Liverpool Marine Biology Committee.

*L.M.B.C. MEMOIRS*

*ON TYPICAL BRITISH MARINE PLANTS & ANIMALS*

*EDITED BY W. A. HERDMAN, D.Sc., F.R.S.*

IX.

# CHONDRUS

BY

OTTO V. DARBISHIRE,

*Owens College, Manchester.*

(With 7 Plates)

PRICE HALF-A-CROWN.

LONDON

WILLIAMS & NORGATE,

JULY, 1902.

*L.M.B.C. MEMOIRS.*

IX.

# CHONDRUS.

# NOTICE.

The Committee desire to intimate that no copies of these Memoirs will be presented or exchanged, as the prices have been fixed on such a scale that most of the copies will have to be sold to meet the cost of production.

The Memoirs may be obtained, post free at the nett prices stated, from Messrs. Williams and Norgate, 14, Henrietta Street, Covent Garden, London.

Memoir I. Ascidia—published in October, 1899, 60 pp. and five plates, price 2s.

,, II. Cardium—published in December, 1899, 92 pp., six plates and a map, price 2s. 6d.

,, III. Echinus—published in February, 1900, 36 pp. and five plates, price 2s.

,, IV. Codium—published in April, 1900, 26 pp. and three plates, price 1s. 6d.

,, V. Alcyonium—published in January, 1901, 30 pp. and three plates, price 1s. 6d.

,, VI. Lepeophtheirus and Lernæa—published in March, 1901, 62 pp. and five plates, price 2s.

,, VII. Lineus—published in April, 1901, 40 pp. and four plates, price 2s.

,, VIII. Pleuronectes—published in December, 1901, 260 pp. and eleven plates, price 7s.

,, IX. Chondrus—now ready (July, 1902), 50 pp. and seven plates, price 2s. 6d.

Liverpool Marine Biology Committee.

*L.M.B.C. MEMOIRS*

*ON TYPICAL BRITISH MARINE PLANTS & ANIMALS*

*EDITED BY W. A. HERDMAN, D.Sc., F.R.S.*

**IX.**

# CHONDRUS

BY

OTTO V. DARBISHIRE,

*Owens College, Manchester.*

(With 7 Plates)

PRICE HALF-A-CROWN.

LONDON
WILLIAMS & NORGATE
JULY, 1902.

# EDITOR'S PREFACE.

The Liverpool Marine Biology Committee was constituted in 1885, with the object of investigating the Fauna and Flora of the Irish Sea.

The dredging, trawling, and other collecting expeditions organised by the Committee have been carried on intermittently since that time, and a considerable amount of material, both published and unpublished, has been accumulated. Fifteen Annual Reports of the Committee and five volumes dealing with the "Fauna and Flora" have been issued. At an early stage of the investigations it became evident that a Biological Station or Laboratory on the sea-shore nearer the usual collecting grounds than Liverpool would be a material assistance in the work. Consequently the Committee, in 1887, established the Puffin Island Biological Station on the North Coast of Anglesey, and later on, in 1892, moved to the more commodious and convenient Station at Port Erin in the centre of the rich collecting grounds of the south end of the Isle of Man. A new and larger Biological Station and Fish Hatchery, on a more convenient site has now been erected, and will, it is expected, be opened for work next month, July, 1902.

In these fifteen years' experience of a Biological Station (five years at Puffin Island and ten at Port Erin), where College students and young amateurs form a large proportion of the workers, the want has been frequently felt of a series of detailed descriptions of the structure of certain common typical animals and plants, chosen as representatives of their groups, and dealt with by specialists. The same want has probably been felt in other similar institutions and in many College laboratories.

The objects of the Committee and of the workers at the Biological Station have hitherto been chiefly faunistic and speciographic. The work must necessarily be so at first when opening up a new district. Some of the workers have published papers on morphological points, or on embryology and observations on life-histories and habits: but the majority of the papers in the volumes on the "Fauna and Flora of Liverpool Bay" have been, as was intended from the first, occupied with the names and characteristics and distribution of the many different kinds of marine plants and animals in our district. And this faunistic work will still go on. It is far from finished, and the Committee hope in the future to add greatly to the records of the Fauna and Flora. But the papers in the present series are quite distinct from these previous publications in name, in treatment, and in purpose. They are called the "L.M.B.C. Memoirs," each treats of one type, and they are issued separately as they are ready, and will be obtainable Memoir by Memoir as they appear, or later bound up in convenient volumes. It is hoped that such a series of special studies, written by those who are thoroughly familiar with the forms of which they treat, will be found of value by students of Biology in laboratories and in Marine Stations, and will be welcomed by many others working privately at Marine Natural History.

The forms selected are, as far as possible, common L.M.B.C. (Irish Sea) animals and plants of which no adequate account already exists in the text-books. Probably most of the specialists who have taken part in the L.M.B.C. work in the past will prepare accounts of one or more representatives of their groups. The following have already promised their services, and in many cases the Memoir is already far advanced. The first Memoir appeared in October and the second in December, 1899, the third in February, and the fourth in April, 1900, the fifth in January, the sixth in March, the seventh in April, and the eighth in December, 1901, while this ninth one will be ready in July, 1902, and a tenth later in the summer; others will follow, it is hoped, in rapid succession. Probably Arenicola, Patella, Myxine, and the Oyster will be ready next.

Memoir I. Ascidia, W. A. Herdman, 60 pp., 5 Pls., 2s.
,, II. Cardium, J. Johnstone, 92 pp., 7 Pls., 2s. 6d.
,, III. Echinus, H. C. Chadwick, 36 pp., 5 Pls., 2s.
,, IV. Codium, R. J. H. Gibson and Helen Auld, 26 pp., 3 Pls., 1s. 6d.
,, V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls., 1s. 6d.
,, VI. Lepeophtheirus and Lernæa, Andrew Scott, 62 pp., 5 Pls., 2s.
,, VII. Lineus, R. C. Punnett, 40 pp., 4 Pls., 2s.
,, VIII. Plaice, F. J. Cole and J. Johnstone, 260 pp., 11 Pls., 7s.
,, IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls., 2s. 6d.

Arenicola, J. H. Ashworth.
Myxine, F. J. Cole.
Buccinum, W. B. Randles.
Bugula, Laura R. Thornely.
Patella, J. R. A. Davis and H. J. Fleure.
Oyster, W. A. Herdman and J. T. Jenkins.
Ostracod (Cythere), Andrew Scott.
Dendronotus, J. A. Clubb.
Peridinians, G. Murray and F. G. Whitting.
Zostera, R. J. Harvey Gibson.
Himanthalia, C. E. Jones.
Diatoms, F. E. Weiss.
Fucus, J. B. Farmer.

Botrylloides, W. A. Herdman.
Cuttle-Fish (Eledone), W. E. Hoyle.
Calanus, I. C. Thompson.
Actinia, J. A. Clubb.
Hydroid, E. T. Browne.
Calcareous Sponge, R. Hanitsch.
Antedon, H. C. Chadwick.
Porpoise, A. M. Paterson.
Gammarus, M. Cussans.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Sagitta* (by Mr. Cole), a Cestode and a Turbellarian (by Mr. Shipley), *Carcinus*, an Isopod, and a Pycnogonid (probably by Dr. A. R. Jackson).

As announced in the preface to Ascidia, a donation from Mr. F. H. Gossage of Woolton met the expense of preparing the plates in illustration of the first few Memoirs, and so enabled the Committee to commence the publication of the series sooner than would otherwise have been possible. Other donations received since from Mr. Gossage, from the Publications Committee of the Victoria University, and from Mrs. Holt, are regarded by the Committee as a welcome encouragement, and have been a great help in carrying on the work.

W. A. Herdman.

University College, Liverpool,

*June*, 1902.

# L.M.B.C. MEMOIRS.

## No. IX. CHONDRUS.

BY

OTTO V. DARBISHIRE,

*Owens College, Manchester.*

### CONTENTS.

## I.—INTRODUCTION.

The Rhodophyceæ are a very distinctive class in the Euphyceæ or Algæ, which form a sub-division of the Thallophyta. They are separated from the other classes of the Euphyceæ by their reddish or violet colour. This colour is produced by the green chlorophyll being obscured by a red colouring matter, called Phycœrythrin. The Rhodophyceæ embrace two sub-classes, namely, the Bangiales and the Florideæ. The representatives of the former have very simple and undifferentiated filamentous or membranous multicellular bodies. The sexual organs are extremely simple. The Florideæ have multicellular bodies, consisting usually of much-branched rows of cells, which often form plants of good size and firm structure.

To the sub-class Florideæ belongs the subject of this memoir, *Chondrus crispus*, the Irish Moss. With the exception of nine genera, five of which are confined to freshwater, the Florideæ are exclusively marine plants.

The arrangement of the natural orders of the Florideæ into series is dependent on the various methods by which the fruit develops after the fertilisation of the female organ. It is unnecessary to refer to the subject in detail here. It must suffice to say that the natural orders are arranged in four series, namely, the Nemalionales, the Gigartinales, the Rhodymeniales and the Cryptonemiales.

The natural order to which *Chondrus* belongs is that of the Gigartinaceæ, one of the Gigartinales. The only other order of this series, the Acrotylaceæ, differs from the Gigartinaceæ in the arrangement of the asexual spores in their mothercell. The tetraspores of the latter are formed by cruciate, those of the former by zonate, division.

The natural order Gigartinaceæ includes nine British genera, namely, *Chondrus*, *Gigartina*, *Phyllophora*, *Stenogramme*, *Gymnogongrus*, *Ahnfeltia*, *Actinococcus*, *Callophyllis* and lastly *Callymenia*. Of these the representatives are all fairly well developed plants, with the exception of the species belonging to the genus *Actinococcus*. One of these has been shown to lead a parasitic life on *Phyllophora Brodiæi*.

The genera *Chondrus* and *Gigartina* differ from the remaining members of the Gigartinaceæ in their structure. They show internally a very well marked hyphal arrangement of the cells—their internal tissues in the younger plants consisting of fairly loose filamentous cells. The central tissues of the other genera are, with the exception of *Actinococcus*, far more compact and pseudoparenchymatous. The species of *Chondrus* have a flattened plant body or thallus. The carpospores in the fruit or cystocarp are not surrounded by any special fibrous integument. The latter is one of the distinguishing features of the species of the genus *Gigartina*.

*Chondrus crispus* is the only species of its genus occurring in British waters, and therefore in the L.M.B.C. district. Quite a large number of varieties are distinguished, but I have not referred to these in this memoir, as I consider their recognition to be of no general value.

The genus *Chondrus* was founded by Stackhouse—the name *crispus* was given to the species by Linnæus. The latter, however, placed the species in the genus *Fucus*, to which he referred almost every seaweed. Stackhouse removed the species, and gave it a place in the genus *Chondrus*, where it has remained ever since. Its name therefore runs thus: *Chondrus crispus* (L.), Stackh., or, according to a certain number of German Algologists, *Chondrus crispus*, L. sp. They wish to indicate merely the author of the species, the "sp." in this case implying that Linnæus was responsible for the specific name only.

*Chondrus crispus* grows very plentifully along our sea-coast, as long as the sea bottom is rocky. It is usually left dry at low tide, when it can be easily obtained. It much resembles *Gigartina mammillosa*, from which plant it is, however, easily distinguished when in fruit, but not so easily when sterile. *Gigartina mammillosa* nearly always has the margins of the thallus lobes slightly rolled in. *Chondrus crispus* will probably be recognised fairly well by referring to our Plate I. It should be carefully separated from *Gigartina mammillosa*, *Gymnogongrus norregicus* and *Phyllophora membranifolia*.

A few remarks may not be out of place here on the collection of material and its preparation for the herbarium and the microscope.

All material collected for an examination of the external morphology or the internal structure should be gathered fresh. Plants thrown up after a gale are usually in poor condition. A glass jar should be taken on every shore collecting expedition, into which the plants should be put, immersed in sea water, as soon as they have been removed from the substratum. The latter can be done with a knife, or a bit of the rock may be chipped off. The water in the jar should not be allowed to get too warm.

The height at which the plants were collected should be noted, also the nature of the substratum, and also whether the plants were growing exposed on the bare face of the rock or in pools.

In the laboratory the algæ should be kept in a dark, cool place. It is usually sufficient to put the jars under the working table. Proper cultures may be set up, and kept for many years, by putting a few seaweeds in a good sized jar, keeping the temperature of the water low and exposing only to the feeblest light. To examine the external morphology of any alga, the specimens should be placed in a shallow white dish, and again kept covered over with sea water.

Before mounting specimens for the herbarium they should be soaked for a few minutes in fresh spring water to remove as much as possible of the common salt present. The phycœrythrin of the Florideæ being soluble in fresh water, too long an immersion in fresh water would destroy their colour. After being washed the plant should be put between sheets of blotting paper, or better, some kind of filter paper. I find that so-called common German filter paper answers very well indeed. This paper is very much tougher than most kinds of blotting paper, and also a good deal cheaper. A board is put on to the top of the drying paper, and this is weighted down by a few not too heavy stones. In the case of certain algæ, which are more delicate than *Chondrus crispus*, it will be necessary to float them out in fresh water on to a piece of white foolscap paper. They will usually be found to stick naturally to the paper they have been mounted on. To prevent their sticking to the filter paper some fine muslin is interposed between them and the drying paper. When the plants have been pressed for a few days, with a daily change of the paper and muslin, the weights may be removed for twelve hours to allow the air to circulate more freely for drying purposes. All the specimens should be carefully labelled with the name, locality, date, and any short remarks which may seem necessary.

To examine any material under the microscope, it should be cut as fresh as possible, and examined in sea water. Transverse and longitudinal sections of every part of the plant should be cut with a razor, with or without clamping the material in pith. The section should then be mounted and examined in sea water. Fresh spring water or glycerine kills the tissues very rapidly, and the former more particularly causes a great swelling up of the cell walls, whereby the appearance of the tissues becomes very much distorted. Iodine should frequently be employed to test for the presence of starch. For this purpose dissolve some crystals of potassium iodide and some of iodine in water.

Permanent preparations may be made by putting a freshly cut section into dilute glycerine, and thence into glycerine jelly. Sections may be stained in a solution of hæmatoxylin ( 1 per cent. solution in water), and then mounted in glycerine jelly. When stained, sections can also be permanently mounted in Canada balsam. To this end they should, after staining, be dehydrated in absolute alcohol, and after replacing the alcohol by xylol, they are mounted in Canada balsam, which has previously been dissolved in xylol.

If it is intended to preserve some material in a bottle for future examination, it should be fixed in a 1 per cent. solution of picric acid in water. The material may remain in this solution for a few hours, and is then washed in 50 per cent. alcohol, till the latter no longer becomes yellow. Then remove it to 70 per cent. and finally to 90 per cent. alcohol for preserving. Some glycerine (about 25 per cent.) may be added, thus preventing the specimens getting too brittle.

In order to cut sections with the microtome, the portions of the plant to be cut must be embedded in paraffin. They should be dehydrated in absolute alcohol, left in cedar-wood oil till they are quite transparent, and then transferred to paraffin at 55° C. They may be cast in a block after about two hours.

Permanent preparations are, however, useless to a student, if similar sections have not been previously examined in a fresh condition. The student should, furthermore, make drawings of the sections before they are permanently mounted. A permanent preparation of an alga is often a very poor guide to the condition of things obtaining in the living plant. A good drawing, or even a careful sketch of a fresh section is at a later date generally a far better reminder of what was seen in the living plant than an old glycerine preparation.

It is a useful plan to make the drawings on loose sheets, and insert them in the herbarium with the dried specimens. It is, of course, necessary to carefully label all slides at once. This prevents any possible confusion to which a later labelling by memory nearly always leads.

## II.—CHONDRUS CRISPUS (L.) Stackh.

The species *Chondrus crispus* has now been definitely recognised from the introductory description given in the preceding part of this memoir. We can therefore proceed to the more detailed description of the plant.

### A.—The External Morphology of the Vegetative Organs.

The plant body of *Chondrus crispus* shows a very distinct morphological differentiation into two parts—namely, into a shoot and a root. Nevertheless it is generally referred to as being a but little differentiated thallus, the differentiation not being of quite the same degree and kind which we meet with in the higher plants. But it is possible to distinguish very clearly a root from a shoot. The latter alone bears the reproductive organs.

The Root is mainly an organ of attachment. In this respect our alga resembles most of the higher aquatic plants. The root is a flat and not very thick plate of tissue, which adheres very closely to the rocky substratum. No food material apparently is absorbed from the latter. There is no reason, however, why the exposed portion of the attachment disc should not extract some food material from the surrounding sea water. It is coloured a faint red, and it may therefore assist in the process of assimilation, but only to a limited extent. It is, however, an important organ for the storage of food material. It grows in circumference along its margin, covering everything that may happen to be attached to the rock and extending into any small holes and crevices in the latter, thereby acquiring a very irregular shape (Pl. III., fig. 9). By this means the whole plant gets very firmly attached to the sea bottom (see Pl. I.)

From the flat root disc arise the numerous upright SHOOTS. These are at first undivided and more or less cylindrical in transverse section. But they soon become flattened, and when they have attained a height of 1·5″ (3 cm.), they are always divided. The full grown shoot is as a general rule more or less flattened throughout. Its lowest end, however, just where it joins the root organ, may be cylindrical, but it soon becomes flattened, even if only slightly. With its first division the shoot becomes very much flattened and very thin. The branching of the leafy portion of the shoot is throughout a very regular kind of forking. No midrib is formed, the texture of the shoot being fairly uniform and almost leathery throughout.

The shape of the separate shoots is very simple and very uniform amongst the individuals even of very different localities—be they broad or narrow forms. A fairly long and undivided stalk can be distinguished from the much divided frond. In the taller plants, found chiefly at low tide, the stalk is very long and very strong (Pl. I., figs. 1, 2, 3). In the forms found higher up on the seashore, and therefore more frequently and longer exposed, the whole plant is smaller and the stalk proportionately shorter, the frond, however, is often broader (fig. 4, 5).

All forms agree in showing a repeated and fairly regular bifurcation of the frond into flat lobes, which gradually get broader at their further ends. A small indentation between two projecting points at the tips of the lobes indicates where the next bifurcation will take place. The segments of the frond not only become broader, but also thinner in texture. The broadening out of the lobes causes an overlapping of the segments.

The colour of the frond varies from dark red to light pink, and a brownish colour with a dash of pink.

The following are some of the measurements taken on our plant. The largest specimens gathered at low-water mark are as much as 15-17cm. (6-7″) high, with a frond 12·5cm. (5″) across (fig. 1). The stem in such a case would measure about 1·5mm ($\frac{1}{16}$″) in thickness. At higher water marks the plants are found in pools only, and not on the bare rock, as at the lower tide marks. In the former case they are much smaller in height and grow in very close, low tufts. They are, however, usually proportionately very broad (fig. 4, 5).

The functions of the shoot are best expressed by the two words assimilation and reproduction. The shoot probably is extremely active in absorbing food material from the surrounding water. This, however, is a point about which we know practically nothing of a definite nature. It is very difficult to keep marine plants in culture, because we do not know what the essential features of the conditions are which obtain in their natural haunts. Algæ may be kept for a very long time in fairly dark and cool rooms in even small glass jars. As a rule, however, they grow very slowly and remain sterile, the conditions being probably very unfavourable.

## B.—Anatomy and Histology of the Vegetative Organs.

### 1.—Anatomy of the Shoot.

The young upright shoot of *Chondrus crispus* shows a differentiation into several tissues, which are, however, not very easy to separate at the points where they pass into one another (see Pl. II.)

The centre is occupied by very much elongated and comparatively narrow cells (fig.7). These central cells lead to a tissue further out of shorter and stouter cells, from which arise the regular rows of external cells, easily distinguished by their red contents. There is no morphological differentiation of these tissues such as we get in the body of a higher, vascular plant—the differentiation here being of a purely physiological nature. The external cells, distinguished by their dark red colouring form the "assimilating system," the large stout ones next inside form the system of "collecting cells," the central cells form the "conducting tissue." The whole arrangement is based on the assimilation, collection and conduction of food. The assimilating cells have been called the cortical layer, the two other tissues the outer and inner medulla respectively. We will employ the nomenclature based on the physiological function of the respective tissues, although the other terms, cortex, inner and outer medulla, are equally good.

The tissues just mentioned are seen at their best and in their most characteristic condition a short distance behind the youngest part of the shoot. The youngest or most actively growing part of a shoot is found at the end furthest away from the basal attachment organ.

A longitudinal section of a young frond should now be cut at right angles to its surface, and rather near a median longitudinal line. The material should be fresh and the sections should be mounted in sea water. These should be examined first, but others can also be examined after being mounted in glycerine (50 per cent. solution in water) or glycerine jelly (fig. 7).

The Central Conducting Cells will be found to be elongated in a longitudinal direction. They are fairly narrow, and they possess fairly thick walls. The peculiar nature of the walls becomes very apparent when a section is mounted and examined in fresh spring water. In this case, owing to the rapid absorption of water by the cell walls, the sections rapidly curl up.

This central tissue of much elongated cells resembles more a strand of interwoven filaments than a close parenchymatous tissue. By this *Chondrus crispus* may, as already pointed out, be distinguished from the species of several allied genera. But it has this feature in common with *Gigartina mamillosa*.

The cells of the conducting tissue are connected with one another at certain points. These points become very evident if the cell walls of a section have been allowed to swell up in water or dilute glycerine. The cell walls encroach on the cell cavity, leaving only a narrow canal of varying length leading apparently from one cell to another. A fine wall, which does not swell up, is stretched across the canal, thus forming a pit, as we find it in the higher plants. The pit membrane probably allows of the cytoplasm of one cell communicating with that of the other. On each side of this pit is a small cap, consisting of what appears to be coagulated cytoplasm. The structure of the pit will be referred to again, when discussing the histology of the shoot subsequently.

Connected with the central elongated cells of the conducting tissue are the Collecting Cells. These are much shorter than the central cells, and as we pass further out they diminish still more in size. They form a rather closer tissue than the conducting cells, and they are extensively connected by pits, with or without the above-mentioned protoplasmic caps, with any of the neighbouring cells they may come into contact with. The nearer we come to the outside the more regularly do they come to lie in rows. Finally there arise from them the very regular rows of Assimilating Cells, which run parallel to one another, but are curved upwards and outwards at a certain very definite angle with regard to the longitudinal axis of the whole shoot. The assimilating cells possess numerous pits, which are however all destitute of caps.

The whole body of *Chondrus crispus* consists of a complete system of very long and very much branched hyphæ. The assimilating cells form the apical branches of these hyphæ. As a general rule the divisions in these threads will take place at right angles to the longitudinal axis of each cell row. But there is evidence to show that some of the divisions are more or less at right angles to this direction. Hyphal tissue of this kind has been distinguished as plectenchyma. The filamentous nature of the tissues becomes very apparent if the growing point of a frond is examined in a longitudinal section, when one can see spreading out in a fan-shaped fashion the hyphæ of all the three tissues (Pl. II., fig. 6).

In transverse section the cells of a young plant differ little in appearance from what is seen in longitudinal section, except that the conducting cells appear rather round, but still slightly oval in outline. In the case of the flat frond, they are usually elongated in a transverse direction and parallel to the two flat surfaces. There is no difference to be noted in the other tissues.

I have already referred to the growing point. It is that part of the plant where the formation of new cells is going on most actively, but it is, strictly speaking, not the only part of the plant which is growing. Cell division is going on very rapidly in this region, as may be seen by looking at the size of the cells. The formation of new cells is, however, not confined to this region, but is also going on, though probably less rapidly, at the tips of nearly all the assimilating cell rows. The innermost cells of these rows gradually become collecting cells, and new rows of assimilating cells are formed by branching. New cells may also, though rarely, be formed by short tube-like cells growing out from older conducting cells. Thus far the formation of new cells, as part of the process by which *Chondrus crispus* grows, has been described.

The growth in length of the shoot is brought about by the cells of the conducting tissue becoming more elongated, by the collecting cells becoming larger and in the end passing into conducting tissue, finally by the assimilating cells gradually passing into the collecting cells and new assimilating cell rows being formed by the branching of the older ones.

The cells of the conducting tissue measure about 8-10$\mu$ in length at a point about 100$\mu$ back from the shoot apex, at further intervals of 100$\mu$ they increase on the average to 10-14$\mu$, 20$\mu$, 30-40$\mu$, 50$\mu$, being finally 80$\mu$ at a distance of about 800$\mu$ from the apex.

The collecting cells, with a measurement of 4-8$\mu$ in their longest diameter at a distance of 100$\mu$ from the apex, increase at intervals of 100$\mu$ to 8-10$\mu$, 10-12$\mu$, and $20\mu$. This may be taken as their greatest diameter, for after this they would be reckoned part of the conducting tissue.

The assimilating cells vary very little in diameter, being about 4-6 × 3-4$\mu$ near the apex, and rarely rising above 8 × 3-4$\mu$ in the lowest regions just above the basal disc. Their longest diameter is generally parallel to the longitudinal axis of the whole row of cells.

The increase in thickness of the lower regions of the shoot is brought about not by the addition of thick layers of assimilating tissue, as is the case with *Phyllophora Brodiæi*. The assimilating layer in *Chondrus* is 20-25$\mu$ deep in a flat frond of about $350\mu$ in thickness, but in a frond which was $840\mu$ thick, the thickness of the assimilating layer was only 25-30$\mu$. The increase in thickness is in fact due to the assimilating cell rows forming new cells at their tips, whilst their inner cells gradually pass into the collecting cells, and these gradually pass into the conducting cells. The increase in thickness is noticeable in the central tissue only to any extent. It is taking place here at the expense of the outer layers, which are, however, continually being renewed by the formation of new cells at the tips of the rows of assimilating cells.

It is probable that a good deal of sliding of cells occurs as the growth in length takes place. The increase in length is probably caused not by the central cells actively growing in length, but by their being drawn out passively during the active lateral extension of the assimilating layer. But frequent longitudinal slits have failed to indicate in what way tension is distributed in the tissues.

The central tissue is very well separated by the filamentous nature of its constituents in the younger parts of the shoot, but in older parts it assumes more and more a pseudoparenchymatous appearance. By this change the tissues become firmer and the shoot, as a whole, is therefore much strengthened in these older parts. The walls of the conducting cells are very much thicker and firmer in the older part of a shoot than in the younger one.

## 2.—Anatomy of the Root.

The basal attachment organ, or the root part of the whole plant, does not show any differentiation into the three tissues met with in the shoot. It forms a flat plate of tissue, from which the upright shoots arise. Its outward form depends entirely on the nature of the substratum to which it is attached. It is thickest, however, at the points from which the upright shoots arise, and it becomes thinner towards its margin. The lower surface of the attachment organ penetrates into all the numerous crevices of the rock in order to firmly fix the plant.

The cells nearest the substratum, forming what might be called the "Attachment Layer," are of very varying shape, and are very irregularly arranged. Their position and shape depend on the varying minute nature of the substratum. They have thick walls, and form a layer of cells touching the surface of the rock which may be two or three cells deep. But in cases where they have penetrated into and completely filled out some small hole, they may form a mass of thick walled cells, connected only by small but very firm strands of much elongated cells to the main mass of the root (fig. 9).

The greater mass of the root tissue proper is made up of very regularly arranged rows of almost square cells, which run more or less at right angles to the surface of the whole attachment disc. These rows of cells are, strictly speaking, always slightly curved. At the point where a shoot arises they have a convex side turned towards the lower end of the shoot, passing finally into and adopting the curve of the assimilating filaments of the shoot. Then again, near the periphery of the whole attachment organ, where the latter is still very thin, the curved rows of cells have their convex sides turned towards the margin. Seen in surface view the cell rows are observed to grow out in a fan-shaped fashion towards the margin.

The growth of the rows of cells is here mainly, if not exclusively, apical. Transverse divisions in the apical cells are common, longitudinal at the most extremely rare. The upright rows of cells will be seen to be completely undivided (fig. 10).

The whole attachment disc grows in circumference by the formation of new rows near the margin. But it grows in thickness by the elongation through apical cell formation of the old cell rows. The cells once formed do not change their form and size to any great extent, as soon as they have attained their full size, about 3 to 4 cells behind the tips of the filaments.

The whole plant is covered by a protective membrane, which is not very thick in older shoots, but is very distinct near the apex of a shoot. It becomes a very deep layer in certain parts of the basal attachment organ. On either side of the insertion point of an upright shoot, it is usually very well developed. It is here produced by successive layers of wall substance being separated off from the apical cell of each filament (Pl. III., fig. 10).

The cells of the attachment organ are usually full of starch. They are reddish in colour, but the latter is not as dark as in the assimilating cells of the upright shoot.

### 3.—Histology of the Shoot.

The cell walls of the central cells are not very thick when examined fresh and in sea water (Pl. II., fig. 8). They do, however, swell up very much in spring water or in dilute glycerine. One can distinguish three layers in the cell walls, which are best differentiated in case of conducting cells when a longitudinal section is stained in hæmatoxylin and mounted in dilute glycerine.

The middle lamella is seen to be fairly thin, but can nevertheless be well made out. It is common to all cells. Each cell is surrounded by a wall, which lies immediately inside the middle lamella, and dces apparently not swell up very much in water. Then follows an innermost layer, which is in its turn lined by the protoplasm. This layer shows a very distinct concentric stratification, and is apparently most affected by fresh water. It swells up very much indeed.

With regard to the protoplasm inside the cell wall very little can be said. It consists of the cytoplasm, and contains a roundish nucleus, one or more plastids, starch and vacuoles. The cyptoplasm never occupies a very large space of the cell cavity. The latter is usually taken up by one or more large vacuoles. The cytoplasm of the larger central cells consists merely of a very fine membrane, which lies between the vacuole and the cell wall. No fine partitions formed by cytoplasmic lamellæ can be seen stretching across the vacuoles.

In the outer collecting, and still more in the assimilating cells, the cytoplasm appears as a slightly frothy liquid. Fine lamellæ are seen to stretch across the vacuoles. It must, however, be understood that the frothy appearance of the cytoplasm so easily seen in many algæ affords no indication as to its ultimate structure, as is so often supposed.

It has already been mentioned that the large central conducting cells are in communication with one another by means of pits. The pit membranes are thin portions of the wall which do not swell up in water or glycerine.

Their position, therefore, becomes very apparent if we allow the other portions of the wall to swell up.

The innermost of the three layers, of which the cell wall is composed, does not apparently take any part in the formation of the pit, except by its being interrupted at these points.

The large pits of the central conducting cells have on either side a cap, which is most likely of protoplasmic origin. The cap is a short cylinder, the one open end of which (fig. 12, 13) overlies the pit membrane, with which it is co-extensive. At its other end the cap is closed, a small depression being noticed in the centre of the wall. It is at this depression that the cytoplasm is most firmly attached to the cap. This depression corresponds with the thinnest portion of the pit membrane. In younger cells nearer the growing point the caps on the sides of the pits in the central tissue are not so marked. It is from observations made in such parts that the protoplasmic origin of the cylindrical caps is made likely. The sides of the cylinder are seen to be continuous with cytoplasmic strands. They seem, in fact, to be hardened portions of the cytoplasm.

Owing to the complete absence of any hard woody tissue in the thallus of *Chondrus crispus*, it seems very probable that these hard caps have the important function to perform of preventing the collapse or closing up of the opening on either side of the pit.

The cells of the collecting tissue usually have smaller pits, which may or may not be devoid of any cap-like structures. The pits connecting the assimilating cells are usually quite unprotected, but nevertheless form clearly marked thinner portions in the separating cell wall.

The Plastids met with in *Chondrus crispus* occur in two different forms, namely, as rhodoplastids and as leucoplastids. Both these are, however, only modifications of the same organ.

The Rhodoplastids are best developed in the assimilating cells (fig. 14, 15). They are seen here to be of a dark red colour. The red colour is made up of a mixture of chlorophyll and phycœrythrin, the latter completely obscuring the former. The latter may also be extracted by submersion in fresh water for some time, preferably in warm water. The plant will remain green, the chlorophyll being insoluble in water.

The outermost cell of the assimilating filament has a very small rhodoplastid. The latter is represented by a very much reduced flat structure, which fits into the outer end of the oval shaped cell. The remaining part of the cell appears colourless. The other assimilating cells possess very well developed dark red rhodoplastids. They form here cylindrical plates, which line two or three or even all the radial walls, and sometimes even the outer tangential wall. They do not form a closed cylinder, for they are open along one side. Each cell here contains only one rhodoplastid.

The Rhodoplastids are well developed in these assimilating cells, but as you pass on to the collecting cells, they gradually change. The red colour becomes fainter, they get drawn out and become very finely divided. When we get nearer to the conducting cells, the rhodoplastids have become almost invisible. Very finely divided narrow strands are seen of a very faint pink colour. These are the plastids. The fine strands are interrupted here and there by rather larger and more deeply stained masses. Finally in the most central of the conducting cells the finely divided rhodoplastids have disappeared, their place being taken by small roundish leucoplastids. These are almost colourless, but often show a very faint greenish tint. These leucoplastids, of which a great many are often found in each cell, have been derived from the typical rhodoplastid of the assimilating cells.

The Leucoplastids of the conducting cells and the faintly coloured rhodoplastids of the collecting cells are both very active in depositing starch. Starch is never noticed in the assimilating cells.

The starch grains take the form of flattened discs. They stain brownish when treated with iodine. The floridean starch is slightly different in its reaction after treatment with iodine from the starch of the potato, the grains of which stain blue with iodine.

### 4.—Histology of the Root.

The histology of the root calls for no special remarks. The cell walls do not swell up much with fresh water. The pits also are not of the same large form met with in the shoot.

The cells of the root are found to be quite full of starch, which by its presence almost completely obscures the rhodoplastids. The root organ is clearly red, but the red plastids are hardly visible. They are apparently finely divided, consisting of darker red masses, which are connected with one another by faintly coloured strands.

## C.—Physiology of the Vegetative Organs.

Under the heading of Physiology, reference may be made to the functions of the three tissues of the shoot. It is, as already mentioned, to their supposed physiological function that they owe their names.

The Assimilating Cells are obviously correctly named. Assimilation is conducted by means of the rhodoplastids. The fixation of carbon dioxide and the subsequent elaboration of complex organic from simple inorganic compounds may be assumed to be going on through the activity and under the influence of the rhodoplastids. Nothing definite however is known concerning the importance and function of the phycœrythrin in the rhodoplastid.

The rhodoplastids in the assimilating cells are on the whole well developed and of a dark red colour. The apical cells of these assimilating rows have, however, only a very small rhodoplastid each. This is a general rule, and it may be due to the fact that these apical cells are actively growing and dividing.

The substances built up are apparently removed very rapidly to the next inner cells away from the assimilating tissue. This latter, at any rate, contains no traceable quantities of starch. The food substances are in fact probably collected by the collecting cells from the outer layers, and are then passed on to the large conducting cells. They are then stored or passed up or down the shoot, according to the direction in which any part of the plant in need of food may draw them.

A certain faint red colour may often be detected in the finely divided rhodoplastids of the collecting and of the conducting cells, but it is impossible to say whether it enables assimilation to be carried on. In the centre of the shoot the red colour has disappeared, and in place of one red rhodoplastid we get numerous very faint green leucoplastids.

Starch is found very abundantly in the collecting and in the conducting cells. Both these tissues, therefore, probably act as storing tissues.

In the root organ the cells are all found to be full of starch. The root is evidently a very important organ for the storage of food. It is not likely that assimilation is going on very actively in the root. The rhodoplastids are faint in colour and very finely divided.

The whole structure of *Chondrus crispus* is very typical for a water plant. No hard tissues and no special water conducting cells are found. The plant as a whole is not able to keep itself upright except when in the water. The arrangement of the tissues is such that the plant is flexible, but not very elastic. The shoot is bent to and fro by the waves and the tides, but owing to the substance being very tough the shoots are very rarely torn off the substratum. *Chondrus crispus*, is, in fact, very rarely found in the entangled masses of seaweed which are thrown on to the beach after a gale.

## D.—The Reproductive Organs.

The reproductive organs of *Chondrus crispus* are fairly well known.

Vegetative reproduction seems to play practically no part in the life of marine plants. If it does occur in isolated cases it certainly plays no important part in the general biology either of the red algæ in particular or the sea in general. The power of reproduction is, in the case of *Chondrus crispus*, confined to special cells or spores. These may be produced asexually and sexually. In the former case, they are called "tetraspores." In the latter they are known as "carpospores," which are the ultimate products of the fusion of the male nucleus of a "spermatium" with the female nucleus of the "egg cell." This fusion—or process of fertilisation—has never actually been observed in our plant, but may safely be assumed to occur.

The nemathecia, the organs which produce the tetraspores, the antheridia giving rise to the spermatia and the procarpia which harbour the egg cell, are never met with on the same shoot. It is impossible to say from the observations to hand as yet whether the shoots bearing different reproductive organs are borne on the same root. It is highly probable, however, that they are not.

### 1.—The Nemathecium.

The tetraspores are formed in great numbers in certain younger portions of the frond. They make their appearance during the winter months, probably from December to March. When held to the light slightly oval but elongated dark spots may be seen near the apical and younger portions of the frond. These darker portions may be accompanied by a slight bulging out of the assimilating layers, but this is never very marked. Each dark part is a nemathecium, containing tetraspores (fig. 19).

In a longitudinal or in a transverse section (fig. 20), through a nemathecium the dark colour of the latter is seen to be due to a dense and rather irregular mass of small round cells. These may be the finished tetraspores, or their mother-cells. Each mother-cell gives rise to four tetraspores—hence their name.

The whole internal tissue of the nemathecium consists of irregular rows of cells, which on the one hand join on to the collecting and a few of the conducting cells, and on the other hand pass into the assimilating layers (fig. 21). It is, however, before they enter the latter that their cells swell up at the expense of the neighbouring cells, which have a large store of starch.

When these cells have attained a certain size they divide into four cells each. They are, in fact, the tetrasporangia or mother-cells of the tetraspores (fig. 22). The original cell-rows are at first easily made out (fig. 21), but gradually the cells by their growth exert a certain amount of pressure in all directions and the regularity of the cell rows is disturbed. The surrounding sterile cells gradually give up all their store of food material, and finally collapse almost entirely. The tissues never break down entirely, but they do get fairly loose when the spores escape on maturity.

The division of the protoplasm in the spore mother-cell takes place by the formation of several walls, but always in such a way that the resulting four tetraspores are arranged either in one plane round a common point, or in the fashion of a pyramid of four billiard balls, or in two pairs, the wall separating the two spores of one pair running at right angles to that of the other pair. The spores are said to have been formed by cruciate division.

The tetraspore is, on its escape, found to be a round, non-motile and naked reproductive cell, which soon after its escape is surrounded by a firm cell wall. It contains a large amount of food material, starch forming an important constituent of the latter. The protoplasm of the spore is also seen to include a rhodoplastid. The latter is rather difficult to make out, owing to the large amount of starch present. It seems to be of the form met with in the old cells of the conducting tissue of the shoot. It consists apparently of larger and darker portions regularly distributed just inside the cell wall of the spore, and these are connected by fine strands. Fresh tetraspores, fixed with iodine, were heated and mounted in glycerine jelly. They then showed the rhodoplastids—now quite green—and their ramifications very well.

When it has escaped, the mature tetraspore is probably able to proceed to germination at once. How soon it starts and how rapidly it continues to grow in nature it is still impossible to say. Probably it starts very soon. The tetraspores have not the appearance of resting spores.

By employing a method, which gave me good results when applied to the tetraspores of *Actinococcus subcu-*

*taneus*, the small parasite living on *Phyllophora Brodiæi*, I was able to germinate some tetraspores of *Chondrus crispus*. The latter were dredged near Kiel, in the Baltic, and sown in a sea-water culture in the Botanical Institute of that University.

Small portions of parchment paper were first thoroughly soaked for a lengthy period, up to six hours, in running water, so as to remove any acid present. The pieces of parchment were of a size to be conveniently put on to a glass slide, and covered with a large coverslip for purposes of microscopical investigation. These strips of paper were put on to the bottom of small glass troughs $2'' \times 3'' \times 6''$ being a convenient size. The troughs were filled with fresh filtered sea water, and kept in a cool and fairly dark place in the Laboratory. For the first two or three weeks constant attention must be paid to the condition of the water in the cultures. The water must be removed immediately on the appearance of the slightest milkiness, the outward sign of bacterial activity in connection with some dead organism. A number of cultures should always be set up, as some will always succumb to some adverse circumstance.

A portion of a fresh frond bearing a nemathecium may be placed, as soon as obtained, on one of the strips of parchment in a culture. After a certain time the spores will be seen to have escaped, and to be lying about on the parchment. The frond may now be removed, the spores remaining in the culture.

When the spores begin to germinate the strips of parchment can be put on to slides and be examined with the microscope. They must be kept supplied with plenty of fresh sea water, and be guarded against too strong light. They may not be kept out of the cultures too long. A coverslip may be employed, but with great caution.

If the water in the cultures is once quite clear, it only wants adding to very occasionally.

In the case of *Chondrus crispus*, I observed that the tetraspore underwent division without at first growing very much in bulk (fig. 27, 28). Then, however, after having formed a small heap of cells, which are all very much smaller than the original tetraspore, longish filaments seem to be formed (fig. 29). These consist at first of unbranched single rows of cells. Finally the commencement of the formation of flat plates has been observed, and in the end no doubt a normal flat attachment organ is formed, from which the upright shoots arise. I have not however been able to follow out the growth of the germinating tetraspore to this stage yet.

### 2.—The Spermophore.

The spermatia or male cells are found on young portions of the frond. The latter are temporarily modified only for this purpose. Later on they evidently again take on the functions and the structure of an ordinary vegetative shoot. They have been called spermophores (fig. 30. 31).

The spermophores of *Chondrus crispus* are small and narrow, slightly flattened leaves. They appear white owing to the fact that the rhodoplastids of the assimilating layers are but poorly developed. They are 3-4mm. long and barely 1mm. broad.

The general structure of the spermophore does not differ from any ordinary young portion of the thallus. The difference lies in the nature of the last few cells of the assimilating filaments. The last two or three cells appear to be colourless owing to the rhodoplastid, though present, being very much reduced. These two or three cells together form an antheridium, or male organ. The last cell of the row, the spermatangium, gives rise to one spermatium, or male cell. This escapes as a colourless, small round cell, devoid at first of any cell wall, with a diameter of 4-5m. It is non-motile. A fragment of a plastid seems to be present in the spermatium, but this is not revealed by any appearance of colour.

When the spermatia have escaped they cease developing any further till they come in contact with the female organ or carpogonium.

The antheridia form a layer, which extends over almost the entire surface of the spermophore, hence the white appearance of the latter. The spermatia are found to be mature between October and December.

### 3.—The Carpophore.

The development of the female cell of *Chondrus crispus* has not yet been made out properly. The following account of its development and structure is based, therefore, on the few established facts, and on our knowledge concerning the state of affairs in nearly allied genera.

Certain portions of the upright fronds take on the function of carpophores, which carry the female organs. They are first very short, being barely 1-2mm. in length. In this condition they show various characteristic structures. The central conducting tissue is seen to consist of slightly elongated cells filled with starch. These cells are destined to play an important part later on in the formation of reproductive cells. In the assimilating layer certain of the cell rows, instead of carrying out their normal function, have developed into procarpia, of which the carpogonia form parts. Each procarp consists originally of four cells (fig. 36). The large basal cell is seen to be continuous with the collecting cells stem inwards. Further outwards it is continued into the two intermediate cells, and finally the one celled carpogonium. This consists of a swollen lower portion, which contains the egg cell and an upper and slightly drawn out part called the trichogyne, which projects beyond the outer limits of the assimilating layers into the surrounding water. The trichogyne is the receptive organ for the egg cell. The spermatium becomes attached to the trichogyne, but only in a very few algæ has the fusion of the male nucleus of the spermatium with the female nucleus of the egg cell been observed (fig. 36).

Shortly before the supposed fertilisation the large basal cell has a small cell cut off called the auxiliary cell. The procarp at this point therefore consists of five cells.

After fertilisation the trichogyne is cut off from the fertilised egg cell by a complete closing up of the passage between the two divisions of the carpogonium. The trichogyne, now functionless, soon withers away.

The fertilised egg cell—the oospore—now grows out, and forms a protuberance in a direction towards the auxiliary cell. This outgrowth is a sporogenous hypha. Its contents fuse with the contents of the auxiliary cell, but as far as has been observed in other cases no fusion of nuclei takes place. The sporogenous hypha has only been fed by the auxiliary cell. From the auxiliary cell a number of filaments now grow out. They are, however, only continuations and branches of the sporogenous hypha just mentioned, and represent sporogenous hyphæ themselves. They grow towards the starch-laden collecting cells. These filaments are long-celled and very thin. In their course they form secondary pits with numerous neighbouring collecting and conducting cells. When they reach the latter they draw on their large store of food, and finally give rise to the carpospores. The end cells of short branches arising from the sporogenous hyphæ, or their last two or three cells give rise each to one carpospore. In the end the carpophore contains a mass of loose carpospores embedded in a mass of exhausted sterile cells. The mass of carpospores forms the cystocarp.

The mature carpospore is not unlike the mature tetraspore. It is roundish, and at first unprovided with a definite wall, which, however, it very soon acquires. Its contents are very dense, a large amount of starchy food being present. The general colour of the carpospore is red. This is due to the presence of a rhodoplastid, which occurs in a very much divided form.

The whole mass of carpospores forms a fairly large cystocarp, which causes a very marked bulging out of the outer assimilating layers of the carpophore. In this way the latter may be distinguished from a frond bearing nemathecia.

What the fate of the carpospores is, we do not know. Presumably they soon germinate, and thus give rise to new plants.

Our knowledge concerning the development of the sexual organs of the Rhodophyceæ is still in a very unsatisfactory condition. The botanist who wishes to obtain any definite results in this connection must, however, live near the sea for a lengthy period, and have a sufficient amount of time at his disposal to carry out extensive and careful continuous observations.

## E.—Ecology.

As a species *Chondrus crispus* is found to be fairly widely distributed, being common on the shores of the northern Atlantic Ocean. It forms one of the commonest plants on the seashore in the L.M.B.C. district—in fact, along the whole British coast, as long as the substratum is hard rock and the water is clear. It is a species which grows best in the temperate zone. I have no doubt that the distribution of the species of marine algæ depends on the same factor as that of terrestrial phanerogams. The limits of the distribution of phanerogamic species as a rule coincide roughly with isothermal lines.

The distribution of the plant form represented by *Chondrus crispus* in any given small district is dependent not on the temperature, but on quite different factors. It is impossible to say as yet fully what these factors are. The following account is therefore only short.

To begin with, it may be stated that a firm sea bottom is generally necessary for the growth of algæ in general. Stones which roll about with every tide never bear red or brown seaweeds, at the most only a few green ones. Sand is always quite barren.

Certain algæ occur very regularly at certain heights above or below certain fixed levels. I have lately been fixing these heights for a few algæ in Port Erin Bay as a preliminary to some more detailed investigations into the vertical distribution of marine algæ.

If we call the level of dead low-water mark of an ordinary spring tide O, then we can divide the shore into a series of regions. We will begin from the highest point. *Pelvetia canaliculata* extends from 12′ to 17′ above O. These plants are often left exposed by the sea water for days. The highest individuals are often moistened only by the spray of dashing waves.

*Fucus vesiculosus* extends from 3′ to 13′, but not in the same condition. In an upper region, 9′ to 13′ above O, the plants are small, rarely fertile, and possess no vesicles. In the lower region the plants are normal.

*Ascophyllum nodosum* extends from 6′ to 11′ above O.

*Fucus serratus* forms a very distinct region, 3′ to 6′ above O.

*Laurencia pinnatifida* begins at about 6′ above O, and is closely followed by *Laminaria digitata*, 5′ above O. *Laminaria saccharina* begins a few feet lower down. *Sacchorhiza bulbosa* and *Alaria esculenta* still accompanied by *Laminaria saccharina* and *digitata*, the latter having about reached its lower limit, are then met with at about 3′ below O. *Halidrys siliquosa* is found at a still greater depth.

These are the chief plants met with in descending from the highest to the lowest water-marks.

The data mentioned so far refer to plants which lie exposed on the surface of the rock when the tide recedes. It is important to mention this, as many plants rise to a greater height when growing in pools.

*Laminaria digitata* may rise to 9′ above O, and probably higher still in a pool. Exposed, however, its upper limit appears to be 4′ lower. The plants at the former heights are much smaller than those growing exposed lower down.

We can say that algæ exposed when the tide recedes attain their best development in size and reproductive powers in the lower part of the region to which they belong. As they rise to the upper limits they become smaller. They may, however, be found above their normal limit in pools. The higher pool plants are always smaller than the lower exposed ones.

*Chondrus crispus*, as a plant lying quite exposed when the tide recedes, extends from 3′ to 4′ above O downwards. It has been actually observed to about 3′ below O. As a general rule the upper plants are shorter, broader and thinner (Pl. I., figs. 4, 5), than the lower ones. The latter are stouter, very much longer, and the frond is divided into narrower lobes than are found higher up. When growing in pools *Chondrus crispus* has been found up to a height of 9′ above O, being often fairly broad, but never very high. It is a plant which is completely exposed only for a short time.

Little is known as to the reason why longer and shorter exposure causes a difference in the habit of an alga. We practically know nothing about the distribution of and the meaning of the plant forms met with in algæ.

Long submergence in sea water is evidently conducive to increase in size and strength. This is possibly due to the necessity of providing for an increase in assimilating power. The forms which are left exposed long become smaller and often rather close set. Plants with bladders are restricted to a limited area, which is probably exposed at every tide, but the significance of the bladders, from an ecological point of view, I have not yet been able to fathom. *Halidrys siliquosa* occurs, with bladders, quite isolated, at great depths.

So far it can only be said that marine algæ, as a whole, are at their best when least exposed. Certain species, however, by the possession of certain structural or other peculiarities are able to live in localities which must be considered less favourable. They were driven there by the strong competition prevailing in better localities. *Pelvetia canaliculata* was probably unable to stand the competition of the moister parts of the sea shore, and was thereby driven to its present position. Many of the green algæ seem to be at their best in the higher regions. A large amount of light seems to be necessary for their well being. Many Chlorophyceæ seem to be quite indifferent to changes in the salinity of the sea water caused by an inflow of fresh water.

The point of greatest interest is still to ascertain that factor, the influence of which the plants have to guard against during exposure. Is it the strong light, or is it the danger of being dried up? I do not think that the latter can be very great. Even with a fairly strong wind and strong and warm sunshine, the large individuals of *Ascophyllum nodosum* of the higher regions can hardly be said to become really dry, when exposed between tides. The upper exposed side may not be very moist, but the under side often remains quite wet.

Nevertheless I think it will be found that moisture and light are the two factors which have a hand in the shaping of the forms of algæ. My preliminary investigations, carried out over a limited area, and during a short period only, certainly point to this conclusion.

One remarkable feature in the life of the marine algæ is the way in which the reproductive cells will germinate apparently anywhere. The presence of a young algal germling is no indication that the locality is quite suitable for the adult plant. The reproductive cells are very easily distributed, and apparently germinate very readily almost anywhere, at least in a good many cases. Thus it is that the flora of every locality is a very accurate expression of what competition and local conditions have allowed to flourish. As a rule everything that has a chance in any locality will be found there.

In this connection reference might be made to a few plants which I have observed growing on *Chondrus crispus*. These are nearly all epiphytes. The only exception is *Entocladia viridis*, a green alga, which I occasionally found growing apparently parasitically on our plant, penetrating in between the assimilating cell rows of the upright shoots.

Some of the very numerous epiphytes met with belonged to the following species; *Rhodymenia palmata, Asperococcus compressus, Fastigiaria furcellata* and species of *Melobesia, Cladophora, Enteromorpha,* *Ceramium, Polysiphonia, Callithamnion, Dermatocarpon* and others.

Not a few animals are also found on *Chondrus crispus*. *Flustra* grows attached to the fronds, whereas others, like *Caprella linearis*, and some of the Halacarini are found crawling about on the upright shoots.

*Chondrus crispus* is a perennial plant. The root goes on growing for several years, sending up new shoots annually. Considering the condition of things, which I have observed in the Baltic species of *Phyllophora*, I do not think that a frond once separated from the base can again attach itself. I have had detached individuals of *Phyllophora membranifolia* and *P. Brodiaei* under observation in cultures continuously for several years. The wound formed by the separation would gradually heal over, but no attempt would be made to form a new attachment organ.

The reproductive organs of *Chondrus crispus* are formed during the winter. The reproductive spores probably germinate in the early summer.

## III.—CONCLUDING REMARKS.

Having surveyed more or less in detail the development, structure and ecology of *Chondrus crispus*, I will now give a brief SUMMARY of what has been said in the preceding chapters. The summary takes the form of a full diagnosis. A diagnosis may include just enough information to distinguish any particular species from nearly allied forms. It is better, however, that it should include more. It should supply as complete but as brief an account of the species as possible.

## *Chondrus crispus* (L.) Stackh.

SYNONYMY AND LITERATURE:

Harvey, W. H., Phycologia Britannica. 1846-1851. Synopsis 197 (plate 63). A full account of the Synonymy will be found here.

Hauck, F., Die Meeresalgen Deutschlands und Oesterreichs, 1885, p. 134.

ILLUSTRATIONS:

Harvey, loc. cit., plate 63 (Syn. 197): general habit of a broad and a narrow form; transverse and longitudinal sections of the stem; general view and section of nemathecia.

Hauck, loc. cit. p. 134, fig. 53: habit of plant with cystocarpia and nemathecia, with sections of both.

Murray, G., Introduction to the study of seaweeds. 1895. Plate VI., fig. 3.

Wille, N., Entwickelungsgeschichte der physiologischen Gewebesysteme bei einigen Florideen. 1887. Nov. Act. Leop.-Carol. Vol. 52, n. 2. Plate VII. fig. 70, 71. Anatomical details.

EXSICCATA:

Nearly every published collection of dried marine algæ contains specimens of this species, so that it is unnecessary to quote here a lengthy list.

REMARKS.—The Synonymy of *Chondrus crispus* is very straightforward. Harvey refers to certain reproductive organs, which he calls "prominent tubercles (nemathecia)," and which are certainly not nemathecia in our sense. Nothing in *Chondrus crispus*, in fact, corresponds to these prominent tubercles. Murray refers to the spermatia as pollinoids. I see no reason why the term spermatium should be replaced by pollinoid, especially as it has nothing whatever to do with the pollen grain. The forms and varieties mentioned here and there in the literature are of no special value.

Diagnosis :

Thallus, consisting of root and shoot. Root, a flat, hard, reddish disc of irregular outline, made up of very regularly arranged cells of very uniform size and shape. Shoot, upright, 15-17cm. high; narrow or slightly flattened stalk; frond repeatedly forked and divided into very much flattened and thin lobes; internal conducting cells elongated, loose, hyphal in younger parts; more external and small collecting cells leading into external rows of assimilating cells, each containing one rhodoplastid.

Nemathecia, slightly prominent dark red spots on young lobes; sporangia in rows; tetraspores roundish, formed by cruciate division: mature December to March; in germination the spores divide into a number of cells before increasing in bulk.

Spermophores, small, narrow, white leaves on apical margins of frond; antheridia formed by two or three outer cells of assimilating layer; spermatangia produce one spermatium each. Mature October to December.

Carpophores, small leaflets on frond; procarpia just inside assimilating layer; basal cell, cutting off auxiliary cell before fertilisation, two intermediate cells, carpogonium and trichogyne: sporogenous hypha of egg cell fuses with cytoplasm of auxiliary cell, and numerous sporogenous hyphæ grow out towards the central starch-laden cells of the carpophore, fusing with them and producing carpospores; cystocarps forming prominent dark red patches on the frond; carpospores roundish. Mature December to March.

Habitat.—Rocky sea bottom, in clear water, very rarely epiphytic on other algæ; low-water mark. Very common in the district.

Distribution.—Atlantic shores of northern hemisphere.

Economics.—It might be mentioned here—although the point is of no interest botanically—that *Chondrus crispus* was formerly often used, and—I am credibly informed—is still occasionally used, in the making of jellies. It is known as Irish Moss, or carragheen, by chemists, and was supposed to be useful against consumption.

In Conclusion, I would like to say that it is most important that the student, who has worked through *Chondrus crispus*, should examine a number of other red algæ.

If staying near the seaside, seaweeds should be collected and carefully examined. Drawings should be made of a few anatomical details and of the reproductive organs. An attempt should be made to name the specimens collected. It may often be impossible for the beginner to determine the species, and he must be content if he can ascertain the genus to which it belongs. If he also fails in the latter, the material, together with the drawings, should be laid aside for future reference.

Unfortunately we are very badly off at present for any book on the British Algæ The very good Phycologia Britannica of Harvey was published in 1871, and is therefore very much out of date. Its illustrations are, however, as a rule very good, and the student can use it as a beginning. But many of the generic and specific names have changed since 1871, and a very large number of new species have been added to our flora.

A British Marine Flora is being compiled, but no date for its appearance has, I have been kindly informed, as yet been fixed by its author.

The works by Murray and Hauck quoted above may be of some help, especially the former, although it treats of foreign as well as British marine algæ. It contains a short list of books and atlases of algological interest.

Vol. I., part 2, of Engler and Prantl's "Die Natürlichen Pflanzenfamilien," which treats of the algæ, is a very useful book to consult. By the aid of this the beginner may often be able to determine the genera.

## DESCRIPTION OF THE PLATES.

### Plate I.: The General Habit.

Fig. 1. A typical form of low-water mark.

Fig. 2. Narrow form, low-water mark.

Fig. 3. Broad form, low-water mark.

Fig. 4 and 5. Broad forms, high-water mark.

All these specimens, drawn natural size, were collected in Port Erin Bay, between the 16th and 19th of May, 1901.

### Plate II.: Anatomy of the Shoot.

Fig. 6. Longitudinal section of frond apex, mounted in glycerine jelly. × 390.

Fig. 7. Longitudinal section of a young frond a short distance from apex, mounted in glycerine jelly. × 190.

Fig. 8. Longitudinal section of older part of frond, examined in fresh sea water. × 390.

### Plate III.: Anatomy of the Root.

Fig. 9. Perpendicular section through the root and the insertion of two upright shoots. The central tissue of the latter is seen to end in the attachment organ in a conical form. The root has attached itself to the rock by anchorlike outgrowths. × 54.

Fig. 10. Perpendicular section through the upper layers of the attachment organ mounted in glycerine jelly. Notice the regular and unbranched cell rows, and the series of caps which have been cut off by the tip of each row towards the surface. × 1075.

Fig. 11. Section in the same direction of the regular cell rows of the inner tissue of the root, mounted in glycerine jelly. ×1075.

## Plate IV.: Histology of the Shoot.

Fig. 12. A central cell from the longitudinal section of an old shoot, stained with hæmatoxylin, mounted in glycerine jelly. The middle lamella, the darker portion of the cell wall, which has not swollen up, and the lighter and stratified inner cell wall, which has swollen up, may be distinguished. ×1075.

Fig. 13. Large pit between two central cells in optical section; on the left the same in end view. Mounted in glycerine jelly. ×about 3000.

Fig. 14. The apical (smaller) and next inner cell of an assimilating cell row. The former has a smaller rhodoplastid than the latter. Fresh material. ×about 4000.

Fig. 15. Transverse section across an inner assimilating cell. The rhodoplastid lines the wall. Fresh material. ×about 4000.

Fig. 16. The much-divided rhodoplastid of an inner collecting cell. Starch is being formed here and there. Fresh material. ×about 4000.

Fig. 17. Leucoplastid from a conducting cell. Fresh material. ×about 3000.

Fig. 18. Starch grain, seen from its broadest (*a*) and its narrowest side (*b*). Examined in iodine and glycerine. ×about 3000.

## Plate V.: The Nemathecium.

Fig. 19. Habit of a plant bearing nemathecia. ×2.

Fig. 20. Longitudinal section of a frond containing a nemathecium. × 43.

Fig. 21. Section showing the undivided spore mother-cells lying in rows, which are continued into the assimilating filaments. Fresh material. × 1075.

Fig. 22. Mass of divided tetrasporangia, surrounded by the sterile cells in a nemathecium. Fresh material. × 1075.

Fig. 23. Form of cruciate division of a sporangium. Diagrammatic.

Fig. 24. Another form of the same. Diagrammatic.

Fig. 25. Another form of the same. Diagrammatic.

Fig. 26. Single free tetraspore. It is filled with food material; the darker portions represent parts of the much divided rhodoplastid. × about 3000.

## Plate VI.: The Nemathecium and the Spermophore.

Fig. 27. Free tetraspore, some time after its escape, and surrounded by a wall. In glycerine jelly × 1075.

Fig. 28. A tetraspore, having germinated to four cells. In glycerine jelly. × 1075.

Fig. 29. Germinal product of a tetraspore forming a rhizoid-like outgrowth. In glycerine jelly. × 1075.

Fig. 30. Frond bearing spermophore at its tips. × 2.

Fig. 31. Two spermophores. × 12.

Fig. 32. Outer layers of the tissue of a spermophore. The assimilating cell rows end in antheridia. The last cell of each antheridium, the spermatangium, gives rise to one spermatium. In glycerine jelly. × 1075.

Plate VII.: The Carpophore.

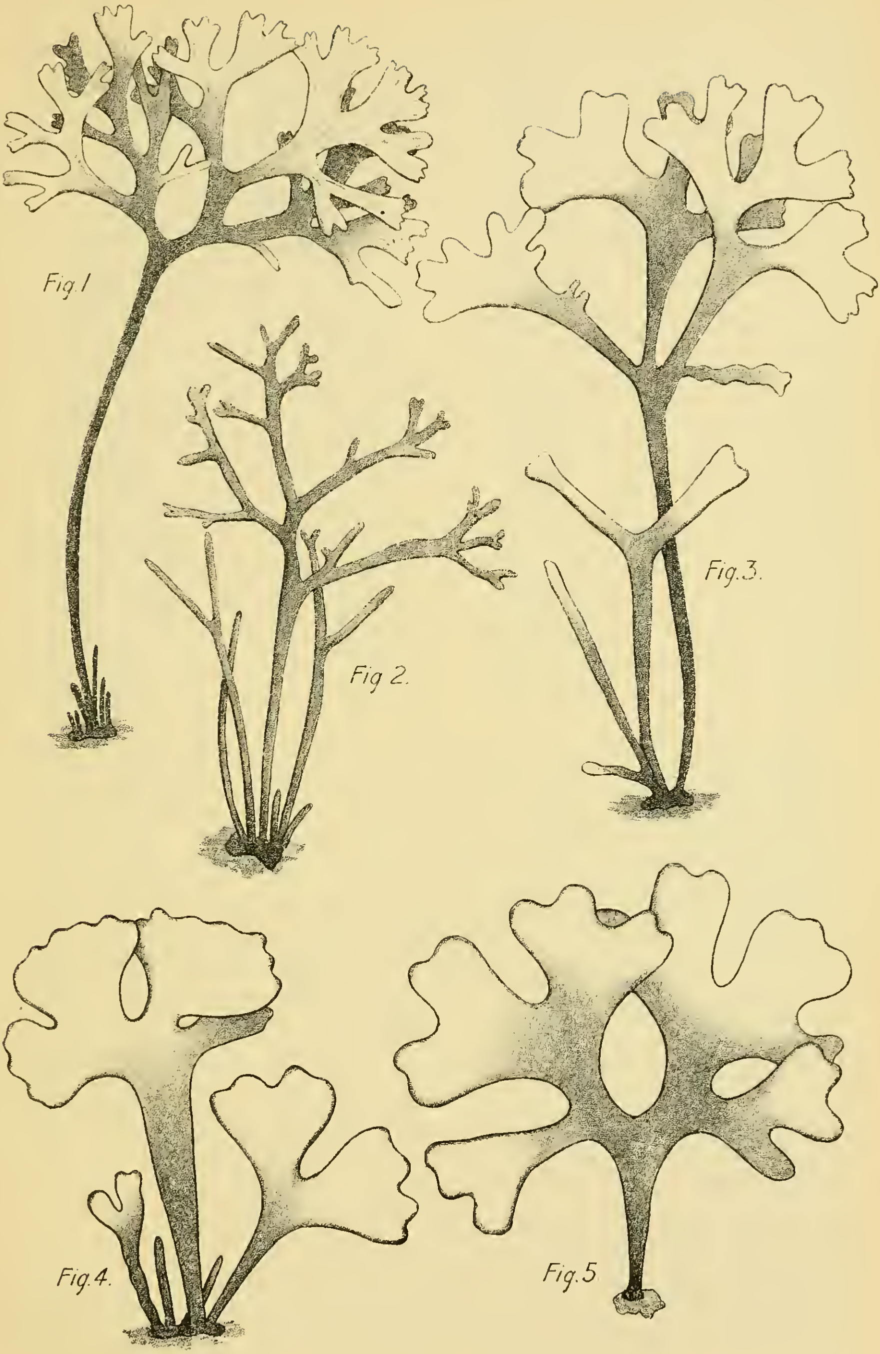
Fig. 33. Frond bearing several cystocarps. ×2.

Fig. 34. Longitudinal section of a carpophore, showing the spore mass of the cystocarp bulging out. ×43

Fig. 35. Group of carpospores surrounded by numerous sterile cells. The two lowest are shown with dark spots, which represent portions of the finely divided rhodoplastid. ×1075.

Fig. 36. Diagrammatic view of the procarp. The single arrow line shows the sporogenous hypha growing out from the fertilised egg cell. The three arrow lines indicate the course adopted by the several sporogenous hyphæ growing out from the auxiliary cell towards the nourishing cells of the centre of the carpophore.

C. Tinling and Co., Printers, 53, Victoria Street, Liverpool.




O.V.D. del S.B. lith

CHONDRUS.

General Habit.

Fig. 6.

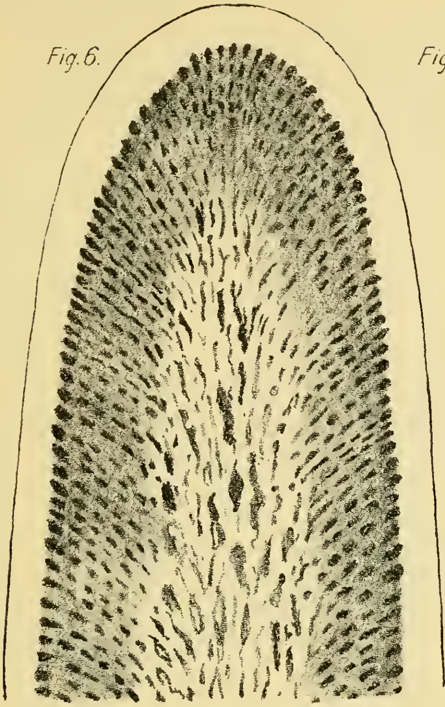
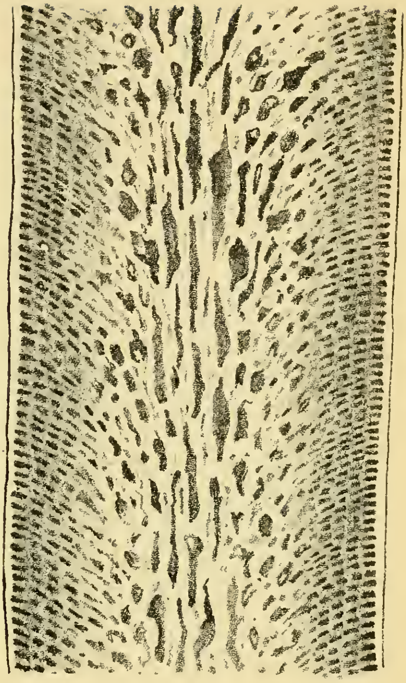


Fig. 7.



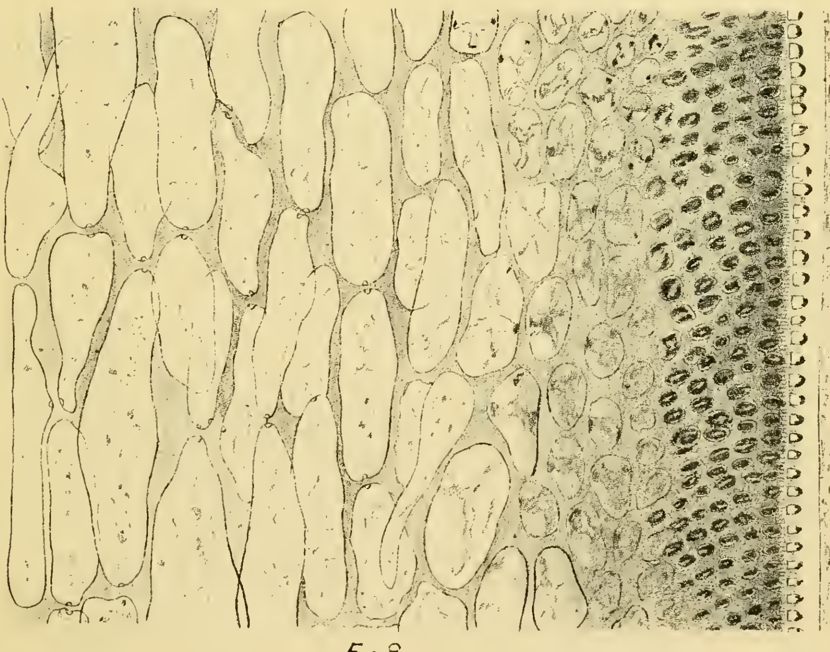


Fig 8

O.V.D. del S.B. lith.

CHONDRUS.

Anatomy of the Shoot

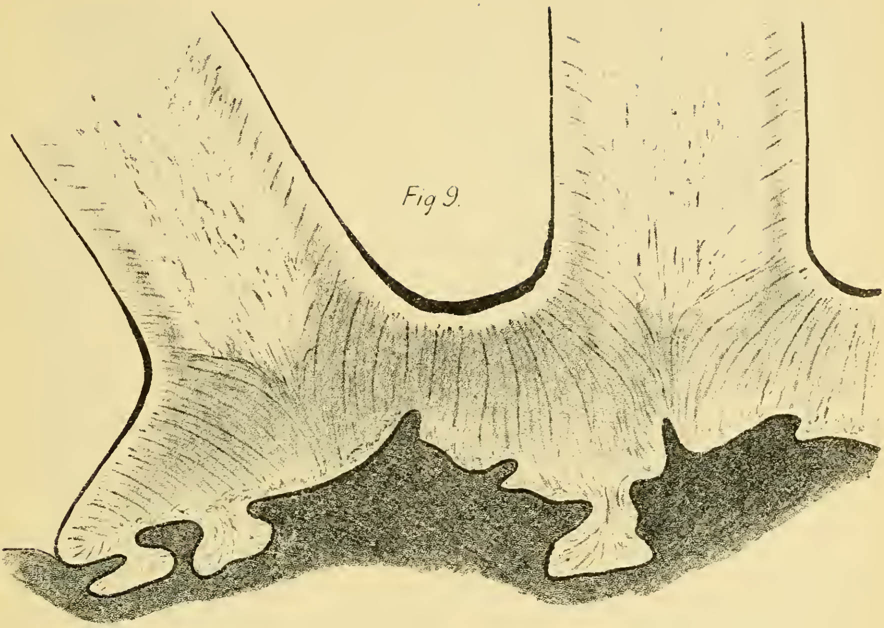



Fig. 10.

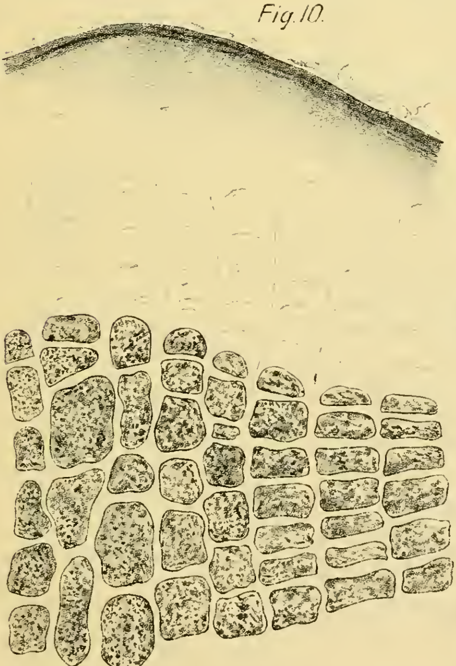
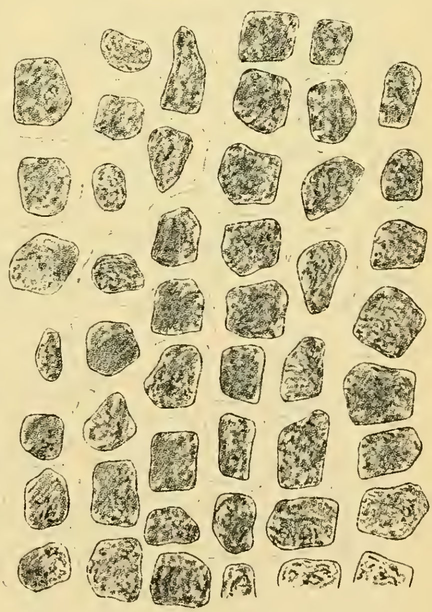


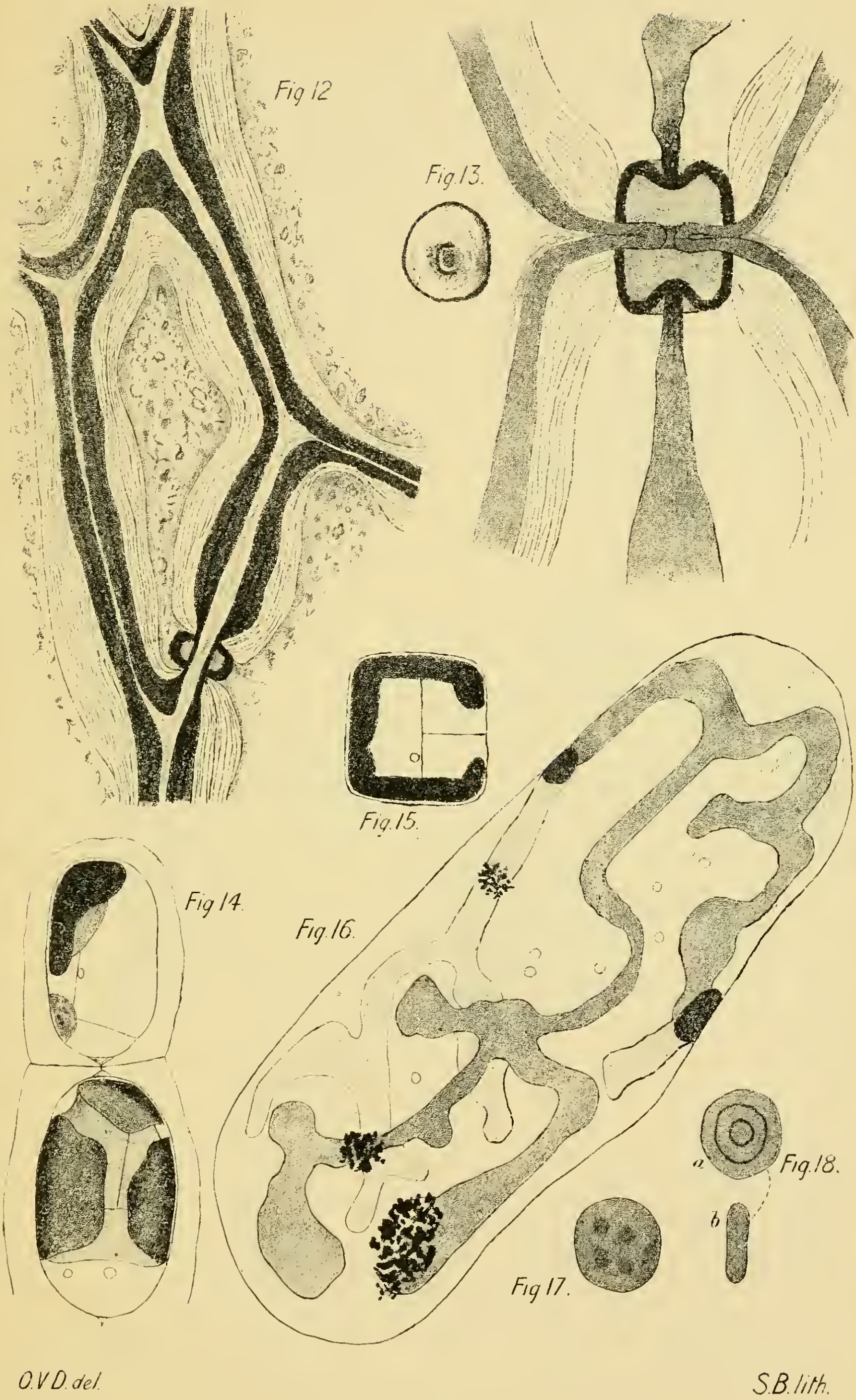
Fig. 11



O.V.D. del S.B. lith

# CHONDRUS.

## Anatomy of the Root.




CHONDRUS.

HISTOLOGY OF THE SHOOT.

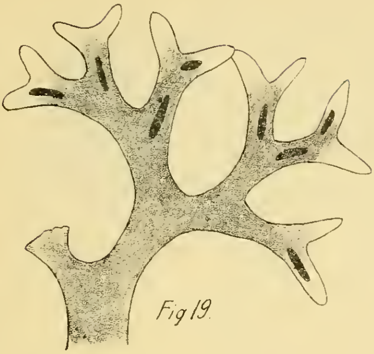


Fig 19.

Fig. 21.

Fig. 20.

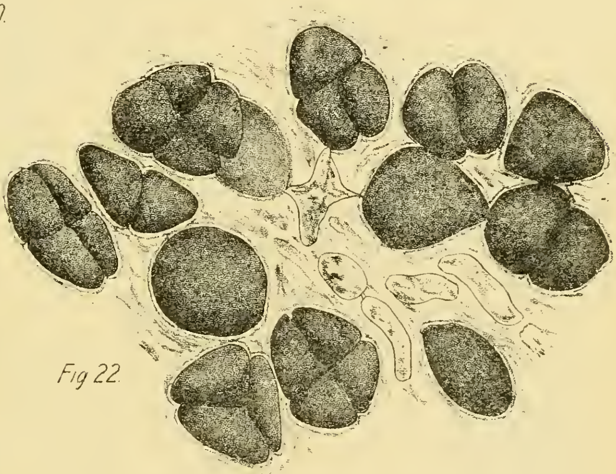


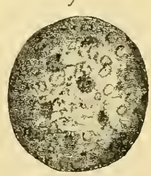
Fig 22.

Fig 23

Fig. 24

Fig. 25

Fig 26.



O.V.D. del. S.B. lith.

# CHONDRUS.

Nemathecium.

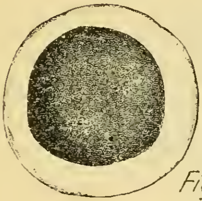


Fig. 27.

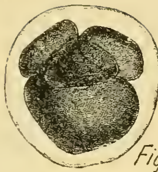


Fig. 28.

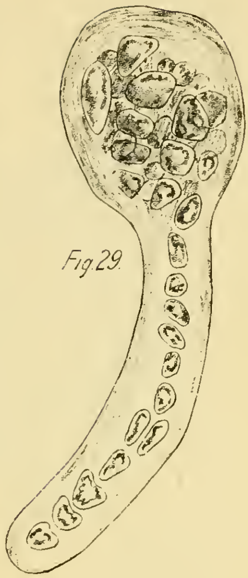


Fig. 29.

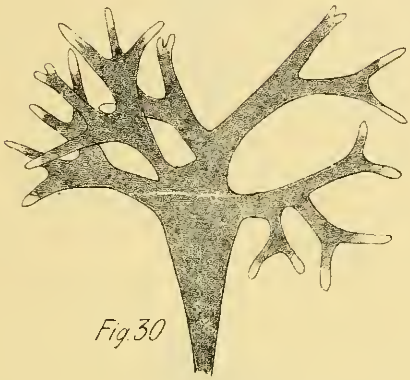


Fig. 30.

Fig. 31.

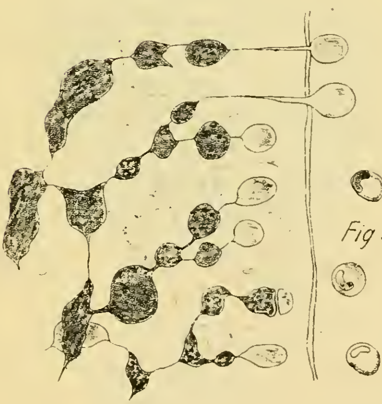


Fig. 32.

O.V.D. del. S.B. lith.

CHONDRUS.

Nemathecium and Spermophore.

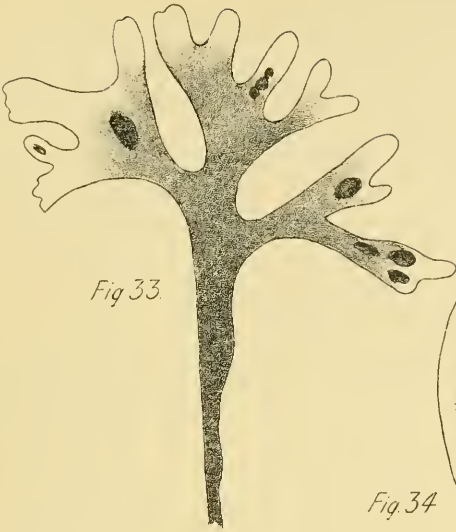


Fig 33.

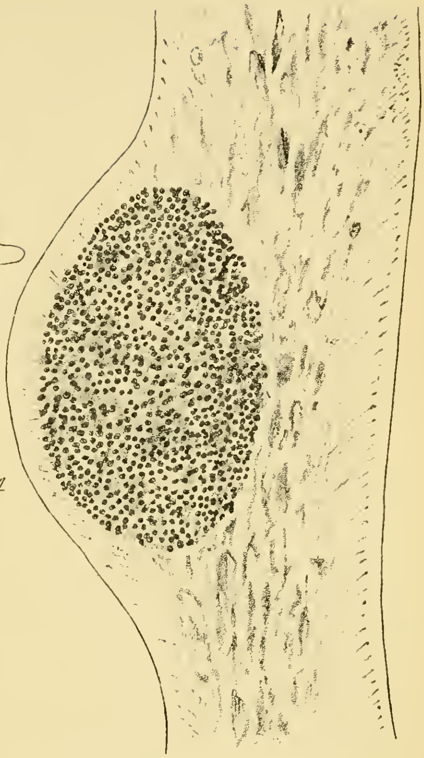


Fig. 34

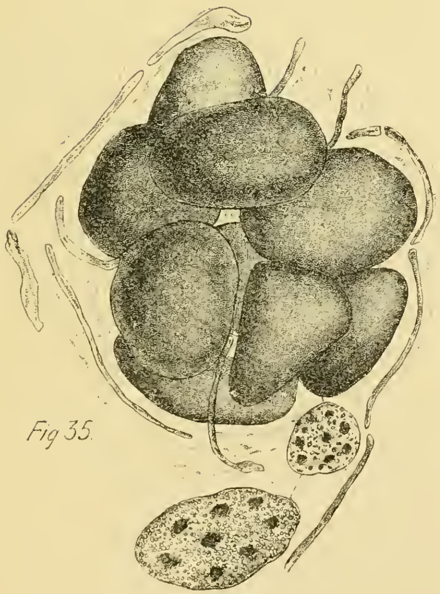


Fig 35.

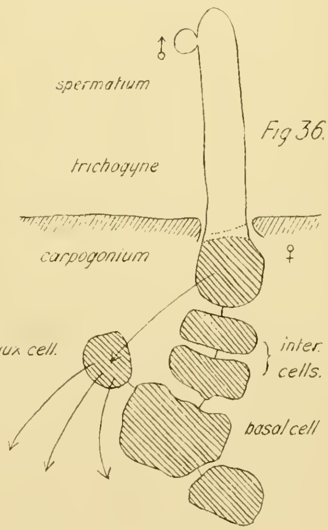



Fig 36.

O.V.D. del. S.B. lith

# CHONDRUS.

Carpophore.