The Apical Cell of Fucus[1].

BY

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With Plate X.

I WAS induced to undertake the work, the results of which are embodied in this paper, by the state of confusion that exists in our present knowledge of the apical growth of the Fucaceae. My work was more especially stimulated by the disparity between the results arrived at by Reinke and by Rostafinski, two investigators to whom is due much of the information that we have upon the so-called apical cells of *Fucus*.

Reinke[2], whose results are based upon the study of *Fucus vesiculosus*, holds that the growing-point of *Fucus vesiculosus* consists of a group of cells uniform in structure, but that one of them is characterized by being larger than the others of the group. The protoplasm of the whole group of cells is denser than that of the other cells, and their walls are thinner. Dichotomy, or branching of the stem, according to Reinke, results from a more active growth at the edge of the growing cells; that is, cell-proliferation is more energetic at two points on the edge of the group, the points being opposite to each other in the direction of the elongated depression at the tip.

[1] The investigations of which the following pages are a record were carried on under the direction of Dr. W. G. Farlow, at the Cryptogamic Laboratory of the Museum of Harvard University, Cambridge, Massachusetts, U.S.A.

[2] J. Reinke, Beiträge zur Kenntniss der Tange, in Pringsheim's Jahrb. für Wiss. Botanik, x. (1876), p. 341. In the notes to this paper a bibliography of the older works on the subject under consideration is given.

[Annals of Botany, Vol. I. Nos. III and IV. February 1888.]

Rostafinski[1] also studied *Fucus vesiculosus*, and his results are the following. The vegetative point consists of a row of cells, 'Bildungszellen,' each of which has the form of a four-sided pyramid truncated at both ends. The sides of the pyramidal cells are slightly convex, and all of them are essentially of the same size, and are of equal value. The row of 'Bildungszellen' lies at the bottom of the terminal depression or pit, and is in the long axis of the same. The number of the cells varies according to age. By division in three directions these cells give rise to segments, which by secondary division are transformed into the different tissues of the plant. The segments are cut off alternately from the sides and base of the pyramidal cells.

Rostafinski holds that bifurcation of the tip takes place when the central cells of the row of 'Bildungszellen' divide into segments, and ceasing to be 'Bildungszellen' by division and proliferation, force aside the two ends of the now divided row, each end becoming a secondary row, and hence a separate growing-point.

From the above it is seen that the results of Reinke and Rostafinski are decidedly at variance. The two views agree in that the growing-point of *Fucus* consists not of a single cell, but of a group of cells. This is not in accordance with what is known of some other members of the group as shown by Kny and Valliante.

Our New England coast offers a favourable field for the study of the genus *Fucus*, from the variety of the species, and their great abundance. Most of my work was done upon *Fucus furcatus*, Ag., for the reason that my material of that species was better than any I obtained of other species. The results obtained from *F. furcatus* were confirmed by sections of *F. vesiculosus*, L., and *F. filiformis*, Gmelin.

The method used in the preparation of the material was the following. The fresh material was preserved in alcohol of about 70 per cent., and, after staining in various aniline dyes,

[1] J. Rostafinski, Beiträge zur Kenntniss der Tange. Leipzig, 1876.

was imbedded in paraffin and sectioned in ribbons on a Jung microtome, then mounted in balsam. By the ribbon method of sectioning every section was preserved, and in its proper order, a most desirable thing for the object in view.

Fucus furcatus, Ag.

Fucus furcatus is one of the commonest of the Fucaceae found on the New England coast north of Cape Cod; it occurs from Massachusetts Bay to Greenland. The material that I studied was collected at Nahant, in the month of February. The ultimate divisions of the frond of *F. furcatus* are more narrow than in other related species, and the midrib is much more prominent. It is characterized by the absence of vesicles or air-bladders, the great length of the receptacles, and the very regular dichotomous branching. It is found in the water at about low-water-mark, and does not occur so high up as *F. vesiculosus*.

The ends or tips of the divisions of the frond may be of two kinds. First the tips may be truncated or flattened with a depression in the centre, the depression being elongated or slit-like, the long axis of the slit being parallel to the broad surface of the frond. In other cases this terminal depression may be wanting, and in such cases the tip is conical and tapers off to a point. In the present connection I shall consider only such tips as have the depression, for the characteristic features to be described in this paper were found upon such.

If we section a tip of *F. furcatus* longitudinally, in a plane at right angles to the terminal depression, we get a state of things as shown in Fig. 1. At the bottom of the pit, which here appears as a cleft, is a large cell, appearing triangular in section, with slightly convex sides and the more acute angle directed upwards, Fig. 1, A. Immediately adjoining the large cell (in this case to the left) is another cell, smaller in diameter than the first, but equal to it in height, A'. A similar cell, but smaller still, is seen to the right, A''. Adjoining the two last-named cells there are on either side

other similar cells, and then a series of long cells. For a certain distance these diminish until they become of about a constant size, and are continuous with the epidermal cells, which dip down into the depression and together with all the cells above mentioned line the cleft, radiating as it were from the large triangular cell first spoken of.

At the bases of the large central cell and the other lateral cells are many smaller ones, somewhat irregular in shape, forming a compact mass. Lower down they are more loosely arranged, and form filaments which are the upper ends of the hyphae composing the central tissue of the stem. A number of sections parallel to this present much the same appearance, the triangular cell perhaps becoming a little smaller.

If a section be now made at right angles to the last, that is a longitudinal section in the direction of the elongated terminal depressions, and parallel to the broad surface of the frond, Fig. 2 will represent what is seen. In such a section the outline of the cavity will not have the steep sides, as in the first, but will be as a shallow depression. At the deepest part of the hollow is seen a cell (A) with convex sides and larger than any of the surrounding cells. This cell is quadrilateral, the longer axis being up and down. The general shape is oblong, the base being somewhat broader than the upper or free end. It does not differ greatly in size from the cells on either side of it, and its most prominent feature is the convexity of both the sides, while the lateral cells are convex on one side only, that being the side farthest from the central cell. The lateral cells here also form a series on either side of the central cell, growing smaller as they become more distant, and eventually merge into the epidermis. Here again, as in the last section, there is seen a compact mass of small cells about the bases of the larger ones, running into the medullary hyphae of the stem.

The central cell A in Fig. 2 is the central A in Fig. 1. The relations to the cells surrounding it are the same, the differences of appearances in form being due to the difference

in the plane of the section. As in Fig. 1, parallel sections show a similar appearance; and, assuming the sections to be of a given thickness in both cases, the characters of A in Fig. 2 are not manifest in so many sections as they are in Fig. 1.

A section made across the tip on a plane just below the bottom of the depression is shown in Fig. 3. Here is seen a series of large cells (in this case seven) A, A′, A″, etc., the central one A being more prominent than the others of the series. The cells in the middle of the series have a quadrilateral shape, particularly A. A in this section is the cell A of Figs. 1 and 2, and is seen in cross section. A does not stand out here so prominently from the lateral cells, because A′, A″, etc. are cut obliquely because they are inclined to A and not parallel with it, Fig. 2. Surrounding the central series there is a compact mass of small irregular cells.

From the three different sections through the growing-point of *Fucus* we can come to correct conclusions as to the nature of the cells and their relations to one another. The three Figures 1, 2, and 3, which represent sections through the growing tip of *Fucus*, were made at right angles to each other, and in each section there is seen a single central cell, indicated by A in all the figures, which is easily distinguished from the surrounding cells by its greater size. On comparing the different sections it is evident that this cell is shaped like a narrow wedge with convex sides and an obtusely rounded apex.

In different sections through the growing-point there is always found one cell larger than any other, and this is always situated at the bottom of the terminal depression. There is found on either side of the large cell a series of cells that become smaller as they are more distant from the central one, and in Figs. 1 and 2 they can be traced as becoming continuous with the cells of the epidermis. Besides, there are smaller cells of irregular shape at the bases of the large ones, and from them the hyphae of the stem can be seen to take their origin.

The conclusions to be drawn from the above are, that the cell A is an apical cell, the growing-point; and that from it are produced all the tissues of the plant, consisting in *Fucus* of an epidermis and a central mass of hyphae.

My studies bring me to such results that I cannot agree with Reinke and Rostafinski in believing that the growing-point of *Fucus* consists of a group of apical cells, or that there is even more than one. What I find for *Fucus* is consistent with what has been found for other genera of the order, such as *Cystoseira* and *Sargassum*, in which the growing-point consists of a single apical cell.

My figures differ so much from those of Reinke as to make explanation difficult, unless perhaps he obtained his material at a different season of the year from that in which I gathered mine.

My figure 1 agrees with Rostafinski's figure 9. In both there is the large triangular cell at the bottom of the pit, and the arrangement of the other cells is the same in each. My figures 2 and 3 correspond to figures 10 and 13 of Rostafinski. There is here a close resemblance, the essential difference being that Rostafinski makes the 'Bildungszellen' B B B etc. of equal value, while in my figure the central cell A with *convex sides* alone can be regarded as a 'Bildungszelle' that has given origin to the lateral cells A′, A″ etc., which correspond to the 'randsichtige Segmenten' of Rostafinski.

I have made a large number of sections through a great deal of material and have found this central cell with its characteristics constantly the same. It is marked by its large size, large nucleus, thin walls and denser protoplasm, and is very difficult to stain, not taking the colour like the surrounding cells.

I will now consider the relations of the *initial* cell, and the origin from it of the tissues of the plant. The series of cells on either side of the central cell are derived from it by division. These are again divided by planes in three directions at right angles to each other, the upper portions become epidermis cells and the lower or basal parts pass into the mass of

small irregular cells already spoken of which form the hyphae of the stem. The segments cut off from the sides of the initial cell may be called lateral segments. Besides the *lateral segments* the base of the apical cell is cut off, forming a *basal segment*, which by secondary division produces cells which belong to those smaller cells producing the hyphae.

Thus lateral segments of the initial cell give rise to epidermal cells and cells of the central tissue, while basal segments of the initial cell go to form cells of the hyphae only, or all of that tissue covered by the epidermis. The segments are cut off from the initial cell successively as basal, right, left, and so on, figures 1 and 2.

Fucus vesiculosus, L., and F. filiformis, Gmelin.

The facts above given for *F. furcatus* were confirmed by sections of *F. vesiculosus* and *F. filiformis*. My work was especially confined to *F. furcatus*, because of the more excellent material I had of that species.

In *F. vesiculosus* the initial cell is not so marked in shape as in *F. furcatus*, it being more blunt at the upper or free end, and on the whole more of a quadrilateral. Its large size relative to the surrounding cells is the same.

In *F. filiformis* the terminal depression is not so elongated as in either of the two other species owing to the more pointed and rounded shape of the tip. The initial cell in this species has the same characteristics as in the other two, but is, however, somewhat broader for its height.

The existence of a single apical or initial cell in *Fucus* is in every way consistent with what has been found for other members of the group by Kny[1], Reinke[2], and Valliante[3].

[1] Botanische Zeitung, vol. xxxiii. (1875), No. 27, p. 450.

[2] J. Reinke, Beiträge zur Kenntniss der Tange, in Pringsheim's Jahrb. für Wiss. Botanik, x. (1876), p. 341.

[3] R. Valliante, Fauna und Flora des Golfes von Neapel. Le Cystoseirae del Golfo di Neapoli. Leipzig, 1883.

Reinke found in *Sargassum*, *Cystoseira*, *Cystophora*, *Cystophyllum* and *Halydris*, one large pyramidal apical cell, from which are derived all the tissues of the plant. Reinke's figures 7 and 8 show the apical cell of *Cystoseira* and *Halydris*.

Valliante found but one cell for *Cystoseira*, and on plate 5, figure 2, figures the apical cell of *C. barbata* as a large wedge-shaped cell, triangular in cross section, at the bottom of the terminal depression.

Kny found one initial cell for *Pelvetia canaliculata*, a close ally of *Fucus*. He describes the apical cell as being prominent by its large size, with a broad base and the smaller end directed upwards. In cross section it appears either triangular, quadrilateral, or even square, varying in different cases. Segments are capable of further division and are cut off from the sides and base of the cell, giving rise to all the tissues. In *Fucus vesiculosus* he could not exactly determine the existence of a single apical cell, there appearing at times to be several in a row.

Thus a number of different members of this group are known to have but a single initial cell; and, should we accept the conclusions of Reinke and Rostafinski, then *Fucus* must depart widely from its allied forms. I am warranted in my belief that the structure of the growing-point of *Fucus* is essentially the same as in the other forms of the group, by the facts arrived at in my observations.

The initial cell of *Fucus*, as found by me, is a four-sided wedge-shaped cell with convex sides, the smaller, upper end being rounded and the base truncated, its greater diameter being at right angles to the broad surface of the frond.

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EXPLANATION OF FIGURES IN PLATE X.

Illustrating Mr. W. McMichael Woodworth's paper on the Apical Cell of *Fucus*.

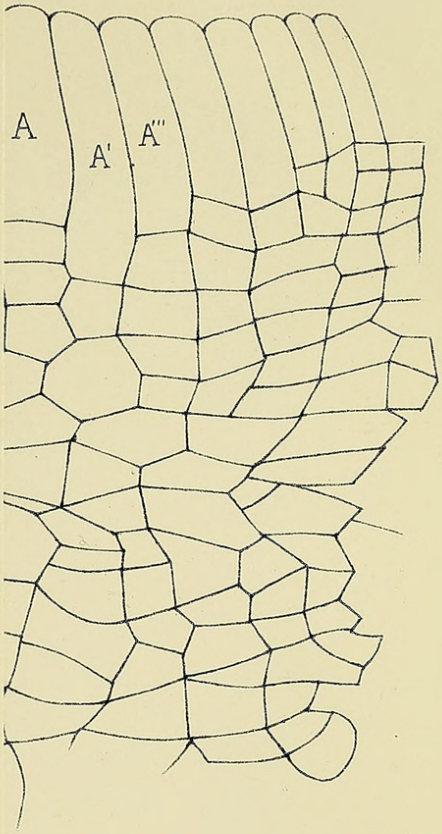
Fig. 1. Section through the growing tip of *Fucus furcatus*, made at right angles to the broad surface of the frond. A initial cell, A′, A″, A‴, A⁗ lateral segments of the initial cell. × 400.

Fig. 2. Section made at right angles to the last, parallel to the broad surface of the frond. Lettering the same as in fig. 1. × 400.

Fig. 3. Section across the tip of *F. furcatus*. The initial cell A is here seen in cross section, the section being through the base. The lateral cells appear larger than natural on account of their being cut obliquely. × 400.

Fig. 4. Tip of *F. furcatus*, showing the terminal depression. Somewhat diagrammatic. × 10.

Fig. 5. A portion of the frond of *F. furcatus*, showing the truncated tips containing the depression shown in fig. 4. × about 2.



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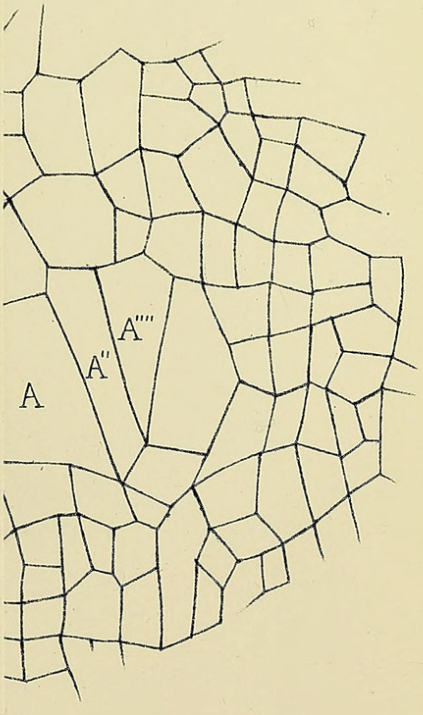

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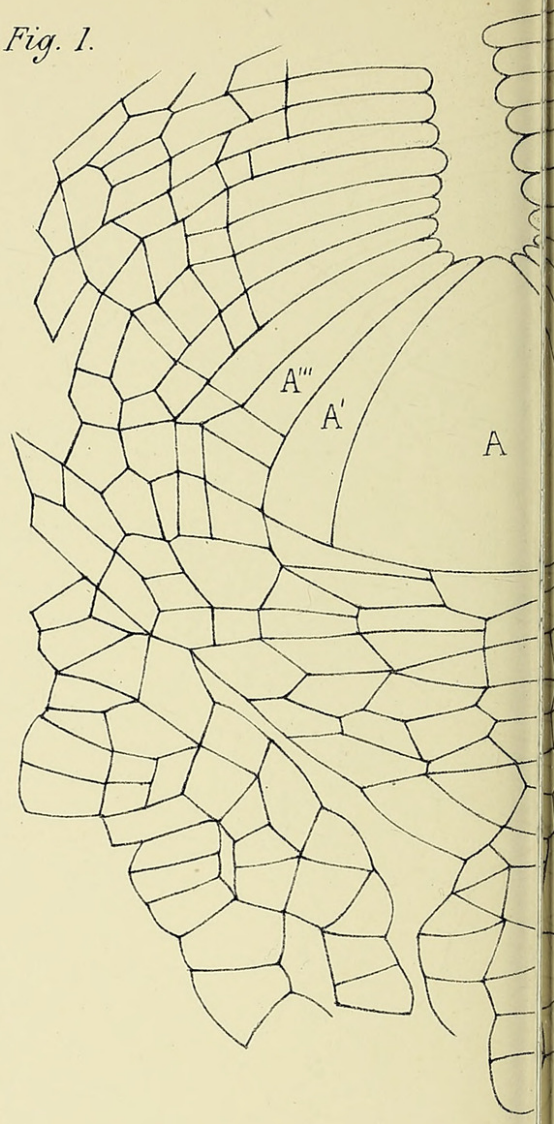

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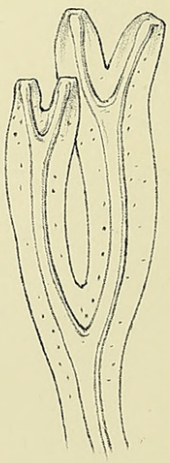

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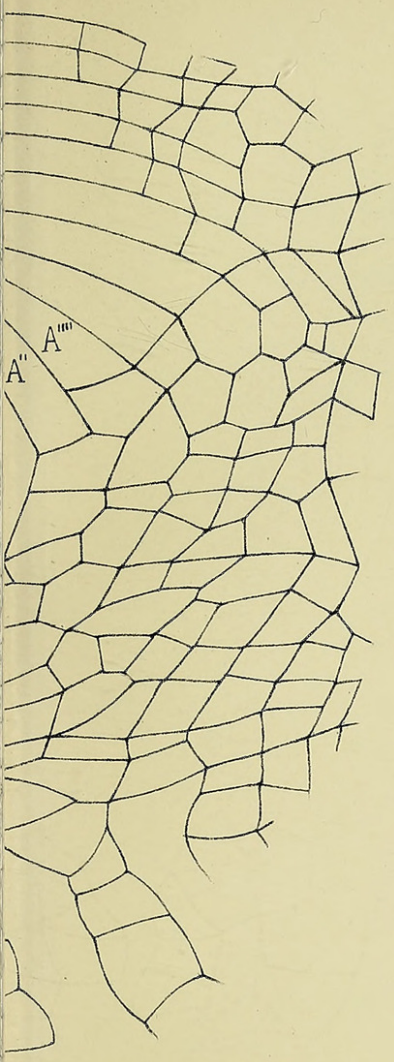

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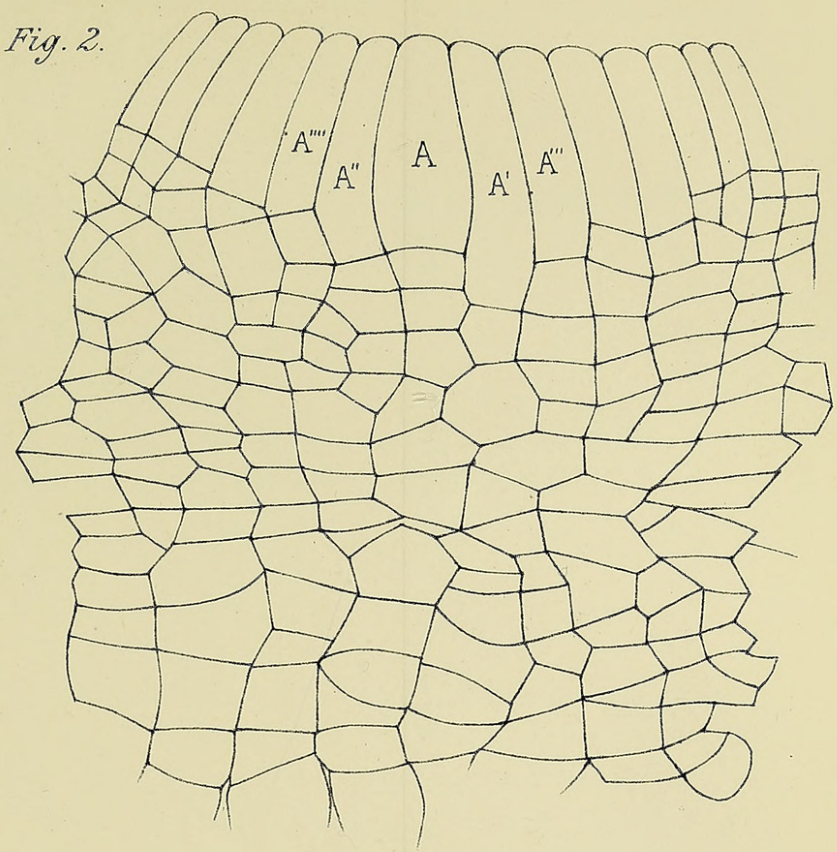

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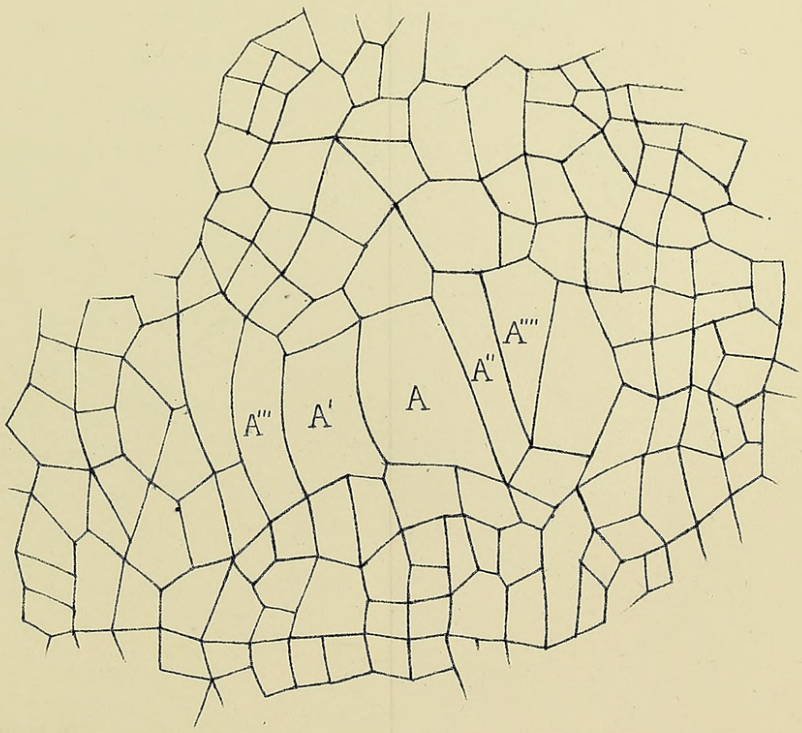

Fig. 4.

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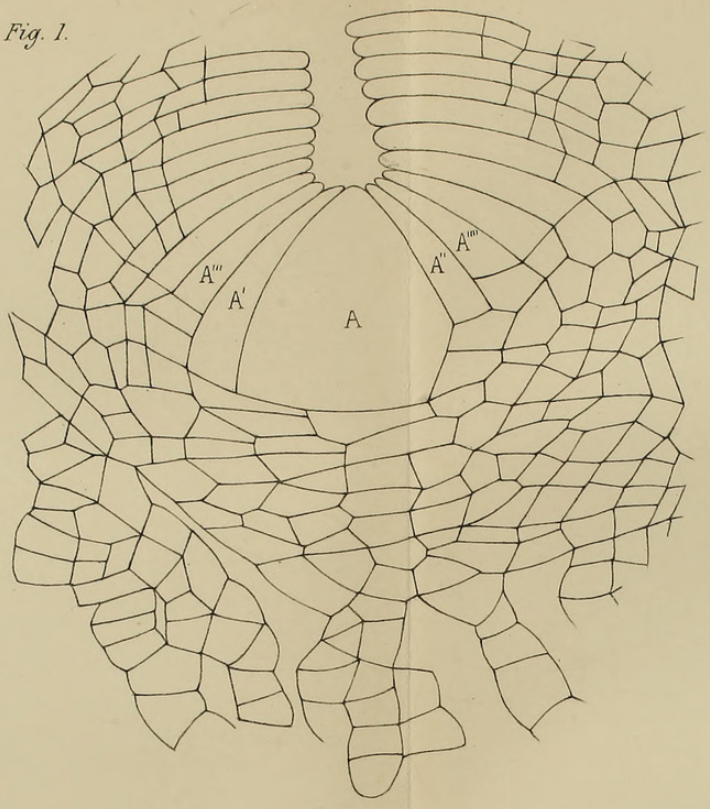
Fig. 1.



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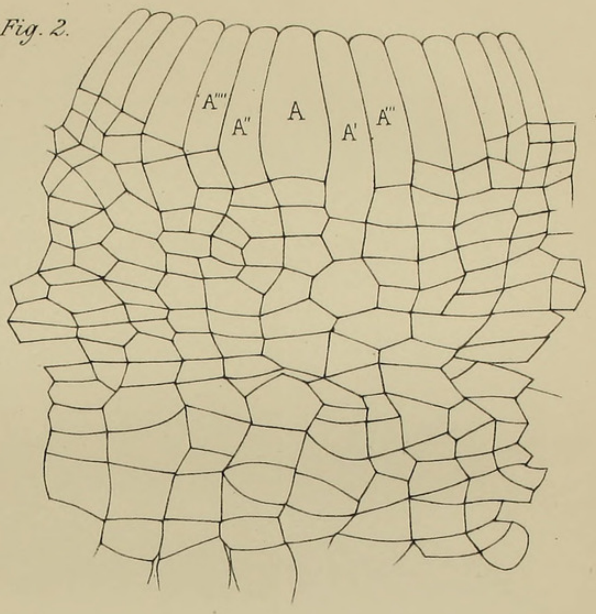

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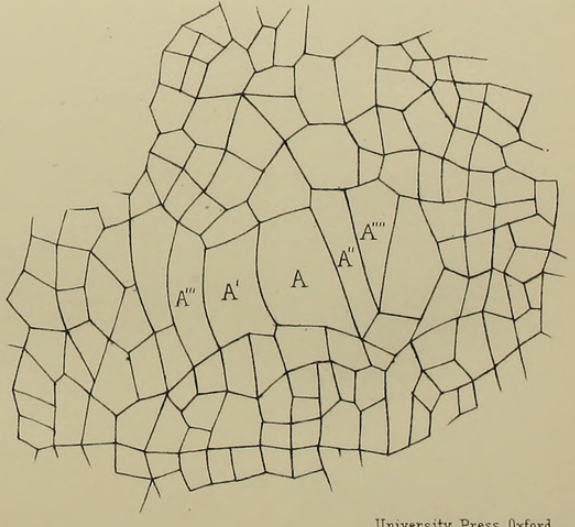

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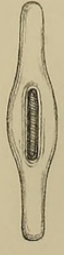

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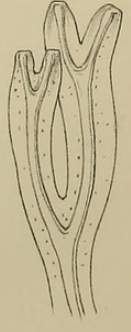

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