between the half wave-length of the gravest vibration and the length (l) of the rod (of uniform section) tends to vanish relatively when the section is reduced without limit."

The experiments lend no support to Macdonald's calculation which requires that the numbers in the table under the heading 'k observed' should be 2·5. It would appear, then, that Sarasin and De la Rive's well known experiments which, hitherto, have only been quantitatively described in terms of Macdonald's theory, still await their explanation.

THE AUSTRALIAN "GREY MANGROVE," (*Avicennia officinalis*, Linn.)

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With Plates XXVII - XLVI.

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1. Introduction.

Several species of plants are commonly known under the name of "Mangrove,"—belonging, however, to different Natural Orders, the term being given by the layman to those trees found growing in muddy, saline, foreshores. Botanically, it is generally restricted to those species assigned to the Natural Order RHIZOPHOREÆ, but the reason for such restriction is not clear. Indeed, I am in favour of its being applied only to those trees which have one common characteristic, *i.e.*, the curious property of having breathing roots or pneumatophores, such as *Avicennia*, *Laguncularia*, *Sonneratia*, etc. As it is probably impossible now to alter the common application of the term, the name "Grey Mangrove" is associated in this paper with the genus *Avicennia*, N.O. VERBENACEÆ, the species being *A. officinalis*, Linn., and as this is one of Linnæus' species, its systematic position dates back a long way in botanical works.

I would like to take this opportunity of acknowledging my great indebtedness to Mr. T. C. Roughley, of the Scientific Staff of the Technological Museum, for the photographs and sections illustrating this paper; to Mr. J. H. Maiden, and Prof. A. J. Ewart for the loan of literature bearing on the subject, and also to Mr.T. Dick for specimens and local information.

2. Description of the Species.

The plant upon which the research is made may be described as a species attaining full tree size, with a pale coloured comparatively smooth, very thin exterior bark, not much more than one-sixteenth of an inch in thickness on the tallest trees. Branchlets angular, leaves opposite, ovate to occasionally lanceolate, mostly acute, petiole about half an inch long, margins slightly recurved, length about three inches and under, breadth varying up to one and a half inches, shining on the upper side, clothed with a short tomentum on the lower. Cymes in capitate heads on fairly long peduncles in the upper axils; bracts and bracteoles small, hirsute with brown hairs, same as calyx, which is five partite, segments ovate, imbricate, the two within smaller than the other three. Corolla tube turbinate (top shaped), lower half glabrous outside, lobes concave, hirsute, anthers not exserted. Pistil short, bifurcated, hidden except the stigma in the straight erect hairs at the top of the ovary, which is glabrous and shining below this tuft of hairs. Ovary imperfectly four celled with four pendulous ovules. Capsule flattened, yellowish, dehiscing by two thick valves, one seeded. Seed erect, hypocotyl villous, but the hairs have not barbed tips.

In this connection it may not be out of place perhaps to mention that Robert Brown in Prod. Fl. Nov. Holl., 1882-5, p. 374, states:—"Embryonis radicula barbata." A feature recently claimed to have been discovered by Karsten, are the anchoring hairs of the hypocotyl of *Avicennia officinalis*, but no traces of such could be found on the specimen examined by me.

3. Synonymy.

It was not until trying to specifically place the botanical material for this research that the confusion surrounding this species of the genus became apparent. The Index Kewensis gives fourteen species in all, and of these twelve are synonymised under *A. officinalis*, the other *A. nitida*, standing as the only other valid species. When the genus is monographed I should not be surprised if the greater number of these were found to be good species.

To me, it seems scarcely possible that one species, *A. officinalis* should have such an extensive range as the synonyms *(ante)* would indicate.

The descriptions of the species are scattered through much botanical literature, and consequently great difficulty was experienced in trying to trace Linnæus' description of *A. officinalis*, and even now I am not sure of my ground, as all the descriptions of this tree, within the last fifty years are no doubt composite ones, and include several good species. As far as I have been able to penetrate the subject, I consider at least *A. tomentosa* and *A. alba* as distinct from what I regard as *A. officinalis.* The nearest description of the species of this paper is that published in Kirk's "New Zealand Flora," p. 271. Forster originally named this *A. resinifera*, but it has since been shown he was in error in ascribing a resinous exudation to his New Zealand Mangrove. The resin found in the mud amongst the New Zealand Mangrove was the Kauri resin now well known, and did not come from this mangrove. The New Zealand Mangrove appears to be identical in some respects with the Australian, and further evidence may show a close connection with the Indian and American species.

As far as I have been able to ascertain, no plate of Linnæus' *A. officinalis* is extant, and most of the illustrations going under the name are either *A. tomentosa* or *A. alba*, or another synonymised species, but in order to more definitely systematically place the species, a full description is given above, in which will be found differences from those descriptions and figures in Wight's Ic. t. 1481, under the name of *A. alba* and *A. tomentosa*, now synonymised as *A. officinalis.* The leaves also figured (*loc. cit.*) differ from those of this species.

4. Systematic Position of this Australian Mangrove.

Most of the descriptions of *A. officinalis* give the leaves as "obovate, cuneate, obtuse" which does not apply to this species, nor can it be *A. tomentosa*, figured by Wight Ic.

Pl. Ind., 1481-2, which has quite a different shaped leaf, stamens, ovary and pistil from those of the Australian plant. It more nearly approaches in its organs the figures of *A. alba*, which is recorded as a small tree or shrub as against the large sized tree of the Australian *Avicennia.*

Linnæus, himself, later reduced his *A. officinalis* under *A. tomentosa* a name now restricted to the American tree, an action which seems rather to have confused matters, and in opposition to this I propose to restore Linnæus' original name until a correct description is available, as well as an original specimen for comparison.

In order that the species may be more definitely placed in future, features other than morphological have been investigated, especially the microscopical structure of its several parts or organs, such as leaves, pneumatophores, timber, bark, and germination of the seed.

5. Leaves.

These trees as a rule have a most luxuriant growth of leaves, and this is what might be expected in view of the fact that the ash of the wood contains a high percentage of potassium salts *(infra).*

(a) *Histology.*—A transverse section, (Plate XXVII, figure 1) shows the structure of this organ to be quite unique. Except for one row of epidermal cells the upper half is composed entirely of a delicately walled material of irregularly shaped cells, evidently for water-storing—the "water tissue" as now understood, the larger cells being towards the middle of the leaf. This structure is succeeded in the lower half from the central axis of the blade by three, sometimes four rows of palisade parenchyma, which occupy the slightly larger part of this half of the leaf, and is followed by thin-walled loose parenchyma cells, or spongy mesophyll. Throughout the structure are scattered trachea vessels of the ordinary type. In the younger leaf the central bundle or mid-rib is surrounded by a band of protoxylem which in the more mature leaf becomes wood fibres. This is backed by loose parenchyma, probably water storing cells (Plate XXVIII, figure 2).

The tomentum, microscopically examined, is seen to consist of cup-shaped, peltate, closely packed hairs, which in outline rather resemble a shallow vase or tazza, or even some forms of fungus, like *Stereum*, with mostly a two-celled stem almost as broad as the cup at the top, the lower cell being the smaller and often filled with a dark substance, probably manganese compound.

Scattered on the upper surface of the leaf were numerous depressions, (Plate XXIX, figure 3) these in section, were found to be quite different morphologically from what obtains generally in stomata, which they were thought to be when examining the leaf by a pocket lens. The cuticle cells of the leaf were found to continue around the side and bottom of this depression, and no opening or guard cells were detected in the specimens examined. A kind of "anchor cell" was found at the base with one cell running into the depression. It may be that this acts as a clamp to close the aperture leading to the water tissue if such is required. Possibly they are air pores, but more probably contrivances for increasing the area of the cuticle, and the "clamp" to strengthen it during expansion or contraction.

(b) *Function.*—The stomata evidently being few and very minute, (I was unable to detect any in my sections), and the tissue of the leaf quite anomalous, efforts were next made to find out what functions other than those which usually obtain with leaves, are performed by those of this mangrove. Studying the trees carefully in their native habitat it was noticed that the stems almost invariably were inclined at an angle (more or less acute) with the foreshore. It was at first thought to be due to prevailing winds, but this, however, was found not to be the cause. Next, it was observed that the leaves of all the trees were disposed towards the north,—a case of heliotropism apparently, and the question naturally arose, why? The answer came in the observation, that by such an orientation, the pneumatophores were in shade, and so it worked out that the directing influence was to shade these breathing organs, and in order to get this protection, the stem, but more often the branches, grew in whatever direction this shade was obtainable. It was also noted that wherever the breathing roots became exposed for a length of time to the sun's rays, they perished, and then the branches on that side of the tree died and fell off,—a truly botanical sympathy. Judging from the structure, the storage of a large amount of water is also an important function of these leaves.

The knowledge of this necessity for the natural shading of the pneumatophores can now be turned to some economic purpose. These breathing roots are of great value to the oyster cultivator, as the crop of oysters to be obtained from them is greater than from any material used, such as slates, stone, etc., and consequently great efforts are made to cultivate this mangrove, but it has always been found difficult to start a plantation on a treeless shore, the young plants soon dying or putting on such slow growth as to be almost useless. Since discovering that shade is requisite for the growth of these organs, action is about to be commenced to introduce artificial shade until trees attain some size, or at least sufficient foliage to make its own shade protection, and these efforts will be watched with much interest by the commercial people concerned in oyster culture.

(c) *Economics.*—Cattle eat the leaves with great relish.

6. Breathing Roots.

These may be divided into two portions for descriptive purposes, viz.—(1) that part embedded in the mud, and (2) the portion projecting into the air when not submerged by the tides.

(1) This section shows that the root is surrounded by a broad loose aërenchyma, composed of cells which seen transversely have three arms, and longitudinally appear like a pile of round edged discs. The epidermal and hypodermal layers are persistent in the specimens examined in the field, and so the ventilating system is thus apparently not brought into direct contact with the water of the surrounding mud. (Plates XXX, XXXI, figures 4 and 5.)

(2) The portion of the breathing roots exposed to tide and air, presents, however, some interesting and distinct features from the part embedded in the mud.

In transverse sections (Plates XXXII, XXXIII figures 6 and 7) it is seen that these organs are composed of distinct concentric groups or structure. The root proper, or inner one, is bounded by a continuous ring of phloem cells surrounding the xylem of the bundles which have the usual proxylem and a stele of thin walled vessels and parenchymatous cells. In this part of the plant there appears to be quite an absence of sclerenchymatous cells, as obtains in the concentric rings of the wood. The intermediate circle of peripheral water tissue,—aërenchyma repesenting a primary cortex, is composed of two kinds of cells which go to make up this structure,—spongy mesophyll, loose in the middle but most compact, with smaller cells towards the outer edge, whilst interspersed throughout is found a cell of unusual structure, which transversely shows strengthening bars and perforations, whilst on a longitudinal section appear thick-walled cells often compressed and twinned, and these can be easily traced on the plates of these roots showing transverse and longitudinal structure. From the nature of this arrangement it is evidently in this portion of the pneumatophore much photosynthesis of the tree is carried out.

The epidermis or outer ring is composed of irregularly shaped thin-walled cells with a tomentum identical in structure with that on the underside of the leaf, but much smaller. In this cuticle, formed by a bulging out of the epidermis and hypodermal layers, are found fairly numerous papillose projections, or special pneumathodes, a section showing these layers of cells to be raised over what is a vacant cavity or air space in direct communication with the ventilating system.

Externally, these appear like so many raised black spots scattered over the surface, with a circular depression on the summit, and supporting what looks to be a circular valve or disc, which from above is apparently made up of three or four concentric growths or rings, but these are lost in a cross section, which shows continuous cells with but yet differentiated from, the contiguous epidermis and hypodermal cells. A section through one of these, when this cap is removed, is not unlike the air pore found in *Marchantia*. It may be that these discs act like a clack valve of a steam engine, and close the orifice when the tide rises and submerges the root, and receding when the air plays round it. But this requires further investigation, as similar markings occur on the ærial roots found on the stem six or ten feet above high water mark. Apparently then, these are pneumathodes or they may be secondary organs of ventilation, of the same nature or function as lenticels.

The tip (Plate XXXIV, figure 8) of this portion of the root is composed of thin walled nucleated parenchymatous cells which gradually increase in size as they differentiate into the separate structures of the root. The extreme tip is quite closed, nor is there any root cap as obtains in ordinary roots as shown in text books on the anatomy of the phanerogams. The tip of the ærial root found on the trunks high above water mark differs from these in that it has a projection as described above.

7. The Seed.

(a) *Germination* (Plate XXXV, figure 9).—The fruit dropping on the ground quickly sheds its pericarp and the hypocotyl soon begins to grow beyond the bunch of simple hairs or blunt ending, from which roots are sent at varying angles. At their earliest stages of growth they are found to have sufficient power to anchor the cotyledons, as it is only a matter of a short time before a miniature plant appears.

(b) *Seed as a food.*—The aborigines ate freely of the prolific crop of fruits which they roasted before eating.

8. The Timber.

(a) *Economics.*—With such a synonymy associated with this species, it is only to be expected that different accounts are recorded as to the quality of its wood, in fact, varying from "worthless" to "very hard and durable."

The following will give some idea of the confusion surrounding the timber knowledge of the species, and so naturally opinions vary concerning the nature of the wood of *Avicennia officinalis*, Linn., as shown by these extracts:

"The wood of Mangrove, *Avicennia officinalis,* is white, straight in the grain, tough, and elastic, but very perishable.—(*The Forest Flora of New Zealand*, p. 270,—T. Kirk.).

"It is very brittle; used in India for firewood. Major Ford says it is used for mills for husking paddy, rice pounders, and oil mills in the Andamans."—(*Dictionary of the Economic Products of India*, Vol. I, p. 361,—Watt.)

"The wood is valued on account of its durability under water, and as a fuel for heating furnaces. It is preferred to other kinds of wood on the West Coast of India."—*(Pharmographia Indica*, Vol. III, p. 82,—Dymock).

"Timber said to be durable as poles and in other places used for ship-building, etc."—(*The Forests and Forest Cape Colony*, p. 287,—Sim).

"In New South Wales, the wood is valued for stone-mason's mallets, on account of its toughness."—*The Treasury of Botany*," Vol. I, p. 112,—Lindley and Moore).

The timber of the Australian tree may be described as a pale coloured, very hard, heavy, cross laminated timber, inclined to slightly darken on exposure. It has several characteristics that easily differentiate it from any other timber known to me, and these are here described in sequence (*infra*). It is used in New South Wales for knee boats, crooks, and generally in boat-building when strength is required.

I am indebted to Mr. H. J. Swain, B.A., B.Sc., Lecturer, Mechanical Engineeering Department, Sydney Technical College, for the following tests:—

No.	Material.	Size.	Area of Cross Section.	Breaking Load in lbs. per sq. in.	Modulus of rupture in lbs. per sq. in.	Modulus of elasticity in lbs. per square inch.	Rate of Load in lbs. per minute.
1	Grey Mangrove	3·03″ x 3·03″ x 36″	9·18sq.in.	6610	12850	168000	3860
2	Grey Mangrove	3·02″ x 3·03″ x 36″	9·15 „	6620	12900	169000	4000
3	Grey Mangrove	3·02″ x 3·03″ x 36″	9·15 „	7070	13800	172500	4000

For comparison the averages of three specimens were—Ironbark 9000; Blue Gum 5000; Burma Teak 6000; Colonial Teak 8000.

(b) *Analysis of the ash.*—An analysis made by my colleague Mr. H. G. Smith, F.C.S., gave the following results:—

The ash was used by early settlers at Port Macquarie in the manufacture of soap, in preference to that of all the other trees in the district. It was probably by empirical means that such a use was found for it, although the practice was quite a common one elsewhere. The percentage of soda as carbonate being so large, it is readily seen how useful such material could be made for such a purpose.

The large amount of alkalis renders the ash easily fusible, and some difficulty was experienced in preparing it in a fit state for analysis; it was necessary to dissolve out the alkalis before all the carbon could be removed.

The percentage of ash calculated on the anhydrous wood was 2·43 per cent. There were no sulphates remaining in the insoluble portion, nor were phosphates detected in the soluble. The amount of silica was very small, and only a trace of iron was present. Manganese was detected, but only in minute traces. The silver precipitates were decomposed by zinc, and in the filtrate bromine was detected but not iodine.

The composition of the ash was determined as follows:—

Potassium sulphate ...	2·26	per cent.
Potassium chloride... ...	19·58	,,
Sodium chloride	7·60	,,
Sodium carbonate	41·61	,,
Calcium phosphate	7·01	,,
Calcium carbonate	9·94	,,
Magnesium carbonate ...	11·73	,,
Silica	0·13	,,
Loss and undetermined ...	0·14	,,
	100·00	

(c) *Macroscopical.*—Viewing a transverse section of a mature tree, (Plates XXXVI, XXXVII, figures 10 and 11) the annual "rings" as obtains in ordinary dicotyledonous stems might be said to be well defined, but with this difference, that the "rings" are not continuous, the break being caused by an intrusion of another "ring," and thus the complete circle is broken.

By forcing the "rings" apart tangentially a good view is obtained of the disposition of the fibres. Each ring of fibres is seen to be at quite a different angle to that in juxta-position to it. Sometimes they run perpendicularly, but more often at varying angles to each opposing ring, (Plate XXXVIII, figure 12).

Dr. Prain's remarks in his "Flora of the Sandabans," 1903, apply equally well to this Australian Mangrove:—

"The structure of the wood is peculiar, in that the fibres of any particular ring of growth do not pass vertically upwards, but instead diverge 'herring-bone fashion" from an indistinct vertical linear raphe, which appears to correspond to the plane of an original branch, at an angle of about 15°, their upper ends blending in a much less definite raphe mid-way between two raphes of divergence. The raphes of divergence of the ring of growth next above and next below any particular ring alternate, so that in weathered trunks, and to a less extent in freshly cut sound logs, a lace-work arrangement of the fibres of the various rings of growth presents itself."

The structure of the timber much resembles what is to-day on the markets as three, four, or five-ply veneer, which can now be shown to be only a copy of nature, for in the manufactured article the fibres of each sheet of wood are at right angles to one another instead of at oblique angles, as obtains in nature, which, is the main reason for the difficulty in splitting.

There is another remarkable feature about this wood, and that is its resistance to splitting radially, for it is impossible to so split a log say three feet or more in length. Tangentially it is much more fissile, and in this direction it is more easily split than any other timber known to me. The aborigines were cognisant of this character, as shown by their preference for it for shield making.

(d) *Histology—Primary or Early, and Secondary Wood.* Many sections were made for examination, and from these, typical samples showing the structure during different periods of growth are here figured and described.

Primary or Early Wood.

(*a*) This is a transverse section of ultimate branchlet measuring 2·5 mm. in diameter. (Plate XXXIX, figure 13.)

(*b*) A larger twig than (*a*) measuring 4·5 mm. (Plate XL, figure 14).

(*c*) Showing older growth than the two previous ones, measuring 6 mm. in diameter. (Plate XLI, figure 15).

(*a*) Figure 13. This may be described as almost quadrilateral in transverse section, the bundles being parallel to the shape of the outer edge of cortex in a continuous line removed from it about one-third of the diameter, and enclosing the central mass of thin wall structure (hexagonal in section). The space between the cortex and the bundles is composed of a smaller irregularly shaped structure of loose parenchyma, most of the cells near the edge containing a substance not determined, and forming the pro-cortex.

(*b*) Figure 14. This section shows an advanced stage of growth upon that of (*a*). The central mass of vessels, etc. forms a much less proportion of the whole, the bundles are well defined, the xylem and proxylem well pronounced, and the phloem coloured purple by hæmatoxylon being backed by what is gradually becoming a distinct ring of stone or sclerenchymatous cells, is followed by thin-walled wood parenchyma cells enclosed the whole way round by a narrow ring of original phloem, and this is subtended by a broader band of cortex. Pores may be noted occurring in the radial lines of the xylem. The whole is composed of a perfect regularity of structure.

(c) Figure 15. This shows a centre made up of vessels and a few sclerenchymatous stone cells (in section) and parenchyma, the whole bounded by a complete ring of bundles, with numerous pores in the xylem (red) with interfascicular rays, the phloem (purple) backed by short sclerenchymatous cells followed by a band of wood parenchyma. Now this structure is repeated in a regular manner outwards to the fourth ring, and then is noticed an intrusion of another "ring" which breaks the continuity of the fifth ring. This section is of particular interest because it shows how, even in the early stages of growth, the rays are restricted or limited to the space between the two walls of sclerenchymatous cells, and so are not strictly medullary rays as generally understood; this feature obtains throughout all the secondary wood in the species, and is more fully illustrated in figure 16, *(infra)*. Up to this stage, the rings are entire and evidently annual, but from this out, they become broken.

Secondary Wood—Transverse Section.—(Plate XLII, figure 16) In this section is seen a bifurcated band of thick walled cells forming the barrier to the progress of the rays to continue beyond the limits of each "ring." This wall of sclerenchymatous cells is bounded on either side by wood parenchyma with thin walls, and between these are the wood fibres with small lumen.

In the wood parenchyma are seen groups of (apparently) broken cells. Tracing these back from a two or three years' old twig, they are seen to be the phloem cells of the bundles and stain purple, with haematoxylon, as with other phloems. They are composed of thin walled bast parenchyma and bast stone cells, the latter showing the long axis in the longitudinal section, and with comparatively thin walls, both being filled with what is probably a tannin substance. Combined they make up the remarkable "dottings" on the outer edge of each concentric "ring," which continue to appear almost regularly as the tree attains maturity, and macroscopically examining a piece of timber they appear as rows of pin pricks. I believe these perform all the functions of the ordinary bark of a dicotyledonous plant, as injury to the outer cortex has no effect on the life of the tree.

Tangential Section.—In this view, (Plate XLIII, figure 17) are clearly brought out the different angles or planes in which the fibres run, and the sclerenchymatous cells are seen to be exactly the same shape as in the transverse section, showing that they are short, isodiametric bodies and not elongated. It is due to this particular form that the timber splits so readily tangentially, there not being a length of fibre to give an interlocking strength, or in other words no cross structure such as would occur if the rays ran through and held together the annual "rings." The phloem cells with the broken content *(supra)* are here seen longitudinally.

Radial Section (Plate XLIV, figure 18).—Owing to the twisting of the wood fibres, it is almost impossible to get a section showing the full height of a ray, which vary from uniseriate to multiseriate, such as are seen in figure 17, which shows conclusively how completely the vertical sclerenchymatous ring of cells restricts them to the width of a "ring" only. In such a case, it seems to me hardly correct to call them medullary rays, for they do not come from the middle of the stem. The phloem of the broken cell contents is as conspicuous as in other sections.

Fibres.—These are distinctly seen in the various sections shown, and microscopically examined are found to belong to the simple variety, the walls being relatively thick, and in the lumen are seen oblique slits. The length is over 1 mm., and these make up 30 per cent. of the wood by nitric acid method.

Results of these Histological Investigations

(*a*) Practically no true medullary rays, as obtain in secondary wood of dicotyledons, are found in the structure, for what must certainly be classed as "rays" yet are not medullary, as they do not extend from the middle to the outer cortex, being quite restricted in their length to the width of each "ring."

(*b*) Bands of vertical walls of sclerenchymatous cells of the round or polygonal or short variety limit the length of the rays,—a feature quite absent in any timber as far as I have been able to ascertain.

(c) The phloem cells in regular clusters on the outer edge of each ring, appear to perform the function of ordinary exterior bark, as shown when the tree is ring-barked.

(*d*) The remarkable disposition of the wood fibres.

(*e*) The work of cambium being performed apparently by the wood parenchyma between the wood fibres and the stone cells.

(*f*.) There is nothing in the wood which corresponds with the spring and autumn growths of other dicotyledonous trees.

9. Bark.

This investigation goes to show that all previous published information (*infra*) stating that the bark is used for tanning does not apply to the Australian species, as the outer bark on very young and fully matured trees is so thin and the quantity so small that it would never pay to use it for tanning purposes. The tannin which it contains does not amount to more than 7 per cent. according to an analysis made by Mr. H. G. Smith. This goes to show conclusively that, when it is spoken of—and it often is—as a valuable tannin bark, several species must have been or are included under the specific name. In fact, this one feature alone seems to prove that we have here a distinct and very probably an unnamed species.

Evidently the following data, appearing under the name of *Avicennia officinalis*, do not apply to the Australian species:—

"The bark is astringent and is used by tanners."—(*Pharmacographia Indica*," Vol. III, p. 82,—Dymock).

"The bark is used as a tanning agent."—(*Birdwood, Bombay, Prod.*)

"In Rio de Janeiro, the barks of various species of *Avicennia* are used in tanning leather."—(*Dictionary of the Economic Products of India*," Vol. I, p. 361,—Watt).

"The next important group are the Mangroves, that grow in the tidal creeks, which are said to make most durable sole leather, even better than oak, but there appears to be a prejudice against this tannin in England."—(*Tropical Agriculturalist, Colombo*," 1903-4, p. 2).

"Fair percentage of tannin in this bark."—(*New Plants in Natal*," 1905, Sims).

"The bark is used in tanning."—(*The Forests and Forest Flora of Cape Colony*, p. 287,—Sims).

"Bark used for tanning,"—Birdwood, (*Products of India*, p. 361,—Watt).

"Bark used in Rio de Janeiro for tanning,"—(Surgeon H. W. Hill).

"Bark astringent," (Surgeon Major W. Dymock, Bombay).

A noticeable feature about this tree is that it is impossible to kill it by ring-barking, for trees are to be seen in the Port Macquarie district that have not suffered in the least by such treatment, but are in just as flourishing a condition as if they had never been touched by the axeman. This tree then is an exception to the rule. The fact that this mangrove should live on in spite of this general method of killing trees is, in my opinion, due to each "ring" being in itself a fascicular bundle, consisting of the elements or factors that go to make up such a combination of phloem, xylem, etc. Cutting away then what is regarded as the bark is really only depriving the tree of a ring of an outer cortex, and further the remaining numerous phloem streaks in the individual rings are quite able to carry on the function of that injured on the outside, and so the tree lives,—a character unique as far as my knowledge goes in the botanical world.

10. Concentric Rings and their relation to the age of the tree.

When carrying out an investigation on the fibres of Australian trees, I was particularly attracted by the peculiar disposition of those of this tree, they being quite unlike anything I had previously met with.

Mr. T. Dick of Port Macquarie, N.S.W., who was much interested in the subject of the manufacture of shields from this tree by the aborigines, also drew my attention to the fact that it was most difficult to split this mangrove timber radially. It was these features which caused me to make an investigation of the histology of the timber (*supra*).

Searching for literature in regard to the matter, I found that Mr. A. W. Lushington had drawn attention to the "concentric rings" of *Avicennia officinalis*, as to whether they were annual or not, in the "Indian Forester" for 1893, Vol. XIX, p. 104, to which the Hon. Editor adds a foot note to the effect that these "rings" are not annual, and gives a picture of a section of *Avicennia* wood after Nordlinger, not mentioned in Solereder—the originals of which I am unable to trace. This was followed by a letter in the same journal, Vol. XXIII, p. 413, by Mr. J. S. Gamble, who, whilst giving a list of so-called mangroves, makes a plea for some one to investigate the wood rings of *A. officinalis*, and to ascertain how far, if at all, the curious structure of the wood is caused by periodical phenomena, such as tides, etc.

Mr. A. W. Lushington, of Masulipatum, in the same journal, Vol. XXIV, p. 56, writes in reference to Mr. Gamble's letter *(supra)*, and takes exception to that gentleman's statement that "the rings of *Avicennia* are obviously in no way periodical, for they are not concentric, but run into each other," and on account of those characteristics periodicity cannot possibly exist. He then goes on to attribute this break in the concentric rings to forest fires. Further, he propounds the theory that, possibly, the monthly difference of the tides might have something to do with these rings, owing to the trees being more flushed with water at one part of the month than at another. He next records how he experimented with *Avicennia*, and found twenty-five of these spurious rings after two (2) trees had been cut twenty-five months, and in another thirty-five rings after thirty-five months.

The editor adds a foot-note to the effect that a section may show a different layer of tissue, probably bark, between each layer of wood.

The Madras Report for 1895-96, states:—"It was found in the Kistna District that the annual growth in diameter of the mangrove *(Avicennia)* amounts to nearly an inch, and from one to two feet in height. It is considered the spurious rings are monthly, and are probably due to the different conditions of nutrition caused by the spring and neap tides."

Perhaps the tropical temperatures may cause such rapid growth, but such a rate does not hold for the New South Wales plants. Mr. Dick is a keen observer of nature, so that his data should not be despised, and having visited the locality and examined the tree *in situ*, I think he is correct in his decisions (*infra*).

From observations made by Mr. Dick on the species occurring at Port Macquare, the monthly rate of growth obtained by Mr. Lushington does not hold in Australia, in fact, it appears that a very slow rate of growth obtains in this country.

Port Macquarie in New South Wales is an important centre of oyster cultivation, and this particular mangrove is much used in the culture of that mollusc, so that the tree has necessarily been under close observation by many people for a long time. Mr. Dick writes me in this connection:—

" I have been for a number of years on this river, and working amongst the Mangrove, and I am in a position after my experience of twenty-five years to state that this tree has a very slow rate of growth. Other people, who have been for sixty years in the same locality, also state that the tree has a very slow growth, and that it is not noticeable, being so very, very slow. I, to-day, went to certain trees that had been marked in reference to the fixing of the boundaries of certain of our oyster leases, this marking having been done in 1897 ; one tree had the broad arrow cut in it, the number of the lease also. Now on examination to-day, the marks are not much altered, and are not overgrown in any way. A barbed wire fence was attached to a Mangrove in 1895, prior to our taking up the lease, this wire being stapled to the tree; this was found to be covered with the new growth of timber and to a depth of 1 inch. The tree is certainly a long while in the growth, and will live to an enormous age. As regards the side to the water being softer, I find the Mangrove the same as other trees, affected on the side exposed to the sun."

Mr. Dick also informs me in a later letter:—

"I duly received your letter *re* the age and rate of growth of what I call the 'Grey Mangrove.' In reference to the rate of growth, I can only state as before, and that is, that the tree as far as we have found it to grow on this river, is slow in its growth. I planted a large quantity, or should say transplanted them, in a very suitable piece of bottom, and I am going to photograph the rows of trees for you, and will send them down. The trees so far have not averaged one foot per year in height. I have asked a number of people about the growth, and they all say the same—very slow, practically not noticeable. Since starting to write, I have ascertained that it is seven years that the trees have been growing." (Plate XLV, figure 19.)

These data certainly illustrate a much slower growth than that recorded for Indian species, and certainly give colour to my contention that here we have a distinct species from that one. I have visited this locality and examined the latter trees above mentioned, and endorse all Mr. Dick's remarks as regards them. I found that they measured five feet in height and three inches in diameter at the base.—a great disappointment to the oyster cultivator, who planted them as a help in the industry. I have also examined a large number of trees from which the aborigines cut their shields very many years ago, and in every instance only the very slightest growth had taken place wherever shields had been cut, in fact, except that the face from which the shields had been taken, was a little weathered, the actual size of the shield would probably about fit the space now left, judging from the dimensions of an original shield.

Conclusions.

Reviewing some of Mr. Lushington's theories *(supra)* of the remarkable growth of this tree, my investigations show (*a*) that forest fires do not play the part he assigns to them, and that the break of concentricity is not due to that cause, as fires are not known to have occurred where the trees abound, and yet breaks occur in the ring, and then the stems are so regularly built up by these rings that traces of retardation of growth are rarely perceptible, such as one finds in other trees that have suffered from artificial or natural causes. My correspondent, who has watched hundreds of trees for many years, dismisses this theory as applied to New South Wales trees, as bush fires rarely if ever occur amongst them, and my own personal examination of the trees in this and other districts does not support this theory. It is in the fifth or sixth year of the age of the tree that these breaks in the rings begin to develop.

(*b*) Neither is there evidence forthcoming to support this gentleman's suggestion that each ring or portion of a ring represents a tide, if I understand his idea rightly, for during the known age of certain trees, far more tides must have passed round the tree than are represented by the rings. Sections were made from a tree planted seven years ago, and the number of rings correspond to this number, and (*c*) Mr. Lushington's experiment of finding the number of spurious rings to correspond to the number of months proves that the growth of trees must be very much faster in India than in Australia, for the data given above under the seven years old trees are indisputable.

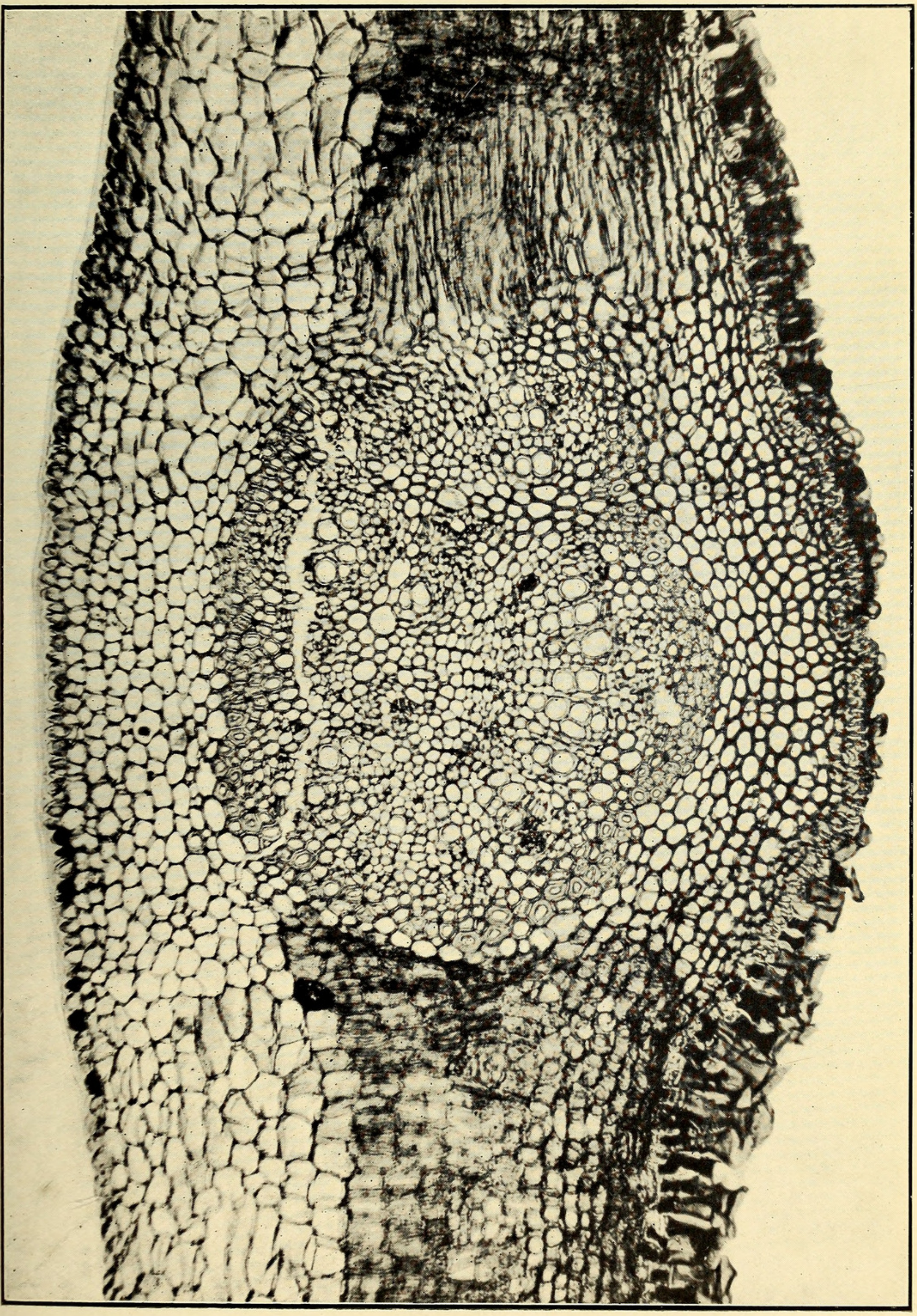
Finally, I can only say that after giving much thought and attention to the subject, I am unable to advance any definite explanation to account for this remarkable structure of the timber. I have thought of several, but the most feasible seem to me to be (1) the attaining of a maximum amount of strength with a minimum amount of weight by the disposition of the fibres and breaks in the "rings" required by the large quantity of foliage carried by the tree, and (2) strength to resist river currents and tides. Further, I believe, that each individual "ring" represents a year in the age of the tree, and this is supported at least by authenticated trees planted during the last six or seven years, whilst evidences certainly favour the theory that these trees grow to a great age.

(3) The *sine que non* of the life of the tree is a shading of the roots, consequently trees are often found overhanging the water at an angle that would be dangerous to the life of an ordinary tree, and yet this inclined stem, carrying a great weight of foliage and branches for the shading of the pneumatophores, flourishes. In some instances stems are almost parallel with the mud or water, hence the necessity for great strength in the timber. (Plate XLVI, fig. 20.)

(4) Then, again, the great vitality of the tree is assured by the collective structure of each "ring," and so whatever accident may happen to a part of the tree, there is always left sufficient independent material to carry on the work of leaf formation to procure shade for the pneumatophores, so essential to the life of the tree.

If these are not the reasons for such phenomena of wood structure and growth, then I am afraid it is a case of knowledge without understanding.

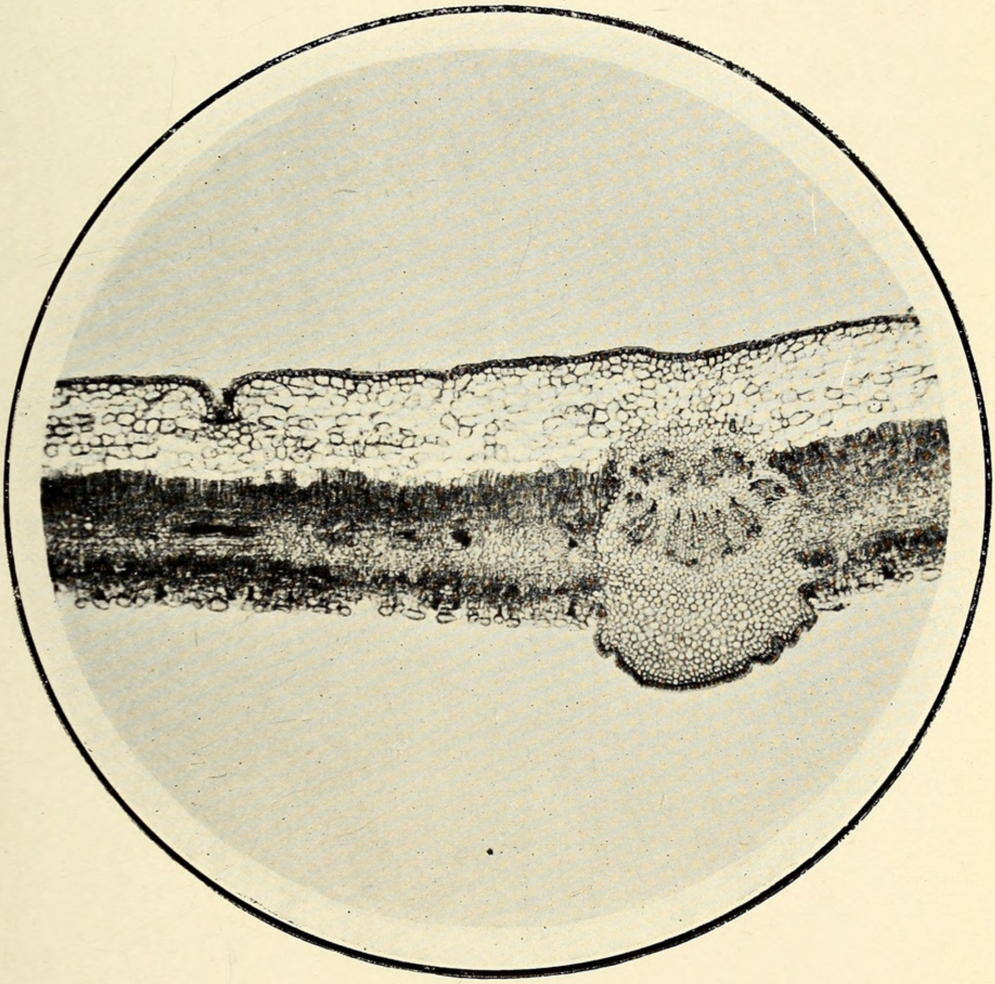
Note:—In the discussion which followed the reading of the paper, Mr. J. Nangle, F.R.A.S., explained that this strong and especially built timber failed in reaching the testing figures of the "Ironbark," owing to want of interlocking fibres between each "ring," there being nothing to prevent a sliding of the surfaces. In the case of beams, architects



T. C. Roughley, Photo.

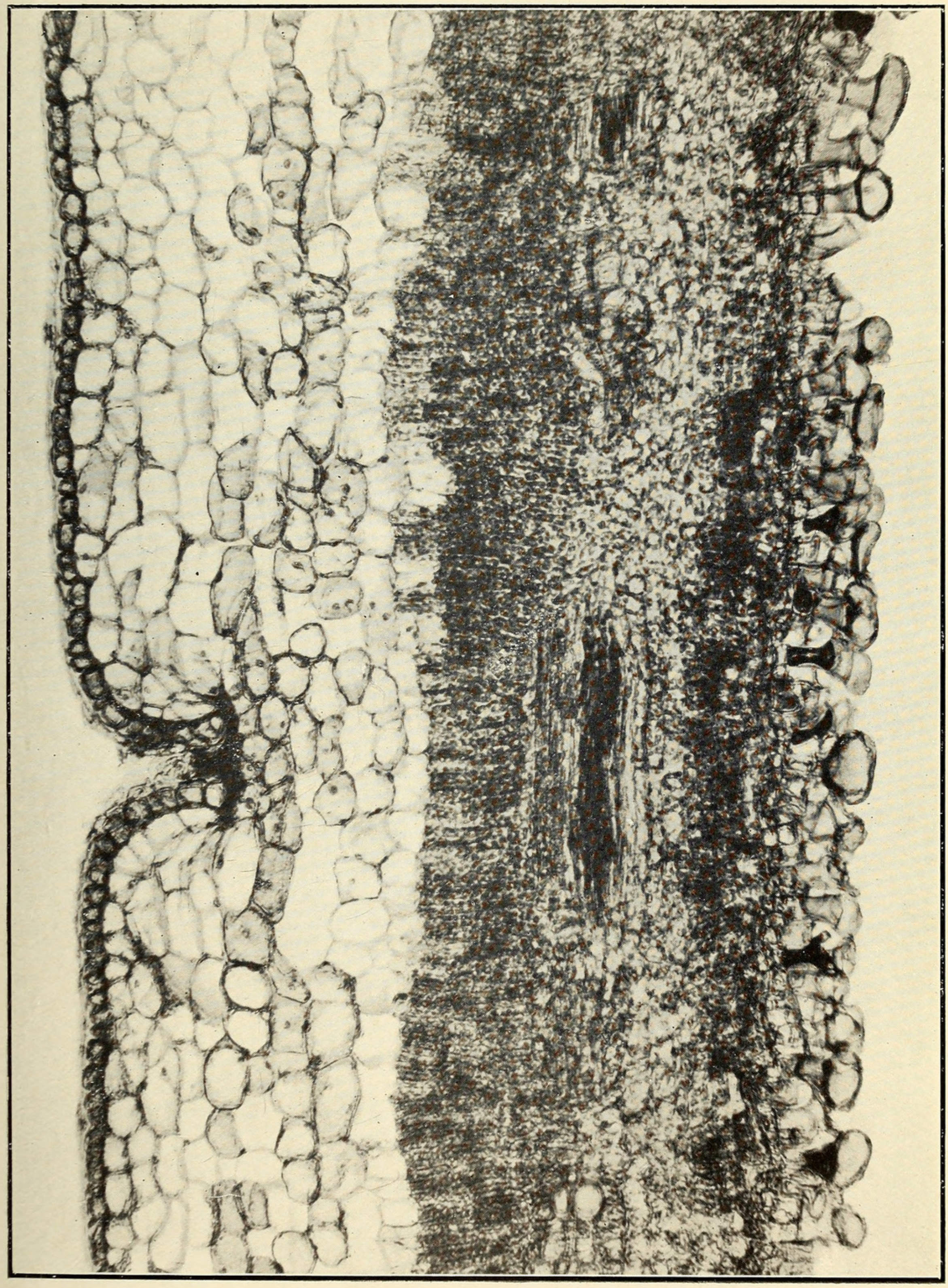
Fig. 1.—Transverse section of a portion of leaf showing central bundle and neighbouring tissue. × 150.

Avicennia officinalis, Linn.



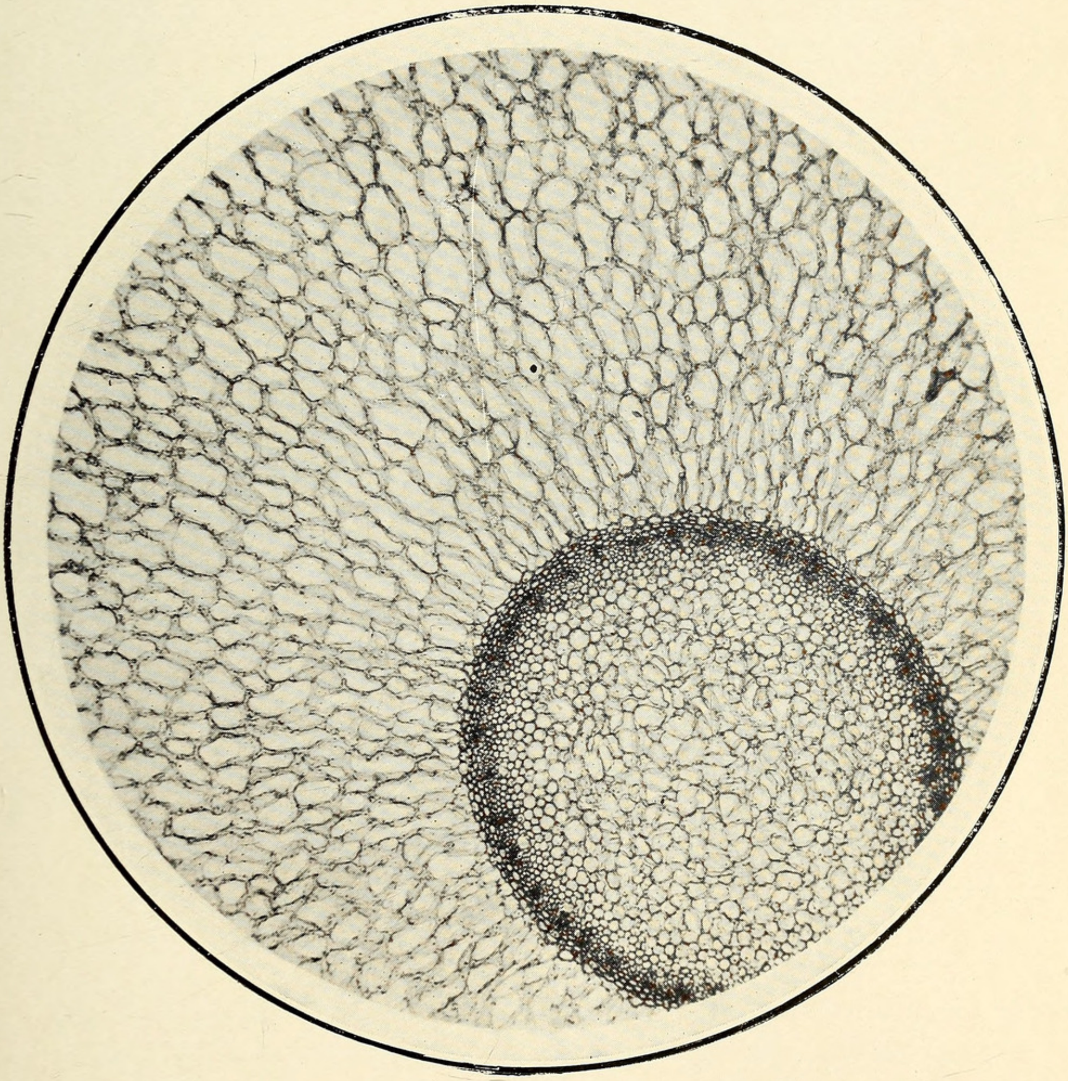
T. C. Roughley, Photo.

Fig. 2.—Transverse section of a portion of leaf showing a depression on the upper surface. × 50. *Avicennia officinalis*, Linn.



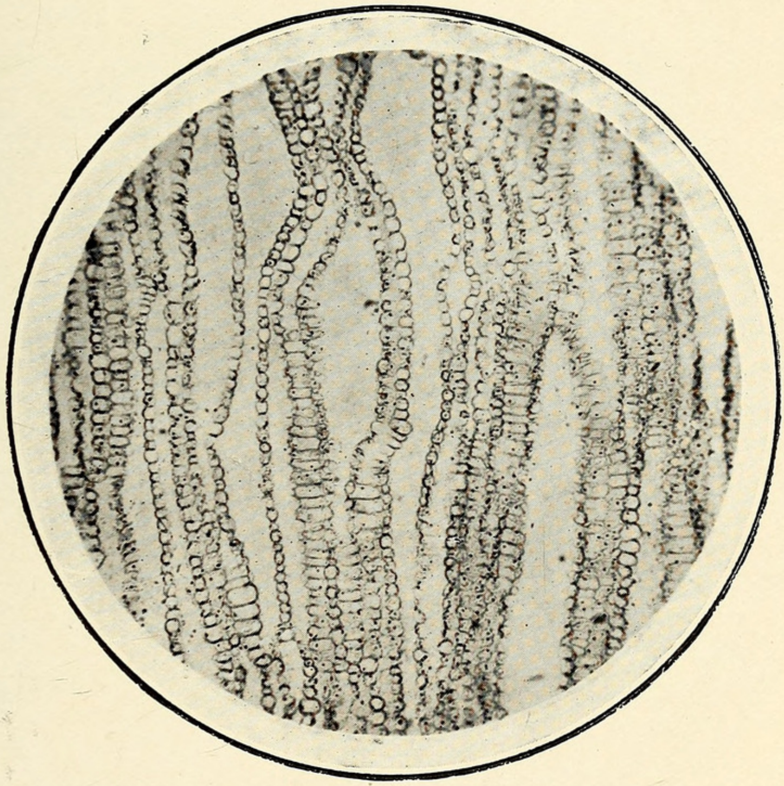
T C. Roughley, Photo.

Fig. 3.—Portion of Fig. 2 showing structure of depression and surrounding tissue. × 150. *Avicennia officinalis*, Linn.



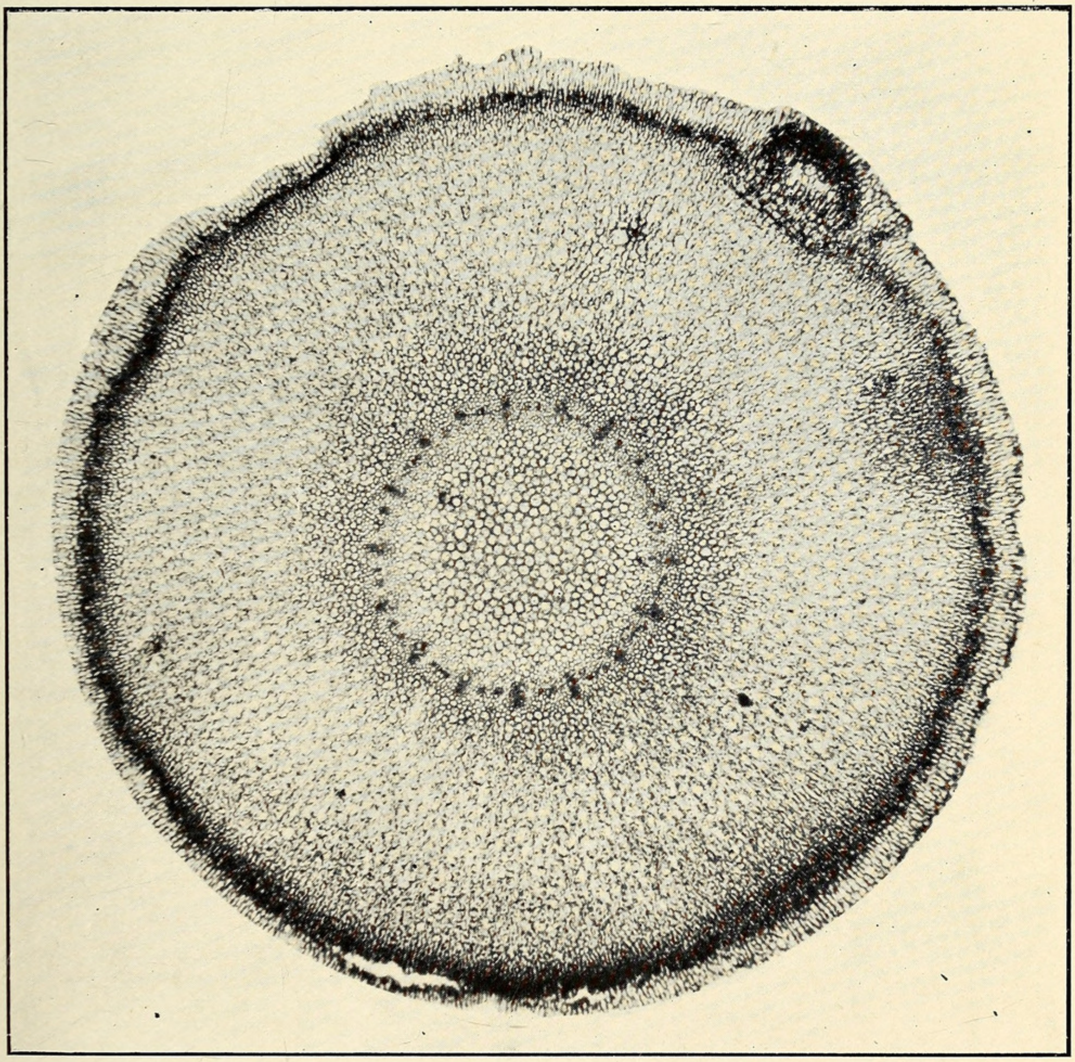
T. C. Roughley, Photo.

Fig. 4.—Transverse section through a pneumatophore below the mud surface. × 30. *Avicennia officialis,* Linn.



T. C. Roughley, Photo.

Fig. 5.—Longitudinal section of primary cortex portion of a pneumatophore below the mud surface. × 15. *Avicennia officinalis,* Linn.



T. C. Roughley, Photo.

Fig. 6.—Transverse section near tip of exposed portion of a pneumatophore, but cutting central root. × 30. *Avicennia officinalis*, Linn.

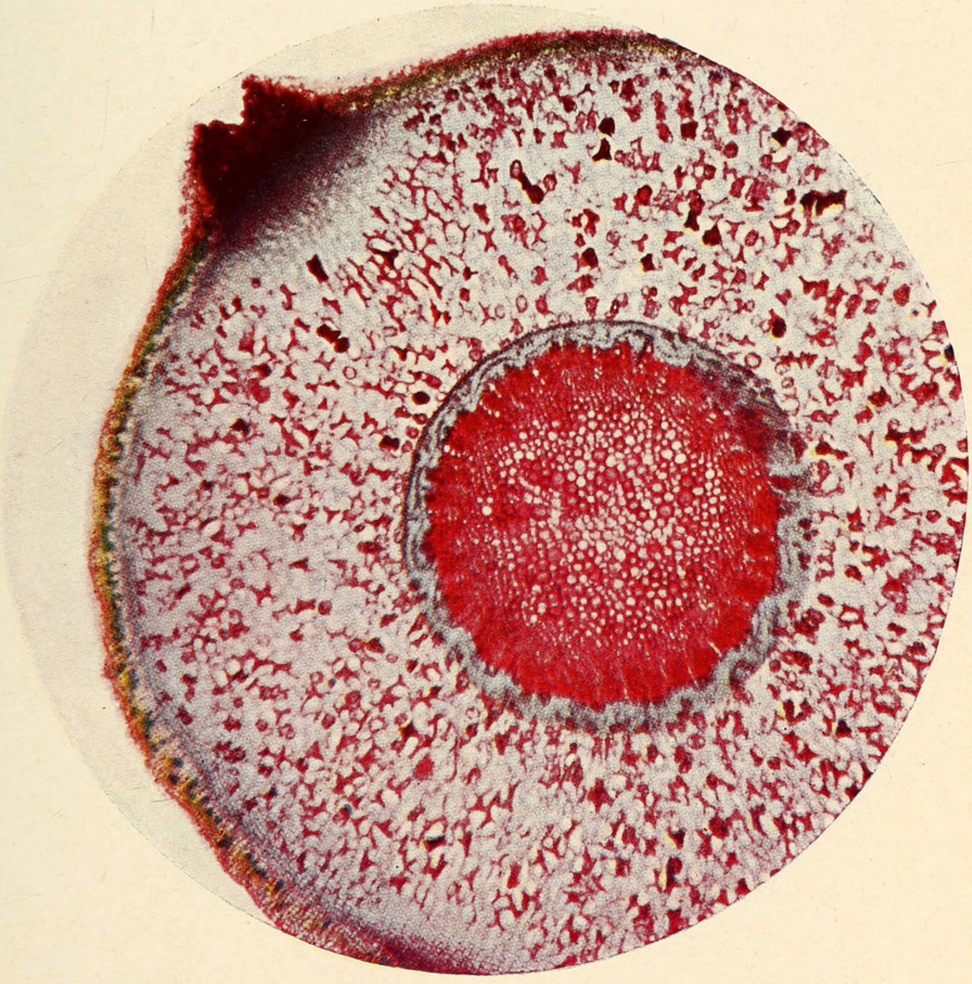
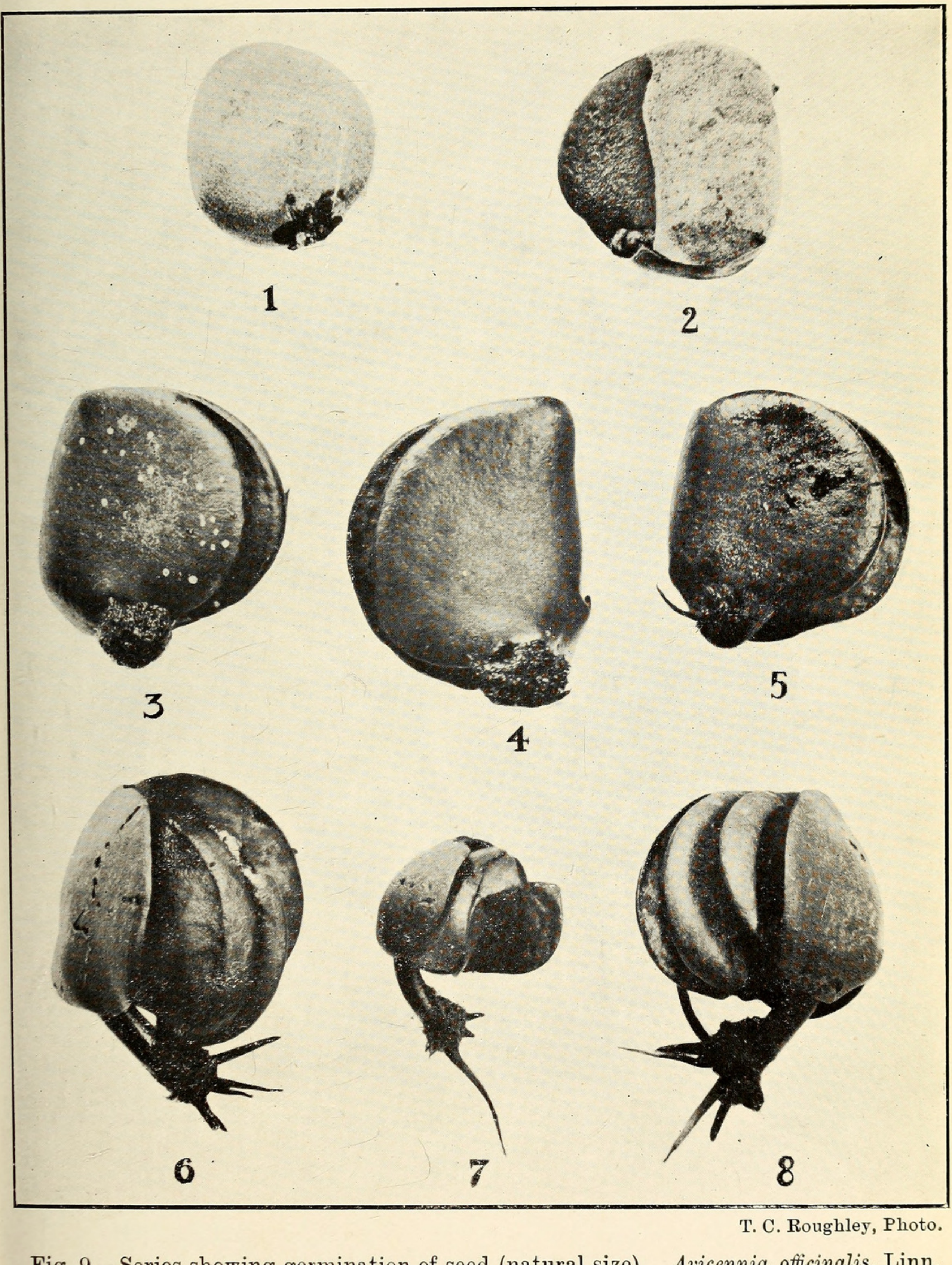


FIG. 7. TRANSVERSE SECTION NEAR THE TOP OF EXPOSED PORTION ABOVE THE MUD OF A PNEUMATOPHORE, BUT CUTTING CENTRAL ROOT LOWER DOWN THAN THAT SHOWN IN FIG. 4. ON THE LEFT IS PORTION OF A PNEUMATHODE IN SECTION. x 30.

AVICENNIA OFFICINALIS, LINN.

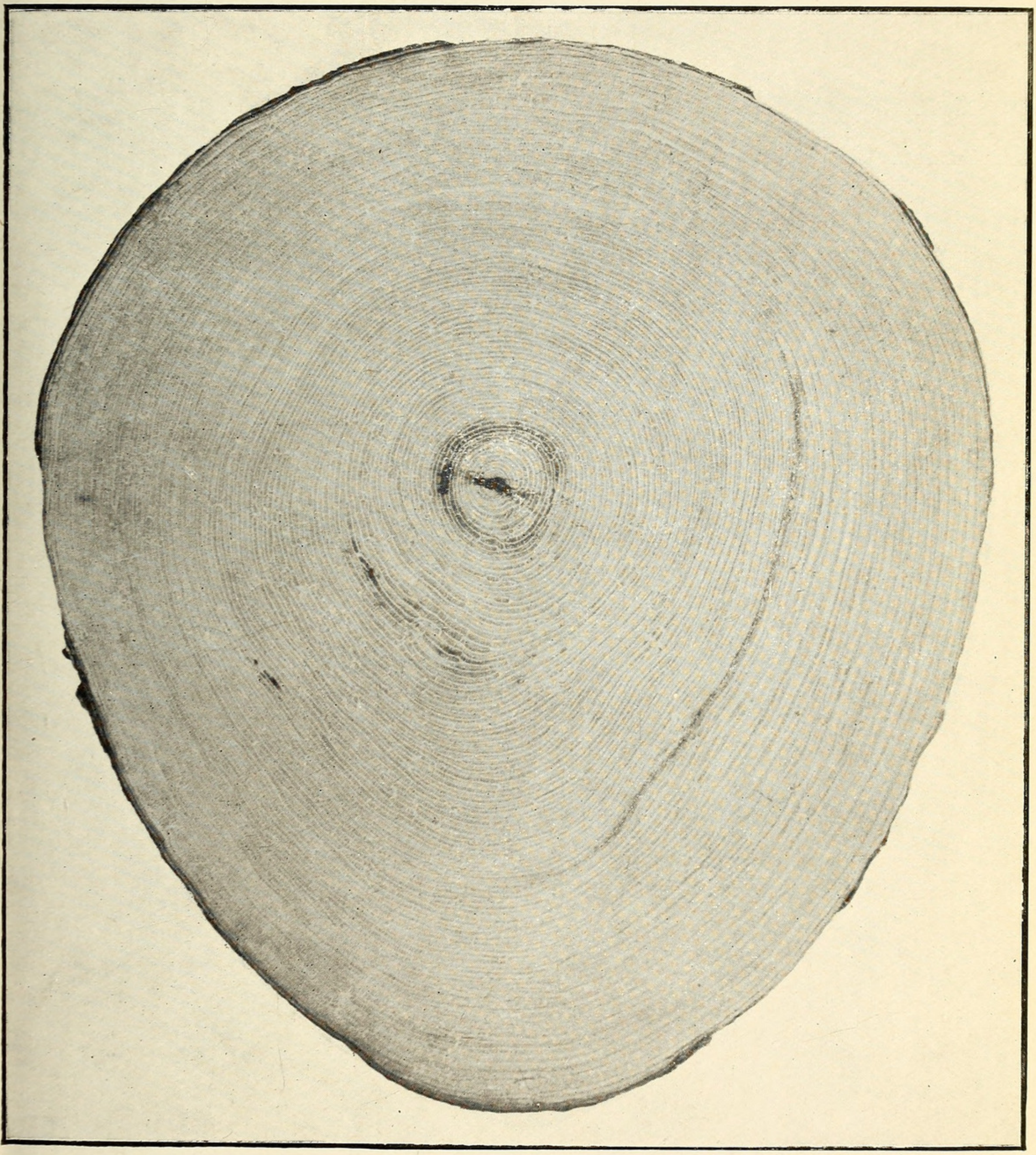
FIG. 8. LONGITUDINAL SECTION THROUGH TIP OF A PNEUMATOPHORE. x 30.

AVICENNIA OFFICINALIS, LINN.



T. C. Roughley, Photo.

Fig. 9.—Series showing germination of seed (natural size). *Avicennia officinalis*, Linn.

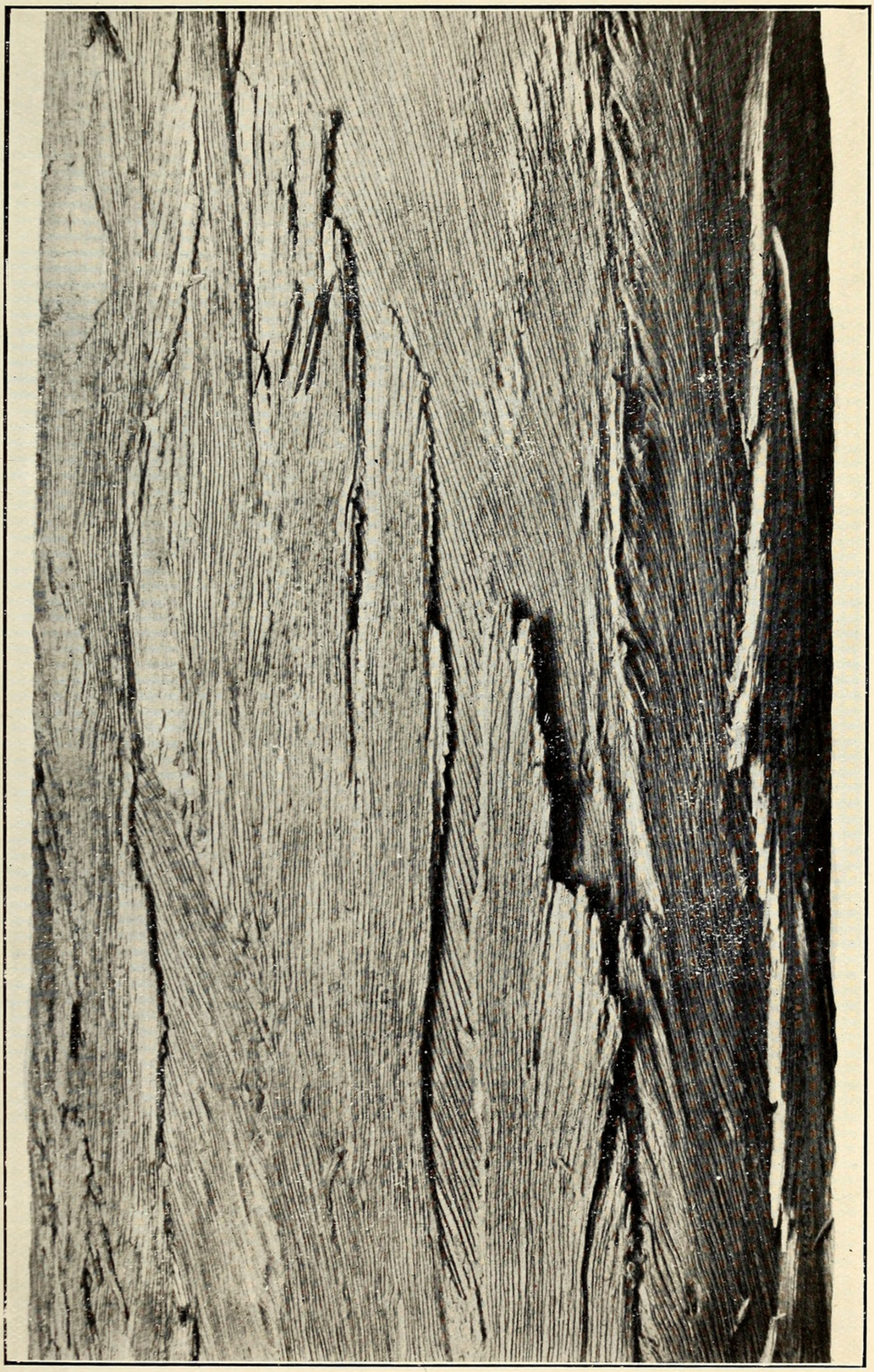


T. C. Roughley, Photo.

Fig. 10.—Transverse section of trunk of tree (reduced). *Avicennia officinalis*, Linn.

T. C. Roughley.

Fig. 11.—Portion of transverse section of trunk of tree enlarged from Fig. 10.
Avicennia officinalis, Linn.



T. C. Roughley, Photo.

Fig. 12.—Section of wood split tangentially, showing disposition of fibres.
Avicennia officinalis, Linn.

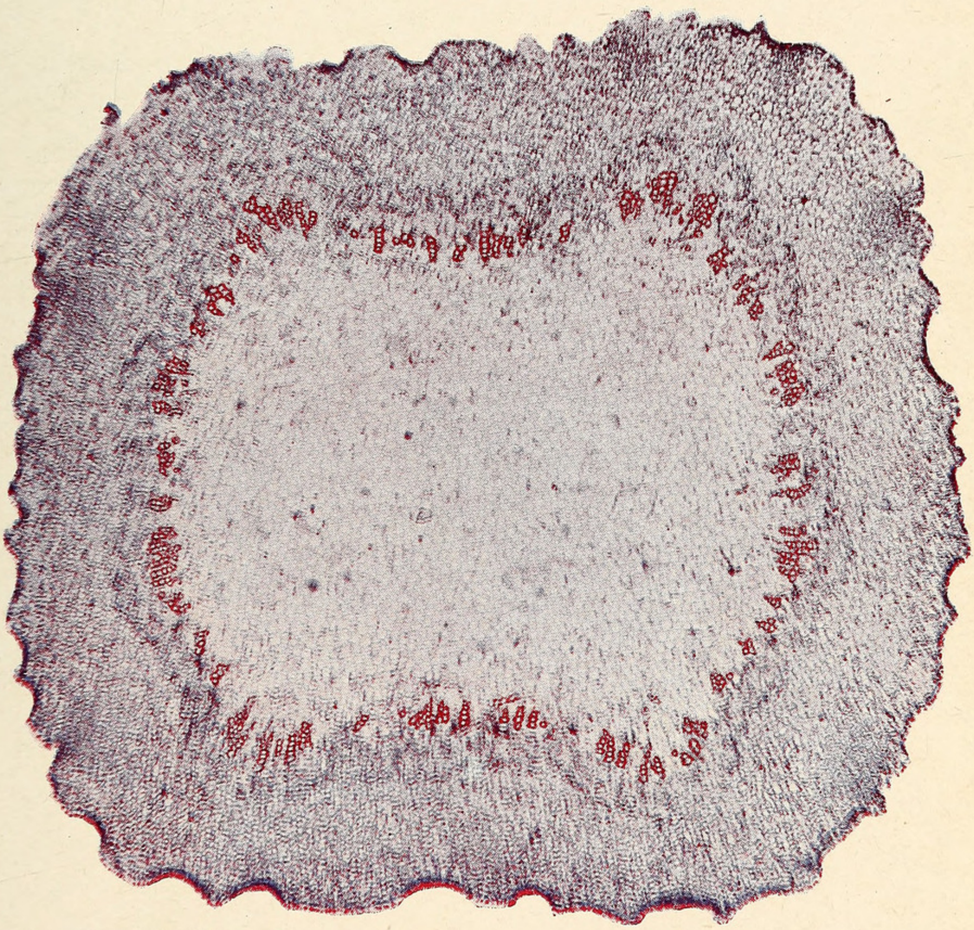


FIG. 13. TRANSVERSE SECTION OF PRIMARY GROWTH. x 30.

AVICENNIA OFFICINALIS, LINN.

T. C. Roughley, Photo.

Fig. 14.—Transverse section of later growth than Fig. 13. × 100.
Avicennia officinalis, Linn.

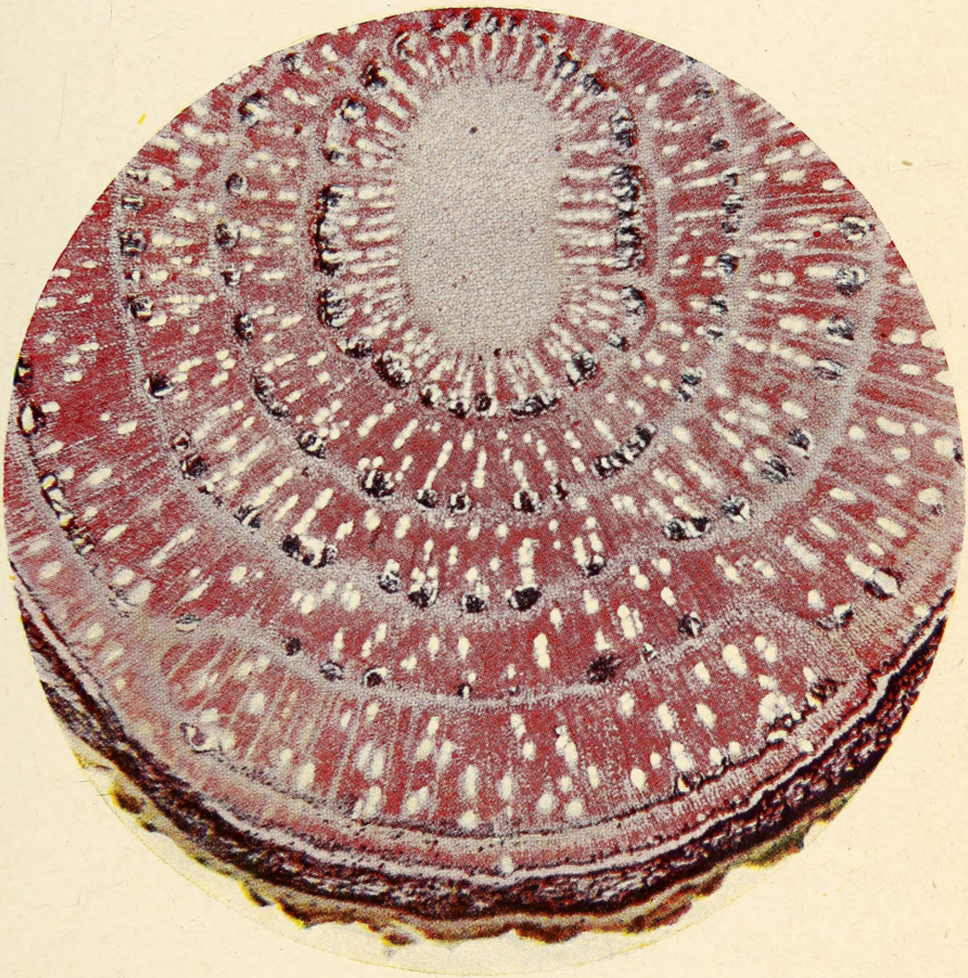
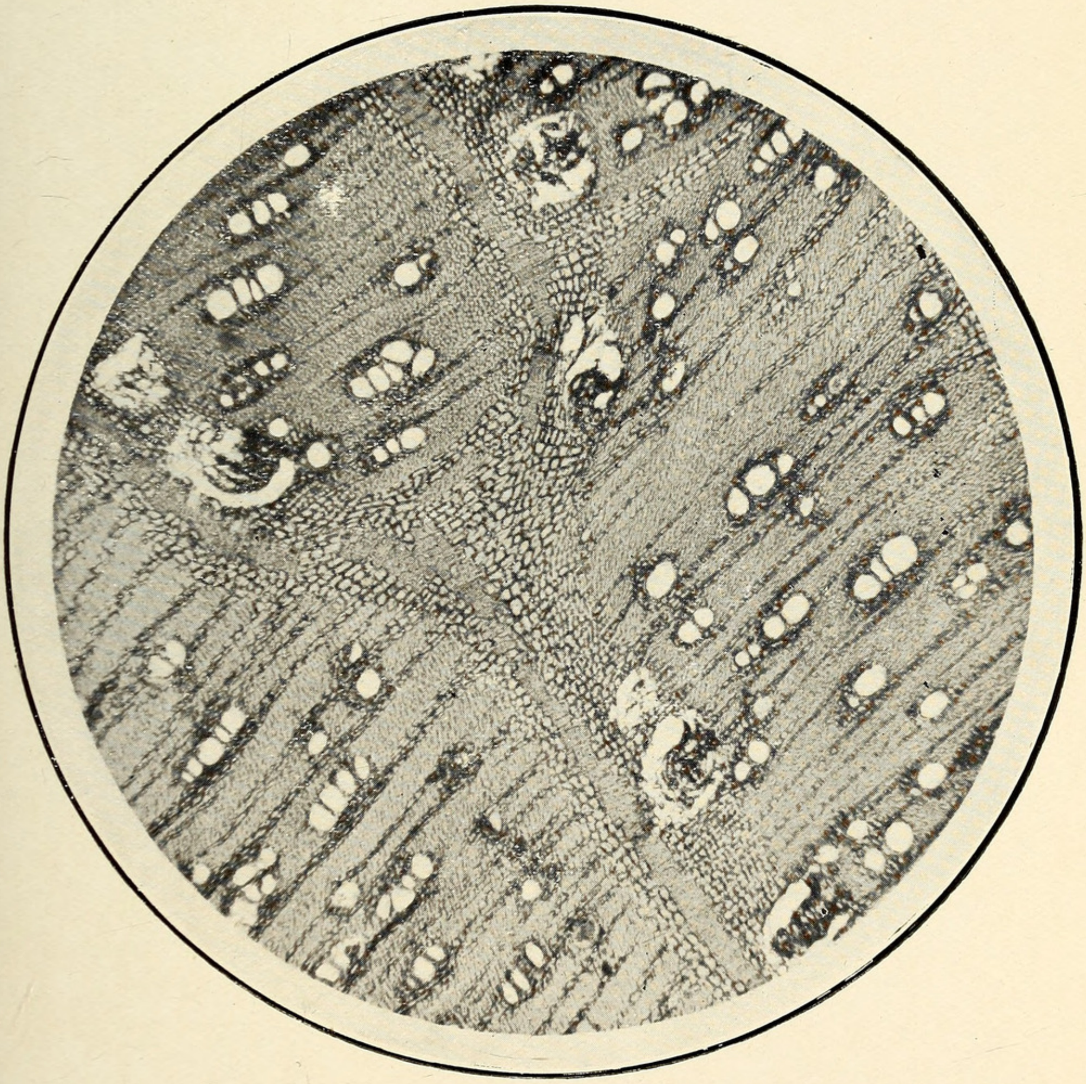


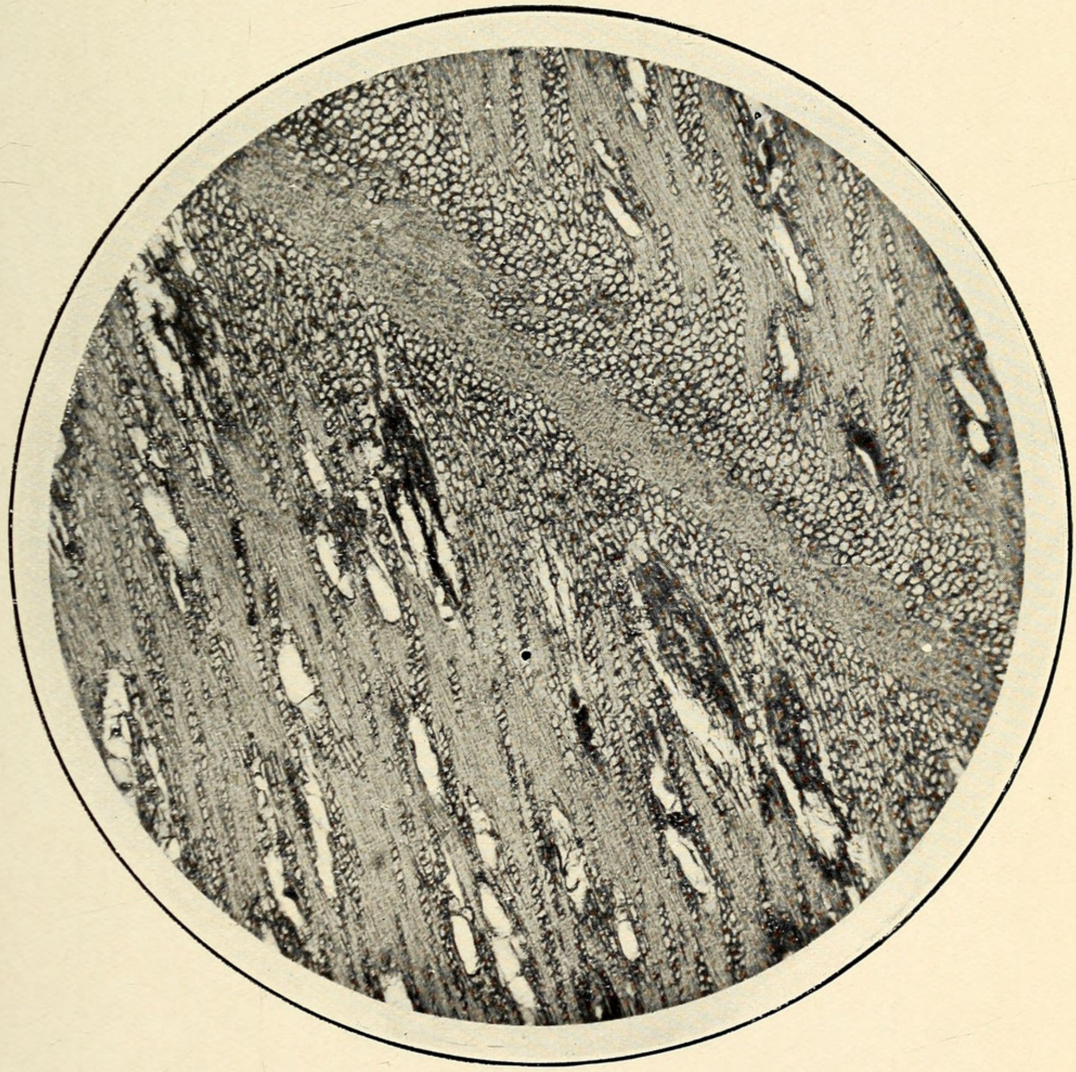
FIG 15. TRANSVERSE SECTION FROM A 6 YEARS OLD STEM. x 15.

AVICENNIA OFFICINALIS, LINN.



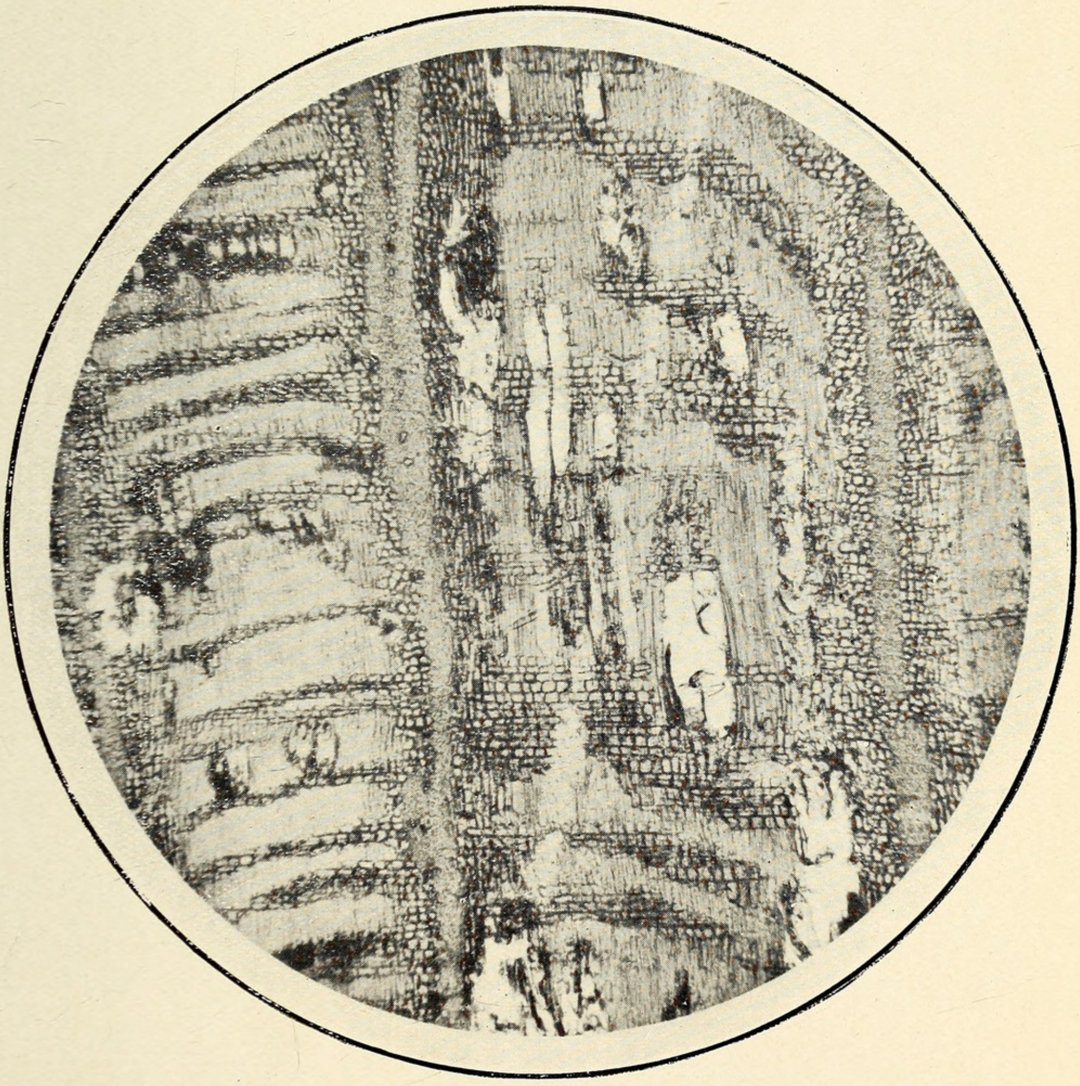
T. C. Roughley, Photo.

Fig. 16.—Transverse section of secondary wood. × 35.
Avicennia officinalis, Linn.



T. C. Roughley. Photo.

Fig. 17.—Tangential section of secondary wood. × 35.
Avicennia officinalis, Linn.



T. C. Roughley, Photo.

Fig. 18.—Radical section of secondary wood. × 35.
Avicennia officinalis, Linn.

T. Dick, Photo.

Fig. 19.—Seven year's old Grey Mangrove trees, five feet high. *Avicennia officinalis,* Linn.

T. Dick, Photo.

Fig. 20.—Grey Mangrove outspreading over exposed portion of breathing roots.
Avicennia officinalis, Linn.

overcame this defect by placing keys between them, and thus preventing a shearing upon each other when subjected to a great weight.

Explanation of Plates XXVII - XLVI.

Fig. 1. Transverse section of a portion of leaf showing central bundle, and neighbouring tissue. x 150.

,, 2. Transverse section of a portion of a leaf showing a depression on the upper surface. x 50.

,, 3. Higher magnification of Fig. 2, showing structure of depression and surrounding tissue. x 150.

,, 4. Transverse section of breathing root below mud surface. x 30.

,, 5. Longitudinal section of breathing root below mud surface. x 15.

,, 6. Transverse section near the tip of air and tide exposed portion of a pneumatophore, but cutting central root. x 30.

,, *7. Transverse section near the tip of air and tide exposed portion of a pneumatophore, but cutting central root lower down than Fig. 6. x 30.†

,, *8. Longitudinal section through tip of a pneumatophore. x 30.

,, 9. Series showing germination of seed (natural size).

,, 10. Transverse section of a trunk of a tree (reduced.)

,, 11. Transverse section of trunk of tree (enlarged from 10).

,, 12. Tangential view of split wood showing disposition of fibres.

,,*13. Transverse section of primary growth. x 30.

,, 14. Transverse section of later growth. x 100.

,,*15. Transverse section of 6 years old wood. x 15.

,, 16. Transverse section of secondary wood. x 35.

,, 17. Tangential section of secondary wood. x 35.

,, 18. Radial section of secondary wood. x 35.

,, 19. Seven years' old "Grey Mangrove" trees, 5 feet high.

,, 20. "Grey Mangrove" out-spreading over air and tide exposed portion of breathing roots.

* Coloured Plates.

† Plate XXXIII read Fig. 6 instead of Fig. 4.