A germinating plantlet, 3 × nat. size.

Delphinium nudicaule.

Fig. 17. A germinating plantlet, side view, nat. size.
18. The same, front view, nat. size.
19. The blades of the two cotyledons, 1⅔ × nat. size,
20 The blade of a cotyledon from the specimen Fig. 18, 1⅔ × nat. size.
21. The blades of three cotyledons, 1⅔ × nat. size.

PLATE VII.

Delphinium nudicaule (continued).

Fig. 22. An older specimen with the cotyledons still persisting, nat. size.

Sarracenia purpurea.

Fig. 23. A germinating plantlet with the testa of the seed still attached, 6 × nat. size.
24. The same, a little older with the cotyledons free and spread out, 6 × nat. size.
25. The same with the first pitcher-shaped leaf developed, 6 × nat. size.
26. A young plant with the cotyledons still attached, and with several pitcher shaped leaves developed, 3 × nat. size.
27. The first developed pitcher-shaped leaf, 6 × nat. size.

Sanguinaria Canadensis.

28. A germinating plantlet, nat. size.
29. One of the cotyledons, 5 × nat. size.
30. A germinating plantlet with two leaves developed next the cotyledons, nat. size.

PLATE VIII.

Sanguinaria Canadensis (continued).

Fig. 31 and 32. Two germinating plantlets with the cotyledons dropped, nat. size.
33 and 34. Two plants, one year old, showing the scale-like leaves preceding the final one and the tuber, formed by the hypocotyl,
nat. size.
35. The rhizome of a full-grown plant, nat. size.
36. A lateral shoot from an old rhizome, nat. size.

Viola palmata, var. *cucullata.*

Fig. 37. A germinating plantlet, 2 × nat. size.
38. The rhizome of a young plant. with the cotyledons dropped, 2 × nat. size.
39. The rhizome of an older, flowering plant, 2 × nat. size.

PLATE IX.

Viola palmata var. *cucullata* (continued).

Fig. 40. A young plant, showing the swelling of the hypocotyl, 2 × nat. size.
41. A young plant with the cotyledons still attached, 3 × nat. size.
42. A leaf with the swollen base, nat. size.

Lespedeza violacea.

Fig. 43. A germinating plantlet, nat. size.
44. The rhizome of a full-grown plant, nat. size.

Lespedeza procumbens.

Fig. 45. A germinating plantlet, nat. size.
46. The rhizome of a full-grown plant, nat. size.

Clitoria Mariana.

Fig. 47. A germinating plantlet, nat. size.
48. One of the cotyledons, nat. size.

PLATE X.

Clitoria Mariana (continued).

Fig. 49. The rhizome of a full-grown plant, nat. size.

Cassia Chamaecrista.

Fig. 50. A germinating plantlet, 2 × nat. size.

Rubus hispidus.

Fig. 51. A germinating plantlet, nat. size.
52. A young plant, one year old, nat. size.

Potentilla Canadensis.

Fig. 53. A germinating plantlet, nat size.
54. The rhizome of a full-grown plant, nat. size.

Saxifraga Virginiensis.

Fig. 55. A germinating plantlet, 6 × nat. size.
56. The same, a little older, 6 × nat. size.
57. A young plant with the cotyledons, still attached, and several leaves developed, 6 × nat. size.
58. A young plant, 3 × nat. size.
59. A stellate hair from one of the first developed leaves, highly magnified.

Dionaea muscipula.

Fig. 60. A germinating plantlet with the cotyledons still enclosed in the seed, 4 × nat. size.

Fig. 61. The same, a few days older, with the cotyledons free, 4 × nat. size.

PLATE XI.

Dionaea muscipula (continued).

Fig. 62. A young plant, showing the first leaves next the cotyledons, 4 × nat. size.

63. The same, a little older, with the first secondary root visible, 6 × nat. size.

64. The rhizome of an old plant. 2 × nat. size.

65. The same, longitudinal section, 2 × nat. size.

Thaspium barbinode.

Fig. 66. A germinating plantlet, nat. size.

67. A germinating plantlet with three cotyledons, nat. size.

68. A young plant with the cotyledons dropped, nat. size.

Thaspium aureum.

Fig. 69. A germinating plantlet, nat. size.

Osmorrhiza longistylis.

Fig. 70. A germinating plantlet, 2 × nat. size.

71. A young plant, one year old, showing a leaf, different from the first one figured in Fig. 70, nat. size.

Sanicula Marylandica.

Fig. 72. One of the cotyledons, 4 × nat. size.

73. A germinating plantlet, 2 × nat. size.

74. A young plant, showing the strongly developed secondary roots, nat. size.

Aralia spinosa.

Fig. 75. A germinating plantlet, 3 × nat. size.

PLATE XII.

Ipomœa paniculata.

Fig. 76. A germinating plantlet, nat. size.

77. A germinating plantlet with four cotyledons, the two of which have grown together, nat. size.

78. The base of the petioles of the four cotyledons with the plumule and the upper part of the root, nat. size.

Rheum Moorcroftianum.

Fig. 79. A germinating plantlet, showing the cotyledons with connate petioles, forming a tube, through the base of which the plumule has come out, side view, nat. size.

Fig. 80. The same, front view, showing the slit in the lower part of the tube, nat. size.
81. Transverse section of the half of the tube, highly magnified.

Pilea pumila.

Fig. 82. A germinating plantlet. Nat. size.
83. One of the second pair of leaves next the cotyledons. Nat. size.

PLATE XIII.

Sabal Palmetto.

Fig. 84. The first stage of the germination with a longitudinal section, nat. size.
85. The same, a little older, nat. size.
86. A young plant, where the cotyledon has dropped, and the first leaves have developed, nat. size.

Nannorrhops Ritchieana.

Fig. 87. A germinating plantlet in the first stage, longitudinal section, nat. size.
88. The same, a little older, × nat. size.
89. An older germinating plantlet, where the plumule has commenced to break through, nat. size.
90. A young plant with two leaves developed, and with the fruit still attached, nat. size.
91. The same, but older, where the primary root has ceased to grow, and the first secondary root has come out, nat. size.

Attalea excelsa.

Fig. 92. The fruit with the germinating seed, nat. size.
93. The same, longitudinal section, nat. size.
94. A germinating plantlet, where the first leaf is visible, the fruit is still attached, nat. size.
95. A young plant, where the fruit has dropped, and the first final leaf has been developed, nat. size.

PLATE XIV.

Carludovica palmata.

Fig. 96. A germinating plantlet with the cotyledon free; two leaves are developed, nat. 5 × size.
97. The same, a little older, with the cotyledon enclosed in the seed, 5 × nat. size.
98. The same still more advanced, showing the first secondary root and four leaves; the seed is still attached, 5 × nat. size.
99. A young plant, of which the primary root has stopped its growth, while two secondary ones have come out, 5 × nat. size.

Agave univittata.

Fig. 100. A germinating plantlet, of which the cotyledon is bent, and the seed attached, nat. size.

101. The same, a little older, nat. size.

102. The same, with the seed dropped, and the cotyledon free and straight. A longitudinal slit is to be seen at the base of the cotyledon for the penetration of the plumule, nat. size.

Eucharis candida.

Fig. 103. The first stage of the germinating plantlet, where the plumule is not yet visible, nat. size.

104. A young plant with the cotyledon free ; the first leaf has developed and a secondary root has come out, nat. size.

PLATE XV.

Smilax rotundifolia.

Fig. 105. A germinating plantlet, with the fruit attached, nat. size.

106. Part of the same, showing the cotyledon, the epicotyl, the hypocotyl and the first leaf, 5 × nat. size.

107. The same, with the sheath of the cotyledon laid open to show the bud in the axil of the cotyledon, 5 × nat. size.

108. The lower part of an older specimen, where the fruit has dropped, and the first secondary root has developed, 3 × nat. size.

109. The same, with the sheath of the cotyledon removed to show the bud in the axil of the cotyledon, 3 × nat. size.

110. A young plant, where a secondary branch has developed from the axil of the cotyledon, nat. size.

111. The base of a young plant, where a tuber has developed from the axil of the cotyledon, 2 × nat. size.

112. The rhizome of a full grown plant, nat. size.

113–120. Leaves of different forms from young plants, nat. size.

121. A leaf of a full-grown plant, showing the typical form, nat. size.

122. A leaf of a full-grown plant, the form of which is very common, but not typical, nat. size.

Smilax glauca.

Fig. 123. A germinating plantlet, nat. size.

PLATE XVI.

Smilax glauca (continued).

Fig. 124. The rhizome of a younger plant, showing one tuber, 2 × nat. size.

125. The same, 2 × nat. size.

126. The rhizome of an older plant with three tubers, 2 x nat. size.

127. Tuberiferous stolons of a full grown plant, nat. size.

Hemerocallis fulva.

Fig. 128. A germinating plantlet, 3 × nat. size.
129. A young plant, where the seed and the cotyledon have dropped ; the first secondary root has been developed, 3 × nat. size.

Yucca gloriosa.

Fig. 130. A germinating plantlet with the seed attached, nat. size.
131. Part of the same, longitudinal section, showing the upper part of the cotyledon, enclosed in the albumen, 3 × nat. size.
132. An older stage of the germination, nat. size.
133. A germinating plantlet, showing the first appearance of the plumule, nat. size.
134. The same, a little older, where the first leaf has developed, nat. size.

PLATE XVII.

Yucca gloriosa (continued).

Fig. 135. An older stage, where the cotyledon commences to fade away, nat. size.
136. A young plant with the sheath of the cotyledon still persistent, nat. size.
137. A young plant, showing the development of six leaves and three secondary roots, while the primary root has faded away, only leaving a scar, R in the figure, nat. size.

Peltandra undulata.

Fig. 138. The fruit, nat. size.
139. The seed, surroünded by the jelly, nat. size.
140. The first stage of the germination ; the testa of the seed has been removed, nat. size.
141. The same more advanced, front and side view ; the plumule and some roots are visible, nat. size.
142. A germinating plantlet, side view ; the plumule, the primary root and two secondary roots are visible, nat. size.
143. The same, front view, nat. size.
144. A germinating plantlet, where the second leaf begins to come out, nat. size.
145. The same (side view), a little older, where the primary root has faded away ; three leaves and three secondary roots are visible, nat. size.
146. The same, front view, nat. size.

PLATE XVIII.

Peltandra undulata (continued).

Fig. 147. A young plant, showing the development of the leaves and roots side view ; the cotyledon still attached, nat. size.
148. The same, a little older, nat. size.

Fig. 149. Diagram, showing the position of the roots.

Orontium aquaticum

Fig. 150. A germinating plantlet, showing the primary root and three leaves, front view, nat. size.

151. The same, a little older, side view, nat. size.

152. A young plant with five leaves and four roots developed; the cotyledon is still attached.

Anthurium Andraeanum.

Fig. 153. The fruit, 3 × nat. size.

154. The seed, 5 × nat. sixe.

155. The first stage of the germination, 5 × nat. size.

156. A germinating plantlet, showing the cotyledon, the plumule and the primary root, 6 × nat. size.

157. A germinating plantlet, a little older, where the cotyledon is enclosed in the seed, and where the first leaf has been developed, 6 × nat. size.

158. The first developed leaf, magnified.

PLATE XIX.

Anthurium Andraeanum (continued).

Fig. 159. A germinating plantlet, where the secondary leaf is visible, 6 × nat. size.

160. A young plant, showing the development of the first internode and four leaves; two secondary roots have come out, 3 × nat. size.

161. The same, a little older, showing the second internode. The seed is still attached, 3 × nat. size.

162. A young plant, five months older than the one in Fig. 161. The seed is still attached, the primary root still persists and several secondary roots have developed from the internodes of the stem, 2 × nat. size.

163. The leaf "L 8" from Fig. 162.

164. A typical leaf, taken from a full-grown plant, ⅕ nat. size.

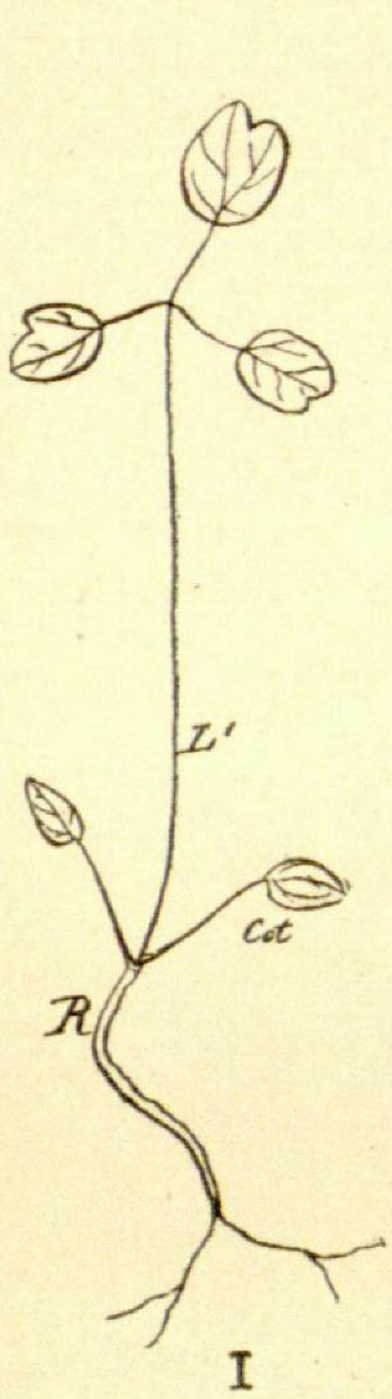
Aglaonema pictum.

Fig. 165. A germinating plantlet, showing three scale-like leaves, 2 × nat. size.

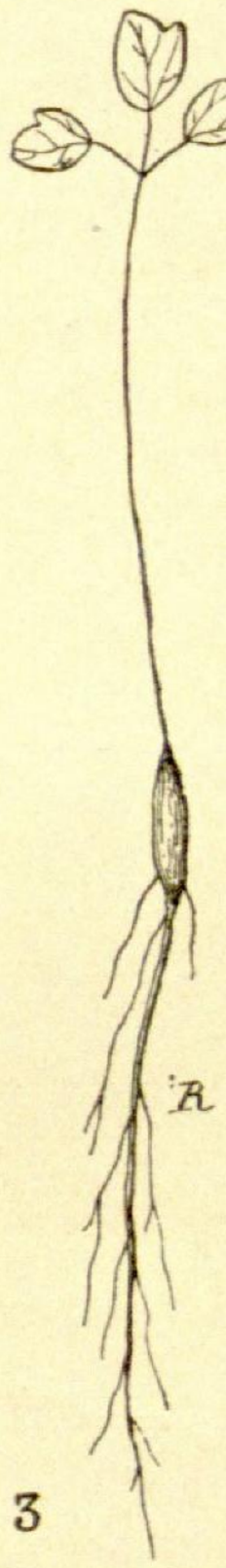
Alisma Plantago var. *Americana.*

Fig. 166. A germinating plantlet, showing the long, terete cotyledon and the primary root, 8 × nat. size.

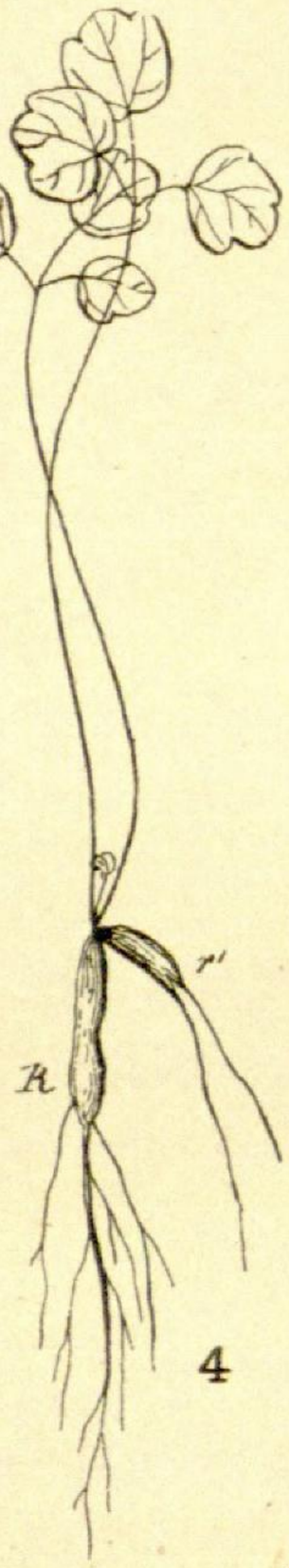
167. The same, a little older, where the plumule is visible, 8 × nat. size.



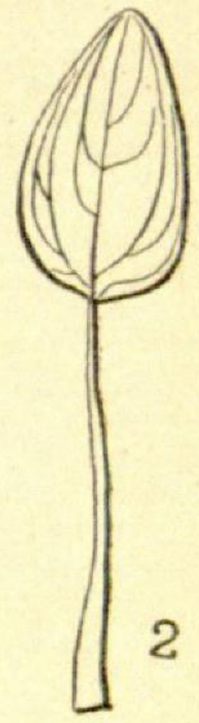
1



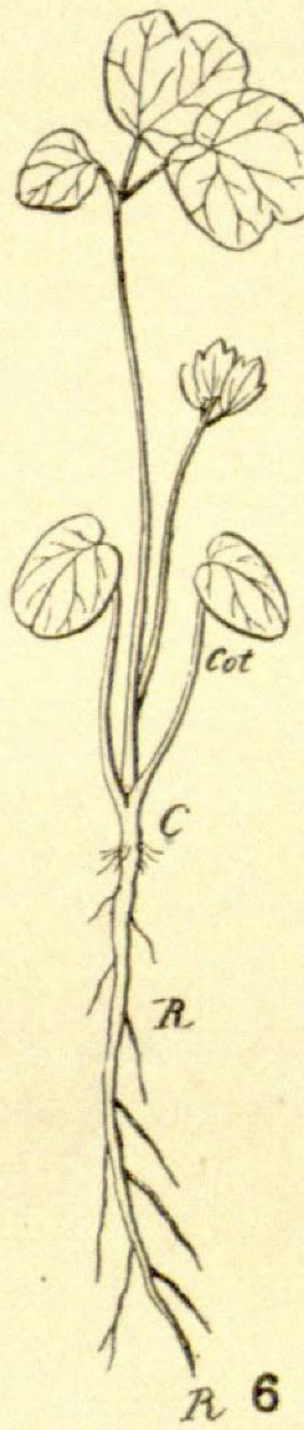
3



4

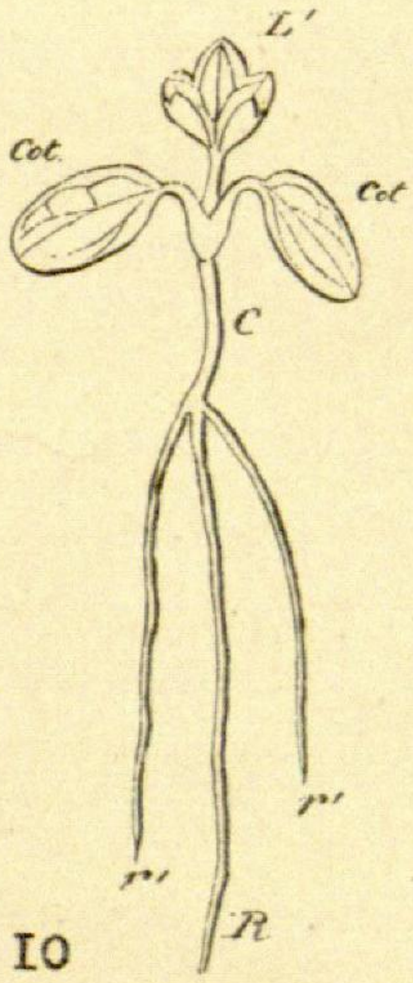


2

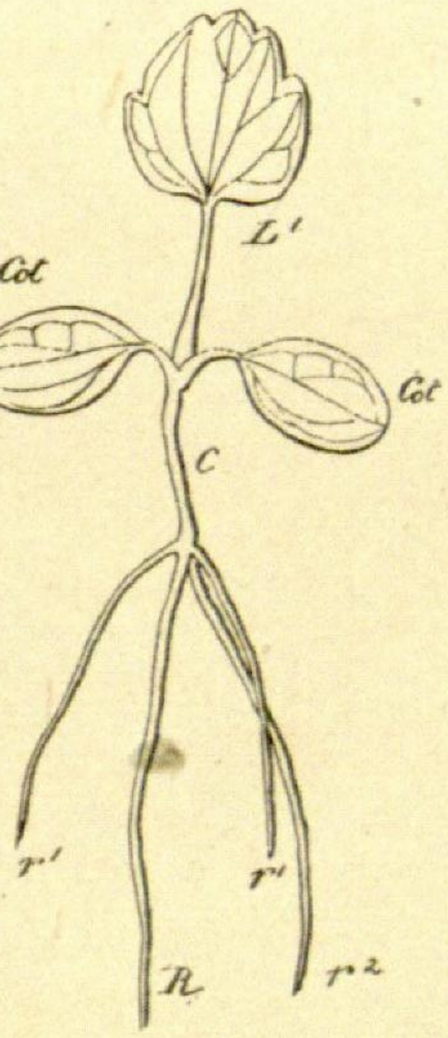


6

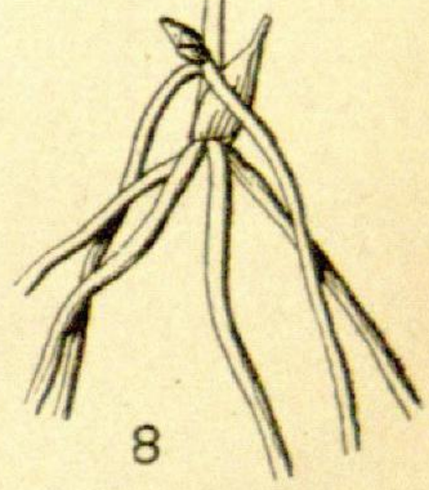
7



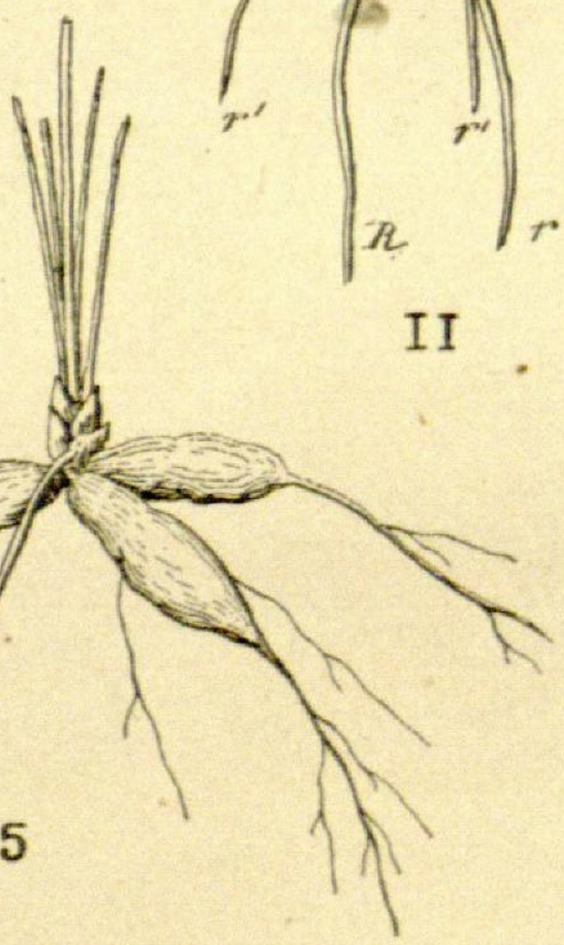
10



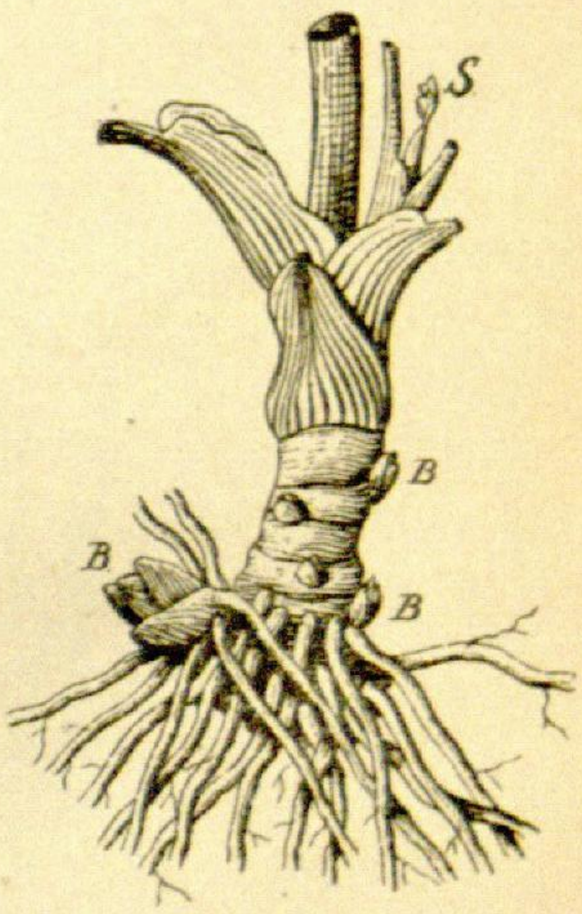
11

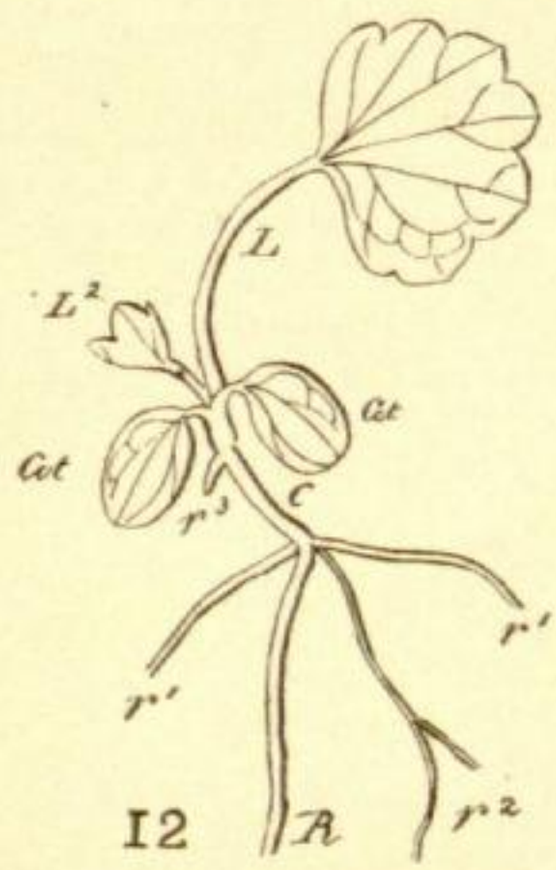


8

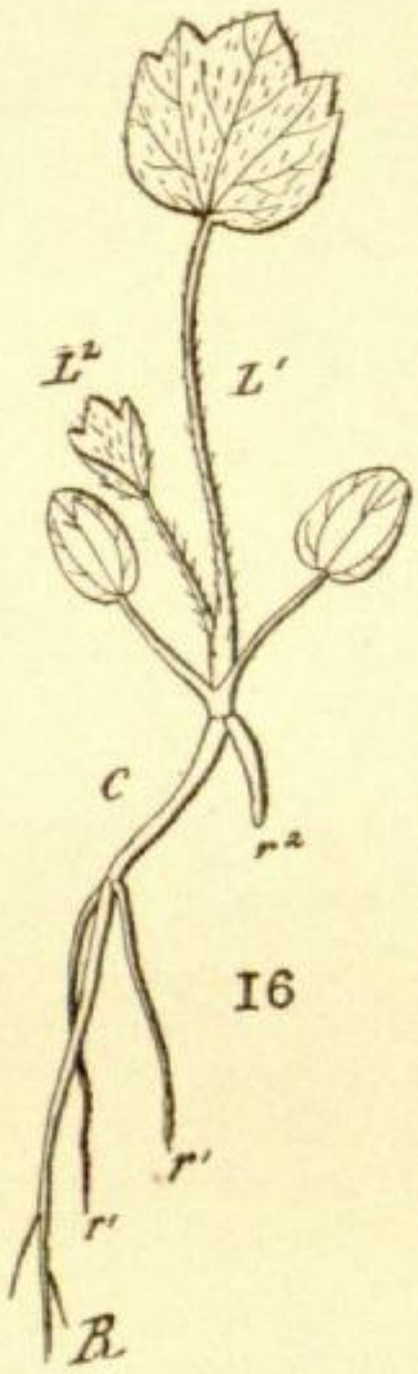


5



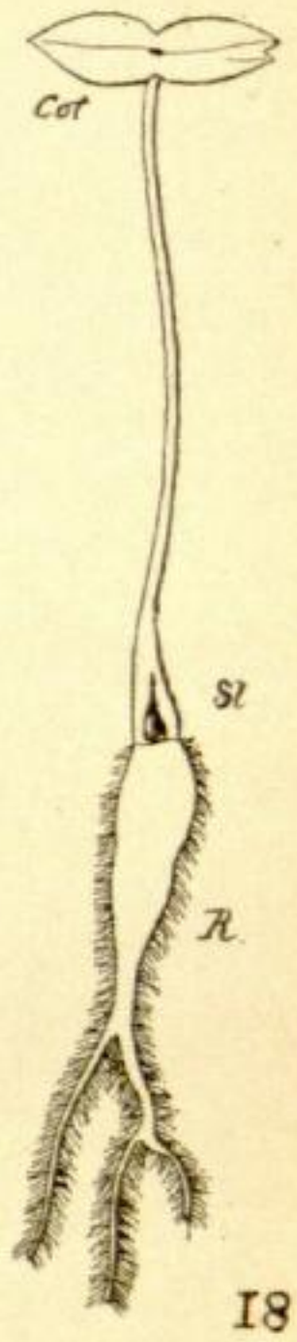


12

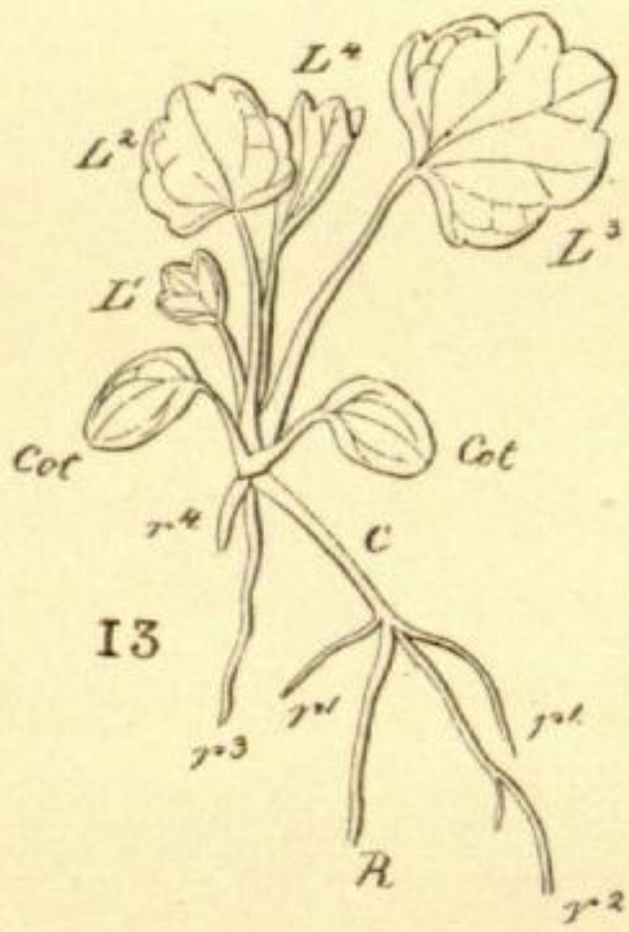


16

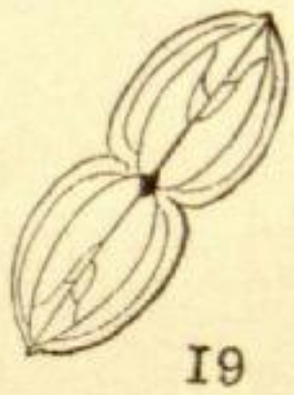
17



18



13



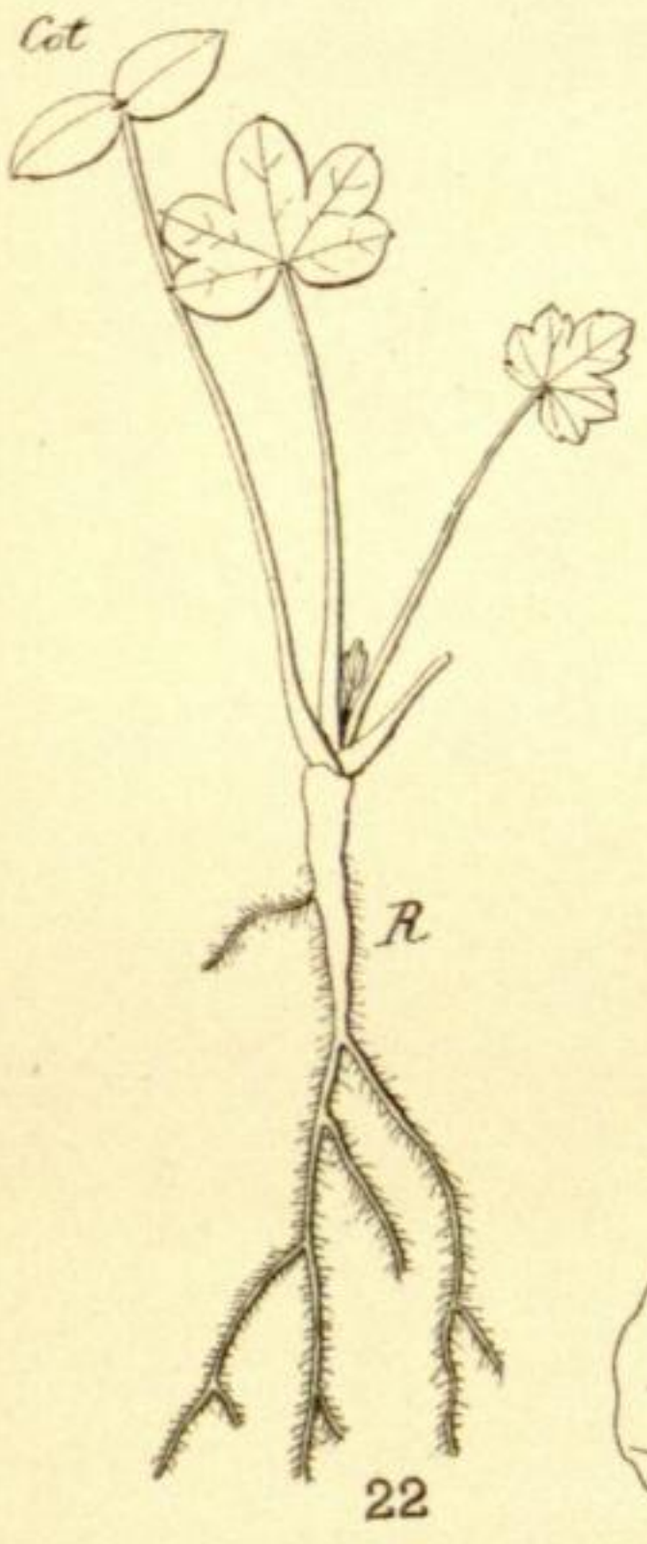
19

20

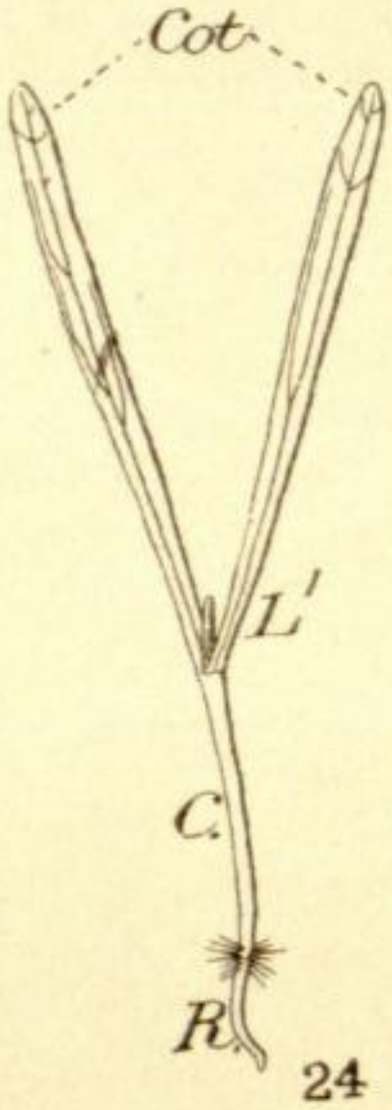
14

21

15

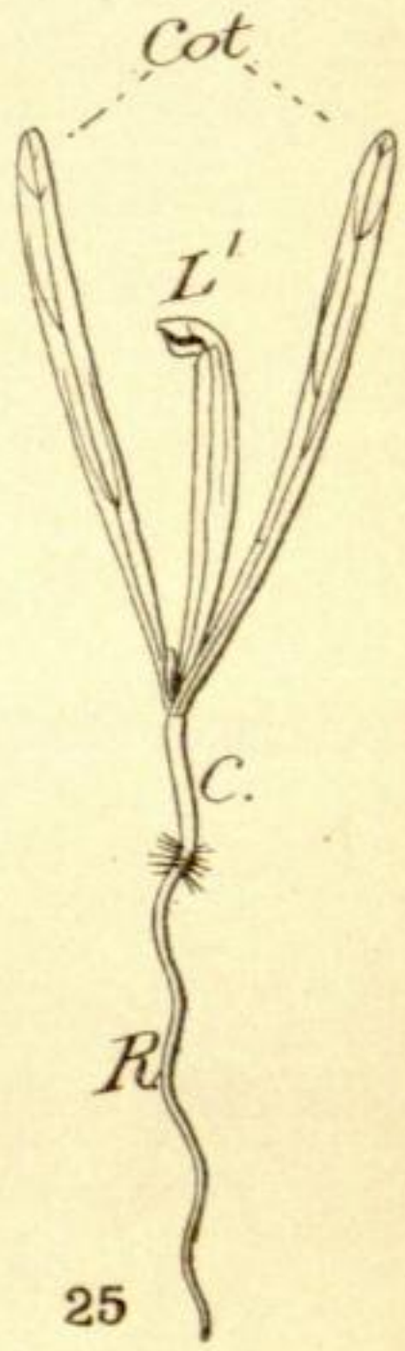


22



24

23



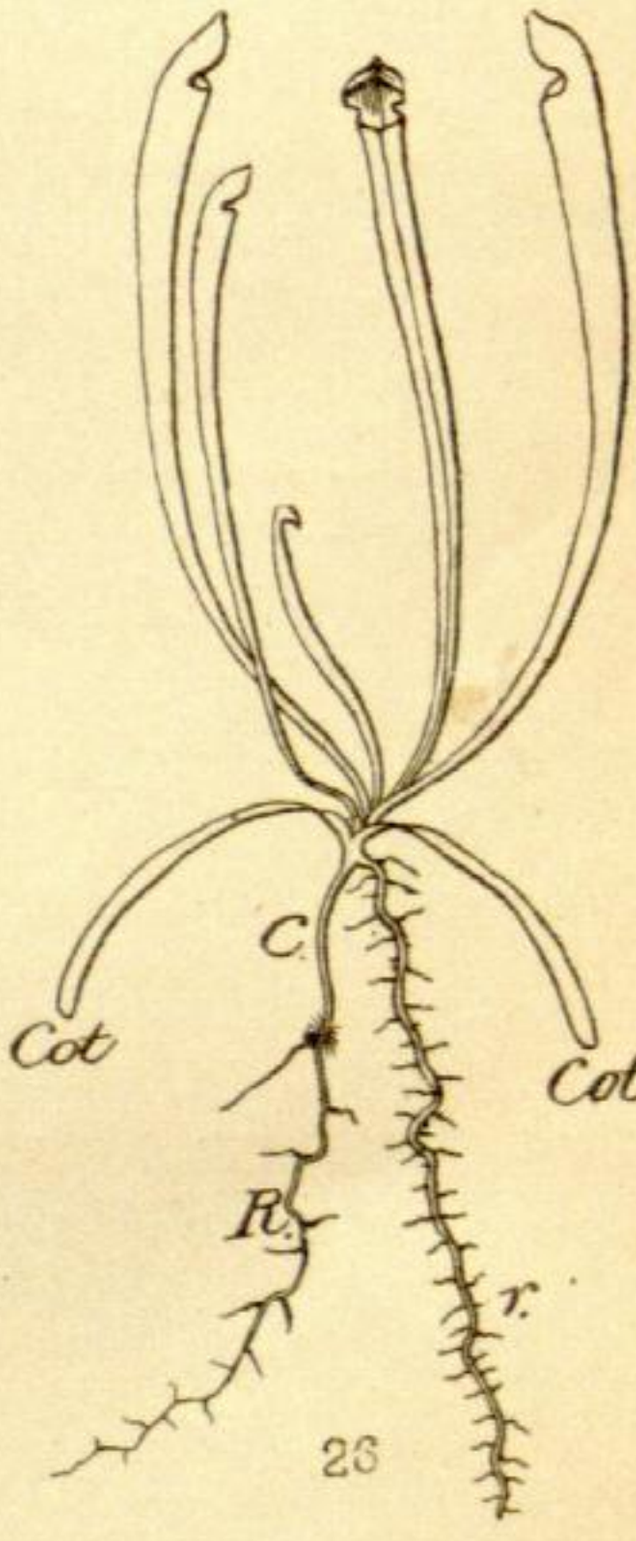
25

29

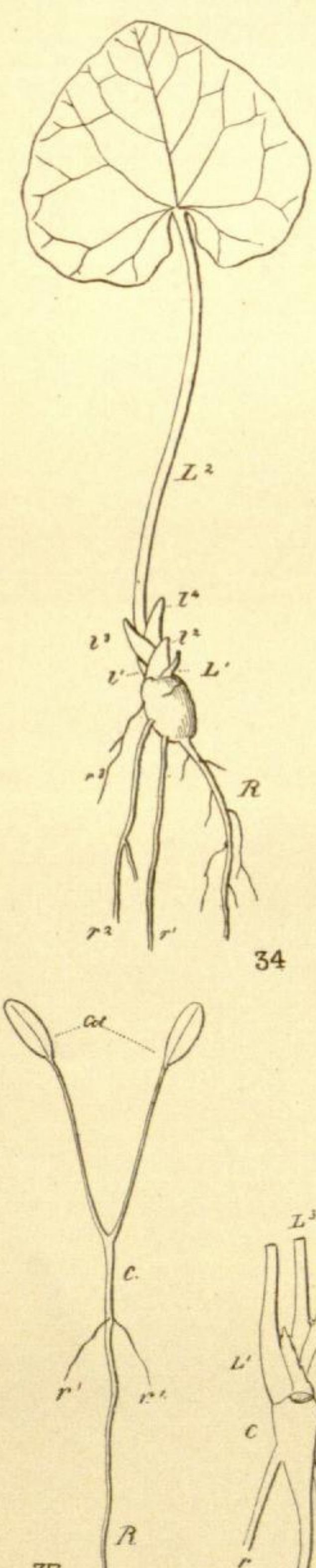
27

28

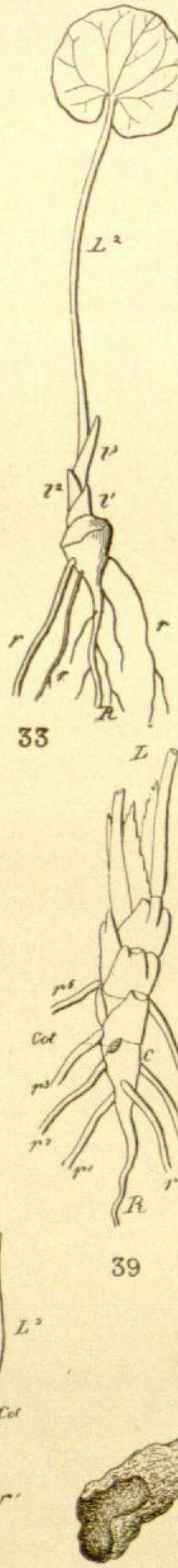
30



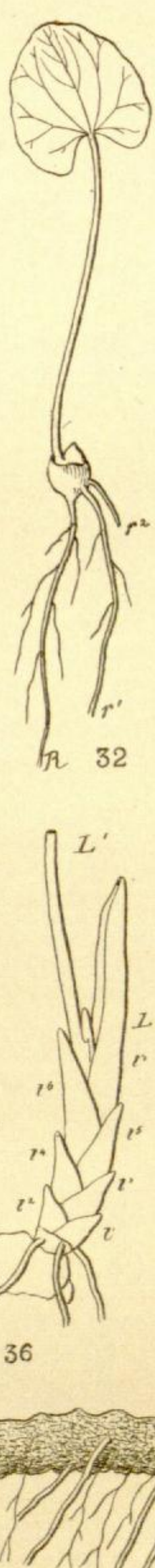
26



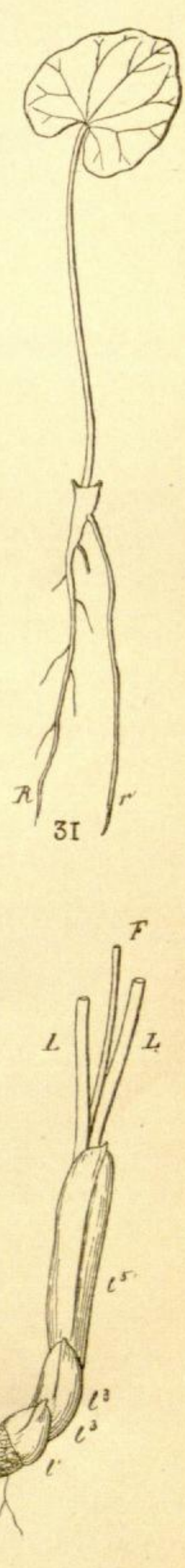
34



33



32



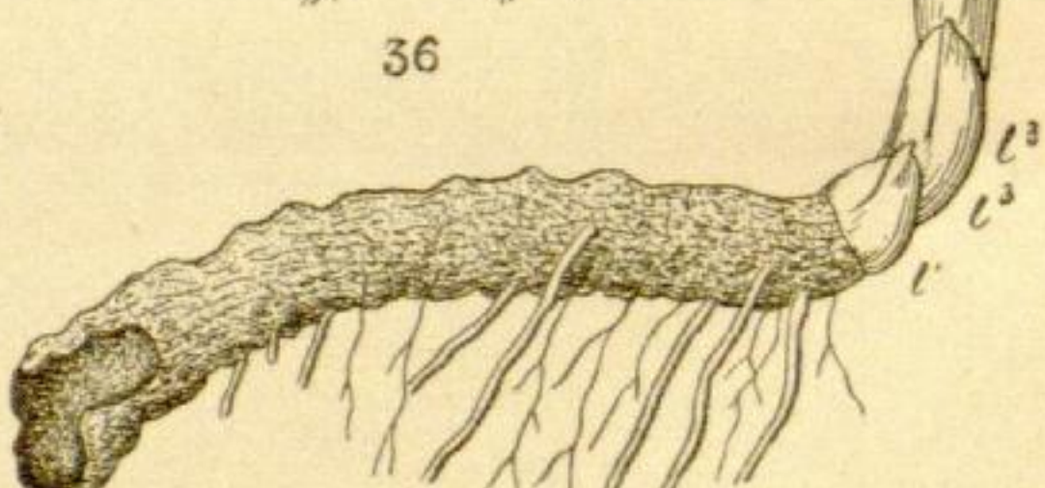
31

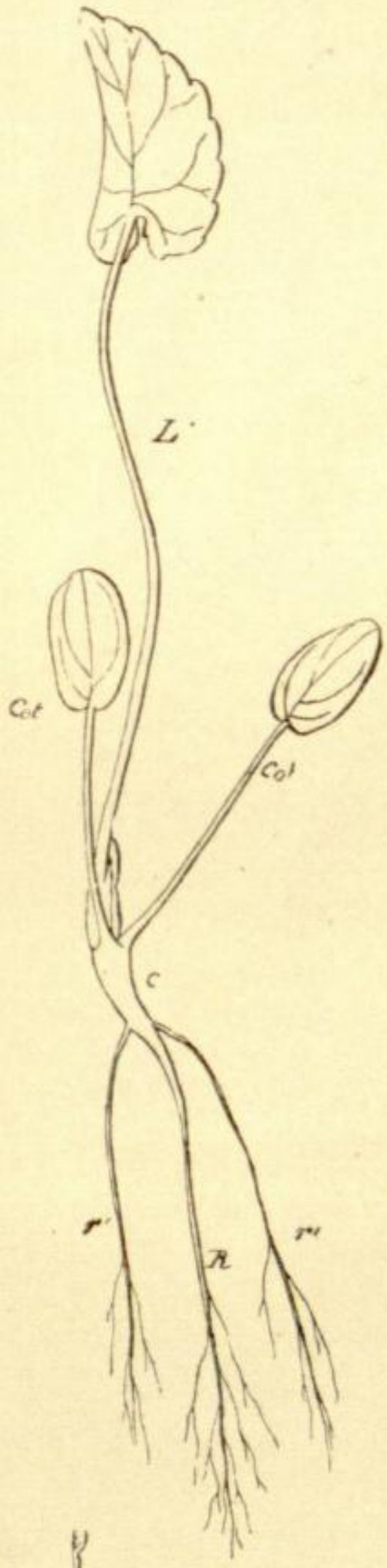
37

38

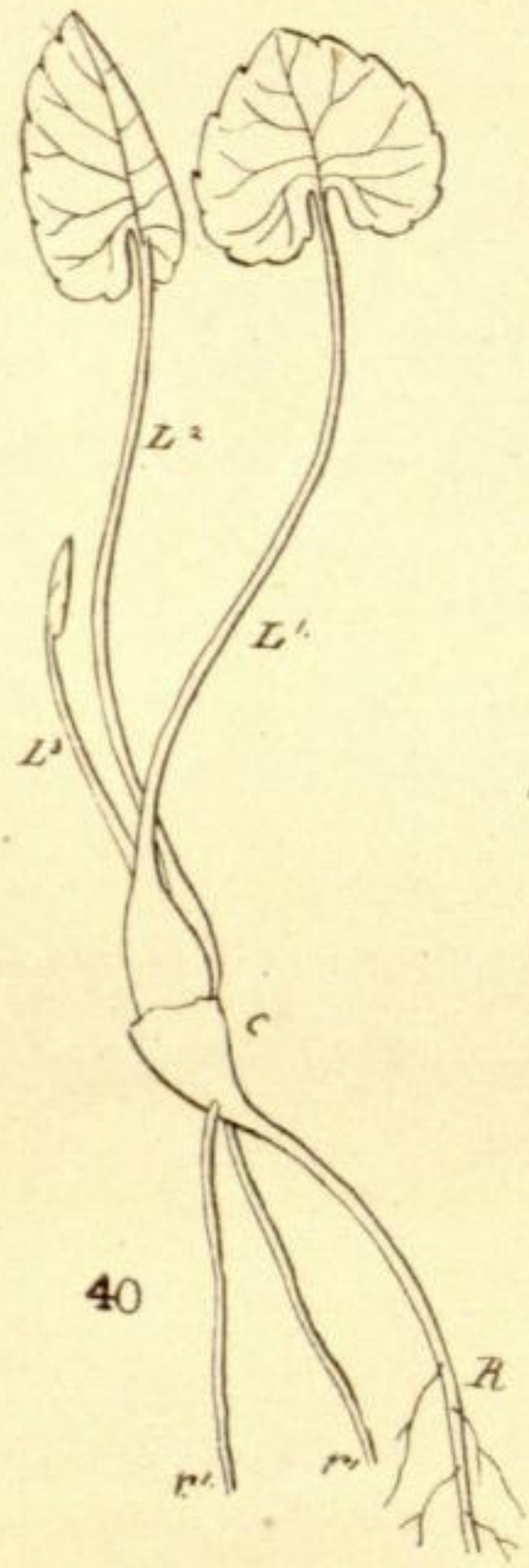
39

36

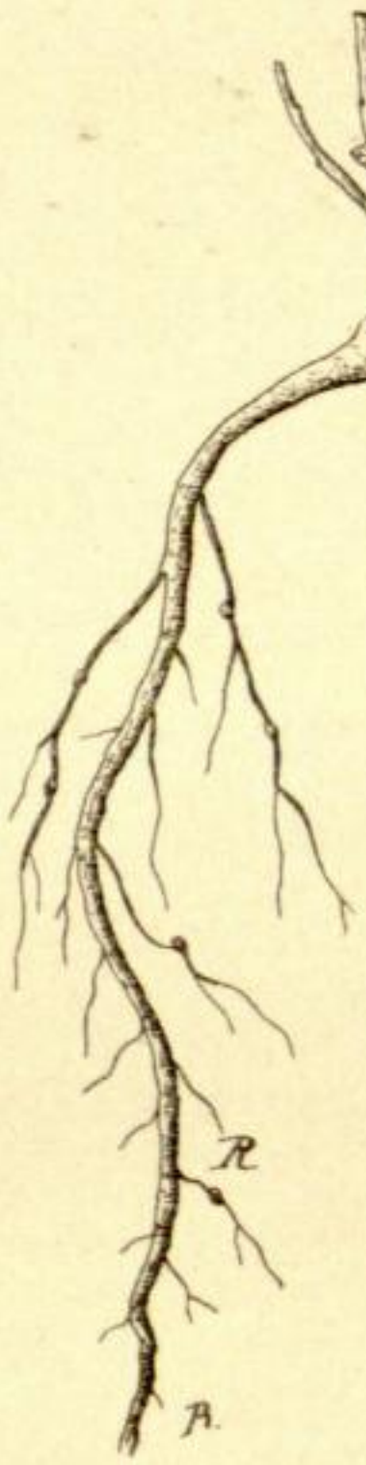

35



41

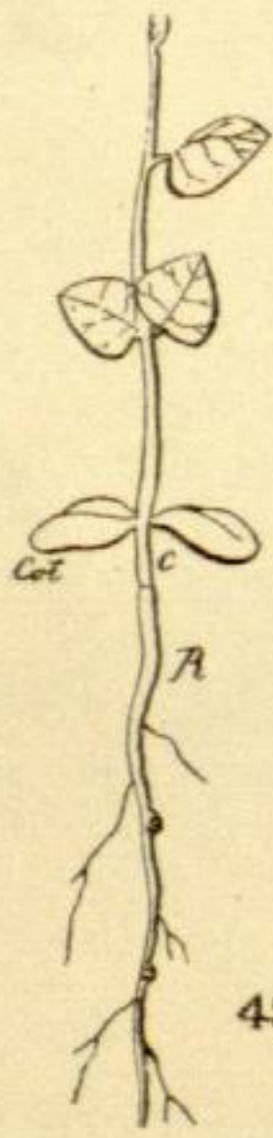


40



44

43

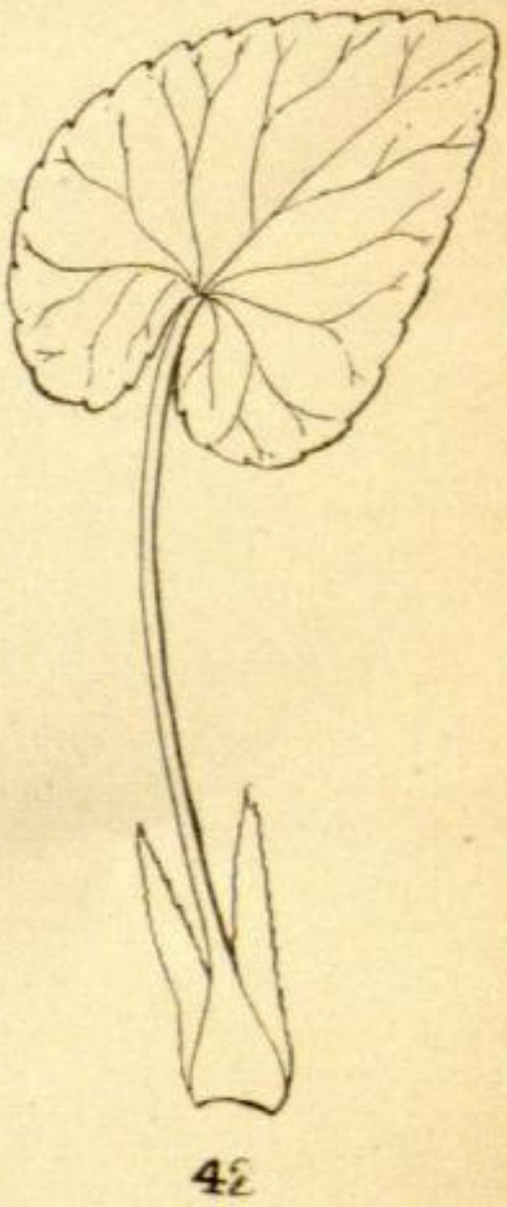


45

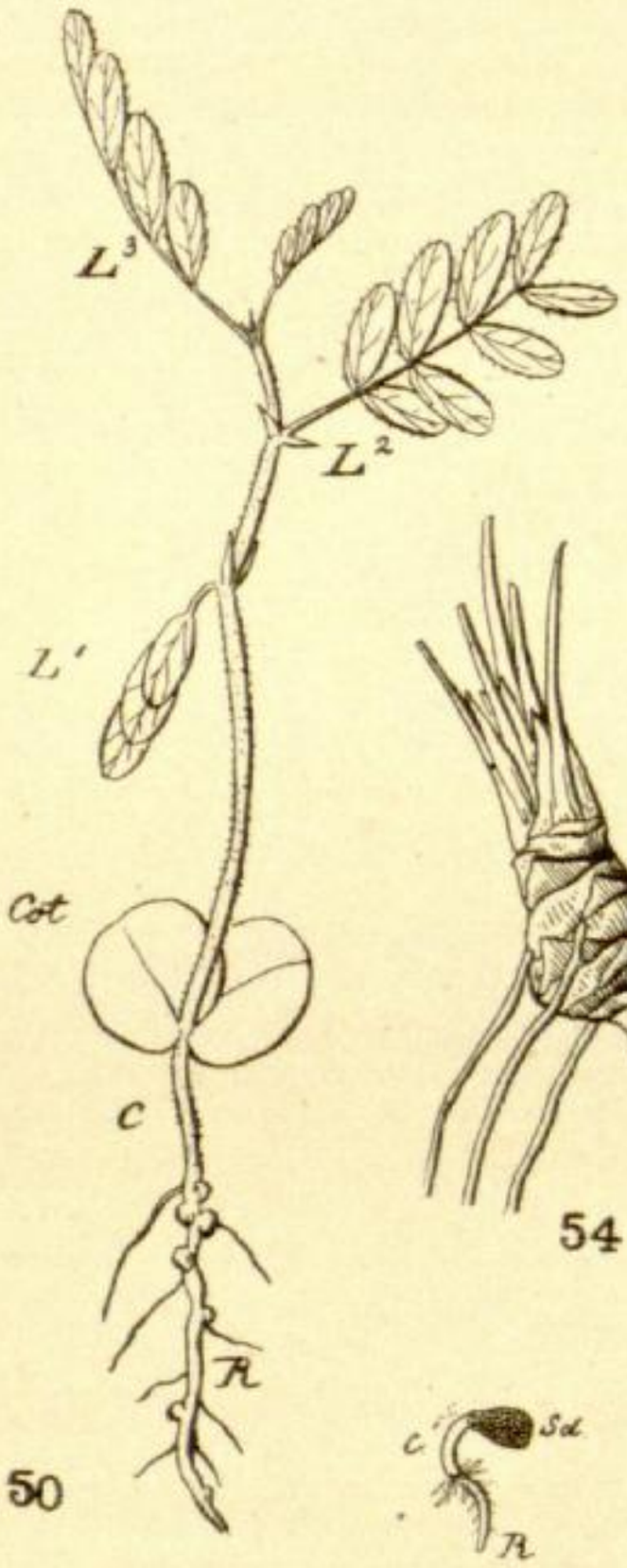
46

48

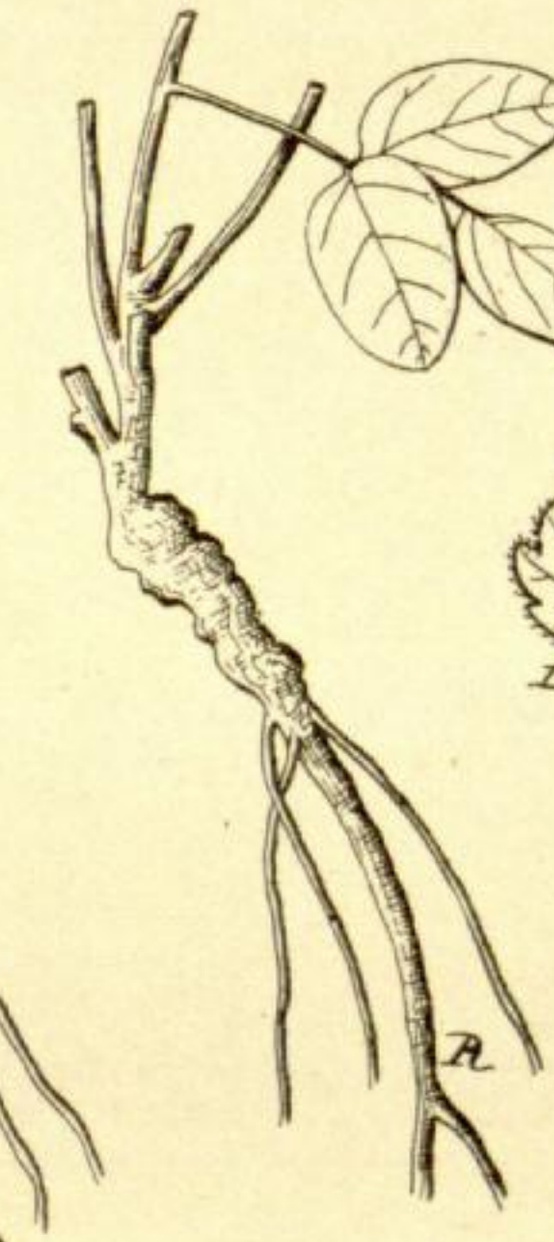
47

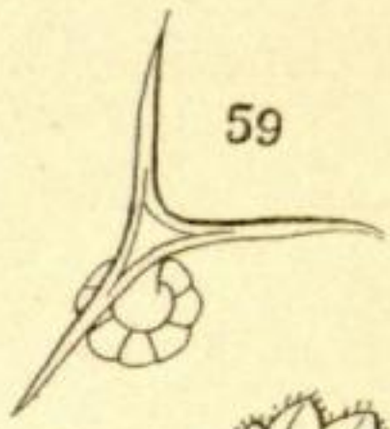


42


L³
L²
L'
Cot
C
R
50

R
54


R
49

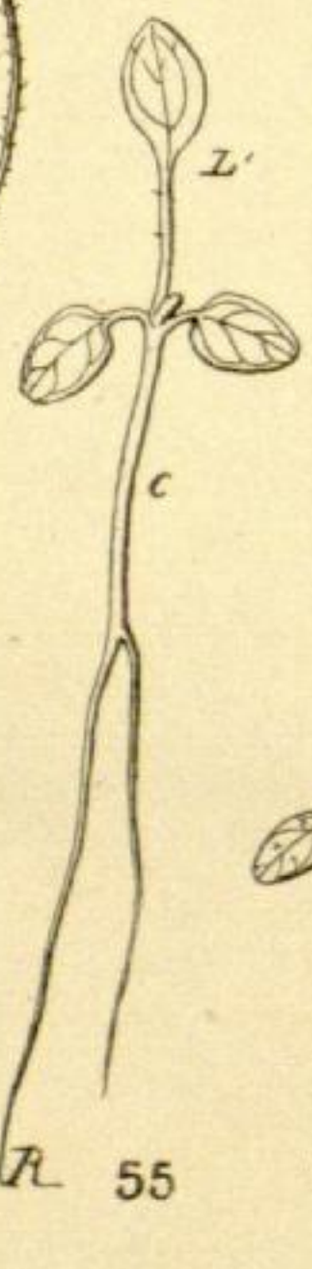

59


L²
L'
Cot
P
C
R
R
51
L'
Cot
R
52

C'
Sd
R
60

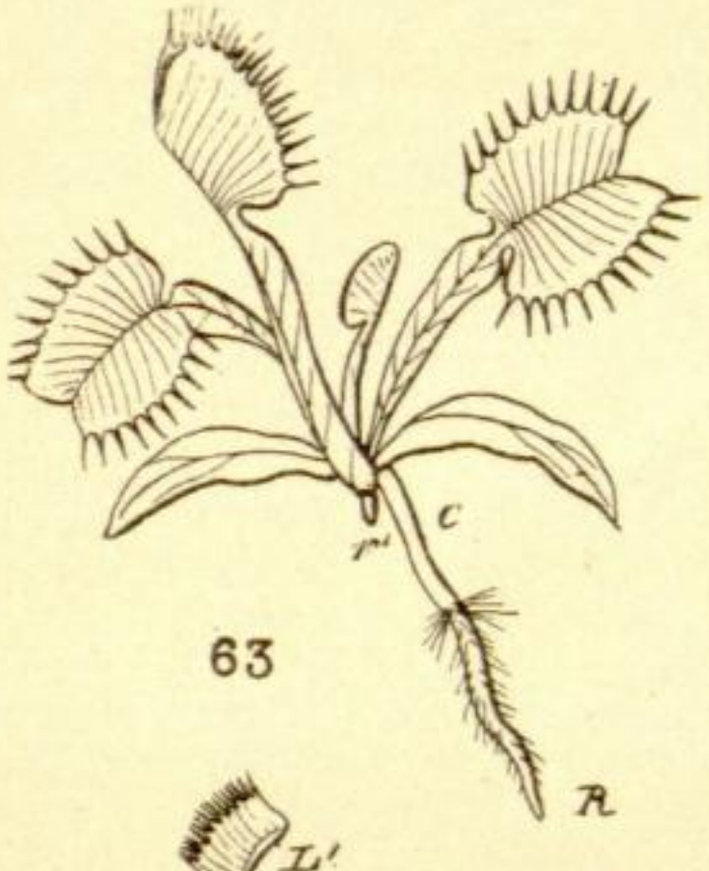

L'
Cot
R
56
Cot
R
57


L³
L²
L'
Cot
C
R
53


L'
C
R
55

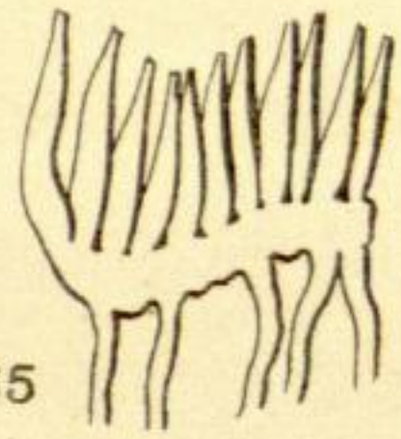
C
58

St¹
St²
r
r
r
R

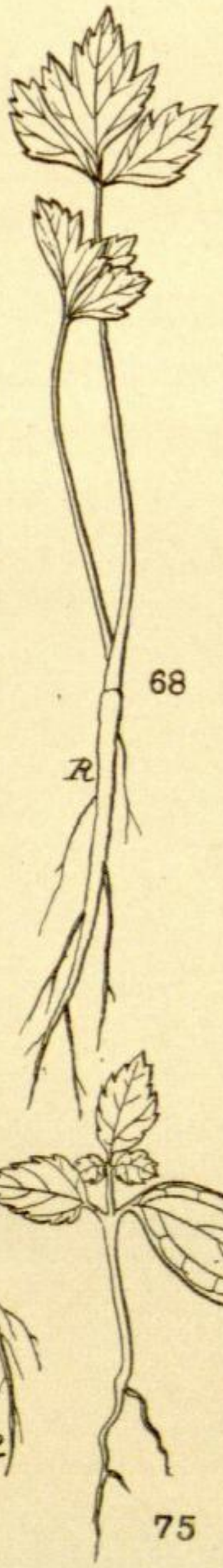


63

62

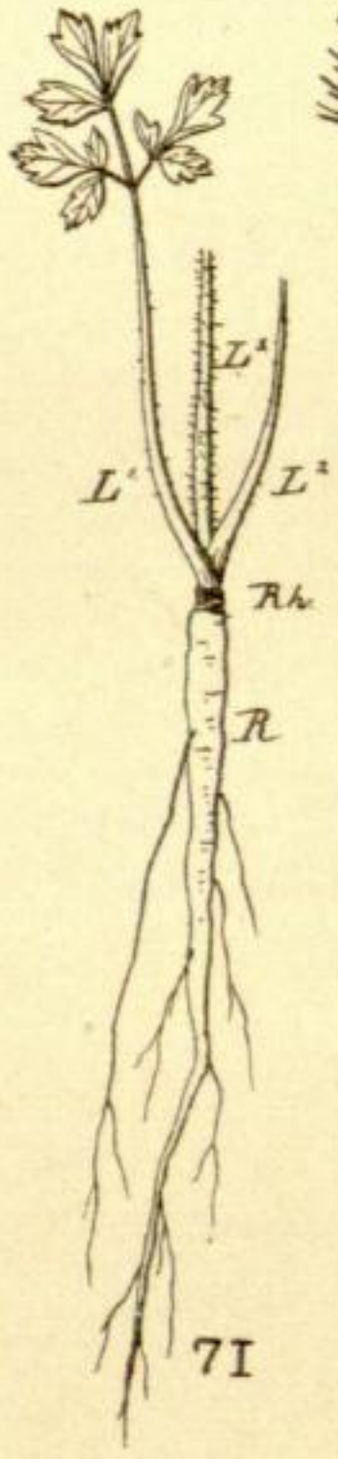


65

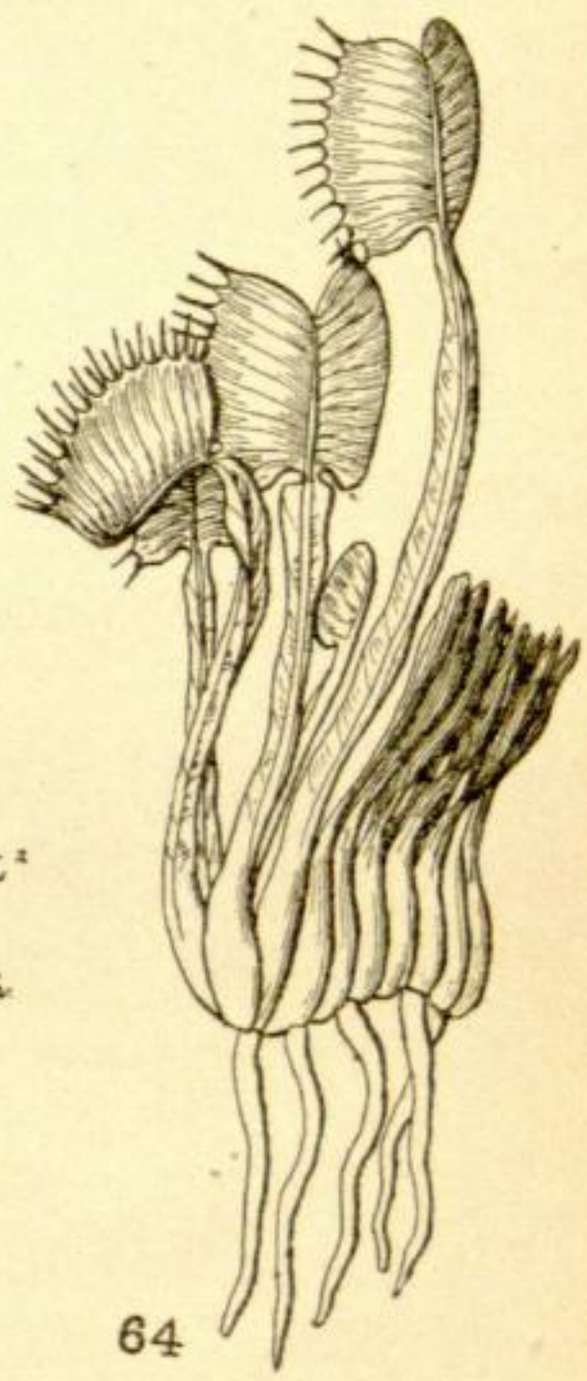


68

70

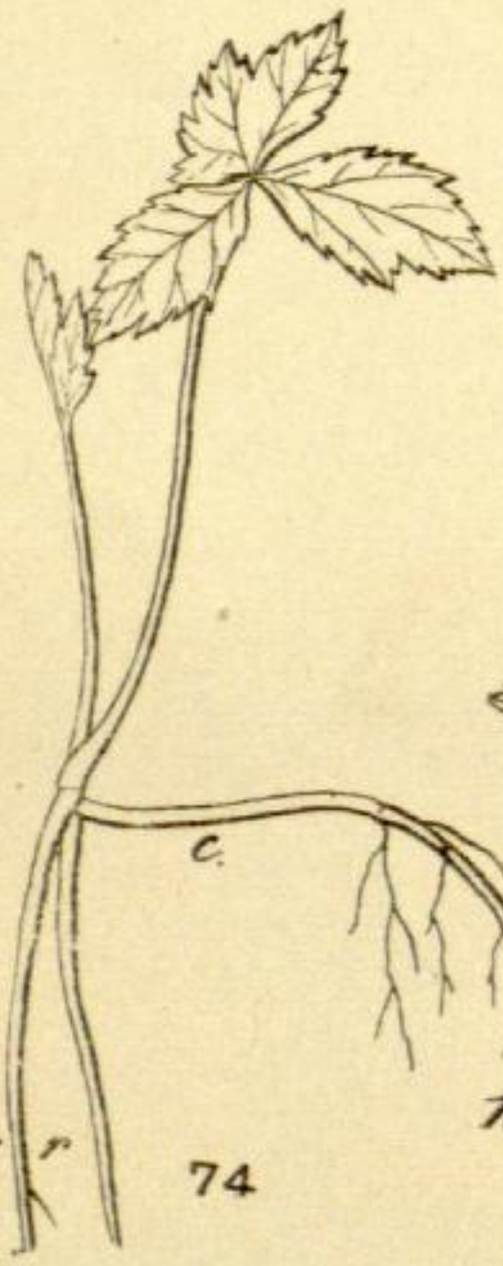


71



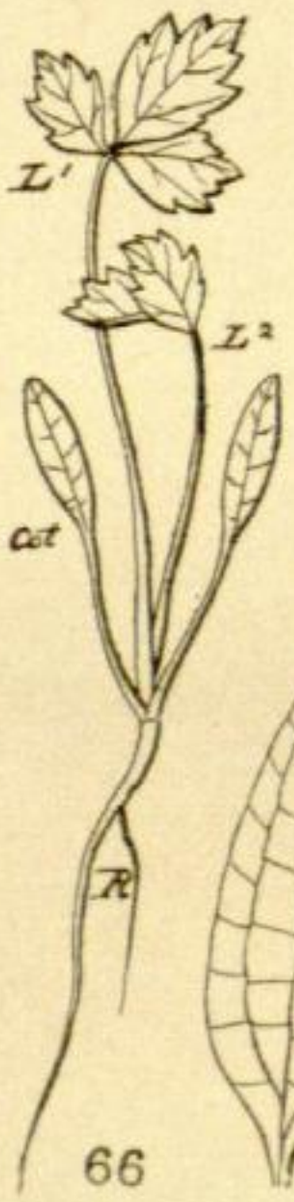
64

69



74

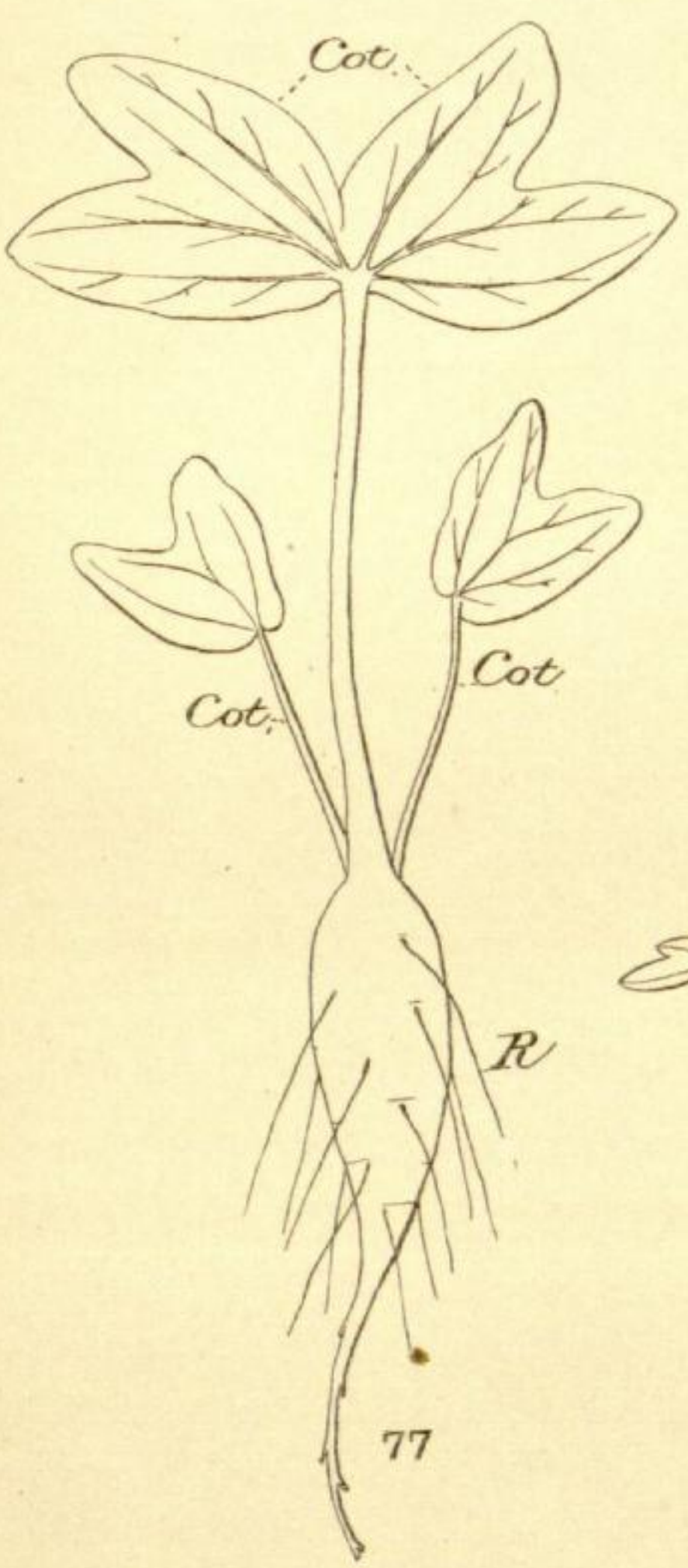
75



66

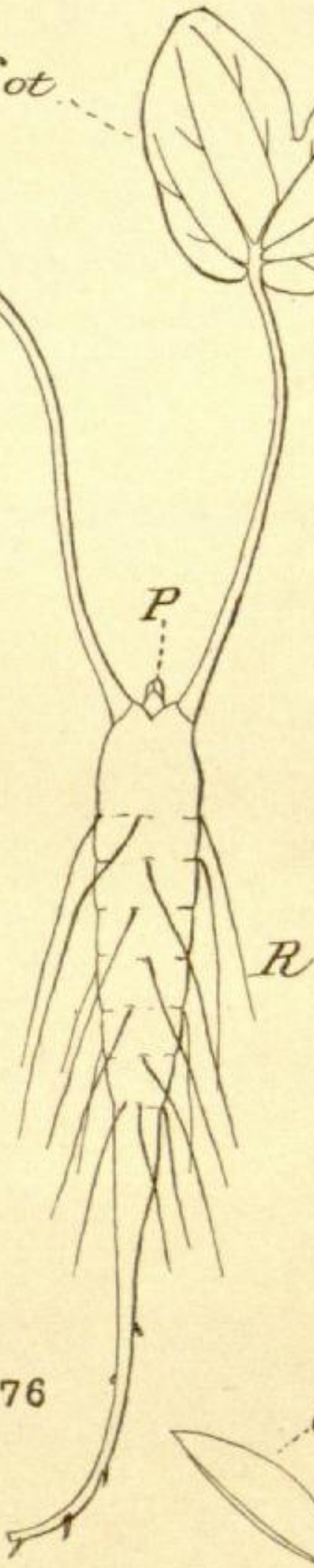
67

73

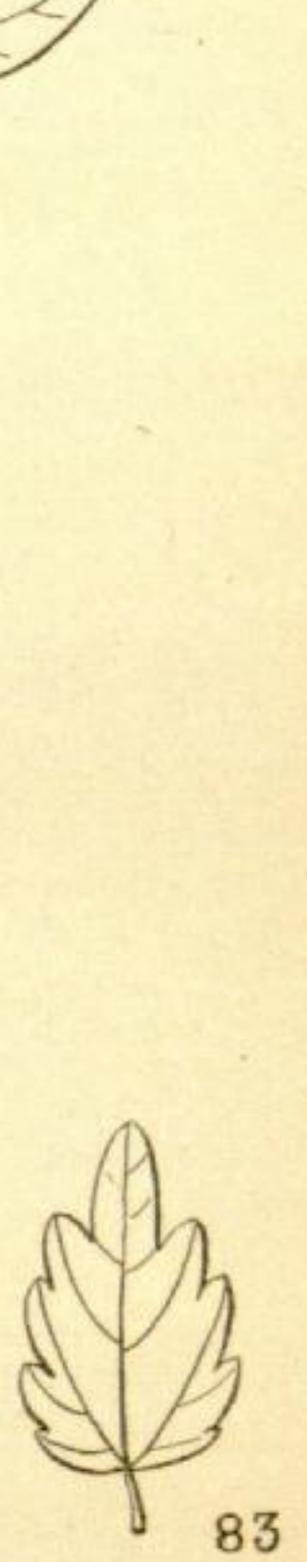


77

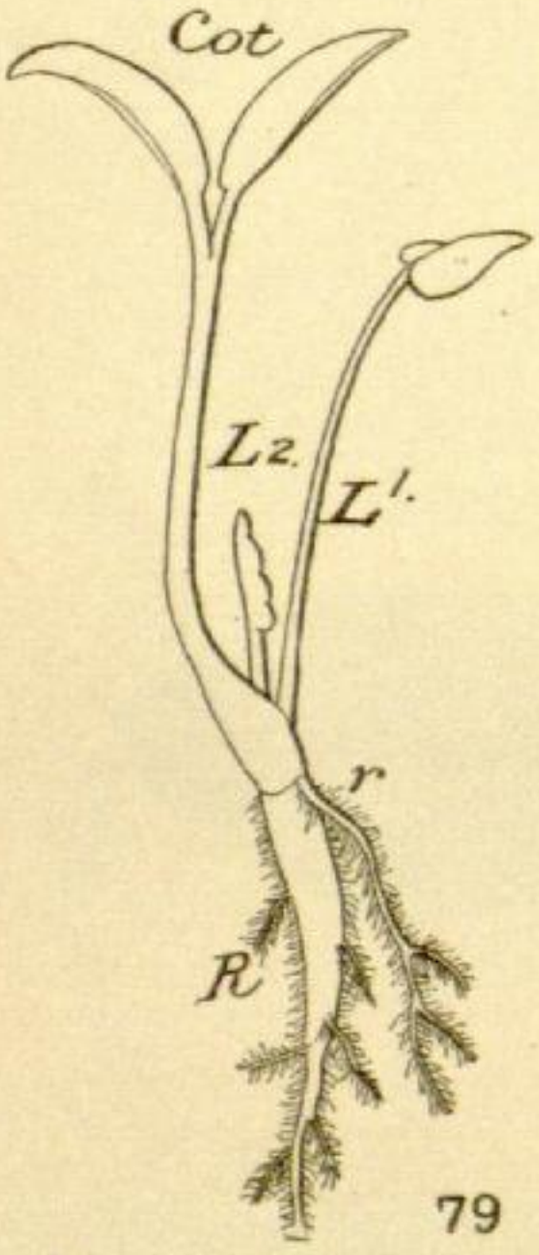
82



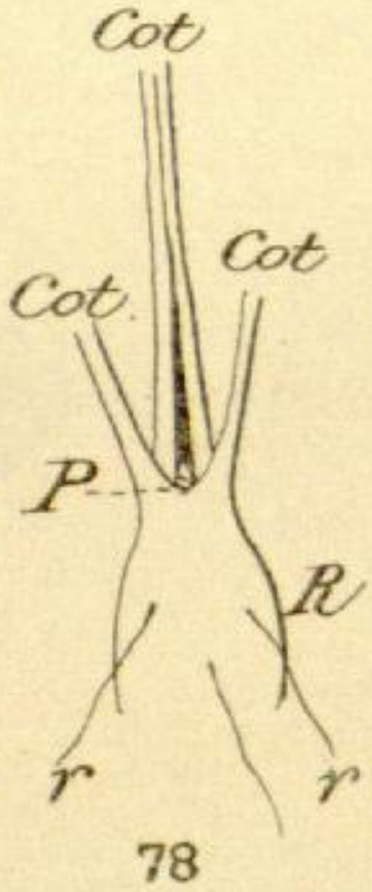
76



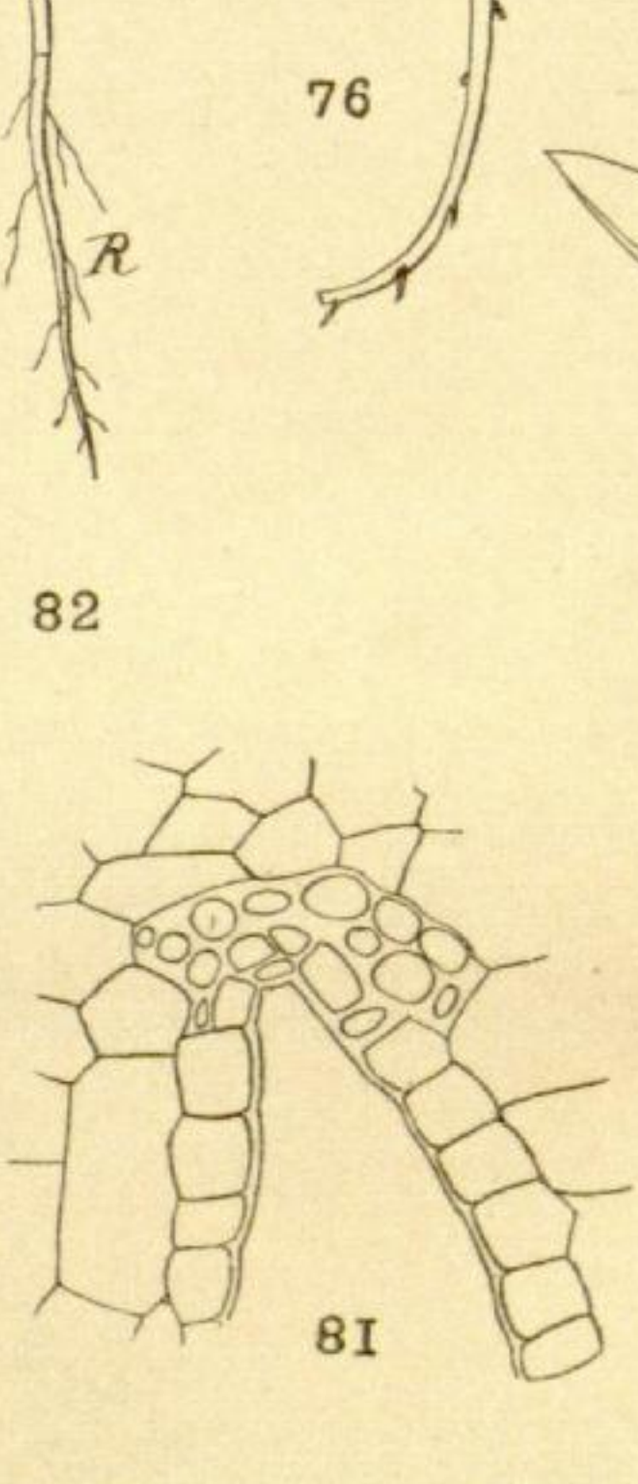
83



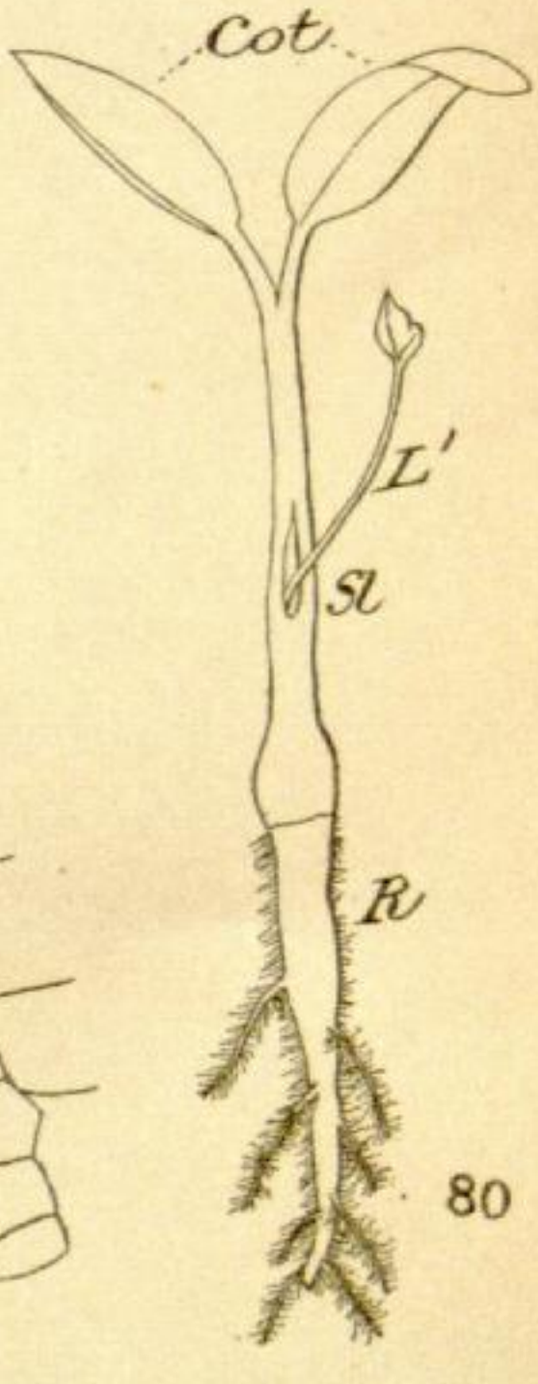
79



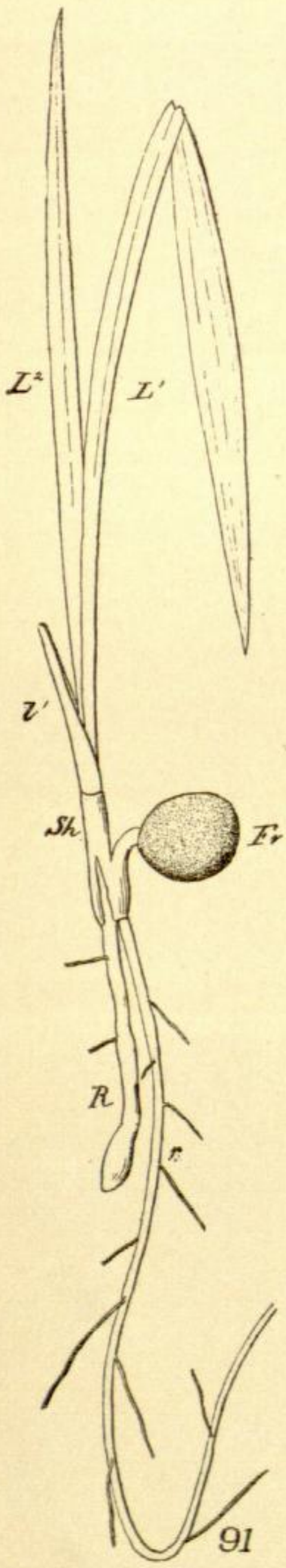
78

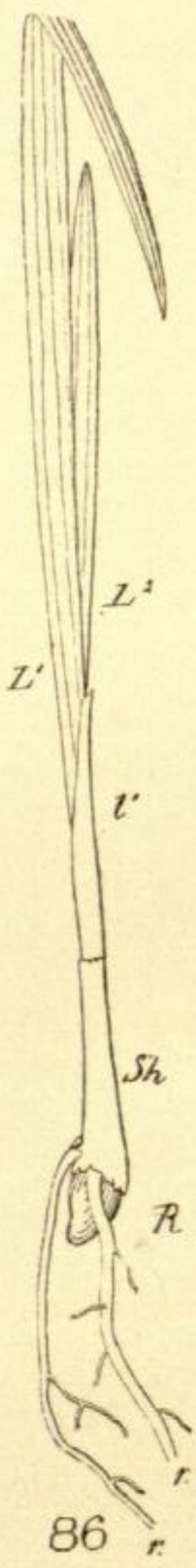


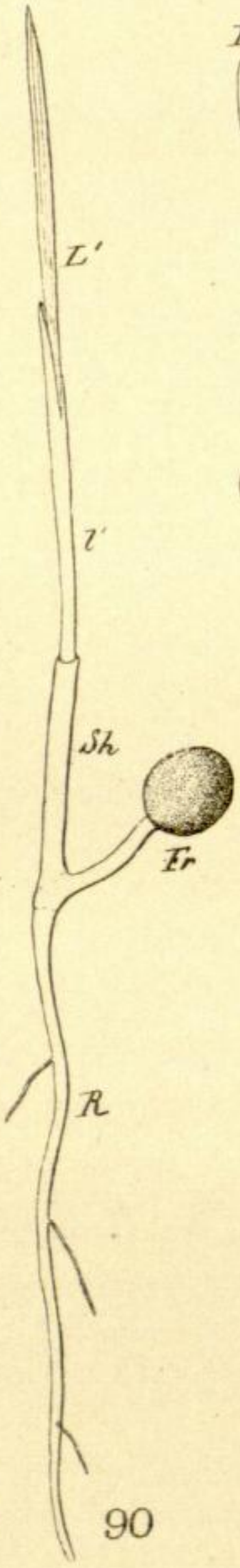
81



80


L²
L'
l'
Sh
Fr
R
r
91

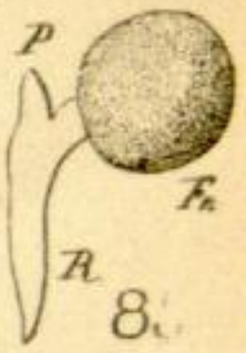

L²
L'
l'
Sh
R
r
86

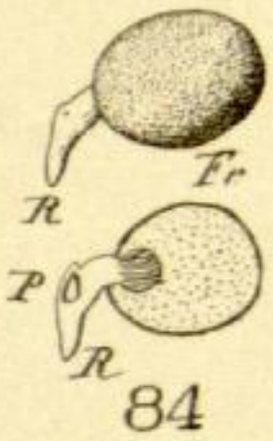

L'
l'
Sh
Fr
R
90


P
Fr
R
89
l'
R
95

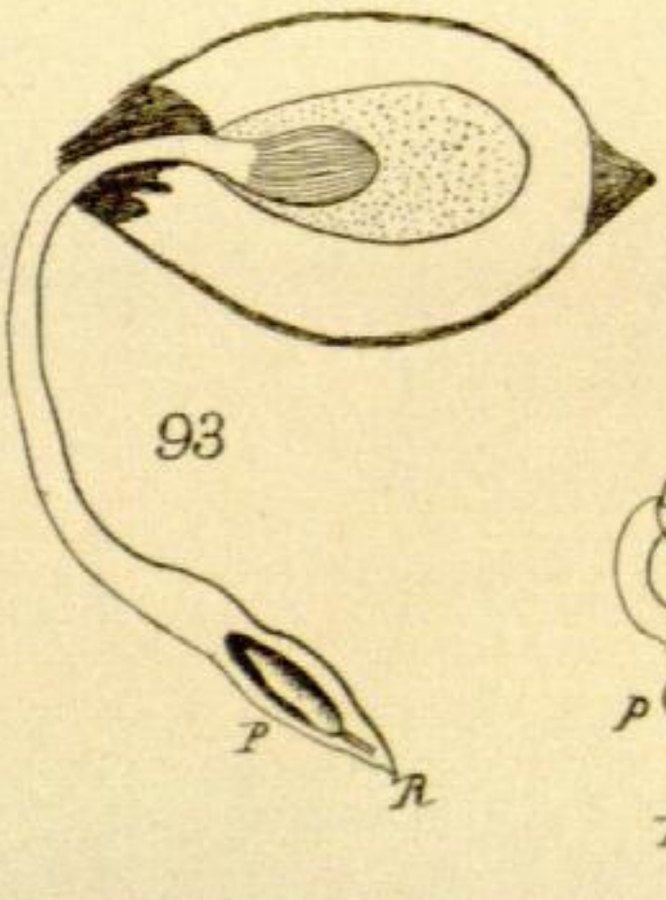

L²
l²
l'
Sh
l'
R
94

F.


P
Fr
R
8

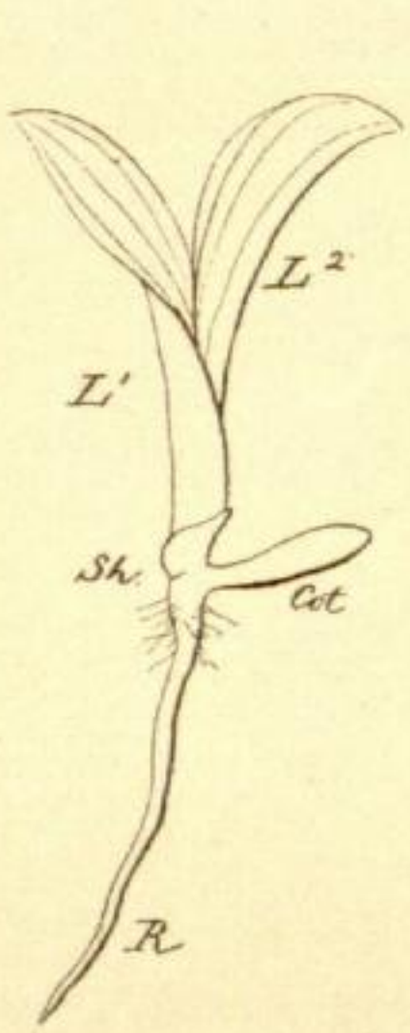

Fr
R
P
R
84

Fr
92

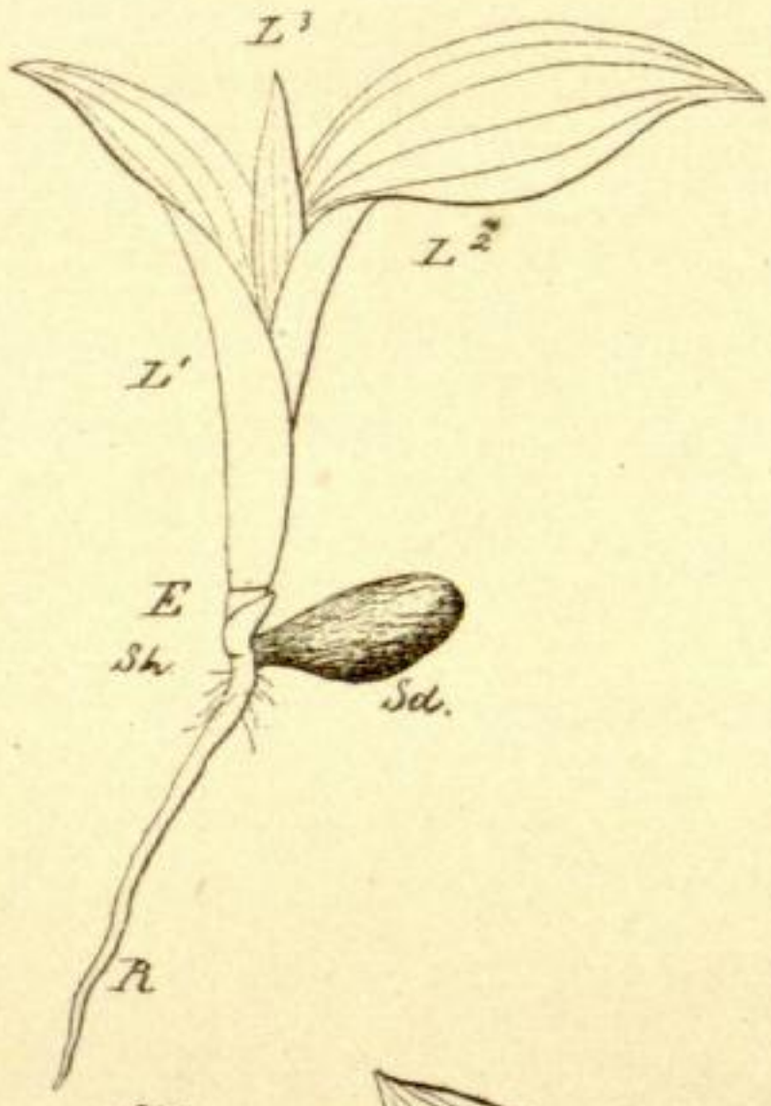

P
R
93


Fr
P
R
87

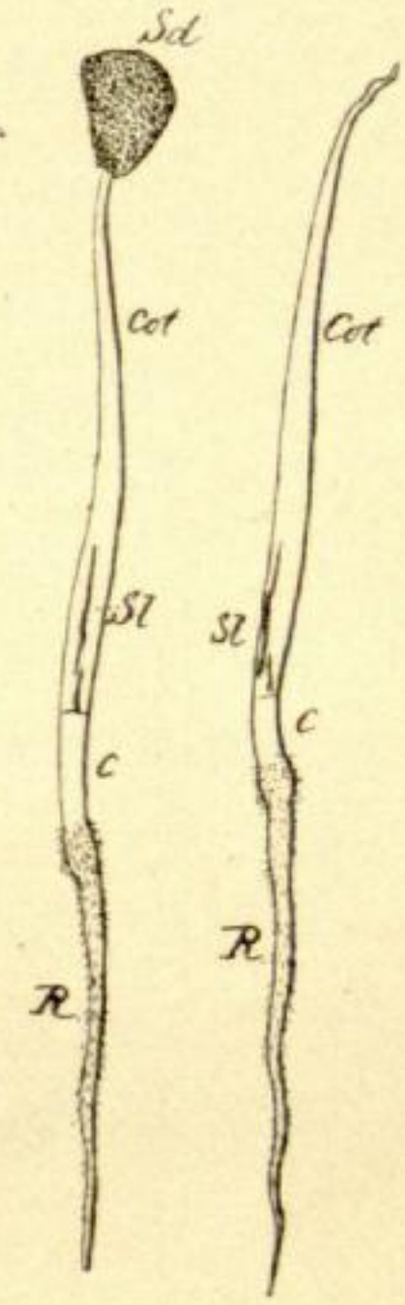
Fr
P
R
88



96



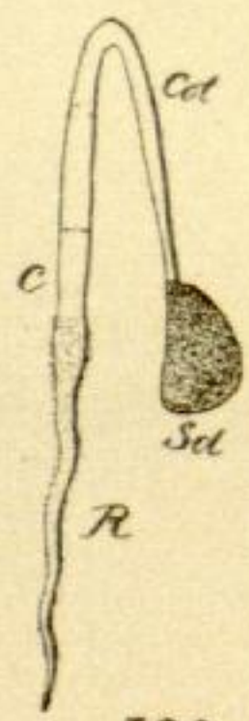
97



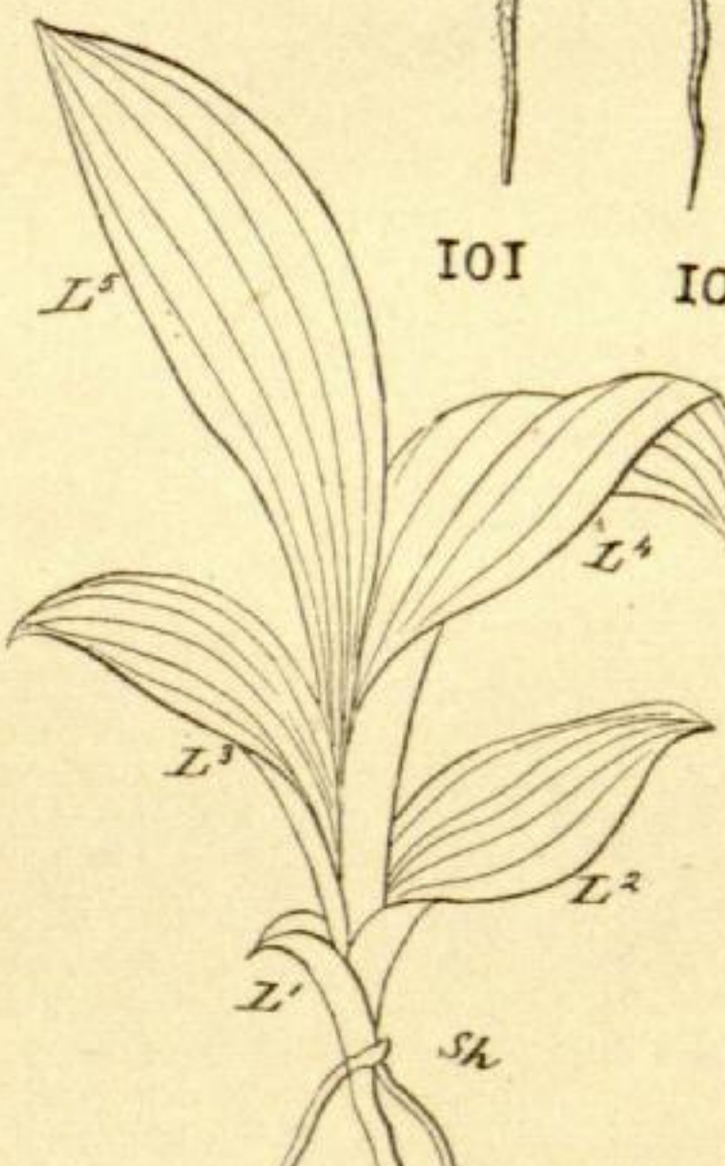
101

102

98

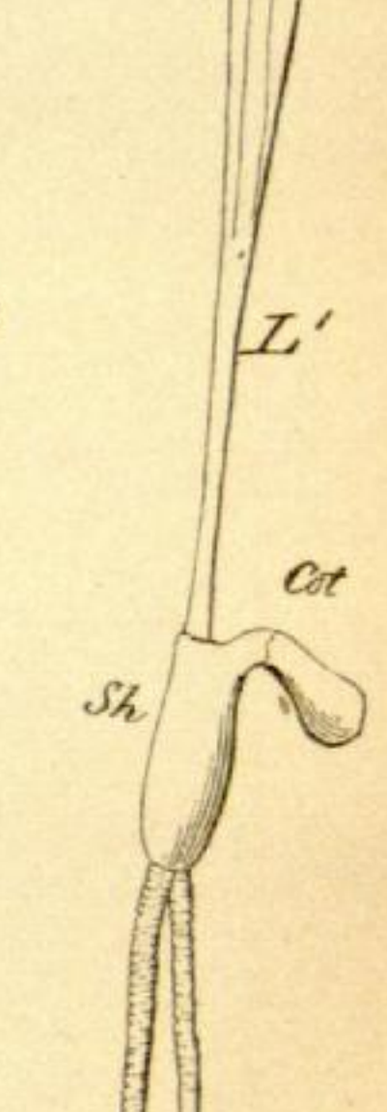


100

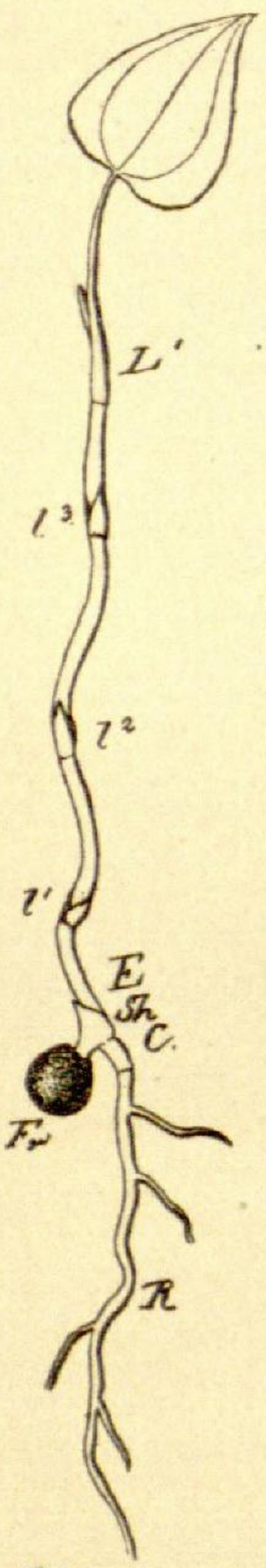


99

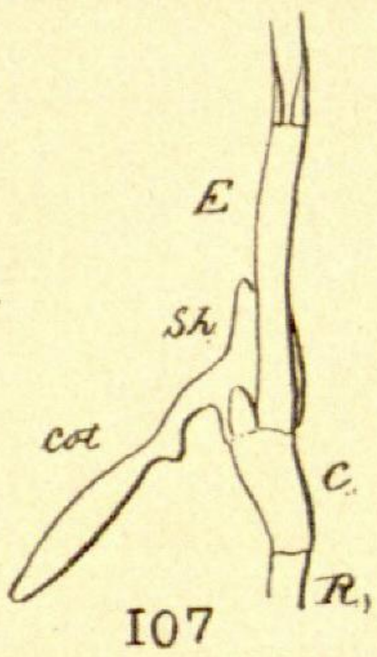
103



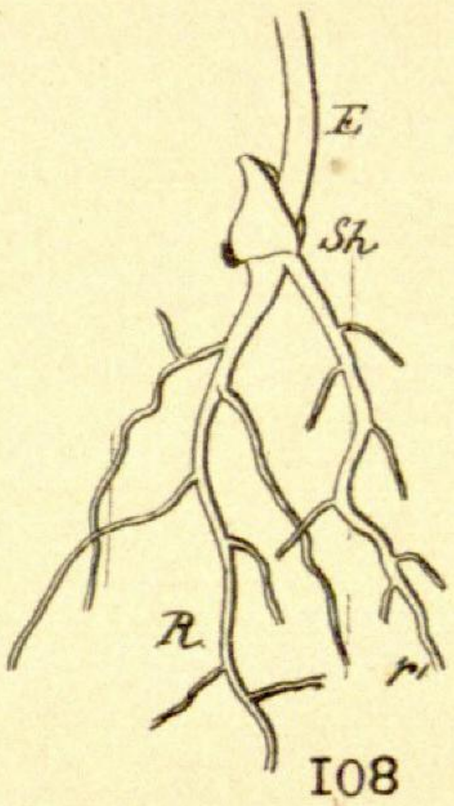
104



105



107

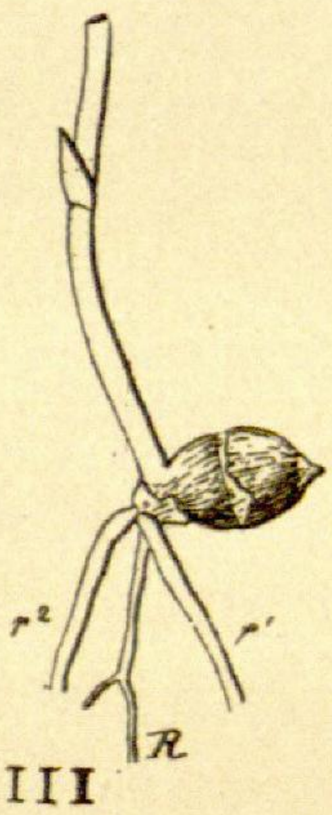


108

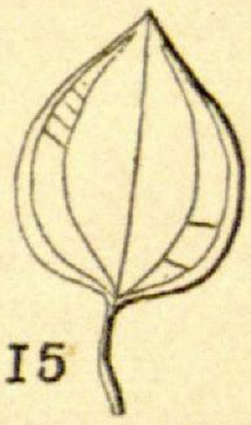
110

109

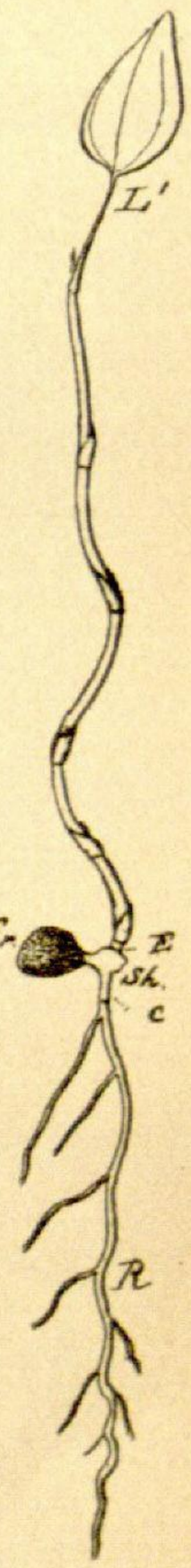
106



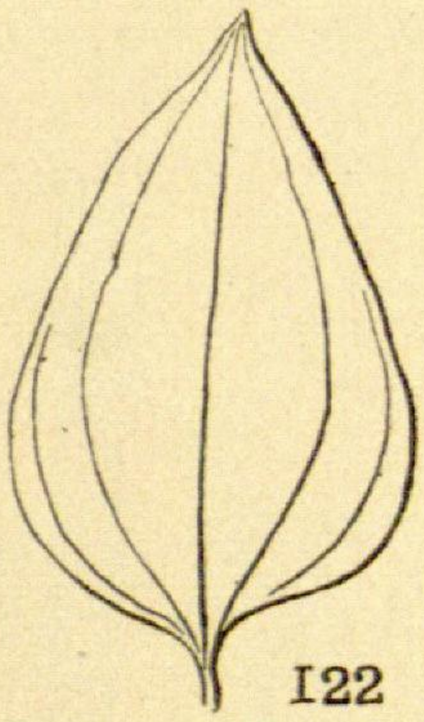
111



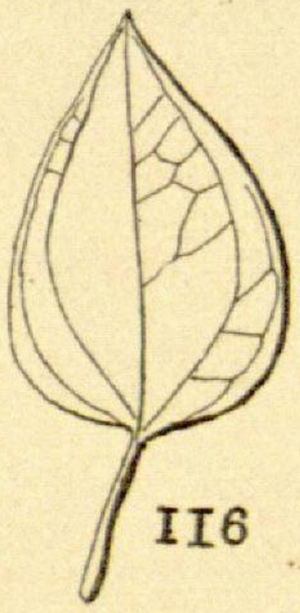
115



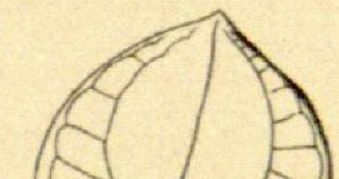
123



122

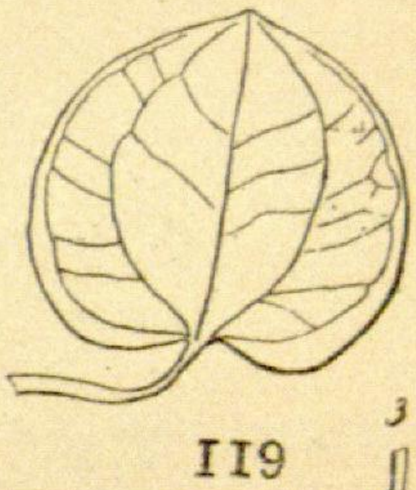


116

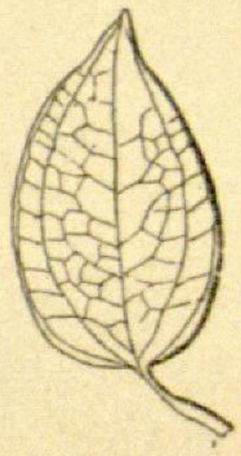


120

114

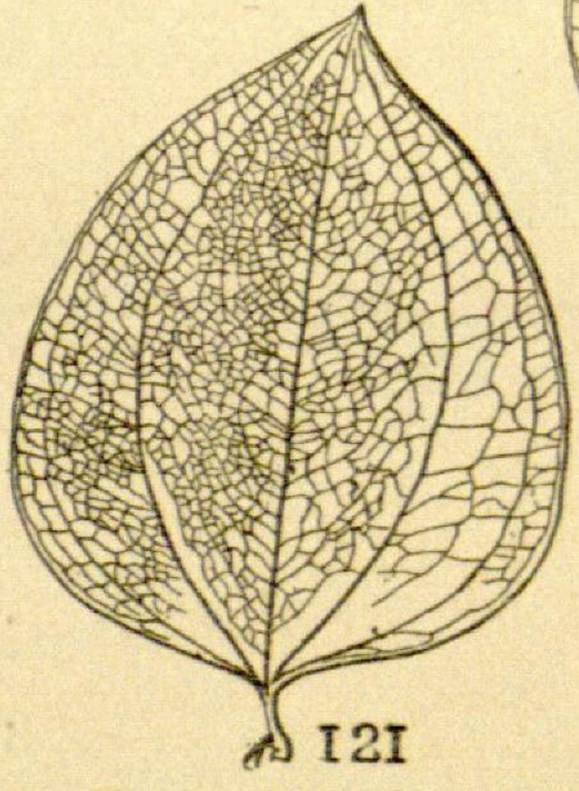


119



113

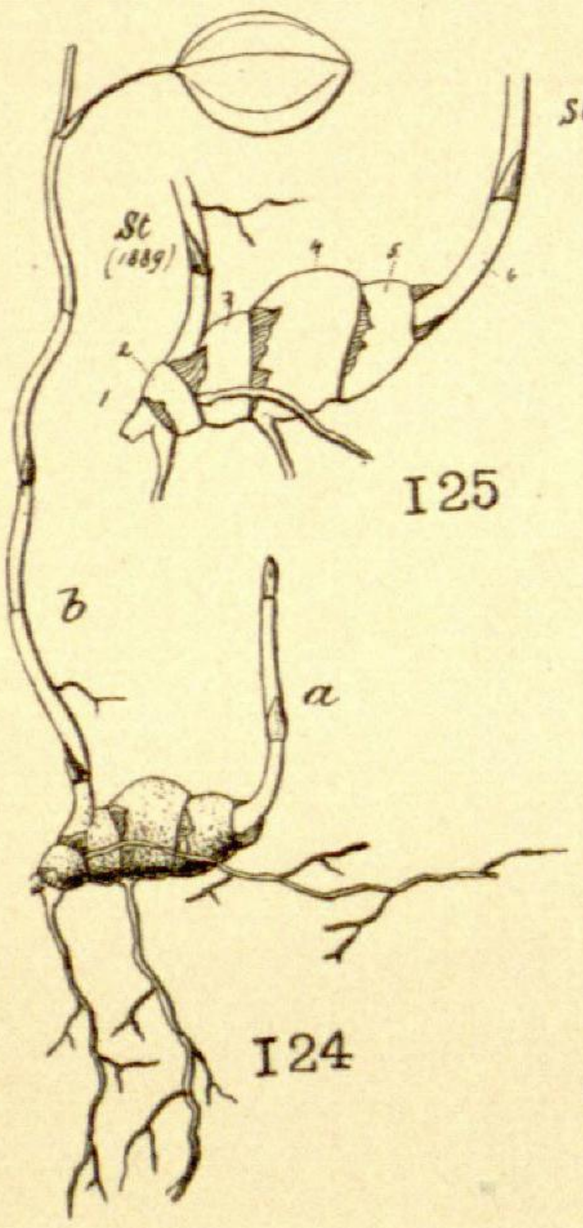
117



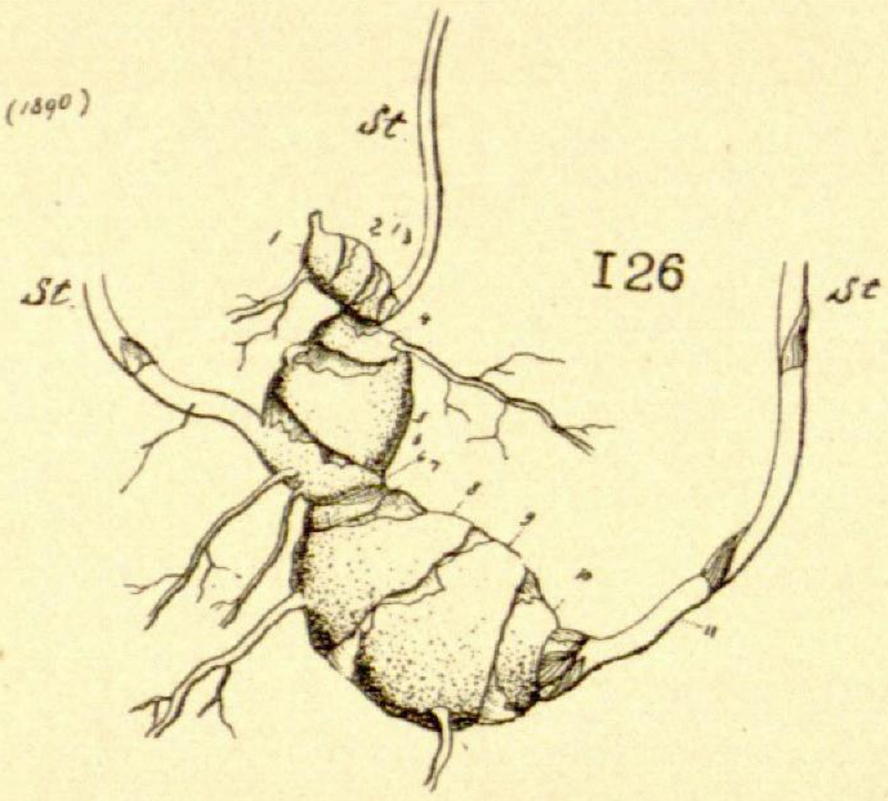
121

112

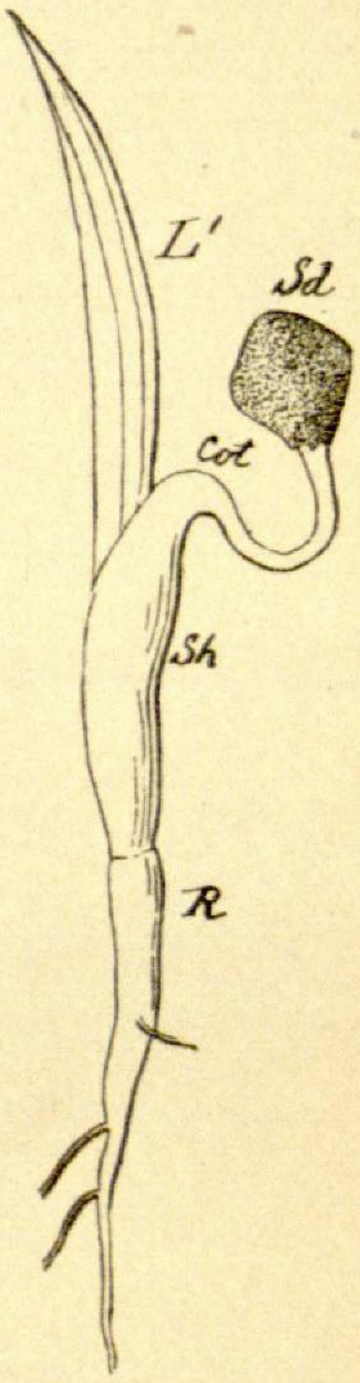
118



I25

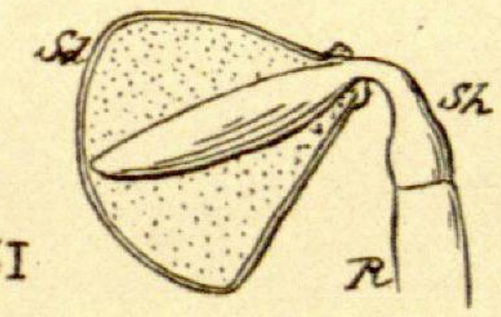


I26

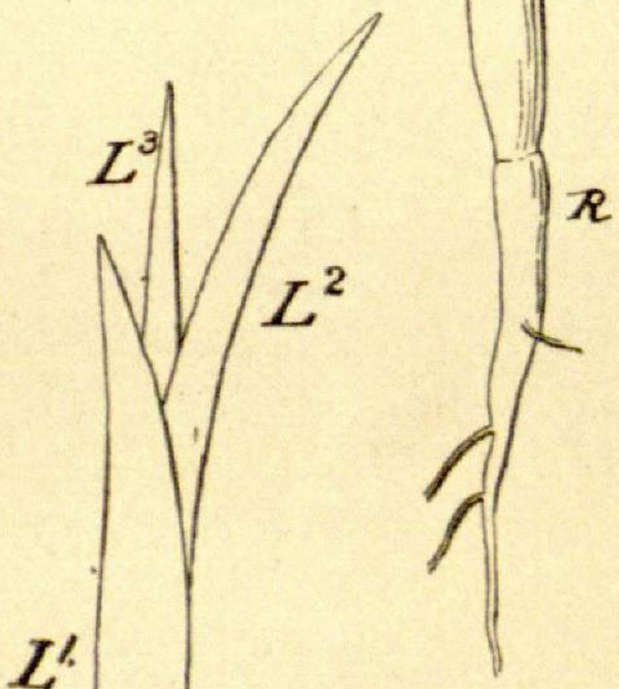


I34

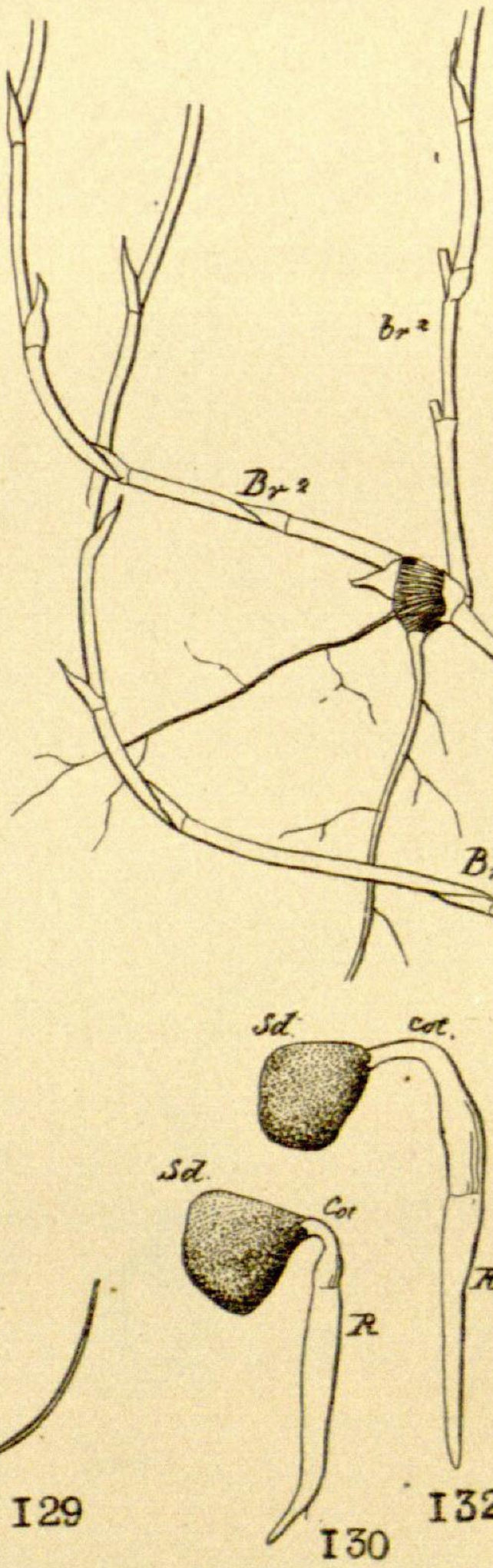
I24



I31



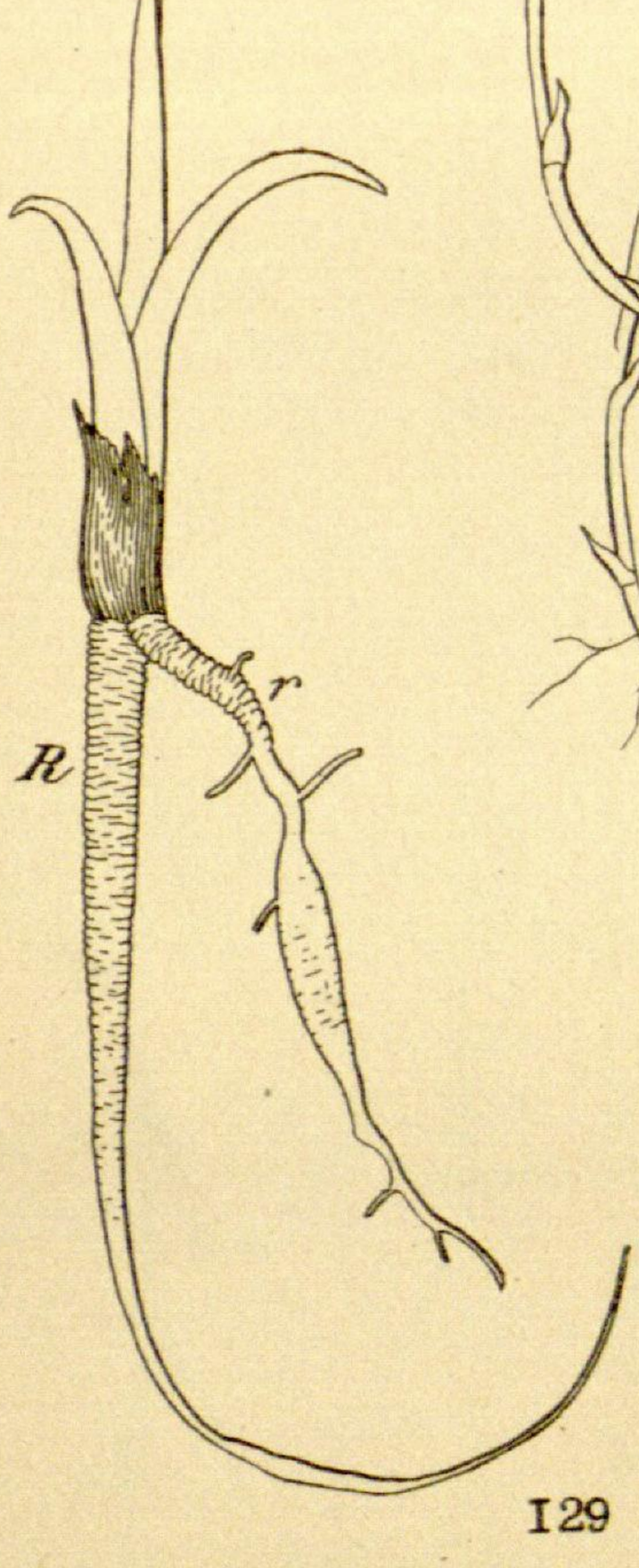
I28



I29

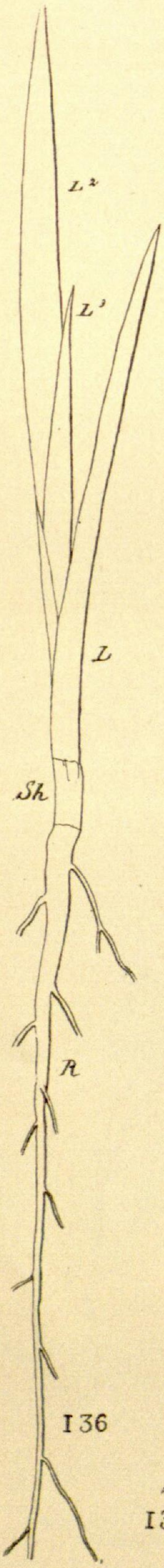
I30

I32

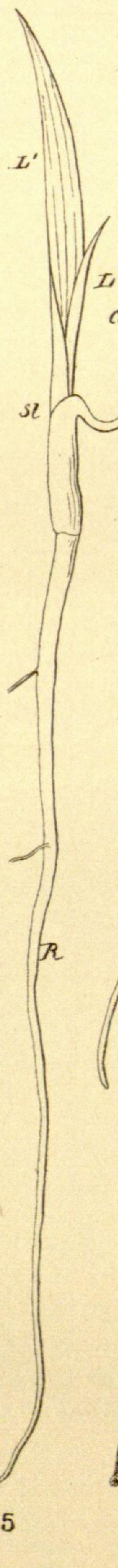


I33

I27



I36

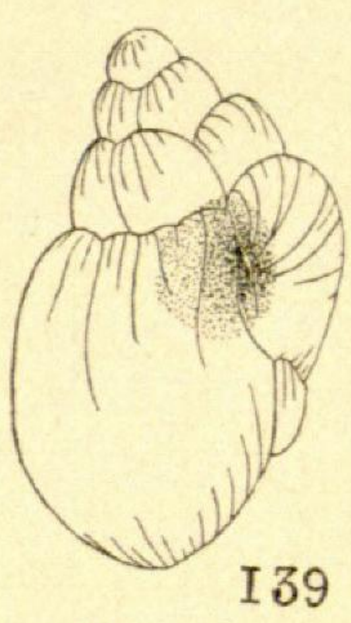


I35

I43

I46

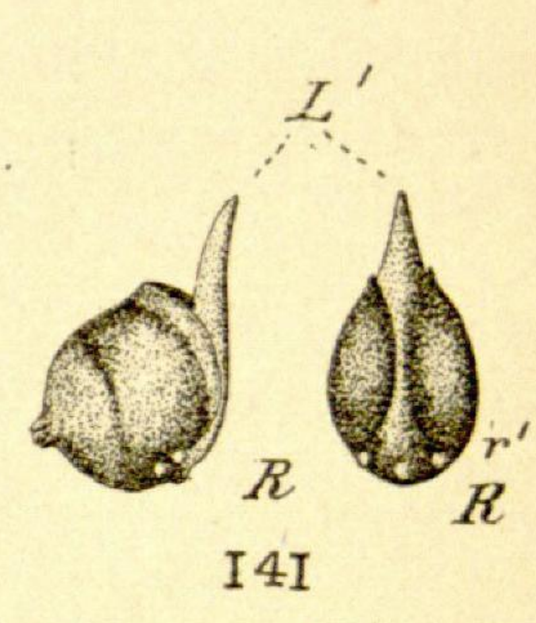
I44



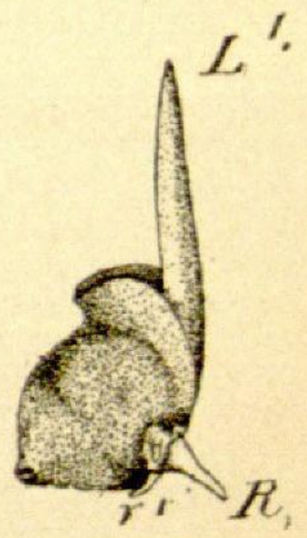
I39

I40

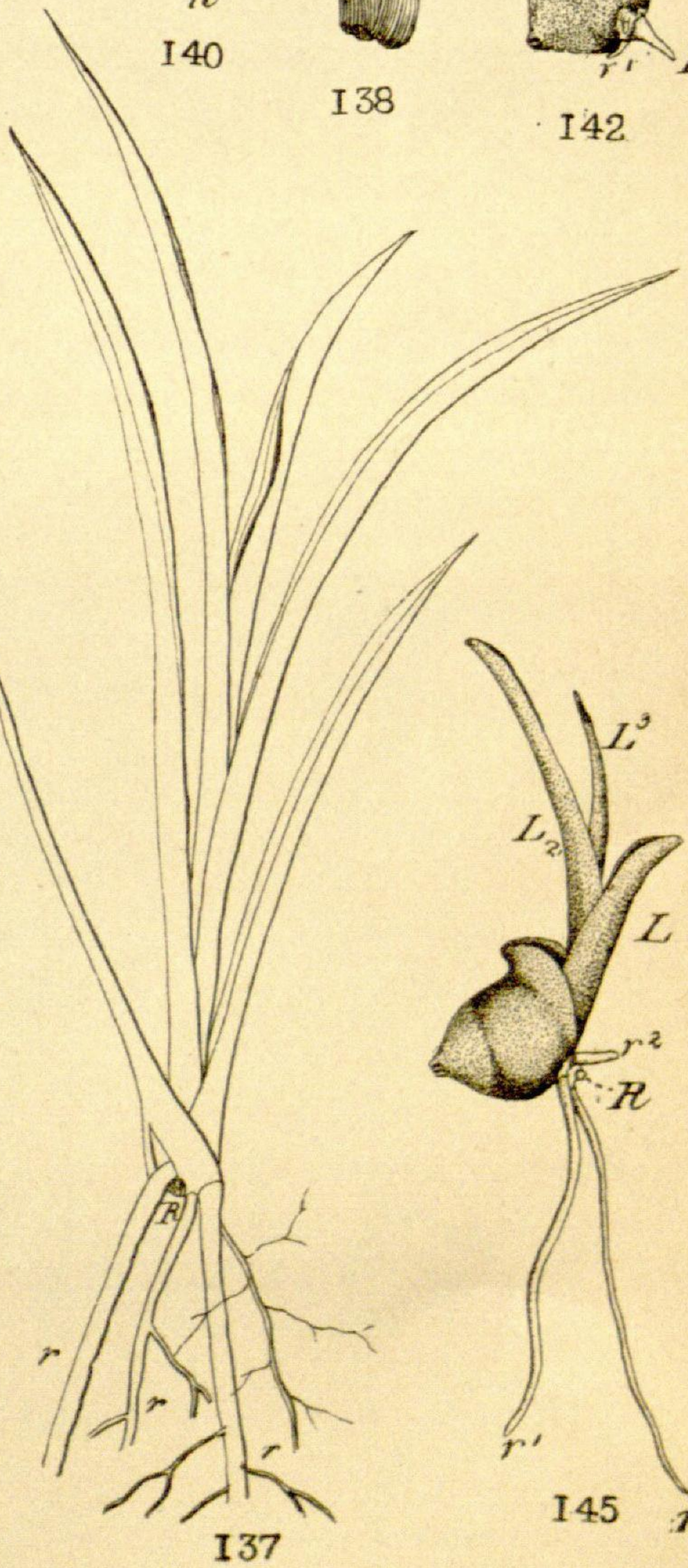
I38



I41

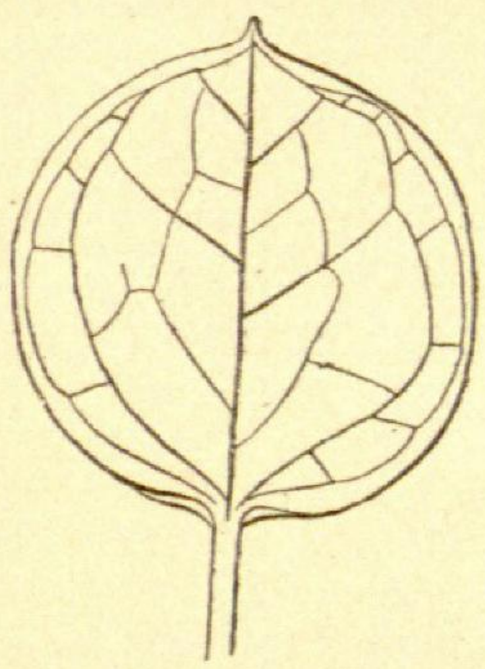


I42

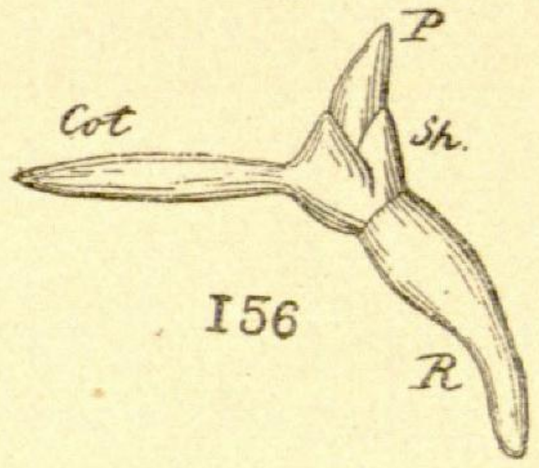


I37

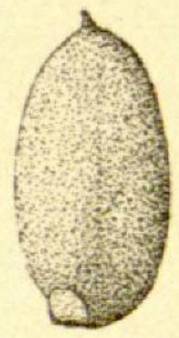
I45



I58

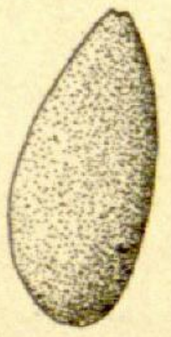


I56

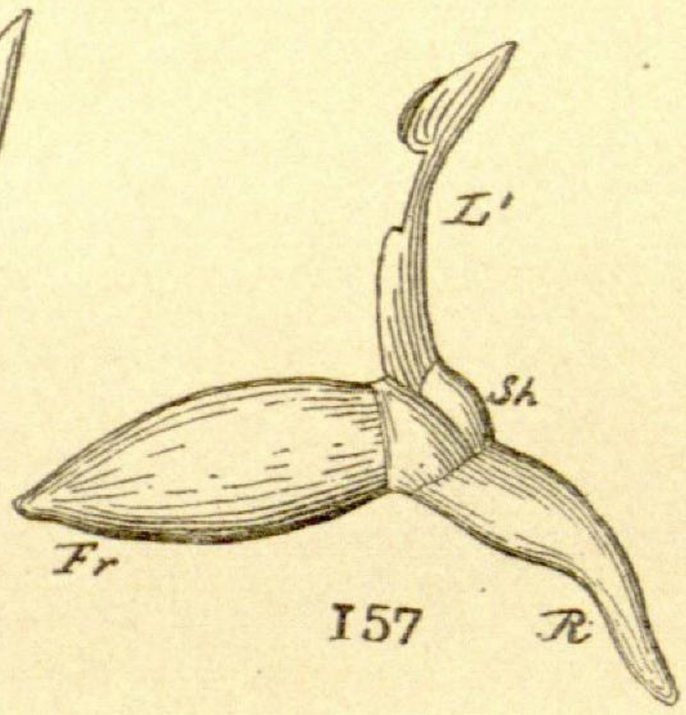


I54

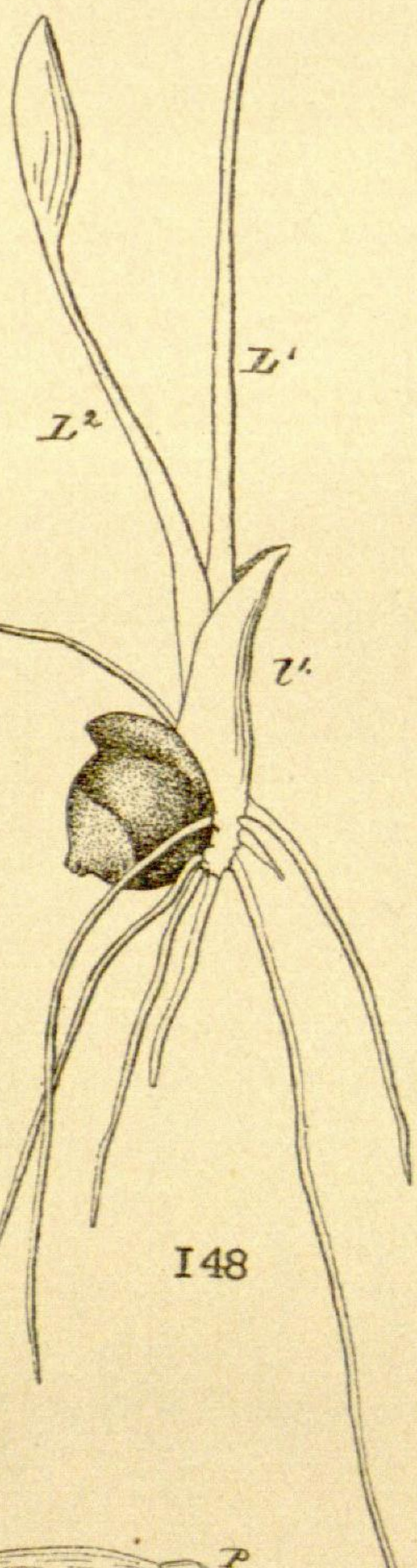
I52



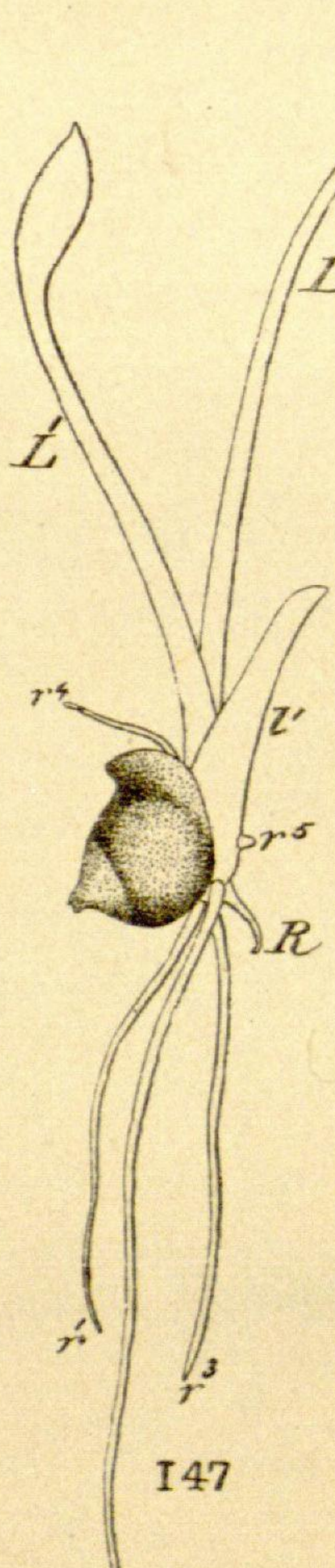
I53



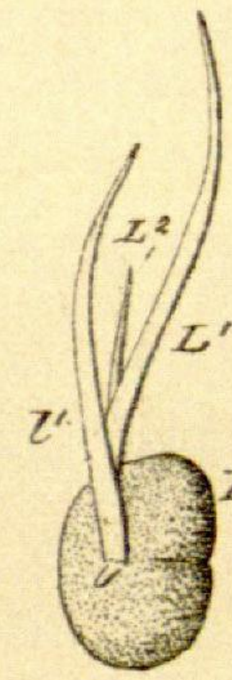
I57



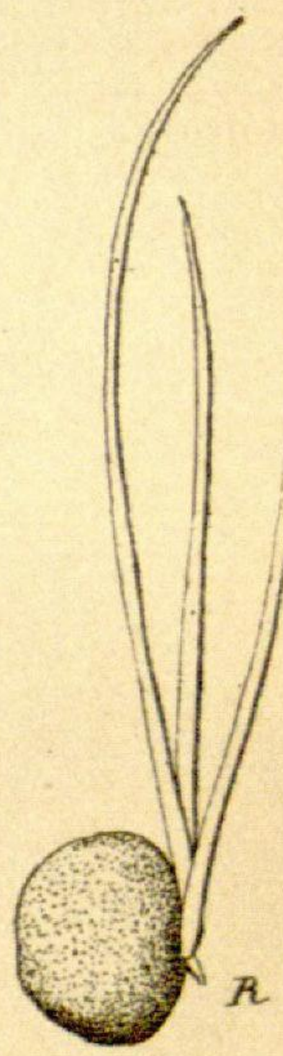
I48



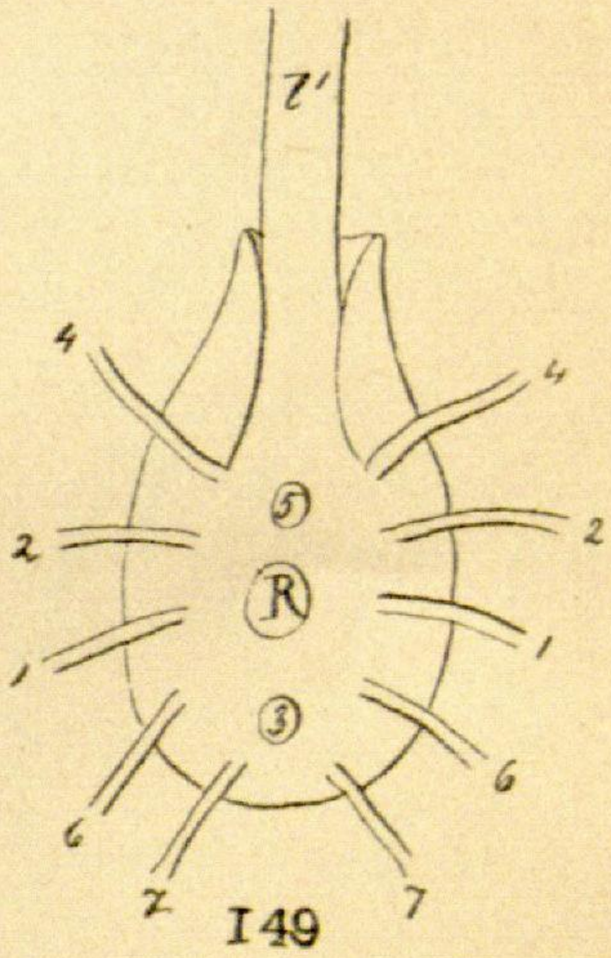
I47



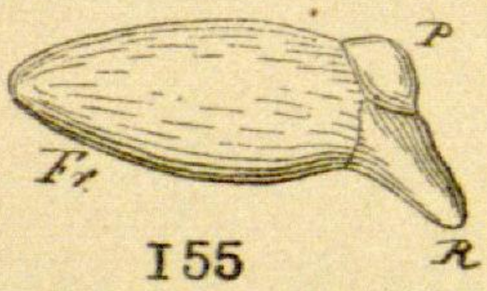
I50



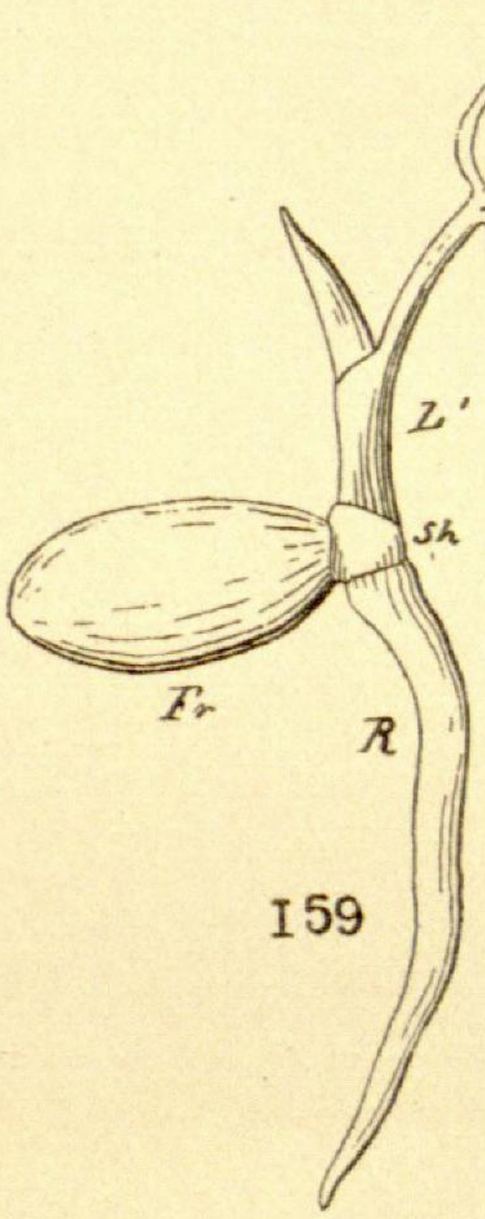
I51



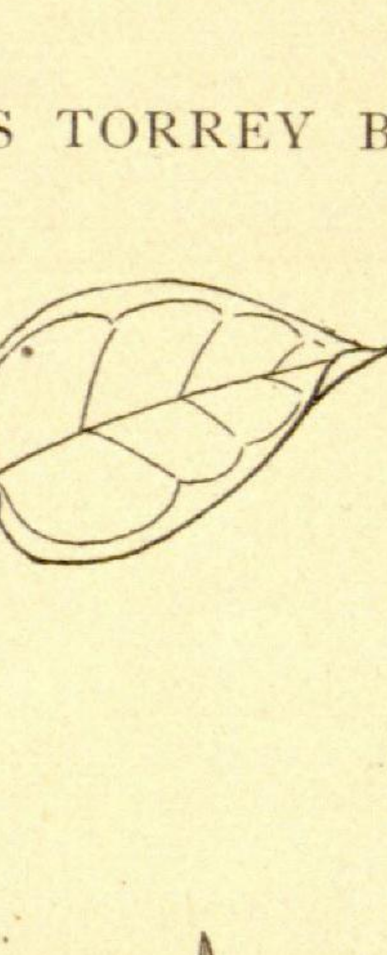
I49



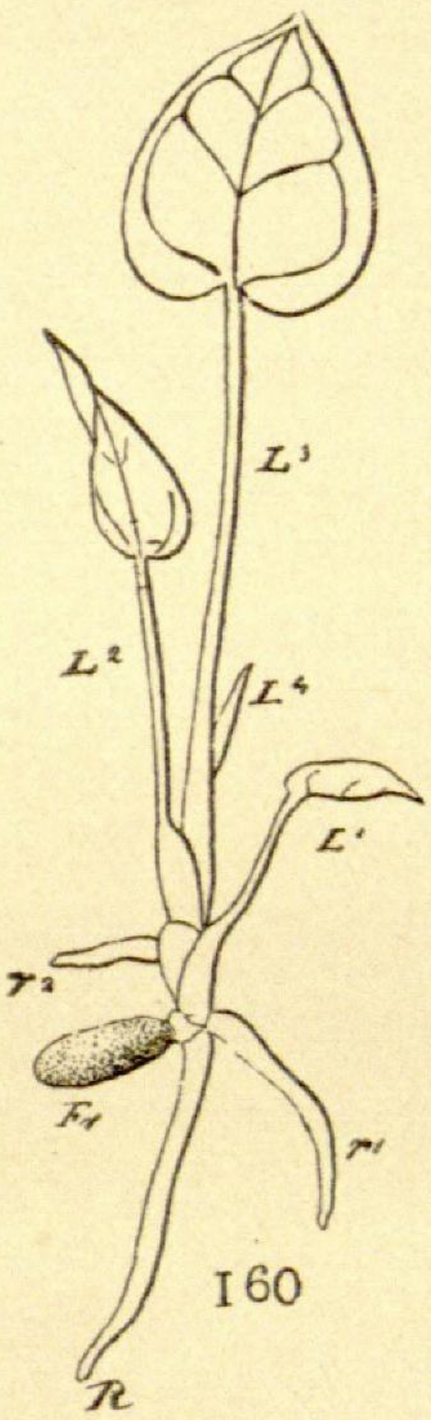
I55



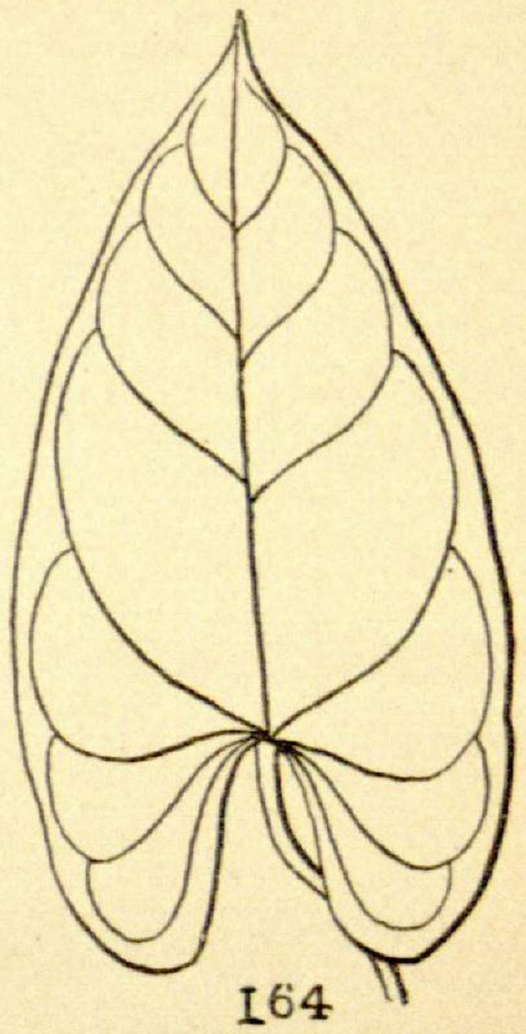
159



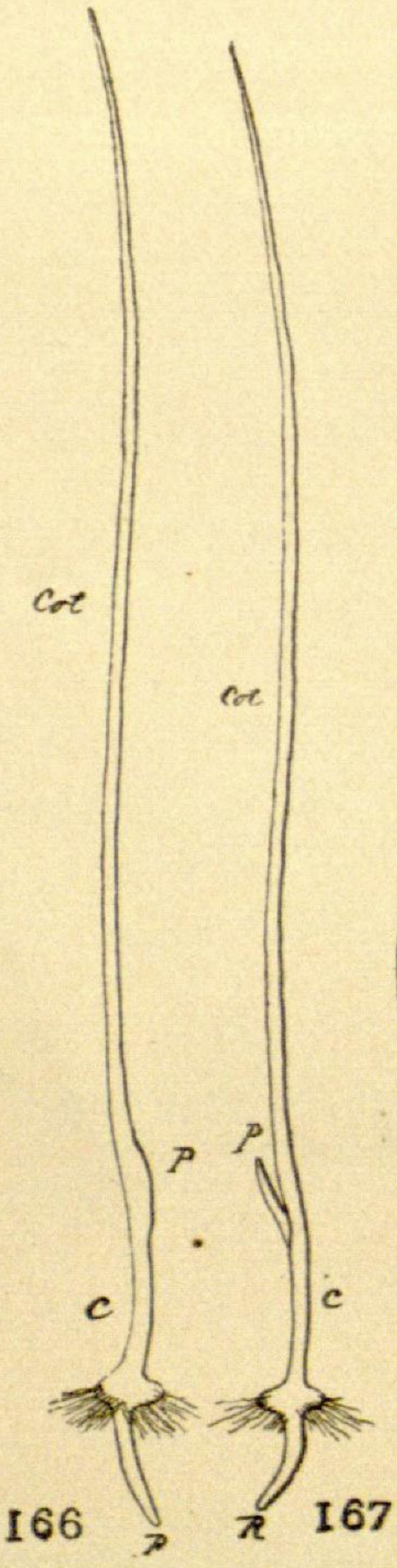
163



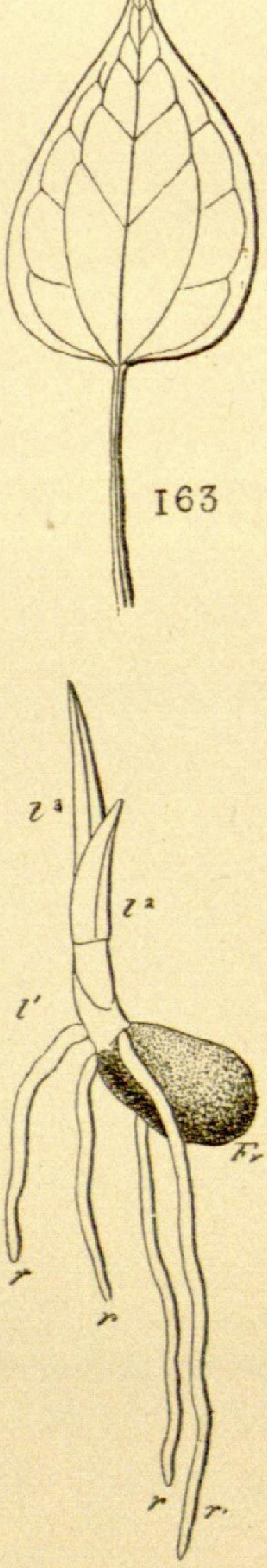
160



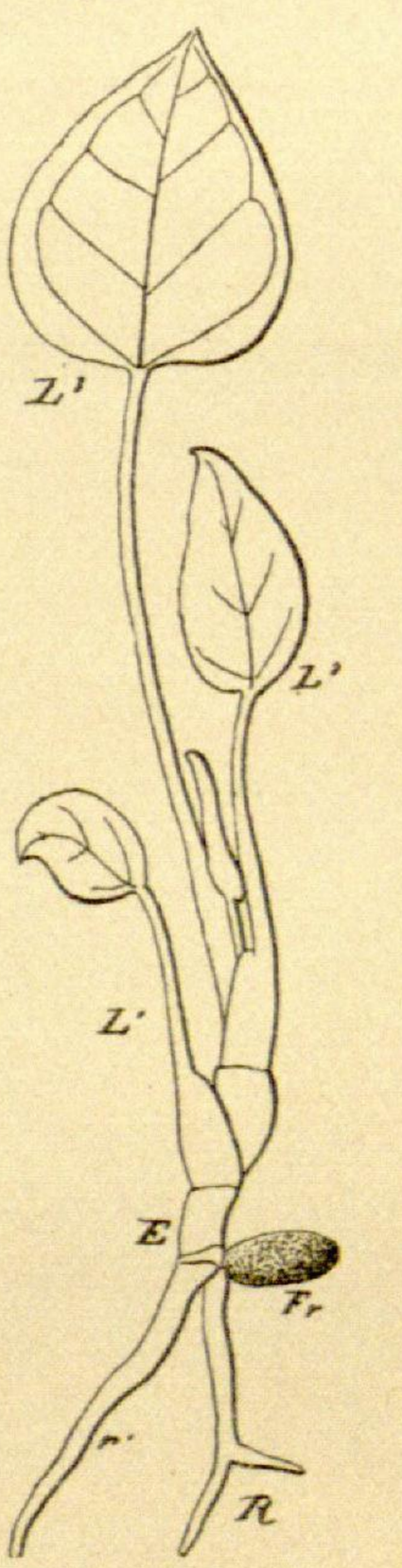
164



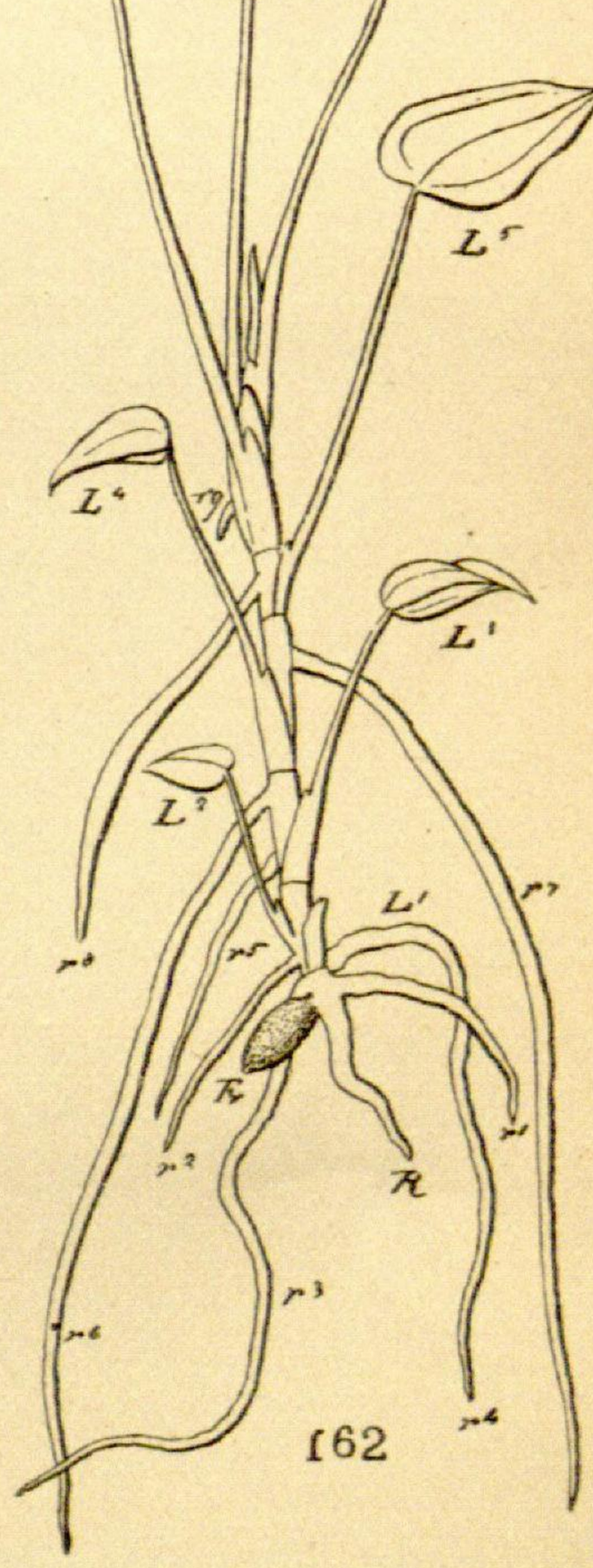
166 167



165



161



162