On some points in the Anatomy of Ipomoea versicolor, Meissn.

BY

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With Plates XII and XIII.

IPOMOEA *versicolor*, Meissn., a native of Mexico, is frequently grown in greenhouses under its older name of *Mina lobata*, Cerv., and has also been described as *Quamoclit Mina*, George Don. Like so many of its genus and order it is a twining plant, and, though an annual, attains a considerable height during its single season of growth. In one of the specimens examined, which was grown in a cool greenhouse, the length of the main stem exceeded 17 ft. (above 5 m.), but no doubt larger dimensions are often reached.

For about the first three internodes above the cotyledons the stem is straight. Twining begins in full vigour in or about the fourth internode. (See Fig. 1.)

The younger part of the stem is cylindrical and contains a normal ring of bicollateral leaf-trace bundles, the xylem-groups of which soon become united by the cambium to form a continuous zone of wood. The bicollateral structure, which is nearly constant throughout the order, is very characteristic

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here[1]. Each group of internal phloëm belongs definitely to one of the leaf-trace bundles, and accompanies the latter on its exit into the leaf.

Before considering the modifications of structure which subsequently arise in certain parts of the stem we will trace the relation between the bundle-systems of stem and root, for this plant illustrates with diagrammatic clearness the changes through which bicollateral bundles pass in the transitional region.

The two[2] obcordate cotyledons each contain four vascular bundles in the petiole, all of which, like those of the leaves generally, are bicollateral. The two median bundles are of large size, and lie close together. The two small lateral bundles are widely separated from them. On entering the axis the bundles of each median pair at once turn their protoxylem-groups towards each other, and pass down through the long hypocotyl to the root. The *lateral* bundles of the cotyledons on entering the hypocotyl approach each other so as to form two other pairs, at right angles to the former, each lateral pair being thus made up of one bundle from each cotyledon. These bundles also turn their protoxylem-groups towards each other and can only be distinguished from the median pairs by their position. The median pairs are further from the centre, the major axis of the elliptical pith passing through them, while the minor axis coincides with the position of the lateral pairs. The opposite median pairs are separated by about 14, the lateral pairs by about 9 pith cells. Lower down the pith of the hypocotyl becomes circular, and here all the four pairs of bundles are in all respects similar. The diagrammatic section (Fig. 2) is taken at a point where the pith is still somewhat elliptical, C–C being the median plane of the cotyledons.

The bundles of the plumular leaves fuse with the lateral

[1] Cf. Solereder, Ueber den systematischen Werth der Holzstructur bei den Dicotyledonen, 1885.

[2] Occasionally three cotyledons are developed, but I did not investigate these exceptional seedlings.

cotyledonary bundles as soon as the latter enter the stem, so that the hypocotyl is traversed by the cotyledonary traces only.

Each pair of bundles in the hypocotyl has a common strand of internal phloëm lying just within the two converging protoxylem-groups. As we trace the bundles down towards the root we find that in each pair the protoxylem-groups slowly approach each other, and as this goes on the internal phloëm-strand passes out between them. Three stages of their course are shown in Figs. 3, 4, and 5, taken respectively at the levels *a*, *b*, and *c* shown in the sketch of the seedling (Fig. 1). As the root is approached the two xylem-groups of each pair meet and fuse, turning their protoxylem outwards. At this point the internal phloëm is seen forming two strands, one on each side of the xylem plate (Fig. 4. ph^2). Lower down still the internal phloëm passes completely to the outside of the xylem (Fig. 5) and ultimately joins the external phloëm. The later stages of the transition are passed through within a very short space, as is shown by the relative positions of the sections as marked in Fig. 1. The main root is tetrarch, and its four xylem plates, corresponding to the four pairs of cotyledonary traces, eventually meet in the centre, the pith dying out. It will be seen that the course of the bundles agrees with the well-known type of *Phaseolus*. Its regularity is very favourable to tracing the passage of the internal phloëm.

The transitional region between stem and root shows remarkable peculiarities when secondary growth begins, and these are now to be described.

The upper and younger part of the stem is cylindrical and typical in structure, as already stated. The lower part of the stem, however, has a flattened form; its greater diameter may be as much as double the lesser, the latter being equal to the diameter of the cylindrical portion. The region showing this flattened form may be many feet in length in well-grown specimens, but the peculiarity is most marked in the neighbourhood of the cotyledons. The flattened appearance is due to the presence of two great masses of secondary tissue, chiefly xylem, which have been added one on each side of the stem. The original ring of xylem can be traced all round; at the flat sides it has received little or no increment, while on the prominent faces the additional masses of wood and bast have been superposed upon it. The xylem of these masses is characterized by the presence of many enormous pitted vessels, attaining ·25 mm. in diameter, while those of the ordinary ring scarcely measure ·05 mm. The phloëm is decidedly more developed on the prominent faces than elsewhere, but the difference is not so marked as in the xylem.

The flattened region extends to the hypocotyl, in which the median line of the prominences is at right angles to the plane of the cotyledons. Towards the root, however, the thickening becomes more uniformly distributed until the transverse section is once more circular (Fig. 2).

In the upper part of the flattened region there is nothing anomalous except the unequal distribution of the secondary tissues, which also occurs in some other Convolvulaceae. A little thin-walled parenchyma is present in the secondary xylem.

In the lower internodes, however, the structure is much less regular and in the hypocotyl is extremely anomalous (cf. Fig. 2). The secondary masses of wood are broken up in all directions by bands and patches of thin-walled parenchyma containing isolated strands of phloëm, in which the sieve-tubes and companion-cells are of normal structure, and perfectly similar to those of the external and medullary phloëm. The diagrammatic section in Fig. 2 is taken from the lower part of the hypocotyl where the secondary thickening is nearly uniform all round. The parenchyma of the wood, whether forming rays or isolated groups, is everywhere traversed by strands of phloëm. In these transitional regions a large proportion of the whole phloëm is interxylary.

The investigation of developmental stages leaves no doubt that these masses of parenchyma, together with the phloëm which they enclose, are produced centrifugally on the inner side of the normal cambium (see Fig. 6). The same cambium subsequently adds lignified tissue outside them, and they thus become enclosed in the wood (cf. Figs. 6 and 7). The phloëm-groups themselves may either be formed directly from the cambium or by the subsequent division of the parenchymatous cells. Both processes occur side by side, as is also the case in *Asclepias* and *Thladiantha*, to be described elsewhere.

The parenchymatous islands with their strands of phloëm extend up into the first internodes above the cotyledons and gradually disappear. They seem never to end blindly in the wood, but ultimately to abut on the cambium. Above the cotyledons they can only communicate with the *medullary* phloëm at the nodes.

The main root in its lower portion is normal. Here, as in the stem, the interxylary phloëm ends in contact with the cambium.

Ipomoea versicolor then presents the curious case of a plant in which the greater part of both stem and root is normal, while the region for some distance on both sides of the transition possesses a complicated system of interxylary phloëm. The anomalous transitional region, with its abundant conducting tissue, serves no doubt as a temporary store-house of food-material, reserved perhaps in part for the period of flowering.

A word must be said on the relation of the *medullary* phloëm to the phloëm-systems of the mature root. As already explained, the former is continuous, at the lower end of the hypocotyl, with the normal external phloëm. Then secondary growth begins; at the points where the medullary phloëm passes out the cambium necessarily cuts through it. Its continuity, however, is not altogether interrupted, for opposite each bundle-pair, through which the out-going phloëm passes, the cambium forms a parenchymatous xylem-ray containing, as already stated, strands of interxylary phloëm (see Fig. 5; the diagram, Fig. 2, is taken *above* the exit of the medullary phloëm). With these strands the medullary phloëm remains in permanent continuity. Thus the interxylary phloëm of the transitional region is in communication both with the medullary and the external phloëm-systems of stem and root.

A further complication of structure appears in the older hypocotyl, for an internal cambium arises by the divisions of the outer cells of the pith, starting from the internal phloëm-groups, and sometimes extending nearly round the whole circumference. It produces some additional medullary phloëm internally, and also gives rise occasionally to a few lignified elements on the side towards the wood.

The chief points then to be noted are the following:—

1. The internal phloëm extends downwards into the hypocotyl and passes out between the converging protoxylem groups of each cotyledonary pair of bundles, thus joining the external phloëm of the root.

2. The hypocotyl and the adjacent parts of stem and root have a complex secondary wood containing numerous strands of interxylary phloëm, imbedded in parenchyma. These 'phloëm-islands' are produced centrifugally by the cambium.

As regards the course of the internal phloëm in the transition from stem to root, *Ipomoea versicolor* may be taken as typical of plants with bicollateral bundles generally. A full discussion of this subject, with references to the literature, will be found in a forthcoming paper by Mr. Brebner and myself.

I am not aware that the existence of phloëm-islands in the wood has previously been observed in any Convolvulaceae. The very remarkable anomalies described by Schmitz[1] and Dutailly[2] in the roots of certain perennial members of the

[1] Über die Anat. Structur der perennirenden Convolvulaceen-Wurzeln, Bot. Zeitung, 1875, p. 677. His results are summarized by de Bary, Comp. Anat., Eng. ed. p. 606. Tschirch, Angewandte Pflanzenanatomie, 1889, figures a transverse section of the root of *Ipomoea Purga*.

[2] Sur quelques phénomenes . . . dans le tige et la racine des Dicotylédones, Paris, 1879.

order are of quite a different kind, depending on the appearance of new cambial regions in the secondary parenchyma of xylem and phloëm.

Both the preparations and drawings for this investigation have been made by Mrs. D. H. Scott. The plants were raised from seed under glass.

EXPLANATION OF THE FIGURES IN PLATES XII AND XIII.

Illustrating Dr. D. H. Scott's paper on *Ipomoea versicolor*, Meissn.

The following lettering is used throughout the microscopical figures :—

c^1 = normal cambium.
ph^1 = normal external phloëm.
ph^2 = medullary phloëm.
ph^3 = interxylary phloëm.
px = protoxylem.
x^1 = primary xylem.
x^2 = secondary xylem.
p = pith.
e = endodermis.

Fig. 1. Seedling, showing the whole plant, with the cotyledons and the first few leaves. *G–G* level of the ground. The upper internodes are already twining round a support. *a*, *b*, and *c*, positions at which the sections shown in Figs. 3, 4, and 5 were taken. Two-thirds of natural size.

Fig. 2. Semi-diagrammatic transverse section of the hypocotyl. *C–C* median plane of the cotyledons. *red* = primary xylem of the cotyledonary traces. *yellow* = secondary xylem. *blue* = phloëm, medullary, interxylary, and external. *brown* = periderm. The parenchyma is left white.

Fig. 3. Part of a transverse section taken at *a* (Fig. 1). A pair of cotyledonary bundles is shown, with converging protoxylem, and a common group of medullary phloëm just within them.

Fig. 4. Corresponding section much lower down, at *b* (Fig. 1). The xylem-groups are now united with outwardly-directed protoxylem. The medullary phloëm is passing to the exterior, forming two strands, one on either side of the xylem-plate. The whole has been enclosed by secondary wood.

Fig. 5. Corresponding section somewhat lower, at *c* (Fig. 1). The medullary phloëm now lies to the outside of the xylem-plate. Observe that the cambium is here beginning to form a medullary ray.

Fig. 6. From a much older hypocotyl, showing a parenchymatous 'island' with interxylary phloëm, in course of development. The cambium is beginning to form new wood and thus complete the formation of the island.

Fig. 7. From the same hypocotyl as Fig. 6, showing a similar island completely imbedded in the wood, and containing much interxylary phloëm. The arrow c^1 points towards the cambium.

Figs. 3–7 are $\times 330$ diam.

Fig. 4.

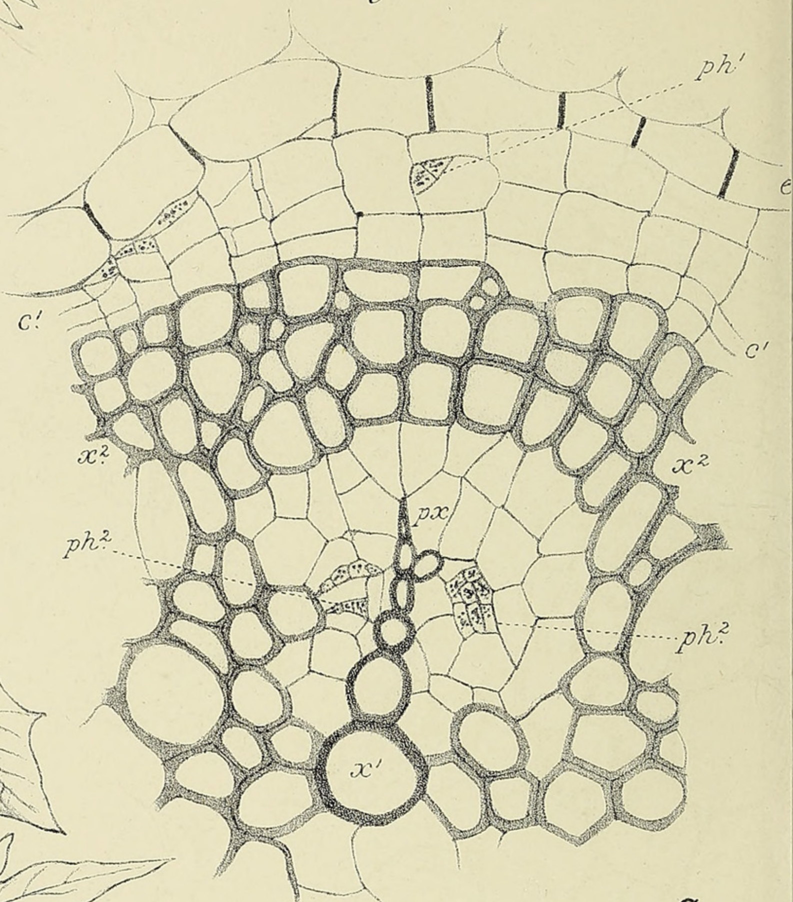

Fig. 1.

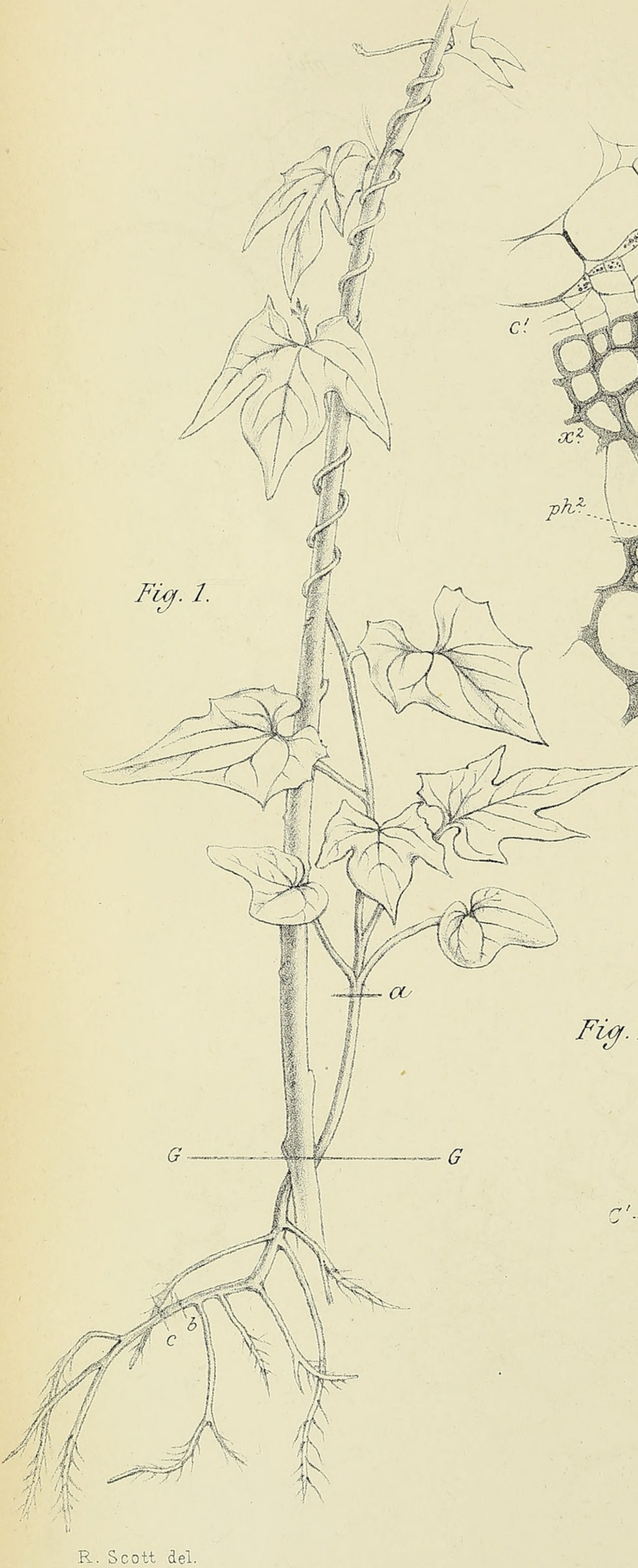

Fig. 2.

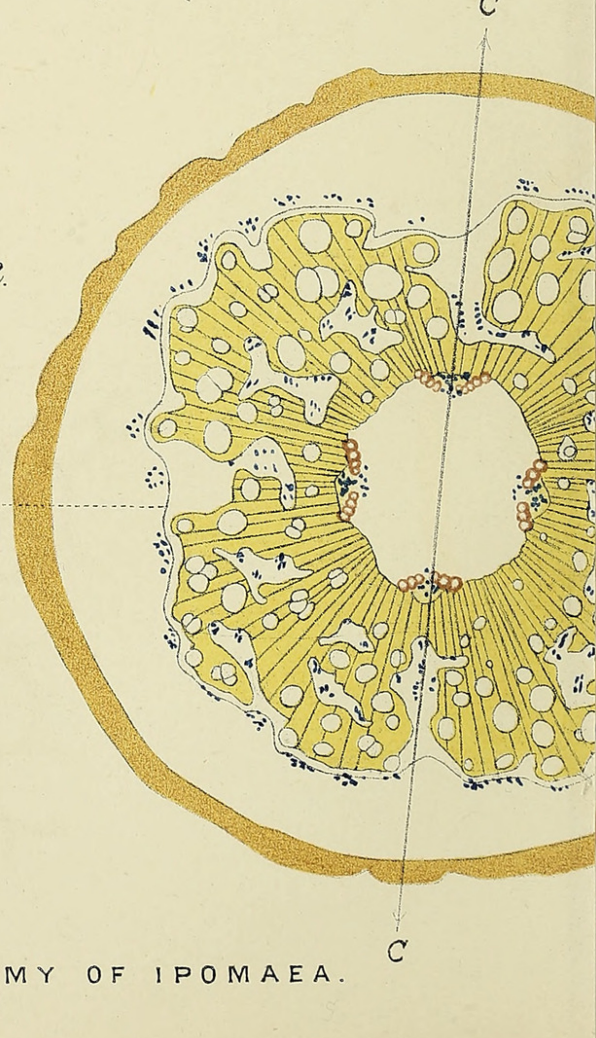

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Fig. 3.

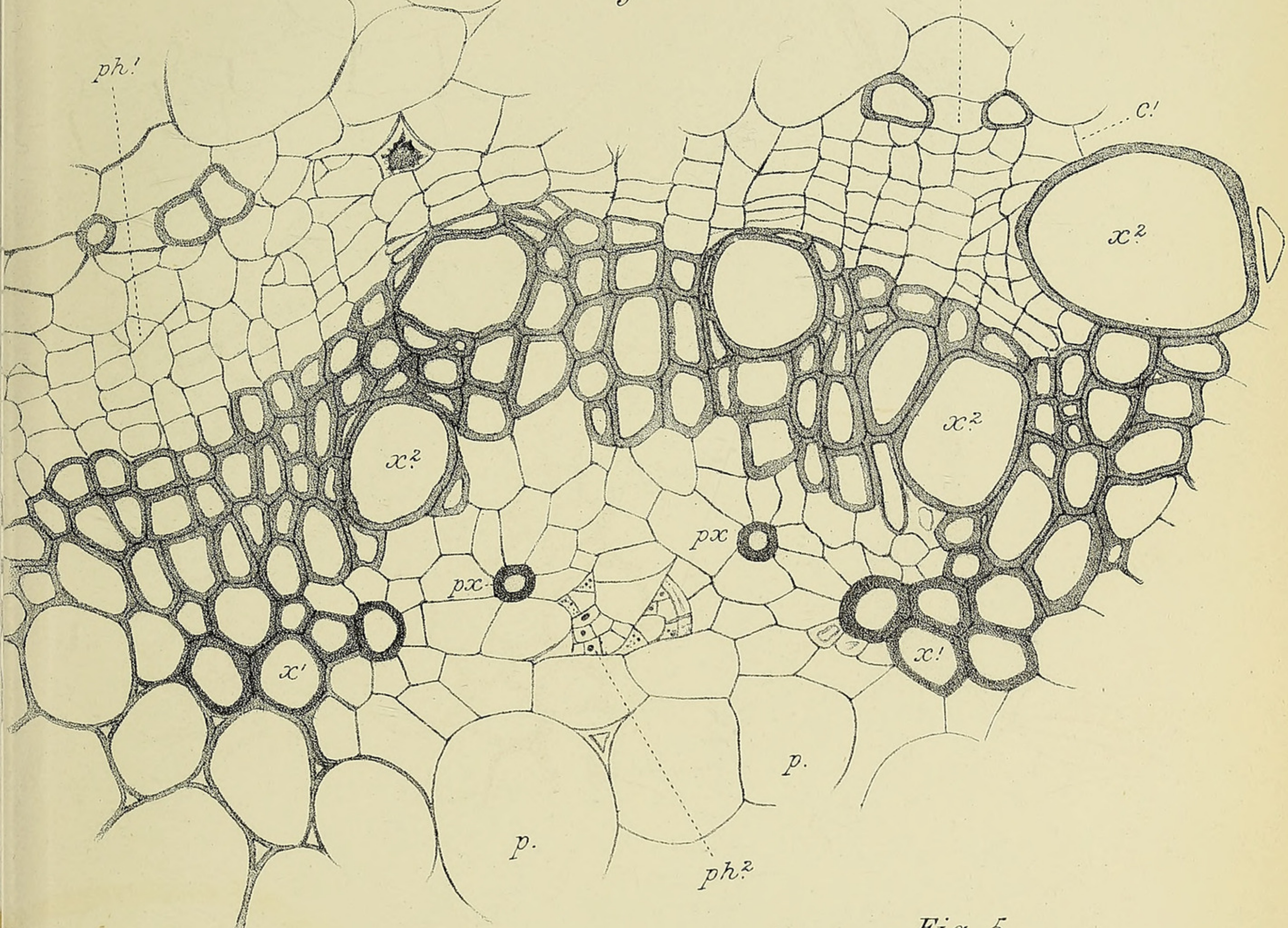
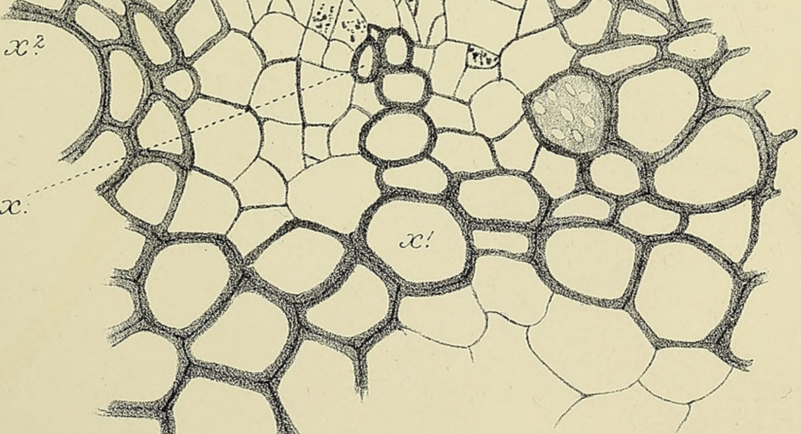
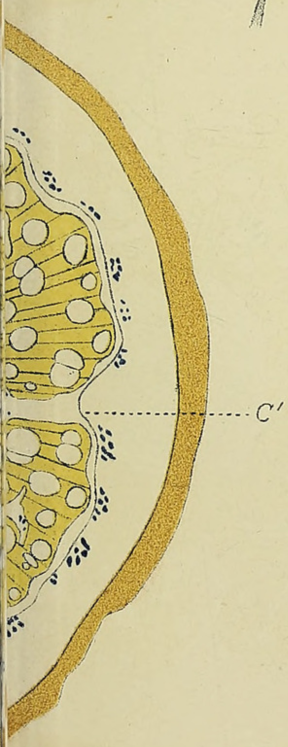


Fig. 5.





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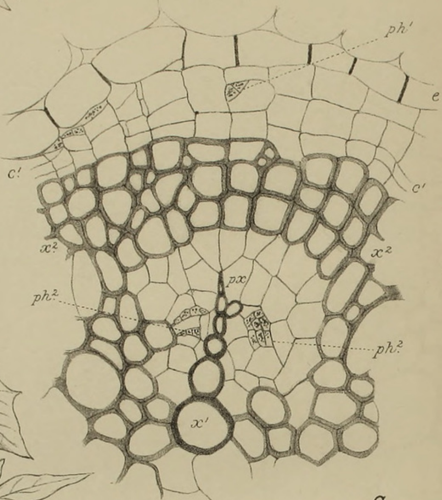

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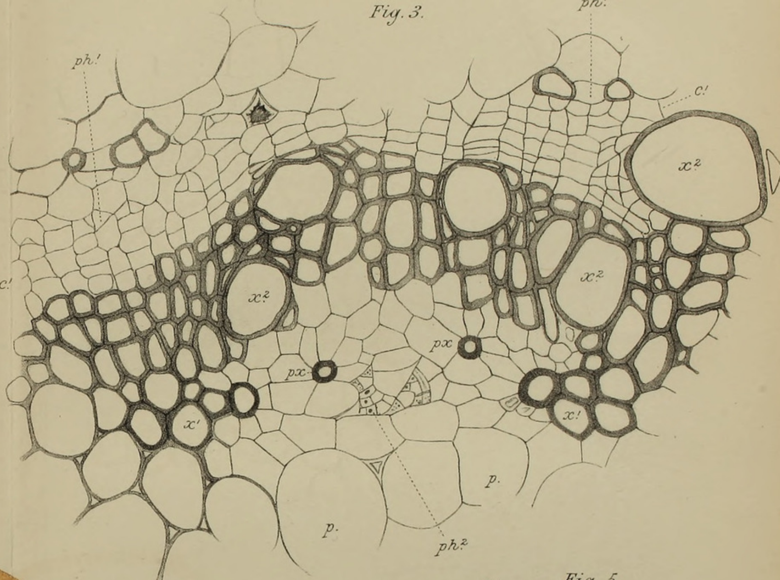

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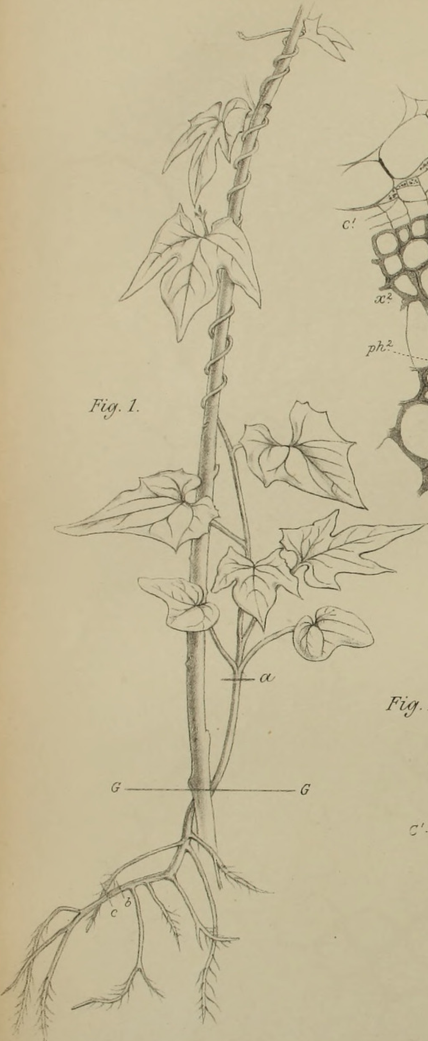

Fig. 2.

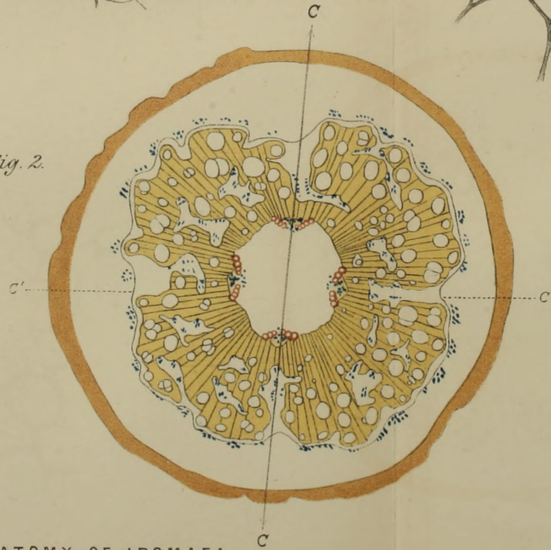

Fig. 5.

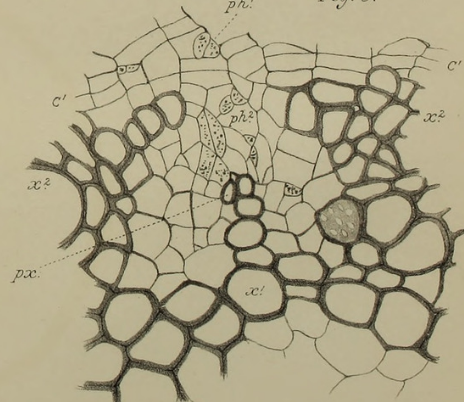

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Fig. 6.

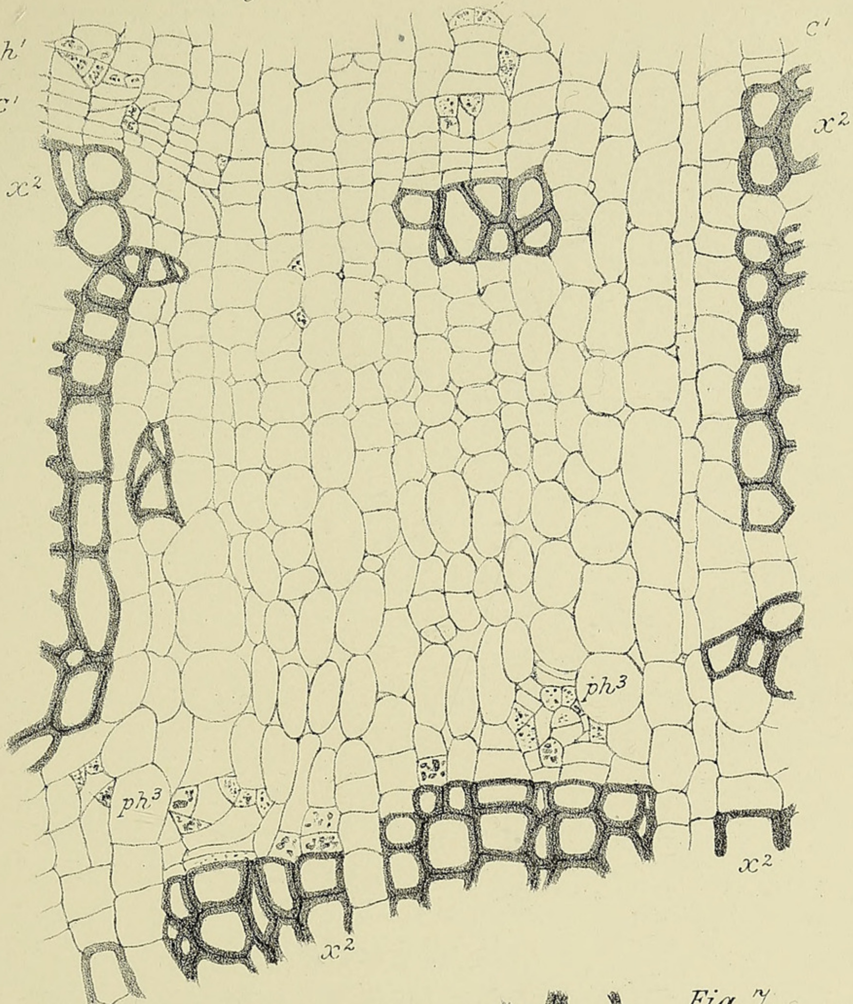
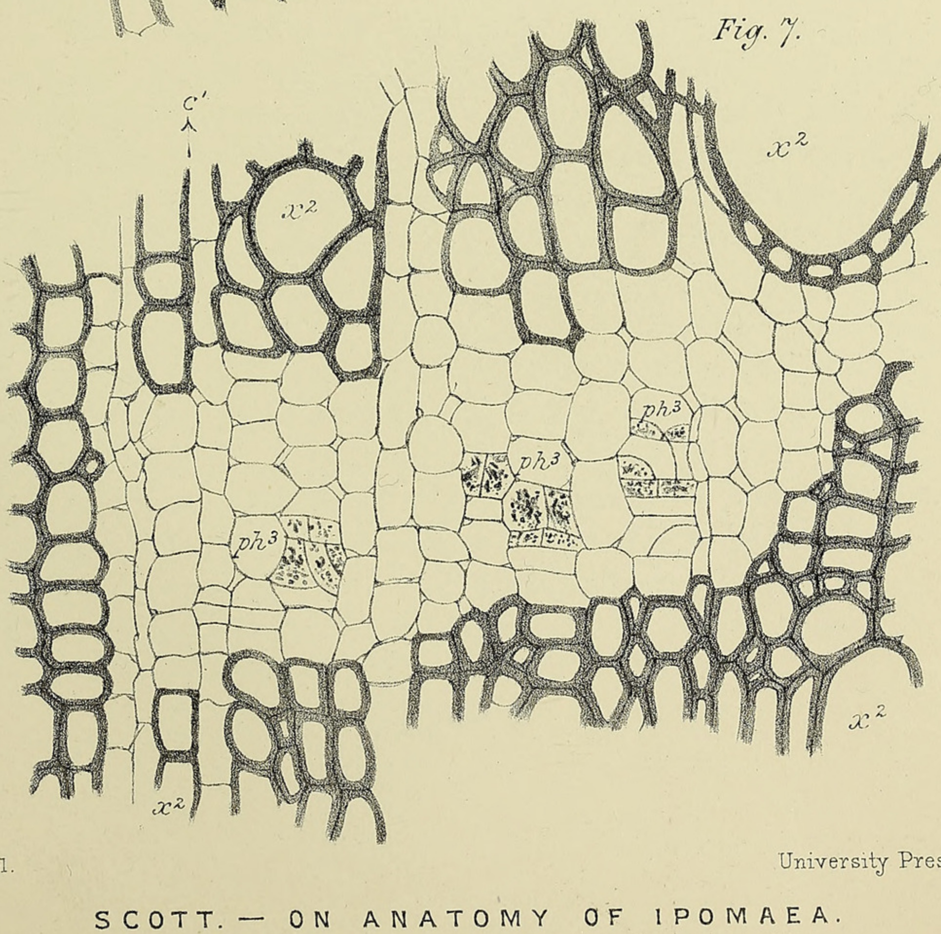


Fig. 7.



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