

THE ANATOMY OF THE TRANSITION ZONE OF SOME SPECIES
OF PASSIFLORA AND THE PHARMACOGNOSTIC ANATOMY
OF PASSIFLORA INCARNATA L.

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Introduction

Passiflora incarnata L. was introduced into America in 1609 by a sailor from Bologna (1). Since that time little anatomical work has been done upon the plant. The present work consists of a comparative study of the transition of the seedling of P. incarnata with other species of *Passiflora*, namely, P. alba Link and Otto, P. adenopoda DC, P. coerulea L., P. coerulea L. v. grandiflora Hort., and P. edulis Sims, and a pharmacognostic study of P. incarnata based upon the scheme presented by Moll and Janssonius in their "Botanical Pen-Portraits"(2).

The early work of Clos (3), Strasburger (4), Gerard (5), Vullemin (6), Herail (7), Dangeard (8), and Van Tieghem (9) included the anatomical change from root to stem in many plants from which the latter summarized into his three types of transitions. A fourth type was found by Sargent (10) in her work on certain monocotyledons. These four types have been characterized in diagram style by Eames and MacDaniels (11). In the first type, the phloem proceeds in its course without change while the xylem divides radially and then swings laterally to join the phloem patches, thus forming the same number of stem bundles as there are phloem

patches in the root. This type of transition occurs in *Dipsacus*, *Mirabilis*, *Fumaria*, *Cicer*, and *Glottidium* (12). Both xylem and phloem patches divide in the second type to form twice the number of bundles in the stem as there are phloem patches in the root. This occurs in *Acer*, *Cucurbita*, *Impatiens* (13), *Phaseolus* (14,15), *Ephedra* (16), and *Tropaeolum*. The third type shows the xylem unaltered except in swinging while the phloem patches divide radially, then move laterally and join the xylem patches to form the same number of stem bundles as there are xylem patches in the root. This type occurs in *Medicago*, *Lathyrus*, and *Phoenix*. Sargent's fourth type varies in that it produces a decrease in the number of stem bundles in comparison to the phloem patches in the root. Here half the xylem patches are unaltered except in swinging, the rest dividing to join laterally the swinging unaltered xylem patch while the phloem patches adjacent to the unaltered xylem strand join together with the xylem combination to form a stem bundle. This condition is found in a few monocotyledons, e.g. *Anemarrhea*, and in some of the *Ranunculaceae* (17). Occasionally, the transition is more complex in that it is not completed by the time the cotyledonary traces leave, but

continues through a few nodes before completion as is found in *Pisum* (18). Another unique type has been recently found in the sunflower, *Helianthus annuus* (19,20), in which an asymmetrical origin of the intercotyledonary phloem groups occur. In this case, the intercotyledonary phloem originates from the double bundles on one side only.

The study of seedling structure has progressed along various lines and has included various orders and families, namely, the Piperales (21,22), the Ranales, Rhoadales, and Rosales (23), the Tubiflorae (24) and the Compositae (25) of the Sympetalae, the Leguminosae (26), the Solanaceae (27), the Cactaceae (28,29), and the Gymnosperms (30). From these studies, various viewpoints have evolved which include the theory of the double leaf trace (31), a theory of the origin of monocotyledons (17), that seedling structure is not a basis for determining plant affinities (22,24,25,29), a discussion regarding the growth of hypogeal and epigeal cotyledons (32), and last, general discussions of the theories of the anatomical transition (33). Economic plants such as the parsnip (34), the potato (35), the sweet potato (36), cotton (37), flax (38), and tobacco (39), have not been neglected in their

transition anatomy.

The second part of the study serves as a means of introducing the pen-portrait method of describing those drugs recognized by the United States Pharmacopoeia and the National Formulary. In applying this method a drug was so chosen upon which little pharmacognostic study has been made.

These botanical pen-portraits according to Moll, are based upon the Linnean method of description, well known in phytography. The Linnean method of description shows three prominent characters, a strict order in the arrangement of facts described, the use of well defining technical terms and a kind of telegram style. The principal advantage secured by the vigorous order of the characters in a Linnean description are in the first place a certain completeness, because nothing is omitted by chance, and in the second place repetitions will be avoided. In the description of so complex structures as plants generally offer, those advantages are indeed of utmost importance. In micrography two additional principles are wanted. The descriptions of sections in various directions must be combined into a perspective description reproducing the tissues as bodies with three dimensions. In the second place

the division of anatomy into cytology, histology, and microscopical anatomy must be emphasized. This method of portraying is intended for use both in phytography and in micrography. In both cases it is combined with, or rather added to, the Linnean method. In the case of micrography the principles of perspective descriptions, of histology and microscopical anatomy and of separate topography and cell descriptions are moreover applied. Thus it is in some sort an extension of the existing methods on which it is based. The method of pen-portraits starts from the Linnean description using its regular and strict order, its telegram style and its terminology. The terminology is restricted within more moderate bounds than in organography and new terms are introduced only in cases of absolute necessity.

The method of pen-portraits has been used in the fourth edition of the *Pharmacopoea Neerlandica*, in describing the macroscopic characters of the drugs and the microscopic characters of the powders. In pharmacognosy, the Linnean method was used with some success and on a large scale by Koch on the micrography of powdered drugs (40).

The drug *Passiflora* was introduced into the

National Formulary IV and retained in the fifth revision (41). It is also official in the Homeopathic Pharmacopoeia III.

Material and Preparation

The fresh matured fruits of P. incarnata was obtained through the courtesy of one of the drug growers from which the seeds were removed from the surrounding pulp, washed, and dried. The seeds of the other *Passiflora* species were obtained from reliable seed growers. Seeds planted in a moist chamber germinated in 3 to 10 days (P. edulis, P. incarnata, P. adenopoda), or in the green house in 30 to 60 days. Soaking the seeds for one to three days before planting lowered the period of germination for P. edulis, P. coerulea, and P. incarnata. The percentage of germination of the seeds was very small in some cases (P. adenopoda, P. alba, P. coerulea grandiflora). The material used for the pharmacognostic study of P. incarnata was grown from the seed, or collected in the vicinity of Dillon, S.C.

The bulk material was killed in stock chromoacetic solution; while the seedlings and other young

material were killed in Flemming's medium, Crooks' modification of Navaschin (38), or Jeffrey's bi-chloride picric solutions. After the usual treatment of washing and dehydrating by alcohol, the material was finally mounted in celloidin, using the hot method of Wetmore (42), or in paraffin through chloroform. For young or any special material, the butyl alcohol method was used to an advantage (43). The sections were stained best by using safranin and counterstaining with Delafield's hematoxylin. The seedling material was cut at 10 to 12 microns.

In order to trace the vascular tissue of the leaf, leaves were cut at the lower portion of the petiole and placed in a weak basic fuchsin solution (alcoholic basic fuchsin solution 2.5% 1 c.c., water 100 c.c.) for approximately 24 hours (44,45). Clearing was accomplished by means of chloral hydrate, lactic acid (46), or through the alcohols and cedar-wood oil. Entire seedlings were similarly treated for a gross examination of the transition.

The photography was made either with the Leica or with a Bausch and Lomb Type K camera. The initial magnifications are given in the explanation of plates. The individual diagrams of the leaf and stem were outlined from sections projected at approximately

100 magnification, assembled, and reduced photo-statically.

Results

Transition

Since the transitions of the *Passiflora* species investigated were similar, they will be considered as a group. The transition of one of the species (*P. incarnata*) is therefore given in detail; the exceptions in the other species are noted.

The primary root is diarch, the protoxylem occurring next to the pericycle. In seedlings a few days old the protoxylem occurs as two small patches separated by pith. Gradually in older seedlings the metaxylem forms centripetally to connect the two strands of protoxylem. The primary phloem patches consist of two small masses of dense parenchyma. The pericycle is clearly discernible consisting of one to two layers of cells and gives an early rise to lateral roots (Plate I, fig. 1). The endodermis is identified by the small size of the cells in comparison to those of the cortex, and occasionally, by the casparian strip. The cortex usually varies from five to eight layers of cells depending upon the seedling. The cortex cells vary greatly in size and shape and contain

many intercellular spaces. The epidermis is thin-walled and gives rise to copious root hairs.

The rapid elongation of the hypocotyledonary tissue occasionally prevents a true spacial version of the transitional changes. In many cases the cotyledonary node may be about 125 mm. above the soil (P. incarnata). In such cases, the cleared entire plant shows little change due to the length of the hypocotyl. Generally, the transition occurs low in the hypocotyl when the gradual changes to the endarch condition is reached about the middle of the hypocotyl. The upper portion of the hypocotyl then shows a typical stem structure.

A seedling two to three days old shows the transition just below the cotyledonary node where the splitting of the xylem occurs (in P. incarnata, about 300 microns). Tracing the transition upwards from the root, a bifurcation of the phloem is noted which continues to such an extent that the xylem is central and flanked on either side by a phloem patch (plate I, fig. 2). The xylem elements in the meantime are less numerous. While the phloem is continuing its course outward, the xylem elements separate from either side of the strand perpendicular to the movement of the phloem (plate II, fig. 3).

Then as the xylem elements approach the phloem patches, the phloem swings inwardly toward the xylem to form on both sides two cotyledonary traces, separated by a strand composed of one or two elements, which locate the position of the protoxylem.

A seedling two to three weeks old shows the connection between the hypocotyl and the epicotyl. In this case the phloem after dividing as in the younger seedling may either spread to form a band which later divides into a number of small patches depending upon the number of leaves already destined (noted in some of the P. alba and P. incarnata seedlings), or the two halves of phloem may further divide laterally, the lateral branches or epicotyl traces passing between the two outer phloem patches (plate II, fig. 4). These two outer phloem patches later form the cotyledonary bundles. The xylem likewise separates as in the younger seedling, the metaxylem swinging outwardly on both sides to form two patches of metaxylem separated by a strand of protoxylem to show its original position. This strand of protoxylem is gradually resorbed in the growing plant (plate XVII, fig. 23,24,25). If the complete xylem plate has already formed in the root, the advent of the pith occurs in such a fashion as

to form the swinging xylem traces (compare figures A in plate VI and VII).

As the plant develops, the swinging xylem patches give off lateral branches from its outermost portions (plate XVII, fig. 22). These lateral branches pass between the cotyledonary traces and unite with the phloem patches present to form the endarch bundles of the epicotyl. The swinging xylem strands meet the tangentially moving outer phloem to form endarch cotyledonary bundles (plate III, fig. 5). The hypocotyl at this time shows a typical stem structure consisting of the larger cotyledonary bundles and the smaller intercotyledonary bundles. However, some of the smaller intercotyledonary traces may consist of phloem tissue only (plate XVI, fig. 19).

Approaching the cotyledonary node the cotyledonary bundles proceed to move outwardly while the smaller endarch bundles and phloem patches move inwardly to form the epicotyledonary structure (plate III, fig. 6), or in the case of *P. adenopoda*, two rows of vascular tissue reaching from one side to the other in a cotyledonary direction. In this latter case, the outer portions of the vascular rows separate in the usual manner to pass into the

cotyledonary buds (plate X), while in P. coerulea grandiflora, the outer portions also move out radially to form the lateral cotyledonary bundles (plate XVI, fig, 20, 21) while the remaining portions tend to form the epicotyl vascular ring.

In the P. adenopoda and P. coerulea grandiflora seedlings, the first formed lateral branches of the phloem and xylem from the opposite cotyledonary bundles join to form a broad bundle which higher in the hypocotyl again divides to form a number of epicotyledonary bundles (plate XIV and XV). In P. coerulea, the xylem traces of the epicotyl bundles sometimes appear to arise de novo from the parenchyma.

In the base of the cotyledon of a young seedling, the two bundles divide laterally, the outermost portions passing outward to form the laterals, while the two innermost halves pass inwardly to gradually combine with the single protoxylem trace to form the midrib of the cotyledon. As the seedling grows, the phloem patches fail to join but form a V-shaped bundle, while in the mature cotyledon, the two bundles have grown apart and remain as the main ribs of the cotyledon (plate IV). This is shown in diagram style on plate XIII.

The basipetal growth in the cotyledons occurs in both directions to take care of the increased thickness of the petiole and to aid in removing the cotyledons from the endosperm sac. Stomata differentiate early in the cotyledons as well as on the hypocotyl. The mature cotyledons were elliptical or oval in outline for all species, margin entire, up to 30 mm. in length and 16 mm. in breadth, the petiole 10 mm. long. The axillary buds of the cotyledons occasionally develop.

A longitudinal section of a young seedling of P. incarnata is given on plate V, figure 10. Sections of the species of *Passiflora* investigated showing the various stages of the transition from root to stem is given in plates VI to XII.

Pharmacognostic Anatomy of Passiflora Incarnata

Since three dimensions are given, it is necessary to mention the direction of each, hence the following abbreviations are used.

- L. - In a longitudinal direction, i.e. in the direction of the main axis.
- R. - In a radial direction, from center to periphery.
- T. - In a tangential direction, at a right angle to the radial direction.
- Lev. - In the direction of the surface of the organ.
- Lev. L.- Parallel to the surface in a longitudinal direction.
- Lev. B.- Parallel to the surface in a transverse direction.
- H. - Height, in a direction perpendicular to the surface.

Stem

Micrography

Epidermis

Epidermis proper. Stomata present, phaneroporous, lying in the level of the epidermal cells or somewhat higher. Trichomes present in the young stem like those of the leaf, for the rest see the leaf.

Epidermal cells proper. R. 16u, T. 24u, L. 25-40u; tetra- to pentagonal tables with a longitudinally directed axis, occasionally pentagonal in radial section; outer wall with cuticle. Cell contents: some small chloroplasts. Stomata. Lev. 18u and 28u; usually longitudinally arranged.

Cortex

Secondary cork tissue. In stems 6 mm. thick, tangential division of the outer layers of cortex to first form lenticels; as many as seven layers of cells.

Cells of the above. R. 25u, T. 30u, L. 35u; cubical with rounded edges. Cell contents: Many of the cells containing a dark brown substance.

Primary cortex proper.

Collenchyma. Mostly apparent in the ridges of small stems; forming one to three layers of cells. For the rest see the common parenchyma.

Common parenchyma. Consisting of about seven rows of

cells intermixed with crystal idioblasts; cells of the hypodermis smaller in diameter. Showing intercellular spaces. Idioblasts containing rosettes, sometimes forming longitudinal rows.

Common parenchyma cells. The largest R. and T. 80u, L. 90u; tetra- to hexagonal prisms with rounded ends, cells mostly irregular. Tangential walls collenchymatous, mostly apparent in the three outermost rows. Cell contents: in the hypodermis, some small chloroplasts, 3-10u in diameter; some of the cells containing mucilage and others become brown and granulated due to chromic acid. Idioblasts. L. 25-35u; otherwise similar to surrounding parenchyma; for the rest see the pith ray.

Endodermis. Ordinarily not clearly defined.

Stele

Pericycle. Consisting of bundles of sclerenchyma fibers, separated by common parenchyma cells. In stems 3.5 mm. in diameter, large oval bundles containing up to eight rows of fibers in a radial direction, and up to twenty rows in a tangential direction, usually opposite the primary xylem; decreasing in stems 6 mm. or more thick. Smaller bundles are found between the larger containing

one to three layers of fibers. Occasionally only small scattered bundles of fibers are found throughout. None present in the apex of the stem.

Common parenchyma cells: similar to those in the cortex. Sclerenchyma fibers. R. and T. 20u, L. very long, 1.2 mm. or longer, tri- to hexagonal, mostly with rounded edges and with tapering ends. Walls thickened, lignified in the mature stem; thin walls and not lignified in stems 1.5 mm. thick.

Compound vascular bundles. Containing each about eight simple bundles, pith rays between the compound bundles usually broader than those within them. Simple vascular bundle collateral; open.

Phloem

Primary phloem. Exarch; in a stem 1.5 mm. thick consisting of sieve tubes and companion cells in the outermost portion and some phloem parenchyma in the inner portion.

Fascicular secondary phloem. Forming a continuous ring up to 750u thick in a 6 mm. stem, consisting of sieve tubes, companion cells, and phloem parenchyma; usually no distinction between primary and secondary phloem. The primary phloem noted by the crushing effect or forming a continuous layer with

the primary phloem parts of the pith ray, especially those lying within the compound bundles. A few secondary rays developed here and there.

Cells of the above. Sieve tubes. R. and T. 25-30u, length of articulation, 300u; sieve plate faint if seen, penta- to polygonal prisms. Companion cells. R. and T. 7-10u. Phloem parenchyma: resembling those of the pith ray.

Fascicular cambium. Joining the interfascicular cambium to form a continuous layer around the stem, one to four layers of radially arranged elements.

Cells of the above. R. 8-10u, T. 18u, L. 100-180u, rectangular in cross-section.

Xylem

Fascicular secondary xylem. In a stem 3.5 mm. in diameter, arranged in a ring, making up about 20 elements in a radial direction. Consisting of large scattered pitted vessels among the almost radially arranged libriform fibers. Forming a ring 750-900u wide in a 6 mm. stem. Intercellular air-spaces lacking. A few secondary medullary rays developed here and there.

Vessels. R. and T. 25-50u, length of articulation 200-375u, hexa- to polygonal prisms, or pyramidal in longitudinal axis, with rounded edges and slit-like

or round pores, simple and bordered, or with reticulate markings. Libriform fibers. R. 15u, T. 12u, L. 200-500u, tetra- to pentagonal with long tapering ends, slightly rounded edges, thick walled and lignified. Primary xylem. Endarch, consisting of radially arranged vessels, decreasing in size toward the pith.

Vessels. R. and T. 18-30u, length of articulations 175-600u, tetra- to polygonal prisms, with rounded edges and blunt or tapering ends; spiral or scalariform. Wood parenchyma. R. and T. 7-20u, L. 50-175u, tetra- to hexagonal prisms. Cell contents: in some of the cells granulation due to action of chromic acid.

Pith rays

Between the compound bundles.

Primary phloem part. In the young stem similar to the cortex, the cells slightly smaller.

Interfascicular phloem. Consisting of parenchyma cells, somewhat radially arranged intermixed with crystal idioblasts.

Parenchyma cells. The largest R. 50u, T. 35u.

Idioblasts. Similar to parenchyma cells; in radial rows; rosette crystals, 15-20u, occasionally 30u in diameter.

Interfascicular cambium. See the fascicular cambium.

Interfascicular secondary xylem. In cross-section, somewhat like the fibers of the fascicular secondary xylem, but larger in the radial dimension. Crystal idioblasts when present usually in longitudinal pairs.

Cells of the above. R. 14-18u, T. 12u, L. 35-50u; mainly tetragonal prisms, lignified, with simple pores. Cell contents: Some of the cells containing a yellow to a dark reddish brown substance, singly or in radial rows. Crystal idioblasts. Cells similar to other cells; crystal prismatic, 15u in diameter. Primary xylem part. Similar and increasing in size toward the pith.

Within the compound bundle. Forming a continuous layer with the primary phloem parts as noted above; in interfascicular secondary phloem and interfascicular cambium same as between the compound bundles. Interfascicular secondary xylem like the fibers of fascicular secondary xylem, differentiated by the presence of pits. For the rest, see between the compound bundles.

Pith. In a 6 mm. stem, composed of a few layers of parenchyma cells next to primary xylem and in the center a cavity. Crystal idioblasts often in short longitudinal rows. Intercellular air-spaces present.

Cells of the above. Parenchyma cells up to 80u

in diameter, L. 150u, cylindrical or slightly oval prisms. Cell contents: similar to those of the wood parenchyma. Crystal idioblasts: L. 50u, otherwise similar to the other parenchyma cells.

Leaf

Micrography

Intervenia

Epidermis upper side. Stomata and trichomes scarce.

Epidermal cells proper. H. 20u, Lev. 30-45u and 45-60u; lateral walls sinuous, outer walls covered with cuticle 5 u thick. Trichomes usually over or close to small veinlets; for the rest, see the vein. Guard cells. Lev. 18u and 27u.

Epidermis under side. Stomata 400 to the square mm., phaneroporous, sometimes slightly above the level of the epidermal cells.

Epidermal cells proper. H. 15-20u, Lev. 25-45u; otherwise the same as the upper side. Guard cells. H. 12u, Lev. 22u.

Mesophyll. Consisting of palisade and spongy chlorenchyma.

Palisade chlorenchyma. One layer of cells showing intercellular spaces.

Cells of the above. H. 35-65u, Lev. 10-15u;

cylinders with rounded ends. Cell contents: some chloroplasts, 3-10u in diameter.

Spongy chlorenchyma. Consisting of 3-5 layers of stellate cells. Large intercellular spaces. For the rest see the palisade chlorenchyma.

Margin

Epidermis consisting of 2-5 rows of longitudinally arranged cells. Glandularly serrated. Under the epidermis a collenchyma bundle of 2-5 layers of cells more prominent at the base of the outer margin and between the lobes. Trichomes present below the serrations of the outer margin and below the lobes. Often a gland, one or two, usually one, present below the first serration of the inner margins between the lobes.

Epidermal cells. H. 20u, Lev.L. 30-60u, Lev. B. 20u; more or less cylindrical with cuticle thicker than in the intervenia. Glandular serrations. On outer margins, 160u, on inner margins 200u in diameter, first serration sometimes up to 325u, round or oval, more developed at the base, usually only the lower serrations will secrete, the secretion containing reducing sugars. Trichomes see under veins. Gland of inner margin. On the under side, close to margin below the first serration, about

300u in diameter; cells externally appearing as a honeycomb; epidermis under side composed of epithelial cells; crystal idioblasts present. For further details see the gland of the petiole, the make-up is similar. Collenchyma cells. R. and T. 10-18u, L. 50-100u; penta-, mainly hexagonal prisms.

Veins

Epidermis upper side. In the larger veins and ribs, cells more or less longitudinally arranged with hairs up to 425u in length. Above the small veinlets the epidermis resembling that of the intervenia.

Epidermal cells proper. R. and T. 20u, L. 50-60u; tetra- to hexagonal prisms, outer wall with cuticle and inner walls collenchymatously thickened.

Trichomes. 1-4 celled, usually 1-2, papillae, diameter at base, 12-25u; length up to 425u; conical, more or less curved, usually upwards, walls thickened at base decreasing to tip.

Epidermis under side. Small veinlets as upper side. For the rest see the upper side.

Mesophyll

Collenchyma. In the ribs two flat bundles, one on the upper, the other on the under side. The upper bundle in the middle 3 layers of cells, at the

margin 1 layer; that on the under side in the middle 5-6, at the margin 2-4 layers.

Cells of the above. R. and T. 15-30u, L. 90-200u; penta- or hexagonal prisms with tapered ends, thickened on upper and under sides, middle lamella faintly visible. The larger cells on the under side.

Colorless parenchyma. Consisting of about 4 layers of cells on the upper and about 6 layers of cells on the under side, the cells on the under side smaller near the collenchyma. Occasional intercellular spaces on the upper side. Crystal idioblasts usually present.

Parenchyma cells proper. Upper side. Small cells R. and T. 25u, large cells 55u, L. 50-150u; polygonal prisms or cylinders. Under side R. 25u, T. 20-30u; for the rest the same as the upper side. Idioblasts. R. and T. 25-50u, L. 40u; crystals 20-25u in diameter, rosette.

Palisade and spongy parenchyma. When found only at the lateral sides of the upper side as a continuation of the palisade and spongy chlorenchyma of the intervenia.

Endodermis. Ordinarily not clearly defined.

Meristele. At the base of the ribs the large meristele generally composed of 4 bundles, the

lateral ones larger. In the midrib the lateral bundles and the one on the lower side form a gutter shaped meristele, the concave side turned upwards leaving a small bundle on the upper side, the xylem of which is facing downward. In the ribs the mentioned bundles converge to form a single gutter later in the rib, the single bundle on the upper side gradually disappearing.

Pericycle. Not to be distinguished.

Vascular bundle. Single bundles collateral, open.

Phloem. Bundles chiefly consisting of sieve tubes and companion cells in the inner part and cambiform cells in the outer parts of the bundle. Crystal idioblasts usually present.

Sieve tubes proper. R. and T. 10-15u, length of articulations about 150u; polygonal prisms, callus present, sieve plate not distinguished in transverse section. Companion cells. R. and T. 2-10u, tetra- to polygonal prisms. Cambiform cells. R. 12-15u, T. 18-24u; polygonal prisms. Crystal idioblasts. See under colorless parenchyma; in longitudinal section, usually 2-4 cells together, occasionally up to 7.

Cambium. Two to four layers of elements.

Cells of the above. R. 6u, T.15u, L. 45-60u;

tetragonal prisms.

Xylem. The large simple bundles at the base of the midrib consists of 2-8 elements in a radial, of 4-7 elements in a tangential direction. Spiral and reticulate vessels. Parenchyma cells not numerous.

Vessels. R. and T. 12-30u, length of articulations 200-300u, the smaller of which are loosely spiralled; polygonal prisms. Parenchyma cells. R. and T. 8-15y, L. about 20u.

Pith ray. Ordinary parenchyma, the cells of which become smaller towards the center. For the rest see the cells of the colorless parenchyma.

Pith. Represented by parenchyma adjoining the xylem and the pith rays. Intercellular spaces wanting. Crystal idioblasts occasionally present.

Parenchyma cell. R. and T. 10-18u, L. average 65u; poly-, mainly pentagonal prisms, walls thickened, the larger ones usually in the center. Crystal idioblasts R. and T. 15u, L. 22u, sometimes up to 60u, forming a longitudinal row containing as many as 7 cells.

Petiole

Epidermis proper. Cells tending to be in longitudinal rows. Stomata present. Trichomes present mainly on the upper flattish side. At the apex

two secretory glands facing toward the upper side. At the very base the tendril leaves the stem attached to the petiole then quickly separating.

Epidermal cells proper. R. 18u, T. 15-25u, L. 12-21u; for the rest see the vein. Stomata. Lev. 21u and 35u on the petiole proper; decreasing to 20u and 25u close to glands; for the rest see the intervenia. Trichomes. Length up to 600u, the larger between the glands, for the rest see the vein.

Glands. Radially about 900u, tangentially 1.8 mm. in length; composed of an outer epithelial layer almost completely covering the gland and an inner portion of common parenchyma cells intermixed with crystal idioblasts; strands of vascular tissue passing throughout.

Epithelial cells. H. 40u, T. 10-12u; composed of one or two layers, without regularity, externally appearing as a honeycomb, rectangular in longitudinal section with round edges; secreting a clear viscous liquid containing reducing sugars. Common parenchyma. Lev. up to 60u; cells variable in size and shape. Crystal idioblasts. Lev. 30-45u, otherwise similar to surrounding cells; crystal, up to 30u in diameter, rosette.

Tendril. Structure similar to very young stem.

Collenchyma. 1-4 layers, absent when opposite the stomata.

Cells of the above. R. 35u, T. 25u, L. 40-50u; penta- to hexagonal prisms, one side tapering, smaller towards the outside.

Colorless parenchyma. Similar to vein on the under side.

Endodermis. More prominent in the petiole proper.

Meristele. In the petiole proper, on the under side a gutter shaped meristele composed of nine separate bundles, the concave side turned upwards leaving a larger bundle on the upper side, the xylem of which is facing downward. The bundles next to the center of the gutter on either side composed of only one or two vessels, the others consisting of 3-5 rows of vessels in a radial direction.

The larger bundle on the upper side consists of about 16 rows of vessels in a radial direction.

These bundles later divide to form the three main ribs of the lamina. For the rest see the vein.

Flower

Bract

Epidermis outer side. Cells usually irregular in size and shape, occasionally tetragonal in longitudinal rows. Stomata few. Trichomes present, unicellular, curved, conical up to 300u in length.

Epidermis inner side. Similar to outer side; over main meristele T. 16u, L. 25-50u, tetragonal prisms in longitudinal rows. Trichomes present; longer and more numerous than those of the outer side, otherwise similar to those of the calyx.

Margin

At the base, entire or slightly papillate; midway to apex, one or two glands, usually one, on either side, similar to the first gland of the inner lobe of the leaf; higher, the margin glandularly serrated, the serrations more acute than those of the leaf, the serration at the apex rising as a spire.

Trichomes along entire margin, numerous at the base and over the lower glands; otherwise similar to those of the petiole. Crystal idioblasts wanting in the glands.

Mesophyll

At the base, common parenchyma with intercellular spaces; above the level of the glands, spongy paren-

chyma in the center; otherwise similar to the calyx.

Meristeles

At the base, three meristeles; the lateral meristeles quickly dividing, the outer strands passing into the lower glands; the central meristele divides and passes with the remaining strands of the lateral meristeles into the serrations.

Calyx

Epidermis inner side. At the base cells tetra- to hexagonal with lateral walls sinuous, becoming somewhat smooth and smaller at the apex. Stomata at the base about 35 per sq. mm., the number increasing towards the apex; slightly below the level of the epidermis. Trichomes wanting.

Epidermal cells proper. Base, Lev. 40-60u and 30-40u; apex, 20-40u in diameter; penta- to hexagonal, nearly isodiametric in a longitudinal directed axis.

Epidermis outer side. At the base cells with lateral walls sinuous; higher, the cells irregular and the sinuosities much deeper; above the principal meristeles, rectangular with sinuous or smooth lateral walls. Stomata numerous at the base, at least 120 per sq. mm., wanting over the main meristeles. Trichomes present over the entire surface, more numerous at the base.

Epidermal cells proper. Base, Lev. 36u and 60u; apex, Lev. 30u and 50u; over principal meristemes, Lev. 22u and 60u. Stomata. Lev. 26u and 32u. Trichomes 300-600u in length, about 20u at the base; mostly curved, uni- and multicellular, conical, otherwise similar to those of the leaf.

Mesophyll

In the intervenia consisting of 3-6 layers of cells, the inner layer and outer one or two layers generally of common chlorenchyma, the rest of spongy chlorenchyma. Large intercellular spaces. In the center on the inner side at least 10 layers of spongy parenchyma and on the outer side, about 6 layers of common parenchyma, the number decreasing toward the margins. In the outer layers the walls thickened with occasional intercellular spaces.

Meristemes. Essentially the same as those of the leaf; vascular bundle collateral; vessels annular and spiral, lightly lignified.

Corolla.

Epidermis inner side. At the base cells irregularly shaped, the walls more or less sinuous; the cells becoming smaller towards the apex. Cells more regular, tetragonal when close to and over

the main meristemes, tending to be longitudinally arranged. Stomata present, the number increasing toward the apex. Trichomes wanting.

Epidermal cells proper. Smaller, Lev. 21u and 30u, larger, Lev. 40u and 70u.

Epidermis outer side. The cells irregular in size and shape otherwise similar to that of inner side. Stomata few, nearly round. Trichomes wanting.

Epidermal cells proper. Lev. averaging about 38u and 55u, over main meristemes Lev. about 25u and 60u. Stomata. 30u in diameter.

Mesophyll.

In the intervenia consisting of 4-6 layers of spongy parenchyma, the cells mostly stellate. In the veins, 1-3 layers of common parenchyma cells on the inner and outer sides.

Meristemes. Similar to those of the calyx, only smaller.

Corona

Epidermis. At the base tetra- to hexagonal, mainly in longitudinal rows; becoming more irregular at the apex; the cells becoming papillose about one-third from the base and increasing going upward. Stomata wanting.

Cells of the above. R. and T. 6u, L. 5-7u; cubical or hexagonal prisms.

Mesophyll. Containing 3-8 layers of common parenchyma cells with intercellular spaces.

Cells of the above. R. and T. 18-26u, L. 50-80u; mainly cylinders.

Meristele. Xylem containing spiral vessels.

Stamen

Filament

Epidermis. At the base tetra- to hexagonal, mainly tetra-, almost in longitudinal rows; outer walls somewhat thickened.

Cells of the above. R. 18-22u, T. 15-24u, L. 45-75u.

Mesophyll. Consisting of 4-8 layers in a radial and about 16 layers of common parenchyma in a tangential direction, the greater numbers at the base. With intercellular spaces.

Cells of the above. Radially, 20-28u in diameter; tangentially, up to 45u in diameter; mainly cylinders. Cell contents: In chloral hydrate, some of the cells show reddish colored granules.

Meristele. Containing a tangentially flat amphicribal bundle, the elements of which are scattered. Xylem with annular and spiral vessels.

Anther.

Connective. Epidermis similar to that of the thecae but smaller. Stomata present, few.

Epidermal cells proper. R. 18u, T. 12-18u, L. 35-60u.

Mesophyll. Consisting of common parenchyma with intercellular spaces.

Meristele. At the base forming a band of 4-6 bundles; at the apex consisting of three bundles forming a slight gutter, one bundle between the lobes, the others facing each pair of loculi.

Xylem. Containing spiral vessels.

Thecae.

Epidermis. Cells slightly papillate.

Cells of the above. The largest Lev. 68u and 90u, in a longitudinally directed axis, R. 35u, occasionally up to 80u, when close to the fissure; penta- to polygonal, mainly hexagonal prisms, occasionally thickened on edges.

Fibrous layer. Consisting of one or two layers of cells, usually two layers near the connective.

Cells of the above. R. 35-70u, T. 45u, L. 15-30u, near the fissure, R. smaller; mostly tetragonal prisms with rounded edges, the thickening of the walls lignified.

Middle layer and tapetum. Already disappeared when mature. Middle layer occasionally to be distinguished.

Pollen. Spherical or nearly so, 60-85u in diameter; exosporium marked with ridges, except at points of cleavage, showing tetra- to hexagonal ridges. Droplet oil present. No starch reaction. In chloral hydrate breaking at four cleavage points.

Pistil

Ovary.

Wall. Epidermis outer side. Cells small tetra- to hexagonal and irregularly arranged; containing a nucleus. Stomata present, nearly round, 15-25u. Trichomes very numerous, many 1 mm. in length; mostly unicellular, otherwise similar to those of the leaf.

Epidermis inner side. Cells mainly pentagonal. Stomata present. Trichomes wanting.

Mesophyll. About 20 layers of common parenchyma cells, the outer layer resembling the epidermis; the cells close to the bundles dense with protoplasm.

Meristemes. Containing 6 principal bundles, lying opposite and between the placentae, the bundles similar to those in a young stem. Vascular bundle collateral; xylem with spiral vessels, lignified.

Ovule. Numerous in number, anatropous. Integuments consisting of two to three layers of cells. Raphe, smaller in diameter than the funiculus; joining the ovule midway to the chalaza. Xylem with spiral vessels.

Style.

Epidermis. Cells occasionally in longitudinal rows. Stomata present, few. Trichomes present at the base, similar to those of the ovary, but smaller; wanting in the upper portion.

Epidermal cells proper. R. 25-30u, T. 16-20u, L. 20-50u; tetra- to polygonal prisms. Stomata. Lev. 18u and 30u.

Mesophyll. In the inner side about 10 layers of common parenchyma with intercellular spaces; in the outer side, a few layers of spongy parenchyma in the upper portion and about 6 layers of common parenchyma in the lower portion. With 7 layers of common parenchyma between the conducting tissue and meristeles.

Common parenchyma cells. R. and T., the largest 30u, L. 30-50u; cylinders.

Meristels. At the base, a single meristele on the outer side; higher, forming a gutter of 5 bundles surrounding the conducting tissue, the

gutter facing inward and passing into the stigma.

Xylem with spiral vessels.

Conducting tissue. Forming an elliptical cylinder about 150u tangentially.

Cells of the above. R. and T. 3-5u, the largest 10u, L. about 30u; polygonal prisms or cylinders.

Stigma.

Covered with trichomes, 2-3 seriate, multicellular; 80u high.

Discussions and conclusions

The root to stem transition of the *Passiflora* species investigated was found to be similar and corresponding to the second type of transition given by Eames and MacDaniels. This type also occurs in *Acer*, *Cucurbita*, *Impatiens*, *Phaseolus*, and *Ephedra*. In *Impatiens* (13) however, the root is tetrarch and forms an eight bundle stele instead of the usual diarch root forming a four bundle stem.

The early division of the phloem strands in the root is also noted in other plants as tobacco (39), *Ephedra*, *Caulophyllum* (47), and linseed (38), even though the transition may not be similar throughout.

The greatest variations in the species of *Passiflora* studied is noted in the upper region of the hypocotyl close to the cotyledonary node. At the cotyledonary node, the vascular traces of the epicotyl is usually circular in outline, whereas in *P. adenopoda*, a tendency toward a rectangular outline is noted. Both *P. adenopoda* and *P. coerulea grandiflora* show lateral divisions of the cotyledonary traces in the middle portion of the hypocotyl to join; then higher in the hypocotyl the newly formed bundles redivide to form the traces for the first leaves. This condition is similarly found in

Ephedra (16). However, the de novo origin of the complementary bundle in the Ephedra epicotyl does not occur here.

The vascular traces of the cotyledonary buds arise from the epicotyledonary vascular strands at the time of the break of the ring and leave in a cotyledonary direction. This position is further characteristic for P. coerulea grandiflora in that the lateral cotyledonary veins arise from the same position as the traces of the cotyledonary buds instead of separating from the main cotyledonary bundles as in the other species. These veins leave in a radial fashion. Usually the lateral veins of the cotyledons divide from the main cotyledonary bundles in the base of the lamina or in the petiole (plate V, fig. 9) whereas in P. adenopoda the division occurs in the cotyledonary node (plate X, fig. D).

From the seedlings it has been shown that changes in the transition from root to stem are mainly in the regions of the phloem, in which the phloem patches of the root divide in half to pass into each cotyledon (young seedling). Further, the xylem after division, recombines in the young seedling to form a middle vein which gradually separates as the seedling

matures to first form a V-shaped bundle, the phloem forming the arms, and finally, when matured to remain separate as the inner veins of the cotyledon. In the meantime in the growing plant, lateral divisions of the cotyledonary bundles have occurred which form the epicotyledonary traces.

The cotyledons are epigeal and function as leaves and show the presence of four bundles in the petiole.

The anatomical study of the leaf of P. incarnata (plate XVIII) shows to be outstanding the presence of secretory glands and that the margin is glandularly serrated. The glands are located at the apex of the petiole and below the first serration of the inner margins of the lamina. The first serration of the inner lobe is usually larger and spherical in comparison to the other serrations.

The description of the leaf as given in the National Formulary namely "lobes ovate, finely serrate, petioles from 1 to 5 cm. in length, with two glands near the apex", is inaccurate and incomplete in that the margin has been shown to be glandularly serrated and that other glands appear in the positions given above.

The glands and the lower serrations of the margin of the leaf secrete a sweet substance which has been found according to the Bose o-dinitrophenol reduction method (48) to contain a reducing substance.

An examination of leaves cleared by the methods given shows that the vascular tissue passing through the petiole into the glands at the apex continues through the gland into the lamina to go directly to the first serration of the outer margins.

An anatomical description of the stem (plate XIX) and flower of P. incarnata is also given.

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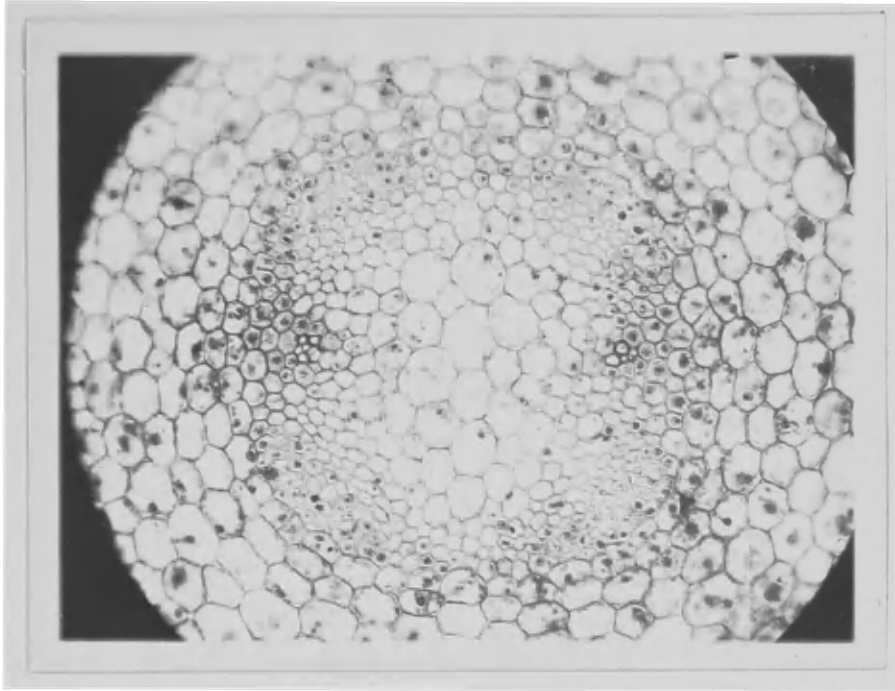
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PLATE I

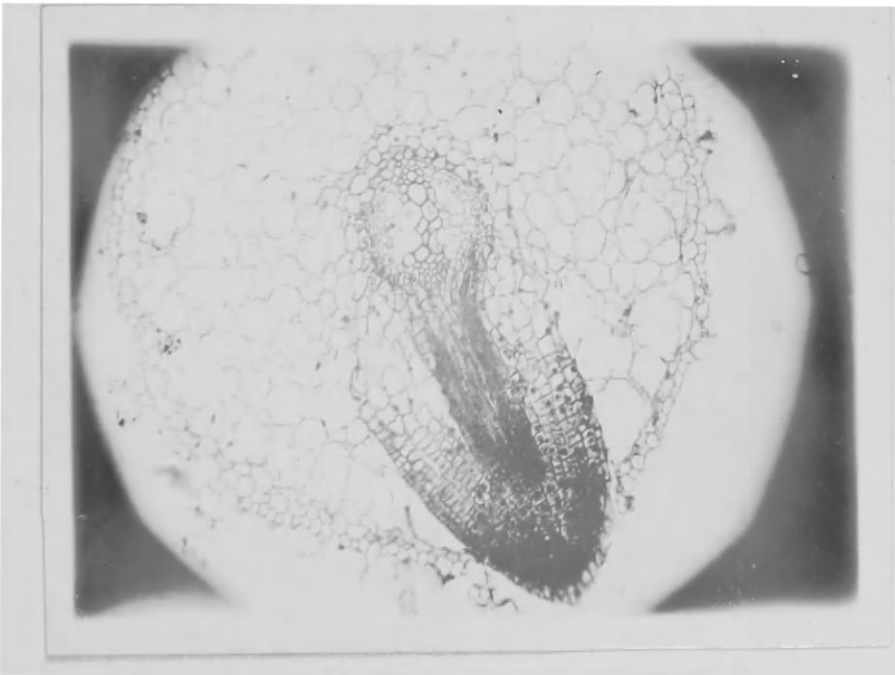
Fig. 1. P. incarnata. Diarch root showing lateral
root arising from xylem end. 100X

Fig. 2. P. incarnata. Diarch root showing
bifurcation of phloem. 225X

PLATE I



2



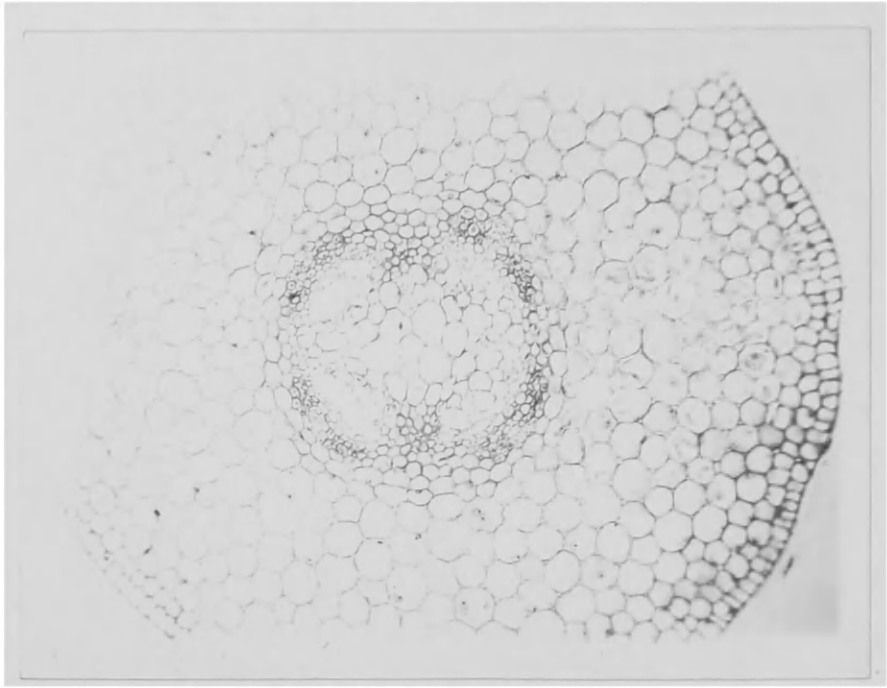
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PLATE II

Fig. 3. P. incarnata. Root showing radial
division of xylem. 100X

Fig. 4. P. incarnata. Cross-section through
the middle region of the hypocotyl
showing intercotyledonary phloem. 100X

3



4

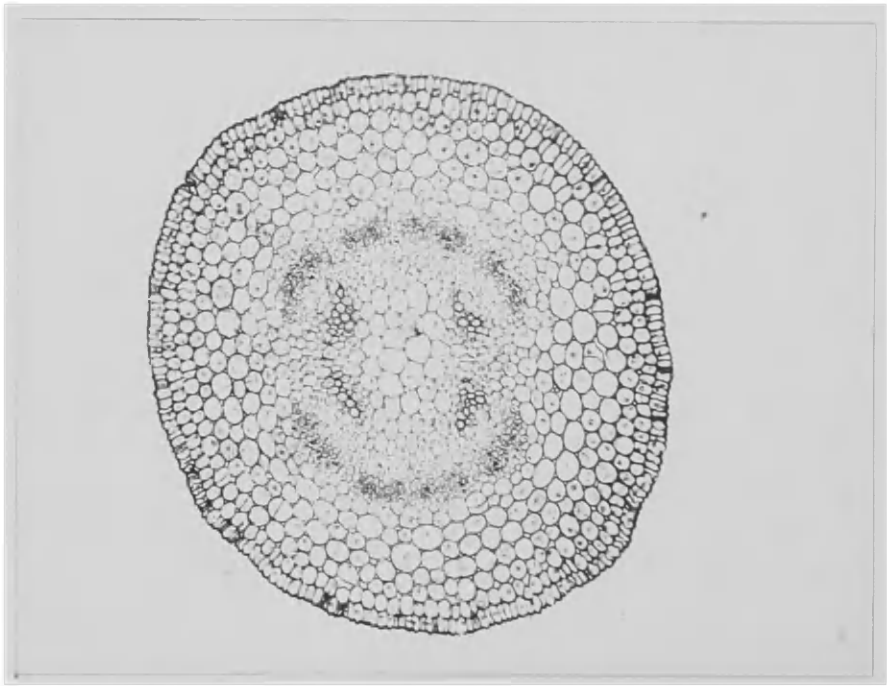
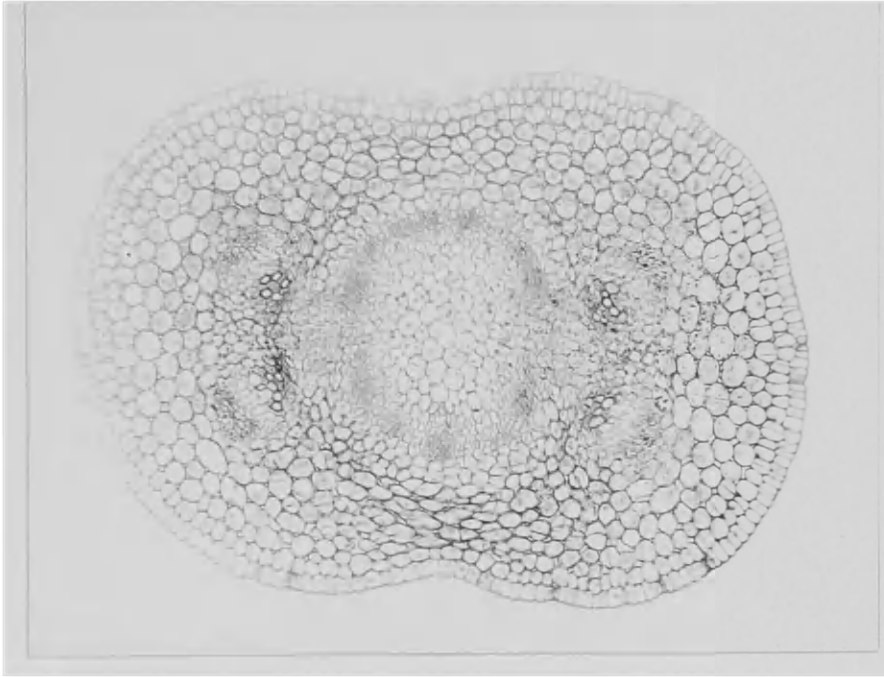


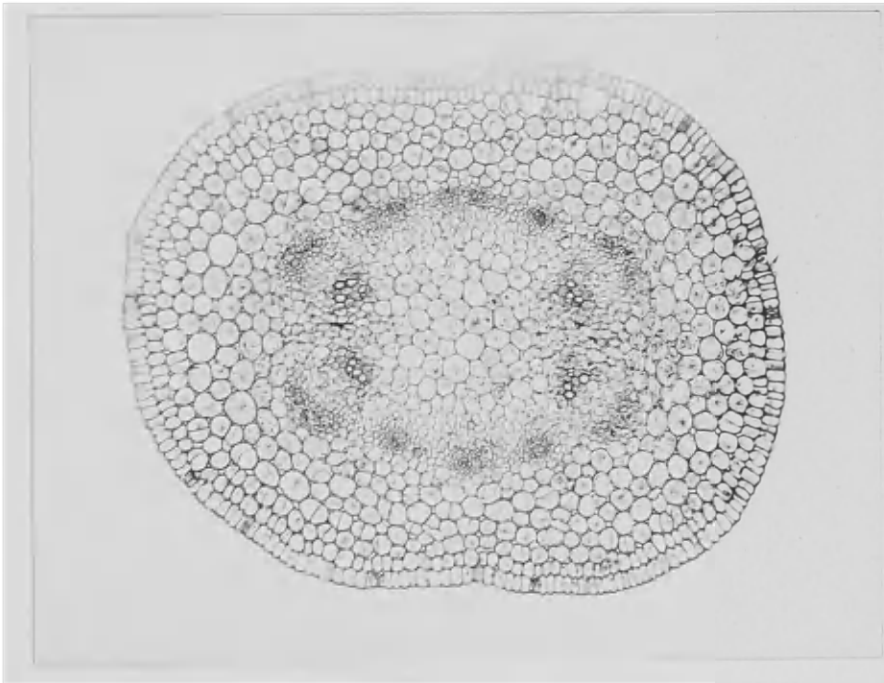
PLATE III

- Fig. 5. P. incarnata. Section just below the cotyledonary node showing the cotyledonary bundles moving outward. 100x
- Fig. 6. P. incarnata. The cotyledonary node showing the epicotyledonary vascular strands and the cotyledonary bud traces between the cotyledonary bundles and the epicotyl.

100X



6

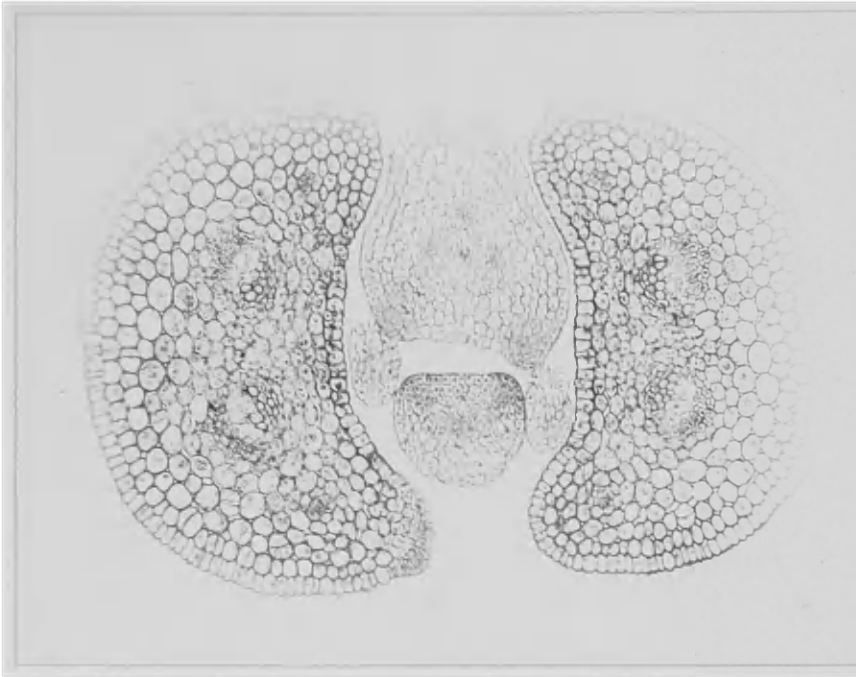


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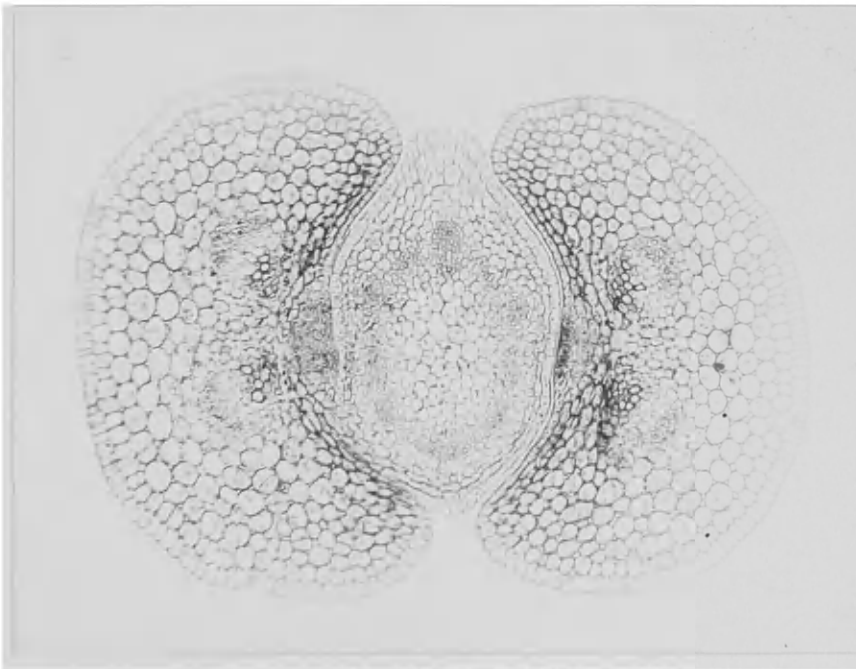
PLATE IV

- Fig. 7. P. incarnata. Just above the cotyledonary node showing the cotyledonary buds. 100X
- Fig. 8. P. incarnata. Cotyledons showing widening of bundles prior to division. 100X

PLATE IV



6



7

PLATE V

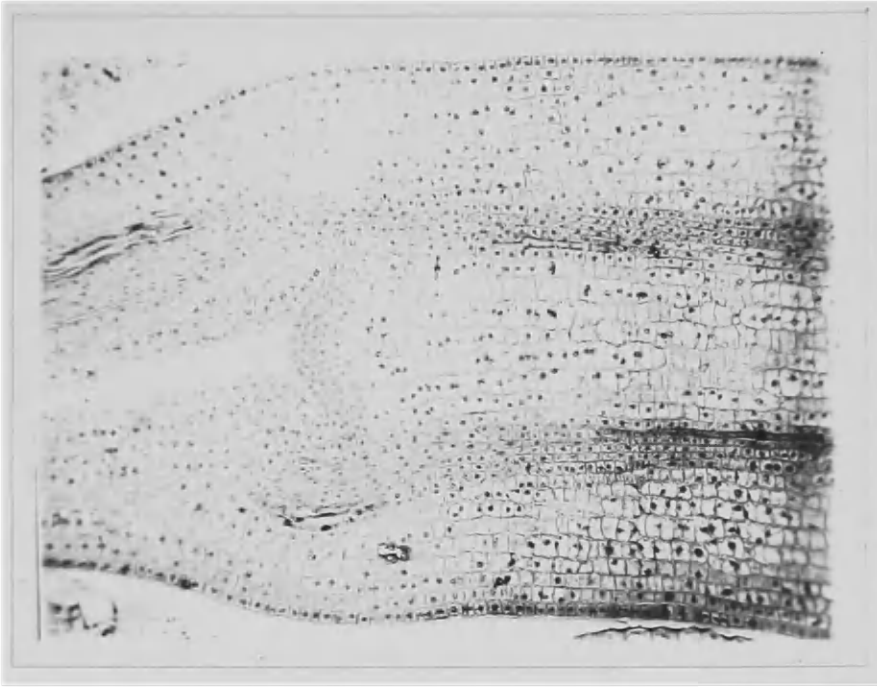
Fig. 9. P. incarnata. Cotyledons showing division
of bundles to form the ribs of the lamina.

100X

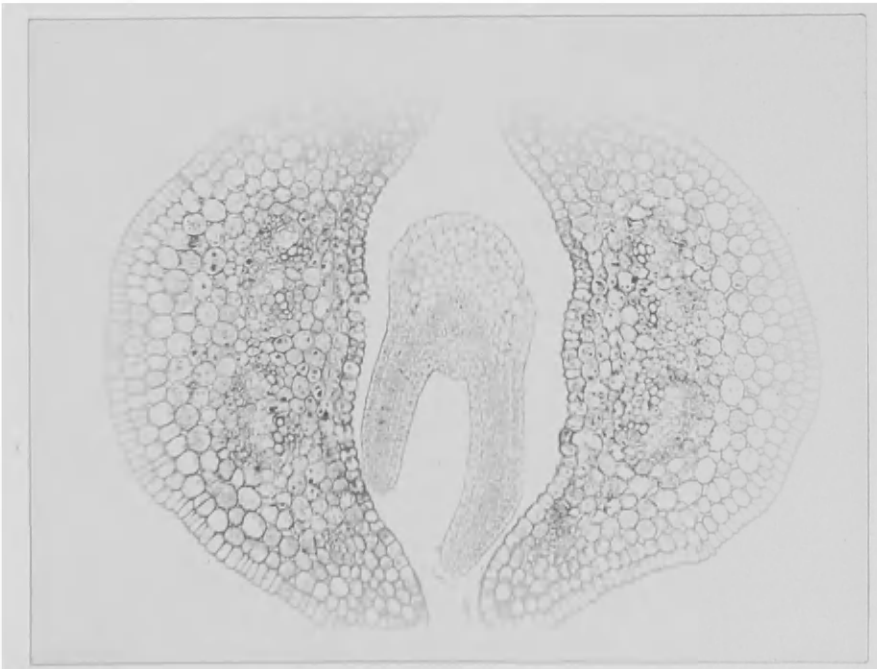
Fig. 10. P. incarnata. Longitudinal section
showing growing point.

100X

PLATE V



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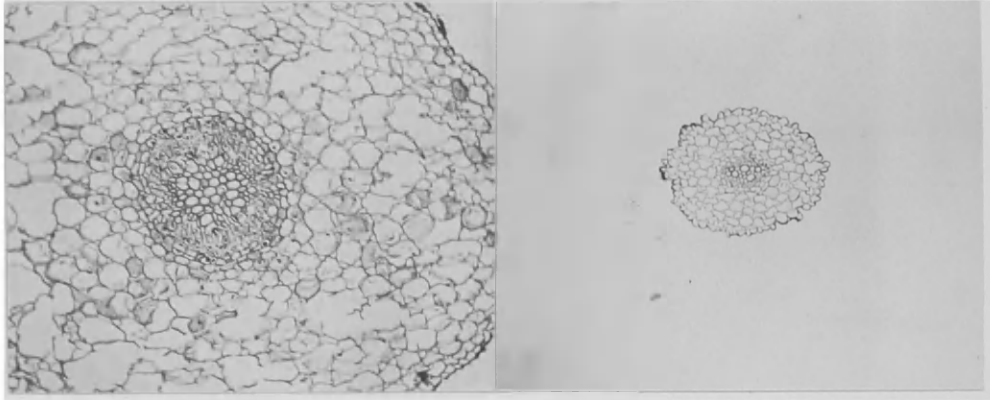
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PLATE VI

Cross-section of roots. 100X

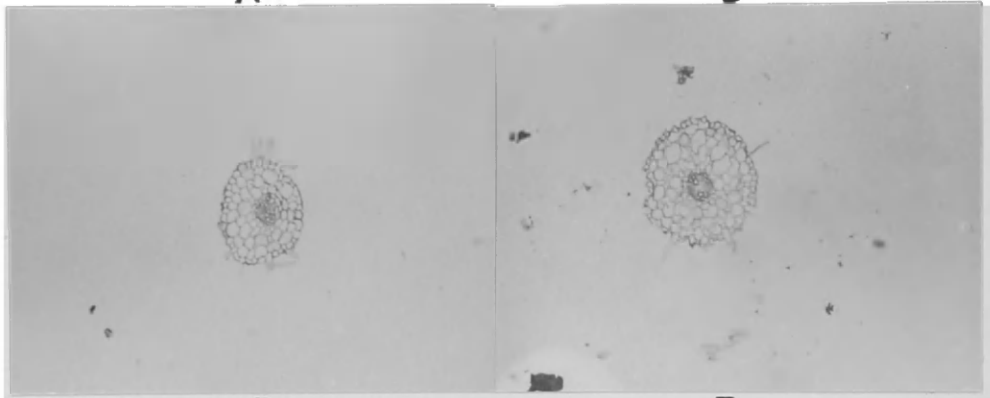
- A. *P. incarnata*
- B. *P. edulis*
- C. *P. coerulea*
- D. *P. adenopoda*
- E. *P. alba*
- F. *P. coerulea grandiflora*

PLATE VI



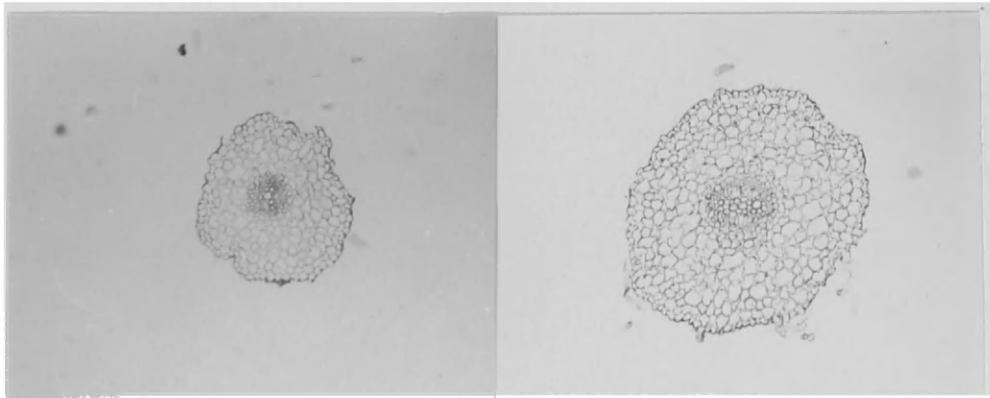
A

D



B

E



C

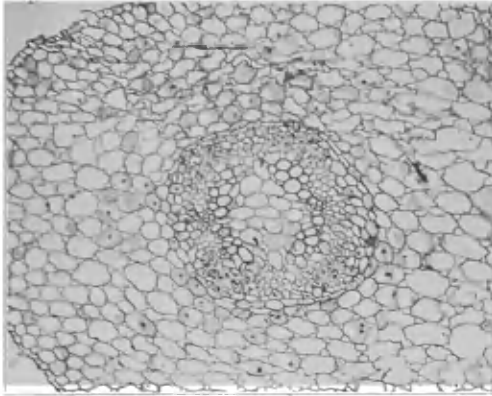
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PLATE VII

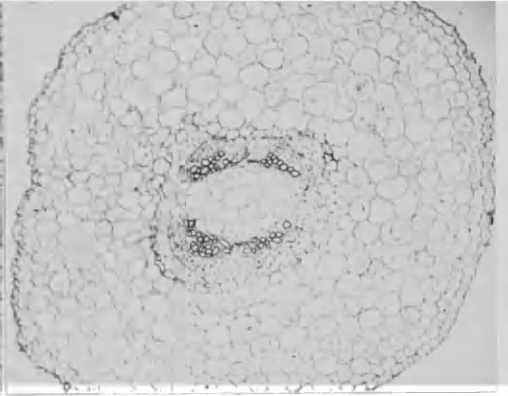
Cross-section of roots showing
division of xylem. 100X

The lettering same as plate VI

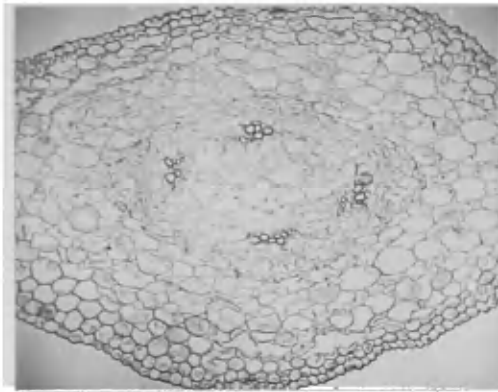
PLATE VII



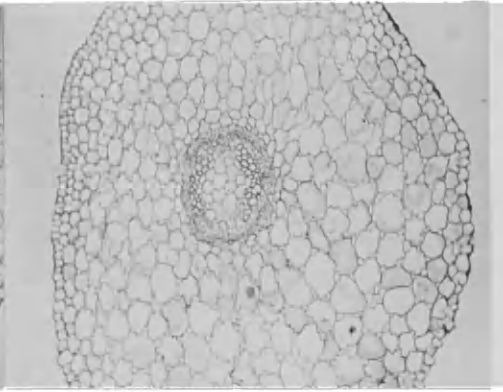
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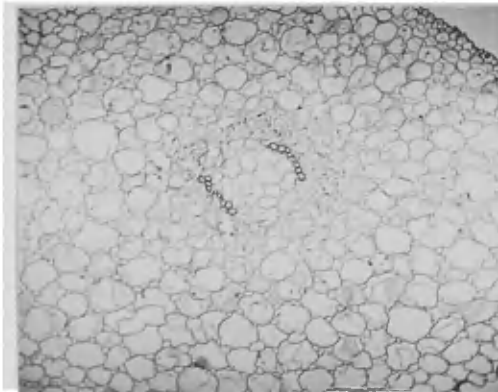
D



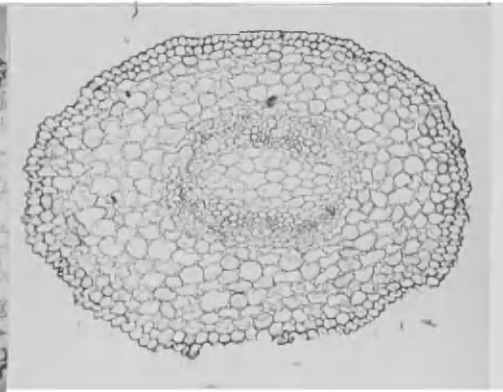
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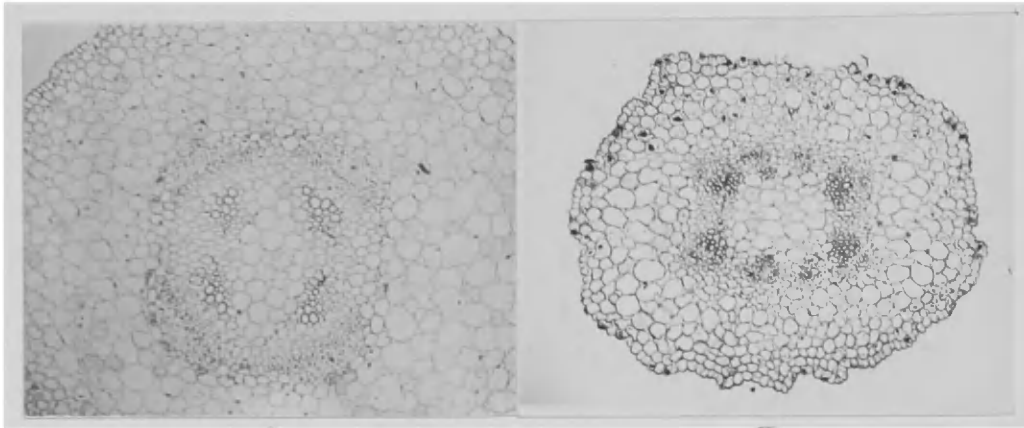
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PLATE VIII

Cross-section through lower
portion of hypocotyl. 100X

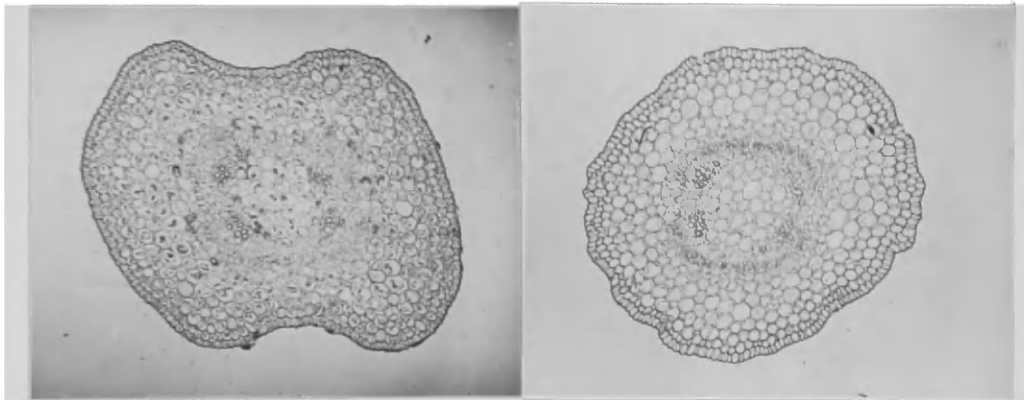
Lettering same as plate VI.

PLATE VIII



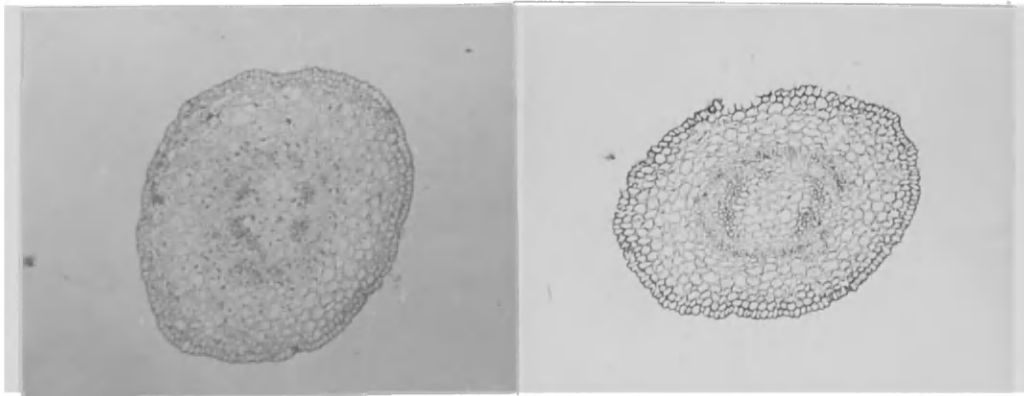
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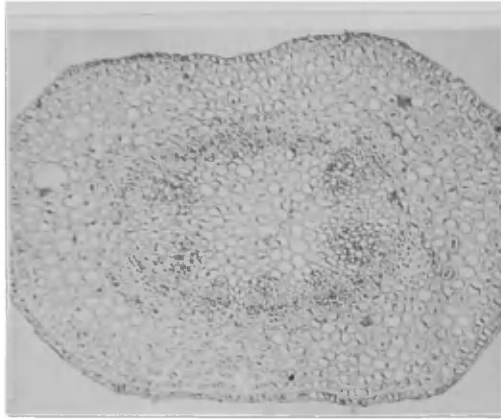
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PLATE IX

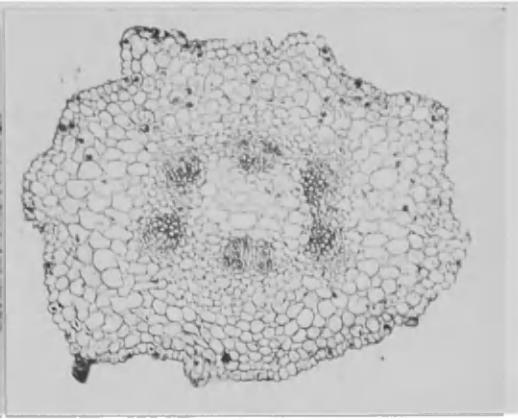
Cross-sections through upper
portion of hypocotyl. 100X

Lettering same as plate VI.

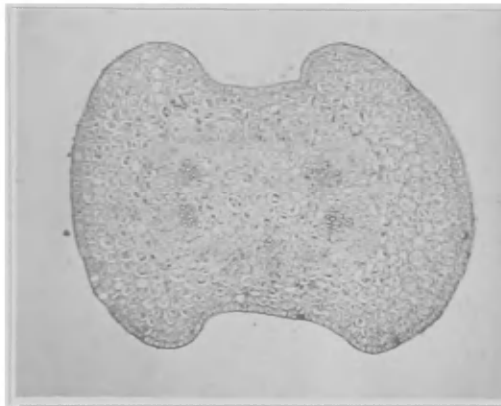
PLATE IX



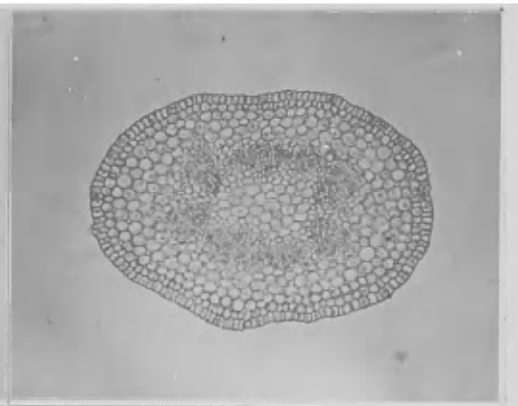
A



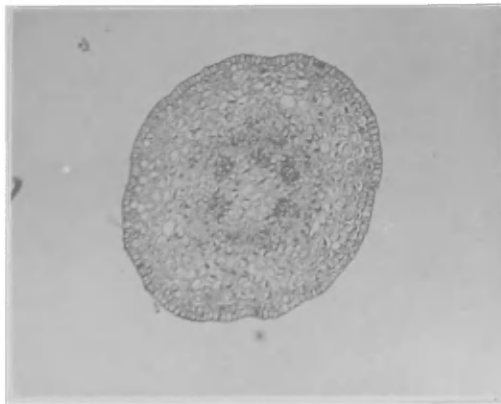
D



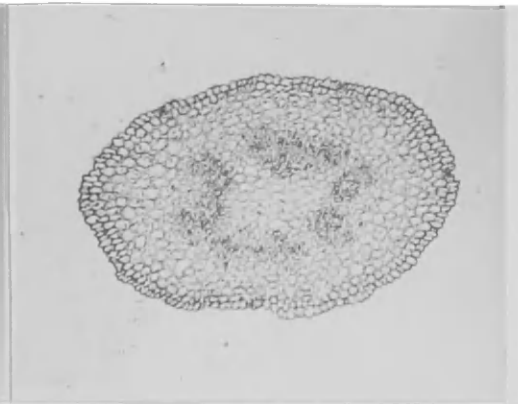
B



E



C



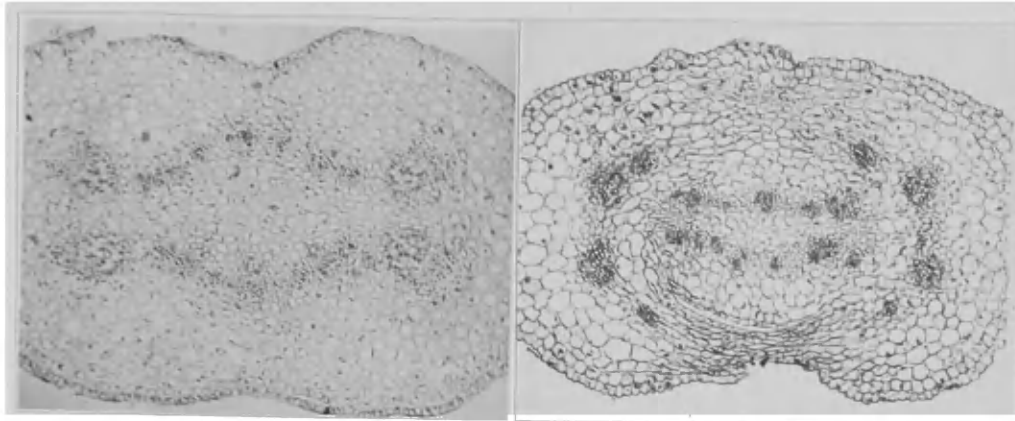
F

PLATE X

Cross-sections in region of the
cotyledonary node showing
epicotyledonary strands between
the cotyledonary bundles. 100X

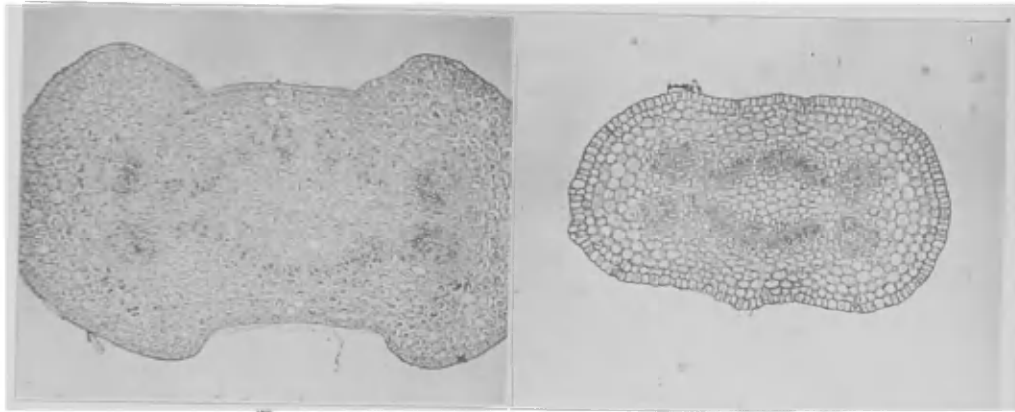
Lettering same as plate VI

PLATE X



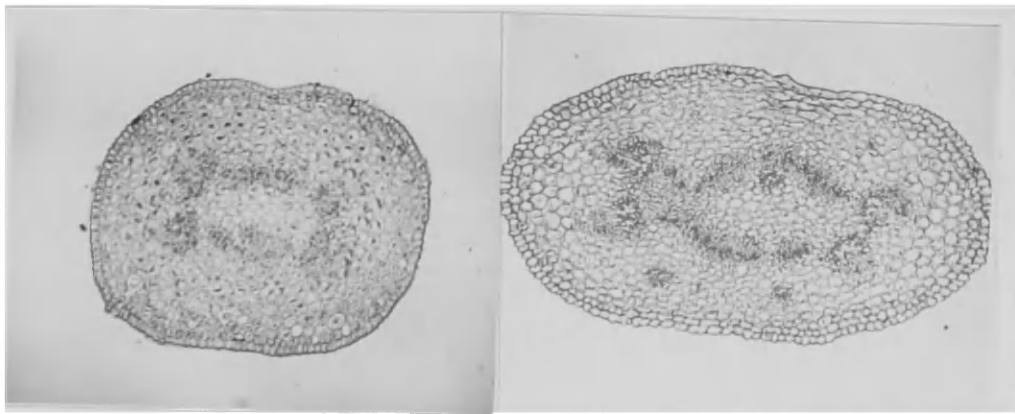
A

D



B

E



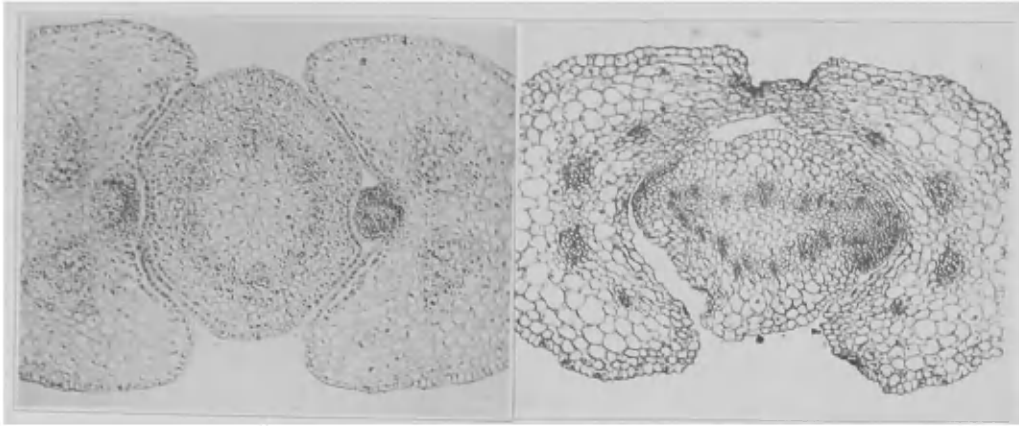
C

F

PLATE XI

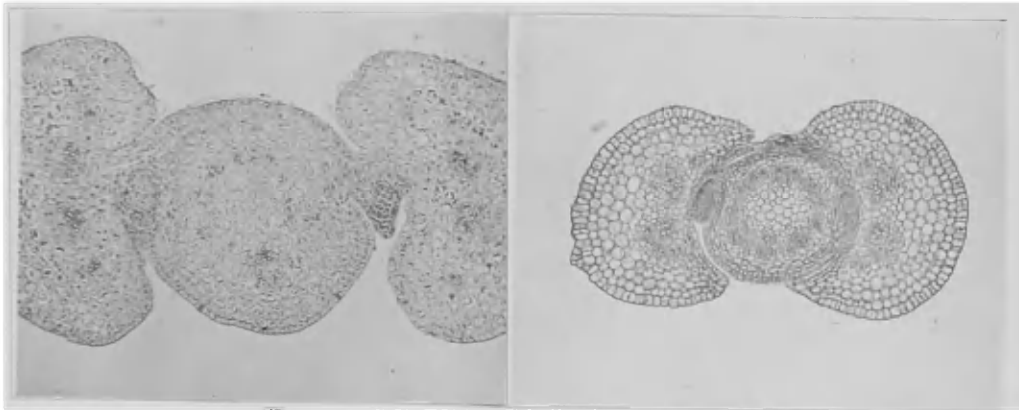
Cross-sections just above the
cotyledonary node showing the
cotyledonary buds. 100X

Lettering same as plate VI



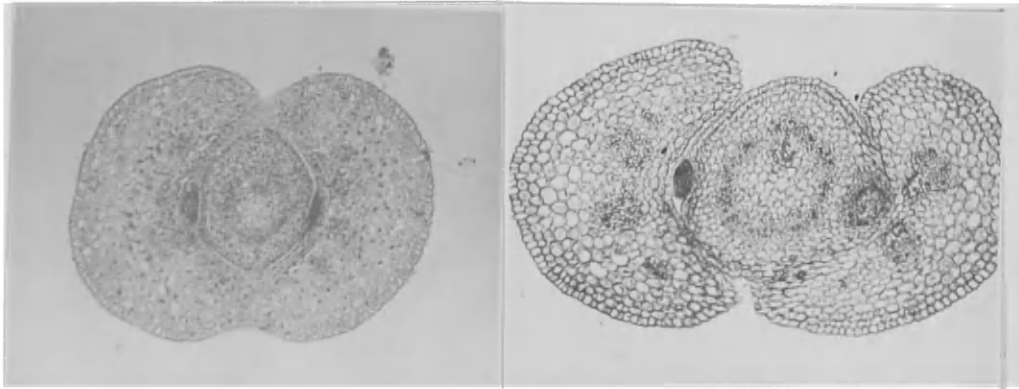
A

D



B

E



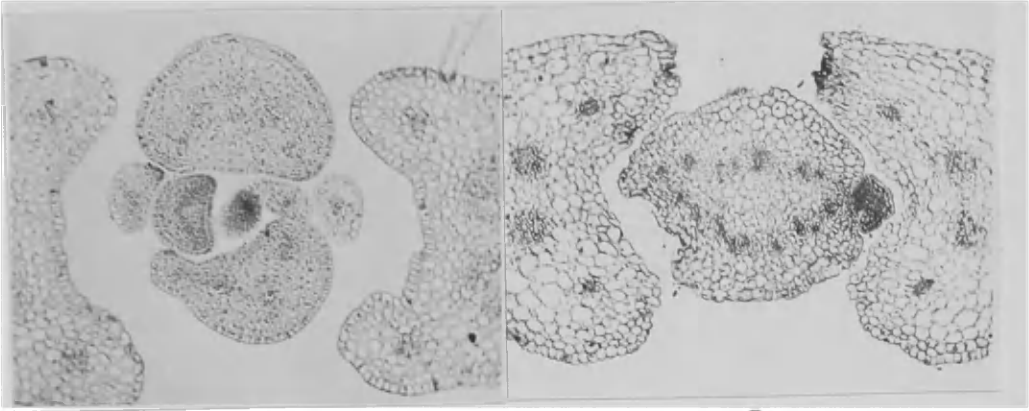
C

F

PLATE XII

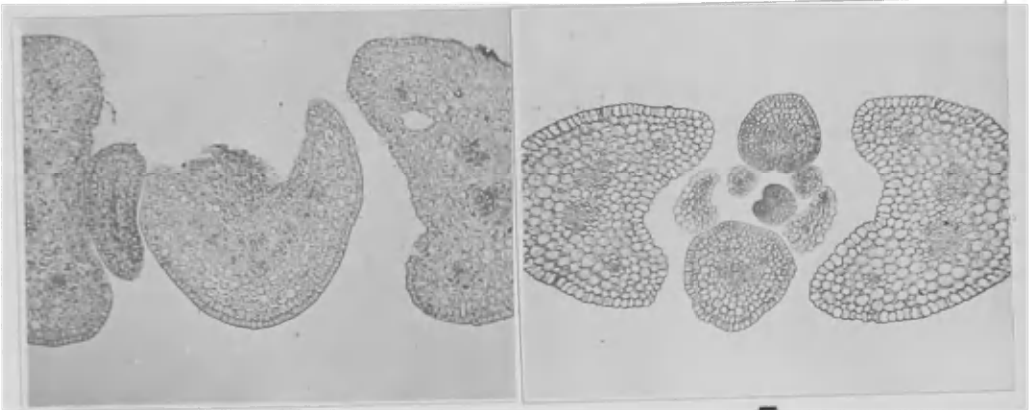
Cross-sections showing
growing point. 100X

D. P. adenopoda showing
tip of cotyledonary bud.



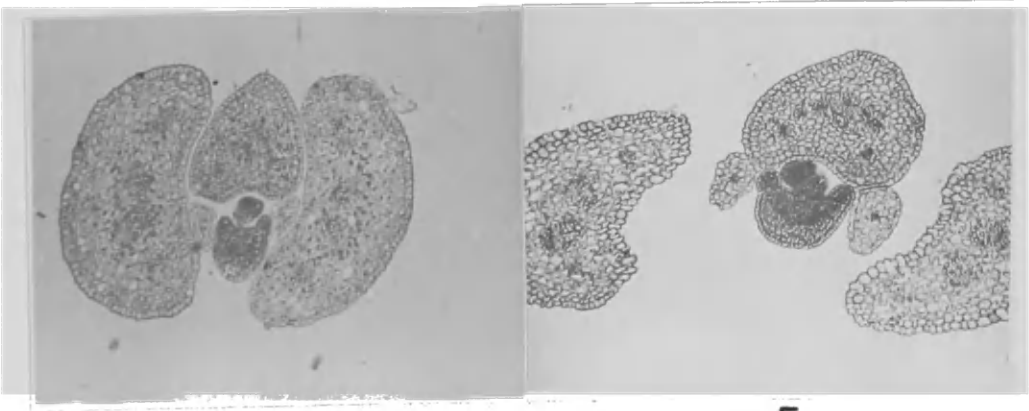
A

D



B

E



C

F

PLATE XIII

Diagrammatic sketches showing the
various stages of the transition.

Fig. 2 - 8. Represents a seedling only a few
days old.

Fig. 2-7, 9. A seedling approximately one week
old.

Fig. 1-3, 4a-9a. Represents a two to three week
old seedling.

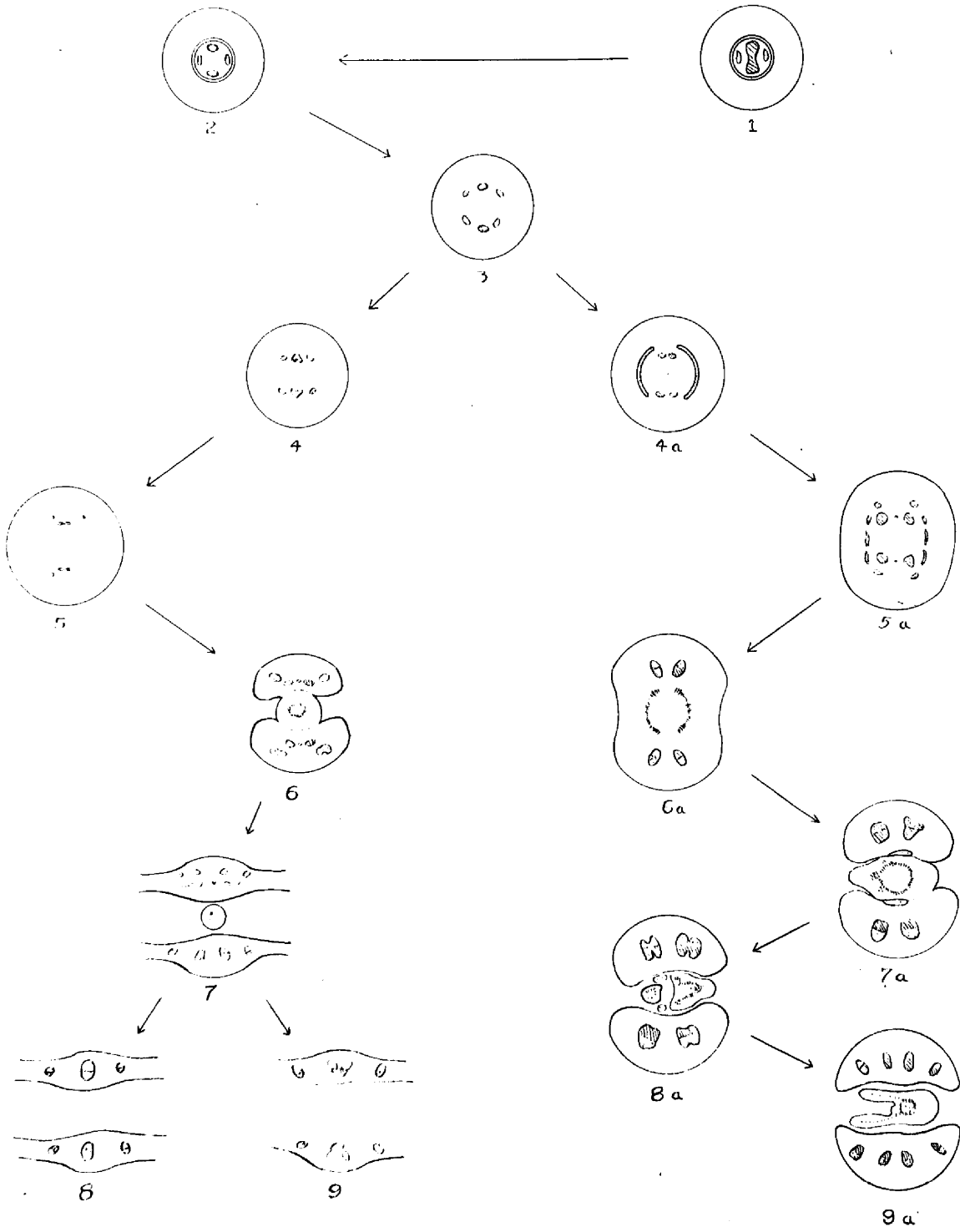


PLATE XIV

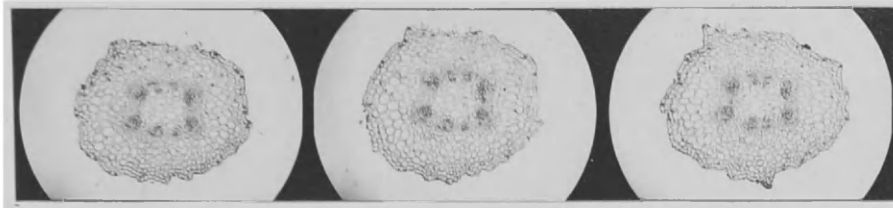
P. adenopoda

Showing various levels in a seedling three weeks old.

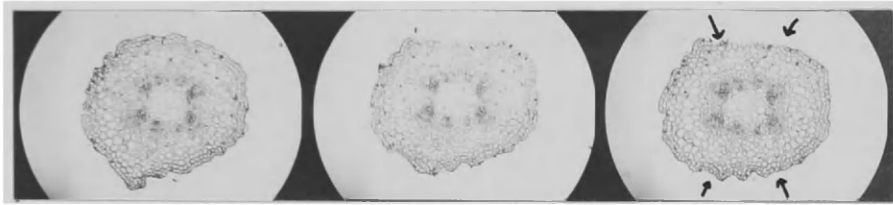
Fig. 11a. Showing radial division of xylem.

Fig. 12-14. Showing a symmetrical lateral division of the hypocotyledonary bundles.

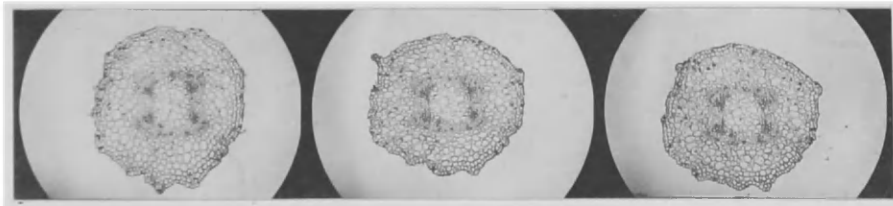
PLATE XIV



14



13



12



A

11

PLATE XV

P. adenopoda

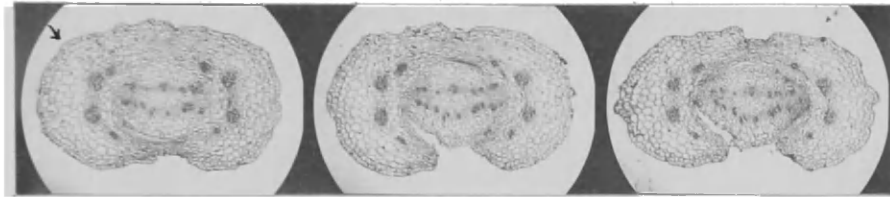
Seedling three weeks old.

- Fig. 15b. Joining of lateral strands to form single bundles on each side.
- Fig. 16. Showing redivision of intercotyledonary bundle to form the epicotyledonary strands.
- Fig. 16-17. The cotyledonary bundles dividing to form the lateral veins of cotyledons.
- Fig. 18c. Vascular traces leaving the epicotyledonary strands to pass into cotyledonary buds. 100X

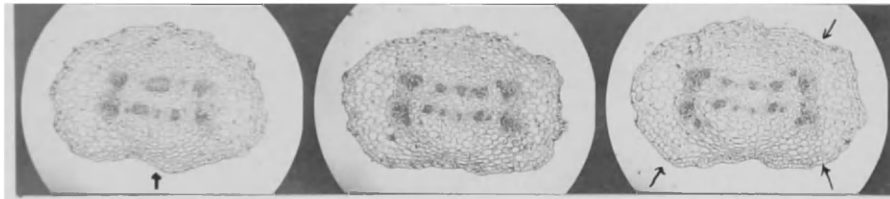


18

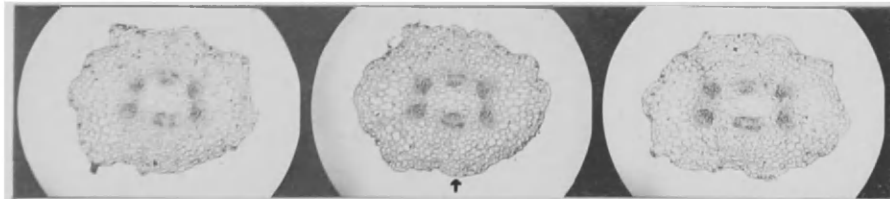
C



17



16



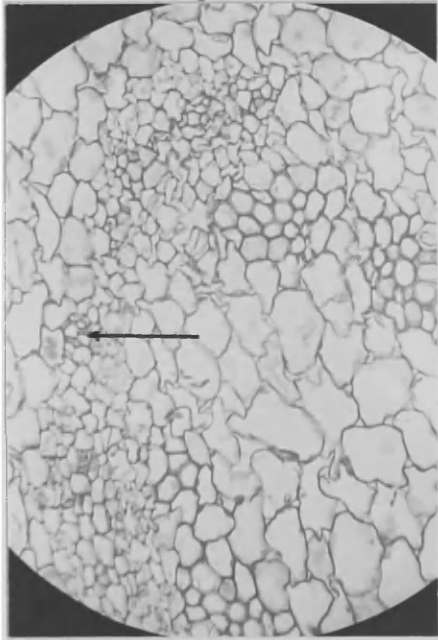
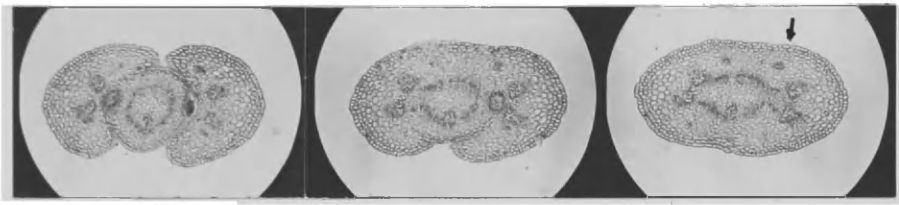
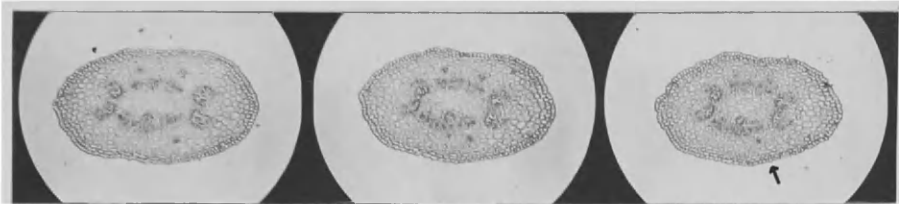
15

B

PLATE XVI

P. coerulea grandiflora

- Fig. 19. Showing a free phloem strand without
xylem tissue. 450X
- Fig. 20A. The cotyledonary node at the level
of the cotyledonary buds. 100X
- Fig. 20B. Showing break of the epicotyledonary
vascular ring with the vascular
strands of the cotyledonary buds.
- Fig. 21C. The lateral cotyledonary bundles
moving inward and toward the
epicotyledonary vascular tissue.
- Fig. 21D. The lateral cotyledonary bundles
joining the epicotyledonary tissue,
the lateral bundle on the left
still free.



A

B

C

D

21

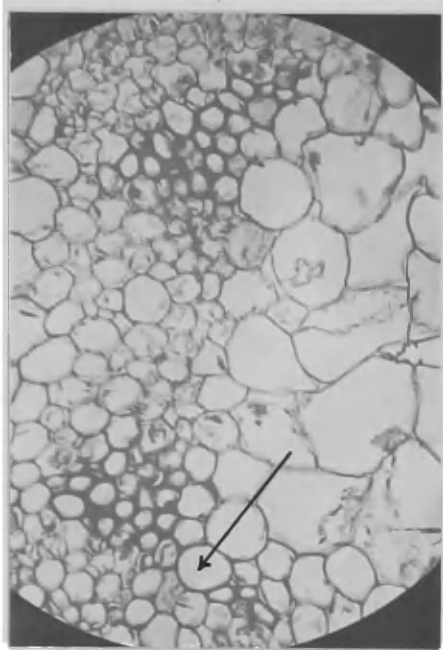
20

19

PLATE XVII

- Fig. 22. P. adenopoda. Showing lateral division of intercotyledonary bundle from metaxylem of cotyledonary bundle, the upper bundle undivided. 450X
- Fig. 23. P. incarnata. Showing position of protoxylem between cotyledonary bundles.
- Fig. 24. P. edulis. Showing resorption of protoxylem. 450X
- Fig. 25. P. alba. Showing resorption of protoxylem. 450X

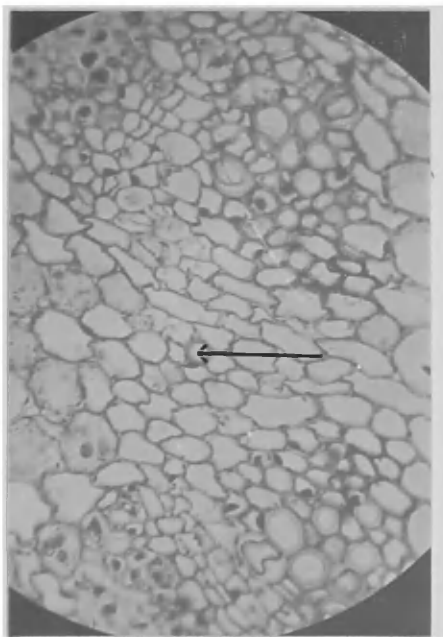
PLATE XVII



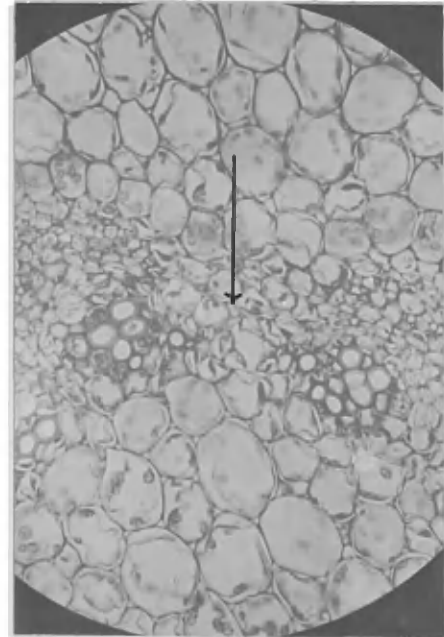
2 2



2 4



2 3



2 5

KEY TO PLATES XVIII AND XIX

As	Air-space
C	Cambium
Col	Collenchyma
Cor	Cortex
Crys	crystal
end	endodermis
epi	epidermis
L epi	Lower epidermis
M	Pith
MR	Pith ray
P	Phloem
Peri	Pericycle
Pp	Palisade parenchyma
PX	Primary xylem
Sect	Secreting tissue
Sp	Spongy parenchyma
St	Stoma
T	Trichome
V	Vessel
X	Xylem
XT	Xylem trace

PLATE XVIII

P. incarnata

Diagrammatic sketches taken from various
portions of the leaf as indicated.

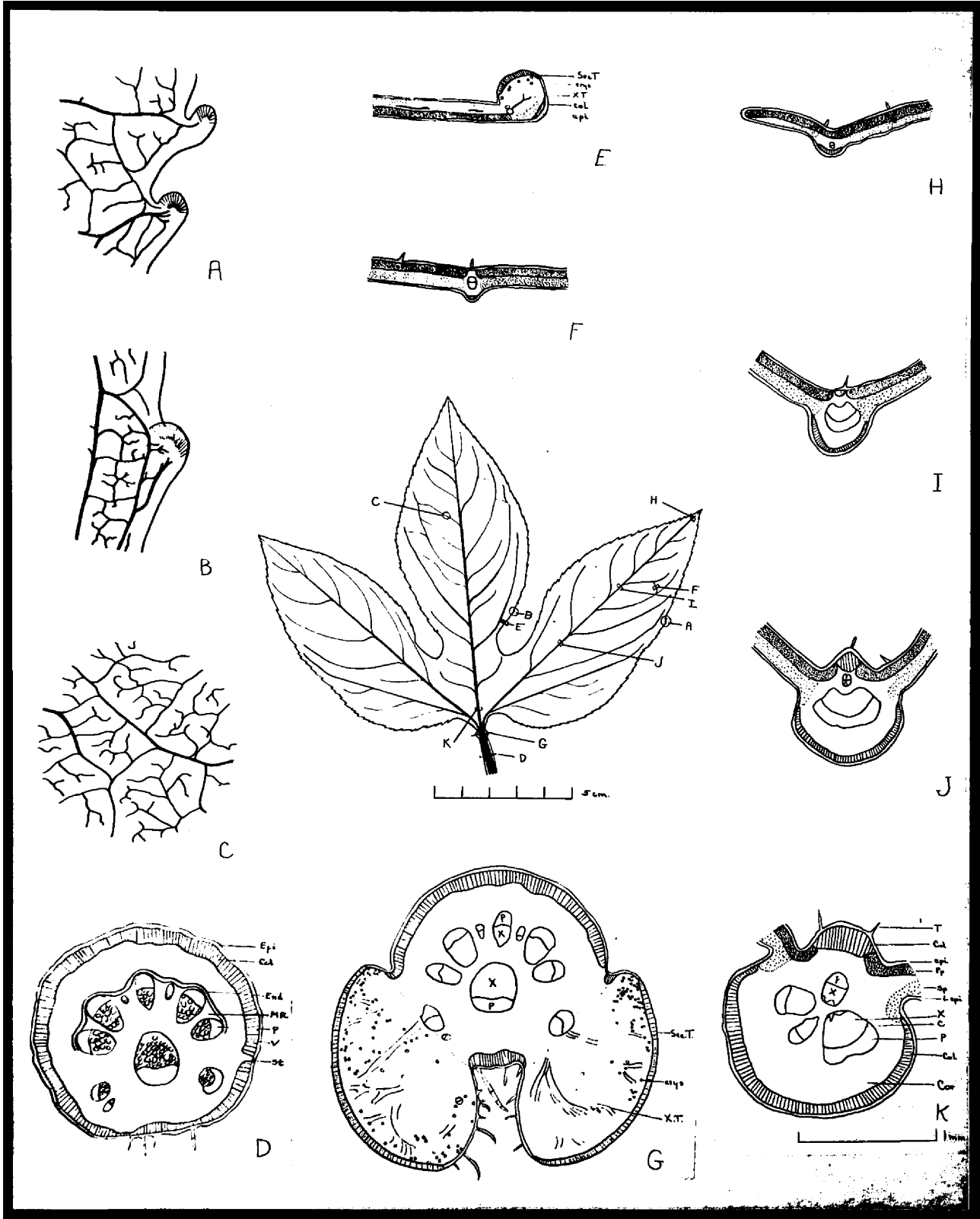
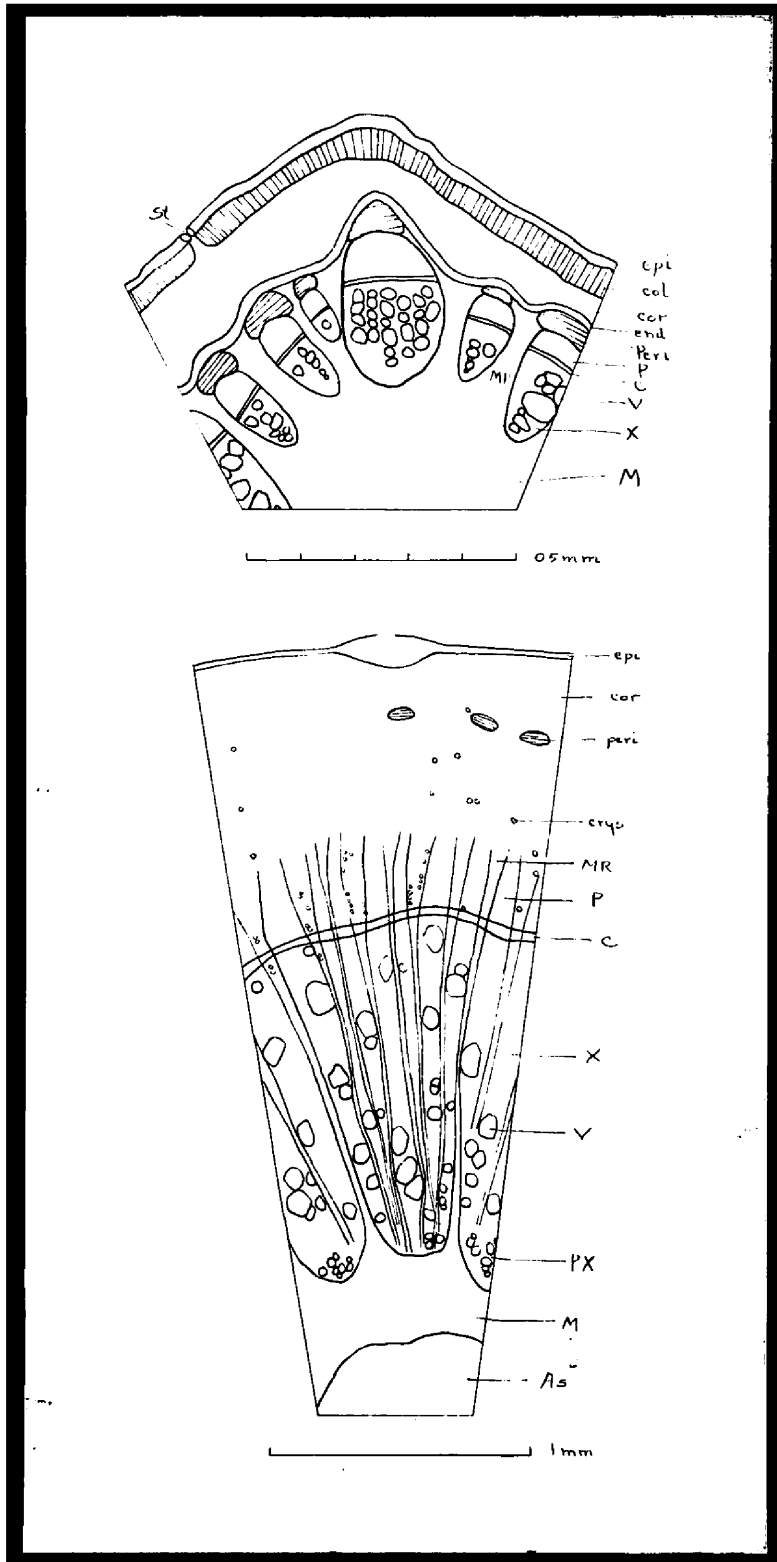


PLATE XIX

P. incarnata

Diagrammatic sketches of a young
and a mature stem.



Approved

A. G. Sumner