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THE UNDERGROUND ORGANS OF A FEW WEEDS.

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A study of some of the troublesome perennial weeds and their methods of extermination has led the authors to look up the botanical descriptions of the underground portions and manner of propagation.

Some writers have called all underground organs by which the plants in question propagate, rootstocks; others have cautiously said nothing about them and a few have called them roots and rootstock. It was this disagreement of authorities, in part, that made it seem desirable to make a more definite study to ascertain exactly how much of the underground portions are roots and how much are stems. This can be done only by a study of cross sections. Very little, so far as we know, has been published in English on the minute anatomy of the plants under discussion.

The plants in which we have been especially interested are Quack Grass, Canada Thistle, Horse Nettle, Wild Morning Glory, Bindweed, and Milkweed.

The present paper gives the result of our study after making stained mounts of all underground portions. Illustrations of the sections were made with the camera lucida and the photomicrograph.

Some Morphological Views.

The text-books on General Morphology consulted were Gray[1], Robinson and Fernald[2], Britton[3], and Van Tieghem[4]. The special papers and bulletins were Hitchcock and Clothier[5], Crozier[6], Dewey[7], Goff and Mayne[8], and Hitchcock[9].

Hitchcock and Clothier state that the European Morning Glory (*Convolvulus arvensis*) propagates by horizontal roots. The same authors also state that the Wild Morning Glory (*C. sepium*) propagates by slender underground stems. The section of Convolvulus in which *C. sepium* occurs, Calystegia, is characterized by Dr. Gray[10] as having creeping filiform rootstocks. The Milkweed, according to Hitchcock and Clothier, propagates by a creeping root on which adventitious buds appear, although Dewey states that the Milkweed and European Morning Glory propagate by rootstocks. Dewey[11] also states that the

[1]Structural Botany, also Manual of Bot. of Northern U. S. (Ed. 1) 1848. XIV. 244.
[2]Gray's New Manual of Bot. (Ed. 7). 882, 858. 1908.
[3]Manual of the Flora of the Northern States and Canada.
[4]Traite de Botanique. 686.
[5]Bull. Kan. Agr. Exp. Sta. 76: 1-23.
[6]Rep. U. S. Dept. Agr. *1886*: 85.
[7]Far. Bull. U. S. Dept. Agr. 28:14.
[8]First Principles of Agriculture. 107.
[9]The Subterranean Organs of Compositæ. Trans. Acad. Sci. St. Louis. *9*: 1, *1pl.*
[10]Syn. Fl. of N. A. 2:215.
[11]l.c. :14.

Horse Nettle is abundantly propagated by slender perennial rootstocks, while others state that it propagates by roots. With reference to the Canada Thistle, Vasey and Crozier[12], Goff and Mayne[13] and Dr. Gray state that the plant has creeping rootstocks which spread in every direction.

Besides one of the present authors[15], many other writers have accepted and made similar statements without giving the subject much attention.

Anatomical Structure.

Since the general characters will not always enable one to determine the nature of the underground organ, a microscopical study was made. In this way, we were able to determine definitely the extent of the root and stem.

The microscopic structure of roots and their origin is sufficiently indicated in many special treatises on this subject, especially by such writers as De Bary[16], Vesque[17], Marie[18], Jeffrey[19], Costantin[20] Gerard[21], Worsdell[22], Sargent[23], Van Tieghem[24], Strasburger, Noll, Schenck, and Karsten[25], Solreder[26], Holm[27], Andersson[28], Dodel[29], Goldsmith[30], and Van Tieghem[31].

Cirsium arvense (L.) Scop. Canada Thistle.

Root. The root is usually horizontal or occupies a vertical or oblique position in the soil, frequently strongly contorted; whitish or light brown with a strong odor; the small roots occur on the stem without definite order; when immersed in water a blackish extractive matter is removed. The thicker roots produce numerous adventitious buds along their course. The depth in the soil

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[12]l.c. :85.

[13]l.c. :109.

[14]Syn. Fl. of N. A. *1*:393.

[15]Pammel. Bull. Ia. Agr. Exp. Sta. 70:324.

[16]Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns. English Translation by Bower and Scott. Oxford. 1886.

[17]De'l Anatomie des tissus appliquee a la Classification des plants. Nouv. Arch. la Mus. d' Hist. Nat. II. *4*:1; *5*:291.

[18]Recherches sur la structure des Renonculacees. Ann. d. Sci. Nat. Bot. VI. *20*: 1-180. *8 pl.*

[19]Coulter and Chamberlain, Morphology of Angiosperms. 311. The Morphology of the Central Cylinder in the Angiosperms. Trans. Can. Inst. 40. *pl. 7-11.*

[20]Costantin. Etude comparee des tiges aeriennes et souterraines des Dicotyledones. Ann. Sci. Nat. Bot. VI. 16:1-176. *pl. 1-8.*

[21]Recherches sur le passage de la Racine a la Tige. Ann. Sci. Nat. Bot. VI. *11*:279-430. *pl. 1-18.*

[22]A study of the Vascular System in certain orders of the Ranales. Ann. Bot. *22*: 651-628. *pl. 32, 33, 55f.*

[23]A Theory of the Origin of Monocotyledons founded on the Structure of their Seedlings. Ann. of Bot. *17*:1. *7 pl. 10 f.*

[24]Recherches sur la symetrie de structure des plantes vasculaires. Ann. Sci. Nat. V. *13*:185.

[25]A text-book of Botany. Eng. Trans., Lang. 128, 142, 154. 1908.

[26]Syst. Anat. d. Dicotyledonen, 1899.

[27]Am. Jour. Sci. *4*:298. (1897); *9*:355. (1908). *9*:355. (1900) 7:5. 1899.

[28]Ueber die Entwickelung der primaren Gefassbundelstrange der Monokotyledonen. Bot. Centrbl. *37*:586.

[29]Der Uebergang des Dicotyledonen Stangels in die Pfahl Wurzel-Pringsheim Jahrb. 8:149-193. *pl 11-18.*

[30]Beitrage zur Entwickelungsgeschichte in Stengel und in der Hauptwuzel der Dicotyledonen—Dissertation. 1876.

[31]Traite de Botanique. 686, 750.

at which these buds occur varies from a few inches to more than two feet from the surface of the ground. It is not unusual for others among our common thistles to produce adventitious buds. This is indicated by Hitchcock and Clothier[32] for *Cirsium undulatum*. It is also true for *Cirsium canescens*[33] which spreads much like Canada Thistle. Dr. Bessey writes us that he observed this many years ago for this species.

The secondary structure is comparatively simple. The epidermis is persistent. The cortial parenchyma consists of twenty or more layers of thin-walled, somewhat irregular cells, and small intercellular spaces. These parenchyma cells are filled with small starch grains. The cells of the endodermis do not differ materially from the cells of the cortex. Projecting into the vascular region and lying between the phloem and xylem plates, are other broad, primary, medullary rays much wider in the region of the sheath, gradually tapering to a point, toward the center. The phloem elements occur in arched area between the medullary rays. The cambial elements lie between the xylem and arched phloem. The elements of the xylem consist of scalariform ducts and parenchyma cells which are thin walled.

Stem. In numerous specimens examined by us the shoots coming from the roots had small scales and buds along the sides; these for the most part do not develop but can do so when the strong terminal bud is cut off or injured. The microscopic structure consists of an epidermis of a single layer of cells, slightly longer than wide with the outer wall thicker than the lateral walls and carrying a brownish pigment. This is followed by the cortex consisting of many layers of thin walled irregular cells, in which starch and other reserve food products occur. The intercellular spaces are small. The fibrovascular bundles are arranged in a circle and are of the collateral type. The sclerenchyma elements are arranged across the outer and inner portions of the bundle. The phloem is situated between the sclerenchyma and the intrafascicular cambium. The tracheary elements vary with the size of the bundle. These elements consist of spiral, scalariform, and ringed ducts.

Conclusion. The most important method of propagation in the Canada Thistle is by means of the large roots by which the plant spreads through the ground. Such stems as do not occur in the ground come from the adventitious buds on the roots. The seminal roots descend into the soil and later form these adventitious buds. Under some conditions, especially when the plant is injured or when a new shoot is produced in the spring, adventitious buds may be found on the stem.

Solanum carolinense L. Horse Nettle.

The roots and stems of some species of the Solanaceæ have been studied by Gerard[34], also by Costantin[35].

Stem. The twisted woody stem with its numerous lateral roots resembles the root in a very striking manner; in fact it is difficult to distinguish root from underground stem except by microscopical examination. During the winter it dies back near to its origin in the root. The thick walled epidermis

[32]L.c.:13.
[33]Con. Bot. Dept. Ia. St. Coll. Agr. and Mech. Arts. 16.
[34]l.c. 375, *pl. 18 f. 53-64.*
[35]l.c. 132.

surrounds the cortical parenchyma, also thick walled in which are stored large, eccentric starch grains which resemble those found in the potato tuber. The fibrovascular bundles are of the open collateral type, with sieve elements next to the cortex, the xylem next to the pith and separated from the phloem by the cambium. The medullary rays extend from the cortex to the pith and contain a few starch grains. The parenchyma cells of xylem are thick walled.

Root. The tortuous roots vary a great deal. In younger specimens they are somewhat slender, becoming thick and hard with ages, lightly brown in color with strong odor. They extend vertically into the soil from one to four feet or even five feet. Numerous adventitious buds are produced along the course.

A microscopical study shows that the organs which produce the buds are roots; these are the usual radial bundles, but the medullary rays secondary and primary are small and lie between the xylem elements. In the secondary structure a few layers of cork cells are developed and underneath a large number of parenchyma cells with walls somewhat thicker than those of the cork cells. These are abundantly filled with large starch grains and a considerable quantity of protein matter. The bulk of the root consists of the cortex. The xylem is separated from the cortex by a well defined area consisting of the endodermis a few layers of very thin walled cells. The medullary rays are harrow and extend into the xylem area between the bundles. These cells also contain starch grains. The xylem elements consist of scalariform and pitted ducts.

Asclepias syriaca L. Milkweed.

Roots. The roots of Milkweed have been traced in the soil for fourteen feet. They are generally horizontal though occasionally vertical. A single root removed from the soil and placed in a moist place at once produced adventitious buds along its surface. At very short intervals several dozen of these buds could be made out with the naked eye; many more could be made out when sectioned.

The roots are whitish and much thickened. Microscopically the roots show that the bundles are of the radial type. The structure in an older root shows thin walled epidermal cells nearly isodiametric although in some cases longer than wide. Underneath the epidermis there are two or three layers of thin hypodermal cells. The cortex is differentiated into two parts, the outer portion of large irregular thin walled cells and small intercellular spaces and the inner cortical region of cells which become smaller toward the endodermis. The cells of the cortex contain a large number of small starch grains and compound calcium oxalate crystals. In secondary growth the xylem consists of bundles of scalariform ducts varying in number from one to five, which are scattered throughout the parenchymatous tissue of the vascular region. Starch grains and calcium oxalate crystals are also found in this parenchymatous tissue.

Stem. The difference in the origin of lateral roots and that of adventitious buds on the root was studied somewhat at detail in the Milkweed.

Lateral roots originate endogenously within the vascular bundles and with a well defined protoxylem push through the cortex. On the other hand stems originate possibly from a single cortical cell just underneath the epidermis. This cell becomes actively meristematic and soon involves other cells which differentiate definitely into plerome and periblem. The epidermis lying just

above organizes the dermatogen. Just back of the meristem appears the protoxylem which for some time is entirely separated from the vascular tissue of the root; the tissues of the cortex remain undisturbed for some time. However, the oldest buds which we have sectioned show signs of the vascular region of the stem extending down to the one in the root.

Convolvulus sepium L. Common Morning Glory.

Roots. The small whitish roots usually spring in pairs from the base of the scales. The roots like the rhizomes are extremely fragile. The number and character of the secondary roots differ in different plants.

Stem. The plant propagates freely by its underground stem. The rhizomes are fleshy, dirty white in color, and very fragile. They extend horizontal, vertical, oblique, ascending, or descending from a few inches to two or three feet into the ground. The nodes occur at short intervals. The small roots usually occur in pairs, a point noted by Hitchcock and Clothier. One or more aerial stems spring from the upper nodes.

The anatomy of the stem has been studied by Gerard[36] and Costantin[37], the latter giving a careful description of the anatomical structure. The root stock is essentially a storage reservoir for food, every part but the vascular tissues being filled with starch, a comparatively small part being occupied by the vascular elements. The epidermis consists of somewhat elongated thin walled epidermal cells, underneath which are small hypodermal cells, and small intercellular spaces. The cells vary somewhat in size. The inner layer of the parenchyma cells forms the endodermis. The vascular elements form a ring connected by the cambium. There are four large bundles with a few intervening very small bundles. The bundles belong to the bicollateral type with sieve elements and cambial layers between the endodermis and pith parenchyma. The sieve elements towards the pith form irregular areas. The xylem elements consist of scalariform ducts. The pith parenchyma is sharply differentiated from the cambium.

Convolvulus arvensis L. Bindweed.

Roots. Convolvulus arvensis propagates by means of small creeping horizontal roots. The younger ones are whitish, becoming much darker in color with age. Small branches appear at irregular intervals.

The anatomical structure consists of the following parts, an epidermial layer of rather large cells, a deeply staining hypodermal layer, followed by two layers of cells somewhat longer than wide. The remaining cells of the cortex are large, gradually becoming smaller toward the vascular region. The cells contain a small amount of protein, the starch grains having disappeared at the time of examination in the spring. Some of the cells contain crystals of calcium oxalate. A conspicuous nucleus and nucleolus is present in most of the cells.

The xylem consists of large ducts and thick walled cells, arranged radially with the phloem. The medullary rays extend from the cambium in toward the center of the root which consists of five rays projecting into the xylem.

The root produces adventitious buds. These give rise to short vertical stems which often give rise to other new stems.

[36] l. c.
[37] l. c.

Agropyron repens L. Quack Grass.

The vegetative reproductive organs are commonly called roots by the laity, but are universally regarded as rhizomes by botanists. A study of the general morphology and histology leaves no doubt as to their stem characters.

Roots. The whitish fragile roots of the rootstock vary in number and they spring from below the scale.

Rhizome. The rhizomes are generally horizontal except where the stems grow toward the surface of the soil, occuring from one inch to 4-5 inches below the surface of the soil. The greater majority, however, are found not more than three inches from the surface. The creeping rhizomes are from 1—3 feet long nearly terete, divided into nodes which are from an inch to two inches apart; at the nodes numerous small roots and buds spring from beneath the scales.

The histological structure of the rhizome is as follows: The epidermal layer consists of thick walled small epidermal cells. Underneath it is the hypoderm, of two or three layers of cells, also thick walled. Between the vascular ring and hypodermal layer are the large cortical parenchyma cells and the endodermis very much thickened toward the vascular bundles. A short account of the histology of the rhizome is given by Fluckiger[38]. Sayre[39] figured the stem, giving no description, while Greenish[40] gives a short description, and a small, unsatisfactory figure. The fibrovascular bundle is of the closed collateral type, consisting of two or three, sometimes four, large tracheae and the small phloem patch between and a little above the tracheae.

To Dr. Trelease of the Missouri Botanical Garden, to Dr. Beal of Lansing, Mich., and to Mr. R. I. Cratty of Armstrong, Iowa, we are indebted for aid in securing some of the material used in this paper, and to Miss King for some drawings.

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[38]Pharmacographia. A History of the Principal Drugs of Vegetable Origin met with in Great Britain and British India. 729.

[39]A Manual of Organic Materia Medica and Pharmacognosy. (Ed. 2.) 440. *f. 298.*

[40]An Introduction to the Study of Materia Medica. 310. *f. 151.*

DESCRIPTION OF PLATES.

PLATE I.

Fig. I. Rhizome of *Lycopus rubellus*, showing scales and roots. Fig. II and III. Root and rhizomes of Canada Thistle (*Cirsium arvense*). Fig. II, *st* underground stem, *r* root, *b* buds from stems and roots, the stem from an adventitious bud at *r;* lateral roots along the stem. Fig. III. *sc* scales on stem, *r* root, *b* young stem from root. Fig. IV. European Bindweed or Morning Glory (*Convolvulus arvensis*). *r* root, *b* adventitious bud, *st* underground stem. Fig. V. Bindweed or Morning Glory (*Convolvulus sepium*). Underground stem with scales at *sc,* and buds at the nodes, also a pair of roots below the scales at *r*. Fig. VI. Wooly Thistle (*Cirsium canescens*) *r* thickened root with stems *s* and *y* from adventitious buds. All figures drawn by Charlotte M. King.

PLATE II.

Upper figure, cross section of the root of Canada Thistle (*Cirsium arvense*) showing the broad cortical parenchyma between the epidermis and the endodermis; inner portion showing radial bundles, the medullary rays extending into the vascular region. Lower figure, cross section of the rhizome of Canada Thistle (*Cirsium arvense*) showing arrangement of bundles. Micro-photograph by Colburn.

PLATE III.

Upper figure. Cross section of root of Milkweed (*Asclepias syriaca*). The vascular cylinder and the cortical parenchyma from which an adventitious bud has sprung. Lower figure. Cross section of the root of Horse Nettle (*Solanum carolinense*). Radial bundles in center; large cortical parenchyma cells densely filled with starch grains. Microphotographs by Colburn.

PLATE IV.

Fig. I. Cross-section of old root of Common Milkweed (*Asclepsias syriaca*). *ep* epidermis, *cor* cortical parenchyma containing crystal receptacles of calcium oxalate *cr, c* cambium, *xy* duct, *pp* parenchyma among the xylem elements. Fig. II, the woody root of Horse Nettle (*Solanum carolinense*). *x* ducts, *pw* woody parenchyma, *p* parenchyma. Fig. III. General view of bundle root of Horse Nettle showing the ducts at *x* and the surrounding parenchyma, less magnified than in Fig. II. Fig. IV. Cross section of outer portion of stem of *Convolvulus sepium. e* epidermis, *p* parenchyma cells with starch, *a* simple and compound starch grains, higher magnification than at *p*. Fig. V. Portion of root of Canada Thistle (*Cirsium arvense*). *Cor* cortex, *par* parenchyma cells of the cortex, *m* medullary rays, *x* ducts, *p* parenchyma, *c* cambium.

PLATE V.

Fig. I. Cross section of root of Bindweed (*Convolvulus arvensis*). *e* epidermis, *h* hypodermal layer, *c* cortex, *n* nucleus, granular cytoplasm evident, *c'* cells of lower portion of cortical parenchyma, *cam* cambium, *p* parenchyma cells surrounding the ducts at *x*. Fig. II. Cross-section of inner portion of root of Bindweed (*Convolvulus arvensis*), showing bundle region, parenchyma cells and five rays. Drawn by Charlotte M. King. Fig. III. Portion of root of Canada Thistle, showing two large ducts and surrounding parenchyma cells. Fig. IV. Cross-section through rhizome of Quack Grass. *e* epidermis with thick walls underneath, *sc* sclerenchyma, *par* underlying thin walled parenchyma, *end* endodermis, *xy* ducts with thick walled sclerenchyma between *ph* phloem. Fig. V and VI. Root of Horse Nettle (*Solanum carolinense*). Fig. V. Cork, cork cells and underneath parenchyma cells and starch grains. Fig. VI. Cortical parenchyma cells with starch grains.

Roots and rhizomes of I *Lycopus rubellus,* II and III *Cirsium arvense,* IV *Convolvulus arvensis,* V *C. sepium,* VI *Cirsium canescons.*

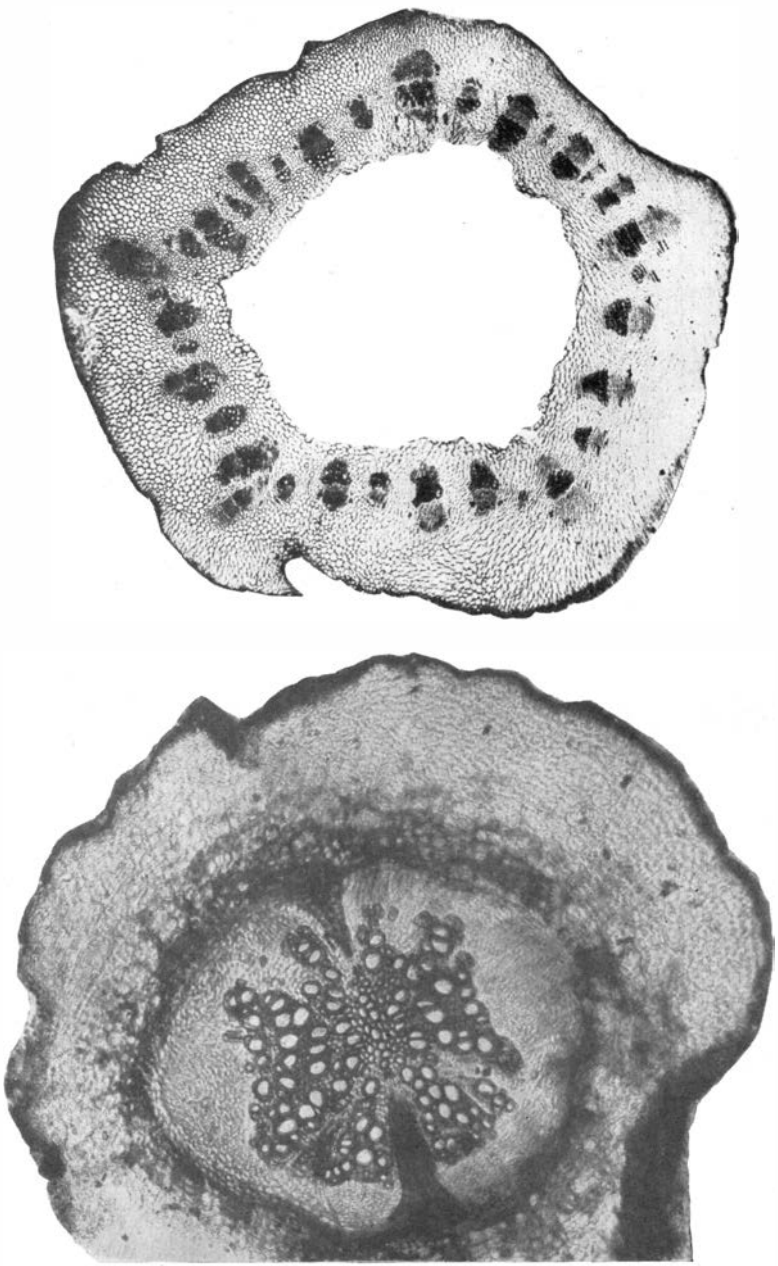

Plate II. Upper figure, stem, lower, root of *cirsium arvense*.

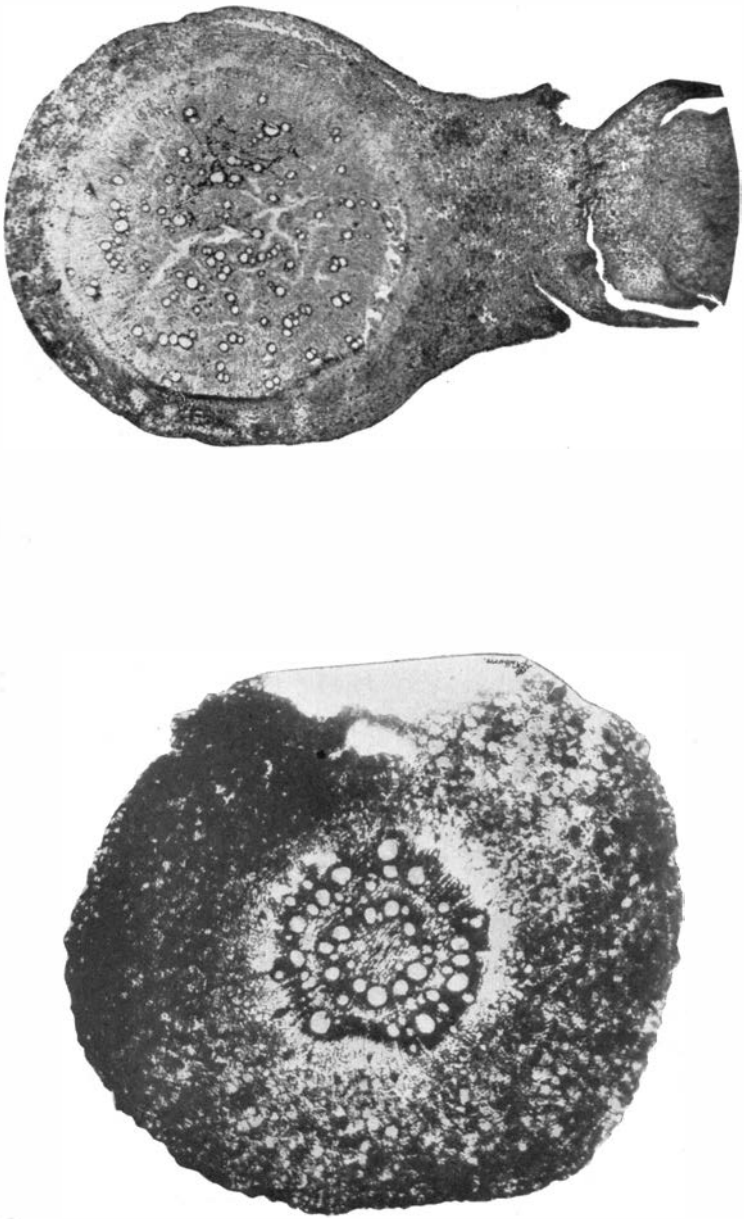

Plate III. Upper figure, root of *asclepsias syriaca:* lower figure, root of *solanum carolinense*.

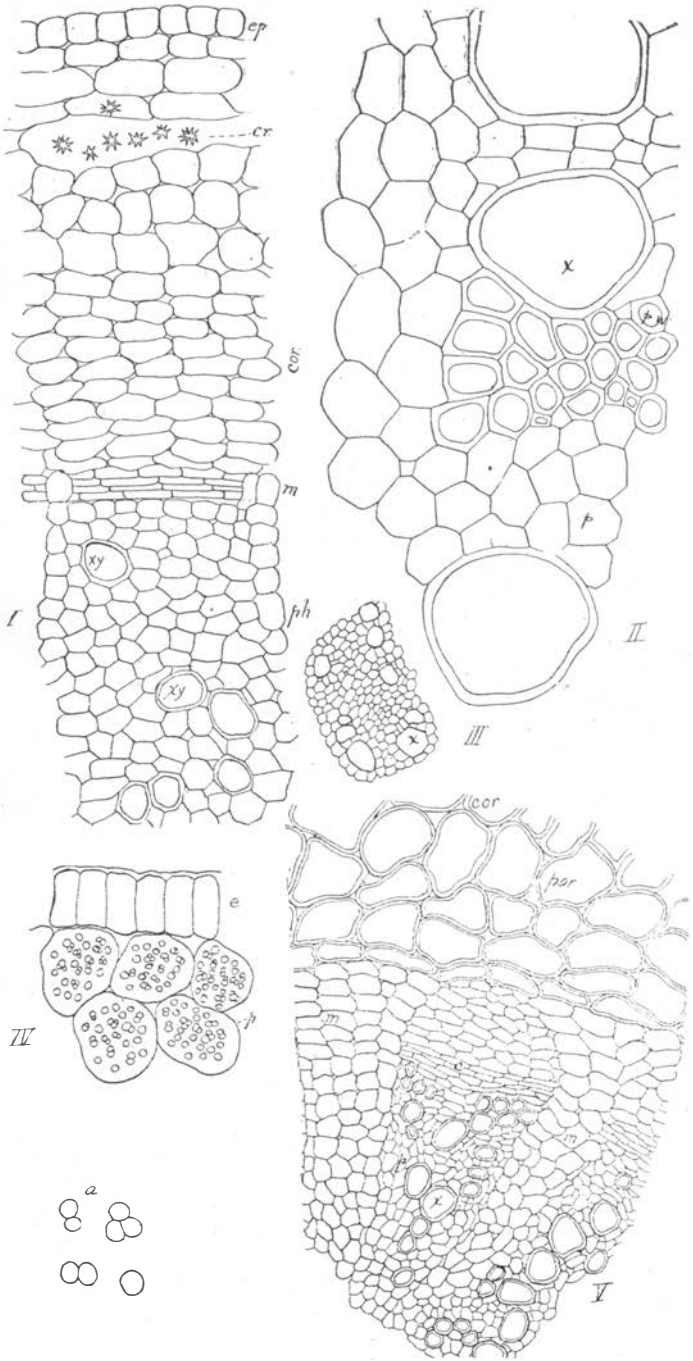

Plate IV—I root of Asclepias syriaca, II and III root of *Solanum carolinense.* IV stem of *convolvutus sepium.* V root of *cirsium arvense.*

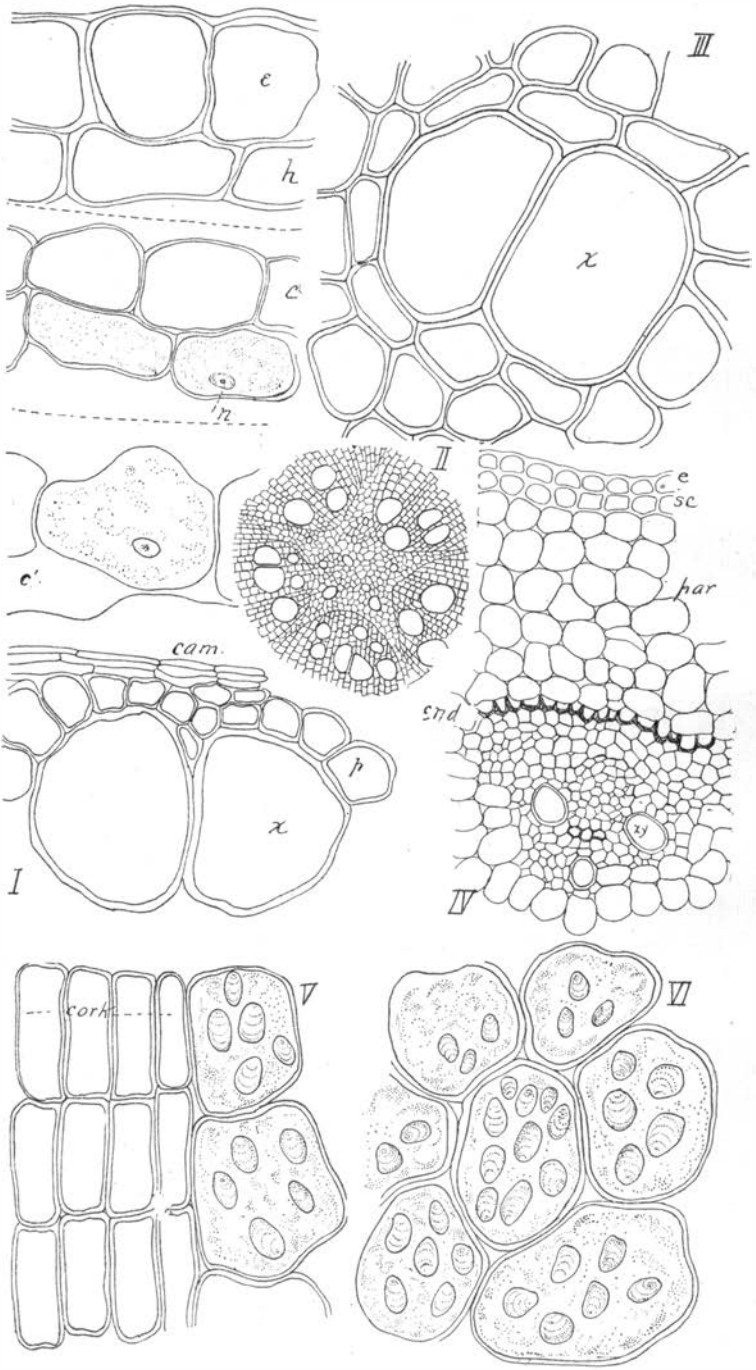

Plate V—I and II Root of *Convolvulus arvensis*. III Root of *Cirsium arvense*. IV Quack grass stem. V and VI Root of *Solanum carolinense*.