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OBSERVATIONS ON SEEDLINGS OF NORTH AMERICAN PHÆNOGAMOUS PLANTS.

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(With three plates, drawn from nature by the author.)

There was a time when botanists were deeply interested in the study of seedlings and the subsequent development of the plant-individual from a morphological point of view. This was during the first half of the nineteenth century when Bernhardi, De Candolle, Mirbel, Richard, Tittmann and some others published their fundamental works on the germination, soon followed by Buchenau, Caspary, Irmisch, Warming, and Winkler, while Klebs and Sachs, but several years later, extended these morphological researches to the equally important and very interesting physiological. However, the literature on this subject may be followed still further back, and Malpighi was actually the first author who contributed to the knowledge of the germination of phænogamous plants; this may be seen from his works: Anatome plantarum (1675), Opera omnia (1687), and Opera posthuma (1697). To Ray we are indebted for dividing the plants into *Monocotyledones* and *Dicotyledones*, names invented by him, and described in his Methodus plantarum (1703). But, as stated above, it was not until the beginning of the nineteenth century that the study of seedlings became undertaken more generally and by some of the ablest writers on botany. In recent years, or let us say the last decennia, very few botanists have paid much attention to this particular question, and it is extremely little that has been brought to light by American writers. This is the more surprising since the American plants are exceedingly interesting from this point of view; moreover, it appears to the writer that the mere systematic treatment of the American flora is not sufficient so long as the younger stages of our plants remain ignored; the sad consequence is that the study of the organs of vegetative reproduction has been neglected to the same extent. It is only, at least in a number of instances, through following the development of the individual from seedling to mature plant that the real structure of the subterranean stem-portions may be ascertained. The beginning of the formation of the rhizome, the location of the overwintering buds, the numerous modifications observable in the root-system, the structure of the foliage, etc., all these points deserve equally as much attention as the floral organs; they really deserve a place in the general diagnosis of the species. But it is a slow process to study and follow these various phases of plant life in nature, besides much literary research is involved.

Having been called upon to contribute a paper to the OTTAWA NATURALIST, I thought that it might be appropriate to present a brief sketch of some of the various types of seedlings which I have observed in this country, in the hope that some of the Canadian botanists might take the matter up and continue. At the same time I take the opportunity to insert some drawings which might serve to illustrate some of the characteristics of these seedlings; if sometimes too elementary, the text as well as the figures, I must ask for indulgence on the part of the reader.

Of the two large classes, of phænogamous plants, *Monocotyledones* and *Dicotyledones*, as proposed by Ray, the former germinate with a single, the latter mostly with two cotyledons; there are, however, several exceptions. In certain plants the seedling resembles a thallus, consisting merely of a globular mass of cellular tissue with no root, stem or leaf, as for instance in *Orchideæ*, *Monotropa*, *Orobanche*, etc., and finally among the *Dicotyledones* there are some cases where only one cotyledon becomes developed, the other being either rudimentary or totally wanting. But, common to both classes, when the germination begins the primary root is generally the first organ which appears, then follows the hypocotyl, and after this the cotyledons. Moreover, we find in both classes two types of cotyledons: above ground or epigeic, and subterranean or hypogeic; in the former of these, which is the most frequent, the cotyledons are leaf-like, green and thin, provided with stomata, and are thus able to assimilate: in the latter the cotyledons remain mostly enclosed by the seed; they are pale, fleshy, thick, and frequently grown together. These hypogeic cotyledons, especially characteristic of seeds without endosperm, are the bearers themselves of the reserve food-substance. In *Pinus* the cotyledons combine both types, since they at first serve as organs to absorb the endosperm, and subsequently become organs of assimilation; or the cotyledons contain some food-material and begin the function of assimilation as soon as the reserve food is assimilated (several *Cruciferæ*). Very peculiar is the structure of the cotyledon in several *Monocotyledones*, for instance the *Gramineæ*, where a part of the cotyledon is developed as a flat, shield-shaped organ, the so-called scutellum, whose function it is to absorb the food-substances of the endosperm; a similar organ occurs, also, in Palms, *Commelinaceæ*, *Canna*, etc., where it represents the apex of the cotyledon.

It is, therefore, very natural that the cotyledons exhibit a number of forms depending upon their function; beside that their varied position in the seed necessarily exercises some influence upon the outline of their leaf-blades. However, the cotyledons are not the only part of the seedling in which modifications as to structure and function may be observed; the primary root and the hypocotyl exhibit, also, some certain types of development, which are of no small interest. The root, for instance, may develop as a nutritive or a storage-root; or it may be the only organ by which the vegetative reproduction takes place in the first season, as in *Rhexia*. Finally, the hypocotyl may persist during the whole life of the plant or die off after the first season; it may persist as an ordinary stem, or develop as an organ for storing nutritive matters. It is, also, important to notice the position and vitality of the plumule; most frequently it gives rise to the main stem above ground, but not a few cases are known, where it stays under ground during the first year, developing into a rhizome; or, it lives only one season, after which it becomes replaced by buds from the axils of the cotyledons. In this way we must expect to find a rich illustration of biologic plant-types by merely examining seedlings; and, if we follow the successive development of these same seedlings, we are gradually led into that most interesting chapter of botany, which teaches us about the morphology of the shoot with its innumerable variations in respect to position and form of the vegetative and floral organs.

In the present paper I intend only to describe some types of seedlings during the first year of their growth, and we might begin with the *Monocotyledones*.

Characteristic of the seedlings of this class of plants is the presence of a single cotyledon, which may be epigeic or hypogeic, and the short duration of the primary root.

A very simple type is represented by *Agave* (Fig. 1). We notice in this that the primary root does not become arrested in its development so early as in most of the other *Monocotyledones*, but that it attains quite a considerable length; the cotyledon is thread-like and forms a sharp knee for penetrating the soil, while the apex remains enclosed in the seed until the endosperm has become absorbed; after that the apex of the cotyledon becomes freed from the seed and stretches itself towards the light. The plumule is located at the base of the cotyledonary sheath and develops mostly only one green leaf during the first season. This manner of germinating is known, also, in *Sisyrinchium* and several *Liliaceæ*, for instance many species of *Allium*.

Another type may be observed in *Alisma Plantago*, L. var. *Americana* R. et S. (Fig. 2). So far as concerns the structure of the cotyledon, the seedling does not differ from that of *Agave*, but if we examine the root we notice that this remains very short, and that it bears a dense tuft of root-hairs at the base, where it passes into the more or less distinct hypocotyl (H). We have, thus, in this type of seedling an indication of a hypocotyl, and among other plants that exhibit this manner of germinating, and in which the seeds have no endosperm, may be mentioned *Butomus*, *Typha*, *Triglochin*, etc.; in *Juncus bufonius* the seeds contain endosperm, but the seedling shows, nevertheless, this same structure, according to Mirbel (1810).

We now proceed to a type of seedlings which is very frequent, and much more so than those described above; in this, the third type, the apex of the cotyledon remains enclosed by the seed in order to absorb the nutritive matters stored in the endosperm. Moreover, the free portion of the cotyledon constitutes a sheath of various length, at the bottom of which the plumule is located; the primary root attains sometimes a considerable length (Fig. 6), or it ceases to grow shortly after the germination has taken place (Figs. 3 and 4). As shown in Figure 7, a hypocotyl is developed, and this stem-portion is more distinct in this type of seedlings than in the former. In *Arisæma triphyllum*, Torr. (Fig. 3), the apex of the cotyledon is readily visible in longitudinal section, and is surrounded by the endosperm; the plumule with its first leaf is yet enclosed within the sheath, while the primary root is free, and provided with hairs. A more advanced stage may be seen in Fig. 4, where the leaf has broken through the sheath, and where two secondary roots have developed. During the first season the rhizome becomes formed by the growth in thickness of the short primary axis (Fig. 5), and attains the shape of a round tuber bearing three secondary roots, which rapidly increase in length, but without ramifying. In *Smilax rotundifolia*, L. (Fig. 6), we notice a long primary root, which stays active for at least one season, and the hypocotyl (H) in Fig. 7) is very distinct; otherwise the cotyledon shows the same structure as in *Arisæma*. The foliage of *Smilax* consists at the seedling stage of several minute, scale-like leaves preceding the green ones, of which mostly only one appears during the first season. It is interesting to notice that a bud becomes developed in the axil of the cotyledon, and that this bud develops into a small tuber (B in Fig. 7). So far as concerns the structure of the cotyledon, its apex and short sheath, this type of seedling is common to many, *Liliaceæ*, *Amaryllideæ*, *Palmæ*, *Dioscoreaceæ*, *Irideæ*, etc.

A fourth type is characteristic of *Commelinaceæ*, and it differs from the former by the prolongation of the free part of the cotyledon, which here represents a long, filiform organ between the apex and the sheath; moreover, the primary root is surrounded by a sheath, the so-called coleorhiza, which it has to penetrate.

These four types thus illustrate the most frequent structure of seedlings of *Monocotyledones* excl., *Cyperaceæ* and *Gramineæ*, and the principal distinction consists in the position of the cotyledon, being epigeic or hypogeic; moreover, in the varied development of the cotyledonary sheath. In regard to the hypocotyl we have seen this to be well differentiated in *Smilax*, while it is either obsolete or undeveloped in the others. The primary root may persist for a longer or shorter period, but the most important character derived from this organ is the presence of a coleorhiza as observed in *Commelina*.

A feature common to these types is, however, that the root is the first organ to appear when the seed germinates; then follows the cotyledonary sheath, and finally the first leaf of the plumule. In this respect the *Cyperaceæ* make a notable exception from all the other *Monocotyledones* with perfect embryos. We might examine *Cyperus vegetus*, Willd., as an example of this type of germination, illustrated on Plate IV, Figs 8 and 11.

When the seed germinates (Fig. 9) the plumule surrounded by the coleoptile is the first to appear, pushing out through the opened base of the achene, and carrying with it the small root, merely visible as a minute wart. If we remove the cotyledon from the seed (Fig. 10), we notice the very simple structure of the embryo: the large clavate cotyledon, the sheath of which (coleoptile) covers the plumule completely, and finally the small root with a wreath of hairs. All these organs are, also, readily to be observed in the still younger embryo (Fig. 8) just before germination. The further development of these organs may be observed in Fig. 11, where the root has commenced to grow out, and where the coleoptile has attained its final shape: as a tubular leaf with a small, blade-like apex; no such advanced development of the coleoptile was observed in the other types described above. In the *Cyperaceæ* the coleoptile thus develops into a long sheath raised high above the plumule, and it turns its back toward the absorbing portion of the cotyledon. Sometimes, as for instance in *Fuirena squarrosa*, Michx., a long stem-like organ develops between the coleoptile and the enclosed portion of the cotyledon, thus the coleoptile becomes situated at some distance from the cotyledon, as if it represented the first leaf of the seedling. If this be really the case we would have two leaves (cotyledon and coleoptile) situated at the same side of the axis, above each other, and such arrangement of leaves would not be very probable. A like structure is exhibited by *Rhynchospora alba*, Vahl. (Fig. 12), but in this the primary root does not develop at all, being replaced by three secondary roots. The structure of the cotyledon, however, is the same as in *Cyperus;* inside the coleoptile is the first green leaf from the axil of which a long bud has developed, provided with a small, adorsed fore-leaf, thus representing the first ramification of the young plant.

In the *Cyperaceæ* we have thus the same structure of the absorbing portion of the cotyledon, while the coleoptile is much further developed than in the third and fourth type described above. The generally adopted explanation of the coleoptile is that it merely represents the sheath of the cotyledon, and in cases where a stem-like organ is developed, in *Fuirena*, for instance, this organ is defined as a node, but as a node that has become unusually stretched. It deserves notice, however, that a root sometimes develops from this "node," while roots evidently but very seldom develop from the nodes, but from above or below these. The greatest difficulty by considering the coleoptile as an independent leaf, the first of the seedling, depends of course upon its position, since it is placed on the same side of the axis as the cotyledon; to overcome this difficulty some authors have expressed the opinion that a leaf is lacking, and this leaf should then be the small, lobe-like organ "epiblast" so very characteristic of certain genera of *Gramineæ*; this organ is in these situated opposite the cotyledon, and below the coleoptile, thus the arrangement of these three organs would correspond very well with that of normal leaves. But, so far, the epiblast has not been detected in any member of the *Cyperaceæ*.

Now, in regard to the *Gramineæ*, the structure of the embryo is very complicated, and has been the subject of an extensive literature from the hands of a number of the most notable morphologists. But so different are the views expressed that the only point which seems settled beyond doubt is that the *Gramineæ* have at least one cotyledon; some authors think they have two.

Let us, however, examine a few of these embryos before we review the various explanations that have been offered. On the accompanying plate (Plate IV) I have figured some germinating grains of *Secale* and *Zea* (Figs. 13-17), and in these we notice the following organs: the primary root (R) with its sheath, the so-called coleorhiza, and frequently accompanied by one or several pairs of secondary roots (Figs. 13, 14 and 17); the so-called "scutellum" (S), which is more or less shield-shaped, and closely appressed to the endosperm, which it absorbs; furthermore, the small lobe-like organ called "epiblast" (E), which is situated opposite the scutellum, and which is not developed in *Zea*; between the scutellum and epiblast is the plumule (PL.) covered by a sheath, the so-called "coleoptile," which in *Zea* is borne on a stem-like organ of quite considerable length. The first green leaf of the seedling (L.) is to be seen in Fig. 17, having broken through the coleoptile. Considering the position of these three organs, scutellum stands opposite the epiblast, and the coleoptile is not only situated on the same side of the axis as the scutellum, but, furthermore, it turns like this toward the plumule, or let us say toward the first green leaf. In other words, in cases where the epiblast is suppressed, which is very commonly the case, the scutellum and coleoptile appear as two organs situated above each other, on the same side of the axis. The question then arises to define whether the cotyledon is represented by one or several of these organs, and whether these organs are really leaves, parts of leaves or independent leaves.

Strange to say, but according to Richard, A. de Jussieu, Hofmeister, and Sachs, the coleoptile should represent the cotyledon, while the scutellum and epiblast should merely be parts of stem and root. Another view was held by Schleiden, and Decaisne, who identified the scutellum and the epiblast as the cotyledon, the coleoptile as the first leaf succeeding this. Or these three organs may be defined as constituting the cotyledon, as proposed by Gaertner, who has been followed by Hegelmaier, Klebs, Van Tieghem (1872), Celakovsky and Schlickum; thus the scutellum should represent the absorbing portion of the cotyledon, the coleoptile its sheath, while the epiblast should be a mere protuberance of the coleorhiza (Schlickum) or a part of scutellum (Van Tieghem, Celakovsky); to this may be added that Van Tieghem, by means of the anatomical method, reached the conclusion that the stem-like portion between the coleoptile and scutellum is not an internode, but a node which has become unusually stretched.

Depending more on the mutual position of these organs than on their structure and homologies Warming has made a very different suggestion, and he considers scutellum alone as the cotyledon, the epiblast as the first leaf succeeding this, and the coleoptile as the second, thus presuming that the epiblast should actually have become completely suppressed in the *Cyperaceæ*; hence the peculiar position of the sheath just above the cotyledon in these. According to this same author the stem-like portion necessarily becomes an internode. The reason why Van Tieghem would not recognize the epiblast as an independent leaf, was because he found no vascular system in it; however, in *Avena sativa* Didrichsen observed the epiblast to possess a very regular lobation corresponding with the presence of several mestome-strands. So far as concerns the internode, which Van Tieghem has declared to show the structure of simply a node, I must say, that in *Coix* for instance, the structure is very different from that of a node, but identical with that of an internode, and especially of a subterranean. In order to settle this question, whether this stem-like portion, by Celakovsky called "mesocotyl," be a node or an internode it is necessary to examine the internal structure in a larger number of genera, when it is fully matured; in *Coix* it is an internode, but it may not be constantly so in *Gramineæ* and *Cyperaceæ*. Furthermore the presence of a bud in the axil of the coleoptile, or according to Warming, in the axil of the second leaf succeeding the scutellum, speaks in favor of defining this leaf as independent of epiblast and scutellum. Such axillary buds have been observed in a number of genera of *Hordeæ;* beside that Van Tieghem observed them in *Avena*, and Bruns in *Bambusa*. The explanation offered by Warming seems so simple and readily to be understood, that it is undoubtedly the most natural.

In revising these various views we notice that there is one point, however, in which all these authors agree, namely, that the *Gramineæ* have only one cotyledon. We shall see now that there were formerly some authors who attributed two cotyledons to this family, the scutellum and epiblast, thus the *Gramineæ* should possess one large and one small cotyledon; these authors were Mirbel, Poiteau and Turpin. Recently Van Tieghem (1897) has abandoned his former theory, and adheres now to the views of these authors; in his new system he thus removes the *Gramineæ* from the other *Monocotyledones*, and places them among his "*Inséminées.*" How untenable this classification is has been shown by Celakovsky, who calls attention to a fact, known long since, that in some genera of *Gramineæ* the seed is not grown together with the pericarp, but is free as in *Eleusine*, *Sporobolus*, *Crypsis* and *Heleochloa*, and these genera should consequently in accordance with Van Tieghem's system be separated from the other *Gramineæ*, and referred to his "Seminées."

The last type of monocotyledonous seedlings which may be described here is exhibited by *Peltandra undulata*, Raf. (Fig. 18). In this plant the fruit is a berry with a thin, almost black pericarp, and contains mostly a single seed with no endosperm. The seed is globular, surrounded by a tenacious jelly which, according to Baillon and Engler, is the transformed exterior integument of the seed. The plumule is green and located in a furrow formed by the large cotyledon, the margins of which tightly enclose the plumule. The germination commences 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; the first leaf succeeding the cotyledon is exactly opposite this, and represents merely an open sheath-like organ with two ribs. This rudimentary leaf-structure may be frequently observed also in the second and third leaf of the seedling, while in some seedlings I noticed that already the second leaf showed a distinct petiole and a small elliptic blade. In regard to the root system, the primary root does not develop, but secondary roots in pairs appear at an early stage, and attain a considerable length, though without ramifying.

Orontium aquaticum, L. germinates in the same way, but the plumule is here located in a shallow cavity of the cotyledon without being surrounded by this. The first leaf succeeding the cotyledon is terete, not bicarinate, and this form of foliage becomes repeated in several of the following leaves; the primary root stays rudimentary, but soon becomes replaced by several lateral.

We have thus in monocotyledonous seedlings several interesting types, in which quite a prominent variation is noticeable in respect to the structure of the cotyledon, the first leaf or leaves succeeding this, and the root system. In some of these the seed is exalbuminous, and the cotyledon epigeic, as in *Alisma*; or we have the peculiar, globular cotyledon in the exalbuminous seeds of the aquatic *Orontium* and *Peltandra*. Epigeic is, furthermore, the cotyledon of *Agave*, but not until it has absorbed the food-substances of the endosperm. The hypogeic cotyledon is much more frequent, but varies in regard to the structure of the absorbing portion, for instance, if we compare the scutellum of the *Gramineæ* with the club-shaped cotyledon of *Cyperaceæ*, *Smilax*, *Commelina*, *Arisæma*, etc. Sometimes the cotyledon possesses a distinct sheath which envelopes the plumule, as in *Arisæma*, *Smilax* and *Agave*; if the coleoptile of the *Gramineæ* and *Cyperaceæ* might prove to represent the sheath of the cotyledon, this would then frequently appear at some distance above the scutellum, separated from this by an internode or node, according to some authors. The cotyledon may subtend a bud as in *Smilax*, and we remember that in several *Gramineæ* a bud has been observed in the axil of the coleoptile, whether this be an independent leaf or merely a part of the cotyledon. The foliage of these seedlings is, also, characteristic; for instance, the epiblast and coleoptile in

Gramineæ, the bicarinate leaves in *Peltandra*.the small, scale-like in *Smilax*, and finally the large, green leaf in *Arisæma* with petiole and blade. However, the structure of the first leaf succeeding the cotyledon does not always depend upon the presence or absence of an endosperm, for instance in the *Araceæ*. A hypocotyl is, sometimes,developed, as for instance in *Alisma*, *Agave* and *Smilax*. In regard to the roots we have seen the development of a coleorhiza in *Gramineæ*, *Cyperaceæ* and *Commelinaceæ*; furthermore, the relative strong growth of the primary root in *Zea*, in *Agave* and *Smilax*, but most frequently the root system consists of secondary roots replacing the early fading primary.

(To be continued).

EXPLANATION OF PLATE IV.

In the figures the letters indicate as follows :—

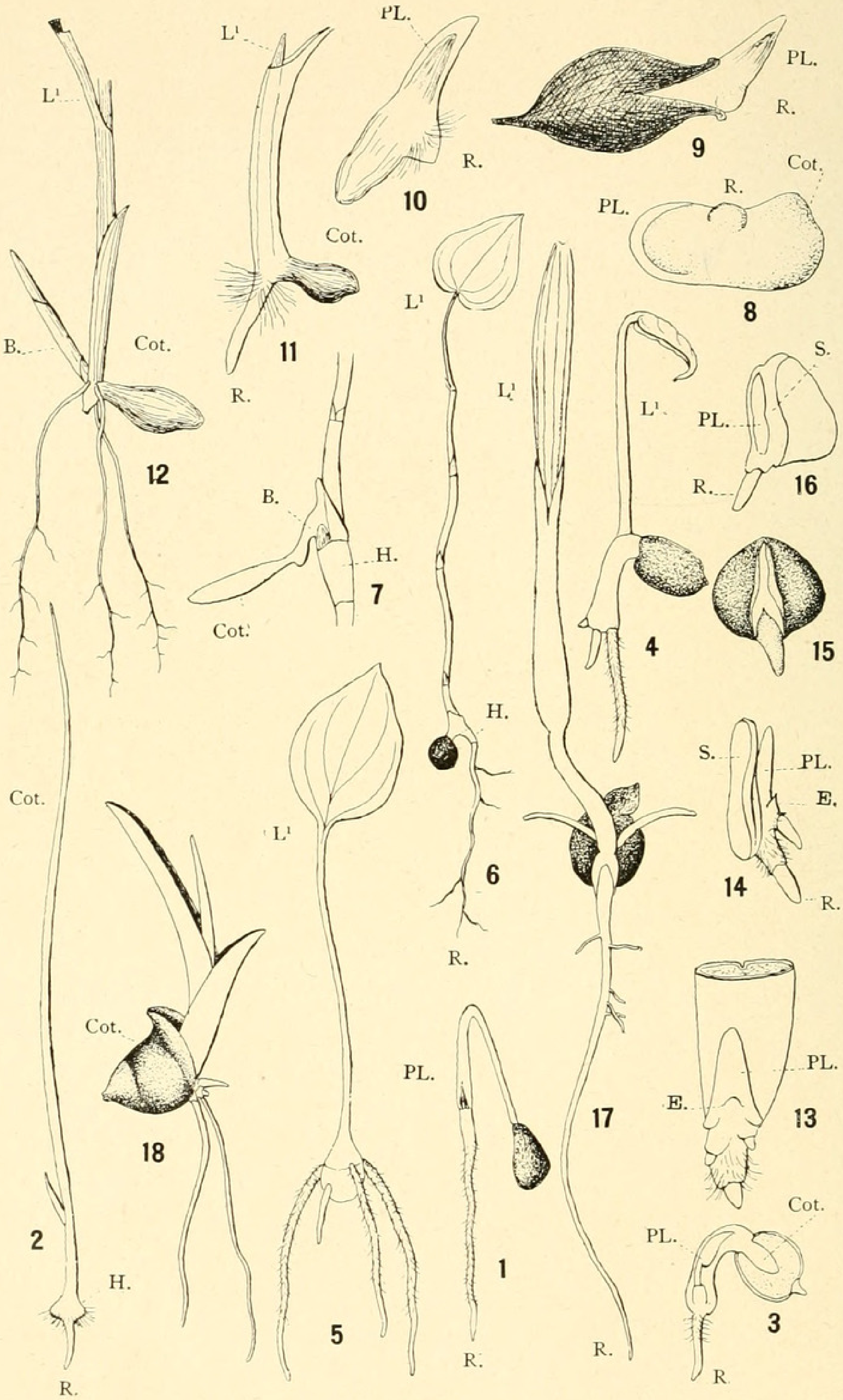
R, the primary root; Cot., the cotyledon; L1, the first green leaf; PL, the plumule; S, the scutellum; H, the hypocotyl; B, bud in axil of cotyledon (Fig. 7), or of the first leaf (Fig. 12); E, the epiblast.

Figure 1. *Agave Americana*, L., natural size.
" 2. *Alisma Plantago*, L., var. *Americana*, R. et S., x 8.
" 3. *Arisæma triphyllum*, Torr., longitudinal section; x 4.
" 4. Same, a little older; x 4.
" 5. Same, still older, showing the first green leaf fully developed; natural size.
" 6. *Smilax rotundifola*, L.; natural size.
" 7. Same, part of the seedling, removed from the seed; x 5.
" 8. *Cyperus vegetus*, Willd., the embryo; x 75.
" 9. Same, germinating seed, surrounded by the pericarp; x 26.
" 10. Same, the seedling, removed from the seed; x 26.
" 11. Same, a more advanced stage; x 18.
" 12. *Rhynchospora alba*, Vahl., seedling; magnified.
" 13. *Secale cereale*, L., germinating grain, seen from the front, but upper half of grain cut of; magnified.
" 14. Same, seedling removed from the grain, side-view; magnified
" 15. *Zea mays*, L., germinating grain; natural size.
" 16. Same, longitudinal section; natural size.
" 17. Same, a more advanced stage; natural size.
" 18. *Peltandra undulata*, Rafin., natural size.

BLUE BIRDS OF THE MARITIME PROVINCES.

By WM. H. MOORE, Scotch Lake, N.B.

As there seems to be a general misunderstanding among people in regard to our blue birds, *i.e.* birds having some blue in their plumage, it has occurred to me that a short paper on this subject might prove of considerable benefit, for at any meeting that the writer has addressed, about birds, this question has always come up. Especially among school teachers, and normal



SEEDLINGS OF PHÆNOGAMOUS PLANTS.