XV. *Account of some Experiments on the Ascent of the Sap in Trees. In a Letter from* Thomas Andrew Knight, *Esq. to the Right Hon. Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read May 14, 1801.

MY DEAR SIR,

THE cause of the ascent of the sap in trees appearing to me not to have been satisfactorily accounted for, I have lately turned my attention to that subject; and, as some facts have come under my observation, which do not appear to have been noticed by any author that I have seen, I take the liberty to trouble you with an account of a few of the experiments that I have made; hoping that some of them may appear new and interesting to you. These experiments were made on different kinds of trees; but I shall confine myself to those made on the crab-tree, the horse-chesnut, the vine, and the oak; and shall begin with those made on the crab-tree.

Choosing several young trees of this species in my nursery, of something more than half an inch diameter, and of equal vigour, I made two circular incisions through the bark, round one half the number of them, about half an inch distant from each other, early in the spring of 1799; and I totally removed the bark between these incisions, scraping off the external coat of the wood. The other half I left in their natural state.

At the usual season, the sap rose in equal abundance in all;

and their branches shot, during the whole spring, with equal luxuriance. But that part of the stems (of the trees whose bark had been taken off) which was below my incisions, scarcely grew at all; whilst all the parts above the incisions, increased as rapidly as in the trees whose bark remained in the natural state: the upper lips of the wounds also made considerable advances towards an union; but the lower ones made scarcely any.

Soon after Midsummer, those parts of the wood which had been deprived of bark became dry and lifeless, to some depth; and the sap, in consequence, meeting obstruction in its ascent, some latent buds shot forth, in some of the plants, below the incisions When one of the shoots which these buds produced was suffered to remain, the part of the stem below it began immediately to increase in size; but, if it was at any distance below the incision above, the part between it and that incision still remained very nearly stationary, so as to be, in the autumn, almost a whole year's growth less than the stem above the incisions.

Choosing other stocks, which had each a strong lateral branch, I removed the bark, in the manner described, in two places; the one above, and the other below, each lateral branch. The sap here passed both my incisions, as freely as in the former experiment; the lateral branches between them grew with the greatest vigour; and the part of the stem between those branches and the lower incisions increased much in size. I varied these experiments in every way that occurred to me; and the result uniformly was, that those parts of the stems and branches which were above the incisions, and had a communication with the leaves, through the bark, increased rapidly; whilst those below the incisions scarcely grew at all, till a new communication with the leaves through the bark was obtained, by means of a lateral shoot, below the incisions. It now appeared to me to be probable, that the current of sap which adds the annual layer of wood to the stem, must descend through the bark, from the young branches and leaves; and to these my attention was in consequence directed.

Towards the end of the summer, when some young luxuriant shoots of my apple-trees had attained a proper degree of firmness, I made four circular incisions through the bark of each, as in the preceding instances; and I removed the bark in two places, leaving a leaf between the places where the bark was taken off. Examining them frequently during the autumn, I found that the insulated leaf acted just as the lateral branch had done; the part of the bark and stem between it and the lower incision being apparently as well fed as any other part of the tree; and it grew as much. Making similar incisions on other branches of the same age, I left similar portions of insulated bark, without a leaf between the incisions; but in those no apparent increase in the size of the wood was discoverable.

I was still unacquainted with the channel through which the sap was conveyed into the leaf; and therefore, having obtained a deeply tinged infusion, by macerating the skins of a very black grape in water, I prepared some annual shoots of the apple, and of the horse-chesnut, in the manner above mentioned; then, cutting them off a few inches below the incisions of the bark, I placed them for some hours in the coloured infusion. Making transverse sections of them afterwards, I found that the infusion had passed up the pores of the wood, beyond both my incisions, and into the insulated leaves; but it had neither coloured the bark, nor the sap between it and the wood; and the medulla was not affected, or at most was very slightly tinged at its edges.

My attention was now turned to the leaves: these, in the apple-tree, are attached to the wood by three strong fibres or tubes, (or rather bundles of tubes,) one of which enters the middle of the leaf-stalk, and the others are on each side of it. In the horse-chesnut, there are seven or eight bundles of a similar kind of tubes in each leaf: through these the infusion had passed, and had communicated its colour to them, through almost the whole length of each leaf-stalk. Examining these tubes more minutely, I found that they were surrounded with others, which were free from colour, and appeared to be conveying, in one direction or the other, a different fluid. On tracing these downwards, I discovered that they entered the inner bark, and had no immediate communication with the tubes of the wood. I now endeavoured, in the same manner, to trace back those vessels which had carried the infusions into the leaves; and I readily found them to be perfectly distinct from the common tubes of the alburnum. They commence a few inches below the leaf to which they belong; and they become more numerous as they approach it; every where surrounding the medulla in bundles, as represented in Plate XXIV. To these vessels, the spiral tubes are every where appendages. I do not know that any specific name has been given to these vessels; and therefore, as they constitute a centre, round which the future alburnum is formed in the succulent annual shoot, I will call them the central vessels, to distinguish them from the spiral tubes and the common tubes of the wood. In Plates XXV. and XXVI. the direction of these vessels, with the spiral tubes, in their passage from the sides of the medulla to the leaf-stalk, is delineated in a transverse and longitudinal section: they extend to the extremities of the leaf, where I believe they terminate. Plate XXVII. presents two sections of the leaf-stalk of the horse-chesnut; the first being taken from the middle of the stalk; and the second from its base. Lying parallel with, and surrounding the abovementioned vessels, appear other vessels, which I conclude return the sap to the tree; for, when a leaf was cut off which had imbibed a coloured infusion, I found that the native juices of the plant flowed from these vessels, apparently unaltered, as has been remarked by Dr. DARWIN. These vessels descend through the inner bark, (as delineated in Plates XXIV. XXV. and XXVI.) and appear to extend from the extremities of the leaves to the points of the roots.

The whole of the fluid, which passes from the wood to the leaf, seems to me evidently to be conveyed through a single kind of vessel; for the spiral tubes will neither carry coloured infusions, nor in the smallest degree retard the withering of the leaf, when the central vessels are divided. But the annexed figures appear to point out at least two kinds of returning vessels. And I think it by no means improbable that two kinds exist, with distinct offices; for there is a new layer of alburnum, and a new internal bark, to be formed. I have, however, seen it asserted somewhere, in the writings of LINNÆUS, and other naturalists, that the internal bark is annually converted into alburnum. But this is totally erroneous; and a vigorous shoot of the apple-tree often presents in its transverse sections, when three or four years old, as many layers in its bark, each of which once formed its internal vascular lining.

As the bark appeared to me now to receive its nutrition through the leaf, I wished to see what effect would be produced by gradually reducing the quantity of the leaves. I had a luxuriant shoot of the vine in my vinery, exactly in the stage of growth I wanted; and this branch therefore was, towards its point, every day deprived of a small portion of its leaf. The bark, in consequence, became shrivelled and dry; and at length the buds below vegetated; and the point of the shoot died, apparently for want of nourishment. I here observed, as I had frequently done before, that almost the whole action of each leaf lies between itself and the root; for the branch, in this case, was perfectly well fed below the uppermost unmutilated leaf, but failed immediately above it.

Every branch in which I had yet attempted to trace the progress of the sap having contained its medulla uninjured, the action of that substance next engaged my attention, and I made the following experiments on the vine. Having made a passage about half an inch long, and a line wide, into a strong succulent shoot of this plant, I totally extracted its medulla, as far as the orifice I had made would permit me. But the shoot grew nearly as well as the others, whose medulla had remained uninjured; and the wound soon healed. Making a similar passage, but of greater length, so that part extended above, and part below, a leaf and bud, I again extracted the medulla. The leaf and bud, with the lateral shoot annexed, (in the vine,) continued to live, and did not appear to suffer much inconvenience; but faded a little when the sun shone strongly on them.

I was now thoroughly satisfied, that the medulla was not necessary to the progression of the sap; but I wished to see whether the wood and leaf could execute their office when deprived at once of the bark and medulla. With this view, I made two circular incisions through the bark, above and below a leaf; and I took off the whole of the bark between them, except a small portion round the base of the leaf. Having then perforated the wood, where I made each of my incisions through the bark, I destroyed the medulla in each place, as in the preceding experiments. The leaf, however, continued fresh and vigorous; and a thin layer of new wood was formed round its base, as far as the bark had been suffered to remain.

Whilst I was waiting the result of the preceding experiments, I made a few efforts to discover another branch of circulation, namely, that which takes place within the fruit, and conveys nourishment to the future offspring. My experiments were here, however, confined almost entirely to two species of fruit, the apple and the pear; and, therefore, as the organization of different fruits is evidently different, I do not consider my observations such as can throw much general light on the subject. Examining the fruit-stalks of the apple, the pear, the vine, and some other fruit-trees, I found their organization to be nearly similar to that of the branch from which they sprang, and to consist of the medulla, the central tubes, a very small portion of wood, the spiral tubes and those of the bark, and the two external skins. Tracing the progress of these in the full-grown fruits of the apple and pear, I found, as LINNÆUS has described, that the medulla appeared to end in the pistilla. The central vessels diverged round the core, and, approaching each other again in the eye of the fruit, seemed to end in ten points at the base of the stamina, to which I believe they give existence. The spiral tubes, which are in all other parts appendages to these vessels, I could not trace beyond the commencement of the core; but, as the vessels themselves extend through the whole fruit, it is probable that the spiral tubes may have escaped my observation. LINNÆUS supposes the stamina to arise from the wood. I should not venture to state an opinion in opposition to his; but I believe he has not any where distinguished those I call the central vessels, from the common tubes of the wood.

Having hitherto found that all advancing fluids appeared to pass either along the tubes of the alburnum, or along the central vessels, I had little doubt that the fruit was fed through the latter; but my efforts to ascertain this, in the autumn of 1799, were not successful. In the last spring, I was more fortunate. Placing small branches of the apple, the pear, and the vine, with blossoms not yet expanded, in a decoction of logwood, I found that the colouring matter readily passed up the central tubes of the fruit-stalks of all; and, in the apple and pear, I easily traced it, through the future fruit, to the base of the stamina. The office of the tubes in the bark did not appear in this experiment; but, as I have reason to believe the motion of the sap in the bark to be always retrograde, I am disposed to conclude that it is so here, and that, through the bark of the stalk, any superfluous humours existing in the fruit, from excessive humidity of weather, or other cause, is carried back, and absorbed by the tree. I have, however, very frequently repeated an experiment on the vine, which, I think, evidently proves that the fluid returned (if any) is essentially different from that which is derived from the leaf. In the culture of this fruit, I have frequently pinched off the young shoot, immediately above a bunch, as soon as the latter became visible in the spring, letting the leaf opposite the bunch remain. In this case, the wood below the upper leaf acquired nearly its proper length and substance. But, when I have taken off that leaf, the wood between the bunch and the next leaf below, has ceased to elongate; and has remained, in form and substance, similar to the small fruit-stalk attached to it.

I was long at a loss to conjecture by what means nutrition was conveyed to the seeds of the apple and pear; for I had reason to believe that it was not done by the medulla; and I had previously ascertained that the seeds would derive nourishment from the pulp, when the fruit was taken prematurely from the tree. At length, in a large apple, which was just beginning to decay, I found a number of minute vessels, leading from the pulp to the tubes which originally constituted the lower parts of the pistilla, and to which the seeds are attached. These now appeared to me evidently to be the channels of nutrition to the seeds; and, since I have known what I have to look for, I find these vessels sufficiently visible in every apple: there are, however, five other tubes, which pass along the external edges of the cells of the core, to which I do not venture to assign an office. It appears to me not very improbable, that the internal organization of this fruit will be found to bear some resemblance to the placenta and umbilical cord of the animal economy. If transverse and longitudinal sections of young apples and pears be made, soon after the blossom has fallen, the pulp will appear to be of two kinds; one of which is included within the vessels which carry up coloured infusions; and this seems to be formed by continuation of the vessels and fibres within the wood. The other part appears to belong, in a great measure, to the bark: it is in very small quantity in the very young fruit; but, at its maturity, it constitutes much the greater part of the pulp. The vessels, however, which diverge into the external pulp, and probably convey nourishment to it, appear to be continuations of the central vessels, every where, I believe, accompanied, as in the leaf, with minute ramifications of the tubes of the bark. The substance of the core is similar to that of the silver grain of the wood, of which it may possibly be a continuation.

The force with which the sap has been proved to ascend, by HALES, banishes every idea of mere capillary attraction. The action of the spiral tubes appears much more adequate to the effects produced; and I readily admit the supposed action of these, wherever they are found; but I have so often attentively searched in vain for them, with glasses of different powers, in the root, in the alburnum, and in the bark, that I cannot but question their existence in those parts. Attached to the central vessels, in the annual shoot, in the fruit-stalk of different trees, in the tendril of the vine, in the leaf, and in the seed, the spiral tubes certainly exist, and are in most cases visible, without the aid of a lens. But, as I have not been able to discover them in other parts of the tree, and as the different authors I have looked into have not distinguished those I call the central vessels from the common tubes of the alburnum, nor marked the difference in the organization of the annual branch, and annual root, I must venture to call their accuracy here in question, though with great deference for their opinions.

LINNÆUS and others have attempted to account for the ascent of the sap, by the expansion of the fluids within the vessels of the plant, by the agency of heat. But the sap rises under a decreasing, as well as under an increasing temperature, during the evening and night, (if it be not excessively cold) as well as in the morning and at noon; and it is sufficiently evident, that the heat applied to the branches of a vine within the stove, cannot expand the fluids in the stems and roots, which grow on the outside. It is also well known, that the degree of heat required to put the sap into motion, in this plant, is not definite, but depends on that to which the plant has been previously accustomed. Thus, a vine which has grown all the summer in the heat of a stove, will not be made to vegetate during the winter by the heat of that stove: but, if another plant of the same variety, which has grown in the open air, be at any time introduced, after it has dropped its leaves in the autumn, it will instantly vegetate. This effect appears to me to arise from the latter plant's possessing a degree of irritability, which has been exhausted in the former, by the heat of the stove, but which it will acquire again during the winter, or by being drawn out, and exposed for a short time to the autumnal frost. On the same principle, we may point out the cause why seedling plants always thrive better in the spring than in the autumn, though the weather be apparently less favourable. In the former season, the stimulus of heat and light is gradually becoming greater than that to which the plant has been accustomed; in the latter season, it becomes gradually less.

There is another circumstance attending trees that have been made to blossom early in the preceding spring, which has always appeared to me an extremely interesting one. If a peach-tree, for example, be brought into blossom in one season in the beginning of February, by artificial heat, it will spontaneously shew strong marks of vegetation at the approach of that season in the succeeding year; and, if it be not well protected, it will expose its blossoms to almost inevitable destruction. I do not see any cause to which this effect can be attributed, except to the accumulated irritability of the plant.

That heat is the remote cause of the ascent of the sap, cannot I think be doubted; and perhaps frequent variations of it are, in some degree, requisite; (for plants have always appeared to me to thrive best with moderate variations of temperature;) but the immediate cause will, I think, be found in an intrinsic power of producing motion, inherent in vegetable life; and I hope to be able to point out an agent, by which the mechanical force required may possibly be given.

There is, you know, in every kind of wood, what workmen call its grain, consisting of two kinds, the false or bastard, and the true or silver grain. The former consists of those concentric circles which mark the annual increase of the tree; and the latter is composed of thin laminæ, diverging in every direction from the medulla to the bark, having little adhesion to each other at any time, and less during the spring and summer, than in the autumn and winter; whence the greater brittleness of wood in the former seasons. These laminæ (which are of different width in different kinds of wood) lie between, and press on, the sap-vessels of the alburnum: they are visible in every wood that I have had an opportunity to examine, except some of the palm tribe; and these appear to me to have peculiar organs, to answer a similar purpose. If you will examine a piece of oak, you will find the laminæ I describe; and that every tube is touched by them at short distances, and slightly diverted from its course. If these are expansible under changes of temperature, or from any cause arising from the powers of vegetable life, I conceive that they are as well placed as is possible, to propel the sap to the extremities of the branches; and their restless temper, after the tree has ceased to live, inclines me to believe, that they are not made to be idle whilst it continues alive.

I shall at present confine my observations to the English oak, though the same are applicable, in a greater or less degree, to every other kind of wood. In sawing this tree into boards, it is usual to cut it, as much as possible, into what are called quarter boards; which are so named because the tree is first cut into quarters. In a perfect board of this kind, the saw exactly follows the direction in which the tree most readily divides when cloven: in this case, the laminæ of the silver grain lie parallel with the surface of the board; and a board thus cut, when properly laid in the floor, is rarely or never seen to deviate from its true horizontal position. If, on the contrary, one be sawed across the silver grain, it will, during many years, be incapable of bearing changes of temperature, and of moisture, without being warped; nor will the strength of numerous nails be sufficient entirely to prevent the inconvenience thence arising. That surface, of a board of this kind, which grew nearest the centre of the tree, will always shew a tendency to become convex, and the opposite one concave, if placed in a situation where both sides are equally exposed to heat and moisture. You may probably have observed, that when an oak has been deprived of its bark, and exposed to the sun and air, its surface has been every where covered with small clefts. These are always formed by the laminæ of the silver grain having parted from each other; and they will long continue to open and close again with the changes of the weather. In the last summer, I very frequently placed pieces of oak, recently deprived of its bark, in a situation where it was fully exposed to the sun, but defended from rain. The surface of the tree, in a few hours, presented a great number of small clefts, into which I put, in the middle of the day, the points of small iron pins. Examining these late in the evening, I found that the wood closed so much as to hold them firmly; and, early in the next morning, they were not easily withdrawn; but, as the influence of the sun increased, the clefts again gradually opened, as in the preceding day, and the pins always dropped out. I could never discover that any weight was gained by the wood during the night; but I was not provided with a balance of proper sensibility to ascertain this point. This experiment was frequently repeated, and always with precisely the same result. After long exposure to the air and light, the wood loses this property.

If the motion I have supposed the silver grain to possess, in the living tree, be more than you think can properly be admitted to belong to vegetable life, I will request your attention to the power of moving in the vine-leaf, on which I have made many experiments. It is well known that this organ always places itself so that the light falls on its upper surface; and that, if moved from that position, it will immediately endeavour to regain it; but, the extent of the efforts it will make, I have not any where seen noticed. I have very frequently placed the leaf of a vine in such a position, that the sun has shone strongly on its under surface; and I have afterwards put obstacles in its way, on whichever side it attempted to escape. In this position, the leaf has tried almost every method possible to turn its proper surface to the light; and I have several times seen one which, having tried during several days to approach the light in one direction, and having nearly covered its under surface, by bending its angular points almost to touch each other, has unfolded itself again, and receded farther from the glass, to approach the light in an opposite direction. As the whole effect here produced appears to arise merely from the light falling on the under surface of the leaf, I cannot conceive how the contortions of its stalk, in every direction, can be accounted for, without admitting, not only that the plant possesses an intrinsic power of moving, but that it also possesses some vehicle of irritation; and, without this, it will I think be difficult to explain how the heat applied to the branch of the vine, within the stove, can put the sap in the roots and external stem into motion. It may be objected, that these are always ready, when the branch calls for nourishment; and that they are no way affected by the internal heat. But this I cannot admit to be the case; because I have found that the stem suddenly becomes extremely susceptible of injury from cold, as soon as the branch begins to vegetate; and that its whole powers will be paralyzed for some days, by exposure for a few hours to a freezing temperature.

I have had very frequent opportunities of observing a remarkable power in trees, of transferring their sap from one tube to another; for I have often intersected, in the trunk, every tube which led to a lateral branch, and still this branch has derived a considerable portion of nourishment from the trunk. And, if the tubes of an annual shoot of the oak be traced downwards in the autumn, they will be found to pass along the layer of wood of the preceding summer, without any apparent communication between them and the tubes of any former year's growth. Yet the sap rises through the whole of the white wood; and it must be transferred from the internal tubes to those near the surface, which alone appear to communicate with the central tubes of the young shoots and leaves. Indeed we have frequent evidence that trees possess this power; for we see that the whole sap of the stock is carried into an inserted bud or graft.

I at one time suspected, that a small portion of sap, in its descent from the leaves, had been carried down by the wood, through my incisions, in the preceding experiments on the crab-tree; because I observed a very small increase in size, in the lower part of the stocks; which, I think, could not have taken place without some matter derived from the leaves. But subsequent observation induces me to believe, that the small quantity of additional matter found in the lower part of the stock came from a different source. In those experiments, I paid little attention to any small shoots which sprang from the trunk at some distance below the incisions; and the buds which usually began to vegetate about Midsummer, were not always rubbed off, till some minute leaves appeared. Through these, I now believe that a small quantity of sap was thrown into the bark, and carried up through its tubes, by capillary attraction, when the current from above was intercepted. For the increase of size in the stock always diminished, as it ascended towards the incision; which, I think, would not have been the case, had it been produced by nourishment descending from the upper parts of the tree.

Nothing has occurred, in the preceding experiments, to throw much light on the office of the medulla, to which LINNÆUS and subsequent writers have annexed so much importance; but I will now endeavour to point out one of its offices. In the young and succulent shoot, this substance is extremely full of moisture; and, as there is an immediate communication between it and the leaf, through the central tubes, I conclude it forms a reservoir, to supply the leaf with moisture, whenever an excess of perspiration puts that in a state to require it. Some reservoir of this kind appears to me to be necessary to plants; for their young leaves are excessively tender, and they perspire much, and cannot, like animals, fly to the shade and the brook. In the mature annual branches, and in those of more than one year old, the medulla is dry, and, I think, it is evidently lifeless; but the space it occupies is never filled with wood, as some naturalists have imagined.

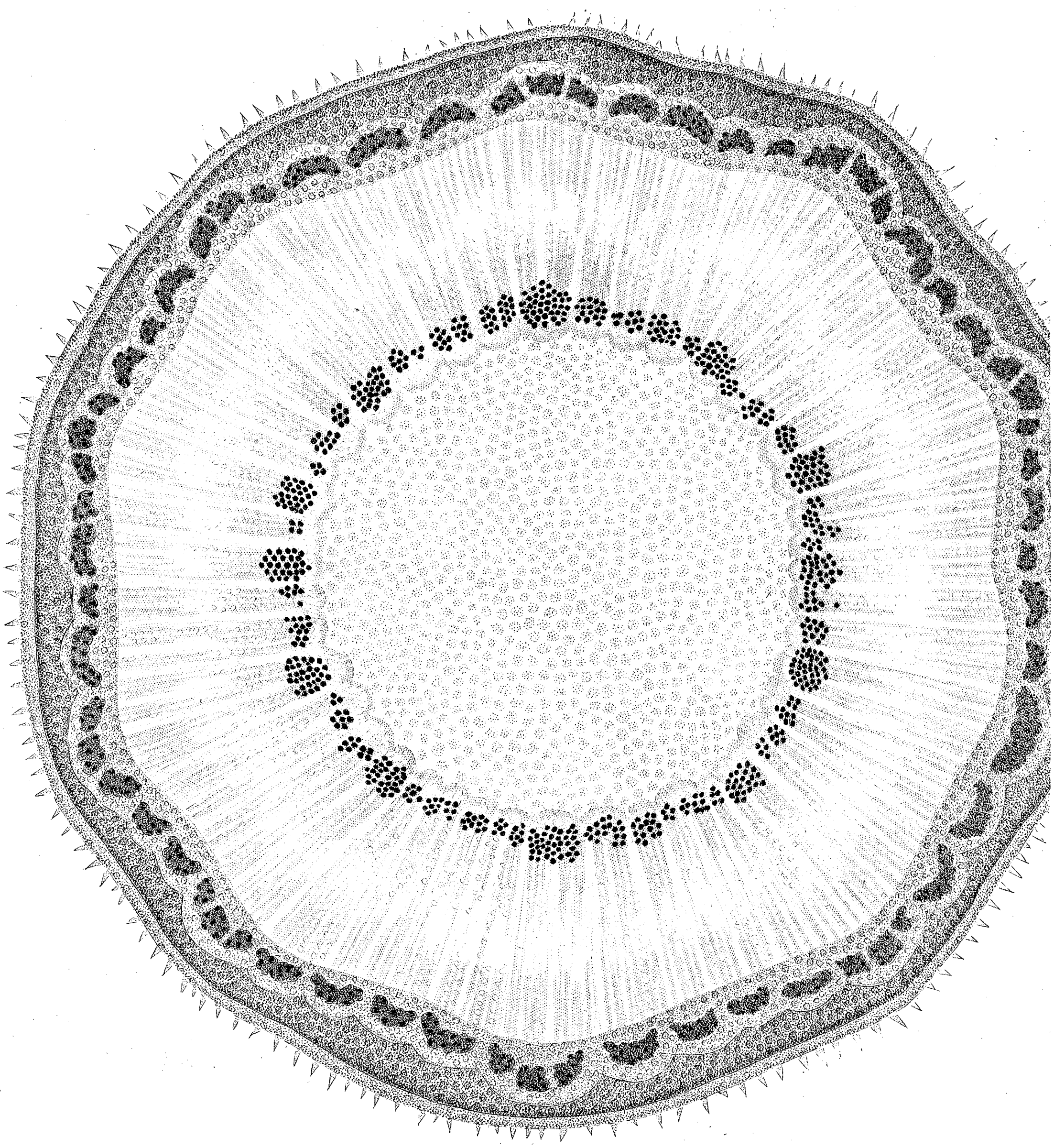
The heart or coloured wood, distinguished from the alburnum, seems to execute an office somewhat similar to the bone in the animal economy. The rigid texture of the vegetable fibre, has rendered this substance unnecessary in the young subject; but, as the powers of destruction, both from winds and gravity, increase in a compound ratio with the growth of the tree, some stronger substance than the alburnum may be supposed to be wanting, to support the additional weight of fruit and seeds. In the root, this substance cannot be wanted, and there it is not found; but, if the mould be taken away from the roots round the trunk, so that they are exposed to the air, and made to support the weight of the tree, they become as full of coloured wood as the trunk and large branches. Having cut through the alburnum of an oak all round, not the slightest mark of vegetation appeared in the succeeding spring; and, having been unable to impel either air or water through its tubes, I conclude that the coloured wood of the oak is without circulation: I see very little reason, however, to admit that it is without life, in a young or middle aged tree. The new matter which enters into the internal part of the alburnum, on its conversion into heart or coloured wood, seems to be of a nature different from the alburnum itself; for it not only changes its colour, which is nearly white, to a dark brown, but it renders it at least ten times more durable. Some portion of this increased durability may, perhaps, be attributable to the superior solidity of the coloured wood; but, a little attention to the common kinds of English timber, (omitting the resinous tribe,) will convince us that these qualities, though frequently found together, have very little connection with each other. If a number of oaks of the same age be examined, it will be found that, in some individuals, the alburnum consists of a greater number of annual layers than in others, and that the coloured wood will have approached nearer the bark on one side than on the other, in the same tree; the termination also of the coloured wood, and the commencement of the alburnum, are often found in the middle of an annual layer of wood; and each substance, at the points of contact, possesses all its characteristic properties. The alburnum, I think, evidently extends itself laterally, without any radicles descending from the leaves or buds above. I have often procured an union, by grafting, between trees of different kinds, and have sometimes found mere varieties of the same species of tree, whose wood was sufficiently distinguishable, in every stage of future growth, to allow me readily to trace their line of union. The wood of the graft, does not at all descend below its original place of junction with that of the stock; which, immediately below, wholly retains its native character; and, in the part where both are spliced together, each constantly extends itself in the direction of the divergent laminæ of its silver grain. The heart-wood also appears to increase by lateral extension; but I am ignorant of the channels through which the additional matter is conveyed to it.

I will now take the liberty to trespass on your patience, by stating a few of the conclusions that I have ventured to draw from the foregoing, and many similar experiments. As I have not been able to find the spiral tubes any where, except immediately surrounding the medulla in different parts, in the seed, and in the leaf, and as they every where terminate at short distances, I conclude that the sap is not raised by their agency; nor by the central vessels, to which they are appendages; for these extend no greater length downwards than the spiral tubes, and terminate with them, at the external surface of that annual layer of wood to which they belong; and they have not any apparent communication with the similar vessels of the succeeding year. In the lower parts of hollow trees, they must long have ceased to exist at all; and, in all trees, except very young ones, they are (as it were) ossified within the heart-wood; and those in the annual shoots and buds are often a hundred and fifty feet distant from the roots, from which they are supposed to raise the sap.

The common tubes of the alburnum, (which do not appear to me to have been properly distinguished from the central vessels, by the authors that I have read,) extend from the points of the annual shoots to the extremities of the roots; and up these tubes the sap most certainly ascends, impelled, I believe, by the agency of the silver grain. At the base of the buds, and in the soft and succulent part of the annual shoot, the alburnum, with the silver grain, ceases to act, and to exist; and here, I believe, commences the action of the central vessels, with their appendages, the spiral tubes. By these, the sap is carried into the leaves, and exposed to the air and light; and here it seems to acquire (by what means I shall not attempt to decide) the power to generate the various inflammable substances that are found in the plant. It appears to be then brought back again, through the vessels of the leaf stalk, to the bark, and by that to be conveyed to every part of the tree, to add new matter, and to compose its various organs for the succeeding season. When I have intentionally shaded the leaves, I have found that the quantity of alburnum deposited has been extremely small.

In speaking of the circulation within the apple and pear, I wish to express myself with much less decision, as I have not seen the effects of taking up any of those vessels into which the coloured infusions did not enter. The internal organization of the leaf, and of the wood, of those trees which have a central medulla, seems to admit but of little variation, and (as far as I have had opportunities to examine) of no essential difference; whilst that of different fruits is extremely various. The external vascular parts of the apple and pear, abstracted from those which seem to carry nourishment to the seeds, appear to me to resemble, in some respects, those of the leaf; and, relative to the offspring, I suspect that they perform a somewhat similar office.

I do not know how much you will have found in the preceding narrative, that is new and interesting to you, for I am not very deeply read in the experiments which naturalists have made on plants. In the authors I have looked into, I have seen many contradictory experiments related, and many conclusions drawn from a small number of facts; and I have found much that does not well agree with the things that have come under my own observation. I will therefore venture to indulge the hope, that you will have found enough that is new, to



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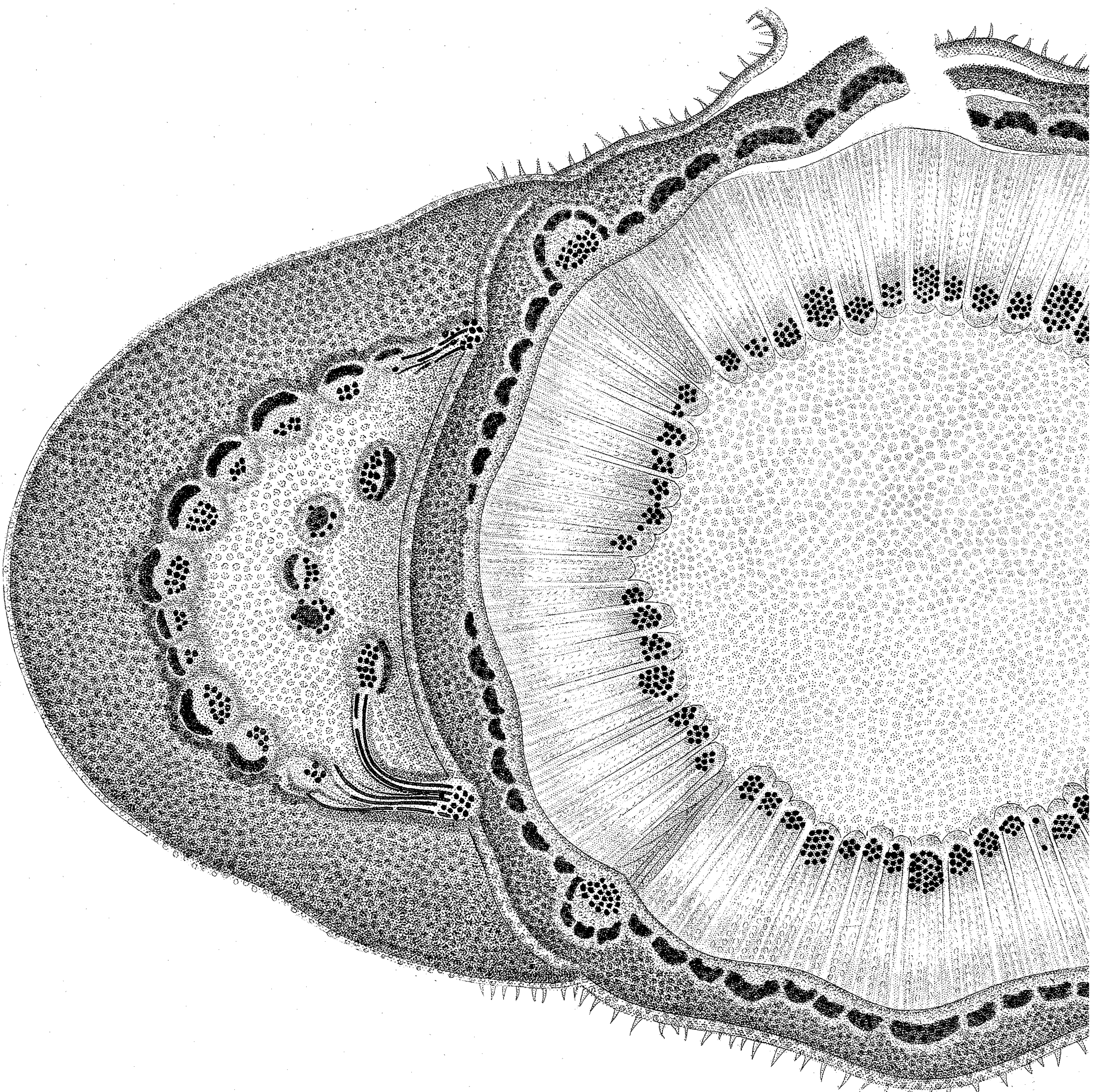

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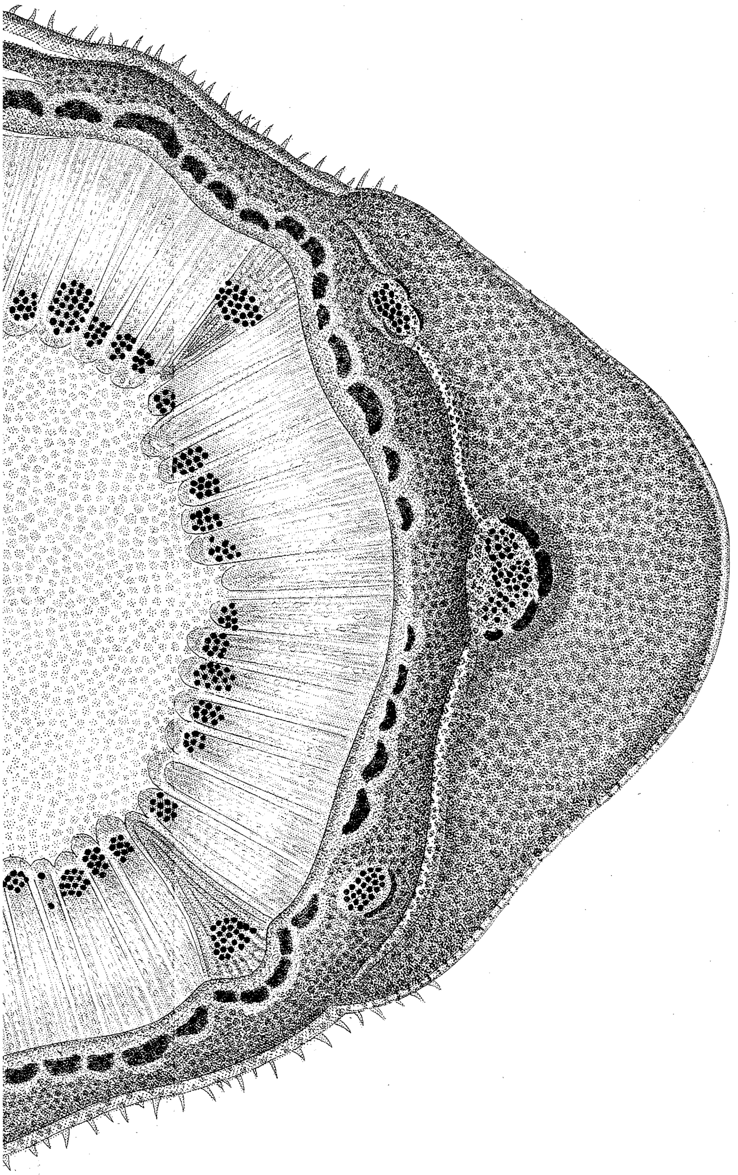

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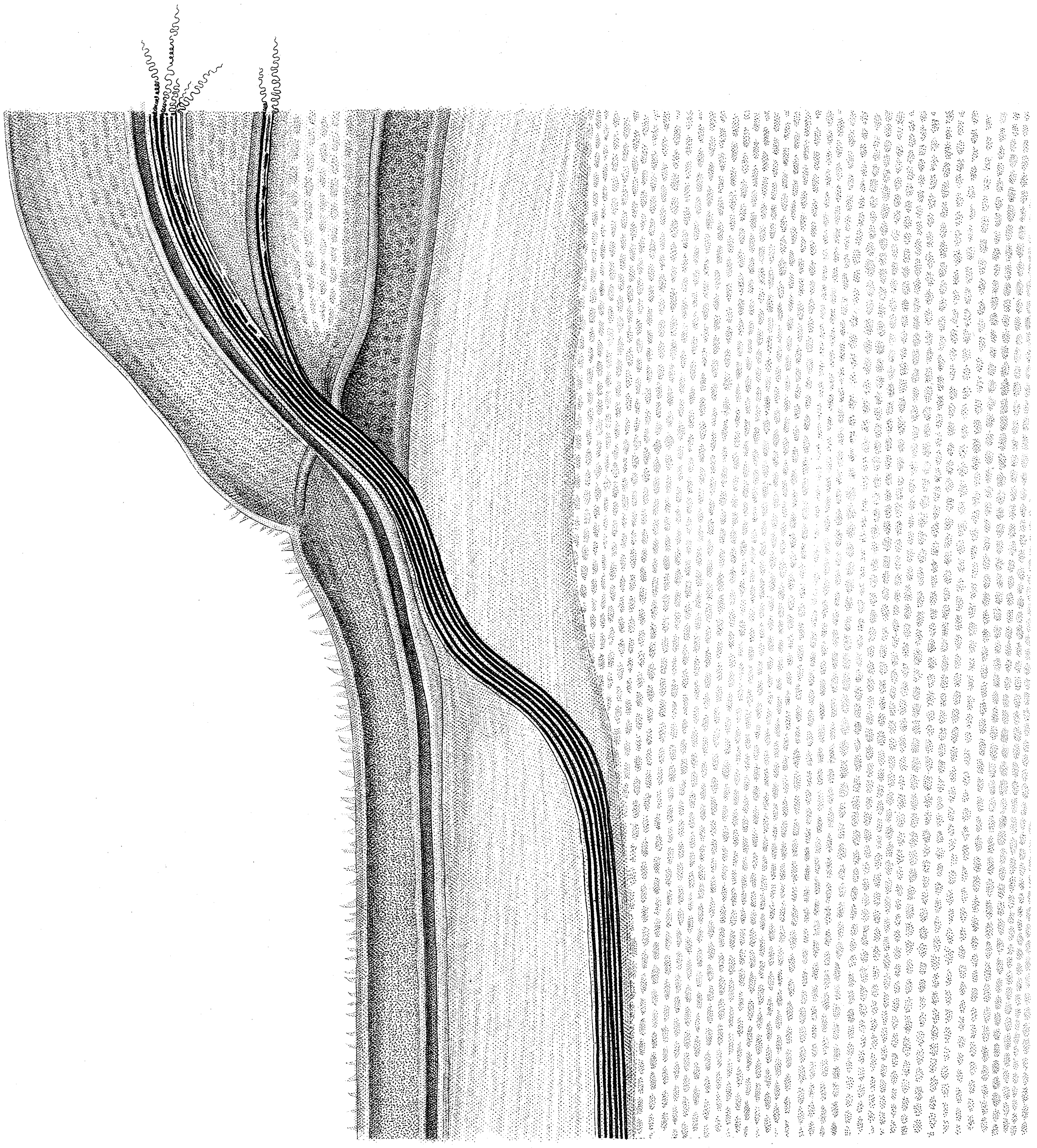


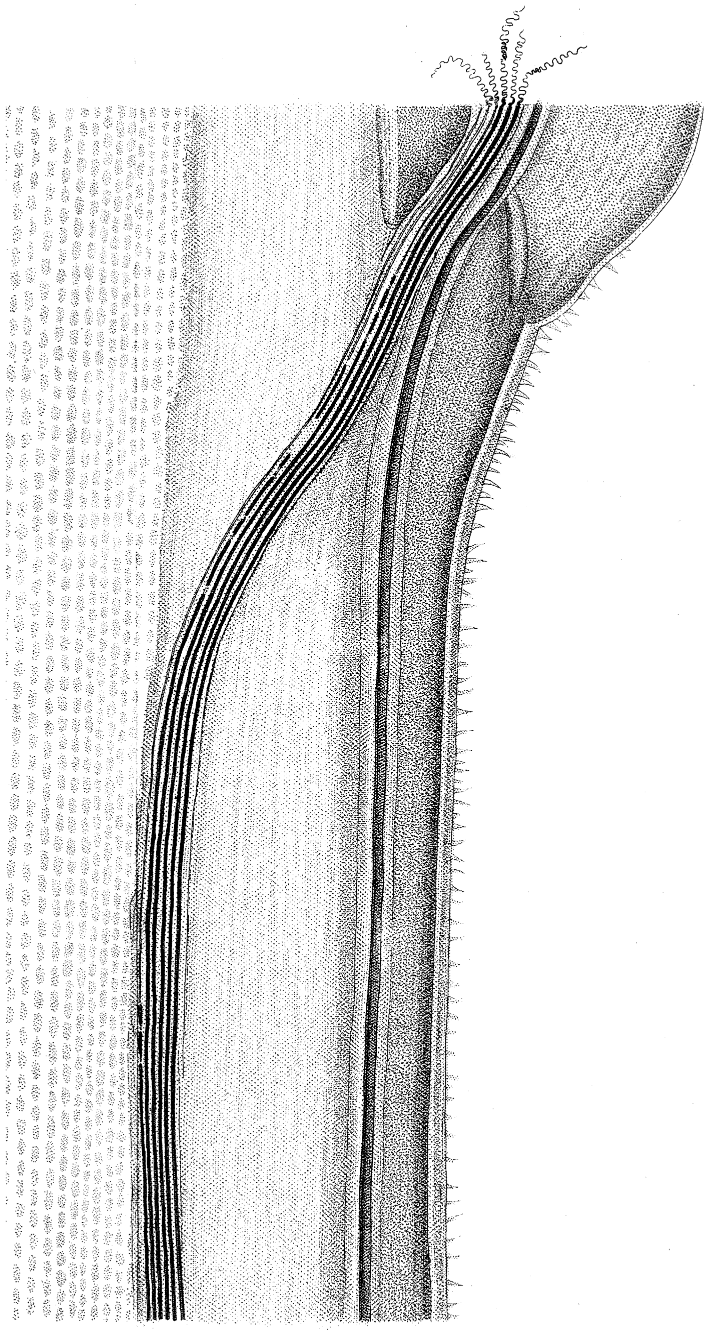


Fig. 1.

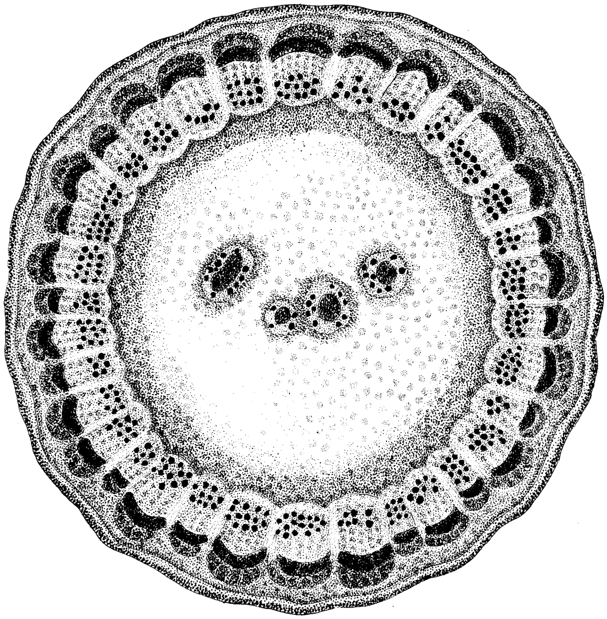
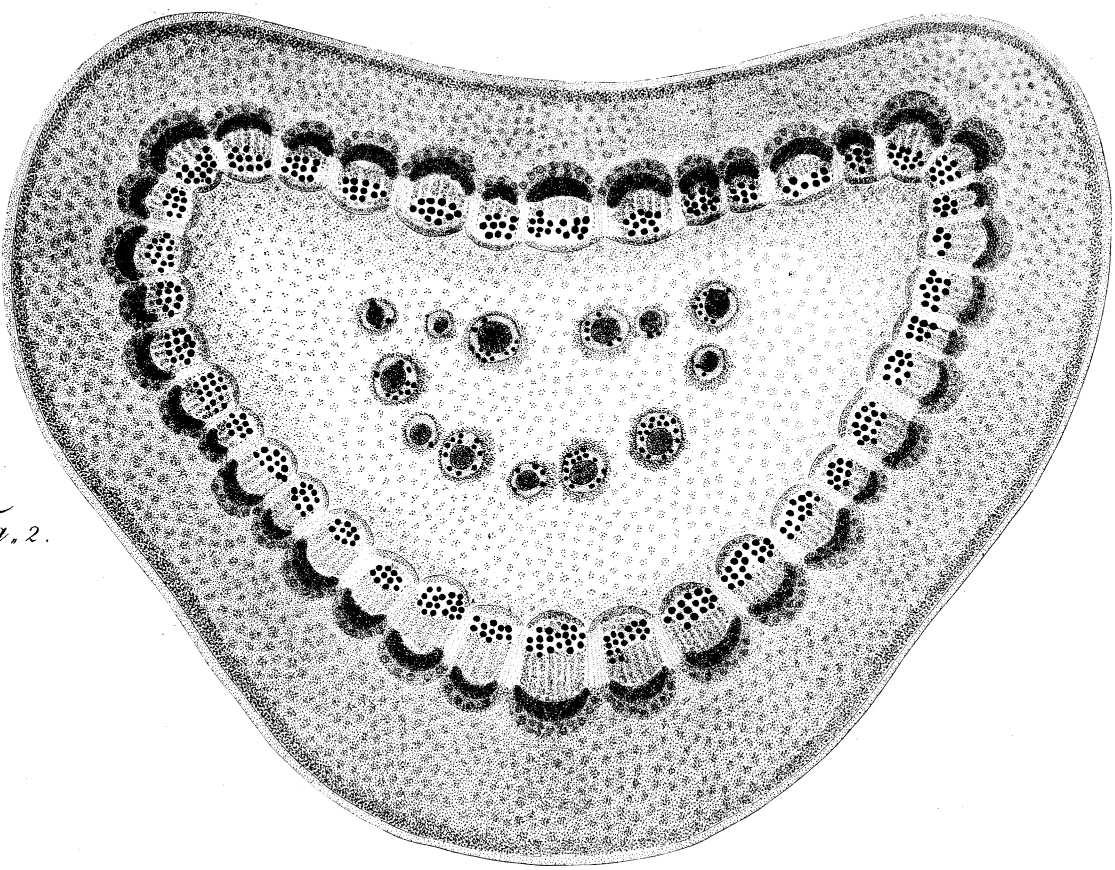


Fig. 2.

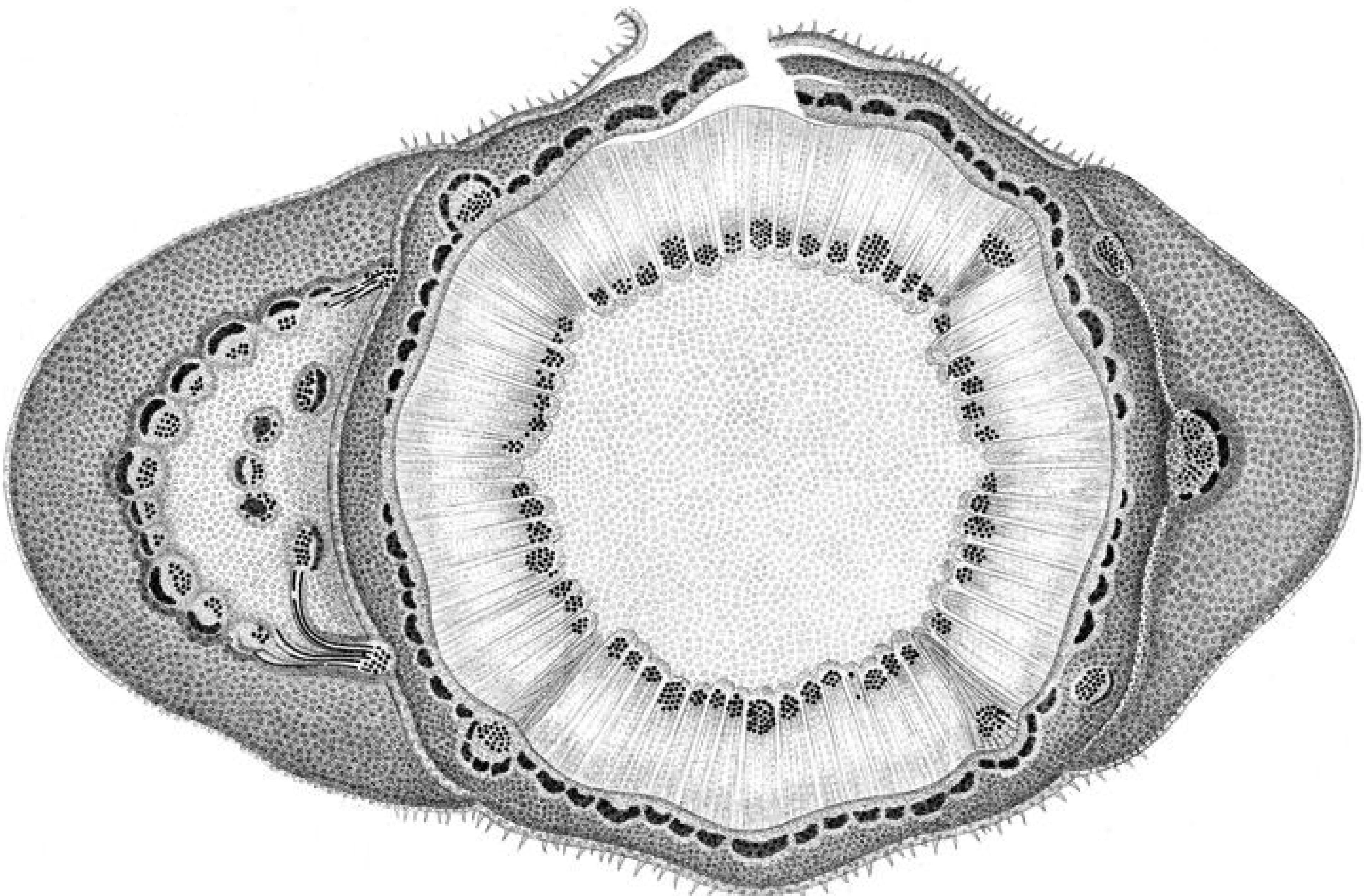


serve as an apology for me, for having taken up so much of your time.

I have the honour to be, &c.

T. A. KNIGHT.

Elton, Feb. 22, 1801.



F. Bauer del. Basire sc.