~~Code Word~~: Arcuate.

[Bennett, Edward William]

On the Species of Cystophora found in New Zealand, particularly in Lyttelton Harbour.

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Botany 1921

THESIS

PLAN of the THESIS.

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I N T R O D U C T I O N.

This thesis proposes to deal with certain species of the genus Cystophora , a fucoid common on many rocky coasts of Australasia. Three species (C. retroflexa, C. scalaris, C. torulosa) were collected from Lyttelton Harbour, South Island, New Zealand, (Map, Figs. 1,2.) and are discussed in some detail; they were identified with certainty only late in the year, after an extensive examination of all the available literature (which was far from complete), and of some herbarium specimens (for the most part doubtfully identified or not at all). The results however have furnished an account of all the known New Zealand species; this account, though in the main a compilation and comparison of earlier writers, is based on the very reliable works of J. Agardh and so can lay claim to accuracy. The anatomy and oecology, and in the main the general morphology, research methods, and some other parts, are based on actual work on the collected specimens of the above three species. Earlier work has been entirely descriptive of the morphology.

H I S T O R I C A L.

The progress of our knowledge of Cystophora is largely that of Australasian algology in general; and this, with the paucity of literature, forbids a detailed historical account.

The earliest descriptions of any New Zealand species are in Turner (1808), where under the all-inclusive name of Fucus, are described C. monilifera and C. torulosa, with a few plates. Other early accounts are given by Brown (Mss. and in Turner '08) and Mertens ("Memoirs"). In 1820, A. C. Agardh ('20) described C. retorta, C. retroflexa, C. torulosa, and C. platylobium. A. Richard ('32) describes C. monilifera ("Cystoseira retroflexa") as collected during D'Urville's first voyage, and Montagne ('45) reports C. retorta ("Blossevillea retorta") in the second. Various authors refer also to Labillard, Decaisne, Kützing, Endlicher, but the works of these and some of the other authors were not available for reference in writing this paper.

These accounts, given from material collected in most cases by visiting naturalists (the genus being confined to Australasia), are scattered, sometimes contradictory, and casual rather than systematic and comparative; and moreover in some cases the identifications have been doubtful. The confusion has been the greater in that a given plant, probably by recapitulation of the phylogenetic history of its species, presents different appearances at different stages in its life history, the earlier phases being perhaps similar in different species (Agardh 1892, Continuatio iii, p. 44.); and moreover is somewhat variable according to conditions (Cf. Laing, 1895, p.311), as the writer

has been able to verify. For these reasons considerable confusion has occurred, and unfortunately this is still the case with much New Zealand algology.

The confusion was largely removed by the writings of J. Agardh, son of C. A. Agardh. His decisions are quite authoritative, and his chief work, "Species Genera et Ordines Algarum" (1848) is monumental in marine algology. In this work he described, discussed, and classified all the then known species of Cystophora, viz., 20, including the N. Z. ones C. retroflexa, C. monilifera, C. torulosa, C. platylobium, C. dumosa, (the latter however being not then reported from N. Z.), and C. retorta (which he reports from N. Z. on Harvey's authority).

Agardh and Decaisne (1841) had independently separated certain species from the genus Cystoseira, creating for their insertion a new genus which Agardh called "Cystophora" but which Decaisne called "Blossevillea." Agardh's claim of priority in time and of sounder taxonomic principles has been generally conceded (though not by Endlicher and Montagne), and he is thus the founder of the genus. Later he removed certain species to the genus Caulocystis.

Apart from Agardh, the chief workers on Cystophora were Hooker and Harvey, who mostly worked together. Harvey is much less accurate than Agardh, and unfortunately was followed by Hooker. Harvey gave in his "Phycologica Australica" (1858) plates and descriptions of ten Australian species, including C. monilifera, and C. torulosa, which also occur in New Zealand.

In Hooker's "Flora Novae Zealandiae" (1855) he gave, with references to other species, a plate and description of C. platylobium, which he thought a new species and called C. Lyallii. In Hooker's "Flora Tasmaniae" (1860) he recorded four New Zealand species as also found in Tasmania. In Vol. VI. of the London Journal of Botany, the two workers gave a list, with descriptions of new species, of the N. Z. seaweeds.

The only formally descriptive account of the N. Z. species in particular is in Hooker's "Handbook of the N. Z. Flora" (1867). This great work is the most readily accessible to most readers; but it does not claim finality, and in the case of Cystophora requires revision, as indicated below.

In 1870 Agardh dealt with the seaweeds of the Chatham Islands, recording all the N. Z. species of Cystophora, including the new ones C. scalaris and C. distenta, which he describes, together with others. Later in 1887, in describing Dr. Berggren's collection, he referred these two species and also two other new ones, C. dissecta (?) and C. dumosa to New Zealand. In his final general review in the "Analecta Algologica" (1892) he discussed briefly the whole genus, describing its general habits and its internal and external relationships.

General references are to be found in Oltmann's "Morphologie und Biologie der Algen" (1904, '05) and probably Engler and Prantl's "P flanzenfamilien" (1889).

Mr. R. M. Laing (1885, 1894), of Christchurch, in dealing with the N. Z. Algae, mentions Cystophora only casually; hence, in part the present paper. He says that Agardh's intro-

duction of the four new species may require revision, and in a later paper (1899) he rejects _C. monilifera_, _C. dissecta_ and _C. retorta_, but inserts two others (this agrees with Agardh, 1877); _C. monilifera_ however must be retained, in view of its undoubted occurrence in herbaria of New Zealand specimens only. _C. retorta_ has not been verified, and Hooker himself later expressed a doubt as to its occurrence.

The position at present is :-

Hooker (1867) gives _C. monilifera_.
C. retorta.
C. retroflexa
C. torulosa
C. platylobium.

Laing's Revised List (1899) gives :-
C. retroflexa.
C. torulosa.
C. distenta.
C. scalaris.
C. dumosa
C. platylobium

to which should be added
C. monilifera.

RESEARCH METHODS.

COLLECTING. Collecting is generally possible only at low tide, from pools or the open sea. In the latter case a stick provided with a hook or blade is of use for dislodging the specimens. Stranded plants can sometimes be collected on a sandy beach after a storm, but are imperfect and unless covered with kelp are dried and useless.

PRESERVING, FIXING, SECTIONING. Collected specimens do not spoil if slightly dried, and so need not be kept in sea-water or immediately preserved: this greatly facilitates collecting. When quite dried, and sometimes when preserved in formalin, the whole tissue (and the formalin) becomes black and except for photographic purposes quite spoiled.

For freehand sectioning, fresh material is preferable; alcohol proved a good preservative, but when above 40 - 50% hardened the material too much, especially for the microtome. For more delicate cytological work, an effective method was found to be that in Murray's "Introduction to Study of Seaweeds" (MacMillan, 1895, p.30.) The fresh material is immersed for an hour in a saturated aqueous solution of picric acid, washed, and then hardened in a graded series of alcohol.

Microtome sections were cut, after the paraffin-method given in Chamberlain's "Methods in Plant Histology".

MOUNTING. For temporary and semi-permanent mounting, glycerine proved a satisfactory medium.

STAINING. Different stains were tried, with varying results.

Eosin and methylene blue did not colour the cell wall, or the protoplasm, except that numerous granules, especially in the outer epidermal cells, stained red and green respectively. This applies to material preserved in various ways. The above stains are delicate and if diluted require several hours or a day. A much more rapid stain is safranin, which should be diluted; this colours the protoplasm a deep uniform red.

The only effective stain found for the walls was Haematoxylin (Delafield's was used). This stains the walls a beautiful bluish-purple. It is rapid, and must be diluted; it may be combined with eosin, etc., for double staining.

USE OF HAEMATOXYLIN. Haematoxylin is the best stain for ordinary work, and costly experience has indicated some essential points in its use. An aqueous solution was used, and with this (and, to a less extent, with safranin) it is quite essential that sections from fresh or preserved material must be washed for some time in several changes of water; alcohol especially must be completely removed. Otherwise the stain becomes gritty, and no amount of washing will save the sections from ruin.

The stain should be diluted till the red colour changes to a delicate blue, and the sections should be immersed for 3 - 10 minutes, washed in fresh water, then placed in a watch-glass with glycerine. The mechanical repulsion of water by the latter prohibits the direct introduction of specimens from water to the slide.

EXAMINATION OF CELL CONTENTS. The protoplasmic contents of the cells were examined by the more well-known methods such as those given in Caver's "Practical Botany". A particular account is given below. ("Physiological Notes").

DISTRIBUTION

The genus *Cystophora* is Australasian (not Australian, as stated in Murray's "Introduction to the Study of Seaweeds", 1895, p.55., and in Harvey 1858, vol I., Pl. LVI.) It is one of the four genera of the Fucaceae confined to Australia and New Zealand, and in the Northern Hemisphere is replaced by the large widely distributed and closely related genus *Cystoseira.*

Over twenty species are reported from Australia, mainly from the west and south coasts and from Tasmania. Hooker's five N.Z. species and *C. dumosa* are reported from the mainland, and also, except for *C. dumosa* and *C. retorta*, from Tasmania. *C. retroflexa* ("abundant," Hooker) and *C. retorta* are reported as far south as Lord Auckland Islands; but the occurrence of *C. retorta* in N. Z. is not verified. All the species occur at the Chatham Islands.

There are thus seven N.Z. species of which *C. scalaris* and *C. distenta*, are, if we include the Chathams in N. Z., endemic; the rest are also Australian.

R E L A T I O N S H I P S.

Cystophora is a Brown Alga belonging to the Fucaceae. Agardh always considers it most closely related to Cystoseira and Sargassum; thus he says ('92, p. 45) :- "Genus inter Cystoseiras et Sargassa quoddammodo intermedium, ab illis vesiculis discretis, ab his partibus magis confluentibus et evolutione nunquam axillari diversum, satis ut mihi videtur naturale." Harvey (1858, Vol I., Pl. LVI) agrees with this. But Oltmann ('04,p.492) puts the genus nearer to Cystophyllum and Landsburgia than to Sargassum.

G E N E R A L M O R P H O L O G Y OF THE G E N U S.

GENERAL. The plant is a large thallus, one or more commonly several feet in length, and consisting of an upright stem (stipe), lateral branches, air-bladders (vesicles), and numerous pinnules containing the conceptacles; it is fastened to the substratum by a holdfast.

The colour, though variable in the different species and in individuals, (mainly according to the illumination) is the characteristic brown of the Phaeophyceae.

From the small disc-shaped (scutate) holdfast rise one or more stems. Agardh says the latter case is due to the division of the original single stem; this does occur (Fig. 3.), but in some cases at least it is a question of the fusion of the young holdfasts of two plants growing close together (Fig.4.) The plant floats erect, where possible, in the water, swaying passively with the waves. The buoyancy is partly due to the bladders, but these are small, few in number, and sometimes absent, and do not seem of much account as floats.

STEM. The stem may divide dichotomously a few (1-3) times (Plate III); it is flattened, except at the base and when very young, and in section is typically spindle-shaped. Agardh considers the variation from this, and the acuteness of the angle at the margin, to be of classificatory value (certainly so in an artificial key). The outline however is made to vary in every case by the insertions of the branches, which cause the size and shape of the section to vary and the stem as a whole to

be wavy or sinuous. This is more pronounced in the older basal parts, where the contraction of the stem with age lessens the distance between the branches.

LOSS OF BRANCHES. A very characteristic feature of the genus is that the older basal branches separate away from the stem and are lost (Plate IV.). The branches are not inserted directly on the stem, but on lateral thickened and expanded processes, which remain when the branches are lost. This gives to the older bared stems a zig-zagged or scalariform appearance - hence the name C. scalaris. (Plate III.) This deciduous habit, in a somewhat modified manner, is shared by related genera, such as Cystoseira and Sargassum. Its significance is doubtful; in the case of Sargassum, Sauvageau (C. rend. Soc. de biolog. Paris, vol. lxii, 1907, p.1082) claims that it is a method of vegetative reproduction, but with Cystophora this is almost certainly not so, for there is no record of planktonic forms. Agardh ('92, continuatio iii, p.45) says :- "Prout nimirum rami ramulique generantur aut sua densitate aut magnitudine nimii aut perfunctis propriis functionibus superflui, eosdem sensimque dejectos (fieri puto)." Indeed, it seems likely that the branches are thrown off as useless when their reproductive functions are fulfilled, like withered flowers. The formation of sexual organs on the pinnules terminates the growth of the latter. In the development of a branch, the basal pinnae may form sub-branches, but ultimately are relegated to reproductive functions, while the distal part continues its development and unfolding, till finally all the pinnules become

fertile. Meanwhile the basal pinnae are cast off in succession, leaving the rhachis bare, and finally the whole branch separates away. In one extreme case, in C. scalaris, a number of successive branches had lost 20 - 25 sub-branches each, and the remaining sub-branches had lost the more basal pinnules. The process is thus not confined to the branches of the first order only, but extends to the older fertile pinnules; and here the evidence supports the view that the significance of the process is found in the uselessness of these parts at the completion of their function, due to the loss of their power of growth. The value of the deciduous habit may be partly physiological, but is also partly mechanical; for it permits the continued production of reproductive organs without adding unduly to the size of the plant and the "pull" by the waves. The consequent increase in length is partly balanced by the contraction of the old stem, which serves to maintain a more or less constant relation with the surface of the water and to lessen the "sway" in the waves.

The base of the stem thus becomes mainly mechanical in function. Occasionally it splits into three, or more rarely two, strands between the articulations, the strands fusing again at the insertion of the latter (Fig. 6.)

BRANCHES. The articulations on which the branches are inserted (Figs. 6,7,20, Plate IV) are thick lateral processes, as wide as or wider than the stem. They are very regularly alternate, and the stem is correspondingly sinuous. They are

gradually confluent with the stem, both above and below, in such a way that the axil is not sharply angular but rounded. This feature, which is highly characteristic of the genus is often so pronounced (C. retorta, C. scalaris) that the branches are at first directed downwards rather than up ---- "quasi ponderosa mole ramorum deflexae," as Agardh (l.c.) observes in a Lamarckian phrase ----- and so supply the specific names of C. retorta and C. retroflexa. The most obvious explanation of the peculiarity is a mechanical one, viz., it appears to aid in the strengthening of the stem above as well as below the branch so as to prevent tearing, and to resist strains from both directions.

In C. scalaris, false tri-chotomy is common, owing to the great development of the two basal sub-branches and their insertion directly on the articulation, rather than on the real axis, of the branch. (Fig. 8a.) The true nature of this is detected both by analogy and by the loss of the sub-branches before the completion of the growth of the true branch.

The branches, except in their smaller size, resemble the stem; they agree with it in appearance and structure, and give rise similarly to further branches, which when old are cast off. The distichous arrangement of the branches, consequent on that of their articulations, may be obscured by the denseness of the ramification; this is often pronounced in the sub-branches, from which the pinnules appear to arise in all directions (C. torulosa). The pinnate arrangement however can be detected in some

part or other, especially if there is a bared scalariform stem (Fig. 59. Plate III).

VESICLES. Typically, one or more basal pinnules of each branch are transformed into vesicles or bladders. These are rare in C. torulosa when the latter grows in rock-pools; otherwise they are fairly numerous, and constantly so in C. scalaris and C. retroflexa. In C. torulosa, numerous examples were found of pinnules expanded distally and ending in hollow spherical or pear-shaped bodies which should probably be called vesicles (Fig. 23d). This seems exceptional, and hitherto not reported. (See specific description below of C. torulosa). The normal bladders are basal on the branches, and shortly stalked (pedicellate). They are described in some species as mucronate or apiculate, but all those examined proved ellipsoid or oval and distally smooth. In a herbarium specimen of C. dumosa a double vesicle was observed (Fig 22c).

PINNULES. The ultimate divisions of the frond are the pinnules, or "leaves". The latter term is quite a misnomer, as they are essentially reproductive in function, and filiform rather than laminate. (In C. platylobium they are more leaf-like in form).

Like the branches, the pinnules are given off alternately in two rows from the pinnae : but their insertions are simple and direct -- indeed, they frequently arise sub-dichotomously .(Plates I - III, Figs 13-16). When young they are

short and terete, and their tips are incurved towards the axis - the so-called circinate arrangement. Later they become elongated (filiform), and straighten out : they may be terete, (C. torulosa, C. scalaris), or angular (C. torulosa), or flat (ensiform - - C. retroflexa). They may be smooth, or more or less beaded or warty (torulose or moniliform - hence the corresponding specific names). Sometimes they divide sub-dichotomously, and are fertile both above and (somewhat remarkably) below the division.

The beaded appearance of the adult pinnule or receptacle is due to the embedded conceptacles. The swellings, obscure or evident, due to these, and the lighter colour round the openings (ostioles), generally enable their position to be readily detected; they are seen to be in longitudinal rows (seriate) along the whole length of the pinnules. In C. retroflexa they are biseriate, in C. torulosa and C. scalaris bi- or tri- seriate; in others more rows are reported; Harvey ('58) figures six for C. uvifera.

EARLY DEVELOPMENT. At about the beginning of Spring (August), some young plants (Figs. 10 - 16) of C. scalaris were found at Taylor's Mistake, mostly in the "emerging belt". In the earliest stages the young plant consists of a small conical holdfast merging into a stem divided sub-dichotomously above, pinnately below. The pinnate arrangement is consequent on unequal growth after the sub-dichotomous division of the axis. If the division is truly dichotomous, it would seem that the axis and the pinnule were originally morphologically equivalent.

The very young pinnules are incurved towards one another (arcuate); they are very short, and soon become clavate and thick in comparison with their length. In these features however they vary greatly according to the relative rapidity of division and elongation.

The older pinnules are seen to be arranged alternately on the two sides of the stem; the latter is as yet quite terete. In the latter point and in a few others there can perhaps be traced some indications of the phylogenetic history of the genus; but such a study cannot well be pursued unless comparison with other species is possible.

The earliest pinnules differ from those produced later, and these again from those of the adult plant. The first are comparatively very long, and simple or branched; somewhat unexpectedly for phylogenetic reasons, they are not terete, as in the adult (of this species at least) but flattened and almost ensiform. (Figs. 11, etc.). A reversion to this "juvenile form" occasionally occurs at the base of older plants, probably as the result of injury (Fig. 5).

The pinnules subsequently produced are thick and terete. Basally they are constricted and almost stalked, and distally they are generally apiculate. The pinnules of the adult plant are terete or slightly triangular, and slightly tapering from the base. (Fig. 21). Three more or less distinct types of pinnules can thus be distinguished.

Meanwhile the holdfast becomes more flattened, and adjusts its shape to the form of the rock. The stem becomes relatively more prominent, and flattened and sinuous.

In some cases the long flat pinnules divide a number of times and so become almost secondary axes bearing pinnae; this differs from the usual method of acropetal development from a "bud". Generally however these pinnules are lost, as growth proceeds, without such development. In any case, some of the pinnules are transformed into branches; they become flattened, pinnate, and sinuous like the stem, and give rise ultimately to pinnules. At a comparatively late stage vesicles are produced by the transformation of basal pinnules. The development of the lateral "platforms" in which the branches are inserted could not be studied from the material available.

LATER DEVELOPMENT. The upper parts of older plants however provide material for the further study of growth. A number of very small pinnules are produced at the ends of the stem and branches (Fig. 17); they appear to arise from all sides, and are incurved, so that the appearance is that of a small bud. On examination the pinnules themselves prove to be branched a few times. Through the elongation of the stem they become less aggregated, and by unequal growth become retroflexed so that the axil is rounded. (Fig. 19.) It is only at a later stage that the "platform" arises at the base of the branch, by a process of thickening and lateral expansion. (Fig. 21).

Meanwhile growth and development continue at the outer end of the young branch, and vesicles and pinnules are produced either directly or on sub-branches.

From what is known of the growth-methods in the Fucaceae (Woodworth, "Apical Cell of Fucus," Annals of BotanyI,

1888. p. 203) it is to be expected that the branching is really distichous from the beginning, though apparently less regular. In *C. retroflexa* one or two cases were noticed in which, perhaps consequent on pathological conditions, poorly developed pinnules were given off from the stem in various directions. (Fig. 8b).

VII. D E S C R I P T I O N S

C Y S T O P H O R A J. Ag. 1841

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J. Ag. (1841) symb.I. p.3. Sp. Alg. 238

Blossevillea. Decne. (1842) in Arch. du Mus. Paris II.
p. 147, and Nouv. Ann. Sci.Nat. xvii,
p.331

Fucus, Cystoseira, etc., (certain species), various
authors, (see below).

DESCRIPTION OF GENUS.

HOLDFAST scutate. STEM distinct, flattened, dichotomously and pinnately divided. BRANCHES flattened, distichous, generally inserted on flat side of stem, bent down at their insertion and lost from older part of stem; distichously pinnate, ultimately into receptacles and vesicles. VESICLES generally present, consisting of transformed basal sub-branches, stalked; spherical or ellipsoid; simple, mucronate or apiculate. RECEPTACLES numerous, ultimate divisions of the pinnae; terete, flat, or angular; linear, ovoid, lanceolate, or clavate; smooth or more or less torulose. SCAPHIDIA (conceptacles) flask-shaped or laterally distended cavities in the receptacles (in the torulae, if any); in two or more longitudinal rows, often paired; opening by an ostiole; hermaphrodite. OOGONIA globose or pyriform, pedicellate, in hyaline mucilaginous membrane. ANTHERIDIA terminal on freely branched hairs, mixed with branched paraphyses.

(New Zealand, Chatham Islands, Auckland Islands, Kent Island, Australia, Tasmania).

C. M O N I L I F E R A. J. Agardh

J. Ag.. Sp. Alg.:241 Om Chath. Alg. 447 Analecta Alg. iii.44 --

Harv. Phyc. Austr. V. 245

Hook. Handbook N.Z. Fl. 651

Harv. in Hook. Fl. Tasm. 283

Blossevillea retroflexa. Decne. l. c.

Harv. in Lond. Journ. Bot. vi. 414

Kütz. tab. Phyc. x., tab. 76

Cystoseira retroflexa. A. Rich. Astrolabe N.Z. 12

Sonder in Pl. Preiss. v. 2. 160

Kütz. Sp. Alg. 629

Fucus retroflexus. Turn. Hist. Fuc. 155 (Not the plant of Labillard).

STEM several feet long, flat, acute-angled, pinnately decompound. PINNAE inserted on flat side of stem, bent back, bared below with obtuse aculeations. PINNULES numerous, dichotomously pinnate, bared below, ultimately into receptacles and vesicles. RECEPTACLES moniliform, filiform, torulose, (apiculate? - Hooker) SCAPHIDIA numerous, close together, biseriate (opening marginally ?) VESICLES stalked, numerous, obovoid- spherical.

New Zealand (Laing, etc - Perhaps common)

(Austr., Tasm.)

C. monilifera closely resembles C. retroflexa, to which species it has been referred not only by early writers (following Turner --- v. references above), but also by later collectors, so

that its frequency and exact localities are uncertain. Though probably not on Bank's Peninsula, it certainly occurs in New Zealand (Laing, Herbarium, though not in the list of 1899).

The species is recognised in general by its characteristic appearance, for though as long as most, it is much more slender than any others, especially in the pinnules. It agrees fairly closely with C. dumosa, but has shorter, almost spherical, vesicles. It agrees closely with C. retroflexa in its ramifications and in most respects, though less robust, and can be distinguished with certainty only when maturely fertile. The receptacles of C. retroflexa are ensiform and fairly smooth, but those of C. monilifera are thinner and very filiform, and are torulose, with numerous close scaphidia. Further differences may be traced in the vesicles.

C. T O R U L O S A Brown (PLATE I.)

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C. Ag., Fl. N.Z., ii. 214.

J. Ag., Sp. Alg. i. 243 Alg. Chath. 445

Analecta Alg. iii. 44 ---

Harv. Phyc. Austr. t. 123.

Harv. in Hook., Fl. N. Z. ii. 214.

Hook. Handbook. N.Z. Fl. 651.

Kütz. tab. Phyc. tab. 72

Harvey-Gibson. Marine Alg. N.Z., Journ.Bot.xxxi.1893

Blossevillea torulosa, Decaisne, Arch. du Mus. x. 214

Hook and Harv. in Lond. Journ. Bot. vi. 527

Kütz. Sp. Alg. 628.

Fucus torulosus. Brown in Turn. Hist. Fuc. 157 Mert. Mem. 14.

Cystoseira torulosa.C. Ag. Sp. Alg. 75., Syst.Alg.290 Arch. Rich. Fl. N.Z. 139.

STEM flattened, obtuse-angled, sub-terete below, alternately pinnate. PINNAE short, on flat side of stem, somewhat retroflexed; PINNULES densely fascicled, ultimately forming receptacles, short, clavate, very thick, rarely branched. SCAPHIDIA bi- or tri-seriate. VESICLES fairly numerous or rare, spherical- ellipsoid : shortly pedicellate at base of pinnae or distally sessile on pinnules.

N.Z. (D'Urville, Lyall, Laing, Harvey-Gibson, etc. common)

Bank's Peninsula (Lyall, !)

(W. Austr. Tasm. Kent Is.)

The species, though perhaps variable, is readily

distinguished. The stem is obviously simple and fairly straight, and less compressed than in most, especially towards the base. The branches are comparatively little retroflexed, short, somewhat flattened, copiously ramuliferous. The pinnae are dense and fascicled, though not extensive, and the distichous arrangement is often obscure. The pinnules are not all fertile, but the barren and fertile alike are very characteristic of the species; they are very fleshy, clavate, blunted at apex. The specimens examined from Lyttelton Harbour were not very torulose; but Harvey's Plate (Phyc. Austr., t. 123) shows the pinnules very beaded, and moreover apically pointed. The receptacles are terete or slightly tri-angular in section, and the scaphidia in two or three rows. Agardh ('70, p.446) says the ostioles open marginally, but this does not apply in a terete receptacle. The vesicles vary greatly in number, and seem generally to be fewer in rock-pool specimens; they are slightly longer than broad. Open-sea specimens from the Harbour showed vesicles very uniquely placed, viz., sessile at the distal end of the receptacles; they are as large as the ordinary vesicles, and thicker even than the receptacles: confluent with the latter, but quite rounded at the outer end. In spite of their peculiar position they are probably to be regarded as true vesicles; their structure is normal, their shape normal within the ordinary limits of variability, and their position is, after all, fundamentally similar. For normal vesicles are the expanded ends of pinnules, which are incompletely sterile, shortened, and generally but not always basal on the branches; the vesicles in question are the expanded ends of

more normal pinnules, unshortened, fertile, and inserted on all parts of the pinnae. Probably however they are not ~~primi-tive~~ "new" organs, but a kind of reversion to what may have been the primitive type, on normal non-specialised pinnules. They do not develop till the pinnules are fairly mature.

C. D U M O S A. GREVILLE

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Greville, Synopsis, P. xxxiii

J. Ag. sp. Alg. p. 241 Analecta Alg. iii. 44 ---
Alg. Chath. 444

Blossevillea dumosa. Kütz. tab. Phyc. x., tab. 73

STEM over a foot long, flat, acute-angled (basally at least), pinnately decompound. PINNAE inserted on flat side of stem, bent back, obtuse-angled or sub-terete, scalariform at the base with alternate obtuse aculeations; pinnately decompound, ultimately into receptacles. RECEPTACLES numerous, siliquiform, somewhat filiform, sub-torulose. VESICLES numerous or few, inserted beyond bases of branches, obovoid.

N. Z., common (Laing) : Lyttelton Harbour (? - drift!)
(Austr.)

The species is recognised by the receptacles. It agrees closely with C. retroflexa, and is described (v. Agardh, '70) under that name by Harvey. The stem is similar, but may be thicker in the middle part; it is over a foot in length, and acutely winged. The receptacles are shorter and the scaphidia more prominent than in C. retorta, and the branches longer and more divaricating.

The stem is notably scalariform. The branches are more obtuse-angled than the stem, and when old are sub-terete. The vesicles may be numerous or rare, or almost absent.

A single drift specimen, found at Charteris Bay, probably

belongs to this species. (See below, "Oecology"). Identification was the more difficult in that the plant was young, and the receptacles immature.

C. RETROFLEXA (Labill) J. Agardh (PLATE II)

J. Ag. Sp. Alg. i. 243. Analecta Alg.iii. 44 --
Alg. Chath. 443.

Harv. in Hook. Fl. Tasm 283.

Hook. Handbk, Fl. N.Z., 657

Fucus retroflexus. Labill. Fl. Nov. Holl. p.113 t. 260
Mert. Mem. p. 14.

Cystoseira retroflexa. C. Ag. Sp. Alg. i. p. 74
Syst. p. 289.

Blossevillea caudata. Hook and Harv. in Lond. Journn. Bot. vi. p. 414.
Harv. in Hook. Fl.Tasm. 119
Kütz. tab. Phyc. x., tab. 76

B. retroflexa. Kütz., Sp. Alg. 629.

B. campylocoma. Kütz. ibm. tab. 81.

STEM flattened acute-angled, obtuse in basal parts, pinnately decompound; PINNAE inserted on flat side of stem, bent down at their insertion, flattened like the stem, axils rounded, pinnately divided, densely above. RECEPTACLES simple or dichotomous, ensiform or siliquiform, sub-torulose. SCAPHIDIA biseriate, externally little prominent and somewhat distant, internally expanded laterally, and so long, opening by single marginal ostioles. VESICLES numerous, shortly pedicellate, obovate when young, later spherical.

N. Z., abundant (Hook, D'Urville, Laing). Bank's Peninsula(!)
Auckland Islands (Hook)

Chatham Islands (Ag.)

(Austr., Tasm.)

C. retroflexa was formerly described as variable, but since it proves to have been constantly confused with C. dumosa, C. monilifera, C. retorta, and others, its variability is doubtful. It is elongated and robust, with a stem several feet long; the branches are unusually large, and widely separated (v. "Oecology," below). The stem is very flat and acute-angled, and though the axils are much rounded, is only slightly wavy. Basally the stem and branches are scalariform, with the persistant bases of lost branches. The species is identified mainly by the receptacles; these are ensiform, very flat, slightly incurved especially when young, only slightly torulose. The apex is sterile, and described by some as often caudate. The vesicles are $\frac{1}{4}$ inch wide, twice as long, stalked, obovate or spherical, sometimes described as apiculate : these features serve to distinguish the species from C. dumosa. It differs from C. monilifera (q.v.) chiefly in the shape of the receptacles, and is also more robust.

C. D I S T E N T A. J. Agardh.

J. Ag. Om Chatham - öarnes Alger. p.443.

Travers. u: o. 109

Laing. Revised List. p. 67.

Schauinsland 1896, '7, Sonder-abdr. a. Abh. Nat. Ver.
Brem. 1899. Bd xvi, h. 2.

STEM flat, sub-acute, distichously pinnate, sinuous, scalariform below, PINNAE on flat side of stem, somewhat distant, rhachis flattened, scalariform below. PINNULES sub-dichotomous, slightly compressed, wavy, forming in bulk rather terete lanceoid panicles. SCAPHIDIA biseriate. VESICLES obovate.

Chatham Is. (Travers,) [illegible])

Bluff (Berggren)

French Pass (Schauinsland).

(Endemic species, including Chathams).

C. distenta resembles C. retorta, and Hooker's inclusion of the latter as a N. Z. species may be due to confusion; but in C. retorta the receptacles are elongated and moniliform, while those of C. distenta are shorter and slightly compressed. They are however longer than in (say) C. torulosa or C. retroflexa. The shape of the vesicles resembles most closely that in C. scalaris.

C. S C A L A R I S. J. Agardh. (PLATE III)

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J. Ag. Alg. Chatham, p. 442.

Laing. Revised List, p. 67.

Travers, u. o. 108.

STEM flat, sub-acute angled, alternately decompound, very sinuous. PINNAE on flat side of stem, distichous, flat, similar to stem, bared below, scalariform, with rounded axils, pinnately decompound, PINNULES numerous and densely aggregated, proceeding in all directions, short, terete, simple or sub-dichotomously branched, sub-torulose. SCAPHIDIA bi- or tri-seriate. VESICLES few, small, obovate.

Chatham Is. (Travers, Ag.) St.Clair (Crosby-Smith).
Bluff, Dunedin, Warrington, Banks' Peninsula, Lyall's Bay (Berggren)
Banks Peninsula (!)

(Endemic species, including Chathams).

The stem is long (2 - 3 feet), flat, somewhat acute-angled : but these features are not strongly pronounced. The stem and branches are noticeably bared below and scalariform. (Plate III) The ramification is unusually extensive and dense, and the pinnules characteristically short, blunt, terete, and sub-torulose.

The pinnules serve to distinguish the species, especially from C. retroflexa, which it otherwise somewhat resembles. Agardh says the scaphidia are biseriate, but as in C. torulosa they are commonly triseriate. The smaller size of the parts, es-

pecially of the vesicles, distinguishes the species from C. distenta.

It is possible that there are two varieties of C. scalaris : two distinct forms of growth were observed, which however may be merely seasonal phases. Early in winter Agardh's remark is very apt, that the pinnules proceed in all directions, forming short terete panicles. But in spring the elongation of the axis makes the distichous arrangement much more apparent : the ramification is less dense, though actually it is more extensive and the pinnules longer. These two forms probably belong to the same variety. Plate III shows a somewhat intermediate form.

C. P L A T Y L O B I U M. J. Agardh.

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J. Ag. Sp. Alg. i. 245. Analecta Alg. iii. 44 et seq.

Hook. Handbk. N.Z. Fl. 651.

C. Lyallii. Harv. in Hook. Fl. N.Z., ii. 214

Fucus Mert. Mem. 11.

Cystoseira. C. Ag. sp. Alg. p. 43., Syst. p. 283

STEM 2 - 3 feet long, compressed, costate, sub-terete at base, flexuous, pinnately decompound. PINNAE distichous, inserted on margin of stem, not bent down, naked below. PINNULES alternate from a costate axis, flat, barren or fertile, with dentated margins. Dentations of barren pinnae alternate, obtuse; those of fertile pinnae thicker, prolonged into stalked lanceolate torulose receptacles, apically sterile, acuminate. SCAPHIDIA biseriate, opposite, opening marginally. VESICLES stalked, spherical, muticate, large, not numerous.

Foveaux Str. (Lyall). Otago (Lindsay, etc.) New Brighton, Kaikoura, and Wellington Heads (drift - Laing) The Bluff (Laing). Lyall's Bay, Napier, Bluff (Berggren). (Tasm).

There is no difficulty in recognising this species, mainly from the unusual marginal insertion of the branches, which moreover are not retroflexed; also from the flat dentated pinnae and flat lanceolate - acuminate receptacles.

The stem and branches are costate, and (at least when dried) longitudinally grooved.

C. platylobium is perhaps the highest species of the genus.

CLASSIFICATION OF THE SPECIES

Agardh has classified the species in various ways. In the "Species Algarum", he relies on the shape of the stem, the method of insertion of the branches, and the shape of the vesicles and receptacles. This system puts together, as closely related, all the N. Z. species except C. platylobium, which is certainly quite unlike the others. The significance of the close relationship of the remaining species, in connection with the distribution and origin of the species, is obscure, especially as only two of the species are endemic.

In the "Algae of Chatham Is.," Agardh insists rather on the form of the receptacles, the arrangement of the scaphidia in rows, and the position of the ostioles. This method of arrangement displaces C. monilifera. The order of the species (reversed) is that chosen in the specific descriptions above. In the "Analecta Algologica" is given another scheme, perhaps somewhat artificial, which combines the features of the other two systems; this method rearranges and displaces from one another the N. Z. species.

The following artificial key has been drawn up from various sources to aid in the identification of the N. Z. species :-

K E Y T O T H E S P E C I E S

I. Branches inserted on margins of stem

not retroflexed . . . . <u>C. platylobium</u>

II. Branches inserted on flat side of stem

retroflexed.

Stem more or less obtuse angled, receptacles short, terete, scaphidia 2 - 3 seriate

Pinnules very thick, clavate, vesicles spherical or obovate . . . . <u>C. torulosa</u>

Pinnules very numerous, short, vesicles obovate. . . . . <u>C. scalaris.</u>

Stem acute-angled, receptacles long, sub-compressed or flat, scaphidia biseriate

Pinnules filiform, vesicles obovoid

All parts short, vesicles obovoid . . . . <u>C. dumosa</u>

All parts long and slender, vesicles obovoid spherical <u>C. monilifera</u>

Pinnules ensiform, very flat <u>C. retroflexa</u>

Pinnules shorter, little compressed, lanceolate. . . . . <u>C. distenta.</u>

A N A T O M Y

- - - -

Apart from a few figures of the reproductive organs and cut stems by Harvey ('55,'58) no anatomical work on _Cystophora_ has been recorded.

I. THE HOLDFAST.

The holdfast ("root") is scutate, i.e., in the form of a much flattened cone (Figs. 3 - 5) The upper surface is smooth, the lower accommodates itself to the surface of the rock.

The tissue is mainly a continuation of the medulla of the stem. The long conducting cells decrease in diameter, and become more definitely associated into hyphae. These hyphae occasionally branch, and are interwoven to form a dense pseudo-parenchyma. Some sections show them running in two directions only, and fairly regularly interwoven like the threads in cloth.

Towards the upper surface, some of the hyphae terminate abruptly, the remainder become parallel with one another and perpendicular with the surface (Fig. 25) The outer tissue is fairly compact, for the hyphae become much swollen. They become frequently septate and so form filaments of almost spherical cells, richly filled with a dense brown granular cell-content. This food-storage is evidently for the purpose of growth, the holdfast increasing in size by the growth of these outer cells. A parasite (Fig. 26) was observed in some cases on this part of the plant. (See "Oecology", below.)

Examination of the surface adjacent to the rock is difficult. The hyphae are wide, distantly septate, and more or less thick-walled. They seem capable of individual growth so as to fill up the rock-crevices. At the edge of the holdfast, loose hyphae may be seen encroaching on more of the rock (Fig. 27).

The inner part seems chiefly mechanical in function. The hyphae are thick-walled, densely interwoven, and contain a little colourless material with large and highly refractive granules: no sieve-plates were observed. In an old holdfast a brown discolouration shows distinction of this tissue into layers; the effect is intensified by staining with Haematoxylin. In one example, as many as six concentric rings were observed; possibly they represent periods of growth.

The holdfast thus seems to have a mechanical function; it is not specially absorptive, and contains little or no stored food except at the periphery for its own growth. Growth is by the increase of the outermost hyphae, followed by that of the deeper hyphae which become interwoven with them beneath the surface.

II. THE STEM and BRANCHES

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CUTICLE. The outer cuticle is thin, and though definite, cannot be readily separated from the cellular tissue beneath. Through it the epidermal cells can be seen as dark round masses; but a separate fragment of cuticle reveals small spaces determined by delicate and extraordinarily wavy markings. (Fig. 28) The shape of these is quite unlike that of the cells, and their significance is obscure.

EPIDERMIS. The cells of the outermost layer (Figs. 29, 30) are both assimilatory and meristematic. They are very small, thin-walled, elongated, and radially disposed parallel to one another. They are capable of division, both longitudinally and transversely, and as a result of their increase the stem grows in length and thickness. The layer is very thin, being 2 - 3 cells deep, and though the inner cells become subsequently modified there is no sub-epidermal meristematic tissue.

The sub-epidermal cortical cells show a more or less obvious relation with the epidermal : viz., they are twice as wide in either direction, and so four times their size (independently of their length), and each is terminally adjacent to four epidermal cells. This relation is a result of the method of cell-division, which occurs in the epidermis in two directions perpendicular to one another (Fig. 31). The process is repeated indefinitely in the outer cells, possibly only in the outermost layer; the inner cells enlarge without division. Transverse division is comparatively

rare, so that growth is in width rather than in length: it precedes the double longitudinal division, which is thus four times as vigorous. Consequently the epidermal cells are always very narrow. The method of division is shown in Figs. 31, 32.

Associated with the growth of the stem is a modification of the cortex and medulla; the cells of both these tissues have lost the power of division, but increase in size and change their shape.

CORTEX. The cortical parenchyma (Figs. 29, 30) said to serve for storage of food, lies immediately beneath the epidermis, and forms a much more extensive layer. The cells are much larger, especially transversely; the outer ones are cylindrical, but the inner ones are more distended and so barrel-shaped.

The cortex is not clearly defined on either its inner or outer side, being continuous with both of the adjacent tissues : it is derived from the outer, gives rise to the inner, and merges into both.

Cortex parenchyma cells are thus in a transitory phase, potentially at least, between the epidermis and the medulla.

The outer cells are similar to the epidermal except probably for functional differences and for increase in size. The inner cells pass from barrel-shaped to hexagonal and then become more irregular as a result of unequal distension. Their relation with the central medulla (Fig. 29) is not easily

followed; but in general they become elongated in the direction of the length of the stem, till they form the long conducting elements which constitute the inner and major part of the stem. Many of the inner cortical cells have an internal incomplete septum, seen in section as a kind of trabecula projecting into the cell-cavity; often apparently two such trabeculae, approaching one another in the centre of the cell, indicate that the section has passed through the opening of the septum. [illegible]).

The significance of these structures is obscure. They are irregular, and seen only in some of the cells; they are frequently directed downwards, and sometimes appear to form funnel-shaped channels which suggest that their function is connected with the translocation of food material. They may reqpresent a stage in the formation of the true conducting elements. They appear incompletely dissolved walls rather than new outgrowths; that such changes can occur in the walls is shown by the occurrence of the sieve-plates (See below).

<u>MEDULLA</u>. The medulla is generally described as a conducting tissue; the evidence for this in the present case lies in the elongation of the cells, their terminal continuity one with another, and the presence of sieve plates.

But the growth of the stem results in the increase of the medulla rather than of the other tissues, whose extent moreover is not influenced by local variations in the dimensions of the stem (Figs 33, 34). The development of medulla

is out of proportion to the need for conducting tissue, and it must be concluded that the medulla is chiefly mechanical in function. The tensile strength of a well-developed stem is considerable; older bared stems and branches consist almost entirely of medulla; the cells are thick-walled, especially the inner, and have colourless disorganised cell-contents. This indicates the mechanical function of the tissue.

On the other hand, there is no doubt that the outer medullary cells are truly conducting elements; this is the primary function, but as growth proceeds the central medulla becomes more and more relegated to the function of resisting the tearing action of the waves. This change of function finds an analogy in the secondary wood of vascular plants

SIEVE PLATES. Sieve plates are perhaps universal in the Laminariaceae, but are not known in all the Fucaceae (e.g. Hormosira -- Mollett, Trans. N.Z. Instit. xiii. 1880. p. 318.) They are however reported from some genera, including Cystosphaera, a ~~xkaaa~~ relative of Cystophora. (Skottsberg; Swedish South-Polar Exped. (1901-3) IV. 146) They are here recorded in Cystophora also, but only a few general remarks can be offered. The material examined was not ideal for study, having been mostly preserved in alcohol and mounted in glycerine.

The existence of pores in the plates, though not definitely demonstrated, can be inferred from analogy. The

plates first appear in the inner cortical cells, where the walls become locally narrowed from both sides, leaving only a thin membrane between adjacent cells (Fig. 35). The plates vary greatly in number in different parts, but are especially common at the junction of stem and branch (Fig. 36).

In the outer medulla the plates are most frequent on the transverse septa of the long conducting cells, and are commonly so extensive as to make these septa mere membranes stretching across long hyphae (Fig. 37). They might easily be overlooked in a hasty examination. In the inner medulla there is a greater proportion of lateral plates (Fig. 38.).

Occasionally a wall is thinned on one side only, and the opposite side is then swollen and laminated (Fig. 38). The wall adjacent to a plate is frequently much swollen (Fig. 36). The bearing, if any, of these points on the origin of the plates, is obscure, especially as in the living plant they may correspond to differences in composition rather than in structure.

III. VESICLES.

The vesicles or bladders are transformed pinnules, and show essentially the same internal structure. Sterilisation is incomplete, as small conceptacles are occasionally found.

There is a thin epidermal layer (Fig. 39), which almost disappears from a mature vesicle. The much more extensive cortex (Figs. 40 et seq.) consists of large thin-walled parenchyma cells, polygonal and loosely packed. The medulla differs from that of the stem; it is of comparatively small extent, contains few or no sieve plates, and consists of short oval thick-walled cells. It increases somewhat in extent as growth proceeds, but does not come to resemble the medulla of the stem.

The innermost lining layer gives rise to glandular outgrowths which protrude into the cavity (Figs. 40 - 45). These may arise before the complete differentiation of the medulla, and are then numerous and long. Otherwise they are formed as erect or prostrate outgrowths from medullary cells, whose walls become thin and then papillate, finally elongating into a hair. When few in number the hairs are often capitate; when old they become disorganised. The structure strongly suggests that they are glandular in function, and probably concerned in gaseous exchange . (The vesicles have gaseous but not liquid contents).

In the vesicles terminal on the pinnules of C. toru-

losa (Figs. 4b, 23), the medulla is still less differentiated from the cortex. These vesicles are formed by the tearing apart of tissues already produced, for they do not arise till the pinnule is almost mature. Fragments of torn cells may be seen projecting into the cavity. The glandular hairs are numerous and long. The cortex is well developed in these vesicles and may contain a few small conceptacles.

IV. P I N N U L E S

The pinnules are essentially similar in anatomical structure to the stem, except that they contain the conceptacles, and the tissues have different relative proportions.

The young pinnule has at first no medulla; this arises later by differentiation of the innermost cortical cells, and is continuous with the medulla of the branch bearing the pinnule. The cells (Figs. 46 - 49) are thick-walled, but at first are only slightly elongated, and without sieve-plates; generally they do not come to resemble the true medullary cells, and the tissue is not extensively developed. In C. scalaris and C. torulosa especially it is a thin central strand (Fig. 46); in C. retroflexa it extends partly or completely round the conceptacles (Figs 47, 48).

The pinnules have the usual epidermal layer, but this disappears from mature pinnules. In C. scalaris and especially in C. torulosa the greater part of the tissue consists of cortex, in which the conceptacles are embedded (Figs 46, 49).

In all three species the conceptacles may be in two or three rows. They are generally tri-seriate in C. torulosa, frequently in C. scalaris, and rarely in C. retroflexa. The conceptacles of different rows correspond in position, so that when biseriate they are paired, when triseriate they are in threes. The surface shows more or less obvious swellings to correspond with the conceptacles. Consequently the pinnule is divided by sterile constrictions into fertile sections con-

taining two or three conceptacles. This is most pronounced in C. torulosa (Fig. 23) in which the sections form more or less distinct beads or torulae (whence the specific name).

In C. scalaris the pinnule is not so beaded and the surface may show little more than swellings round the ostiole. In both these species, the pinnules are respectively oval in section with the ostioles on the longest diameter, or sub-triangular, convex on the three sides, and with the ostioles on the longest radii, according as the conceptacles are bi- or tri- seriate (Fig. 46).

In C. retroflexa, the pinnules are generally flat, and the swellings are confined to the margins. The occasional tri-seriate pinnules (Fig. 47) are three-edged, the surface between the edges being concave. The ostioles are again marginal.

The tri-seriate arrangement in C. retroflexa is so rare that for purposes of identification the description as "bi-seriate" will not cause confusion. There seems to be some variability in the number of rows of conceptacles, and the variability is less in C. retroflexa. In the other species a pinnule is commonly bi-seriate at the base but tri-seriate above. (Fig. 23a)

The need for the extensive cortex of C. torulosa in comparison with the poor development in C. retroflexa is obscure. In the former the conceptacles are flask-shaped (Fig. 46) and do not extend inwards as far as the medulla; so that there is more than sufficient space for the conceptacles.

In *C. retroflexa* the conceptacles are necessarily less deep, but the space-requirement is met by the extreme lateral expansion, so that the conceptacles become almost continuous (Fig. 48).

The development of the conceptacles was not studied

V. REPRODUCTIVE O R G A N S.

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The reproductive organs are the antheridia and oogonia, which are mixed with sterile paraphyses, and contained in the conceptacles. The latter are bisexual : no sterile conceptacles ("Fasergrübchen") ~~are~~ were found.

The sexual organs and paraphyses have a similar origin. They arise as outgrowths from the lining cells of the conceptacles; these cells become papillate (Fig. 53), and then send out tubular processes whose ultimate nature is not at first distinguishable.

Those which become oogonia appear to become twice septate, and the outer cell so formed becomes swollen and densely filled with dark granular protoplasm; the inner cell, whose constant occurrence is doubtful, forms a short pedicel to the oogonium. The latter varies much in outline; it may be ovoid, pyriform, or more or less irregular (Fig. 52). It becomes enclosed within a mucilaginous membrane whose origin was not determined; the membrane is large, spherical-ovoid, and hyaline or striated after preparation (Fig. 52). Although many hundreds of oogonia were examined at all stages till maturity, no trace of a division ~~xxxxxxxxxxxxx~~ was found.

The antheridial hairs have a similar origin, but are capable of continued growth and branching (Fig. 53). The outgrowth from the cell becomes septate several times, and beneath each septum so formed protrusion and septation of a papilla results in the formation of a branch. The branches

may further divide or may develop at once into antheridia; the latter are thus lateral branches of a monopodial raceme. They are small and ovoid, and the antherozoids appear as numerous small highly-refractive granules. The method of development of the paraphyses is essentially similar, but these are less branched in the upper parts and much more elongated (Figs 55, 56). They have granular contents which are frequently dense at the tips of terminal cells (Fig. 55b).

The oogonia are borne singly on the cortical cells, but two or more antheridia may arise from one of the latter. The paraphyses arise more profusely, but this is probably due to branching at the base rather than independent origin.

Although the conceptacles are hermaphrodite, the reproductive organs show more or less obvious localisation (Fig. 56). The antheridial hairs especially are grouped in certain definite regions of the cell. The oogonia are more scattered, and the intermediate spaces are occupied by the paraphyses. In many preparations no antheridia were seen in the conceptacles; but this is not proof that such conceptacles were exclusively female. The frequent occurrence of this in the more basal conceptacles suggests however a possible tendency to protogyny.

The length of the sterile and male hairs varies. The latter are much compressed in C. retroflexa, and generally shorter in C. scalaris than in C. torulosa (cf. Figs. 54, 56). The paraphyses are much longer, and almost meet in the centre

of young conceptacles (Fig. 55d) or of those of C. retroflexa. In the ostiole they are densely packed and little branched; they are disposed parallel with one another, and directed slightly outwards. They do not protrude through the ostiole, as in some of the Fucaceae.

PHYSIOLOGICAL NOTES.

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I. THE PIGMENTS.

Temporary or continued immersion in fresh water, alcohol, formalin, etc., results in the usual extraction of brown and green pigments. The delicate green assumed by young parts after immersion in 70% alcohol for an hour is very beautiful.

Herbarium specimens or material preserved in formalin frequently become blackened throughout, and the preservative is also blackened; but this is probably not to be attributed to the true pigments.

Stranded or shallow-growing plants become bleached to a lighter colour as a result of pigment-decomposition. This result of intense illumination is responsible for a seasonal variation in colour, which is darker in winter than in summer. Perhaps this is in part the explanation of the rapid growth of the reproductive parts in winter rather than in the warmer seasons.

II. THE CELL CONTENTS.

A brief examination of the cell-contents was made by a few simple experiments on fresh material, mainly as indicated in ch. 2 of Caver's "Practical Botany" (1911). Before examination the pigments were generally first removed.

Proteins were readily detected by the Xanthoproteic and Iodine Tests and by Millon's reagent (Cavers pp. 39,44). Fehling's test and Iodine failed to demonstrate the presence of sugar or starch (pp.54 - 57), but an abundance of oil was shown by osmic acid and alkanet root (p.76) and by Sudan III solution.

Proteins were naturally found most abundantly in cells rich in protoplasm, viz., the epidermis and outer cortex of the stem and especially of the pinnule, and in the oogonia. They occur less plentifully in the medullary cells, whose contents are almost colourless (except for large brown granules), and seem disorganised. In the medulla however the proportion of oil to protein is greater than in the outer tissues. Oil occurs most abundantly in the oogonia.

III. FERTILISATION.

The behaviour of the reproductive elements was followed, though the actual process of fertilisation was not definitely witnessed; this was partly because these organs do not mature till late in the year, and partly because of the bisexuality of the conceptacles.

The oogonia and antheridia are extruded, when mature, in the usual way : they form black dots over the ostioles shortly after the removal of the plants from the water. They may be removed with a penknife : in this way over 300 oogonia were obtained from a single conceptacle. The antheridia and oogonia may also be collected in vast numbers by rubbing the plants through the fingers or on paper, by which means can be obtained a plentiful supply, forming a black sticky mass.

The adhesiveness is due to the presence of mucilage, derived, in part at least, by the dissolution of the oogonial membranes. The latter may rupture and discharge the oogonia, or be extruded with them (Fig. 52); in either case they soon become dissolved.

The antheridia are set free as small colourless ovoid masses (Fig. 58): the antherozoids appear as minute colourless highly-refractive granules, and are enclosed in a mucilaginous membrane. They are liberated by the dissolution and rupture of the latter. They are very minute, and appear to be spherical, or flattened at one end with

a small "body" (Fig. 58). No cilia were detected, though slight yet conclusive motility was seen.

The oogonia vary much in shape and in the colour and denseness of their contents. In most a reddish round body was very plainly visible, and may have been a nucleus; but this and possible indications of phenomena such as fertilisation, nuclear division, and germination, were not followed with any certainty.

IV. FUNCTIONS OF THE VESICLES.

In the species examined, the vesicles are small and few in number, and sometimes absent in C. torulosa: they are unknown in certain species. This may indicate their vestigial nature; yet special vesicles are sometimes developed in C. torulosa as if for a definite purpose.

It was found that though isolated pinnules of C. torulosa floated upright in water, they sank when the terminal vesicles were removed. The terminal position however is more efficient than the basal for the purpose of buoyancy. While there can be no doubt that the vesicles do act as floats, it does not seem improbable that they may have other functions, such as the storage of oxygen. Evidence for this view is :-

(1.) The probable insufficiency of the alternate hypothesis

(2.) The absence of watery contents: the vesicles normally contain gas of undetermined composition, at about atmospheric pressure.

(3.) The presence of the glandular hairs, which may be concerned in gaseous interchange.

(4.) The collapse of the vesicles on drying. This may be due to the removal of the gases in question (e.g., for respiration); the gases cannot be renewed after drying since they enter the vesicle only in solution.

V. TISSUE TENSIONS.

In cutting sections of the pinnules, a constant difficulty was the tendency of the former to curl up, as in Fig. 60. This suggested the existence of tissue tensions, which were investigated by the following experiments, made on well-developed pinnules of C. torulosa freshly gathered from the water.

EXP. I A pinnule was cut off straight at both ends, so as to measure 0.5 inch in length. A thin strip of epidermis was then removed from the whole length. It became curved so that the outer surface was convex (Fig. 61), and its length increased to 0.55 inch. This indicates that the epidermal tissue tends to expand longitudinally.

EXP. II. The end of a pinnule was cut off straight, and a thin strip (.25 inch wide) was partially removed from the circumference (Fig. 63). The strip, when replaced, proved more than sufficiently long to encircle the pinnule. This indicates a tendency in the epidermal tissue to expand tangentially.

EXP. III. This sections were found to curl more than thick sections (Fig. 60). Short radial cuts were made at frequent intervals through the epidermis, and the tangential expansion causes the divided parts to overlap as in Fig. 62.

These experiments show that the outer layers

are restrained by tissue tensions from a normal tendency to expand in both directions. Although a corresponding tendency of the inner tissue to contract was not definitely demonstrated, it may be inferred as a necessary consequence.

The significance of such tensions is not plain, since there may be variations according to age, or conditions such as the water-content. The tensions are less in partly dried material, and this is at least partly the cause of the loss of rigidity. Further possible effects of tension, besides rigidity, may be the stimulation of epidermal cell-division (which however may be a cause rather than an effect); the extension of the oogonia and antheridia; and the development of the vesicles, particularly those terminal on the pinnules.

O E C O L O G Y

An attempt has been made to develop in some detail that interesting but obscure study, an oecological account; only the three species however are dealt with.

These three species, C. scalaris, C. retroflexa, C. torulosa, were found in Lyttelton Harbour; also a drift specimen, probably C. dumosa. Like most of the larger seaweeds, they were found near low tide on a rocky coast. C. scalaris and C. torulosa were also found in rock-pools. A map of the Harbour is appended, showing the known habitats, and the nature of parts of the coast. (Figs. II.).

C. scalaris, the commonest in the Harbour, occurs in rock pools and attached to rocks below (or a little above) low-tide mark. (PLATES V. VI) Unless left exposed to the air, it sways passively with the waves, and floats erect or oblique according to the depth of water. The lengthy and flexible stem of the deep-growing specimens gives an obvious advantage, especially when the "sway" of the plant is as great as that of the waves. But the long stem forbids growth close inshore, as in such case the plant would be dashed against the rocks. Although the plants above low-tide mark have generally much shorter stems than those growing further out, yet in them the tearing on the rocks is very evident; young plants were fairly common in some parts, but the older ones are much torn, and sometimes only bare and broken stalks are left. Irregular growth, evidently due to wounds, is shown in Figs. 8b, 9. 14.

C. scalaris was found in Lyttelton Harbour (Map, Fig.II)

at Charteris Bay, Church Bay, Diamond Harbour, and outside the Heads in a much more exposed position at Taylor's Mistake. With this species is frequently found a zone of *Macrocystis pyrifera* in the deeper water further out (PLATE V), and occasionally even the kelp *D'Urvillaea utilis* and on the rocks the black mussel *Modiolus ater.* ~~*Mytilus, (M. edulis?)*~~ . The presence of these two latter are especially indicative of the exposure to the waves to which *C. scalaris* can submit. But it is more common in spots where *D'Urvillaea* and *Modiolus* ~~*Mytilus*~~ are not found.

In the more sheltered spots *C. scalaris* is generally accompanied by *C. torulosa* (PLATE VI.). The latter is much less common, and requires more protection and less depth of water. It is more especially an inhabitant of rock pools, and does not occur below low tide mark, but only in what Schimper calls the emerging belt.

The best indication of the suitability of a locality in the search for *Cystophora* is the presence of large quantities of *Hormosira banksii* whose beaded fronds constitute the most conspicuous element in the marine flora. (PLATES VI,VII,VIII) The association with *Hormosira* is perhaps not altogether accidental; *C. torulosa* in particular proved to be almost invariably surrounded with masses of its copious stout fronds, which afford a very real protection against tearing on the rocks ; the acuteness of which danger is easily under-estimated), and perhaps incidentally against bleaching and drying also. But in the pools, (Fig.59 PLATEVII) *Hormosira* grows in abundance round the edge, so that its fronds float out across the surface; while *C. scala-*

ris and C. torulosa rise from the bottom of the pool, and are thus partly screened from the sun.

It is more or less evident that, whether individual plants or species as a whole are considered, the less the depth of water the shorter the stem, the denser the ramification, and the greater the thickness of all parts. C. scalaris and C. torulosa show this feature to a variable extent according to the depth, so that rock-pool specimens may generally be distinguished from open-sea ones (cf. PLATES I,II, III)

Caution must be exercised in pronouncing this peculiarity as a directly adaptive response to conditions, or otherwise. Marine Algae are of comparatively low organisation and are not generally credited with such responsive powers. The immediate cause may be partly associated with the degree of illumination, which is greater nearer the surface than at a depth; so that shallow-growing plants, including C. torulosa as a whole, are lighter in colour through bleaching. This effect is often modified by the presence of Hormosira. Another possible factor is the pressure, which increases with the depth. Warmth and salinity are variable conditions in rock-pools, especially in the shallower, but not to any extent in the open sea. The pools in question are almost invariably about a foot deep at least, and moreover are below high-tide mark, so that the water is renewed at each tide. There is room for a series of experiments on the effects of changes in these conditions.

Comparatively few specimens (about 20) of C. retro-

flexa were found (Purau, Charteris Bay North); they were discovered at low tide mark on exposed rocky shores. The oecology of this species could not therefore be thoroughly studied: still less could that of another species, probably *C. dumosa*, of which only a single specimen was found; this occurred on a beach in Charteris Bay, South. In both these species, every specimen proved to be attached to a small loose stone, which could easily have been dragged shoreward by the drifting plant; some were in fact actually stranded at low tide. This fact, also the exposed nature of the localities concerned, the general absence from other spots, and the elongated stem and sparse slender foliage, support the view that these specimens had grown in deep water, till the ever-increasing pull of the waves on the growing plants finally brought ashore such as were attached to small loose stones. The species as a whole may perhaps frequent deeper water. These results however are at best only inferential and the results mainly negative.

Within the Harbour, search for *Cystophora* was fruitless near Lyttelton: indeed the specimens were found only on the other side. The chief localities, with the other chief forms and the nature of the coast, are partly indicated in the map (Fig. II.) Most of the coast was examined in some detail at least once.

Cystophora is not found (except as drift) on sandy beaches, such as at Sumner and New Brighton; nor were specimens found on rocks at Scarborough and elsewhere without the Heads (except for *C. scalaris* at Taylor's Mistake. This is evidently to be associated with the protection afforded by the Harbour.

Corynophloea cystophorae (J. Ag. Syst. ii. p. 22., De Toni Syll. p. 421.) is reported as epiphytic or parasitic on Cystophora (Harvey-Gibson, Journ. Bot. xxxi, 1893., etc.) It is a brown Alga belonging to the Chordariaceae, and is described as being of the size of a pea. Oltmann (1905, ii, p. 319) mentions Sphaecelaria palvinata Hook and Harv. (after Reinke) as a penetrating parasite on Cystophora. No exact descriptions were available for the study of these parasites, or to see if they are the same plant under different names. In both C. torulosa and C. retroflexa however a penetrating filamentous epiphyte (Fig.50) was discovered in several cases on the pinnules. It might belong, so far as available references show, to either of the above parasites, and shows also some correspondence with the Endosphaeraceae (West, "Algae", 1916, p.210 - 212). The penetrating habit is certain, but this is not sufficient proof of parasitism.

The Alga discovered consists of a tuft of filaments, about 0.5 m.m. in length and composed of a single row of disc-like cells joined by the flat surfaces. The outermost cell is hemispherical : the basal cells become gradually attenuated, till the epidermis of the host is pierced by a thread-like attachment cell. The filaments are sparingly branched, and each branch ends in a large ovoid unilocular body, evidently reproductive in function, and densely filled with granular highly refractive contents.

Covering the upper surface of the holdfast of C. torulosa there was found in some cases a dense mass of ap-

parently fungoid hyphae (Fig. 26). These hyphae consist of 10 - 20 small round cells, and are arranged perpendicularly to the general surface. They are compact, and peripherally form a pseudo-parenchyma (broken through in places, either naturally or by accident). Basally the hyphae can be traced into the tissue of the holdfast, and ramify extensively between the richly-stored outer cells of the latter. The evidence of parasitism in this case is strong.

Numerous epiphytic animals and plants were found on Cystophora, such as sea-mats, sponges, Hydrozoa (PLATE IV), the marine slug Pleurobranchaea novae-zelandiae, ~~and a kind of sea-slug~~, Cystophyllum sp., a few Rhodophyceae and microscopic forms such as that on the epiphyte of Fig. 50. These associations however are evidently accidental, and it was verified in most cases that the organisms were not peculiar to Cystophora. No consequent abnormalities of growth were observed.

CONCLUSION

Probably the chief points of interest in the genus are :-

1. The method of insertion and the loss of the branches
2. The presence of sieve plates in the medulla.
3. The undivided oospheres.

The latter two points especially require further investigation, which should be comparative. There is need also of a better definition and description of the New Zealand species ; this however would involve a study of the whole genus.

D E S C R I P T I O N S of FIGURES and PLATES.

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Fig. 1. Map of N.Z., showing recorded habitats of Cystophora.

2. Map of Lyttelton Harbour, showing chief habitats and nature of the coast.

3. Base of young plant with divided stem. (x 3).

4. Bases of two young plants with fused holdfasts (x 3)

5. Part of older plant of C. scalaris, with reversion to "juvenile" type of pinnules. (x 2).

6. Old stem of C. scalaris, split into short strands.

7. Bared stem and branch of C. scalaris, with persistent bases of lost branches.

8. a : False tri-chotomy in C. scalaris.
b : Abnormal arrangement of pinnules in C. retroflexa : apparently spiral.

9. Abnormal growth of stem (C. scalaris) resulting from injury by the waves. (Nat. size).

10 - 16. Stages of development of C. scalaris (x 3).
(a : Long flattened pinnules -- 1st type.
b : Short terete pinnules -- 2nd type.
c : Young stages of adult (third) type of pinnules.
d : Abnormal growth due to injury.)

17 - 20. Unfolding of pinnules in older plant of C.scalaris (x 6).

21. Branch of C. scalaris on old bared stem : showing vesicle, almost mature pinnules, and bare scalariform rhachis (x 6) .

Fig. 22 Vesicles. (x 3).

a : C. scalaris, C. torulosa.

b : C. retroflexa (adult)

c : Abnormal double vessicle of C. dumosa .

23. Pinnules of C. torulosa (x 3).

a : With conceptacles biseriate below, triseriate above.

b : With conceptacles biseriate.

c : Sub- dichotomously branched.

d : With terminal vesicle.

24. Pinnules of C. retroflexa, sub-dichotomously branched (x 3).

25. Transverse Section through holdfast.

(c. swollen cells at outer surface; hy : interwoven hyphae beneath).

26. Ditto., with parasite (par.) (x 150)

27. Loose basal hyphae at outer edge of holdfast.

28. Wavy markings on epidermis of stem.

29. Longitudinal Section of stem.

(cut = cuticle; ep. = epidermis of stem
med. = medulla; sept.= septa in cortical cells ;
s.p. = sieve plates in medulla).

30. T. S. Stem.(Similarly lettered)

31. Diagrammatic representation of cell-division (a -- d : successive divisions.) (ep. = outer dividing epidermal cell : cort = inner cell, incapable of division).

32. Diagrmmatic representation of T. S. or L. S. through stem.

Fig. 33. T. S. stems.

a : C. torulosa, lower part : sub-terete.

b : Ditto., upper part : flattened, obtuse.

c : C. retroflexa : very flat, acute, grooved through drying.

d : C. scalaris : two-winged, sub-acute (asm = general assimilatory tissue : mech. = mechanical tissue).

34. L. S. stems.

a : typical stem.

b : through junction of stem and branch.

c : through old scalariform stem.

35. T. S. cortex. (s.p. = sieve-plates).

36. " at junction of stem and branch. (s.w. = swollen cell - walls).

37. L. S. outer medulla. (t. sp. = terminal membraneous sieve-plates).

38. L. S. inner medulla (l. s.p. = lateral sieve-plates).

39. T. S. mature vesicle (ep = epidermis; cort = cortex; med. = medulla).

40 - 42 T. S. vesicles of C. retroflexa.

40 : young, with glandular hair (h) and small amount of medulla (med)

41 : older, with more hairs and medulla

42 : old, with disorganised hairs.

43. T. S. vesicle of C. scalaris, with copious hairs.

44. Formation of glandular hair (h) from medullary cell (med).

Fig. 45: T. S. Terminal vesicle of *C. torulosa*, with numerous short hairs, and small conceptacles (*con.*).

46. T. S. Pinnules of *C. torulosa*

a : through terete pinnule with triseriate conceptacles (con.).

b : through sub-triangular pinnule.

c : through an ostiole.

d : partly through an ostiole.

(*ep* = epidermis; *cort.* = corticle; *med* = medulla; *conc* = conceptacle ; *ost* = ostiole).

47. T. S. Pinnules of *C. retroflexa*.

a : through pinnule with triseriate conceptacles; through an ostiole.

b : do., semi-oblique, through only two conceptacles.

c : through normal flattened pinnule with biseriate conceptacles.

48. L. S. Pinnule of *C. retroflexa*, near margin, through one row of conceptacles : showing lateral expansion of latter.

49. T. S. Pinnule of *C. torulosa*, through two rows of conceptacles (cf. amount of cortex in fig. 48).

50. Epiphyte (*epiph*) on epidermis (*epid*) of *C. torulosa* (*a.o.* = attachment organ; *spg* = sporangium ; *Cyan* = microspic plant, apparently a Blue-Green Alga, on the

parasite) (160).

Fig. 51. L. S. young conceptacle of C. scalaris (oog = young oogonia; anth = young antheridia; par = paraphyses).

52. Oogonia in various stages.

a - d : with membrane (laminated in b., ruptured in d.)

e - h : variously shaped oogonia whose membranes have dissolved.

(mem = mucilaginous membrane; ped = pedicel).

53. Development of antheridium.

a - f : development of antheridial hair from papilla (pap), with formation of septa (sep)and branches (br.)

g - i : development of antheridia (anth.) on the hairs.

54. Mature antheridia of C. torulosa on elongated hairs.

55. Sterile paraphyses.

a : C. retroflexa

b : do., with dense protoplasm at the tips.

c : C. scalaris.

d : C. retroflexa : young conceptacle with paraphyses almost meeting in centre.

56. L. S. conceptacle of C. retroflexa, with localised and much compressed antheridia (anth), scattered oogonia (oog), and numerous hairs (par).

Fig. 57. Mature oogonium and antheridium, drawn to same scale. (mem = membrane; spz = spermatozoids; n = nucleus - ?)

58. a : antheridium, not yet ruptured.
b : spermatozoids (h = head ; b = body - ?)

59. Diagrmmatic representation of rock pool, with *C. scalaris* (c) partly screened from the sun by Hormosira banksii : (h) (cf. Plate vii).

60. Slices of mature pinnules of *C. torulosa*, showing method of curling due to tissue tension.

61. Elongation and curving of epidermal strip from pinnule of *C. torulosa*.

62. Lateral expansion of outer part of slice of pinnule snipped through the margin at frequent intervals.

63. Lateral expansion of epidermal strip partially removed from pinnule.

PLATE I. *C. torulosa*.Upper part of frond, with vesicles and almost mature pinnules; rather small specimen from rock pool, without vesicles on ends of pinnae. (Somewhat dried). (x 1/3).

PLATE II *C. retroflexa*. Specimen not quite mature; showing loss of branches and the incurved young pinnules at the apex. (x 1/3)

PLATE III. *C. scalaris*. Part of comparatively small specimen, fairly

densely branched. With vesicles (more numerous above) and pinnules (not quite mature). Stem bared below (x 2/5).

PLATE IV. Bared scalariform stem and branches of C. scalaris, with holdfast. The remains of an old plant from an exposed spot (Taylor's Mistake). Covered with small Hydrozoa. (x 1/3).

PLATE V. Rocky shore at low tide, Diamond Harbour. Hormosira banksii, C. torulosa, C. scalaris, on rocks; Macrocystis pyrifera, C. scalaris in water.

PLATE VI. Do., with Hormosira and C. scalaris on the rocks

PLATE VII. Rock pool, on headland N. of Purau, at low tide. Hormosira round edge of pool, C. scalaris in centre. (cf. Fig. 59).

PLATE VIII. Low rocky bank, Purau, at low tide; mostly Hormosira, with C. torulosa in centre.

PLATE IX. Low wide pool, on headland E. of Diamond Harbour, at half-tide. Hormosira and C. scalaris.

B I B L I O G R A P H Y.

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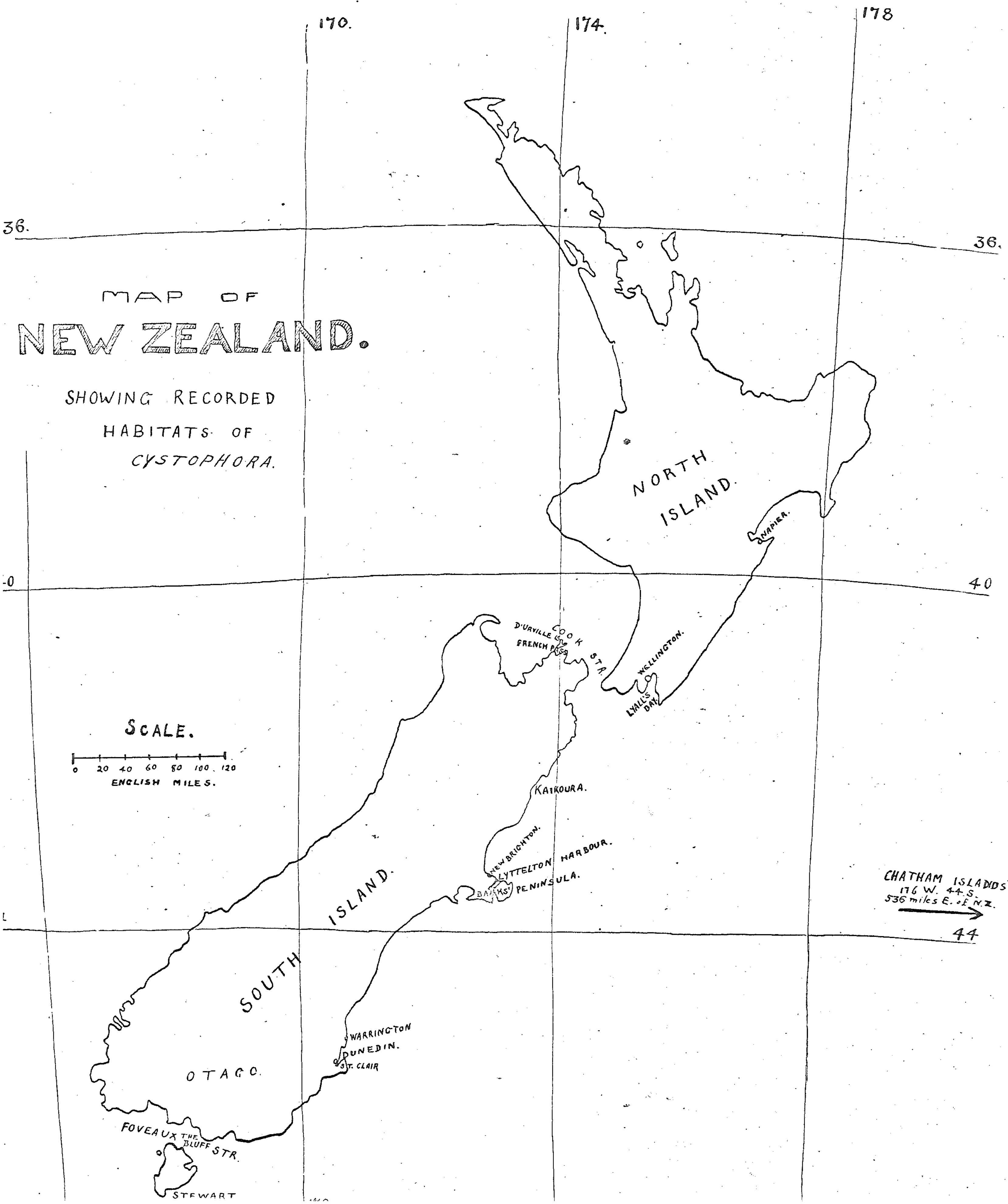
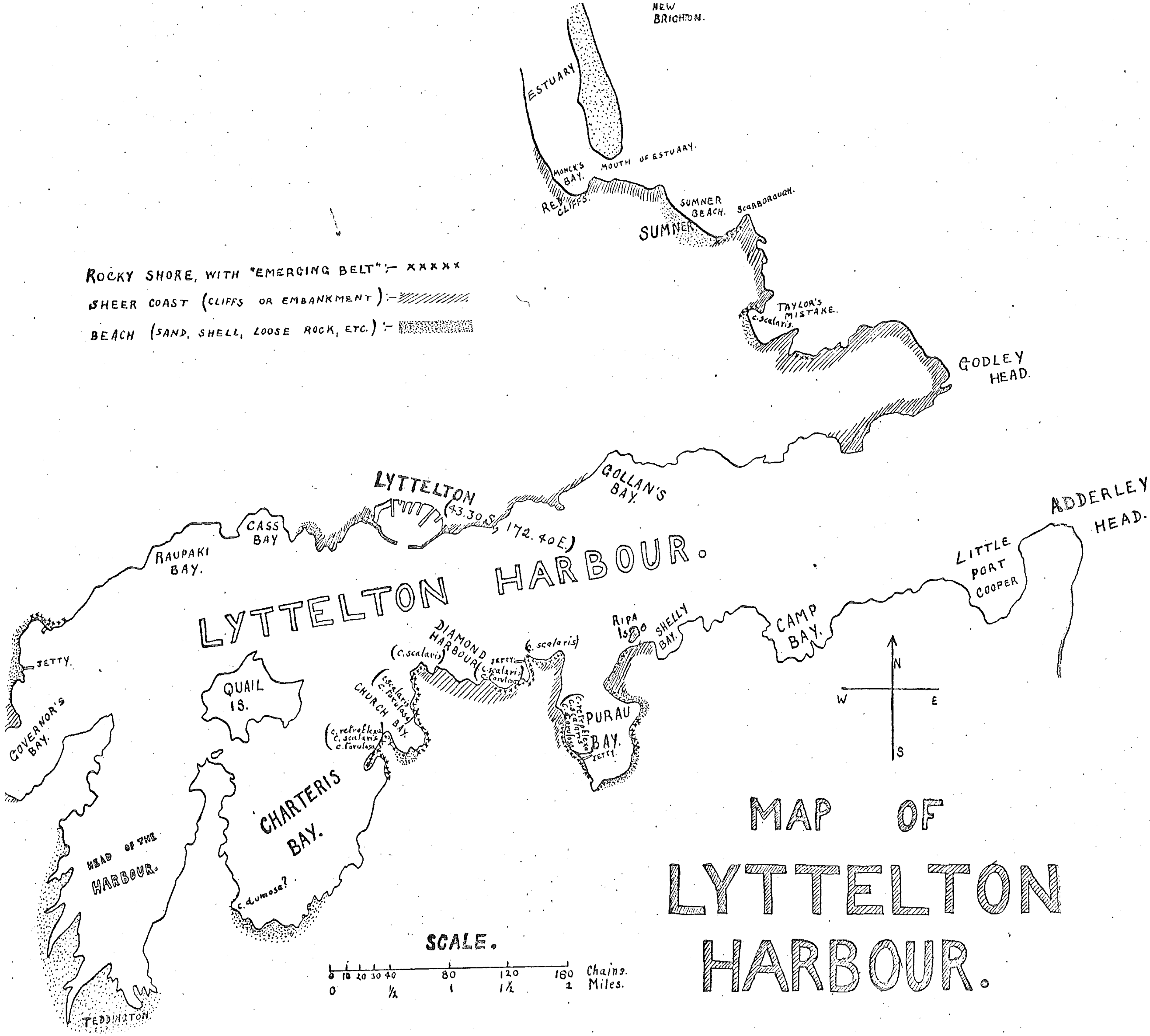
The following bibliography is as complete a list of works as possible, dealing with Cystophora. The more general references are given in the text .

Agardh C. A.	1824.	Systema Algarum
	1820	Species Algarum
Agardh J.	1841	Symbolae .... (Linn. Soc.)
	1848	Species Genera et Ordines Algarum
	1870	Om Chatham - öarnes Alger .(Ofersigt af Kongl. Vetenskaps - Akademiens Fordhandlingar, 1870, No. 5.)
	1877	De Algis Novae Zelandiae marinis. Lunds. Univ. arsskrift. 14. 1-32.
	1872-'99	Till Algernes Systematik.
	1892	Analecta Algologica.
Brown	1808.	Mss. and in Turner (1808)
De Toni	1895	Sylloge Algarum
Decaisne	1841	Archives du Museum
	1842.	Annales des Sciences Naturelles xvii, 331
Endlicher.	-	Genera Plantarum, et (1843) Supplementum.
Engler & Prantl.	1889.	Die Naturlichen Pflanzenfamilien.
Greville	-	Synopsis
Harvey	1858-'63	Phycologica Australica.
Harvey in Hooker	1855	Flora Novae Zealandiae. ii.
	1860	Flora Tasmaniae.

Harvey & Hooker	---	London Journal of Botany. vi.
Hooker	1867	Handbook of the New Zealand Flora
Kützing	1845	Tabulae Phycologicae.
	1849	Species Algarum
Labillard	-	Flora Novae Hollandiae.
Laing R. M.	1885	Fucoideae of Banks Peninsula (Trans. N.Z. Instit. xviii.p.303)
	1894	Algae of New Zealand (Trans. N.Z. Instit. xxvii. p.297)
	1899	Revised List of New Zealand Seaweeds (Trans. N.Z.Instit. xxxii p. 57.)
Mertens	-	Memoirs.
Montagne	1845	Voyage au Pole Sud. (Botanique i)
Oltmann	1904-'05	Morphologie und Biologie der Algen
Richard	1832.	Voyage de l'Astrolabe (Essai d'une Flore de N. Z.)
Turner	1808-1819	Historia Fucacearum.


MAP OF
NEW ZEALAND.
SHOWING RECORDED
HABITATS OF
CYSTOPHORA.
170.
174.
178
36.
36.
40
44
NORTH
ISLAND.
NAPIER.
COOK STR.
D'URVILLE Id.
FRENCH PASS
WELLINGTON.
LYALL'S BAY.
SCALE.
0 20 40 60 80 100 120
ENGLISH MILES.
KAIKOURA.
NEW BRIGHTON.
LYTTELTON HARBOUR.
BANKS' PENINSULA.
SOUTH ISLAND.
CHATHAM ISLANDS
176 W. 44 S.
536 miles E. of N.Z.
WARRINGTON
DUNEDIN.
ST. CLAIR
OTAGO
FOVEAUX STR.
THE BLUFF
STEWART


MAP OF
LYTTELTON
HARBOUR.
ROCKY SHORE, WITH "EMERGING BELT":- xxxxx
SHEER COAST (CLIFFS OR EMBANKMENT):-
BEACH (SAND, SHELL, LOOSE ROCK, ETC.):-
NEW BRIGHTON.
ESTUARY.
MOUTH OF ESTUARY.
MONCK'S BAY.
RED CLIFFS.
SUMNER BEACH.
SCARBOROUGH.
SUMNER
TAYLOR'S MISTAKE.
C. scalaris.
GODLEY HEAD.
GOLLAN'S BAY.
LYTTELTON
(43.30 S., 172.40 E.)
CASS BAY
RAUPAKI BAY.
LYTTELTON HARBOUR.
ADDERLEY HEAD.
LITTLE PORT COOPER
CAMP BAY.
SHELLY BAY.
RIPA IS.
DIAMOND HARBOUR
(C. scalaris)
JETTY
QUAIL IS.
CHURCH BAY
PURAU BAY.
JETTY
GOVERNOR'S BAY.
CHARTERIS BAY.
HEAD OF THE HARBOUR.
C. dumosa?
TEDDINGTON.
N
W
E
S
SCALE.
0 10 20 30 40 80 120 160 Chains.
0 ½ 1 1½ 2 Miles.

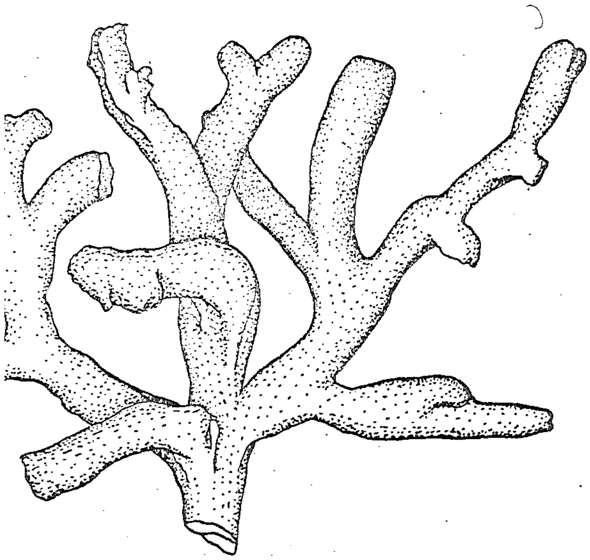


Fig. 9.

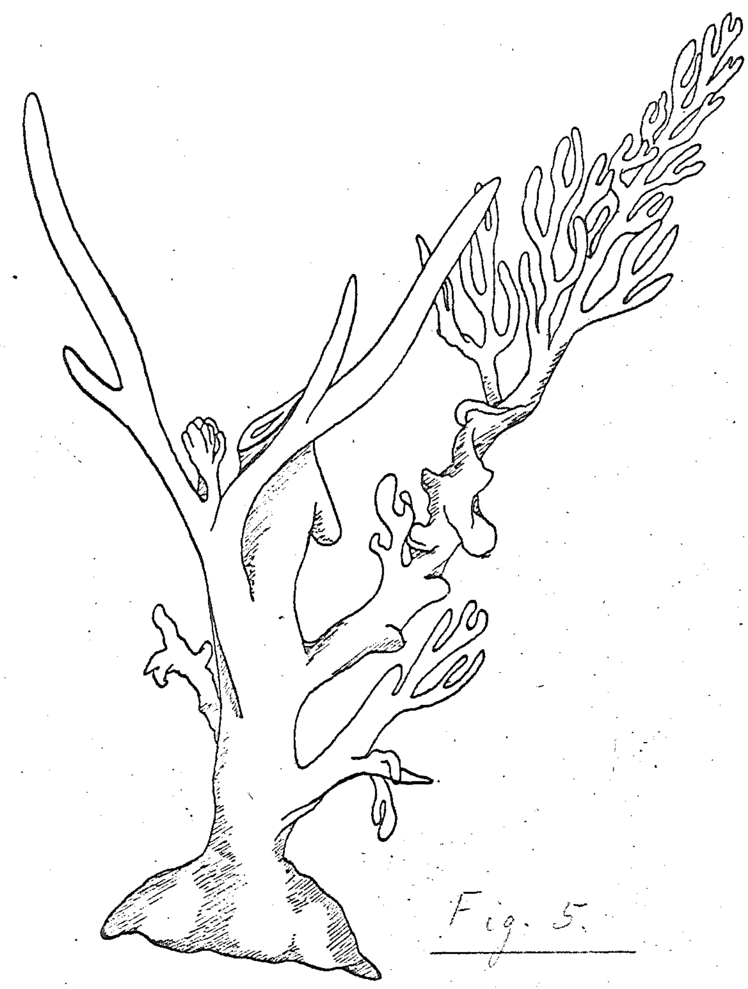


Fig. 5.

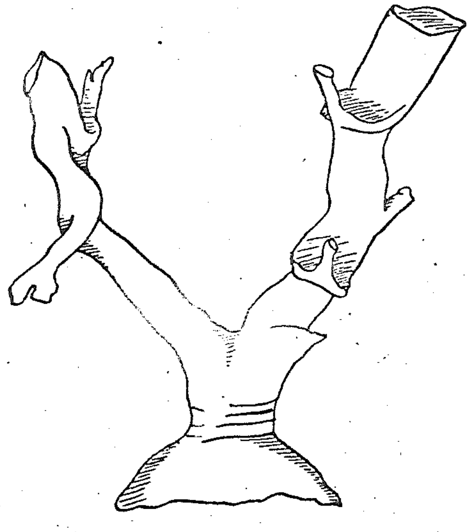
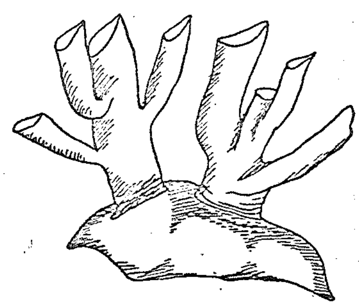


Fig. 3.



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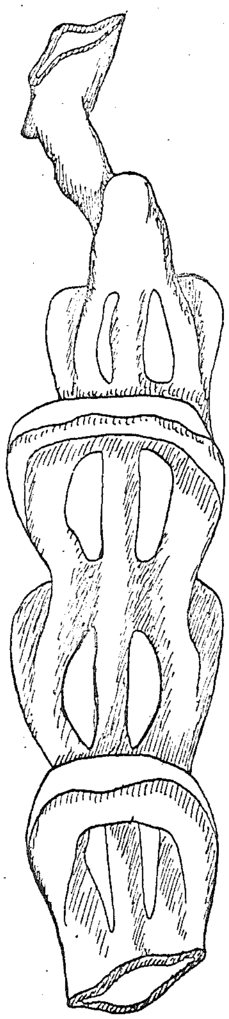

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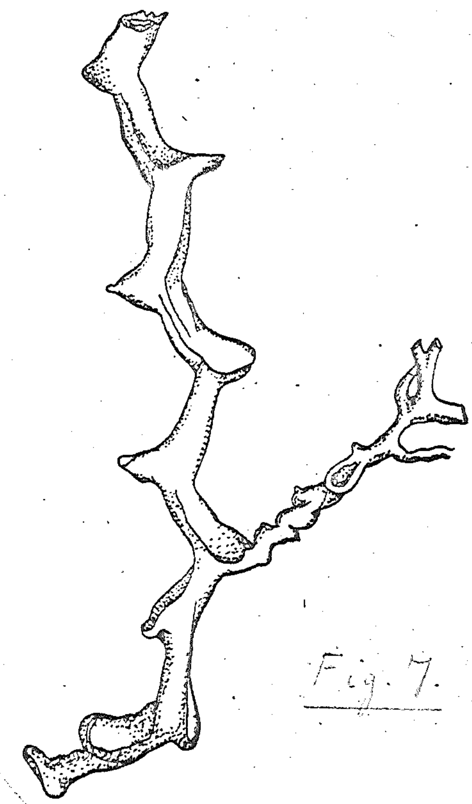

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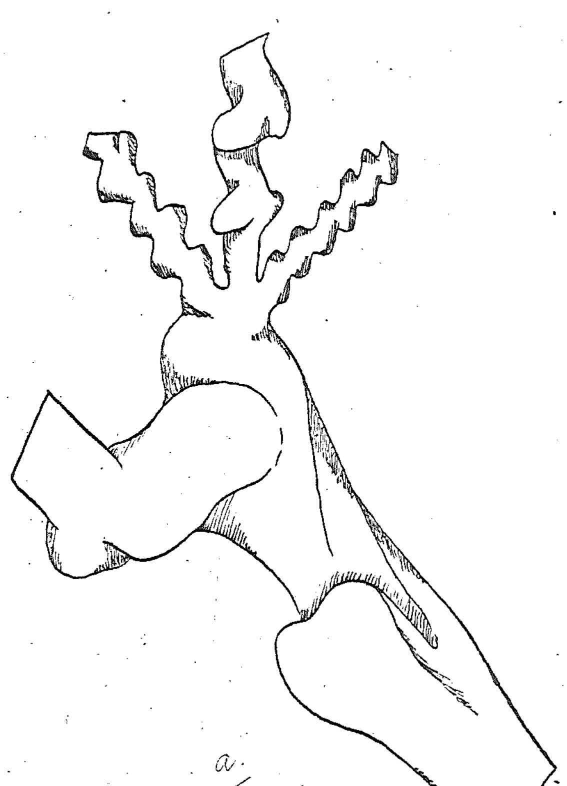
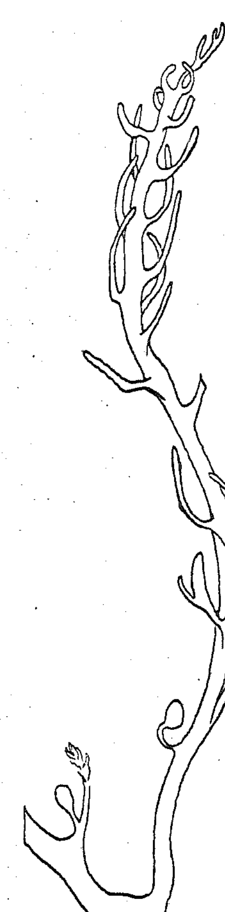


a.

Fig. 8 (a, b)



b.

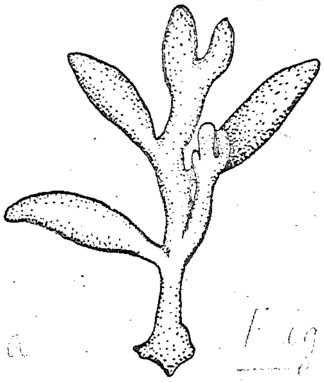


Fig. 10.

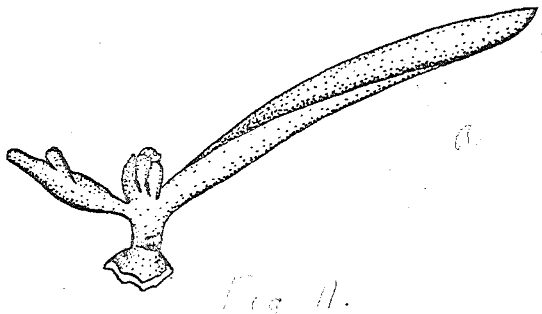


Fig. 11.

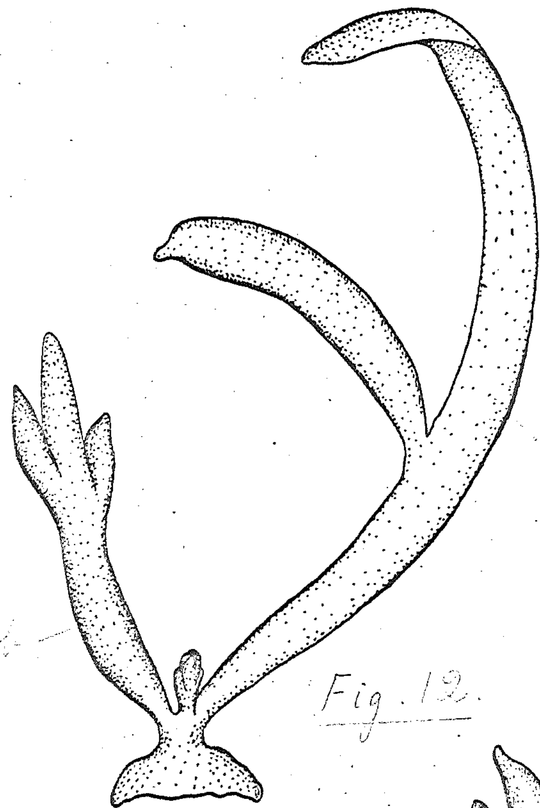


Fig. 12.

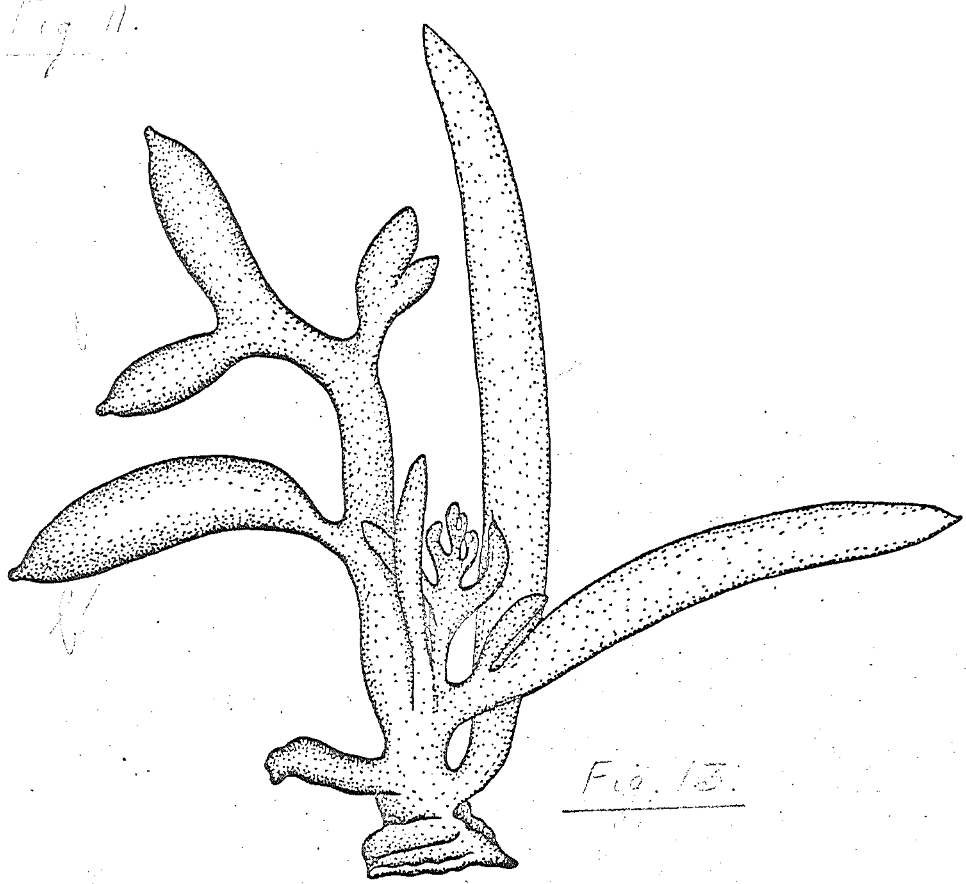


Fig. 13.

Fig. 14.

Fig. 15.

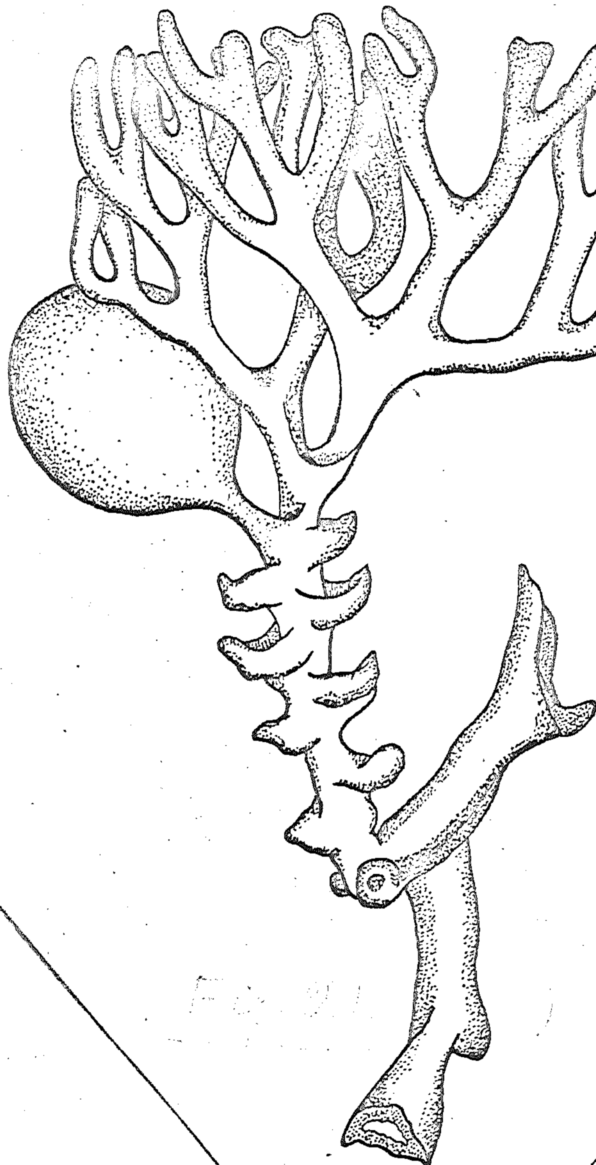


Fig. 21

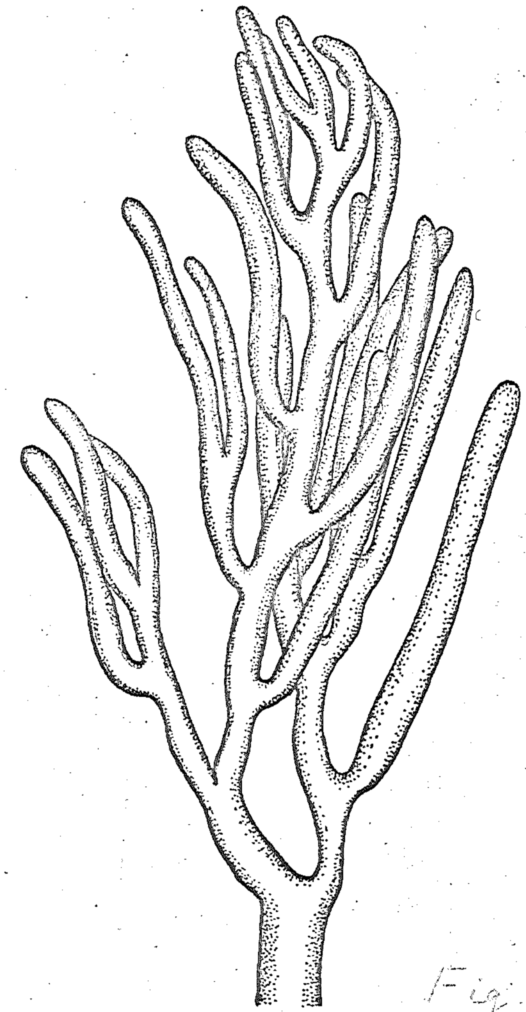


Fig. 20

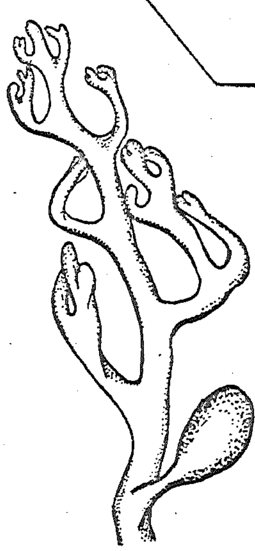


Fig. 18.

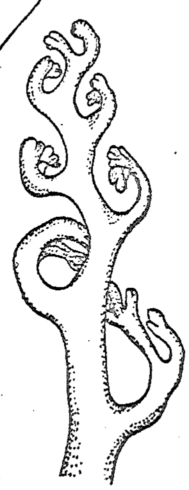


Fig. 17

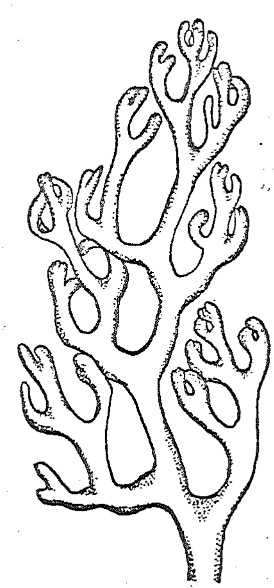


Fig. 19.

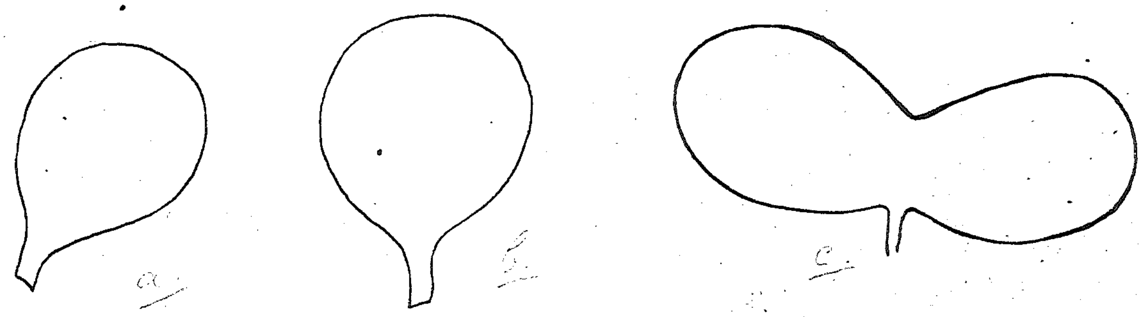


Fig. 22 (a-c)

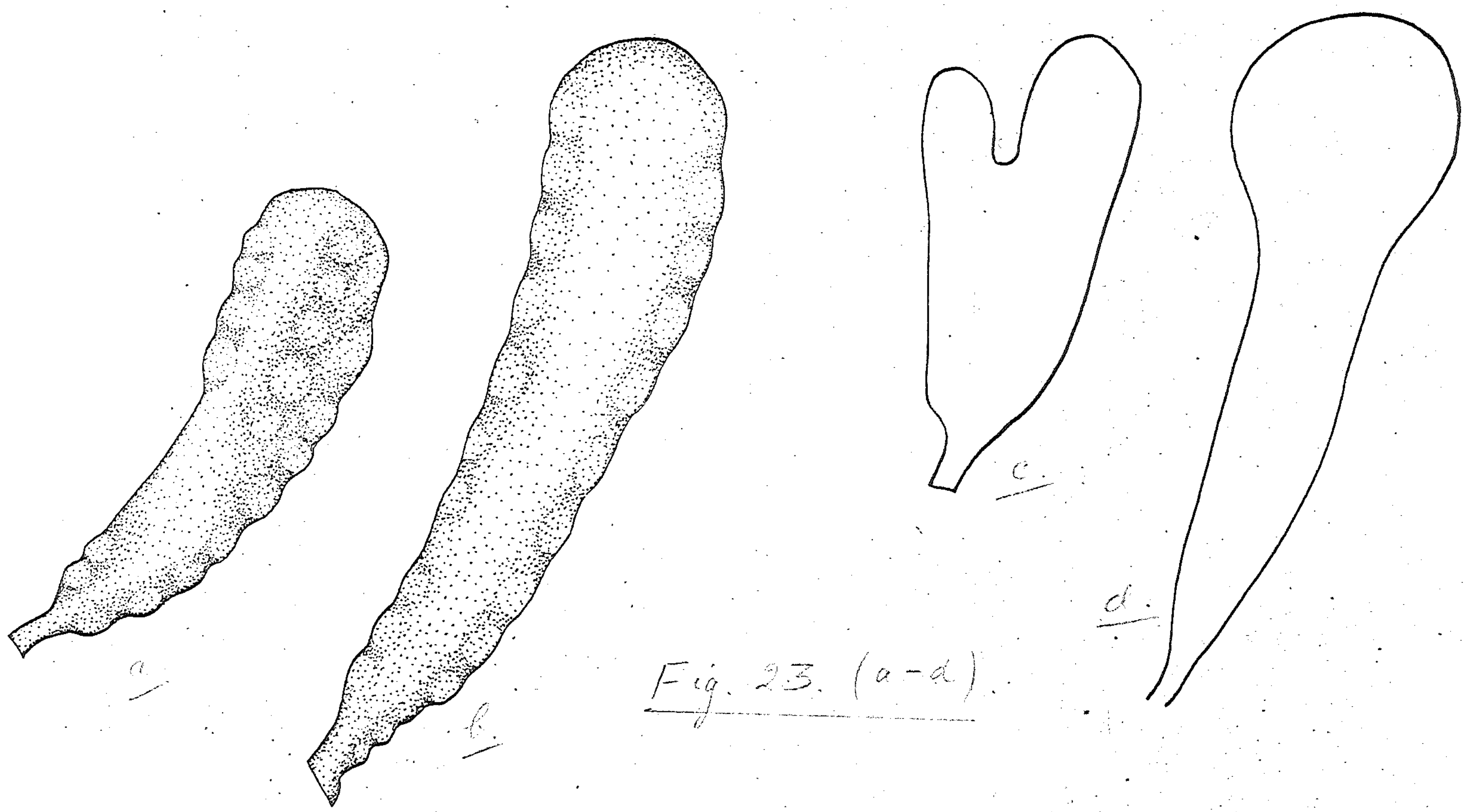
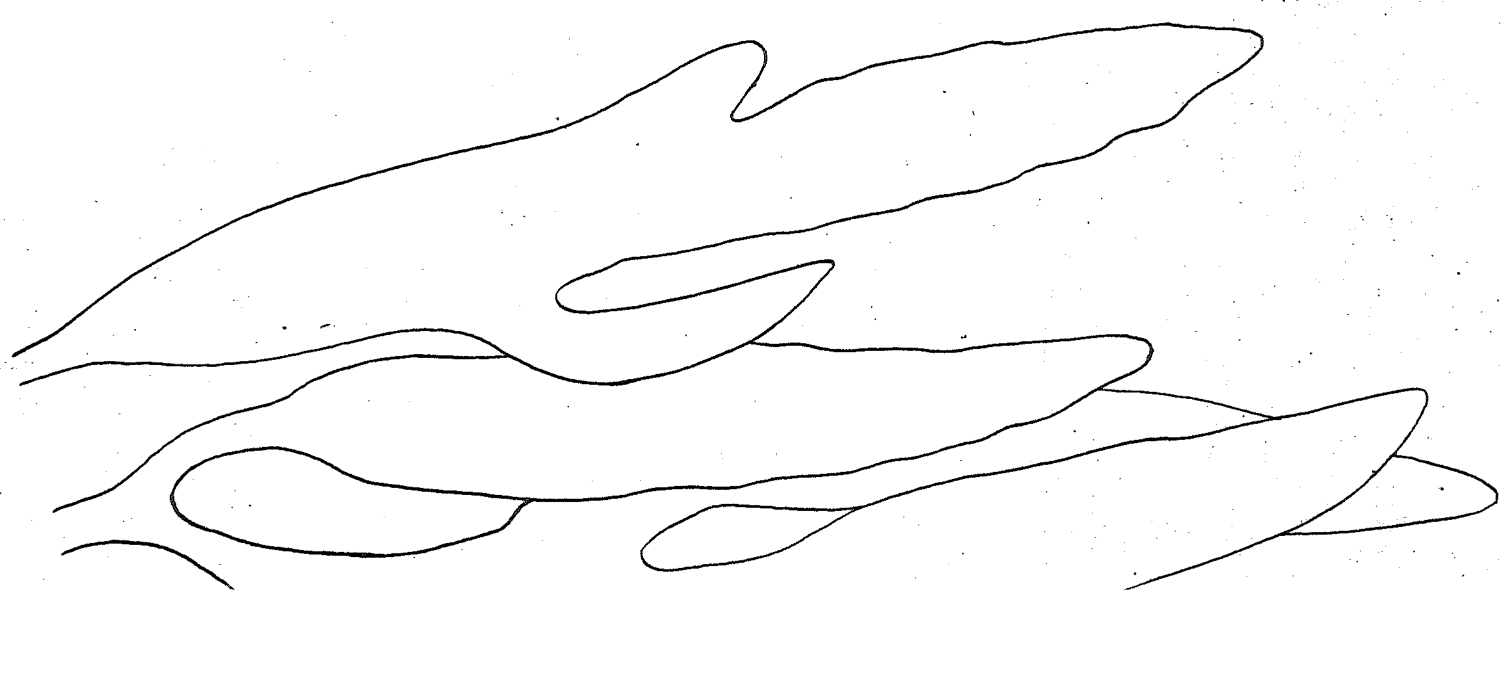
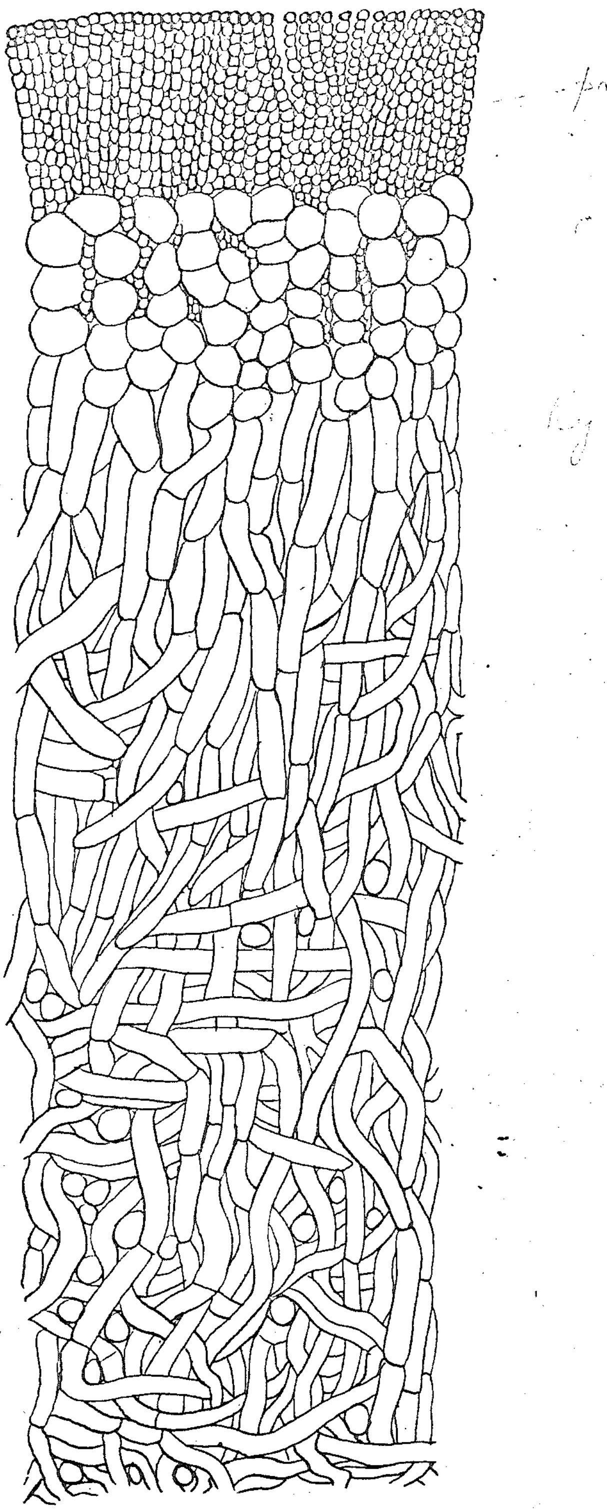
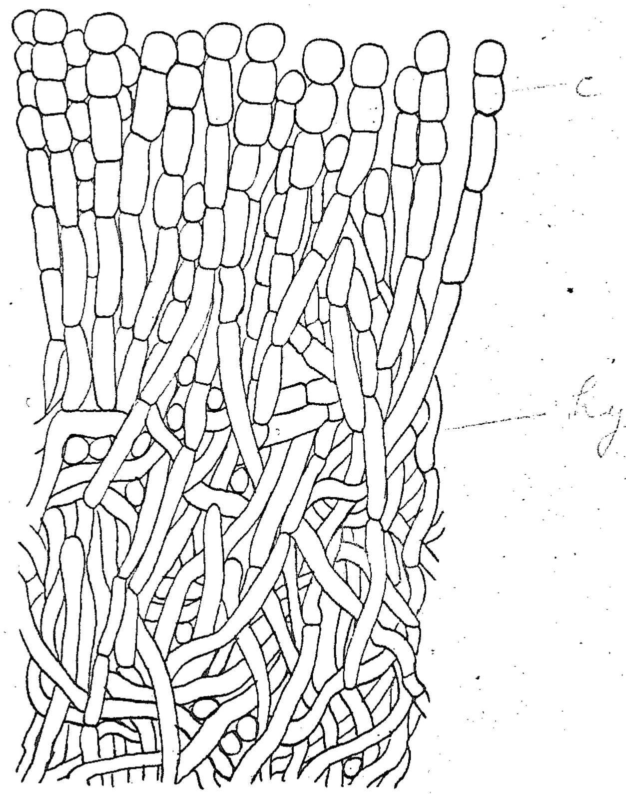


Fig. 23 (a-d)





g. 26.



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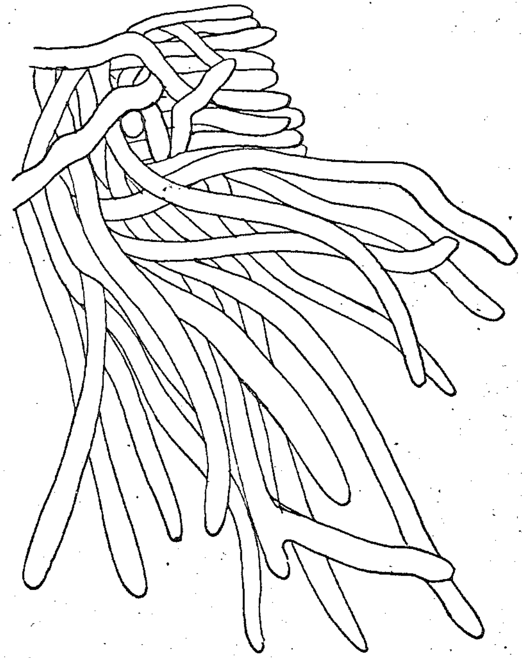

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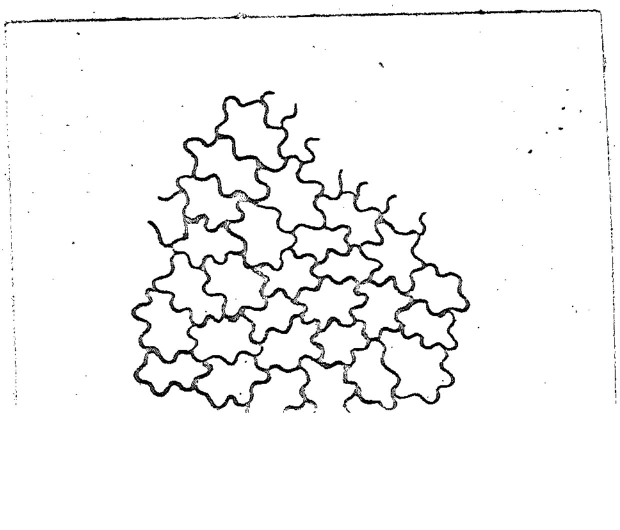

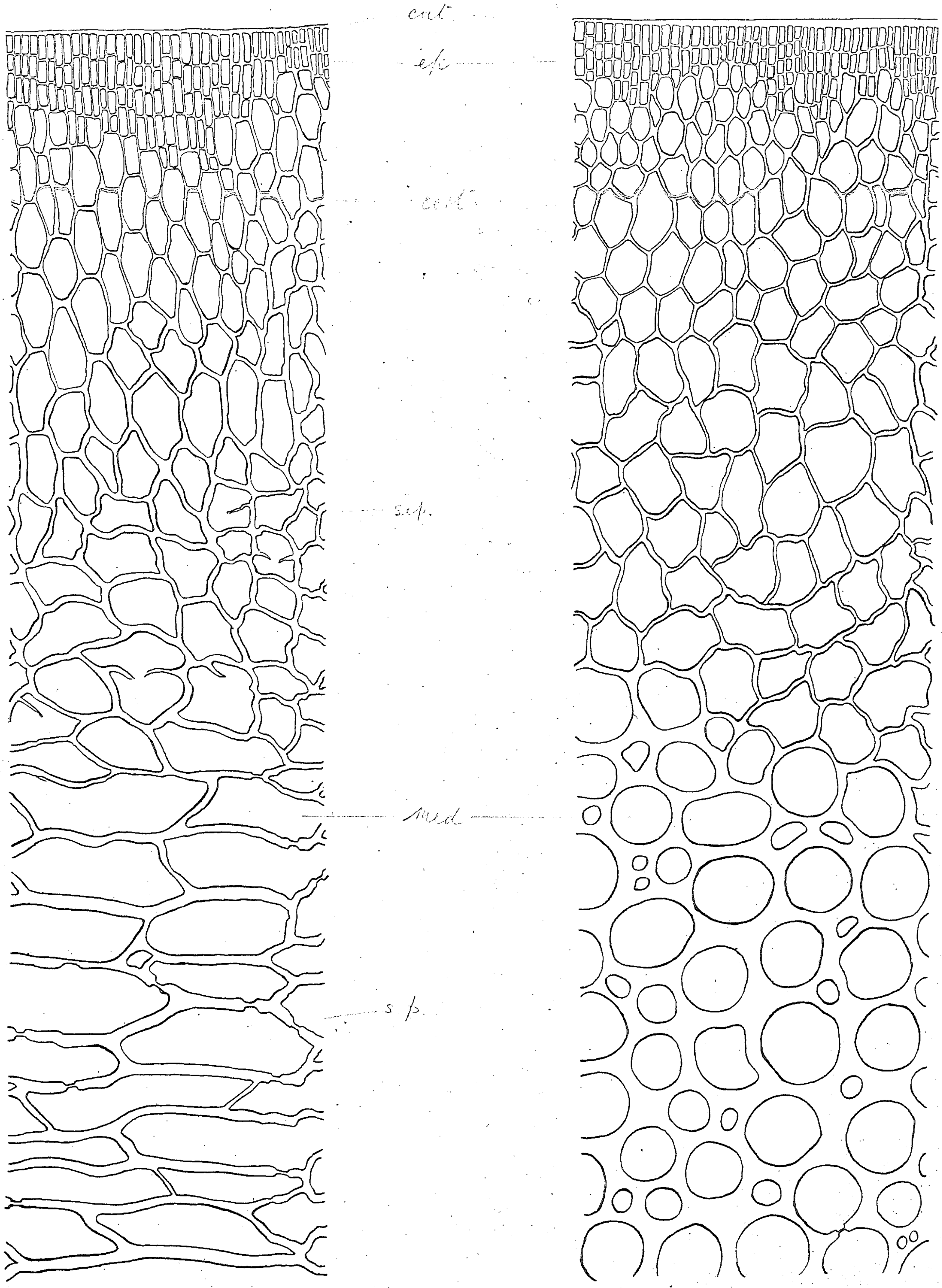
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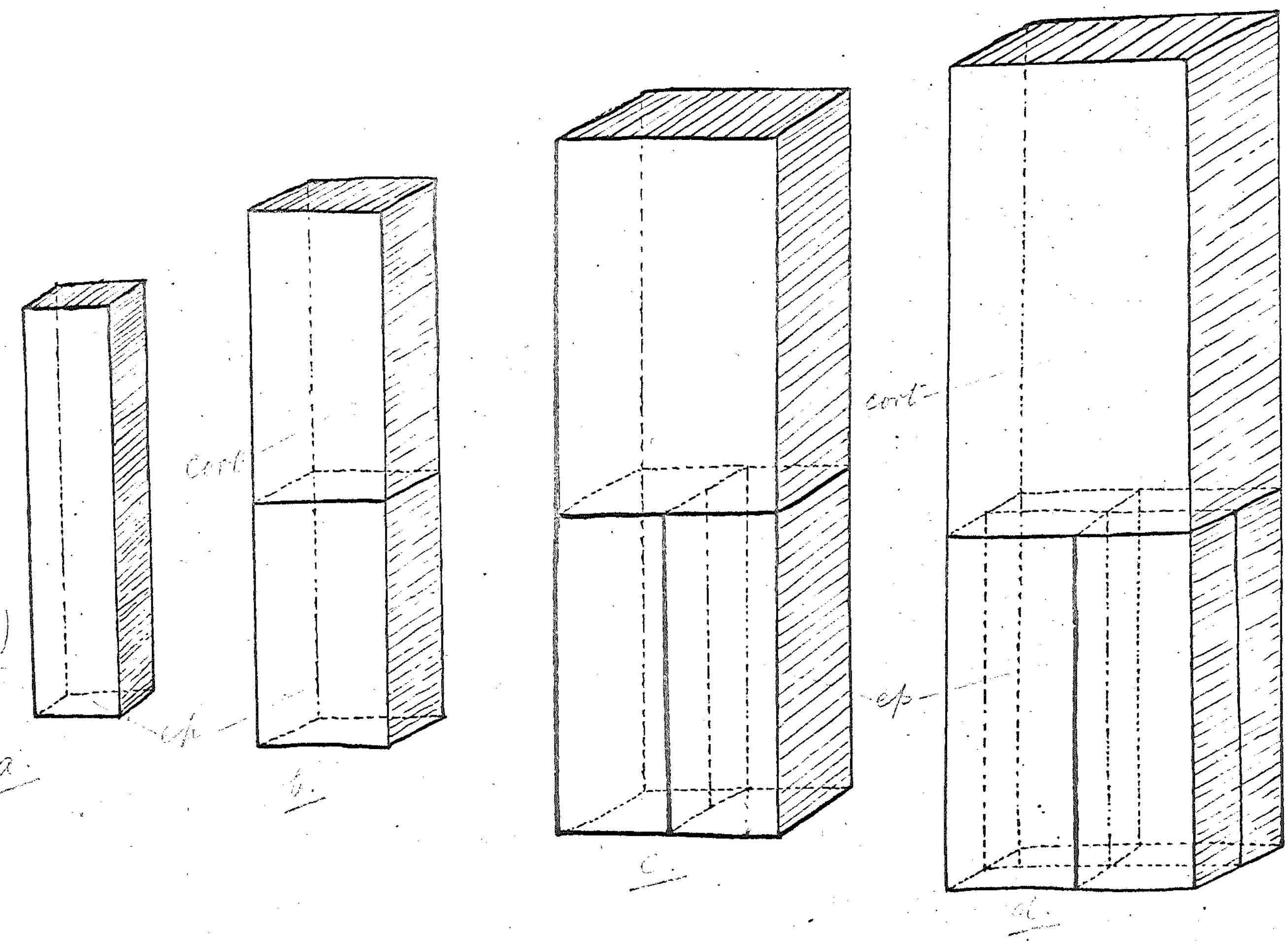


Fig. 31. (a–d)

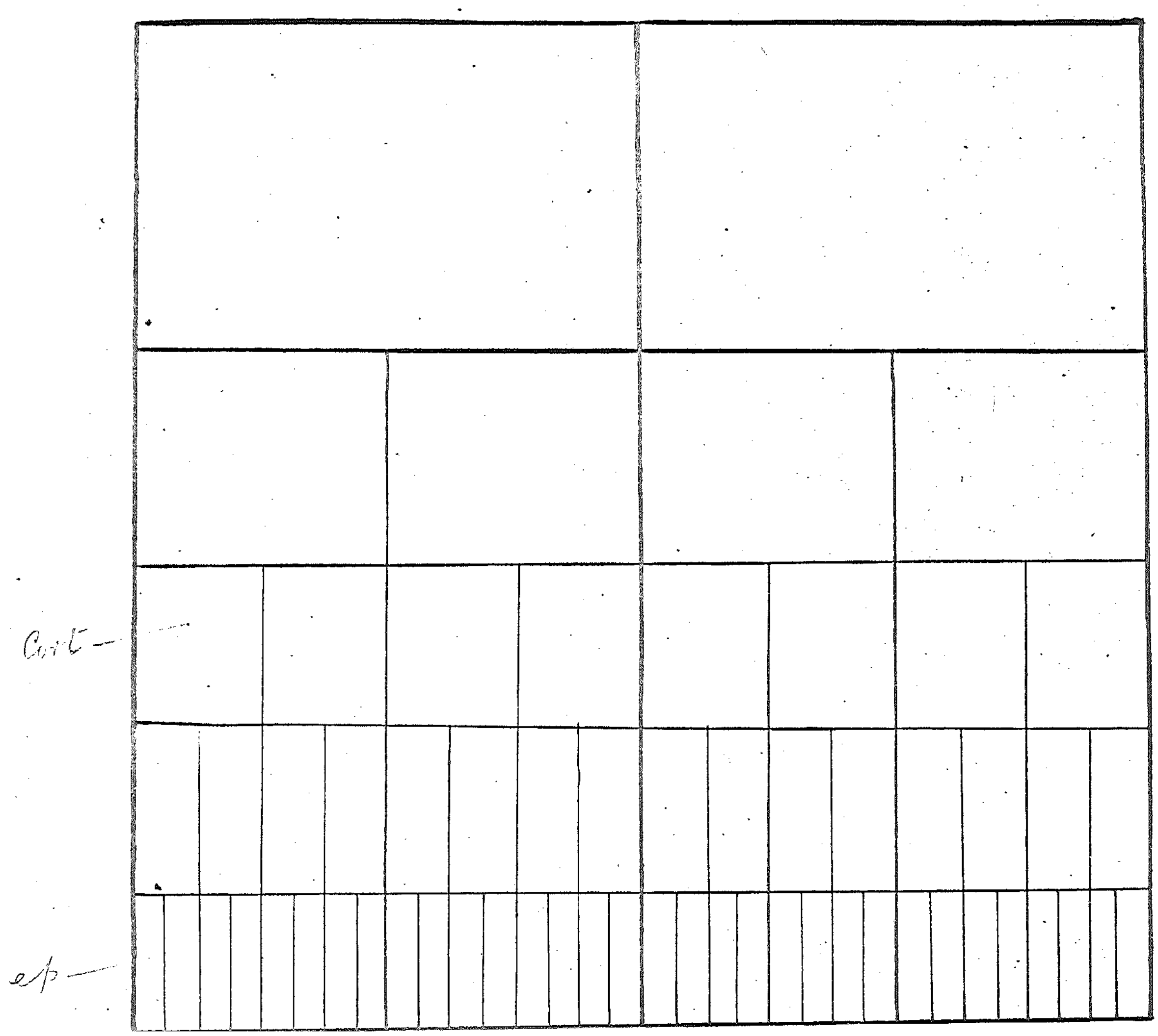


Fig. 3.2.

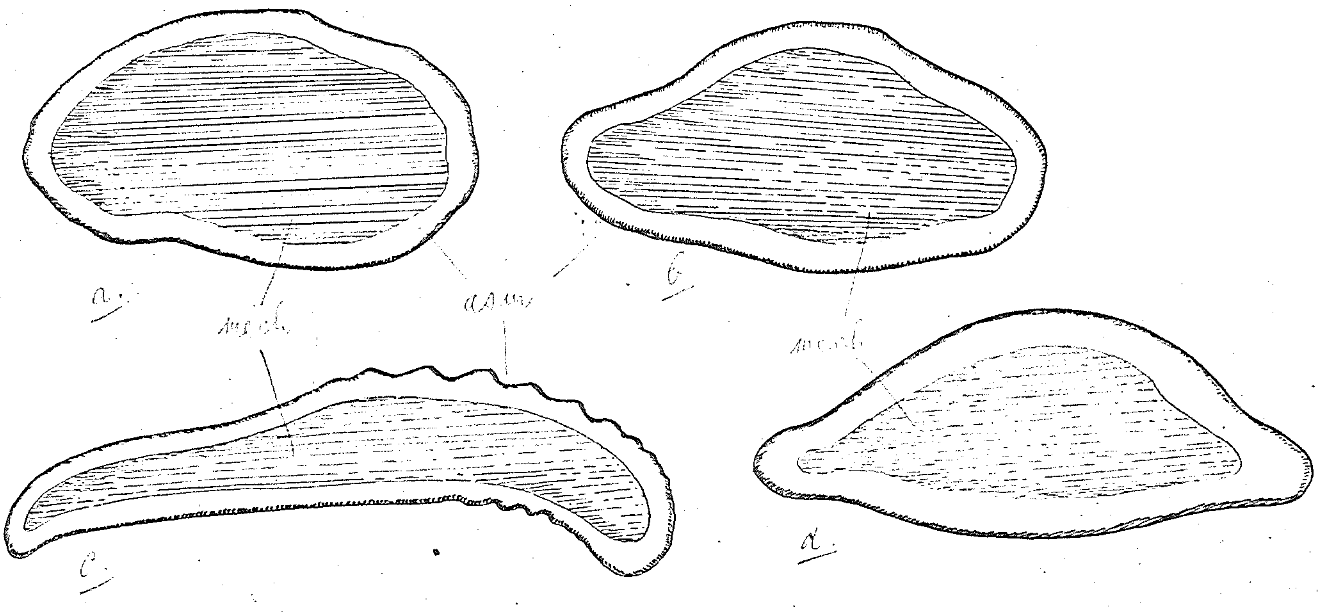


Fig. 33. (a - d)

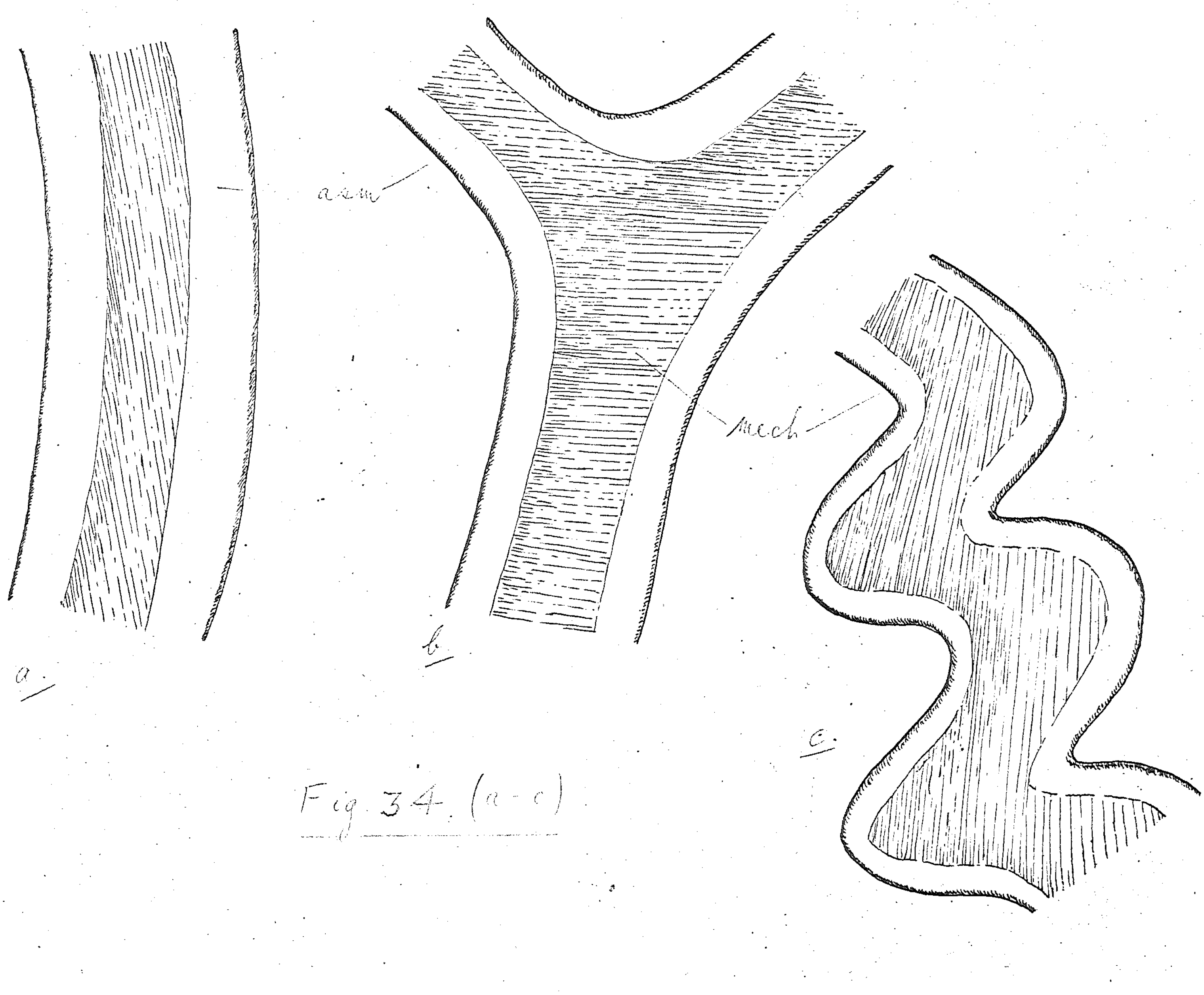


Fig. 34. (a - c)

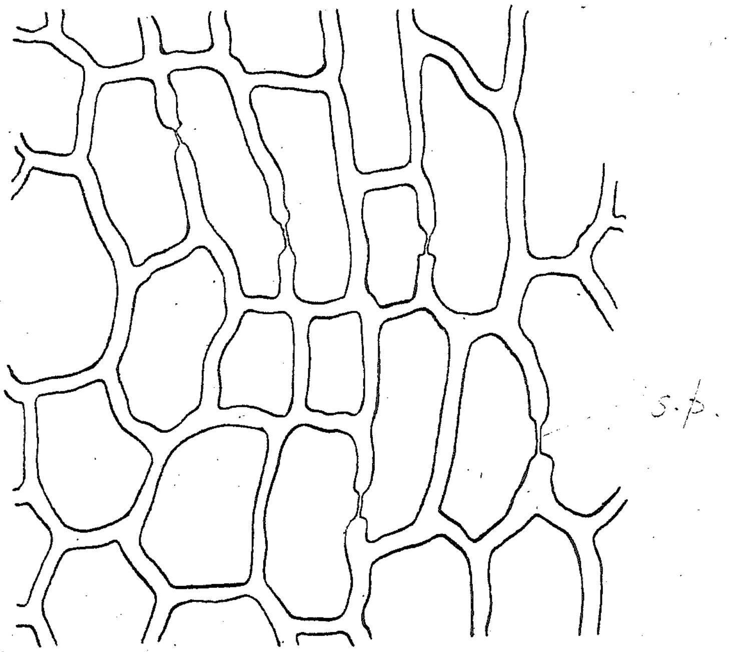
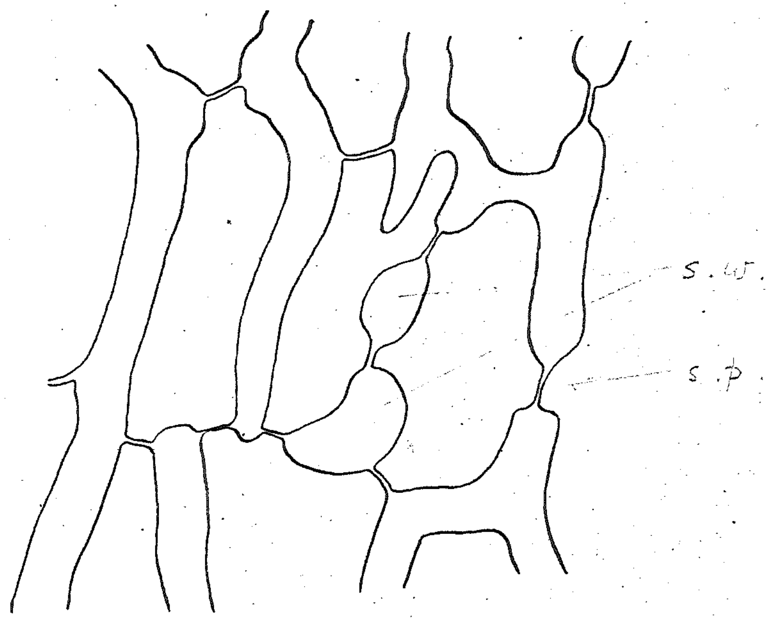


Fig. 35



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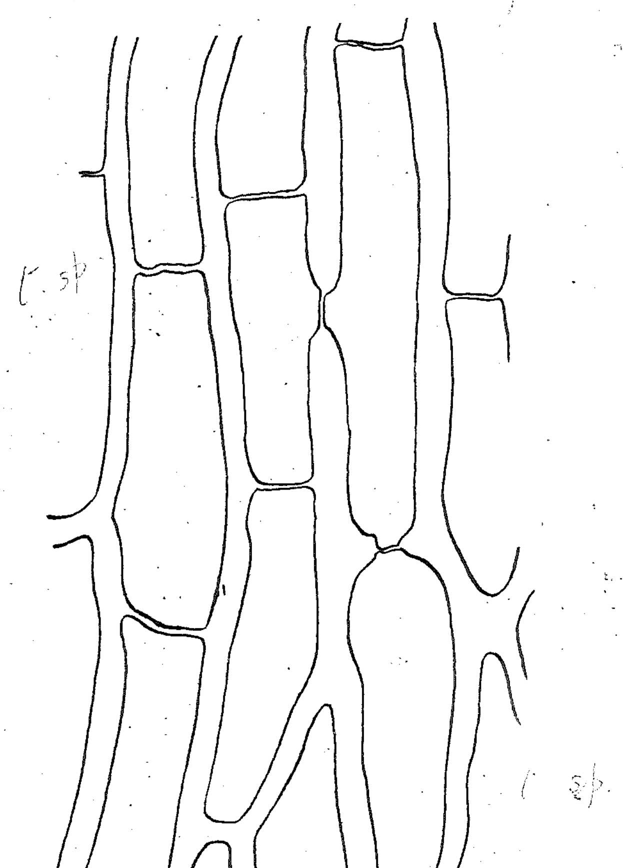

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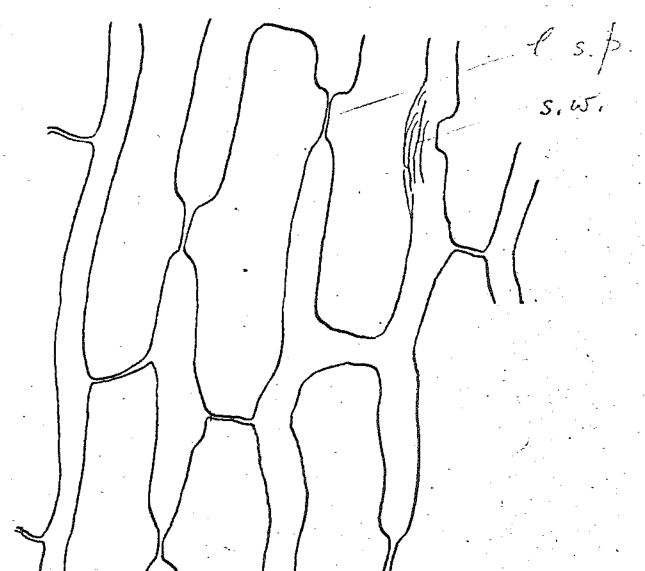

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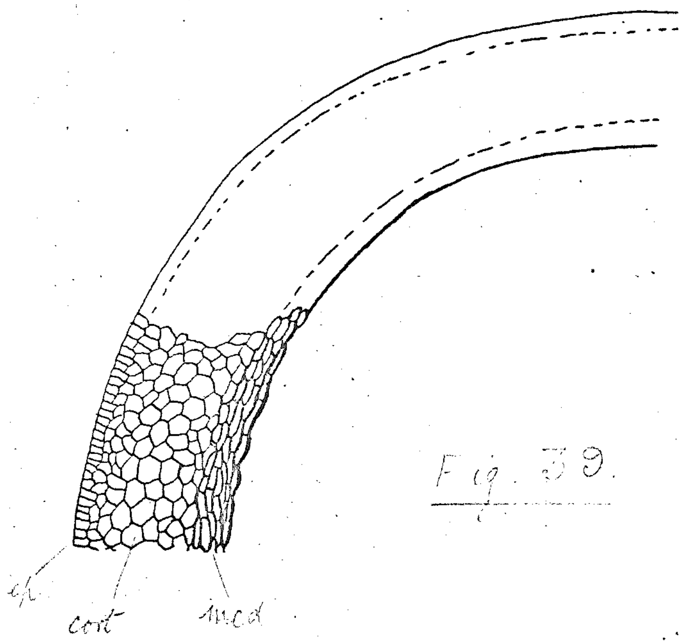

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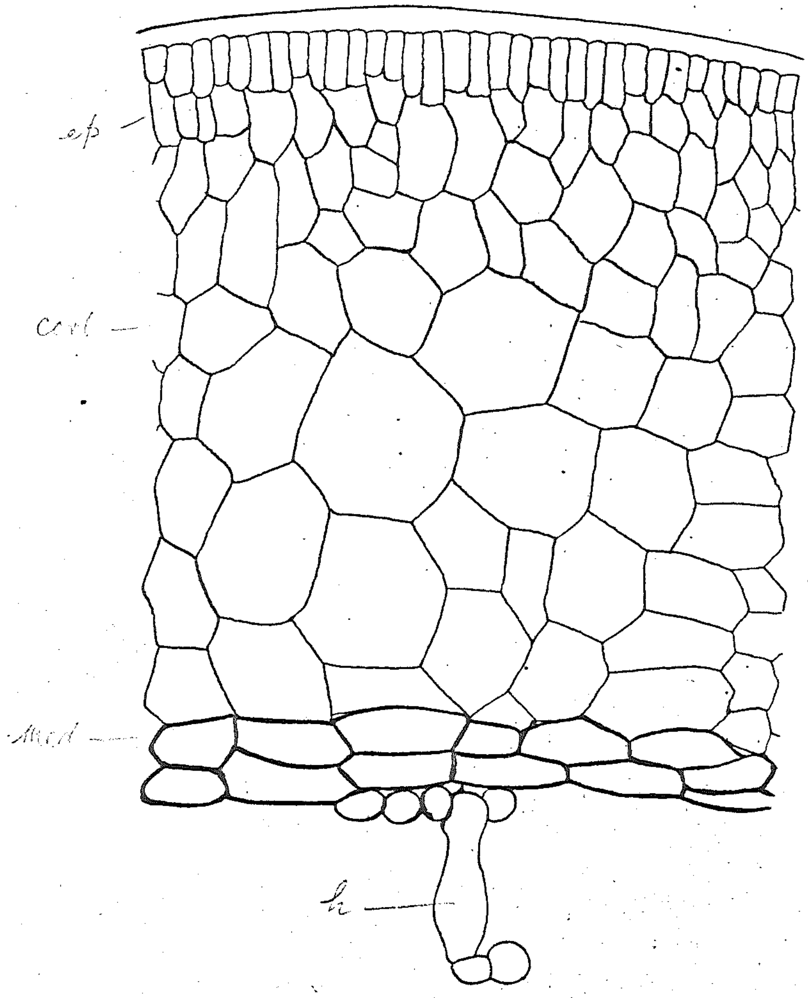

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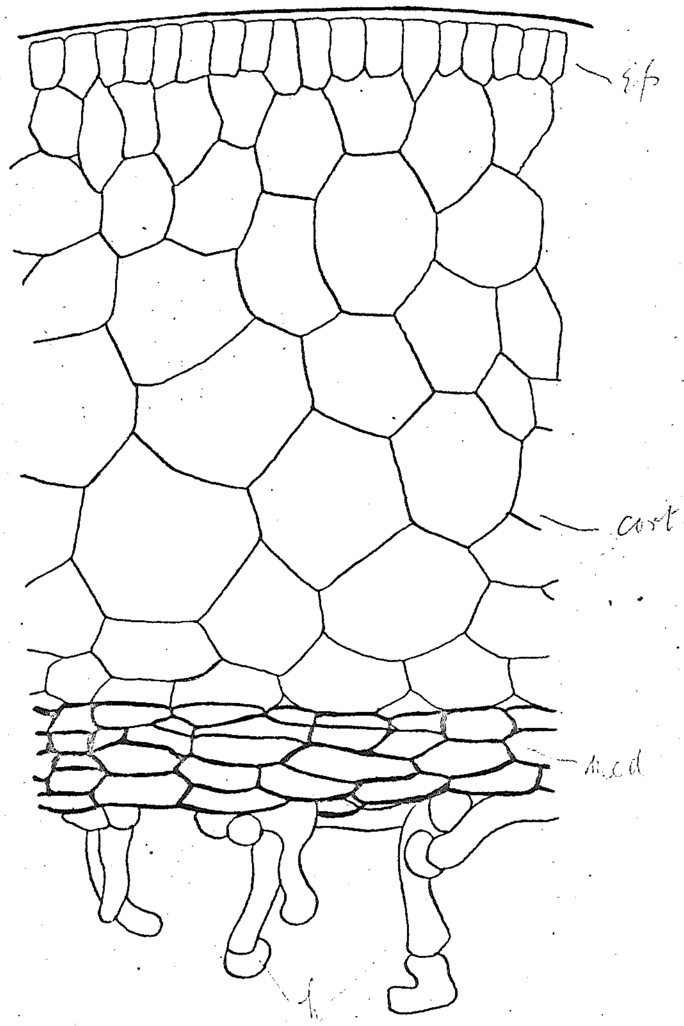
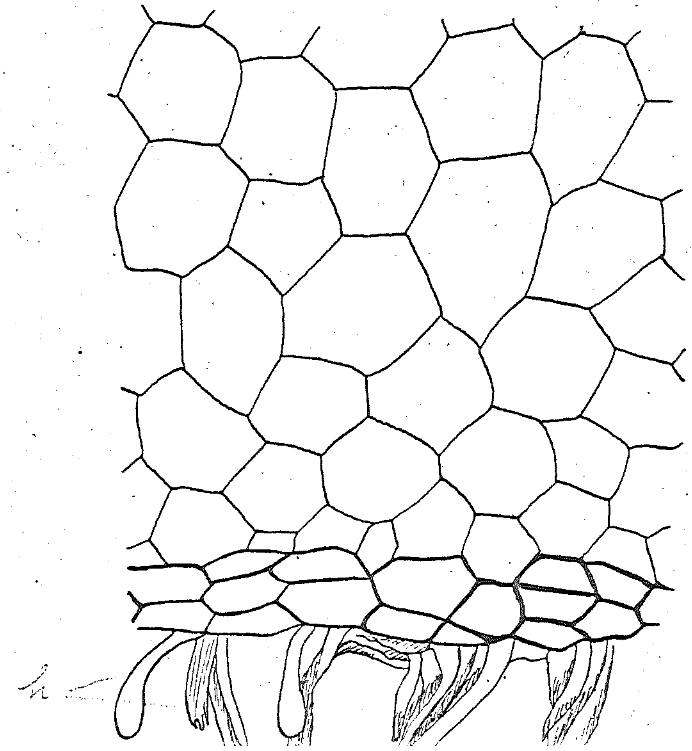




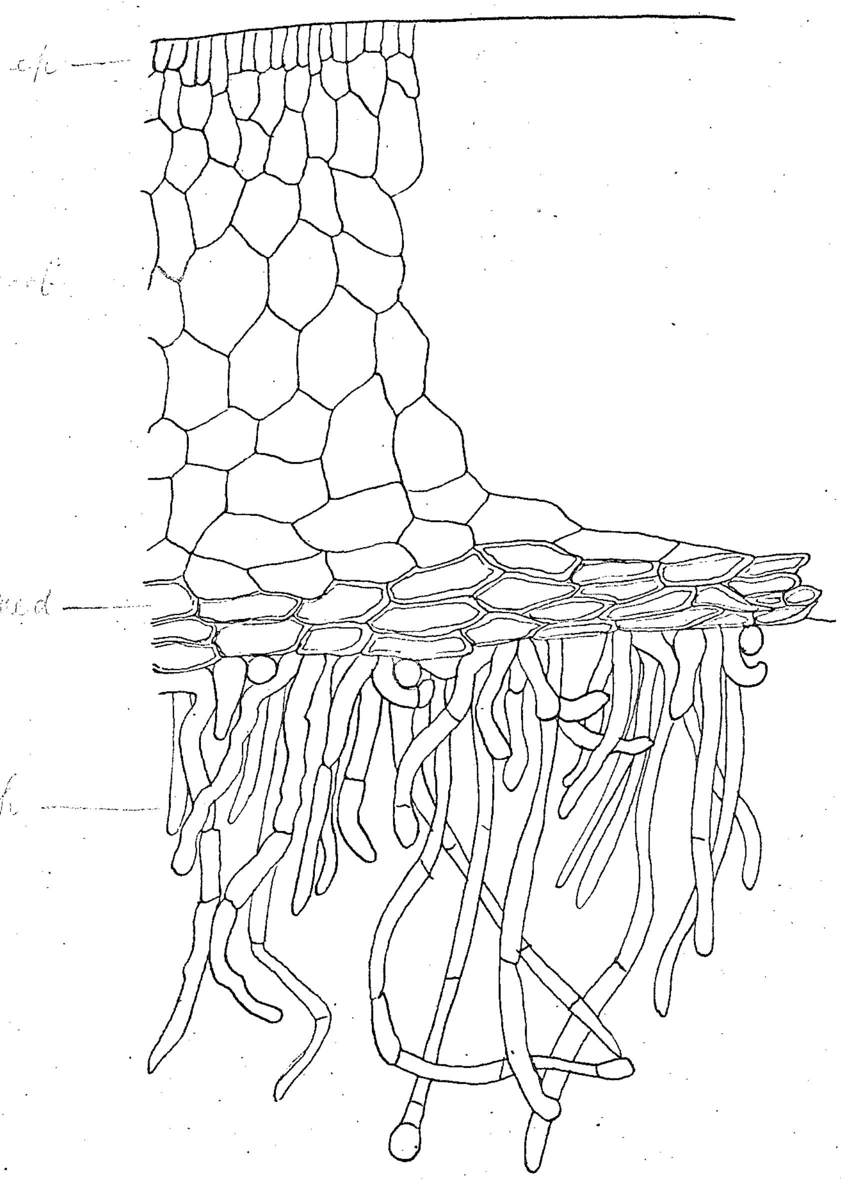
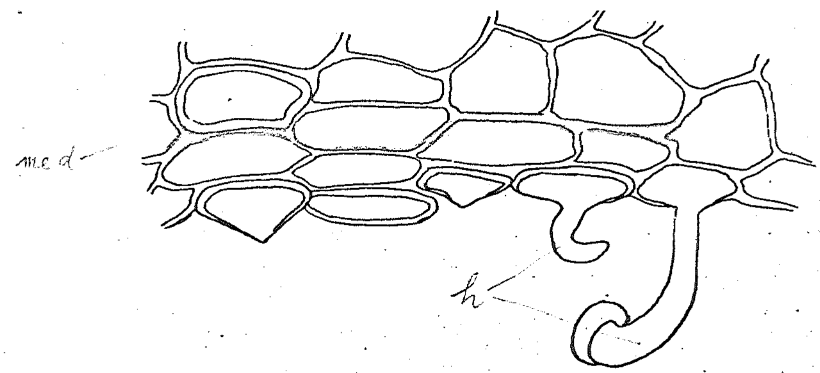


Fig. 43.



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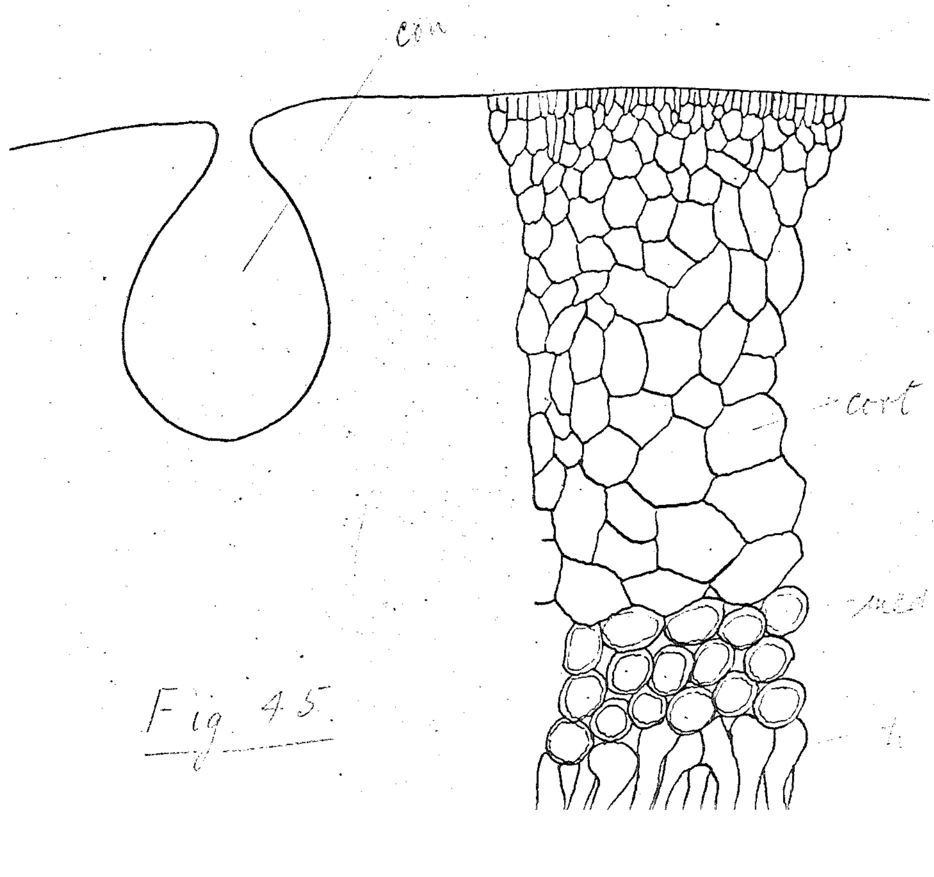

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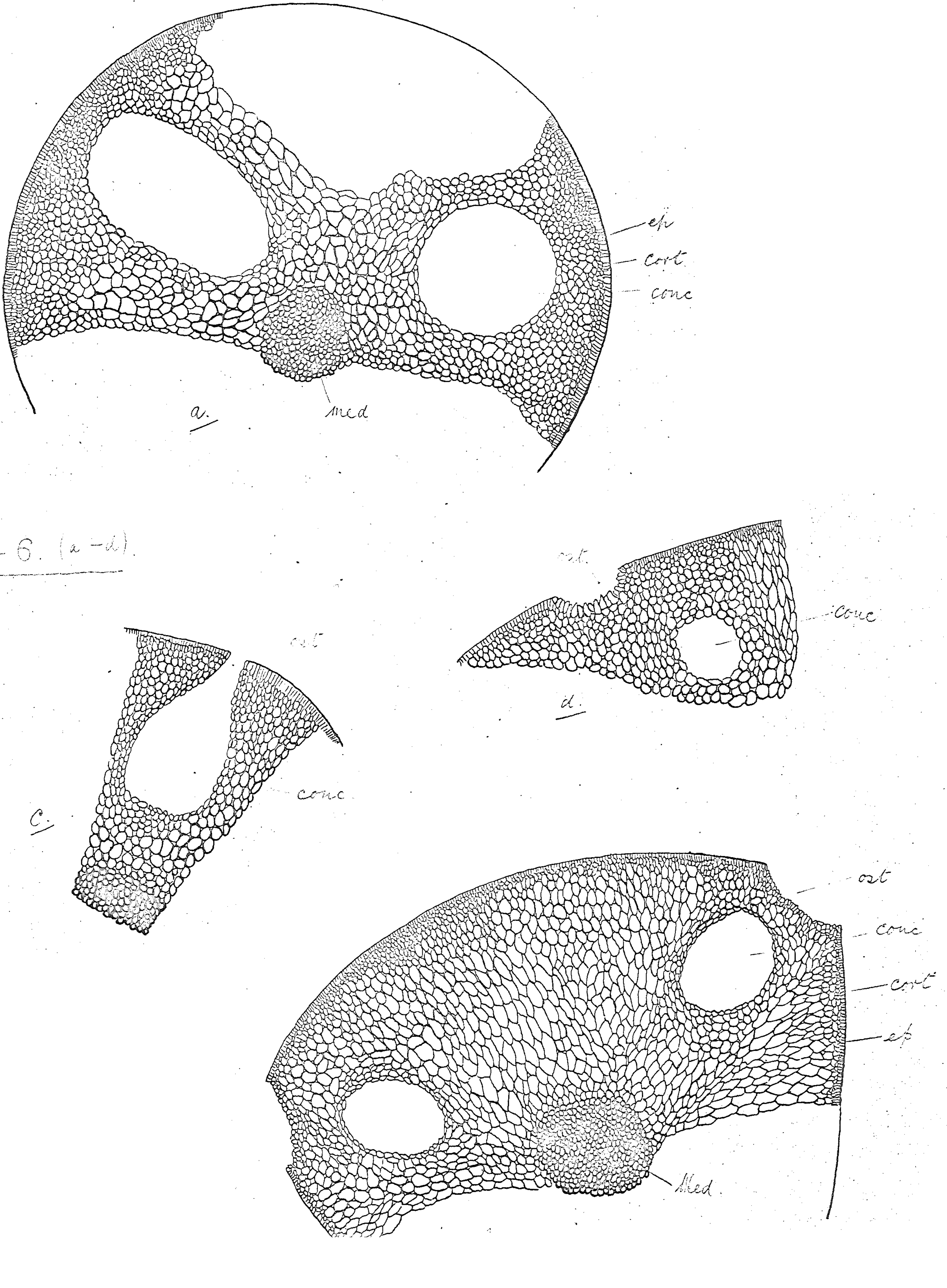


Fig. 46. (a–d)

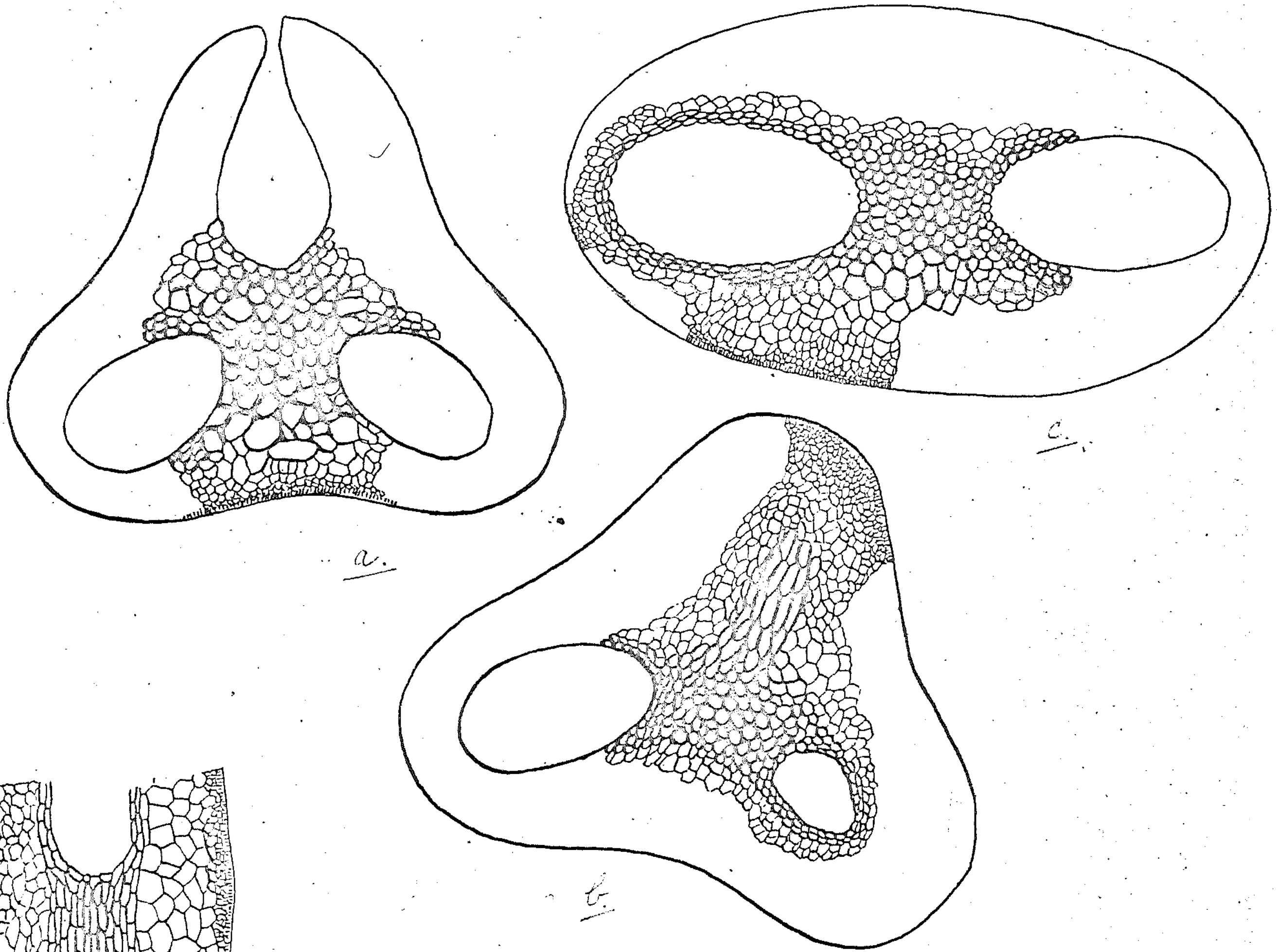
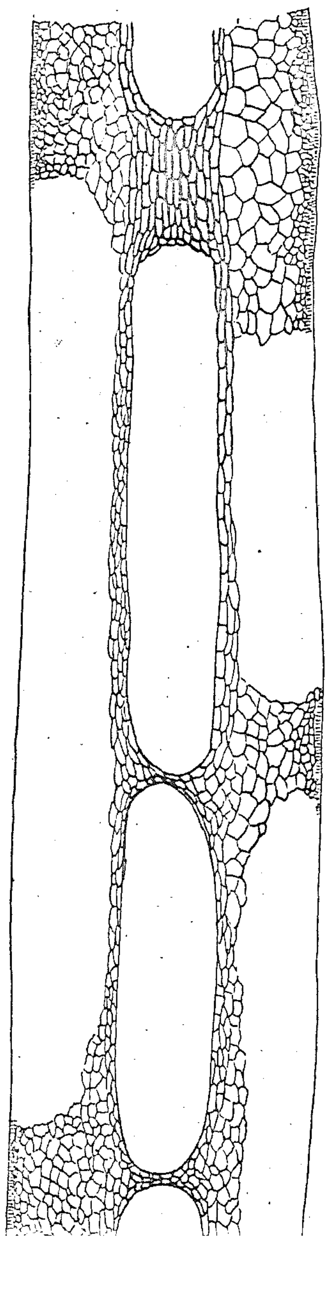


Fig. 47. (a–c).



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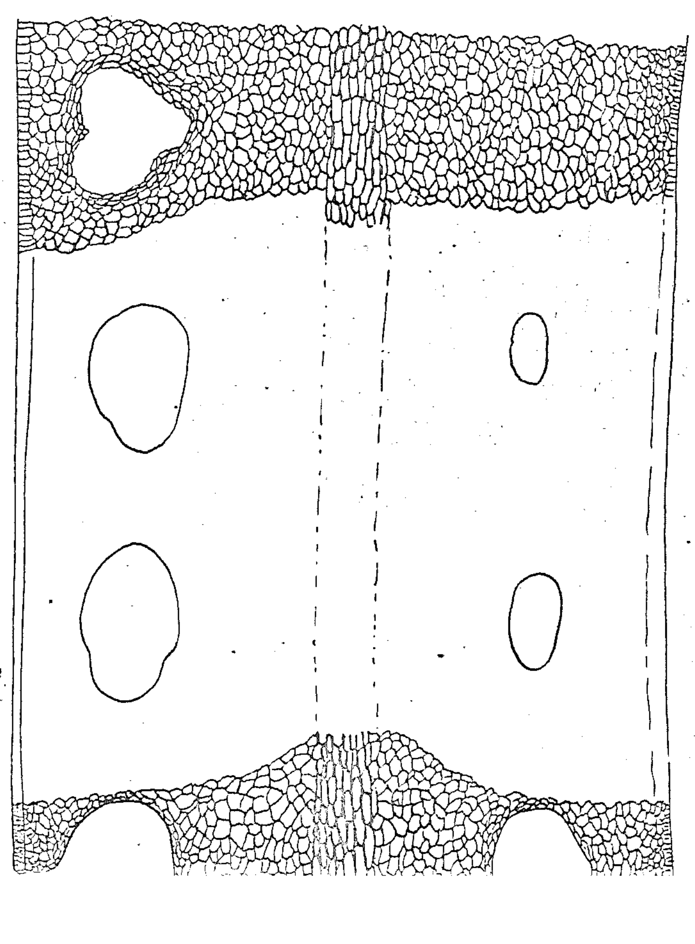

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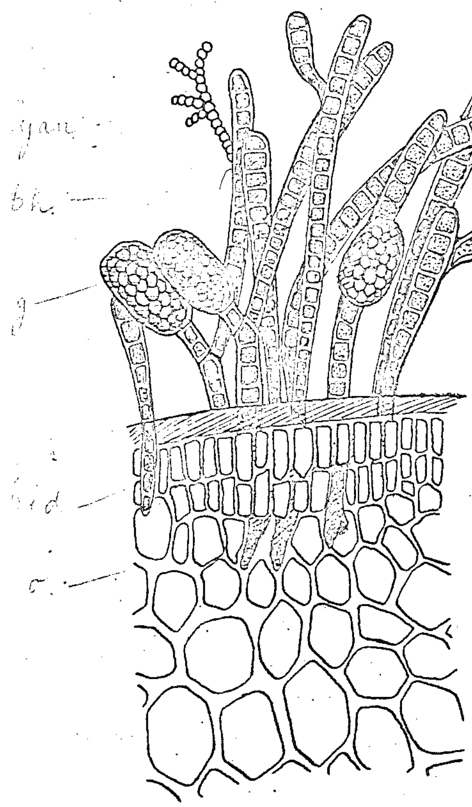

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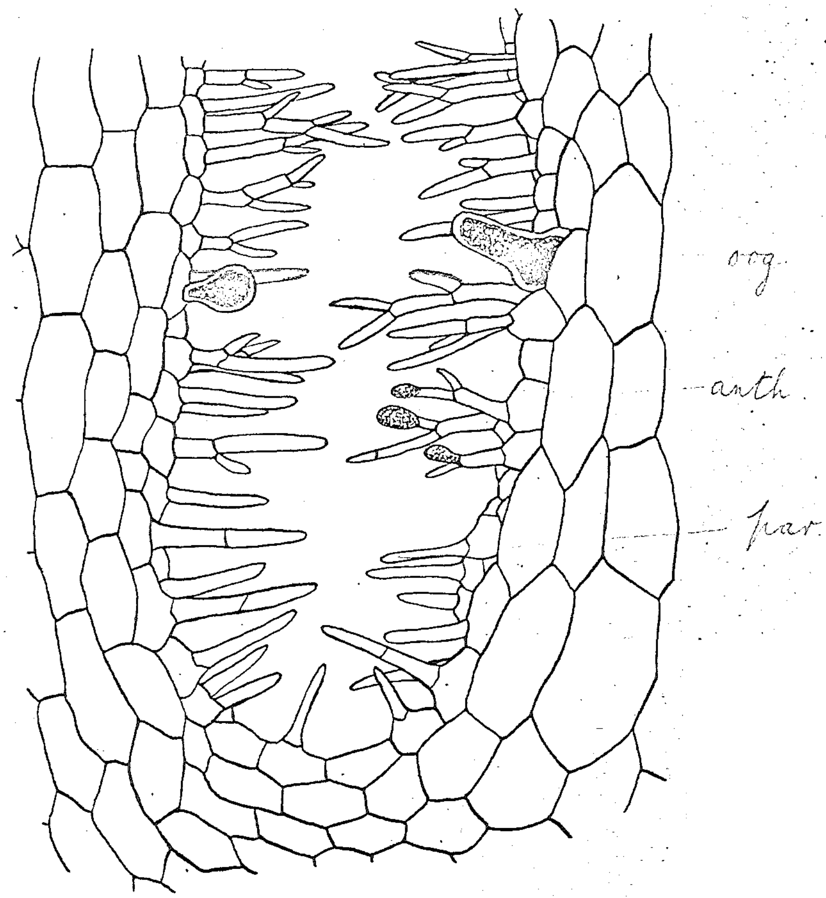
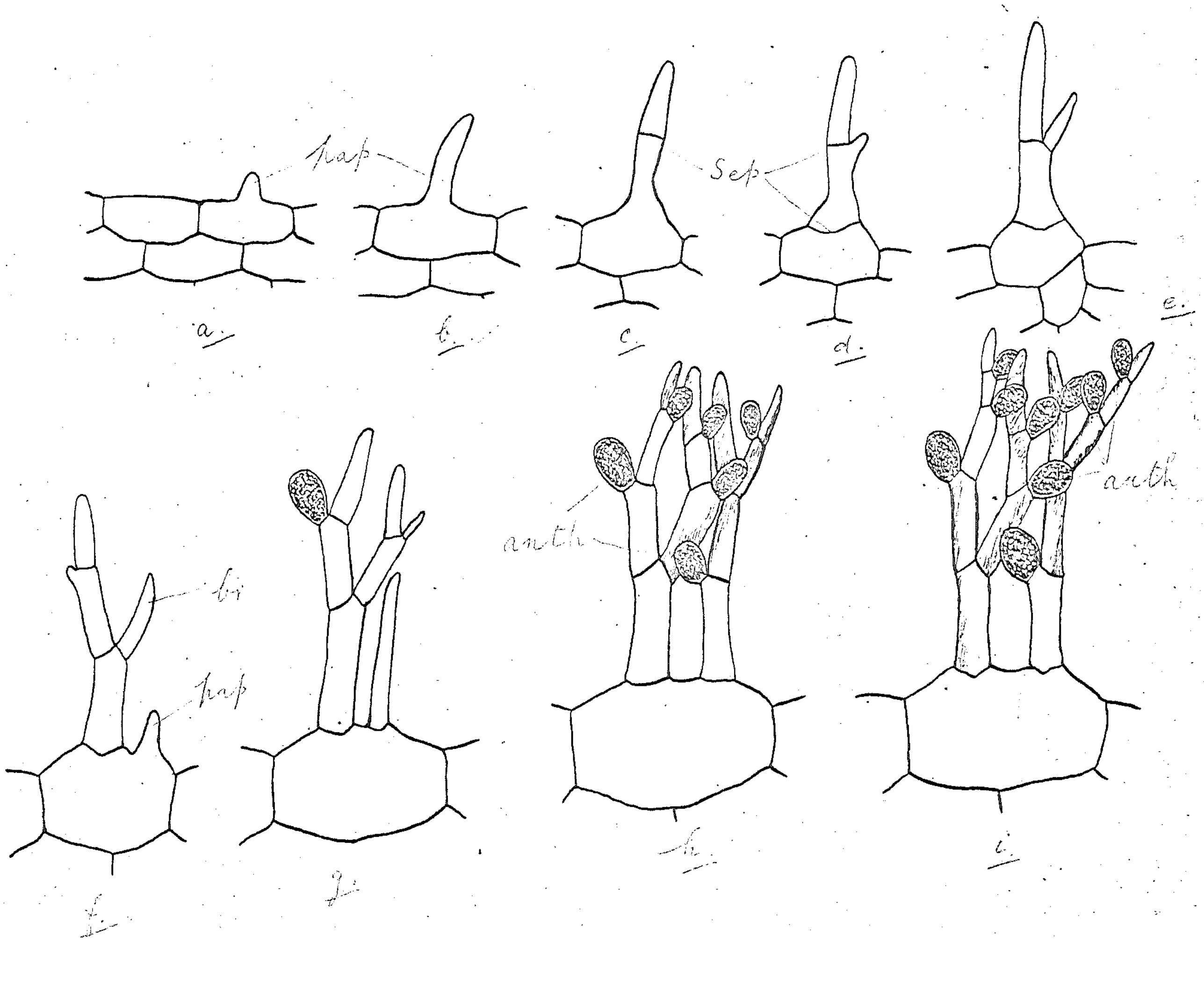


Fig. 51.



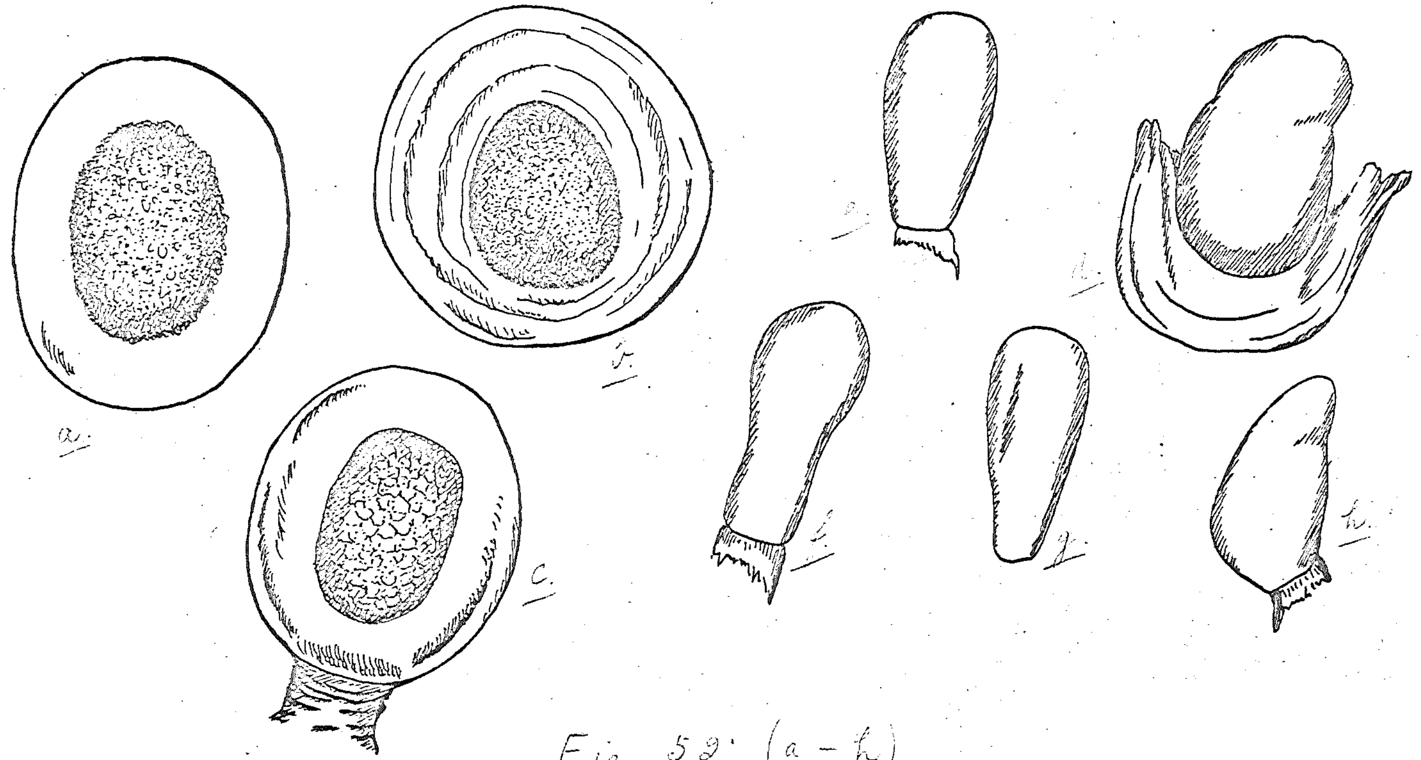


Fig. 52: (a – h).

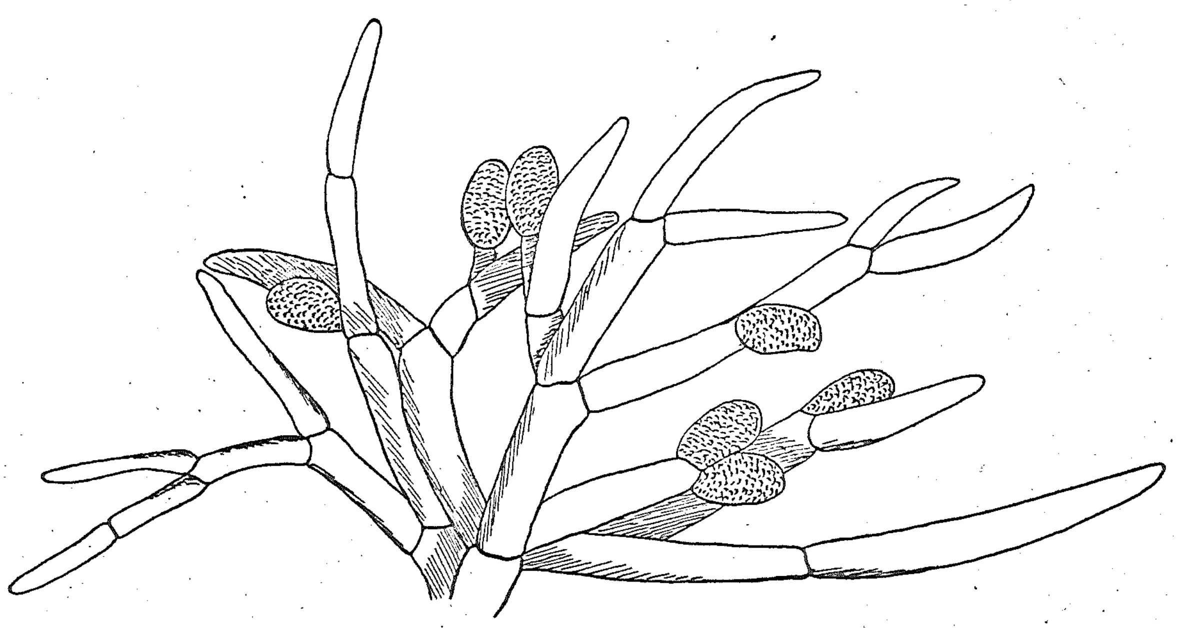


Fig. 54

Plate V

Plate VI

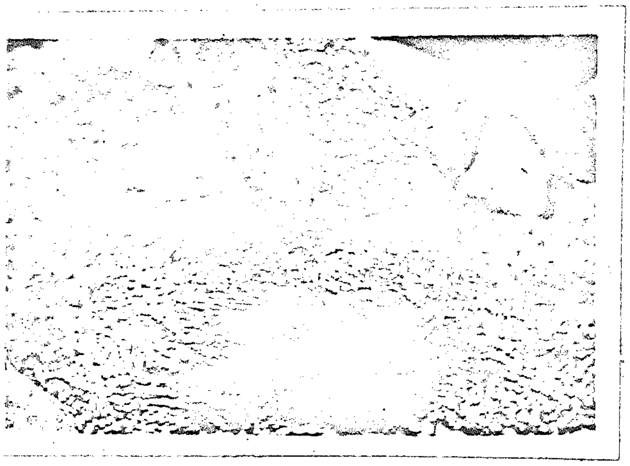


Plate VII

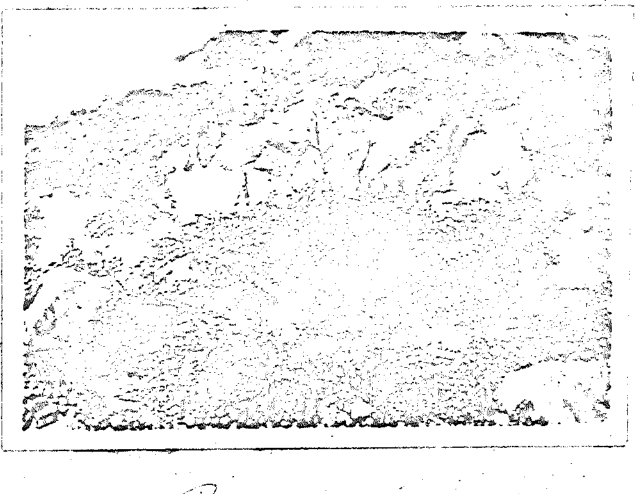
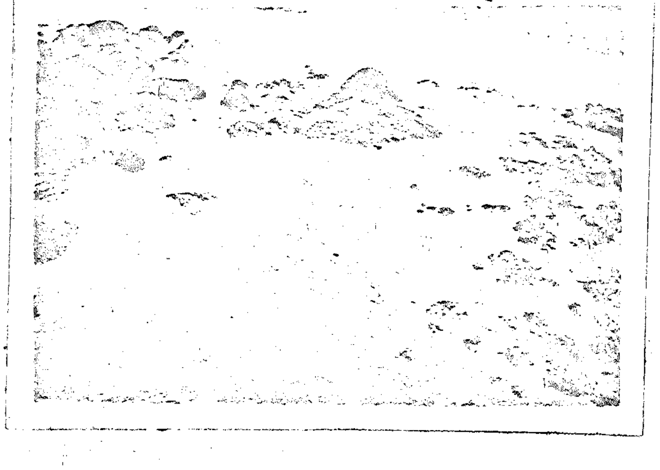


Plate VIII



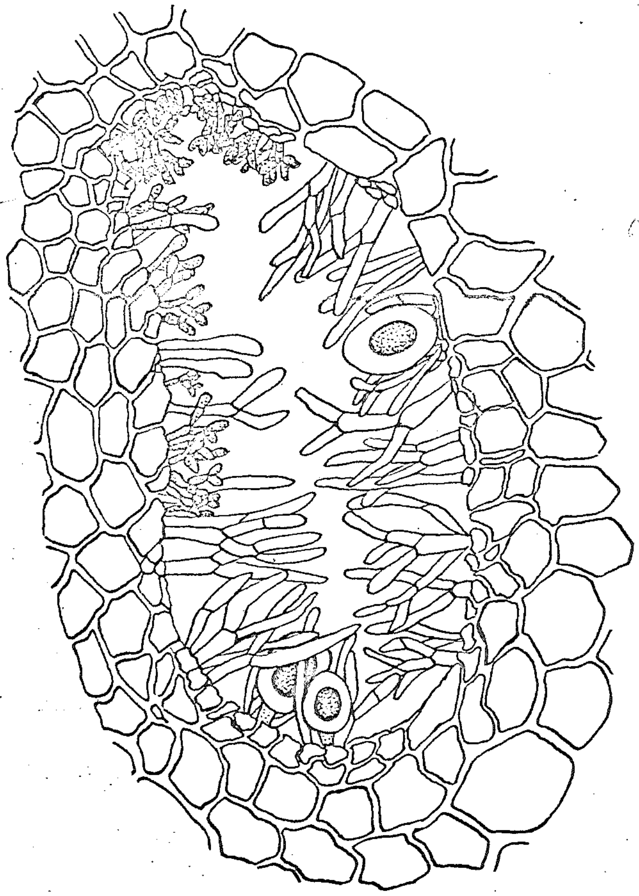
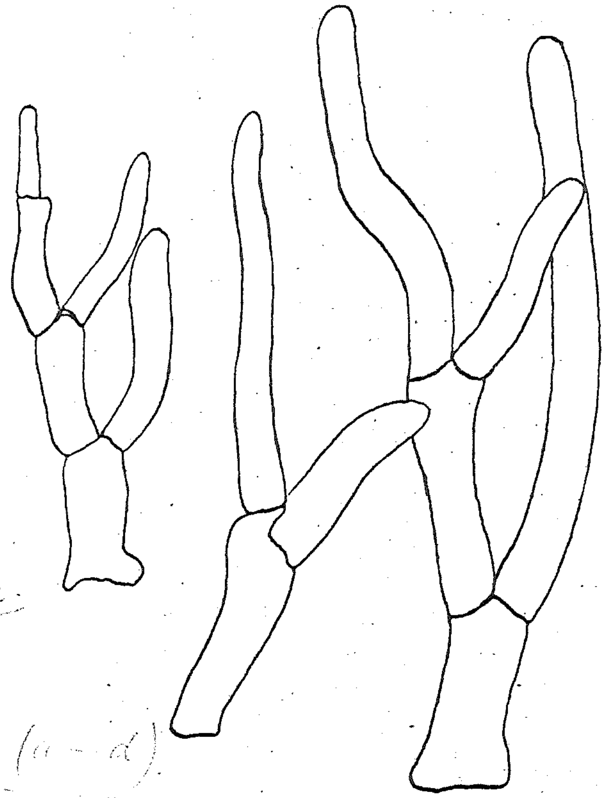
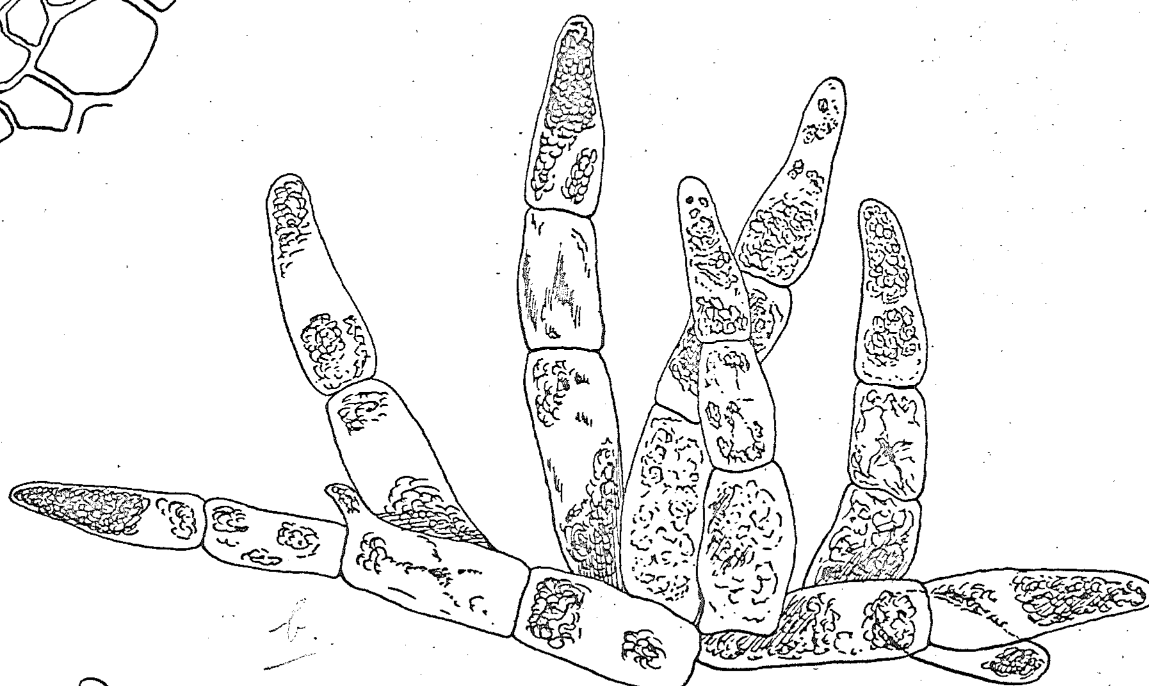


Fig. 56

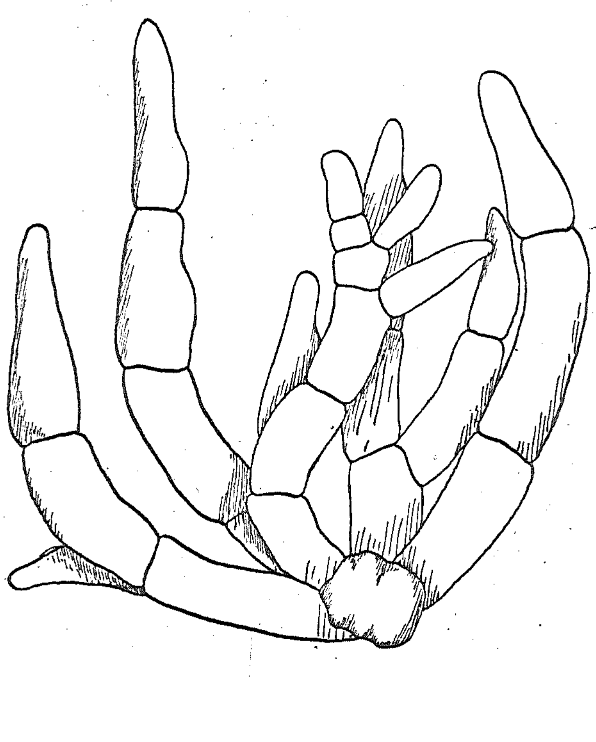


a.

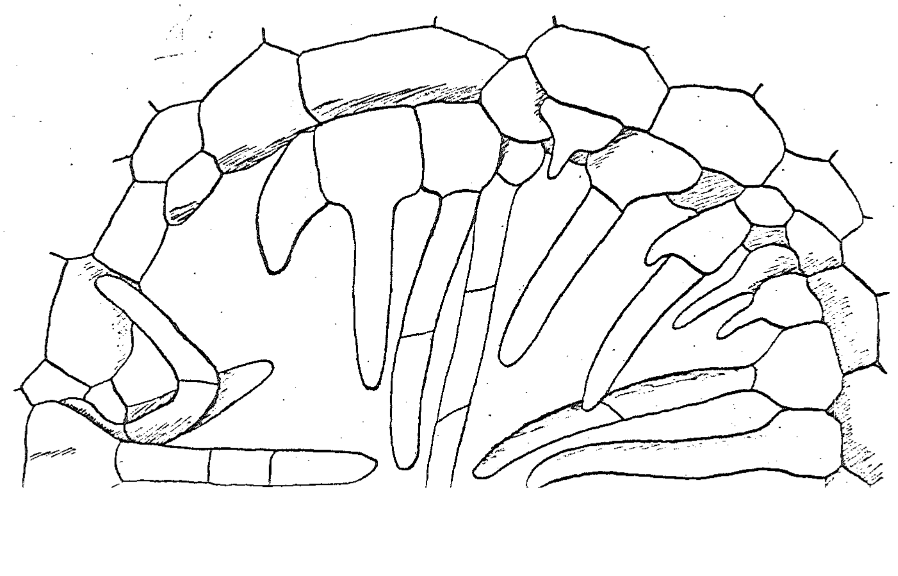
Fig. 55. (a–d)



b.



c.



d.

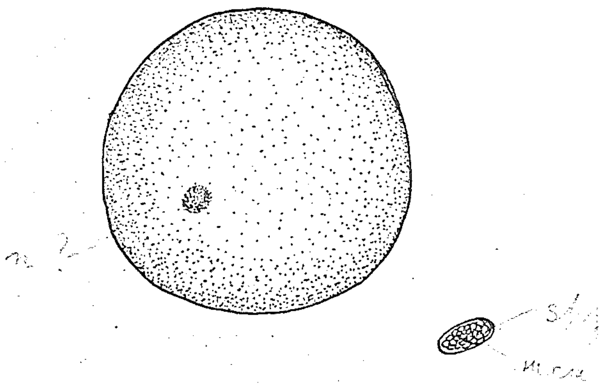


Fig. 57

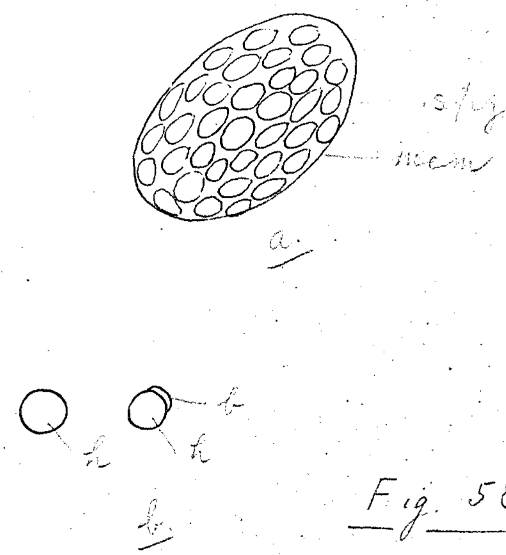
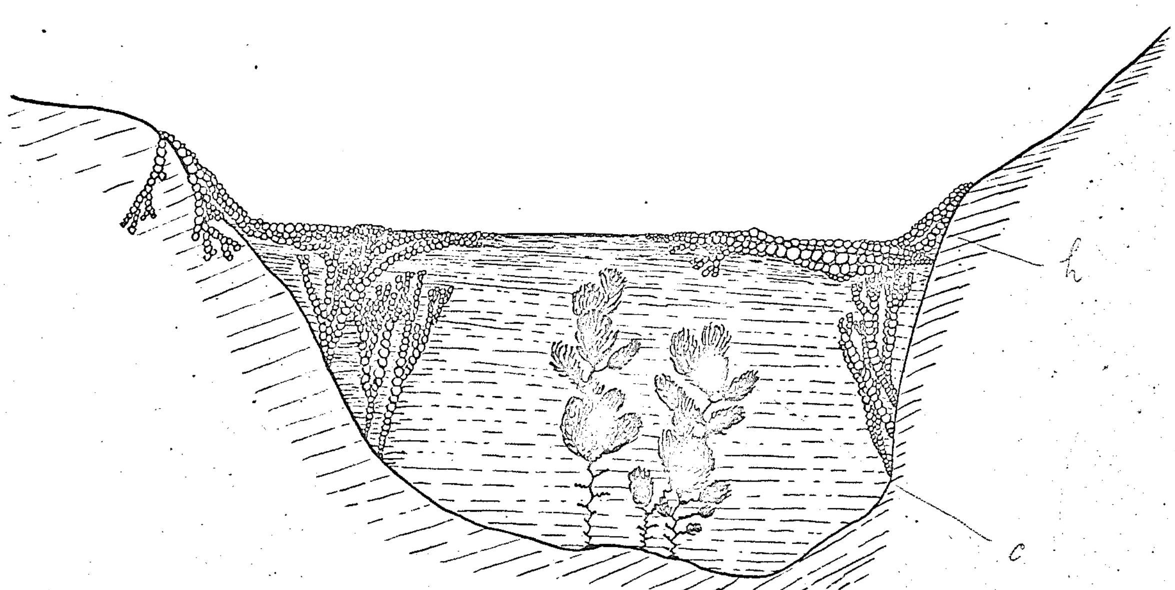


Fig. 58.



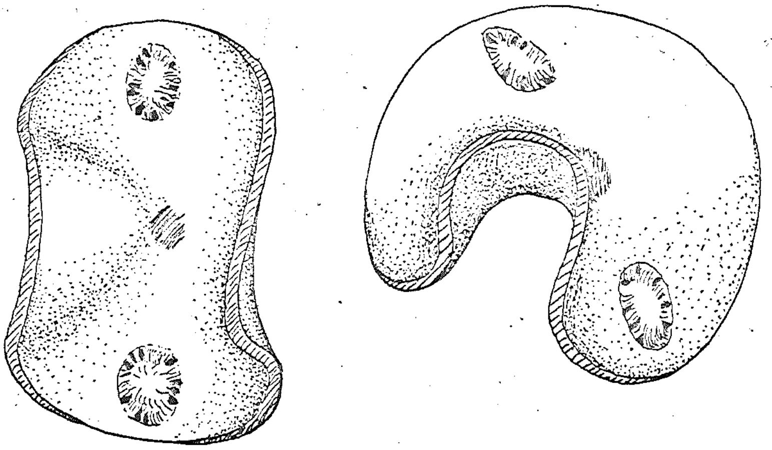


Fig. 60.

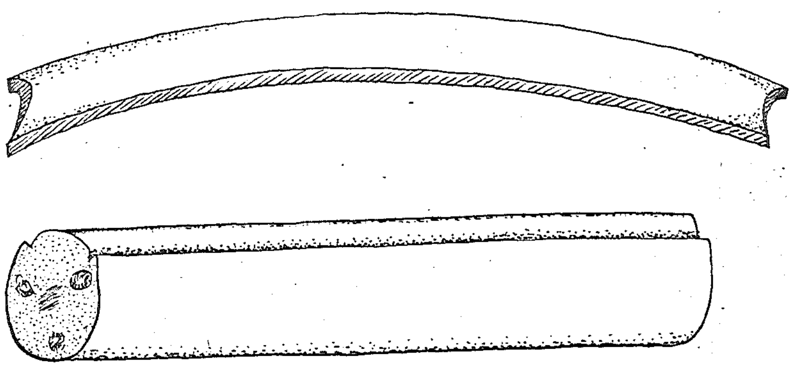


Fig. 61.

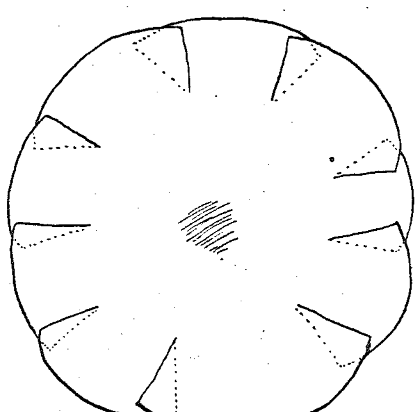


Fig. 62

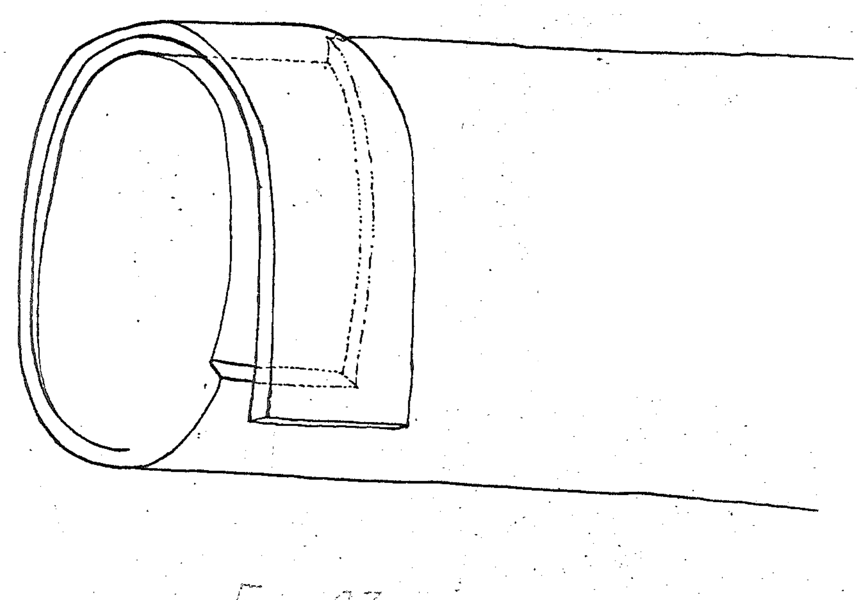
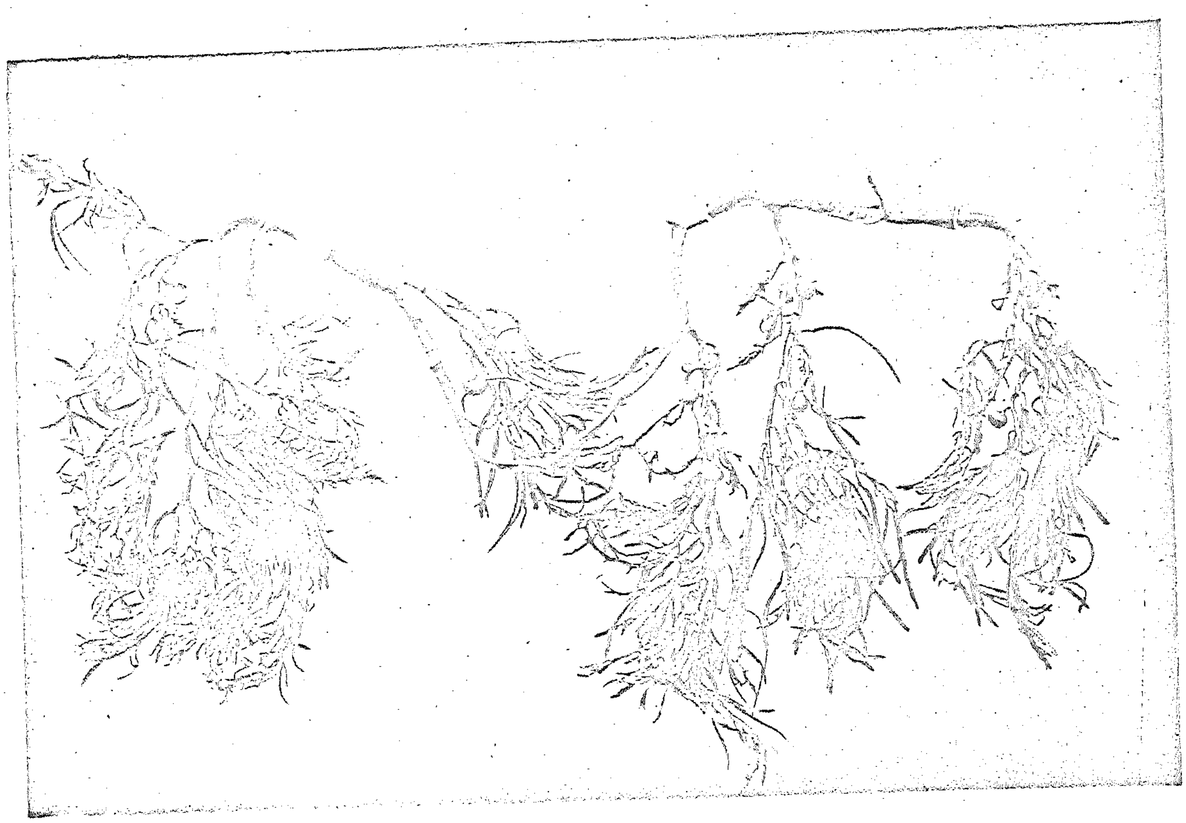


Fig. 63.

Plate I.



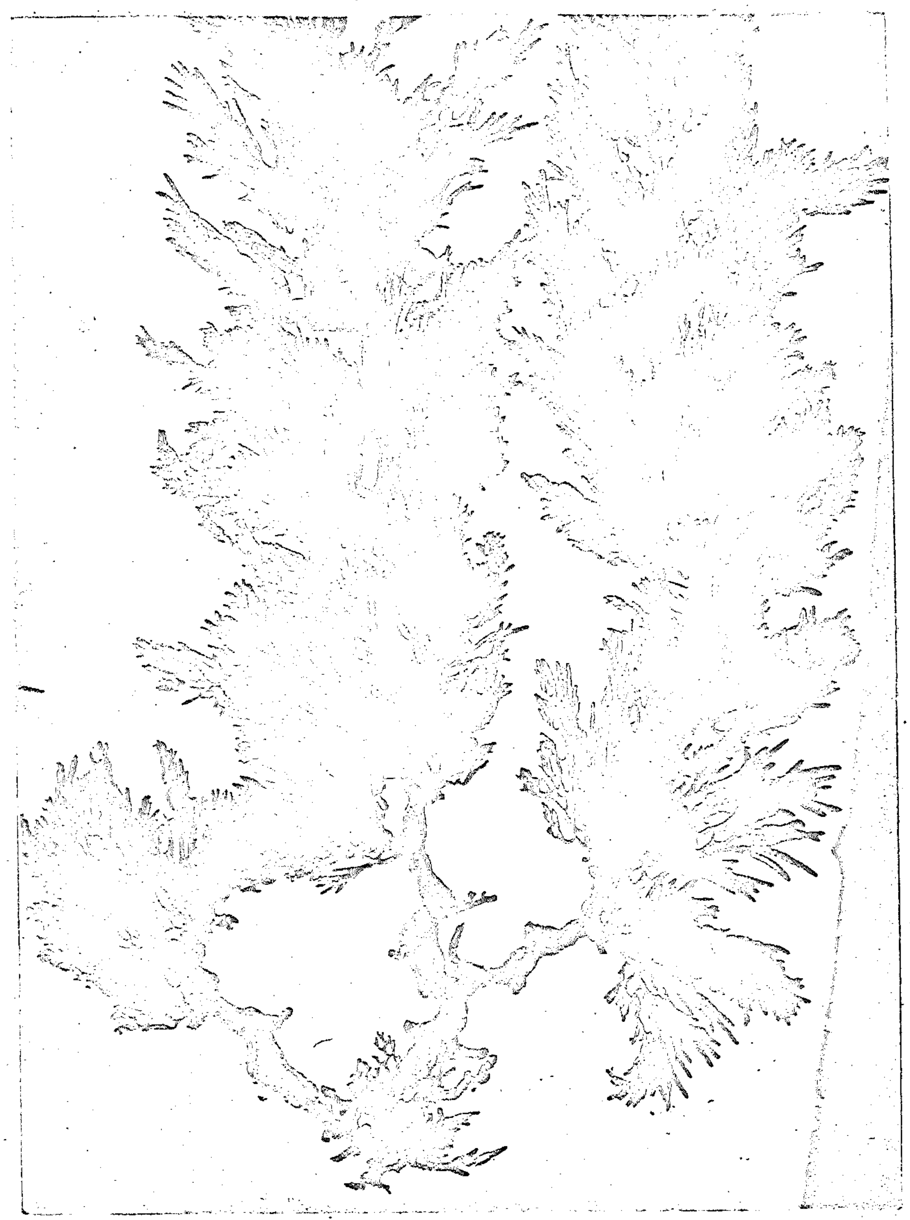


Plate. III.