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INTRODUCTION

TO

FRESH-WATER ALGÆ

WITH AN

ENUMERATION OF ALL THE

BRITISH SPECIES

BY

M. C. COOKE, M.A., LL.D., A.L.S.

AUTHOR OF

"FUNGI, ITS NATURE, USES, ETC.," "BRITISH FRESH-WATER ALGÆ," ETC.

WITH THIRTEEN PLATES

ILLUSTRATING ALL THE GENERA

LONDON

KEGAN PAUL, TRENCH, TRÜBNER & CO., LTD.

1890

PREFACE.

No apology is needed for the production of this volume, and hence there is little necessity for a preface. One justification may be found in the fact that the whole edition of my larger and copiously illustrated work on the same subject was soon exhausted, and could not be reproduced. Another justification will be the form and price of this book; for, with all the "manuals," and "handbooks," in the various departments of Natural History, there has never, until now, been any attempt to publish a cheap "handbook" of the British Fresh-Water Algæ. In these days of microscopical research the number of persons interested in this subject must be considerable, and a still larger number would have been attracted towards it, but for the almost prohibitive price of the books absolutely essential to the study. With the removal of this disadvantage it is to be hoped that

the ranks of the students will be largely augmented. To have included the Desmids, and Fresh-Water Diatoms, would have prevented the realization of a cheap and popular handbook, whilst their absence will not interfere with the practical utility of this volume which is now commended to the care of the student and lover of nature.

M. C. COOKE.

UPPER HOLLOWAY,
1890.

CONTENTS.

INTRODUCTION
TO
FRESH-WATER ALGÆ.

CHAPTER I.

INTRODUCTION.

THE uninstructed observer practically encounters no difficulty in distinguishing the lower Cryptogamia from the higher Cryptogamia, and both of these from flowering plants. In other words, the unscientific person will readily recognize the differences between a Fern and a Seaweed, or between a Moss and a Fungus, without having recourse to an elaborate scientific diagnosis of character. General characters, which shall be unimpeachable, are exceedingly difficult to construct, and none yet attempted, even for the primary divisions of the lower Cryptogamia, are by any means perfect. With the progress of knowledge the difficulty increases, for the links multiply which unite one series of forms with another, so that logical demarcation seems almost impossible. In the majority

of instances, and to the ordinary observer, there seems to be no great difficulty in distinguishing a Lichen from a Fungus or an Alga, and yet instances may occur in which it is so perplexing that some authors have hoped to surmount the difficulty by constituting an intermediate group of Fungo-Lichens, because they are supposed to partake of the character of both. It may be that the similarity, in external appearance, in some species of *Cladonia* amongst Lichens to *Clavaria* in Fungi, will at first produce hesitation, but this is soon dispelled. It is not so easy, however, upon a casual inspection, to distinguish a *Nostoc*, which is included amongst Algæ, from a *Tremella*, which is a Fungus, or a *Collema*, which is a Lichen. From part of this difficulty some writers have sought to deliver us by maintaining that a *Nostoc* becomes eventually developed into a *Collema*, and therefore the *Nostoc* is not an Alga, and the *Collema* not a Lichen, but a combination of both. Whether this view be accepted or not, it demonstrates that there are difficulties in the way of generalizations.

Thallogens, or Thallophytes, are names which have been applied to the lower Cryptogamia, as indicating that they produce an expansion called a thallus, instead of leaves; but unfortunately the whole plant sometimes consists of a single cell, without any kind of thallus, unless the cell be accepted as a thallus in itself. Name or no name, this name or any other, is of little importance; the entire class or group may be

again divided into two component sub-groups, one of which represents the Algæ, and the other the Fungi and Lichens. Let us accept, therefore, as sufficient for our purpose, the following definitions of the two sub-groups:—

A. Algals, or Algæ. Cellular flowerless plants, for the most part without any proper roots, or mycelium, living, with rare exceptions, entirely in water, and imbibing nutriment by their whole surface, from the medium in which they grow.

B. Mycetals. Cellular flowerless plants, at first furnished with a mycelium, very rarely immersed, deriving nutriment from the matrix, or from the surrounding air.

This latter sub-group being also subdivided into—

a. Fungi. Deriving nutriment, by means of a mycelium, from the matrix, never producing from their component threads green bodies resembling chlorophyll (*gonidia*).

b. Lichens. Deriving, for the most part, nutriment from the surrounding media, producing from the component threads of their thallus abundant gonidia.

We need not stay to inquire what objections may be urged against these distinctions, inasmuch as we are only concerned in distinguishing Algæ from Fungi and Lichens, for which the above will be sufficient. All authors have felt dissatisfied with paper definitions, and yet, with all their imperfections, are compelled to resort to them. Nearly fifty years ago the

late Professor W. H. Harvey remarked, "Whoever has paid the slightest attention to the classification of natural objects, whether plants or animals, must be aware that, if we desire to follow natural principles in forming our groups—that is, to bring together such species as resemble each other in habit, properties, and structure—it is a vain task to attempt to define, with absolute strictness, the classes into which we are forced to combine them. At least, no effort to effect this desirable object has yet been successful. Natural groups are so interwoven into each other, and often exhibit such an exaltation and degradation of characters within the limits of an order or a genus, that the distinctive marks, as they approach each other, gradually disappear, and two tribes, which in the more highly developed species scarcely resemble each other, are found in the lower to be either undistinguishable, or with difficulty distinguished. If it be difficult to *define* groups among highly organized plants, it can be no matter of wonder that when we come to the Cryptogamia, whose structure is so much more simple and uniform, and whose forms are still more sportive, the difficulties become vastly increased. But it fortunately happens that these difficulties are much more formidable on paper than in the field. Thus, while the systematizer, in his study, may consume the midnight oil, till his aching brains are weary with the fruitless task, in attempting to express in words a character which shall include

every species of the class *Algæ*, and at the same time exclude every denizen of the allied groups, *Fungi* and *Lichens;* the student, roaming through the fields or along the seashore, finds no difficulty whatever in recognizing a *Seaweed,* as distinct from a *Mushroom* or a *Lichen.*" *

Algæ constitute the principal vegetation of the waters, especially of the sea, but largely of fresh water, very few of them being found to inhabit stations which are not submerged, or exposed to constant dripping; in all situations, great dampness is an essential of their existence. The lowest form of development consists of a single cell; the highest, of a kind of stem, with fronds, resembling leaves, many feet in length, and a basal expansion, or fibrils, which fulfil the functions of a root. Between these two extremes lie an endless variety of forms, and even the same species is subject to great variation.

Although Algæ flourish in salt water and in fresh, it by no means follows that the same species or genus is found under both conditions. Indeed, the contrary is the prevailing rule, to such an extent that the Fresh-Water Algæ may be studied independently of Marine Algæ. Very few Marine Algæ are to be found in fresh water, and these chiefly at the mouths of tidal rivers, and of but few species, whilst intrinsically *fresh*-water species cannot exist in salt water. It may appear to some to be a singularly artificial arrangement to treat

* "Manual of British Algæ," by W. H. Harvey (1841), p. v.

separately of Fresh-Water Algæ, making the separation to depend upon the medium in which they grow, but it will be discovered, upon better acquaintance, that, artificial as the arrangement may be, the fresh-water species and genera are sufficiently distinct to justify such a scientific heresy. It is no new thing to treat of the Fresh-Water Algæ, as if they were entirely distinct, and not at all related to the Marine, so that we may plead companionship in our crime. If we revert to the past history of the literature of British Fresh-Water Algæ we shall find this to be correct.

The historical review may be briefly summarized, by dividing it into three epochs, of about forty years' duration for each, the first being limited by the publication of Dillwyn's "Confervæ," the second by Hassall's "Fresh-Water Algæ," and the third by Cooke's "British Fresh-Water Algæ."

Prior to the first epoch there were but two works of sufficient importance to be mentioned here—Ray's "Synopsis," which was published in 1724, and Dillenius' "Historia Muscorum" in 1741. Each of these, as far as they can be identified, included somewhere about 20 species of Fresh-Water Algæ.

The epoch commences in reality with Hudson's "Flora Anglica," the first edition of which is dated 1762, and contains about 25 species. Then came the first edition of Withering's "Arrangement of British Plants" in 1776; Lightfoot's "Flora Scotica" in 1777,

also with 25 species; Robson's "British Flora" in the same year, with 26 species; the second edition of Hudson's "Flora Anglica" in 1778; Relhan's "Flora Cantabrigiensis" in 1785, with 12 species; and Sibthorp's "Flora Oxoniensis" in 1794, with 7 species. This brings us to the third edition of Withering in 1796, with 38 species; followed by Abbot's "Flora Bedfordiensis" in 1798, with 14 species; and Hull's "British Flora" in 1799, with 34 species. These were all the predecessors of Dillwyn, and did not achieve much for the Fresh-Water Algæ until the climax was attained by the publication of Dillwyn's "British Confervæ" in 1809, with 88 species enumerated. The first edition of "English Botany" had already commenced in 1790, extending to 1814, but it was not until after the appearance of Dillwyn's work that the Algæ of the British Botany were published, ultimately including about 100 species. Undoubtedly Dillwyn was, therefore, the parent of a systematic study of the British Fresh-Water Algæ, and with him the first epoch culminated.

The second epoch commenced well with the continuance of "English Botany," and then followed several botanists whose influence has passed down even to our own times. Following the example of the first epoch, we may enumerate the most important of their works. The "Midland Flora" of Purton in 1821 only includes about 14 species. Hooker's "Flora Scotica" in 1821, about 39 species; Gray's "Arrange-

ment" in 1824 was confessedly devoted chiefly to systematic classification, including nominally 103 British Fresh-Water Algæ. Greville's "Flora Edinensis" in 1824 had 50 species, the working period for Algæ having scarcely commenced, his "Algæ Britannicæ" appearing in 1830. Jones and Kingston's "Flora Devoniensis" in 1829 included but 29 species. Johnston's "Flora of Berwick-on-Tweed" in 1831 had 40 species. Near this time (1833) Berkeley's "Gleanings of British Algæ" was published. The latter volumes of "The English Flora" appeared also in 1833, under the editorship of Sir William Hooker, the Algæ being contributed by Dr. W. H. Harvey, and included 160 species. This was Harvey's first important contribution to the History of British Algæ, which was succeeded in 1841 by the first edition of his "Manual," containing 198 fresh-water species. Between these two Mackay's "Flora Hibernica" was issued in 1836, with 87 Irish species. These all culminated, in 1845, in the appearance of Hassall's "Fresh-Water Algæ," enumerating 297 species, exclusive of Characeæ, Desmidiaceæ, and Diatomaceæ, thus closing the second epoch. The time at which this latter work appeared was an active one in British Fresh-Water Algæ. Ralfs was preparing his work on Desmids, and contributing papers to the scientific journals, notably the "Annals of Natural History." Dr. Greville had commenced his "Scottish Cryptogamic Flora" in 1823. Harvey was at work earnestly with

Marine, and of course casually with Fresh-Water Algæ. The volume containing the Algæ of the "English Botany," second edition, appeared in 1844, so that about this time, which we distinguish as the end of the second epoch, characterized by the publication of Hassall's work, there was greater promise than came to be realized in the early part of the next epoch.

It is not uncommon to hear observations made disparagingly of the work with which the second epoch closed, when no account is taken of the difficulties which had to be encountered in preparing an illustrated work of that nature. It cannot be fair to judge it by its successors, but by its predecessors, and if it was fairly up to the general standard at the time of its production, that is all we can expect. It must be remembered that Kutzing's large and splendid work, the "Tabulæ Phycologiæ," was only commenced in 1846, and that therefore it could not be consulted. It is certainly to be regretted that in Hassall no indication is given of the measurement of the objects figured, or the magnification employed. That there are faults no one will deny; but, on the whole, we are not prepared to condemn it as unworthy of the time at which it appeared. A comparison of the figures of Desmids with those in Ralfs' work, of but three years later, will show that in *execution* something was left to be desired.

The third epoch is one on which we must necessarily

be very brief. Coming so near our own time, we must be content to indicate what has been done, and leave conclusions to others. Closer relations with the Continent, cheap postage, more general acquaintance with foreign works, all tended to raise greater expectations for the closing work of the third epoch than any of its predecessors. The works of Kutzing, the Memoirs of Pringsheim, De Bary, Cohn, Bornet, Thuret, Borzi, Wittrock, and many others, all contribute to illustrate British Fresh-Water Algæ; and although during forty years very little has been done in our own island, even in the identification of species, there has been considerable activity in investigation, especially in the North of Europe. The scattered memoranda, notes, and observations of Professor Henfrey, Dr. Braxton Hicks, and Mr. W. Archer constitute the bulk of our home manufacture of the literature of Fresh-Water Algæ for about thirty years. The later portions of the "Supplement to English Botany," containing Algæ, date from 1843; and Harvey's second edition of the "Manual," in 1849, was wholly confined to Marine species. Hence there is not an independent work on British Fresh-Water Algæ belonging to this third epoch, until we come to its close, the only contributory work being Berkeley's "Introduction to Cryptogamic Botany," in 1857. But if there was an extraordinary dearth of books on this subject after 1845 in Britain, such was not the case on the Continent. The consecutive publication of the volumes of Kutzing's

"Tabulæ" must have been an important influence, although it was not until 1864 that Rabenhorst's "Flora Europæa Algarum, Aquæ Dulcis et Submarinæ" was commenced. The advent of this work was hailed with pleasure, notwithstanding its many faults; and various authors set themselves to work on different genera and families, such as Œdogoniaceæ, Zygnemaceæ, etc., so that in twenty years it is left far behind. As a work written in English, although not containing much original observation, we must mention Dr. Horatio Wood's "Fresh-Water Algæ of North America," published in 1872, which was at length superseded by "Fresh-Water Algæ of the United States," by the Rev. Francis Wolle, in 1887, or within four years after the completion of "British Fresh-Water Algæ," by M. C. Cooke, which we have taken as the close of the third epoch of our brief summary. This latter work contained 445 species, as against the 297 species included in Hassall's "Algæ," and a few species since discovered would raise the total to about 450 species, all told, although some of these must be excluded as "doubtful Algæ."

The history of the changes which have taken place during fifty years in the location and interpretation of most of the Fresh-Water Algæ will have but little interest for the general reader, who will not concern himself that the majority of species were formerly *Fucus*, *Ulva*, or *Conferva*, or that the Nostocs were joined with *Tremella* and thus linked with Fungi.

Possibly, in respect to the latter, he will hint at the irony of fate, which threatens to associate *Nostoc* again with Fungi, in somewhat degraded relations of commensalism. Here, again, it is rather the duty of an author to give a record of facts, than to concern himself with theories, either in support or controversion. The unfortunate tendency to the multiplication, often inordinately and recklessly, of technical nomenclatures for trivial differences, which characterizes most of the recent text-books in biological science, will have little sympathy with those who desire the extension and popularization of Natural History studies.

In times still within the memory of living men, it was not difficult for any one person, with a moderate amount of leisure, to pursue with advantage the study of two or three cognate subjects, but many things have conspired to render such a course at present unadvisable, if not impracticable. Specialism has become more and more the order of the day, so that, instead of meeting constantly with students devoted absolutely to general algology, and capable of holding their ground with Marine Algæ and Fresh-Water Algæ, including both Desmids and Diatoms, we find a growing tendency to split up even these into sections; hence no one feels it to be an imputation on his mental capacity to confess that he confines his studies to Desmids, or to Diatoms, or to the Fresh-Water Algæ, exclusive of the latter, and, if not to the whole scope

of Marine Algæ, to content himself with the *Florideæ.* Not only has a process of subdivision become absolutely necessary, on account of the increase in the number of species, but also by reason of the great extension of the literature of each subject, which has to be mastered; the more intimate and searching investigation which each species demands, and which improved microscope power has fostered; and the tendency to trace the whole life-history of the several organisms, which is wholly incompatible with a wide and almost unlimited field of operations. Considerations such as these have led to the production of books like the present, which endeavour to limit the scope of investigation within attainable boundaries, and, by the selection of well-defined groups, offer, within a reasonable compass, a "guide, philosopher, and friend" to assist in the pursuit of a scientific study which shall be recreative and not oppressive, circumscribed and not illimitable.

Introductions have been written and published to Cryptogamic Botany as a whole. We have had Introductions, or Handbooks, to the study of Mosses, of Lichens, of Fungi, and sections of Fungi, and also for the Marine Algæ, but hitherto nothing has been attempted in this direction for the subject of the present volume. The only substitutes are too voluminous and expensive for the youthful student of limited means. If excuse were needed, this would be sufficient; but it may be added thereto that, even in the larger and more expensive books alluded to,

there was practically no introduction, and all the information on the rise, progress, and development of the various forms was scattered through the volumes, whereas it is now collected and arranged at the commencement.

The periodic outcry against systematic Botany, and the varied attempts which have been made and continue to be made against it, urging its inferior position and value, are senseless and unjust. There would be no *science* of Botany without it, and the systematist would by no means seek to exclude physiological investigations which could assist but not hinder in his work. The only danger is in seeking to elevate the one in public esteem to the depreciation of the other. It is by no means an unusual experience to meet with individuals who will condemn that which they do not comprehend, or with which they fail to sympathize, in order to cover or excuse their own ignorance. An effort to combine the two phases within the scope of one work may possibly fail to satisfy extremists, but will commend itself to the judgment of the student in search of information.

CHAPTER II.

COLLECTION AND PRESERVATION.

The earliest and most elementary process in regard to any organisms must be their recognition as members of the group under investigation. In this instance the objects are Algæ, and hence it seems imperative that the first step taken should be to recognize a few generic types as representatives of what kind of objects they are. This is not a difficult task, since, from a dipping of pond-water, the tiro will soon discriminate the algæ from the infusoria, even though, like *Volvox,* endowed with "perpetual motion." Therefore, to commence with a few hints and instructions as to the collection and examination of algæ, appears to us the most natural method of leading into the subject. It is only reasonable to suppose that the first impulse of the would-be student will be the ocular demonstration of what is an alga, and that he will be desirous at the outset to collect sundry little bottles of ditch-water, in the hope that some of them will contain objects of which he is in search. It may be taken for granted that every person of education

and intelligence, in these latter days, is able to manipulate with the microscope, so that, the objects once secured, the progress of examination will succeed uninterruptedly, and culminate satisfactorily. Of course there will be failures at the commencement, and disappointments, but all these will receive full compensation in the ultimate successes. Even the town-dwelling recluse, who hardly comes within sound of a babbling brook once a week, may hazard the experiment of exploring the green slime on a water-butt, the shining treacley stains at the base of brick walls, or the thready filaments floating in an old horse-trough or around a dilapidated pump, and amongst these acquire first experiences with the new "hobby."

The collection of fresh-water algæ can scarcely be undertaken without some previous notion, however vague, of localities in which they are to be found. It must not be assumed, as a positive fact, that these organisms are *only* to be found in water, because there are many of the unicellular algæ which are effused, like a slimy coating, on rocks subject to dripping water or continuous moisture. Some occur on the trunks of trees, where water trickles down from the branches, or even at the base upon the ground. Greenhouses and conservatories will generally show the traces of some of them on the walls, or stains upon the floor. Some of the commonest sights in damp weather are the dark patches and streaks on the

ground at the base of walls, indicating the presence of some *Oscillaria.* After plentiful rain gelatinous lumps of *Nostoc* flourish in the morning on garden walks, but dry up and shrivel into nothingness as the day advances. Even dripping aqueducts, cattle-troughs, leaky pumps, and all situations in which there is a constant percolation of water, should be explored. And, last of unsuspected places, may be mentioned the damp surface of naked soil, or swampy places in lawns, and on heaths or moors. The most usual, and one might say legitimate, habitats of fresh-water algæ will be in the water, in sluggish or stagnant ditches, but by preference in ditches which are not stagnant, or at the least have no stagnant odour, slow-running streams, and lakes, moor-pools, ponds, canal-banks, attached to timber or stones, on twigs, sticks, and stems, which have for some time been immersed in water, and amongst bog moss in swamps, especially where there is a little depression and a miniature pool of clear water is extemporized. Swift rivers, torrents, etc., will be found valueless, or never repay the time employed.

General suggestions only can be made on a subject of this kind, and experience will soon suggest a likely spot for exploration, but it must always be a moist one, and continually moist, or at least for the greater part of the year. As to the period when the most persistent efforts should be made for the collection of algæ, some indication will be expected, and yet, for

our own part, we should not relax at any period of the year, except, perhaps, when the ground is covered with snow, because we have often broken the ice upon a pool and dipped out water containing interesting forms. It may be cold work, but is sometimes well rewarded. As may be anticipated, algæ are not in the same condition all the year, and even the same species collected about February would have a different appearance, and be in a different condition from the same species collected in June or September, especially the filamentous kinds. It may be taken for granted that all species are not in fructification at the same time. Perhaps *Spirogyra* will be found in fruit, or in conjugation, in spring, and most species of *Œdogonium* not until the autumn. So that something may be collected at all seasons of the year. The novice may be reminded that he will save himself a world of trouble, anxiety, and vexation, if he abandon all endeavour to identify species of algæ which exhibit no trace of fructification. Long filaments of regular cells, differing only in length and thickness, may look pretty enough, but in that condition they are of little interest to the student who desires to become acquainted with algæ upon scientific principles, and not empirically. The only way in which they could give promise of becoming useful would be by committing them to small aquaria or tanks in order to watch their growth and development.

Some provision has to be made even for a short

stroll in search of these organisms. The requisite apparatus is small and by no means cumbersome, but if the excursionist desires to prove himself a sane man, rather than a reckless enthusiast, he will take good care that his boots are good—not of the drawing-room pattern, but good substantial boots, intended to keep all the moisture on the outside. Wet feet are by no means pleasant to one's feelings, even without fear of rheumatism, or colds in the head, as a remote contingency. The sensible naturalist will have less regard for personal appearance than for personal comfort. Young men, like young ladies, dislike to be caught in *deshabille,* until they discover that kid gloves and patent-leather shoes are not the essentials of field work. In order to be prepared for dipping out the water of a pond, and examining its contents for floating algæ, a dipping-bottle, with a wide mouth, will be requisite, and with it a brass collar fitted to the end of a walking-stick. A pocket lens, with about one inch focus, must be provided for casually examining the water when dipped out of the pond. This hint should be quite unnecessary, for a true naturalist would as soon think of leaving his home without his boots, as without his inevitable pocket lens. Handy collecting-boxes can be purchased, holding a dozen small tubes with corks, into each of which consecutively the results of dippings for the floating algæ may be transferred. Filamentous algæ can be folded in small squares of thin gutta-

percha, or even in paper, and conveyed home for examination. Slimy algæ, encrusting rocks and stones, can be removed by the aid of a strong knife, and stowed in paper or tin-foil. They may even be sent by post to a distant friend in the same manner, and be quite fresh at the end of a long journey.

Most smokers are aware of the existence of small metal match-boxes, which, when freed from their original contents, are available for stowage of such algæ as *Nostoc*, and even of *Batrachospermum* and filamentous algæ in general. The specimens will keep moist and fresh for some days, and the boxes will occupy but little space in the pockets. After a day's collecting, it may be well to transfer the contents of the various bottles and boxes to small white artist's saucers, with a little water, and examine each at leisure.

A sort of cultivation may be carried on by the means of a series of tumblers, each restricted to its own particular gathering, and every one raised a little above its fellow, and connected with it by a thread, so that, like a syphon, water flows through the whole series in a slow gentle stream. Of course the first, or upper, tumbler will be supplied by a constant drip, and waste from the last, or lowest, tumbler will be carried off into a jar or similar receptacle. By this means, specimens collected in an immature condition may pursue their growth and development, and a constant source of amusement and instruction be pro-

vided for a wet day or a leisure evening. Those who do not like the trouble of so many receptacles, and can carry out all their designs upon a simpler scale, adopt a single inverted bell-glass, converted into an aquarium, into which all species are cast pell-mell, and flourish in concert. Certainly a very heterogeneous assemblage may be obtained in this way, and for the purposes of most people this will be sufficient. There will be no lack of objects, animal as well as vegetable, and, with a little management, such an aquarium may be kept sweet and prolific for a lengthened period.

Preservation for the herbarium, or for future study, may be secured by the usual methods of floating and mounting marine algæ, first cleansing the specimens (where practicable) by well washing in a flat dish or soup plate, and finally passing under them a slip of clean white paper, which is raised so as to take up the algæ in the middle, well floated into position, draining off the water, and then drying, with the least pressure possible. In some cases, where the algæ are gelatinous, no pressure at all must be used until the algæ are partially dried, or the papers will be firmly glued together. Some prefer placing a thin fine muslin over the specimen, before laying down the upper sheet of paper, to prevent adhering. For minute species and small specimens, thin flakes of mica are preferable to paper, for many reasons, especially that they can be placed at any time under the microscope and examined. The *Palmellaceæ,* and

similar groups, will be of very little service if dried in any other way. Most species will adhere of themselves to either paper or mica; the exceptions, such as *Vaucheria* and some *Cladophoræ*, can be fixed with gum tragacanth. It must not be expected that the fresh-water algæ will make pretty objects when dried, in the same manner that the red seaweeds are beautiful. Indeed, with very few exceptions, they will only present themselves to the naked eye as discoloured blotches or a congeries of green threads. On the other hand, they have their utility in the midst of their ugliness, for, whenever moistened, the cells will swell again, and something of the old form will be restored, although in most cases the bright green chlorophyll will have disappeared. No one would attempt to preserve them in this way for their beauty, but simply for evidence and comparison, and other cases of utility.

Some difficulty may probably be experienced in mounting specimens for the microscope. Every one has had to struggle more or less through these difficulties. We have seen "slides" in which the specimens were still green and life-like, after having been mounted for twelve years in the water in which they were collected, but unfortunately there is always a risk of leakage in mounts with fluid. If the medium is denser than the contents of the alga-cells, the endochrome will be contracted and the walls collapse. One objection to mounting in glycerine, or glycerine

and water, is the density of the medium, and consequent collapse of the cells; another, that in time, use what precaution you may, the cells *will* leak, more or less, and the object become dry. No medium has yet given us absolute satisfaction; but, all things considered, we are most favourably disposed towards glycerine jelly, which is too dense to enter the cells, and does not alter the form more than glycerine would do. We may add that slides should always be *flat* in the cabinet, and *not* on the edge; and they should not be left exposed to the light, or the green colour will soon be lost. We have in most vivid recollection a large collection of fresh-water algæ, consisting of some hundreds of specimens, mounted by a most competent German algologist, and which would, if permanent, have been invaluable. These were mounted on squares of mica, covered with mica, or in some instances on glass, covered with mica. The fluid was some combination of glycerine, consequently not one specimen in fifty is of the slightest value whatever, so that a vast amount of skilled and intelligent labour has been thoroughly wasted, giving no advantage to any one, and no satisfaction to any one, but is a permanent source of disappointment and regret.

Whether in the case of specimens dried for the herbarium or preparations mounted for the microscope, experience has taught us to urge upon all students the very great importance of attaching to the object certain information which may be found invaluable

in the future, although of little moment at the present. The first item in this information should be the locality where the specimen was collected, because localities are of considerable value in ascertaining geographical distribution, in drawing up local lists, and, having regard to the changes which the extension of large towns, the encroachments of the house-builder, and the destructive drainage pursued in public parks, and open recreation grounds, have upon small ponds and pools, swampy places, and, indeed, almost all habitats where fresh-water algæ are chiefly found, it is of the utmost importance to secure evidence of the existence of all species in such localities, which may be doomed in the near future to become obliterated. Another item of possible interest would be the addition of the precise date of collection, because this will not only fix the year when the course of nature had not been diverted by the encroachments of civilization, but, by being precise as to the month and the day, it will serve to indicate the precise period when the particular species was found in any stage of fructification. It is by no means certain when the majority of species should be sought after, if it is desirable to obtain them in mature fruit, hence the accumulation of evidence of this kind may prove of value in the future, and only requires a due appreciation of its value to make its acquisition sure. It may seem unnecessary to those who are experienced in the collection of these organisms to urge such points as

these upon the student, and more unnecessary still to append one or two cautions, which we deem prudent to suggest. Young collectors are likely to select, for instance, the brightest green tufts of filamentous algæ seen floating in a clear pond, under the impression that such tufts will exceed all others in beauty. This is a false impression, for specimens of that kind will be in most vigorous growth, will exhibit all the glories of exuberant vegetation, but will be deficient in fruit, whereas the accurate determination of species depends almost entirely upon the fructification. Older, duller, discoloured tufts, less pleasing to the eye, will prove the most valuable, because of the greater probability that they will carry evidence of fructification. It is a common mistake to suppose that the filaments of any confervoid alga, in any condition, can be readily determined by an adept, whereas the fact remains that the expenditure of time and patience on the attempts to identify sterile threads or fragments is absolutely wasted, except in connection with fruiting specimens, or when the phenomena of vegetation alone are the points in question, without reference to absolute identity of species. Another suggestion may be offered as to the value or interest of examining carefully the old, and apparently exolete, threads of decaying tufts. When all the vitality and beauty has departed, these old threads may become invested with a new interest by reason of the small parasitic species which establish themselves upon them. Such species will probably

never be met with except under such conditions, and therefore these should be sought after diligently, under the conditions most congenial to their development. *Mischococcus* is one of these parasitic species.

There is still another suggestion which relates to making the most of one's opportunities. This applies to acquiring facility in the practice of camera-lucida drawing. Without staying to discuss what particular form of camera should be employed, whether a single glass disc or a more complex prism, for this is beyond the question, and may be regulated by individual judgment and experience, the main point is to urge that some method should be adopted of throwing down the image upon a sheet of paper, so that the outline can be traced. It will often happen that some peculiar condition of cell-formation is met with, or some stage of conjugation or fructification encountered, which it is desirable to remember, and this is best done by at once making a drawing by the aid of the camera-lucida. Wise persons are in the habit of making such sketches of cells, or spores, for the purposes of securing accurate measurement of their dimensions. Microscopists need not be told that it is quite possible to construct carefully a scale of measurement, whereby the image of any object, accurately traced, can be measured correctly and with facility, so long as the conditions of distance, position, etc., are adhered to. This is really a point of microscopical manipulation, and need not be expatiated upon, whilst

urging the value of making sketches and cultivating, by practice, facility in its accomplishment. No previous knowledge of drawing is essential, although it might be useful, and early difficulties are not insurmountable, although there are difficulties at first, and until the eye and hand are educated to the task they have to perform. All living objects will present certain features which vanish on dessication, and the only way to secure representation of them is by camera-lucida sketches.

The most elaborate instructions would be useless, in connection with this or any other subject, unless they are met by a corresponding earnestness and perseverance on the part of the student. A certain amount of enthusiasm must be imparted to every pursuit of this character, and this enthusiasm will grow as the initiatory difficulties vanish. That there will be difficulties at first, no one can deny, but application, experience, and resolution will prove the best antidotes. "It is the first step which costs," is an old axiom, applicable here as elsewhere, and when the early steps are taken the succeeding ones will become less and less difficult, more and more gratifying and satisfactory, until the fascination of success will lead on to the full fruition of a work which, ceasing to become a work, attains to the position of a pleasure, which will amply repay for all the labour it has cost.

CHAPTER III.

CELL-INCREASE.

THE multiplication of cells by subdivision is the simplest form of increase in such organisms as the fresh-water algæ, and whether, in unicellular species, we should regard this as a simply vegetative process, or a low form of reproduction, is practically of very little importance. Being disposed to regard it in the light of a vegetative process, we place it under the above heading, as a prelude to the more determinate cell-increase of filamentous forms hereafter described.

In the majority of unicellular algæ the only known mode of increase is by the ordinary process of cell-division. In such cases the contents of the cell divide in one or both directions, into two or four daughter-cells, and a septum is set up between them by the secretion of cellulose over the whole surface, the flat adjacent suıfaces gradually recede and become rounded, until the mother-cell encloses two or four daughter-cells, which, on the rupture of the membrane of the parent-cell, escape as individual plants, in all respects like the parent from which they sprang.

In this manner a perfect colony is formed, each of which in turn becomes a mother-cell. Sometimes they are held together in a kind of mucilaginous thallus, and sometimes they are free. In certain cases the cell-membrane is increased by successive deposits which appear like concentric rings, until the hyaline investment is considerable; and in other cases there is, apparently, only a simple investing membrane. This is the entire process of rejuvenescence in some simple forms of algæ, if they are to be regarded as autonomous plants, which is now being called in question.

The *Palmellaceæ* and the *Chroococcaceæ* furnish illustrations of this mode of increase, which Braun has characterized as "reconstruction of the cell," and he says that, "if the transformation of the entire cell-contents is combined with a division of them, a multiplication of the cell takes place, constituting the basis of the formation of tissues in plants where the cells remain connected together, multiplication of the individual where they separate. In the majority of cases the entire contents, that is to say, the whole active living organism of the cell, passes directly into the new structure, so that nothing remains behind, unchanged, of the old cell (the mother-cell) except the passive membranous wall. The daughter-cells are therefore not to be considered as young produced by the mother-cell, existing contemporaneously with it, nourished by and gradually developed in it, but as the

rejuvenized and metamorphosed mother-cell itself. This is most strikingly evident in those cases where the entire and undivided cell-contents become loosened from the membrane of the mother-cell, and, shaping themselves in a different way, become a new cell." *

In *Tetraspora* the cell-contents divide in both directions, and as the quaternate divisions separate (Fig. 8) they continue in the same position of proximity within the frondose thallus, so that the daughter-cells lie in groups of four, which originated the generic name. In the *Palmellaceæ* and its allies many undoubted cases of true quartering, or apparent quartering, may be met with. In *Protococcus* mere halving and true quartering have been observed intermixed. In some generations no true cell-membrane is developed, only a gelatinous envelope. And where a true cell-membrane exists, it sometimes splits and is cast off after subdivision, as in the genus *Schizochlamys* (Fig. 3). The globose cells of this alga "produce a hyaline cell-membrane, which becomes removed to some distance from the green body of the cell by subsequent secretion of fluid-like jelly; soon, however (probably from endosmose), becoming unable to withstand the expansion of the jelly, it splits in the direction of an equatorial circle, by a clean line, into two similar halves, or if the dehiscence takes place by two circular lines, cutting at right angles, into four similar pieces. This splitting and peeling

* Braun on Rejuvenescence (Ray Society), p. 227.

of the membrane either coincides with a division of the internal cell-mass, or it occurs without any such division. By frequent repetition of this process the cell gradually becomes surrounded by an accumulation of old fragments of the membranous shell, which are held together by the extremely transparent jelly set free. The division of the cell may be either a simple halving, in which case each part is immediately clothed again with a hyaline cell-membrane, or double, through the cells produced by the first division separating immediately into two cells, without previously acquiring a coat of cell-membrane, and therefore without skinning." Braun observed a similar tearing and exfoliation of the outer layers of stratified cell-membranes in species of *Chroococcus* and also in *Glœocapsa.*

The general character of cell-division and the formation of daughter-cells in filamentous algæ is maintained, with the modification that the multiplication usually takes place in the direction of the filament, with the division, and new septum transverse to the length. A few illustrations will serve for this portion of the subject.

The process of fissiparous division of cells in *Spirogyra* was observed by Thwaites. Herein the endochrome is arranged in one or more spiral coils within the cells. "When the latter is about to become divided, a slight disturbance of the regularity of the spirals may be observed just in that part of the cell

where the division will take place; their continuity is subsequently broken at this spot, and soon afterwards the original cell may be seen to have become converted into two, with no apparent disturbance of the endochrome, except just at the point where separation took place. Various explanations have been given of the mode in which the division of the cell takes place, but I believe the correct one is to consider that each half-endochrome develops around it a new cell-membrane, the old one remaining or becoming absorbed."

It has also been observed by the same writer how cell-division takes place in *Cladophora glomerata.* "In this species the cells are extremely large, and the endochrome is in considerable quantity; and the cells apparently continue increasing in size during the whole period of their vitality, so that those at the base of the plant are larger than those recently developed. Some species of *Conferva* consist only of single unbranched filaments, so that, in these, new cells are added only at one point; but in the species under consideration new cells originate from every part of the plant, and thus we have a favourable opportunity of observing what takes place when a new cell is being produced from one which has been some time developed. A slight protuberance is observed upon the cell-membrane, which has the appearance of being caused by the enlarged contained endochrome endeavouring to force its way out of the cell. This protuberance

increases at the same time with an increase of the endochrome, and becomes of some considerable length before there is any appearance of a septum dividing it from the original cell. The endochrome, however, subsequently divides, and a membrane is developed over each of the divided ends; or, what is the probable explanation, a development of cell-membrane has been taking place during the whole process, and, still going on, a membrane is now naturally formed over those ends of the endochrome where the previous continuity has been broken. That an addition is continually being made to the cell-wall is evident, since there is no other way of accounting for the increasing size of the cell and thickness of its membrane."*

Excellent opportunities occur for watching the division of cells in *Œdogonium*. In this genus the cylindrical filaments are like those of a *Conferva*, from which they may be distinguished at a glance by the transverse parallel striæ at one or other extremity of many of the cells. These striæ are indications of the mode of cell-increase, which takes place in the following manner:—"When a cell has reached maturity, and is about to divide, a little circular line is seen near its upper end. Gradually the line widens, and it is seen that the wall of the mother-cell has divided all round, and the cell above is slowly raised by the growth of the daughter-cell, arising, as it were,

* *Annals and Magazine of Natural History*, vol. xviii. (1846), p. 18.

out of the apex of its parent-cell, and carrying upwards the first streak, or cap, left by the breaking away of the wall of the mother-cell. In this manner the new cell soon attains a length equal to the one from whence it sprung. When the young cell has matured it becomes in turn a mother-cell, the splitting round is repeated, a second streak or cap is carried upwards, and thus as many as four, five, or six successive cells are formed, as indicated by the four, five, or six striæ or caps which may be counted at the apex of a cell, the number of caps corresponding to the number of cells produced consecutively immediately beneath the caps (Fig. 67).

"Related to this subject of vegetative increase is the known fact that some species of algæ possess power of compensating for injuries by abnormal methods. Thus, when the filaments of *Vaucheria* remain in a purely vegetative condition, they are without septa, but if a filament is injured, the protoplasm in the neighbourhood of the injury contracts, and a septum is formed, shutting off the injured part. Schaarschmidt affirms that while this is the case, the filaments no longer have the power of reproduction; that they break up into gemmæ, or buds, which remain for a longer or shorter time in that condition, and then germinate, producing new filaments. Gemmæ, he says, are also formed on uninjured filaments, going through a great change of form before germination. A similar power of re-

juvenescence has also been observed in *Conferva bombycina*. A portion of the contents of the injured apical cell invests itself with a double membrane, and separates itself from the injured cell." *

It may be remarked in passing that there are not uncommonly found to be septa thrown across the threads of *Vaucheria* which cannot be accounted for by the above phenomenon. The normal condition of *Vaucheria* filaments is that of continuous cells, without septa, but it is not yet explained why an abnormal condition should so often be met with, even in comparatively young threads, which have never been injured, and yet in which distinct septa are visible. Not only have we had ocular demonstration of this ourselves, but attention has been drawn to it by various correspondents, and yet we have found no opportunity of searching further for the cause or explanation.

* *Journal of the Royal Microscopical Society* (1883), p. 261.

CHAPTER IV.

POLYMORPHISM.

The suspicion that amongst so-called species of the fresh-water algæ there were some, and probably many, which were not stable, soon took possession of the mind of those who were working at this subject. With the advance of knowledge suspicion is ripening into certainty. When Berkeley wrote, more than thirty years ago, he expressed this feeling. "It is very doubtful how far many of the supposed algæ, such as *Glœocapsa*, are autonomous species. Where a plant bears fruit, and is reproduced by that fruit, there can be little doubt that a species is true; but where all the propagation is a simple repetition of the division of the endochrome, as in *Glœocapsa*, there is some room for doubt. Mr. Thwaites, in the course of his investigations, was led to suspect that many of these lower algæ, however beautiful and interesting as microscopical objects, were not autonomous; many seemed to pass into each other by intermediate forms, and some were so constantly the attendants of others,

as *Palmellæ* of *Sirosiphon*, that he was led strongly to suspect very close and intimate connection." *

Nearly all who have of late studied these low forms have come to the conclusion that amongst them are a large number of so-called species which are merely conditions of other algæ, and ultimately a thorough revision will be imperative, dependent upon a knowledge of the life-history of each species. Richter, in 1880, published some observations upon *Glœocystis*, in which he contended † that this genus has a form of development consisting of cylindrical cells, which may be encysted or free, and which alternate with the familiar spherical encysted form; a Palmella condition with tetrahedral divisions occurring also within the latter. The first form is termed the *Cylindrocystis* condition. Each of these forms may be developed from another, so that *Glœocapsa*, *Cylindrocystis*, and *Microcystis* are probable synonyms of *Glœocystis*. By this means four genera, so called, will be resolved into one.

Subsequently the same author suggested ‡ whether various forms of unicellular algæ, for some time considered to be distinct, and ranged under the genera *Glœocapsa*, *Chroococcus*, *Aphanocapsa*, *Glœothece*, and *Aphanothece*, are not really genetically connected, displaying a kind of polymorphism; a form with but

* "Introduction to Cryptogamic Botany," by M. J. Berkeley (1857), p. 92.

† "Hedwigia," xix. (1880), p. 154–159.

‡ *Ibid.*, pp. 169–171 and 191–196.

slightly encysted cells (as *Aphanocapsa*) intervening between one with encysted spherical cells (*Glœocapsa*) and one with encysted cylindrical cells (*Glœothece* and *Aphanothece*). Thus *Aphanothece caldariorum* presents an intermediate form between that genus and *Glœothece,* and would appear to be completed in its cycle with two other forms, called respectively *Glœothece inconspicua* and *Aphanocapsa nodulosa,* being a maturer condition of the first of these two. In like manner *Aphanocapsa biformis* is shown to occur in three different forms. Here, then, is a very strong indication of polymorphism amongst related genera.

In this communication, the following conclusions are arrived at. Amongst the *Phycochromaceœ* the lowest form is the naked *Aphanocapsa* condition, which corresponds to *Palmella* amongst the *Chlorophyllophyceœ.* From this naked, or but little encysted condition, is developed the *Glœocapsa* or *Glœocystis* form, with several gelatinous envelopes; the *Chroococcus* type, wherein the investment is altogether wanting; or, when there is only a single vesicular envelope, the cœnobium types. The *Glœocapsa* type is specially adapted for exposure to the air, and growth upon a comparatively dry substratum; the cœnobium type is developed in water; the *Chroococcus* type in water, or a moist substratum. With this is connected the cylindrical form, a higher state, showing a development towards the filiform condition.

This is not always developed, and may be divided into stable and unstable forms. The latter may occur in two or three varieties, and go through the following successive conditions:—

1. Stable *Aphanocapsa* and *Palmella*.

2. *Aphanocapsa* and *Palmella* which have attained to *Glœocapsa*, *Glœocystis*, or cœnobium type, but which always revert to the naked solitary spherical form.

3. Stable *Glœocapsa*, *Glœocystis*, *Chroococcus*, and cœnobium forms, without reversion (*Merismopœdia*).

4. Cylindrical forms, the generations of which pass through the solitary spherical (*Aphanocapsa* and *Palmella*) conditions, as well as the *Glœocapsa* and similar forms.

5. Cylindrical forms which pass through only the *Glœocapsa* and similar forms.

6. Cylindrical forms, the generations of which revert to the *Aphanocapsa* and *Palmella* condition, while the *Glœocapsa* or any similar form is suppressed.

7. Stable cylindrical forms (*Synechococcus*).*

These dry details are sufficient to show that, amongst a large number of simple unicellular forms, polymorphism is admitted to exist to a considerable extent. Kirchner has declared his belief that "the genus *Protococcus* contains a number of heterogeneous forms, of which certainly the most, if not all, are

* See *Journal of the Royal Microscopical Society*, 2nd series, vol. i. (1881), p. 292.

developing forms of higher algæ, as copulating microspores, resting macrospores, or products of a peculiar disintegration of filamentous plants;" and the Rev. F. Wolle says, "I reason from analogy and say that all the forms of *Pleurococcus, Protococcus, Chlorococcus, Glœocapsa,* etc., belong to and are mere developing forms of higher algæ. I have had such positive evidence of transformation, I cannot think otherwise." This latter author and some others contend that the common green form of *Pleurococcus* may be traced to a filamentous condition, and that therefore the *Pleurococcus* is only an imperfect unicellular condition of some *Ulothrix* or other confervoid alga. The researches of Dr. Braxton Hicks * not only confirm these views, but carry them still further; for he contends that certain species of *Ulothrix, Schizogonium,* and *Prasiola* are but developments of the *Pleurococcus* form, and are indeed but one polymorphous species. Two or three quotations will explain the position.

"If we observe a batch of *Lyngbya* (*Ulothrix*) in its first appearance in spring, and also at other times, we shall find many of the threads throwing off from one extremity its terminal cells, which, relieved from pressure, become globular. Watching these, and carefully tracing their history by keeping them under

* "On the Diamorphosis of *Lyngbya*," by J. Braxton Hicks, M.D., in *Quarterly Journal of Microscopical Science*, vol. i. New Series (1868), p. 257.

continuous observation, I find that they undergo segmentation in the same manner as the so-called *Palmellaceæ.* It will be seen that this process assumes the same type as prevails in the gonidia of lichens, proceeding in various manners until, in some instances, the subdivisions are very minute. By means of this gonidial increase, considerable surfaces are covered with a palmelloid growth, and it has constituted one of the forms included under the term *Protococcus viridis,* and thus gives another example of the temporary nature of that order."

He then proceeds to describe how these small cells assume the linear form of segmentation and become threads. Taking up the mature thread, he shows the strong tendency, under certain circumstances, for cell-division to extend laterally instead of lineally, so that there appear to be two threads side by side. Then, by extension of the same process, a band is produced of four rows of cells, or more, etc.

"Thus it will be remarked that a constant struggle is going on between the linear and lateral mode of growth, and between either of these and the gonidial, with its changes; the balance seeming to be always uncertainly suspended between them." Thus he claims to have pointed out the following series of existences:—

1. The mature *Ulothrix.*
2. Its gonidia and their segmentation.
3. Their recurrence to *Ulothrix.*
4. The lateral segmentation of the cell of *Ulothrix,*

in part or wholly, passing ultimately to the formation of broad wavy fronds, the cells being held together by colourless intercellular substance.

5. The formation of gonidia from these fronds and their segmentation.

6. The assumption of linear growth by these cells.

"The whole of these changes are so palpable, can be observed so constantly, and are, at the same time, so simple in their relations to one another, that one can scarcely imagine how they can have been separated not only into distinct species, but into different families of algæ. Thus the linear stage is called *Ulothrix*; the early stage of collateral segmentation the *Schizogonium*; the adult stage *Prasiola*; while the gonidial growth has been classed under *Palmellaceæ*."

"The only real difference between *Ulothrix* and *Schizogonium* is that whereas *Ulothrix* is a tube containing distinct cells within, which, when old, undergo collateral subdivision, to form a band of two, four, or eight rows of cells; *Schizogonium* is a band of two or eight rows of cells, which, when young, was but a single row, contained in a tube; which is only two different ways of stating the same facts. The comparison of *Schizogonium* and *Prasiola* is of the same kind. For as *Prasiola*, when old, is composed of many rows of cells, but which arose from a single row, there must have been a time in its life when it had two, four, or eight rows, and thus have been a

Schizogonium, for there is no other structural difference between the two."

"Thus it seems that we cannot but conclude that *Ulothrix radicans, Schizogonium,* and *Prasiola* are but different stages of the same organism, which, with the segmentation of their gonidia into the Palmelloid cells, form a circle of phases, each of which has a powerful tendency to recur in shorter cycles to the form which preceded it."

Cienkowski and others have seen the disintegration of *Stigeoclonium* and other confervæ into *Protococcus* cells, whilst Schnetzler * traced the cells of *Palmella uvæformis* into a filamentous alga, probably a *Stigeoclonium,* and back again by disintegration into gelatinous colonies of *Palmella.* Indeed, as much as this is generally accepted, so that to multiply instances or authorities is needless.

According to the researches of Woronin, instances of polymorphism occur in *Botrydium,* but these take such a form, and form part of a cycle, in a manner which appeared to justify us in giving extended details in our chapter on "Alternation of generations." Nevertheless the points may be indicated here, viz. that a plant placed in water, its contents are modified into zoospores, which ultimately escape, soon come to rest, lose their flagellum, become surrounded by a membrane, and germinate on damp earth, in which stage they represent the so-called *Protococcus botry-*

* *Journal of Royal Microscopical Society* (1882), p. 64.

oides. Take another instance. If *Botrydium* be exposed to drought, the wall collapses and the contents break up into a number of cells, each surrounded by a membrane, with contents which are at first green and then red. These are called spores, and have been known by the names of *Protococcus coccoma,* of *Protococcus palustris,* and also of *Protococcus botryoides.*

Professor Cohn, at the conclusion of his treatise on *Protococcus pluvialis,* emphasizes the polymorphism of that and some other species; for, he says, "it cannot be doubted that the great diversities exhibited in the above respects, at different stages of its growth, by *Protococcus pluvialis,* exist also in other algæ, if they were duly sought after, and that researches in other species, from the same points of view as those embraced in the present memoir, would probably reduce very materially the large number of genera and species of algæ."

"Thus we see that a single species, owing to its numerous modes of propagation, can pass through a number of very various forms of development, which have been either erroneously arranged as distinct genera, or at least as remaining stationary in those genera, although, in fact, only transitionary stages. Thus the still Protococcus cell corresponds to the common *Protococcus coccoma.* When the border becomes gelatinous it resembles *Protococcus pulcher;* and the small cells, *Protococcus minor.* The encysted motile

zoospore is the genus *Gyges granulum* among the infusoria, resembling also on the other side *Protococcus turgidus*, and perhaps *Protococcus versatilis*. The zoospores divided into two must be regarded as a form of *Gyges bipartitus*, or of *Protococcus dimidiatus*. In the quadripartite zoospores with the secondary cells arranged in one plane, we have a *Gonium*. That with eight segments corresponds to *Pandorina morum*, and that with sixteen to *Botryocystis volvox*. When the zoospore is divided into thirty-two segments it is a *Uvella* or *Syncrypta*. When this form enters the 'still' stage it may be regarded as a form analogous to *Microhaloa protogenita;* this alga genus is probably, speaking generally, only the product of the *Uvella* division in the *Euglenæ* or other green forms. The naked zoospores, finally, would represent the form of a *Monad* or of an *Astasia;* the caudate variety approaches that of a *Bodo*." * But, he adds, as if to guard against the prospect of misrepresentation, "it must not hence be concluded that the result of these investigations implies the existence of a state of anarchy in the domain of microscopic organisms; or that any one form among them may assume any other form indifferently; that, in fact, there are no real *species* in the invisible world. Such is by no means the case."

Another instance of polymorphism, or at least dimorphism, may be observed in the Conjugatæ.

* Professor Cohn on *Protococcus nivalis* (Ray Society), p. 559.

The ordinary form of conjugation, recognized in the time of Hassall as the only one pertaining to the genus *Spirogyra,* was the conjugation of two separate threads, by conjugating canals uniting the threads, and the discharge of the contents of one cell into the corresponding cell of the copulated thread. In another supposed genus, then called *Rhynchonema,* only one thread was concerned in the process, and conjugation was accomplished by a loop channel between one cell and that immediately below or above it. Whereas it is now known that the two forms of conjugation not only occur in the same species, but also in the same thread, and hence the old genus *Rhynchonema* is abolished, whilst *Spirogyra* remains as a sort of dimorphous genus with two kinds of conjugation, namely, the scalariform (Fig. 45*b*) and the lateral (Fig. 45*c*). In the majority of the species both forms of conjugation may be seen, and it is by no means uncommon to observe one portion of a thread in conjugation with a neighbouring thread throughout a considerable portion of its length, whilst the remaining portion is free, and exhibits lateral conjugation between the neighbouring cells of the free extremity. It can hardly be said that polymorphism exists in the *species* of *Œdogonium,* although the *genus* might be called polymorphous from the fact that in the different species three modes of fructification are known to prevail; but in this case each species remains true to its own special mode of reproduction,

and the two or three forms are not found to occur in the same species. Naturally we must seek for the most pronounced conditions of polymorphism in the vegetation, rather than in the reproduction, of species; and we shall not have to travel far without encountering them.

In his memoir on *Batrachospermum* Sirodot indicates that there are three modifications of form in the species; that is, (1) the primordial condition, or prothallus; (2) the non-sexual condition, or *Chantransia;* and (3) the sexual condition, or *Batrachospermum.* The prothallus is a kind of pellicle which covers the surface of stones, etc., on which the plant grows. It is capable of growth and reproduction, increasing at the circumference, and reproducing itself by sporules. The non-sexual form is composed of tufts of filaments, ramifying and producing sporules, analogous to those of the prothallus. Since this form can reproduce itself through a number of generations, it has long been regarded as a distinct genus under the name of *Chantransia.* M. Sirodot believes that he has traced three species of so-called *Chantransia* into species of *Batrachospermum.**

In this same relationship we may refer to recent observations on changes of form in the common *Conferva bombycina.* In the normal condition the cells are cylindrical, one and a half to two times as

* Sirodot, "Les Batrachospermes;" and *Journal of Royal Microscopical Society* (1885), p. 494.

long as broad, but these subsequently pass through several changes by division, until at length they become not dissimilar from those in *Ulothrix.* These are again segmented in the ordinary way, daughter-cells are developed within the mother-cells, and these latter swell irregularly; the filaments become ribbon-shaped, resembling *Sirosiphon,* curve, and assume forms which might readily be mistaken for micro-sporiferous filaments of *Ulothrix.* The daughter-cells, on becoming free by the bursting of the mother-cell, are like *Schizochlamys.* These cells, now free and already segmented, closely resemble *Chroococcus turgidus.**

Without being prepared to endorse all that has been written by Dr. Hansgirg on this subject of polymorphism, it is impossible to ignore the position he has assumed in its entirety. It is the case, unfortunately, that most men, when absorbed by one idea, such as this, are very apt to observe all events through a distorted medium, or, at the least, to see everything in the light in which they would wish it to be seen. Nevertheless there is so much ground for belief that polymorphism prevails amongst algæ to a greater extent than is generally admitted, and that his strictures have a broad basis of truth. The propositions with which he sums up one of his contributions are to the following effect:—(1) "Most, if not all, of the *Schizophyceæ* or *Cyanophyceæ* are polymorphic algæ,

* *Journal of Royal Microscopical Society* (1885), p. 283.

which occur in nature in different stages of their development, whether unicellular or multicellular, and may, under certain conditions, maintain themselves through many generations at any particular stage; their genetic connection can be proved by observation of the history of their development." (2) "Most, if not all, of the algæ hitherto included in the family *Chroococcaceæ*," belonging to certain genera, of which he enumerates fifteen, "are connected genetically with other more highly developed algæ; that is, they are descended, by retrogressive metamorphosis, from various filamentous *Schizophyceæ*, which pass into the unicellular condition by their filaments breaking up into separate cells." (3) In at least ten genera of the family *Oscillariaceæ*, he contends, "are numerous forms, most, if not all, of which are connected genetically, not only with one another, as younger and older stages, and with various *Nostochaceæ* and *Chroococcaceæ* by retrogressive metamorphosis, but also with others, belonging to other families, as higher developments." (4) Several genera belonging to the family *Nostochaceæ* "include many heterogeneous forms, which, like the *Chroococcaceæ*, must be regarded as stages of development, analogous to certain zooglæa-conditions of the *Schizomycetes*." (5) In ten genera of the *Rivulariaceæ* and *Scytonemaceæ* which he enumerates, are included, according to his view, "the highest developments of various algæ, hitherto mostly placed among *Oscillariaceæ*." (6) He suggests develop-

ments from the *Oscillariaceæ* and *Sirosiphonaceæ*. (7) "Some *Chlorophycaceæ* are, like most *Schizophyceæ*, also polymorphic algæ. Most of the filamentous chlorophyll-green algæ" in ten genera then enumerated, "are connected genetically with other more highly developed algæ belonging to other families." By the swelling and separation of the cell-walls, and by continuous division, there arise from the last-named, and other families of the higher algæ, various unicellular algæ which are placed "under the twenty-one genera thereinafter named." * This is a long indictment, which could not be set forth in full without a recurrence to too much of technicality that would be out of place in a work of the present pretensions. The above is sufficient to indicate the vast extent to which this author attributes polymorphism, and mostly amongst the fresh-water species.

* See *Journal of Royal Microscopical Society*, vol. v. (1885), p. 1037.

CHAPTER V.

ASEXUAL REPRODUCTION.

There is a charming variety in the modes of reproduction in fresh-water algæ, a variety so remarkable that its polymorphism can scarcely be equalled in any other group of plants, and yet these varied phenomena might be classed under two primary groups —the asexual and the sexual. The former group may possibly be gradually reduced in size by the discovery of sexual elements; but it is by no means uncommon for an asexual multiplication to be co-existent with a sexual method in the same species. By asexual it must be understood that we refer to a method by which the species is reproduced and multiplied, without the intervention of fecundation. Leaving out of the question the mere increase of cells, by a vegetative process, the normal method of reproduction is by the development of zoospores, mostly active, which do not pair or conjugate, and are, as far as we know, neutral. The sexual methods are more varied, and fall under several types, such as conjugation, the pairing of zoospores, fertilization by

spermatozoids, etc., to be described hereafter. There may also be a sort of interchange between the same modes, so that after one, two, or more asexual generations, one of a sexual character intervenes, and there occurs a practical alternation of generations. All this complicity necessitates a somewhat extensive purview of reproduction, which cannot be dismissed with a few general observations, as, indeed, the phenomena of reproduction are the most important, and always the most prominent in the life history of these lowly organisms.

In *Apiocystis Brauniana* the young zoospores attach themselves by the ciliated end to *Cladophora* and other objects, and become invested with a club-shaped enveloping membrane. The first division of the green body then takes place in the direction of the axis of the vesicular envelope, and is repeated alternately in each direction of space. During this the vesicle in which the cells lie continually expands, and generally becomes very evidently produced below into a stem. Young vesicles contain a regular number of cells, namely, two, four, eight, sixteen, thirty-two, etc.; but the number afterwards becomes indefinite, in rather large vesicles attaining about three hundred, and in the largest about sixteen hundred cells.

The cells, or gonidia, are at first uniformly distributed over the whole cavity of the vesicle. Subsequently, they generally become collected on the internal surface of the wall of the vesicle, where they

lie in one or more strata. But the cell-division always takes place in all directions of space, the cells situated internally advancing outwards towards the periphery. In old vesicles the cells are sometimes arranged in rings of eight upon the wall. When the family of cells is mature for swarming, which may occur at very different sizes, and with very different numbers of gonidia, the cells begin to move, at first slowly, from their places, and then gradually to circulate more rapidly in and out and about each other; the vesicle bursts, and the gonidia emerge by the orifice which is formed. Sometimes the swarming is preceded by the state in which the cells are arranged in parietal rings.*

The most simple and ordinary form of asexual reproduction is that in which germ-cells, or zoogonidia, are formed within certain privileged vegetative cells of the parent plant. This is exemplified in such genera as *Draparnaldia, Stigeoclonium*, and *Chætophora.* In these genera the terminal cell of the branches, or sometimes some intermediary cell, exhibit their contents differentiated into a more or less large number of ciliated germ-cells, and these escape through a pore or rupture into the surrounding media, and for a time enjoy a free existence. In the comparatively recent genus *Pithophora* the process is somewhat similar. The upper part—about half—of the mother-cell is somewhat widened. The green contents in the

* Cooke, "British Fresh-Water Algæ," p. 18.

lower half of the cell pass, little by little, into the upper or widened part of the cell, until that is quite filled with the green protoplasm, whilst the lower part is nearly emptied. Then a transverse division, or septum, is gradually formed just below where the widening of the cell commences, and when this is completed the original cell has become separated into two cells, the upper of which is filled with green contents, the lower being nearly empty (Fig. 66). The upper cell ultimately becomes the spore. Its shape is cask-like, or rather cylindrical. When the membrane of the spore has attained the requisite thickness, the spore reposes for some time before germinating. As to its origin, being neutrally formed without fecundation, it has been termed an agamospore. Spore-formation may take place in all the cells of the upper, or cauloid, portion of the plant. As a rule it begins in the youngest, which are the terminal cells, proceeding downwards. In this manner one neutral generation follows another in an uninterrupted series, without any alternation of generations or fecundation.*

Asexual reproduction takes place sometimes in *Œdogonium*, although some form of sexual reproduction is the prevailing rule. It occurs by the formation of a single zoospore in one of the cells of the filament. This body is globose or somewhat ovate in shape, furnished about the apex with a tuft of vibratile

* Wittrock, "On the Development, etc., of the Pithophoraceæ."

cilia. When this zoospore becomes matured it escapes by the splitting or rupture of the containing cell, and floats about for a little while, impelled by the movable cilia, and at length becomes attached by the ciliated end. Growth soon commences, and the located zoospore develops into a young plant.

In *Hormiscia* another modification of asexual reproduction prevails. Certain bodies called macrozoospores, or large zoospores, originate in the cylindrical cells of the filaments. These may be from one to four in a cell, and are of a thick, short pear-shape, furnished with four movable cilia, and possess also a coloured spot and a contractile vacuole. After becoming invested with a transparent bladder they make their exit through a slit, or opening, in the side wall of the mother-cell. After floating about for a short period, they come to rest, and fix themselves by the mouth-end, lose their cilia, and develop a new covering membrane. The fixed end soon exhibits a kind of root-like attachment, the free end acquires a club-shape, then divides by a cross division into two cells, each of which again subdivides, and so on, so that a young plant is speedily in active growth and develops into a counterpart of the parent from whence it sprung.

In *Coleochæte*, again, one form of reproduction is asexual. The zoospores which are produced in the early part of the year from the resting spores of the previous year give origin only to asexual plants, which

only form zoogonidia. After a series of asexual generations, variable in length, a sexual generation appears, and the method of reproduction is changed.

In *Hydrodictyon* there are two kinds of moving germ-cells; the larger are "macrogonidia," the smaller "microgonidia." The macrogonidia, more or less numerous, according to the size of the mother-cell, combine to form a new plant, which they do after a short trembling movement, lasting about half an hour; then they unite together into a miniature net within the confines of the mother-cell, but gradually become free by the dissolution of the cell-wall. The microgonidia, which are smaller and elongated, have four long cilia each, and when the mother-cell bursts they swarm out into the water, where they disport themselves actively for about three hours, then settle to rest, become green globules, vegetate a little while, and then die away without making any further progress.* A more succinct account of the macrogonidia represents them as formed in the protoplasmic stratum, occupying the outer portion of the interior of the *Hydrodictyon* cell. The first alteration in this, presaging their formation, is a disappearance of the starch granules, and a loss of the beautiful transparent green colour. Shortly after this, even before all traces of the starch-grains are gone, there appear in the protoplasm numerous bright spots placed at regular intervals; these are the centres of development, around

* Braun on Rejuvenescence (London, 1853), p. 138.

which the new bodies are to form. As the process goes on, the chlorophyl granules draw more and more closely around these points, and at the same time the mass becomes more and more opaque, dull, and yellowish brown in colour. This condensation continues until at last the little masses are resolved into dark hexagonal or polygonal plates, distinctly separated by light, sharply defined lines. In some the original bright central spot is still perceptible, but in others it is entirely obscured by the dark chlorophyl. The separation of these plates now becomes more and more positive, and they begin to become convex, then lenticular, and are at last converted into free, oval, or globular bodies. When these are fully formed they are said to exhibit a peculiar trembling motion, mutually crowding and pushing one another, compared by A. Braun to the restless, uneasy movement seen in a dense crowd of people in which no one is able to leave his place. Whilst the process just described has been going on, the outer cellulose wall of the *Hydrodictyon* cell has been undergoing changes, becoming thicker and softer and more and more capable of solution, and by the time the gonidia are formed it is enlarged and cracked, so that the room is afforded them to separate a little distance from one another within the parent-cell. Now the movements are said to become more active—a trembling jerking which has been compared to the ebullition of boiling water. There is, however, with this a very slight

change of space, and in a very short time the gonidia arrange themselves so as to form a little net within the parent-cell, a miniature in all important particulars of the adult *Hydrodictyon.* The primary cell-wall becomes more and more gelatinous, and soon undergoes solution, so that the new frond is set free in its native element.

It is uncertain what precise value or position should be assigned to the moving spores in *Spirogyra,* described by Pringsheim.* Meyen noticed that secondary, but not moving, cells were often formed inside the spores of *Spirogyra,* and he conjectured that there were likewise propagative cells. Pringsheim also found these secondary cells, in which the contents are frequently transformed into spores *not directly germinating,* in spores which had originated through copulation. They were always, however, motionless, and he was equally unsuccessful in observing a further development of these cells. But he also frequently found the contents of the filament cells, when no large spore had been previously formed in them, transformed into peculiar cells, which appear as the mother-cells of smaller *moving* cells, and the latter appear to stand in close relation to the development of the *Spirogyræ.* He says, "I frequently found in conjugated filaments that the contents of one or more pairs of conjugated cells were not transformed into the well-known large spore, but into a number

* *Annals of Natural History,* xi. (1853), p. 292.

of little cells of regular, definite, and unchangeable form. This regular occurrence led me to conjecture that these cells were more than mere pseudo-forms of decaying cell-contents. I first obtained an insight into these structures by observation of their production in the cells of the young *Spirogyræ* which I had myself seen emerge from large spores. In the cells of these young *Spirogyræ* the existing spiral bands are often broken up, and from their substance are formed, in a manner still unknown to me, little cells in which a membrane can be clearly detected surrounding green contents. I call these cells 'spore-mother-cells.' They soon increase in size, their membrane separating itself from the contents and expanding into a largish hollow vesicle. The contents at the same time acquire a yellowish or yellow-brown colour, and separate into a central denser, yellow-brown nucleus, and a finely granular mucilage, which surrounds the nucleus and does not entirely fill the space between it and the membrane. This finely granular mucilage then becomes balled together, in the space between the yellow nucleus and the surrounding membrane, into a single large corpuscle, exhibiting a sharply defined outline, and appearing as a transparent vesicle with finely granular contents. The new cell thus formed pushes the brown body out of its central position against the wall of the parent-cell or the 'spore-mother-cell.' The pressure of these two bodies causes the rupture of the membrane of the

'spore-mother-cell;' the transparent cell emerges and moves about independently and freely in the filament cell in the manner of the zoospores.

"The expelled zoospores are small elliptical cells, and their aspect resembles that of the moving spores of *Achlya prolifera* more than of any others. Their movement is much slower than that of other zoospores, and is further distinguished by the fact that in advancing they do not make a complete revolution round their longitudinal axis, but merely slight oscillations to the right and left. In moving about they traverse the cavity of the filament cells in all directions, mostly gliding onwards along the wall as if, as it were, seeking an orifice whereby to escape; but, notwithstanding that, I observed very many of these moving cells for long-continued periods. I never saw them emerge from the filament cells in which they had been produced, since no orifice was ever formed in the everywhere-closed filament cells. That these cells possess locomotion threads, or cilia, is certain. I could often detect them in vibration with the greatest clearness; but I remained in uncertainty as to the number oi the vibrating threads. I think it most probable that they have one single thread at the anterior extremity; yet in certain cases it appeared as if they bore a crown of several threads.

"After wandering about unceasingly for several hours, they finally fix themselves by the point. All, however, that I have observed, after they had come

to rest, became decomposed without further organic development, and their contents, which as long as they were in motion were always coloured yellow, and never blue with iodine, became transformed into a number of very small irregular starch granules, coloured blue by iodine, around which could often be detected an enveloping coat, the membrane of the dead spore.

"The question now arising, how are we to interpret these moving structures, it appears to me that their mode of formation and the regularity of their appearance necessarily repel the idea that they are accidental, abnormal productions, without further value in the development of the plant. In my opinion the most direct and simplest assumption, in the present condition of science, is, that they are propagative cells of the *Spirogyra*, capable of development, and, if set free under favourable circumstances from the filament cell, during their motion they would reproduce the parent plant."

The production of these moving spores, or zoospores, within the true spore or in the vegetative cells, does not appear to be confined to *Spirogyra*, but extends also to *Œdogonium*, and may probably yet be recognized in many other genera of the filamentous freshwater algæ.

In *Chroolepus* the process of reproduction appears to be asexual, according to the present state of knowledge. "The apical cell of the threads has often a

globose or pulvinate appendage, of a highly refractive nature, furnished with transverse wrinkles, and frequently also with a protuberance at the top. The whole cavity of the cells is filled with granular matter, mostly of a brownish-red colour, but it frequently happens that the inner granules only are brownish red, whilst the outer ones are green. The reddish-brown granules seem to be oil-drops. A great number of the threads terminate with a globose, much-thickened cell, which subsequently becomes the mother-cell of the zoospores. This mother-cell is rarely found in the middle of the threads. Occasionally, but still more rarely, the cell immediately under the mother-cell elongates itself sideways and upwards into a thread. The mother-cell of the zoospores, when it forms the terminal cell of the thread, bears a conical mass of gelatin, often of considerable size, which, however, is seldom on the crown of the cell, but usually at its side. In those mother-cells, in which the zoospores are about to escape, a division of the contents into small oval cells is clearly perceptible, and at the side, or near the top, the wall is extended into a short papilla. The contents emerge in the form of a well-defined vesicle, with the zoospores penetrating through the ruptured papilla; sometimes, however, no vesicle is formed. A few moments after emerging the vesicle bursts, doubtless by absorption of water, and the zoospores swim about in every direction. The remnants of the

vesicle are of a gelatinous nature. The escape of the zoospores was observed from nine in the morning until four in the afternoon, and seems to depend not upon the influence of light, but solely upon the effect of moistening with water. The zoospores are very small, about $3\frac{1}{2}\mu$ long. They are filled with reddish-brown granular matter, the apex alone being free and hyaline; there are two cilia, about three or four times as long as the spore, the apex being directed forwards. They rotate perpetually whilst swimming, their motion being so rapid as to prevent a clear view of them, except when stopped by some obstacle or when their motion is becoming retarded. The cell is surrounded by a clear, highly refractive border, looking like gelatin, but which may be only an optical appearance. After continuing in motion for about an hour the zoospores become sluggish, sink, become globose, elongate themselves, and shortly a division of the cell takes place by a transverse septum. Some reddish-brown granules usually remain behind in the empty mother-cell and in the remnant of the vesicle. Oftentimes some zoospores cannot emerge from the mother-cell, and then they sometimes germinate within it." *

A peculiar mode of asexual reproduction has been investigated by Wille,† with the unpleasant result

* Caspary, in *Flora* (Regensburg), Sept. 28, 1858, and *Quarterly Journal of Microscopical Science*, viii. (1860), p. 159.

* Wille, "Centralblatt" (1883), p. 215; *Journal of Royal Microscopical Society* (1884), p. 272.

that it has added two new terms to the already overdone catalogue of technicalities proposed in cryptogamia. Let us hope that *Akinetes* and *Aplanospores* will not survive a winter of disapproval. The reproductive process alluded to is not uncommon amongst filamentous algæ, such as species of *Conferva*, etc. All the cases agree in the reproductive cells being immotile, not produced by any sexual process, and not resulting from swarm-cells which have come to rest. They are classed under two forms—(1) those produced without any special cell-formation, and (2) those produced after special cell-formation. Both kinds may germinate immediately after formation, or only after a period of rest.

The membranes of the filament become thicker and encrusted with iron and lime; as soon as the separate cells again begin to grow, the outer dead layer bursts, and the form arises which previously was known as a distinct genus under the name of *Psichohormium*. In *Cladophora fracta* single cells at the end of filaments often swell up in the autumn, and become thicker walled and fuller of protoplasm. These hibernate, filaments with thin-walled cells springing from them in the spring. The author's view is that these structures are formed whenever the conditions are unfavourable for the production of zoospores, or for sexual reproduction. Where they are abundantly produced, usually the formation of zoospores is rare. These reproductive cells have been termed "resting

cells," as well as the two names applied above, which we have no anxiety to repeat.

In the group of algæ known as *Nostochineæ,* no sexual reproduction has been discovered. What are the real functions of the heterocysts is problematical. That certain special cells are capable of enlargement, and conversion into spores, which will germinate and produce new plants, has been admitted, but without any evidence of fecundation. The other process, and more usual one, is by the conversion of fragments of the thread, or trichome, into hormogones. The mucilage of the old plants is softened, and portions of the threads are detached and escape from the mucilage, whilst the heterocysts remain behind. These escaped fragments become endowed with motion, similar to that observed in *Oscillaria.* The cells of the hormogone increase by division, at right angles to the filament, so as to result in a double row of cells, which ultimately separate longitudinally, and become the centres of new plants.

CHAPTER VI.

SEXUAL REPRODUCTION.

The subject of sexual reproduction will come most naturally and effectually under three headings and aspects—general sexual reproduction, conjugation, and pairing of zoospores. It is hardly possible to accomplish this in a satisfactory manner without a certain amount of technicality, but an effort will be made to reduce rather than increase merely technical distinctions, which would only embarrass the reader, without corresponding practical advantage in the further pursuit of the study. Cienkowski's researches into the history of *Cylindrocapsa* exhibited what may be regarded as a normal form of sexual reproduction. "This alga possesses antheridia and oogonia, representing the male and female element. The oogonium is a globular inflated joint, consisting of contents and wall. The first presents a protoplasmic gonosphere, coloured by chlorophyl, containing numerous starch granules; it presents at one point of the periphery very often a clear spot. The gonosphere is loosely enclosed by the several (3-6) concentric gelatinous

(as it were swollen or expanded) membranes. Such oogonia lie either several together, forming a moniliform chain, or they present themselves in the middle of a series of antheridia, or between unaltered vegetative joints, upon which, further on, may abut antheridia. *Cylindrocapsa* is thus monœcious. At both poles of the oogonium the coats are produced into a short cylindrical process; adjoining processes are mutually apposed. The size of the oogonia varies; it may reach ·042 mm., the gonosphere ·024 mm.

"The antheridia are discoid or sphæroidal little cells; like the oogonia possessing a multi-laminated coat, they may form a long series or little groups of pairs; they are often enveloped in twos or fours by numerous laminæ. The contents are clear reddish yellow. The male cells (like the vegetative) are formed by binary division of the mother joint, with the distinction that they cease to grow, remain smaller, and gradually assume the yellowish-red colour. Each antheridium develops by division of its contents two spermatozoids. At maturity they are ejected with a jerk; when free, they lie for a while motionless, enclosed in their gelatinous envelope. Presently they assume a tremulous motion, at last bursting the vesicle and swimming about. They are protoplasmic fusiform bodies of about ·015 mm. in length, contents sparing, yellowish red; at the anterior hyaline point are borne two flagella, below which are two minute pulsating vacuoles.

"Shortly after their exit they are to be found in the neighbourhood of the oogonia. The whole cavity of the oogonium becomes pushed out laterally, dissolving and leaving an opening at the apex of the expansion. The spermatozoids seem now to be no way aimless in their movements, their whole object being seemingly to effect a penetration; with great energy they drive against the wall, and retreat, and so persist for hours, until at last the movement ceases, and they shrink into formless little masses. The actual confluence of the spermatozoid with the gonosphere was not observed, but the conclusion drawn by the author seems to be legitimate.

"The next change consists in the appearance of a thick gelatinous stratum directly on the surface of the gonosphere, which soon hardens into a doubly contoured membrane. After some days the chlorophyl with the starch granules gradually disappear, becoming replaced by the reddish-yellow oily substance. In this way we obtain from the gonosphere an oospore surrounded by the mucous layers of the oogonium. The author could never see any further development; they lasted the whole autumn and winter without the slightest alteration.

"In some instances the gonospheres on having become enclosed by the gelatinous envelope began to germinate; they divided into two segments, each then becoming clothed by its own gelatinous envelope, and soon divisions followed just as in the ordinary vegeta-

tive joints. The author supposes that these still green gonospheres could not have been fertilized, and that only the latter pass over into a state of rest." *

Similar in many respects to the reproductive process in *Cylindrocapsa* is that which is found in *Sphæroplea.* The female element is represented by red globular spores surrounded by two hyaline membranes, the inner of which lies close upon the contents, whilst the outer is somewhat separated and elegantly creased, so that they have been called stellate; after a time, and subsequent to fecundation, they become resting spores, ultimately breaking up into zoospores. The male element is represented by active rod-like spermatozoids which originate from the differentiation of some of the cell-contents.

The full-grown cells exhibit in their contents most elegant structures. The constituents—colourless protoplasm, green chlorophyl, watery fluid, and starch granules—are distributed in a peculiar manner; the watery fluid forming large bubbles or vacuoles, which attain nearly to the diameter of the cell, and hence stand in rows like pearls, often in contact at their poles, and flattened there so as to form apparent septa. In the interval between the vacuoles is compressed the green plasma and starched granules, mixed with numerous smaller vacuoles. Under a low power, the whole appears like a regular alternation of narrow green and broad colourless rings. If the vacuoles are

* *Quarterly Journal of Microscopical Science* (1877), p. 181.

smaller and the chlorophyl more abundant, the cell appears uniformly green, more intense only in the interval between the vacuoles.

Later on, the regular arrangement of green rings will disappear in particular cells, the vacuoles increase in number, so that the whole contents assume the appearance of a green froth, with the starch granules irregularly diffused through it. These are soon seen to become grouped in twos or threes, and largish masses of the green plasma become accumulated around them. After a certain time the middle line of the cell is occupied by a great number of green lumps at regular distances, the frothy matter being distributed between them. As the majority of the vacuoles gradually disappear, these lumps assume the form of green stars, remaining connected together by the green radiating filaments of plasma. Between each pair of these stellate masses a large vacuole is formed, which becomes flattened to level septa, so that the whole cell appears as if divided into chambers by a number of parallel plates. In each of these chambers follows an uninterrupted metamorphosis of the green mass—the mucilaginous filaments gradually retracted; the green substance sometimes contracting towards the right, sometimes to the left. In a short time the colourless plasma becomes so distributed around the chlorophyl that the septa of the chambers separate, and the whole contents are broken up into a large number of free globular masses sharply defined, composed chiefly of

colourless mucilage, and enclosed in their centre an irregularly diffused, most laterally situated heap of chlorophyl. These masses, which are the young spores, then pass through various stages. At first they are in contact, forming by their adjacent boundaries the plasmic septa, which are consequently double; the substance becoming somewhat contracted, the two layers of these septa separate, the spores thereby becoming isolated; the chlorophyl in the interior is constantly changing its mode of distribution. The colourless mucilaginous envelope at one time contracts strongly, so that free regular globules are produced; at another it expands again, so that they are flattened against their neighbours; or sometimes one becomes elongated laterally. Finally the nascent spores become rounded off into smooth spheres, which are larger than when mature, and not completely filled with chlorophyl. The colourless plasma is more elaborated and excreted, so that the spore is constantly becoming more condensed and diminished in size, and finally becomes a regular sphere, composed entirely of a green granular substance, enclosing a few starch granules, bounded externally by a smooth, clearly defined layer of plasma. There is no cellulose membrane, and the green structure is very soft and elastic.

This course of development does not take place in all the cells of a filament. During the same epoch totally different processes are being completed in other cells. Here the green rings between the colourless

vacuoles will gradually assume a peculiar colour, becoming reddish yellow, and the starch granules will have vanished. The orange-coloured substance is soon seen to acquire a peculiar organization. In it may be detected, progressively, a separation into granules, then into little streaks, and finally it becomes converted into myriads of short, confusedly crowded little rod-shaped bodies. After this the rings begin to dissolve. Suddenly one of the little rod-shaped bodies, embedded in the substance, acquires its liberty, and begins to move about in the cavity of the cell; more follow the example; the movement of these bodies becomes more and more rapid. In a few minutes the entire ring becomes decomposed into a countless number of actively moving corpuscles; then the rod-shaped bodies of a second and third ring enter into the movement, until finally the entire cell becomes filled with these corpuscles, which shoot about and circulate in all directions amongst each other.

The rod-shaped bodies now emerge through a hole in the wall of the mother-cell into the water. Their movements are at first very weak; they adhere firmly together, and oscillate in masses; but in a short time they acquire greater energy, and become scattered like dust, with infinite rapidity, through all parts of the water, so that within a few hours all the moving corpuscles will have left the parent-cell.

It is not rare to find in the cells, after the exit of

the rod-shaped corpuscles, other larger brownish globules, which often display a sluggish movement. These have been termed *pseudo-gonidia* by Braun, and are the remnants of the cell-contents which have not been converted into rod-shaped corpuscles, but have acquired a power of independent motion. Similar bodies are sometimes found in other cells mingled with the spores.

The rod-shaped bodies, above alluded to as swarming out of the cells, differ from the spermatozoids of the *Fucoideæ* and others. They are elongated and rod-like, with the posterior extremity somewhat expanded, often spread out flat, and of a yellow colour; the other extremity runs out into a long, narrow, colourless beak, bearing at the end two long cilia. Their movement is characteristic. When the energy is weak, they oscillate; when the motion is more active, they rotate on their transverse axis, like a stick fastened in the centre. Sometimes the corpuscles rotate upon themselves without moving from one spot, like a cat around its tail; but they mostly dart off in cycloids, frequently advancing with jerks and springs; more rarely they screw themselves straight onwards. Cohn states most distinctly that he "succeeded in demonstrating their fecundating power, by direct observation, with an evidence such as can only be possessed by a fact of natural science; there can be no doubt that the active rod-shaped corpuscles are the spermatozoids of *Sphæroplea*, and therefore the

cells in which they are formed must be denominated the antheridial cells."

When the discharged spermatozoids have become dispersed through the water, they are soon seen to assemble around those cells of the filament the contents of which have been metamorphosed into spores. They dance about in the vicinity of those cells, attach themselves to the membrane, sometimes tearing away again, soon to return. After a while a spermatozoid approaches one of the little orifices, perforating the walls of the sporangial cells, where it fixes itself, and pushes the slender beak into the hole. The posterior extremity is often too broad to pass uninjured; then it screws itself forward with evident effort, the beak constantly working its way, compressing the elastic body; finally it succeeds in forcing its way through and entering into the cavity of the sporangial cell. In the mean time other spermatozoids have slipped in through various orifices; frequently three or four crowd at once into one orifice. The more slender corpuscles make their way, at the first attempt, in a remarkable manner, swimming in wide curves from the water, through the hole, without obstruction, into the cavity of the cell; after a time, as many as twenty spermatozoids circulating about in its interior, and swarming round the young spores. The spermatozoids rush from one spore to another, as if electrically attracted and repulsed, so rapidly that the eye can scarcely follow them; they often swarm from one

end of the sporangial cell to the other. Now and then the spores are thrown into slow rotation by the vibratile cilia of the spermatozoids; but this is only accidental, possibly only when the spores are in a very free position. Cohn has seen the spermatozoids moving about in the sporangial cell for more than two hours. Gradually their motion becomes more sluggish; they become adherent to the young spores in such a manner that one or two spermatozoids become fixed to each spore, cleaving firmly to it with the beak and cilia, so that their body stands perpendicularly upon the spore. In this position they oscillate backwards and forwards for some time longer. Finally they come quite to rest, and apply themselves with their whole length against the surface; their body is converted into a drop of mucilage and loses its form, finally melting away.

After a short time the impregnated spore becomes enveloped by a true cell-membrane; then a second is soon produced beneath the first. Ultimately the first-formed membrane is cast off by a kind of "moulting," and the second becomes the outer stellate coating, beneath which, again, a smooth coat is produced. The contents of the spore, originally of a uniform green, subsequently become opaque, and pass through olive-green and reddish-brown into a pure red.*

In most instances these fertilized spores pass into

* Cohn on *Sphæroplea* in *Annals of Natural History*, xviii. (1856), p. 81.

a resting condition, in which they remain for some months, ultimately breaking up into zoospores; but under cultivation the process has been hastened, so that zoospores were produced within forty-eight hours. The remarkable fact that the spores of *Sphœroplea* do not always give origin to one individual, but mostly to several swarming cells, and therefore to several plants, has not been explained. Cohn suggested whether it may not be connected with the action of one or more spermatozoids upon the nascent spore; but this, he says, must remain unanswered, the only analogy being afforded by the origin of several embryos in the ova of the *Planariæ*.

Sexual reproduction in the genus *Œdogonium* is of a rather complex form. Some of the species are monœcious; that is to say, the male and female organs are present in the same plant. Other species are diœcious, the male and female organs being found on different plants. In the latter group there are two modes of fructification, and in the former but one. In the monœcious species, the oogonium, or spore-cell, is inflated and more or less globose, enclosing a single spore of the same form. This oogonium, or spore-cell, is perforated by a pore, or splits all round and opens with a lid. The same thread which bears the oogonium has also, either above or below, as the case may be, shortened cells in the common filament, in which the male element, consisting of one or two active spermatozoids, are

produced. When these spermatozoids are fully mature, they escape from the cell in which they are generated, and fecundate the oospore through the pore or opening of the spore-cell, or oogonium, after which they disappear, and the oospore ripens into a perfect, fertile, resting spore.

In the diœcious species, which are those in which the male and female elements are found on different plants, there are two modes of reproduction. In one series of species the male organs are dwarf, so that they might almost be termed antheridia. The oogonium, or spore-cell, and the spore are practically the same as in the monœcious species. There are also shortened cells in some other part of the same thread, but instead of producing spermatozoids, they develop small active, ciliated bodies, which move about for a time, and then attach themselves either immediately upon, or in close proximity to, the oogonium, or spore-cell. When attached, they grow into the form of an inverted flask, being supported by a more or less elongated stem, and in this form they constitute the dwarf male plants. The cells at the apex of these little males contain the spermatozoids, or fertilizing elements. The upper cell opens by means of an operculum, or lid, to permit of the escape of the spermatozoids, which soon find their way into the oogonium, near which they are seated, and the fertilization of the spore takes place (Fig. 67).

In the second series of diœcious species there are

male filaments, which in all respects resemble those of the sterile females, except that they are a little thinner. The female threads produce only oogonia, or spore-cells. The male threads have shortened cells in certain positions, which give origin to the spermatozoids, and these in due time escape and fertilize the oospores of the female plants.

So that in the first series the dwarf males are generated in certain privileged cells of the female plants, whilst in the second series the male and female plants are from the first distinct. In both cases the spermatozoids are discharged into the surrounding water, in which they float, endowed with ciliary movement, and ultimately find their way either through the pore, or the opening of the lid, of the spore-cell of the female plants, and fertilization is accomplished. It need not cause any surprise that, in earlier times, when so little was known of the processes of reproduction amongst the simplest of vegetable organisms, the movements of zoospores and spermatozoids, directed apparently in a definite direction, and for a special purpose, in a manner suggestive of instinct, should have been credited with the possession of animal life.

Sexual reproduction in *Vaucheria* bears some resemblance to that in *Œdogonium*, but there is a special male organ developed in the former, directly, and in close contiguity to the sporangium or female organ. In this sense it reminds one of certain phenomena of sexual reproduction in some fungi, and is

sufficiently distinct from the reproductive process in *Œdogonium* to require detailed description, on the basis of the investigations of Pringsheim and others. In *Vaucheria* the male and female organs arise like short teat-like branches from the filament, and in close proximity to each other. It is usually the case that the projection which is to become the " hornlet," or male organ, is developed sooner than that in which the sporangium makes its appearance. The two papillæ differ from the first so considerably in their dimensions that they can scarcely be confounded. The papilla which is to become the "hornlet" soon elongates into a short cylindrical branch, which at first rises perpendicularly from the filament, then curves downwards until it comes in contact with the tube or filament, often forming a second or a third curve, and, in this way, always represents a more or less stunted branch, which frequently exhibits several spiral turns. The papilla of the neighbouring sporangium usually begins to appear at the time when the hornlet is commencing its first turn; but the period at which it arises is very indeterminate, for it sometimes appears much earlier, whilst the hornlet is still perfectly straight; sometimes much later, after it has curved, so as to form two limbs of equal length.

The papilla destined to become the sporangium gradually enlarges into a considerable-sized lateral out-growth of the tube, far exceeding the hornlet in width, whilst in length it is barely equal to the

straight limb of the latter. This out-growth, which is afterwards symmetrical, ultimately throws out a beak-like prolongation on the side looking towards the hornlet, the rostrum or beak of the sporangium, whence the latter acquires its peculiar form, resembling that of a half-developed vegetable ovule. Up to this period the hornlet, as well as the sporangium, are not shut off from the tube by any septum; the cavity of the hornlet and that of the sporangium consequently remain uninterruptedly continuous with the parent-tube or filament, and are filled with similar contents. A number of chlorophyl granules in an albuminous plasma, and rounded oil globules, constitute a dense lining to the tube, the sporangium, and the hornlet. Between this and the cellulose membrane is the thin colourless skinlike layer.

At this stage a septum is suddenly formed at the base of the sporangium, which is henceforth an independent cell, completely separated from the parent-tube. Even before this septation there may be noticed in the rostrate elongation directed towards the hornlet, the gradual accumulation of a colourless fine granular substance, of the same nature as that with which the wall of the parent-tube and the sporangium is lined on the inner surface, which has already been termed the skinlike (or cutaneous) layer. This accumulation in the fore part of the rostrum is continued after the formation of the septum between the sporangium and the tube, and, in consequence of

its continued increase, the remaining contents of the sporangium are by degrees pushed back towards the base. Whilst these phenomena are being manifested in the sporangium, the hornlet also undergoes remarkable changes. In its apex, the contents, owing to the disappearance of the chlorophyl, have become almost colourless, more or less. Thus the point of the hornlet, like that of the sporangium, appears at this time to be filled with a colourless substance, which is *not* constituted by an accumulation of the cutaneous layer, but manifestly arises from a molecular change, associated with an alteration of form and colour, in the contents previously existing at the apex. So soon as the contents at the point of the hornlet have thus become colourless, they appear to be constituted of a very fine-grained granulose mucous substance. As soon as the transformation of the contents has taken place, the colourless apex of the hornlet is suddenly separated from the lower green portion by a septum, and is thus transformed into an independent cell, without communication with the parent-tube. The point at which the septum is formed is not very determinate, the portion cut off being sometimes larger, sometimes smaller.

After the formation of the septum in the hornlet, the colourless mucus in its apex gradually assumes a more determinate form, and at this time a large number of minute, perfectly colourless, rod-like bodies may be readily perceived crowded together irregularly,

and, as it were, embedded in the surrounding mucus. Close observation will disclose an indistinct movement, exhibited even thus early by some of the little rods, from which their destination may be anticipated.

This perfecting of the hornlet coincides with that stage of development of the sporangium at which the accumulation of the cutaneous layer in the anterior part of the rostrum has attained its greatest extent, and these conditions immediately precede the act of impregnation, which is effected in the following manner :—

The pressure within the sporangium, especially in the direction of the rostrum, becomes greater and greater in consequence of the continued increase of the cutaneous layer in the fore part, until ultimately the membrane is ruptured exactly at the point of the rostrum, and allows a portion of the cutaneous layer to escape. The extruded portion becomes detached, and assumes the character of a drop of mucus, which remains lying near the opening of the sporangium, and ultimately perishes. The accumulation of the cutaneous layer in the fore part of the rostrum, and the escape of a portion of it, are merely the mechanism by which the opening is produced in the sporangium destined for the admission of the spermatozoids. Immediately after the formation of this opening in the sporangium, and in remarkable coincidence with the escape of the cutaneous layer through the rostrum, the hornlet opens at the apex, and pours out its

contents. Innumerable excessively minute rod-like corpuscles, mostly isolated, escape at once through the orifice. Those already isolated exhibit an extraordinary rapid movement in all directions, and those still embedded in the mucus do not become detached until afterwards, when they follow the others with equal rapidity. The field of view is soon covered with mobile corpuscles. In great number they enter the neighbouring orifice of the sporangium, which they fill almost entirely, penetrating through the portion of the cutaneous layer remaining, which, though without any definite boundary, offers a solid resistance to their further penetration into the sporangium. The corpuscles continue thus to struggle forwards into the cutaneous layer for more than half an hour; bounding against its outer surface, they retreat, again push forwards, again retreat, and so on, in an uninterrupted succession of assaults and retreats.

After this commotion has lasted some time, an abrupt boundary line suddenly appears in the outer aspect of the cutaneous layer, the first indication of a tunic forming around the contents of the sporangium, which were before bare. From this moment the mobile corpuscles are separated from the cutaneous layer by a membrane which effectually prevents their further action upon the contents. They continue, it is true, to move to and fro, and this movement often lasts for hours together, but at last they perish in the

rostrum itself. Even after the lapse of several hours the dead corpuscles may be seen in the rostrum, lying on the front of the sporangium, until at last they are completely dissolved and all vestige disappears (Fig. 55).

The cutaneous layer surrounding the green contents of the sporangium becomes transformed, after impregnation, into the coat of the true spore, which, thus formed, represents a large cell occupying the whole of the sporangium, surrounded on all sides by the persistent tunic, which is open in front and prolonged into the rostrum.

In this condition the spore remains for some time longer without being thrown off from the parent tube on which it was produced, but the colour of its contents gradually becomes paler and paler. The spore is at last rendered quite colourless, and presents in interior only one or more largish dark-brown bodies. When it has lost its colour it is detached from the parent-tube, in consequence of the decay of the membrane of the sporangium enclosing it. After some time—say, three months—the spore suddenly resumes its green colour, and immediately thereupon grows into a young *Vaucheria*, exactly resembling the parent plant.*

The essential elements in all these details of reproductive phenomena are the active and passive, special

* See also *Quarterly Journal of Microscopical Science*, vol. iv. (1856), p. 63.

fecundative, and receptive organs, male and female developments, for the sexual reproduction and multiplication of the species. Further and more exact investigation will doubtless increase the number of examples, and probably demonstrate that the sexual is the general and normal method of reproduction in the majority, if not in all the species.

Those interesting algæ, called Batrachosperms, which are the desire of all amateur microscopists and algologists, are reproduced sexually by the following process:—

"The antheridia are small roundish cells, full of a colourless protoplasm, which is remarkable for the very numerous bright granules which it contains. They occur either scattered or in groups, and are placed upon the upper ends of peculiar ovate cells, also filled with a colourless protoplasm. Most frequently there is a single antheridium to the basal cell, sometimes two; the latter number appears never to be exceeded. When matured, the antheridia open, and allow their contents to escape in the form of roundish or flattened bodies, which never, as far as known, acquire cilia, and have, therefore, no power of spontaneous motion. These bodies, which are believed to be *spermatozoids,* are unprovided with anything like an external membrane, and are composed of protoplasm identical with that in the antheridium. While these changes are occurring, certain cells in other localities are being transformed into female organs, to which

the name of *Trichogonia* is applied. These are borne upon cells similar to those supporting the antheridia. At first they are not markedly different from the other cells, but soon undergo a very rapid growth. This is not, however, regular, and is not partaken of by a band of tissue about one-third way from the basal end, so that at last a long somewhat flask-shaped cell is produced, with a very marked contraction at the point indicated, separating it into two portions. The wall of this cell is thin, but very distinct, and the cavity is filled with a homogeneous or very sparsely granular protoplasm, which is continuous through the narrow neck-like portion. After a time there appear one or more large irregular vacuoles, with actively moving corpuscles in them, and at the same time the neck appears to be stopped with a slimy substance. Careful examination with reagents shows that this is cellulose, and that it does not completely block the passage way through the isthmus. At this time there appear lying upon the free end of the trichogonia globular or flattened bodies, without external membrane, corresponding in all respects with those already described as being produced in the antheridia. The end of the trichogonium generally enlarges at this period into a sort of roundish knob, and by-and-by the end wall between this and one of these globules becomes absorbed, so that there is a free communication between the two. Whilst this is going on, the globule acquires a thin delicate coat, and there appears

in it a vacuole similar to those pre-existing in the trichogonium.

"The first result of this impregnation of the trichogonium is the deposit of new cellulose, and the complete blocking up of the passage way through the isthmus or narrowed portion. Already, before the fecundation, the upper cells of the branches supporting the trichogonia have produced numerous branchlets, which, growing upwards, more or less completely cover that organ. After impregnation, the cells near to the trichogonium become much larger and broader, their vacuoles disappear, and are replaced by a dense granular dark greenish-brown protoplasm.

"These cells now show a great activity in the production of numerous branches in the usual way; but it is the upper two alone which, with the trichogonium that they support, are concerned in the formation of the fruit glomerules. These put out all over their surface an immense number of protrusions, which soon, in the ordinary way, become the parents of as many twigs or branchlets, which, growing and branching precisely as do the vegetative branches, soon become excessively crowded. The base of the trichogonium participates also in the production of branches, and at last a dense ball is formed of pseudo-parenchymatous tissue by the forced adhesion of the crowded twigs. The central cells of the glomerule thus formed are very large and bladder-like. The outer part of the ball is composed of innumerable radiating rows of small cells, the end

cell of each branch being roundish, so as to present a convex external face.

"At maturity these cells open and allow their contents to escape as round masses, which appear to have no membrane, but begin at once to grow and secrete cellulose. Their after-history has not been made out with absolute certainty, but they are believed to directly develop the new plant." *

In addition to ordinary asexual reproduction, Carter † has detailed his observations on the sexual reproduction in *Eudorina*, which differs but little from that which prevails in allied genera. He says—

"When the process of impregnation occurs, the division takes place at the second stage, that is, when the *Eudorina* consists of thirty-two cells of the largest kind, each of which is about the 1-1866th of an inch in diameter within its capsule, which is therefore a little larger. The process is as follows:—

"At a certain period, after the second stage has become fully developed, the contents of the *four* anterior cells respectively present lines of duplicative subdivision, which radiate from a point in the posterior part of the cell (in the subdivision of other cells the lines of fissiparation tend towards the centre of the cell). These lines, which ultimately divide the green contents of the cell into sixty-four portions,

* Solms-Laubach, in "Botanische Zeitung" (1867), p. 161, and Wood's "Fresh-Water Algæ of the United States," p. 218.

† H. J. Carter on Eudorina, in *Annals of Natural History*, October, 1858.

where the division stops, entail a pyriform shape on the segments, from whose extremities a mass of cilia may be observed waving in the anterior part of the cell of the parent, while yet her own pair of cilia are in active motion, and her eye-spot still exists *in situ* on one side of her progeny, thus showing that the latter may be almost fully formed before the parent perishes. At length, however, this takes place, and the progeny (*spermatozoids*) separate from each other, and finding an exit, probably by rupture, through the effete parent-cell and her capsule, soon become dispersed throughout the space between the two large ovoid cells mentioned, where they thus freely come into contact with the capsules of the twenty-eight remaining or female cells.

"The form of the spermatozoid now varies at every instant from the activity of its movements and the almost semi-fluid state of its plasma. Its changes, however, are confined to elongation and contraction; hence it is sometimes linear-fusiform, or lunular, at others pyriform, short, or elongate. The centre of the body is tinged green, by the presence of a little chlorophyl, while the extremities are colourless; the anterior one bears a pair of cilia, and there is an eye-spot a little in front of the middle of the body, also probably a nucleus. It is about 1-2700th of an inch long and about one-fifth as broad.

"Once in the space mentioned, the spermatozoids soon find their way among the female cells, to the

capsules of which they apply themselves most vigorously and pertinaciously, flattening, elongating, and changing themselves into various forms as they glide over their surfaces, until they find a point of ingress, when they appear to slip in, and, coming in contact with the female cell, to sink into her substance as by amalgamation. This author explains that there was some difficulty in seeing the act of union, but of the act itself he entertained no doubts. *Eudorina* in this stage also may frequently be seen with all the four anterior cells absent, and only a few spermatozoids left, most of which are motionless, and adherent to the capsules, indicating that the rest have disappeared in the way mentioned. Lastly, many *Eudorinæ* in this stage may be observed with not only the four anterior cells absent, but with hardly a spermatozoid left, indicating that the whole had passed into the female cells, or had become expended in the process of impregnation.

"What changes take place in the *Eudorina* after this he has not been able to discover. At the time the female cells appear to become more opaque, by the incorporation of the spermatozoids, and the crenulated state of the posterior part of the envelope in this stage seems also to indicate an approach to disintegration.

"While undergoing impregnation the female cells always contain from two to four nuclei, as if preparatory to the third stage of development into which

they are sometimes actually seen passing, with the spermatozoids present and scattered among them; but the effect of impregnation generally seems to arrest this stage, and thus save the species from that minute division which leads to destruction.

CHAPTER VII.

CONJUGATION.

Fertilization by conjugation is a phenomenon widely known and readily observed in fresh-water algæ. There is a large section in which it prevails, known as the *Conjugatæ*, to which Desmids and Diatoms are affiliated. Both these latter are excluded, for manifest reasons, from this work, as they can be more profitably studied by themselves, whilst sufficient still remain to prove that fertilization by conjugation is one of the common modes prevalent in fresh-water algæ.

Conjugation in the *Zygnemeæ* is the union of two cells, either of separate filaments or of the same filament, the result being the formation of a kind of spore, called, after its mode of development, a zygospore. The cells containing the male and female element cannot at present be distinguished from each other, although De Bary states that he has observed a constant difference between the fertile and sterile cells of *Spirogyra*. Usually, all the cells of one filament appear to be either giving or receiving cells, so that the male and female elements would seem to

be distinct; but this requires more certain confirmation, inasmuch as in such of the species of *Spirogyra* as exhibit lateral, as well as scalariform conjugation, all the cells in one filament cannot be of the same kind.

Not long since Mr. Bennett endeavoured,* but, as it seems to us, unsatisfactorily, to establish the fact of the existence of distinct sexual filaments in *Spirogyra*, which could be easily recognized when not in the act of conjugation. The chief points on which he relied to prove his case were—(1) The difference in the size of the cell, the so-called germ-cells being the largest; (2) that the portion of the conjugating canal contributed by the germ-cell is shorter and wider than that contributed by the sperm-cell; (3) that the protoplasmic contents of the cells always travel in one direction—that is, that in scalariform conjugation the contents of the cells of one thread invariably pass over into the cells of the other thread with which it is conjugating; and (4) some observations belonging to the *Mesocarpeæ*, which we think fit to regard, with Wittrock, as distinct from the *Zygnemeæ*.

However plausible, at first sight, the contentions might seem to be, they were not novel, for similar ideas had already been propounded by preceding authors, and set aside, nor was this resuscitation permitted long to remain unchallenged. Mr. F. Bates made a very successful effort to show that the conten-

* "On Reproduction in the *Zygnemaceæ*," by A. W. Bennett, in *Journal Linnean Society*, April, 1884, vol. xx. p. 430.

tions were untenable.* Firstly, by reference to the well-known differences in the length and diameter of the threads in the same species. "Moreover," he adds, "it has to be admitted that conjugation must have *commenced* before even a guess can be made as to which is a male and which a female cell. Now, when we consider the many curious changes which take place in the form, etc., of cells at the time of conjugation, we must needs be careful how we draw conclusions from them on which to base a theory of sexuality. Again, one may find mixed in the same gathering, of one and the same species, threads having the spore-cells cylindrical and longer than the spores, or swollen and more or less wider than the spores, or so abbreviated that the spores are crowded together and placed sideways, being longer than their cells. Considering all these things, then, how can we place any value or reliance on conclusions based on an infinitesimal increase in the diameter of one cell over another?" Having examined the conjugated cells of the species operated upon by Mr. Bennett, where the cells preserved their cylindrical form he did not find any appreciable difference of diameter; as a rule the two conjugated threads were equal, or might vary to a slight extent on either side. Another argument adduced was that *lateral* conjugation was common, even in the same threads as those which in other

* "On Sexuality in the *Zygnemaceæ*," by F. Bates, in *Journal Quekett Microscopical Club*, Ser. ii. vol. ii. (1885), p. 104.

parts conjugated in a scalariform manner. Already it had been admitted that the lateral conjugation which had been described as taking place between adjacent cells of the same filament, if correctly observed, would raise a difficulty, since "all idea of sexuality of the filaments must be abandoned in these cases." In passing, it may be remarked that in the fifteen British species of the genus *Spirogyra* figured in Cooke's "Fresh-Water Algæ," the majority are represented with lateral as well as scalariform conjugation. Therefore, if true, the theory would only be partially applicable, and partially "all idea of sexuality must be abandoned."

"As to the second point, that the portion of the conjugating canal contributed by the so-considered germ-cell is shorter and wider than that contributed by the sperm-cell; the suture marking their point of union will consequently show nearest the spore-containing cell. This conclusion has evidently been arrived at from observations made at the early stage of conjugation, and before the commencement of the passage of the contents of the one cell into the other. At this stage it is true that the tubular protuberance put forth by the so-considered sperm-cell does, when it comes into contact with the opposing protuberance, force slightly inward the opposing face; but this I take to be transitory, for afterwards there is doubtless resorption of the opposing membranes, with fusion of the tubular walls, so that a perfectly open channel of

communication is formed. When this is effected, and not till then, does any passage of the contents of the one cell to the other begin to take place. Then also it will be seen that the shortening and widening of the so-considered germ-tube was only due to the temporary pressure exercised upon it by the sperm-tube, for, when all is completed, the suture resulting from the fusion of the two portions will be found, as a rule, in the middle; although, as might reasonably be expected, it is sometimes met with nearer the one cell, and at others nearer to the other."

As to the third point, that the protoplasmic contents of the cells in conjugating always travel in one direction, Mr. Bates writes, "It is doubtless the rule that in scalariform conjugation, the one thread parts with, and the other receives the contents of the cells; but this fact is so overborne by others as to be deprived of all its significance as a test for sexuality. In several species I have found *both* scalariform and lateral conjugation; whilst it is also a fact that *both* forms of conjugation may be *going on together in different parts of the same threads.* In my mind this settles the question; for it must not be forgotten that Mr. Bennett abandons all idea of sexuality in threads conjugating laterally; and yet, really, this form of conjugation is nearly as common as the scalariform. It is unnecessary to continue the observations on the fourth point at issue, as it refers wholly to the *Mesocarpeæ,* which we prefer to hold distinct.

Enough has now been said of the sexuality of the threads in *Zygnemeæ*, for the observations coincide with our own experiences and opinions, albeit we are not prepared to affirm dogmatically that such a thing is impossible, but that those who have asserted and affirmed sexuality have not yet proved their case, or invested it with plausibility.

Returning to the original test of conjugation, the following remarks may serve to illustrate the process:—

"The first perceptible change in a cell about to produce a resting-spore appears to be a loosening of the primordial utricle from the outer wall, and a contraction of it upon the cell-contents, which thus are crowded together and more or less deformed. Simultaneously with this, or a little after or before it, the side wall of the cell is ruptured, and a little pullulation or process is pushed out, which directly coats itself with cellulose and rapidly enlarges to a considerable diameter, at the same time growing in length until it meets a similar process pushing out from an opposing cell, or has attained as great a length as its laws of development will allow. When two processes meet they become fused together, the end walls are ruptured, and the contents of one cell passing over are received within those of the other, or else the contents of both cells meet within the connecting tube, and there fuse together. This is the more common mode of conjugation, in which two cells of distinct filaments become joined together by a con-

necting tube. It is evident that, if the filaments are fertile to their fullest extent, there will be as many of these connecting tubes as there are pairs of cells in the filaments, and a ladder-like body will be formed, the original filaments corresponding to the side pieces, the connecting tubes to the rounds. Hence this method of conjugation has received the name of *scalariform* (Fig. 48).

"In the so-called *lateral conjugation*, instead of cells of different filaments joining, adjacent cells of one filament unite together to complete the process. The union of the two cells appears to take place in several ways. In accordance with one plan, connecting tubes, pushed out from near the ends of the cells, grow for a short distance nearly at right angles to the long axis of the filaments, and then bend at a right angle to themselves, so as to run parallel to the filament cells. The ends of these processes are, of course, opposed to one another, and, coming in contact, fuse together so as to form a continuous tube for the passage of the endochrome. Another method by which neighbouring cells are sometimes connected is by the formation of coadjacent pouch-like enlargements of the opposing ends, and a subsequent fusion of these newly formed enlargements by the absorption of the end wall between them (Fig. 45*c*).

"There is still another method of conjugation, the so-called *genuflexuous*, in which, instead of a connecting tube being formed as the medium of union, two cells

of opposing filaments become sharply bent backwards, so that their central portions are strongly thrust forward as obtuse points, which, coming in contact, adhere, and allow of a passage-way between the cells being made by the absorption of their cohering walls." *

This latter method prevails in the genus *Sirogonium*, of which there is one British species.

These three methods of conjugation, the scalariform, the lateral, and the genuflexuous, are found in the *Zygnemeæ*. The two first may not only occur in the same species, but on the same individual thread; the latter is excluded from the genus and species in which the former prevails, and is confined solely, to the exclusion of the other forms, to that little genus of which it is characteristic, if we except the modifications it assumes in the *Mesocarpeæ*, hereafter noticed.

What are the conditions which influence the operations of scalariform and lateral conjugation respectively does not seem to have been ascertained. We know that one portion of an individual thread may conjugate with the similar portion of a neighbouring thread, in a scalariform manner, and that the remaining portion of the same thread may diverge from its neighbour, and develop lateral conjugation; but wherefore should it do so whilst an available neighbour thread is not only in close proximity, but really attached to it, by connective processes, at a short distance? This is the enigma to which, as yet, there

* Wood's "Fresh-Water Algæ of the United States," p. 161.

is no satisfactory clue. The only hypothesis suggested is that the cells, before evidence of conjugation, are really sexual; that a series of male cells, following each other uninterruptedly, must conjugate with a neighbouring filament of female cells, to the extent of the uninterrupted series; that beyond this the male and female cells alternate, and therefore, instead of seeking to ally themselves with a neighbouring thread, the proximate cells conjugate laterally. Whatever the explanation may be, it may be assumed that it is not a method of haphazard. The portion of a fertile thread which declines to conjugate in a scalariform manner, but at once conjugates laterally, will hardly do so because there is no suitable thread in proximity, but rather from some innate reason which prohibits scalariform conjugation. It may be that this reason will be found in the fact that male and female elements were already provided for in alternate cells. Evidence has not yet been adduced of the possibility of distinguishing active from passive, male from female, cells until the act of conjugation is accomplished, and the movements of the plasma give indication of the fecundating cell.

Conjugation in the *Mesocarpeæ* differs somewhat from that of the *Zygnemaceæ,* which has led to their recognition as separate families. The process may be summarized on the basis of the exposition made by Professor Wittrock in his memoir on this subject.*

* "On the Spore-Formation in the *Mesocarpeæ.*" Stockholm, 1878.

Two cells grow together in the ordinary manner by the projection of conjugating outgrowths, and absorption of the double cell wall at the point where the conjugating cells coincide. By this means a cross-shaped or H-shaped double cell is formed, in which at first no other change is observed than that the canal of conjugation is somewhat widened, and the green contents of the double cell move into the conjugating canal, and those parts of the double cell which are nearest to it. This cross-shaped cell, which is formed by the conjugation, is regarded by De Bary as the zygospore, but it exists only for a short time as such. The movement of the chlorophyl-like bodies into the connecting canal having been accomplished, the zygospore is divided by two or four septa into three or five cells, of which the central one has been termed a *hypnospore*, or "resting-spore," whilst the two or four lateral cells are sterile, and ultimately die. Thus the *Mesocarpeæ*, according to De Bary, have spores of two kinds—the zygospores, which are formed simply by the growing together of the two opposing cells, and do not rest; and the hypnospores, which are formed by the partition of the zygospores, and which rest for a time before germinating. On the contrary, the *Zygnemeæ* (and the Desmids) have spores of only one kind, which are typical zygospores, in the formation of which a fusion and contraction of the entire protoplasm of the conjugated cells takes place, and which

become "resting-spores" without a preceding partition. Wittrock, in assenting to this, observes that the resting spores of the *Mesocarpeæ* are not analogous to the zygospores of the *Zygnemeæ*, and, indeed, that they are not zygospores at all; the resting spores of the *Mesocarpeæ* being formed by partition, and not by an immediate fusion of the contents of conjugating cells, as the case ought to be with zygospores.

Pringsheim, in referring to the same subject, describes the act of conjugation as consisting of two stages. The first, which is introductory, consists in the two cells which participate in the conjugation growing together by the conjugation outgrowths, and the septa between the conjugating cells being absorbed. This part of the process he calls *copulation*. The second stage consists in an intimate fusion taking place of the contents of the conjugating cells. This fusion is effected by the moving of the green parts of the protoplasm into, or into the neighbourhood of, the widened connective canal. This stage he calls the *connubium*. The conjugation having taken place in this manner, its effect appears in the three-parting or five-parting of the cross-shaped or H-shaped cell formed by the copulation. Of the cells formed by this partition, the central one is fertile, and the two or four lateral ones sterile. The result is consequently not one cell, but several cells, and not cells of one kind, but of two, namely, one propagative cell or spore, and around it two or four cells incapable of

germination. His conclusion is that the result is a *sporocarp.* Although it remains in a very low state of development, it yet possesses the constituent parts of a sporocarp. It has a nucleus and a pericarp, the nucleus being the central spore-cell, and the pericarp is represented by the two or four lateral sterile cells * (Figs. 51, 52).

At one time it was thought that a method of conjugation similar in principle to the lateral method was to be found in *Œdogonium* and *Bulbochœte.* Both Decaisne and Hassall had observed that, in these two genera, the cell which immediately precedes the swollen mother-cell of the spore, or oogonium as it is called, had little or no green contents. Hassall thought that from this fact it might be deduced that the contents of the lower cell had passed into the upper, in a similar manner to the lateral process of spore-formation in *Spirogyra,* with this distinction, that the contents of one cell did not make their way into the next cell through the medium of a lateral connecting canal, but probably through an opening in the partition or septum dividing the two cells. To this hypothesis objection was taken, that it is not unusual to find both the lower and the upper neighbour-cell with unchanged green contents; also that sometimes two, three, or four cells containing spores may be seen following each other in immediate succession. Braun says, "If there were only two, it

* See Pringsheim's "Jahrbucher," xi. 1877.

might still be asserted that one had attracted the contents of the cell next below it, the other the contents of the cell next above it, in order to form the spore out of coupled contents; but, when three or four sporiferous cells follow in succession, such a coupling is no longer conceivable." * It must be remembered that this theory of pseudo-conjugation in *Œdogonium* had its origin at a time when the real method of sexual reproduction in that genus was either unknown, or but imperfectly understood.

* Braun on Rejuvenescence (Ray Society), p. 301.

CHAPTER VIII.

PAIRING OF ZOOSPORES.

It has generally been assumed, in species of fresh-water algæ where the only known method of reproduction is by means of zoospores, that, in consequence, in all such cases the process is asexual. Something more than a doubt was cast upon this inference by the researches of Pringsheim, who has shown that, in some cases at least, these zoospores being of two kinds, and presumably of two sexes, a process of copulation takes place, and, as a result, one kind of zoospore, after contact, passes into a state of immobility, becoming a kind of resting spore; and that these resting spores, produced by the so-called microgonidia, reproduce the mother-plant. "If it be not assumed," he says, "that all the plants without resting spores are asexual, it must follow either that their resting spores remain to be discovered (which is improbable), or that in the *Zoosporeæ,* and in their already known organs, the sexual act takes place in a special manner not yet discriminated. The existence of two kinds of zoospores in the same plant seemed to afford a clue to the

discovery of this unknown sexual act." What has been called by Pringsheim the "pairing of zoospores" seemed to him a modification of the sexual act, forming a link between the known forms of reproduction, and showing that the different sexual products are a series of variations, passing into one another, of one and the same form; the essential difference between this and other forms of reproduction being in the appearance of motile "brood-spheres," which are externally just like the zoospores.

Something very similar to this was known to take place in some species of fresh-water algæ, between the active gonidia or zoospores. For instance, in the well-known *Botrydium*, certain zoospores conjugate in twos, sometimes several together. They come into contact by their ciliated ends, then touch laterally, and fusion takes place, when they present a cordate figure with a central colourless vacuole (Fig. 54). If these zoospores be isolated before conjugation, they ultimately break up, without presenting any products capable of germination.

Pringsheim * illustrates his views principally by reference to *Pandorina morum*. He says that asexular reproduction takes place in *Pandorina*, as in other multicellular *Volvocineæ*, by the formation of a perfect young plant in each cell of the mother-plant. By the gradual dissolution of the general envelope, and

* Monatsbericht, Roy. Acad. Sciences, Berlin, Oct., 1869. Translated in *Annals of Natural History*, vol. v. (1870), p. 272.

of the special membrane of the mother-cells, the young plants become free, and escape. In sexual reproductions, as in the asexual, the membrane of the old plant swells, and sixteen young plants are formed. The young plants, however, are (at least in part) not neuter, but sexual, and either male or female. Whether the mother-plant is monœcious or diœcious is difficult to determine, because the male and female plants are externally alike, and can hardly be distinguished with certainty during copulation. There is no striking difference in structure between the sexual and asexual plants, although, amongst the former, plants with less than sixteen cells, especially with eight cells, are oftener produced. Moreover, the dissolution of the membrane of the mother-cell proceeds more slowly than in the case of neuter plants, one result of which is that the young asexual plants vary much in the extent of their growth, and continue united in groups of different sizes for a long time after their formation, according as a greater or less number of them have happened to become free from the gelatinous mass in which they were embedded.

As the individual groups are at first motionless, and the mother-plant loses its cilia during the formation of the young ones, the entire group is at first entirely quiescent. But afterwards the young sexual plants, like the neuter ones, produce upon each of their cells two cilia, which commence their motion as soon as the enveloping mucus admits of it, and thus ultimately

the entire group assumes a state of active rotation. During the rotation of the groups the same process of expansion and dissolution takes place in the membrane of the sexual plants as occurred in the mother-plant; but the contents of the cells of the sexual plants do not undergo division, but combine to form a single zoospore, which becomes free by the rapid dissolution of the membranes. In their general structure these zoospores differ in no way from other zoospores. At their colourless apex they exhibit, like other zoospores, a red body placed on one side of the apex, and two long vibrating cilia, by which they move in the manner common to zoospores. The individual zoospores exhibit no marked differences, except that they vary in size within tolerably wide limits, but not in a manner to indicate the existence of two different sorts.

Amongst the groups of isolated zoospores of different sizes some are at last seen to approach one another in pairs. They come into contact at their anterior hyaline apex, coalesce with one another, and assume a shape resembling a figure of 8. The constriction which marks their original separation disappears by degrees; and the paired zoospores form at last a single large green globe, showing at the circumference no trace of their original separation. It may be seen, however, that the globe is larger than the individual neighbouring zoospores, that it has a strikingly enlarged colourless mouth-spot, with two red bodies on the right and left, and that it is furnished with four vibrating cilia

originating in pairs near the two red spots. The four cilia, however, soon become motionless, and together with the red spots disappear.

This act of conjugation occupies some minutes from the first contact of the zoospores to the formation of the green globe. The latter becomes the zoospore, which, after growing slightly larger, and assuming a red colour, germinates after a long period of rest, and brings forth a new *Pandorina.* There is hardly any appreciable difference, except in size, between the male and female zoospores. Most frequently a small zoospore pairs with a larger one; but two of equal size often unite. Probably both the females and the males vary much in size, the former more so than the latter.

With regard to the entire plants from which the zoospores are produced, there is little doubt that those of the largest size are females; but the sex of the smaller and middle-sized ones cannot be determined with any certainty. The germination of the oospore is like that of other *Volvocineæ*, especially resembling in its early stage the germination of the resting spores produced by the microgonidia of *Hydrodictyon utriculatum.* The oospore bursts, and produces a single large zoospore (in rare cases two or even three), which divides into sixteen cells, and becomes a young *Pandorina.*

Thuret has shown that there is such a phenomenon as the "pairing of zoospores" to be observed in

Monostroma bullosum (or, as sometimes called, *Tetraspora bullosa*).

In *Hydrodictyon*, which possesses zoospores of two kinds, pairing has also been observed. "In certain cells are formed somewhat larger and less numerous gonidia (according to the size of the mother-cell, from seventy thousand to twenty thousand), in other cells of the same net somewhat smaller and more numerous gonidia (from thirty to one hundred thousand). Only the macrogonidia form a new net, which they do after a short tremulous movement, lasting about half an hour, without leaving the mother-cell, by uniting into a daughter-net, which is gradually set free by the dissolution of the coat of the mother-cell. The microgonidia, on the other hand, distinguished not only by their smaller size, but by a longer shape and four long cilia, swarm out from the bursting of the mother-cells, move about very actively, often for the space of three hours, and, after coming to rest, become green *Protococcus*-like globules, which vegetate for some time, and at length die away." Thus far was known to Alexander Braun, with something of a suspicion that somewhat more had to be discovered, which something is now interpreted by "pairing of the zoospores."

It is impossible to predict to what extent this pairing prevails in such species as possess two kinds of zoospores, probably in all of them, although at present it has practically been demonstrated only in

a few; *Chroolepus* being one of the genera in which it is known to take place.

The polymorphous reproduction in *Hormiscia* includes "pairing" as one of its phases. Microzoospores are produced, from eight to thirty-two in each cell. These have two cilia, and, after swarming for a time, conjugate laterally in pairs, forming a zygospore, which attaches itself by the ciliated end. It grows slowly and finally breaks up, by simultaneous division of the contents, into from two to fourteen swarm-spores, which constitute the beginning of a new sexual generation. If any of the microzoospores remain behind in the mother-cell, they are able, without pairing, to germinate, and grow into independent plants, which may be seen, singly or in groups, projecting from the mother-cells.

That remarkable little stipitate *Mischococcus*, not unfrequently found parasitic on *Confervæ*, has of late been added to this list by Professor Borzi. In addition to the ordinary branched, or treelike form, he describes a palmelloid form, spreading as a thin layer over the surface of water-plants, and dividing in two directions only. The cells in this form at length give birth to zoospores; sometimes one, sometimes two to four from each cell. On germinating they originate palmelloid colonies. The cells of the dendroidal colonies also give birth to zoospores, either one or two from each cell. These are microzoospores, as distinguished from the macrozoospores produced by the palmelloid

colonies. Under certain conditions the microzoospores conjugate, or pair, and the resulting spore has at first two cilia.*

Another proven example is *Stephanosphæra pluvialis.* The vegetative primordial cells, or macrogonidia, when about to divide, which is usually in the afternoon, retract all their protoplasmic threads, by which they were attached to the enveloping membrane, round themselves off, and then divide into microgonidia. Usually all the cells of a vegetative family become transformed into microgonidia at the same time. These microgonidia unite in the ordinary way by "pairing," their anterior ends coalescing in the production of isospores, which are scarcely larger than the original microgonidia. Those which do not conjugate have been found in all cases to perish. The resting cells are always the result of the pairing of the microgonidia.†

* "Malpighia" (1888), ii. p. 133.
† Cohn's "Beitrage" (1884), p. 51.

CHAPTER IX.

ALTERNATION OF GENERATIONS.

"Alternation of generations," as applied zoologically, differs materially from metamorphosis, although they are sometimes confounded as though they were convertible terms. The fundamental idea is that of an organism "producing an offspring, which at no time resembles its parent, but which, on the other hand, itself brings forth a progeny which returns, in its form and nature, to the parent animal, so that the material organism does not meet with its resemblance in its own brood, but in the descendants of the second, third, or fourth degree or generation, and this always takes place in the different animals which exhibit the phenomenon in a determinate generation, or with the intervention of a determinate number of generations." * The characteristic difference between this and a simple metamorphosis is that each generation completes its career in the same form as it commenced, so that each starts from an ovum, and the cycle is *not* the career of a single individual, but of a consecutive series of

* Steenstrup, "Alternation of Generations" (Ray Society), p. 1.

individuals, which revert to the original form after one, two, or more intermediate and differing generations. Not only does this phenomenon take place amongst animals, but its analogy is to be found amongst plants, and amongst the fresh-water algæ instances are to be met with in which something of the nature of alternation of generations occurs. It may perhaps be objected that these generations are not so distinct and pronounced as in the animal world, but still sufficiently so to justify the application of the same term to the phenomena of alternation.

Recent researches * into the life-history of *Botrydium* have furnished the following indications of a cycle of generations in that interesting little plant:—

"If a plant be placed in water, its contents become modified at the latter part of the day, or at night, into zoospores. Ultimately the wall swells, then bursts somewhere at the top, and the zoospores resulting from the division of the wall stratum escape. If the plant be only moistened, the zoospores do not swarm out, but come to rest within the collapsed wall. Such were known to previous observers as 'germ-cells' or 'gonidia.' The zoospores are elongated egg-shaped, with a single thread or flagellum, and two to four chlorophyl granules. Having swarmed out, they soon come to rest, lose the flagellum, become surrounded by

* Rostafiuski and Woronin, "Ueber Botrydium granulatum" (1887); Cooke, "British Fresh-Water Algæ," p. 112.

a membrane, increase in size, and germinate on damp earth, in which stage they represent *Protococcus botryoides.*

"The large ordinary zoosporangia are also otherwise modified. If one is allowed to dry, its membrane collapses, loses colour, and soon becomes empty. The protoplasmic contents pass down to the branches of the root. Here they break up into numerous cells, sometimes two or three side by side, but chiefly in a continuous chain; each cell furnished with a separate membrane. These are capable of three forms of development. (1) If removed from the soil and placed in water, the cell becomes a subterranean zoosporangium. The formation of the zoospores is independent of light, at any hour of the day or night. The zoospores are similar to those above described, and germinate in the same manner. (2) If a chain of these root-cells be laid on moist earth, each protrudes a hyaline process, which enters the soil, the opposite end being elevated, and thus each root-cell becomes a vegetative plant. (3) If the root-cells are not removed, and kept equably moist, they also germinate in the earth, become inflated, put forth a root process, the wall of which becomes very much thickened on the inner side below the inflated upper portion. By intercellulary growth of the root portion, the upper part becomes raised aloft, so that the apex is carried above the surface of the soil. These products of modified root-cells are named 'resting sporangia' (*hypnospo-*

ranges), and are equivalent to the so-called *Botrydium Wallrothii*. When dried, the resting sporangia retain their power of germination during the whole year, and, when placed in water, form zoospores at any hour of the day or night, germinating and forming young plants as above.

"The zoospores germinate on a moist substratum. On earth or sand they thrive badly, but better on clayey or muddy soil. In water they never germinate, but come to rest, are surrounded by a double membrane, and lie dormant for months. If these be transferred upon a clayey soil, they commence to form a vegetative plant. If the zoospores be sparingly distributed over the soil, and the whole kept equally moist, the vegetative plants become ordinary zoosporanges. The plants are sometimes modified into 'resting sporanges' (*hypnosporangia*).

"Thus, vegetative plants can be increased by cell-division directly from zoospores, become ordinary zoosporanges, with such consequences as root-cells, etc., or they may be directly modified into 'resting sporanges.' But there is another way in which existence may be carried on. If exposed to drought, the following phenomena occur:—The wall collapses more or less, and the protoplasmic contents break up into a number of cells, each surrounded by a delicate membrane, its contents homogeneous, at first green, then passing into red. These are the *spores*, and have been known by such names as *Protococcus coccoma, Protococcus*

palustris, and *Protococcus botryoides.* These spores become changed in water to zoosporangia, their contents giving rise to zoospores in the manner already described. If the spores be still green, their zoospores will have a distinct fusiform figure, with two cilia at the end. They consist of slightly coloured protoplasm. These zoospores conjugate in twos, sometimes several together. They come in contact by their ciliated ends, then come to touch laterally by the uncoloured portions, when the fusion of the conjugating zoospores takes place, immediately after which they present a cordate figure, and in the middle a colourless vacuole. Finally the spore (*isospore*) thus originating becomes globular, the vacuole occupying the centre. If the zoospores be isolated before conjugation they will in the end break up, without presenting any products capable of germination."

The zoospores originating from red spores have a different figure, their posterior end being rounded, but they have otherwise the same structure, and behave in the same manner as the others. The red spores maintain their germinative power for years, but after two years their zoospores are languid, and offer a parthenogenesis of a peculiar kind. The red spores, if kept moist only, become nothing altered after weeks, whilst the green, under these circumstances, may directly germinate into vegetative plants.

"The isospores (resulting from conjugation) are at first globular, and capable of immediate germination.

They also present resting stages, the original form becoming modified. Soon after conjugation these are flattened, with irregular lateral boundaries, which become on the following day hexagonal. The membrane becomes thickened and presents tuberculations at the margin, but no secondary membrane is formed. Brought upon damp earth, they soon become globular, and otherwise behave as ordinary *isospores*.

"In order to distinguish that which appertains to the cycle of alternation of generations from the rest, the simple method is to start from the fertilized germ, and see what are the modifications which are essential in order to arrive again at the same reproductive process. In this case we have the *isospore;* it germinates, produces the vegetative plant, which needs neither to divide, nor produce a sexual zoospore, nor to become an ordinary zoosporange—it can directly produce spores. These close the first generation. The second oospore generation occurs in the germination of these spores in the form of sexual zoospores, which directly lead to the formation of the isospore—the limits of two generations. All the rest are but phenomena of adaptation.

"Thus in nature the vegetative plants, in spring, almost all become zoosporangia, and spread the growth over considerable areas. Zoospores which fall into the water are not lost; they acquire a double membrane, and lie dormant until they chance mechanically to arrive on moist soil. If drought sets in, the plasma

retreats to the roots; if the earth be some time a little moist, the root-cells become 'resting spores' (*hypnospores*), awaiting the rain in order to develop multitudes of zoospores; but if the earth becomes rapidly dried, the root-cells remain unaltered, until a moistening excites the formation of the zoospores. A great many of the root-cells can manifestly accidentally reach the surface of the soil, and thus, according to the state of the moisture of the earth or air, sometimes germinate, sometimes become zoospores." All this is in the spring. The hotter months favour the formation of spores, but at that time only the vegetative plants are mostly to be found, either undergoing cell-division or spore-formation. They can also furnish uniciliated zoospores, without becoming modified into ordinary zoosporanges.

Formation of the ordinary zoospores may be accomplished in a fourfold way: (1) From the vegetative plant; (2) from the ordinary zoosporange; (3) from the root-cell; (4) from the resting sporangium (*hypnosporangium*).

Further modes of increase are—(5) By cell-division; (6) the formation of spores; and (7) the formation of zoospores.

This plant possesses also fivefold resting stages: (1) Of the asexual zoospores laid in water—for months; (2) of the root-cells—the year throughout in which they originated; (3) of the hypnosporanges—the year throughout in which they originated; (4) of the spores

—for years; (5) of the isospores—at least over the year in which they originated.

Much of the foregoing phenomena might be eliminated and transferred to polymorphism, some relegated to ordinary asexual reproduction, and some bearing the impress of sexual conjugation, but on the whole the history is so complex that the narrative is better retained here in its entirety.

From this we pass to another organism which Professor Cohn made the object of careful and special investigation, and now called *Chlamydococcus*, but at that period *Protococcus pluvialis;* his brief summary of results being—(1) "That *Protococcus pluvialis* is a unicellular alga, a simple cell, or at least the individual represents an organism which exhibits the conditions of a simple cell; each multiplication of the cell reproduces the species, and is at the same time an act of propagation; each dissolution of the parent-cell into secondary ones constitutes a new generation; each secondary cell is an independent individual of the same species. (2) It is a plant subject to an 'alternation of generations;' that is to say, the complete idea of the species is not exhibited in it until after a series of generations. The forms of development which can be possibly comprehended in the idea of the species, do not in reality make themselves apparent until a series of independent successive generations has been gone through. (3) The individuals of each such generation are capable of propagating

themselves in new generations. The individuals of the second generation are among themselves, speaking generally, of equal value; as respects the individuals of the parent generation, they are sometimes of equal value with them, sometimes not. (4) If the secondary cells are not of equal value to their parent-cells, a series of successive generations must precede the last generation, the individuals of which are, again, equivalent to the first mother-cell. The number of these generations does not appear to be determinate.

"Let us assume that a parent-cell has produced a number of secondary cells, which are of unequal value to their parent. The individuals of this second generation propagate a third generation equivalent to their parent-cell, or not equivalent. In the first case there may be also a fourth generation, a fifth, and more, which are all equal among themselves, and to their parents, but not equal to the parent-cell of the first generation, until at last a generation is produced which is not equivalent to its own parent. Now this is either equivalent to the first generation, and the cycle closes with it, or it is still not equivalent to it. In that case, it either propagates again a number of equivalent generations, or non-equivalent, until at last one appears which is equivalent to the first generation, and thus the cycle closes." *

This is the only place in which we can quote the

* Professor F. Cohn on *Protococcus nivalis* (Ray Society), p. 541.

fuller observations of Cohn on the life-history of this remarkable organism.

"Normally fully developed cells of this multiform creature," he says, "sometimes like a plant, sometimes like an animal, present the appearance of globules from ·02 to ·04 mm. diam., with a thick, tough cell-membrane, and granular-punctate, opaque contents, sometimes of a brown, sometimes (at other periods, or in other localities) bright red colour. In the mass of the dark contents lie hidden several other structures, which at this period are completely concealed, namely, 4–6 starch globules of ·0033 or at most ·005 mm. in diameter, in which, as in those of *Hydrodictyon*, a nucleus and an envelope may be distinguished, acquiring a violet colour with iodine, the nucleus becoming rather redder. Sulphuric acid causes a considerable swelling up of the coat. There also appears to exist in the centre of the cell a large, very delicate nuclear vesicle, which, however, is so covered up by the rest of the cell-contents, that it can only be very indistinctly perceived, and cannot even be clearly displayed when the contents are squeezed out. When these resting globular cells are placed in water they give birth to four gonidium-like swarming cells. Even before the commencement of the division of the contents by which the latter are formed, a change begins in the colour of the parent-cell, the red colour retreating to some extent from the periphery, and a yellow (sometimes rather greenish) border forming round the

deep red inner mass. The young swarmers also, for a short time after they issue out, have only a narrow yellow rim round a dark red middle. During the two or three days' period of movement and growth of these swarming cells—in which they grow to about four times the original size, changing their obtusely ovate form at the same time to a reversed pear-shaped apiculated shape—important new changes take place in the contents of the cells. The red colour becomes more and more concentrated into the middle of the cell, so that a sharply defined bright red nucleus is formed, in the interior of which a lighter space is often clearly perceptible, corresponding to the nuclear vesicle above mentioned, around which the red colouring matter forms a covering, mostly complete, but sometimes imperfect and interrupted. The rest of the cell-contents have become a brilliant green, and in them may be clearly distinguished the above-mentioned starch granules, as well as many more smaller green granules. The ciliated point of the cell, often drawn out like a beak, is colourless. This first moving generation is succeeded by a not yet accurately determined number of similar active generations populating the water for some weeks, and often giving it a bright green colour, till at length universal rest recommences, and the cells sink to the bottom, or attach themselves to the sides. The transition from one active generation to another takes place through a transitory resting generation of extremely short

duration. The full-grown swarming cells finally come to rest within their wide shirt-like envelope, and almost simultaneously divide into two cells, which, without becoming active, divide again into two cells. Thus within the mother envelope are produced four daughter-cells (more properly grandchildren), which begin to move soon after they are completely formed, and, tearing open the delicate enveloping vesicle, part company. The whole of this process of development is gone through very rapidly, being completed in one night and the succeeding morning. The second active generation, thus formed, resembles the first, with the single distinction that the active cells are green from the first, and have a smaller red nucleus in the interior. The subsequent active generations bear a general resemblance to the preceding, but many modifications present themselves. Thus, for example, we not unfrequently see the full-grown swarm-cells assume strange two-lobed, or even four-lobed, shapes, beginning to divide before they come to rest; or sometimes a transverse constriction and bisection of the cell takes place, caused by a partial protrusion of it from the loose shirt, etc. The formation of vacuoles is a pretty constant phenomenon in the later active generations, and there may be several of them eccentrically placed, with the red nucleus retaining its central position, or a single central vacuole, causing a lateral displacement of the red nucleus. This red nucleus often becomes very small in the last generations, so

that it very much resembles, especially when rendered parietal by the formation of a centre vacuole, the red corpuscle occurring in the gonidia of many genera of algæ belonging to very diverse families, and which was called the 'eye' in the *Volvocineæ* by Ehrenberg.

"A total disappearance of the red colour not unfrequently occurs. In the later stages of the cycle of generations arrives, finally, the formation of microgonidia; many individuals, instead of producing four daughter-cells, undergo further division, so as to give birth to a brood of sixteen or thirty-two minute cells, which, before they separate, form a mulberry-like body, but separating at length, commence a very active swarming inside the parent envelope, terminating in the rupture of this coat and the rapid dispersion of the little 'swarmers.' These are of longer shape than the large 'swarmers,' only about ·0066, rarely ·01 mm. long, of yellowish or dirty yellowish green colour, with reddish ciliated points. They do not exhibit increase of size, like the large 'swarmers,' never become coated with a perceptible and loose membrane, and have no further power of propagation. Most of them die after they have settled to rest, dissolving away; others turn into little red globules, and it is doubtful whether they can grow up to the normal size. If we now further examine how the cycle of active generations is closed and carried over to the resting vegetation, we find that the large 'swarmers'

of the last active generation, when their growth is completed and they have attained the stage of rest, instead of dividing again remain undivided, assume a perfectly globular form, and in the course of a few days become clothed by a thick, closely applied cell-membrane, while the earlier loose distant membrane gradually disappears. The contents, which at the commencement of the rest were all green, except the little red nucleus, or even often entirely green, now gradually become red again, passing from green through many tints of brown, or of brilliant golden green and golden brown, into red. These globular, thick-coated cells (the same as those with which we began) behave like seed-cells or spores, passing into a state of perfect rest. They do not exhibit any growth, and after the membrane has attained its proper thickness, and the contents their red colour, no further visible alteration takes place so long as they are kept in water. A dessication must take place before a new cycle of generations can begin. Perfectly dry specimens placed again in water ordinarily produce active gonidia the next morning. Original specimens, obtained in 1841, had retained their vital force during a preservation of seven years in a herbarium.

"In order to complete the main features of the picture of the alternating generations of this multiform creature, I must notice that, in addition to the described active generations (macrogonidia and microgonodia) and the concluding generation, passing into

the spore-like condition of rest, there are other generations which, as compared with the gonidium-like and spore-like conditions, must be regarded as the proper representatives of the vegetative development. These are generations endowed with quiet and slow vegetative growth, which multiply by pure vegetative division, unaccompanied by any swarming movement. It depends solely upon external conditions whether the resting cells, which are here characterized as seed-cells (spores), at once give rise to the new active generations, or to a series of quietly vegetating generations of cells. The former is the case when the seed-cells are totally immersed in water, the latter when they occur on a spot which is at once damp and exposed to the air, as is the case in the native condition, especially in the milder intervals of winter, and in the damp season of approaching spring, but temporarily also at all other seasons, on the margins of the little basins inhabited by *Chlamydococcus*, as often as they are filled by showers of rain. In cultivation in the house these vegetative generations are rarely observed, while in their native stations they certainly occupy the most important place in the alternations of the various conditions of life, as may be concluded from the thickness of the crusts and membranes formed by such vegetative multiplication. The formation and multiplication of these vegetative generations also take place by the division of the cell-contents, either by simple division, the first generation being transi-

tory, or by double halving (apparently quartering). But the newly formed cells do not slip out, like the young 'swarmers,' from the mother-envelope; they remain in the same place and position. The membrane of the mother-cell appears to become softened, expands, and becomes gradually drawn out to nothing, rather than regularly burst open; it at length vanishes in some undistinguishable way, the daughter-cells meanwhile acquiring a tolerably thick, closely applied cell-membrane of their own. The division is repeated many times in this way, and as the cells all remain in intimate contact, first small families, but by degrees large conglomerates of cells, are produced. The size of the single cells in these groups varies from ·01 to ·02 mm.; their shape is not truly globular, but partially bounded by flat surfaces, as results from the alternating divisions, according to the three directions of space. Ordinarily the colour is light brown. If ignorant of the rest of its history, one would be led by the form and mode of division of the cells to regard these crusts as belonging to a *Pleurococcus*. In the same crusts occur isolated large cells, loosened from their connection with the others, perfectly globular in form, and appearing to divide no more, but to have passed again into the condition of resting spore-cells. They are distinguished from the rest by their darker contents and thicker cell-membrane. Probably the return of these to renewed resting vegetation takes place by a passage through the series of active genera-

tions. Every shower of rain will wash away these loose ripe cells of the crusts of *Chlamydococcus;* carried into collections of rain water, they will soon produce the active brood, which, returning to rest after a few active generations, settles on the margins of the little puddles, and then recurs to the resting mode of vegetative multiplication."

Another example may be found in the well-known *Volvox,* the life history of which has been subjected to close scrutiny during the past twenty years. It has been shown that this organism affords an instance of true alternation of generation. "As may probably be affirmed of all living organisms, the life history would be incomplete without a process of sexual reproduction, and, accordingly, after a long sequence of asexual generations, a strictly sexual process intervenes, from which result certain spores destined to lie dormant for a while, and, like the zygospores of the conjugate algæ, to resist vicissitudes of condition and climate through the rigours of winter, and then to produce the parent form in the succeeding year, when external conditions again favour its development." *

A similar alternation takes place also in *Eudorina elegans,* and probably in all the members of the *Volvocineæ.* In his elaborate memoir of *Stephanosphæra,* Professor Cohn has demonstrated its existence,

* Cooke, "British Fresh-Water Algæ" (1882), p. 62.

by passage through numerous stages to a resting condition, from which originate new moving generations.*

* Cohn on *Stephanosphæra* in *Annals of Natural History*, vol. x. (1852), p. 408.

CHAPTER X.

SPORE GERMINATION.

EVEN as there are many varieties of spores amongst the algæ, so are there modifications in the modes of germination. There is perhaps a general similarity in all, accompanied by a variation in detail, but the similarity is most observable in the results.

It was an old notion, originating with Agardh, that the dark body which resulted from conjugation in the *Zygnemaceæ* was not a true spore, but a kind of zoosporangium, which, after a time, did not germinate, but became resolved into zoospores, to which notion Hassall gave his adherence. As will be seen hereafter, the zygospores of this order pass into a condition of rest, but ultimately germinate and produce plants after the pattern of their parent. One spore one plant, is the normal condition, although in some cases, illustrated by members of other families, a division takes place in the contents of the resting spore, and a corresponding number of new plants are produced.

Young filaments, the results of germination, whether of fecundated spores, or the analogue of spores pro-

duced asexually, sometimes expand at the base so as to attach themselves from the commencement. In other cases there is no basal expansion, and consequently no attachment, but the resulting filaments are free swimming; this depends, however, on the habits of the parent-plant. After germination, and the gradual elongation of the filament, its growth and extension is dependent upon cell-division, and this proceeds regularly, and rapidly, to the full evolution of maturo threads.

Spore germination in *Œdogonium* takes place in the following manner:—"The fertilized oospore becomes a resting spore, which ultimately passes through these stages. Previous to germination, the spore has an egg-shaped figure; the cell-contents are densely crowded, and composed of minute brownish-green granules, closely surrounded by a distinct cell-membrane. Outside this membrane there is found besides quite a distinct cell-membrane. Upon germination there are formed in both membranes slit-like openings, through which the cell-contents emerge, surrounded by an extremely delicate hyaline covering. The cell-contents are composed not of one, but usually of four green masses, each surrounded by its cell-membrane. Sometimes also, as it appears, abnormally, the masses are two or three in number. The four cells which proceed from germination possess an oval form, and their cell-membrane is hyaline. After the contents of the spore have emerged there remains behind the outer membrane,

enclosing the inner one. After the four cells have remained some time enclosed in the hyaline covering, this becomes resorbed subsequently, and the four cells lie still and motionless; but after the course of a short time the cells burst on one end by means of an annular slit, and the apex, separated thereby from the remainder of the cell-membrane, become elevated like a lid. Through the circular opening the cell-contents now emerge, and this, at the part turned towards the opening, is colourless. This apex moves with vigorous motion backwards and forwards, and after an hour the cell-contents, in the form of a zoospore, leave their place of detention, which we now find to be a doubly coloured cell-membrane. The little zoospore wheels about in a lively manner, with a circling movement, whereby the colourless point becomes directed downwards. Its appearance is like that of an ordinary zoospore, and, like it, possesses an oval form and a lighter apex, furnished with cilia, which during the motion is always directed forwards. After a time the movements become faint, and finally cease. The cilia disappear, and the light end becomes elongated into a root, which sometimes becomes an organ of attachment quite like that produced in the germination of the ordinary zoospores. The rounded end of the germinating zoospore acquires a little point-like apex. This growth becomes divided by a transverse septum, and a little two-celled *Œdogonium* has originated. From each spore there are thus derived, in general, four plants.

It is worthy of note that so long since as 1846, Mr. G. H. K. Thwaites observed a similar phenomenon of the division of the contents of the spores in *Mesocarpus* into four portions. In three species this peculiarity was observed and confirmed by the Rev. M. J. Berkeley. "The separation," it is remarked, "of the contents of the spore into four portions does not take place in our three species until the fruit is nearly mature, and this soon afterwards becomes too opaque for the character to be seen, so that it can be observed only in a particular state of the plant." * Alexander Braun, in reference to this, admits that "the observations of Thwaites, who saw the contents of the ripe spore separate into four portions in certain *Zygnemaceæ,* particularly *Mesocarpus* and *Staurocarpus,* testify that a formation of several germ-cells or young plants in one spore may occur in this family."

The ordinary germination of the spore in *Spirogyra* is not, however, associated with the breaking up of the cell-contents into four germinating bodies.

The changes which the spore does undergo previous to germination were faintly indicated by Braun, when he wrote, "The contents of the spore appear totally changed when it is about to germinate; the multitude of large and small oil-drops has vanished, and the opaque mucilage, now become green, again exhibits, but indistinctly, a few small drops or vesicles. Newly formed spiral bands become visible as dark, very

* *Annals of Natural History,* xvii. (1846), p. 263.

closely approximated, frequently somewhat flexuous, oblique streaks, even before the germinating internal cell has broken through its double envelope."

For information as to the process of germination in *Spirogyra,* we are indebted to Pringsheim's memoir.* "Conjugated specimens of *Spirogyra jugalis,* collected in August, maintained themselves in this condition through the winter, in my room, in a little glass vessel full of water, to the bottom of which they gradually sank. Some spores germinated as early as February, but most of them did not open until April, so that some eight months elapsed between their formation and their germination. We observe in the spores of *Spirogyra,* as in all motionless spores of algæ, a long period of rest between formation and unfolding; yet, during this time of *apparent* rest, processes are unceasingly active in the interior of that germ, not immediately manifesting themselves to the eye, but resulting in effects which may be detected in the spores of *Spirogyra* in demonstrable alterations of the contents, and of the membranes of old spores. Immediately after formation the spore possesses only one single, perfectly colourless, thin membrane, composed of pure cellulose. In many spores this is still so thin for a short time after the formation of the spore, that it is incapable of withstanding the strong endosmose excited by the addition of sulphuric acid, and bursts

* "On the Germination of the Spores in *Spirogyra,*" by Dr. W Pringsheim, in *Annals of Natural History,* xi. (1853), p. 210.

at some point, allowing the escape of the contents. The contents of the new-formed spores consist of the almost unchanged spiral bands of the cells concerned in the formation of the spore, contracted far more closely than in the filament cells, but retaining their form scarcely changed. The older the spores grow the more does the form of the spiral bands in their interior disappear, and their contents become uniformly diffused over the entire inner surface of the spore membrane. Finally, just before germination, the original spiral arrangement is still indistinctly indicated by several close spiral streaks in the coating, spread uniformly over the wall. It is a peculiar circumstance, that during this time the spiral arrangement of the contents of the spore presents itself, sometimes distinctly, and sometimes indistinctly, and almost wholly vanishes at the moment of germination, but always appears with surprising clearness when the spores are left for some time in glycerine, or are allowed to become perfectly dried up. Chemically speaking, the contents of the spore appear to be more changed in the relative proportions of quantity of the particular constituents than in their quality before germination.

"The differences between the membranes of old and young spores are more important than the changes perceptible in the contents. Instead of the one colourless membrane of the young spore, this latter exhibits, shortly before germination, three distinct

membranes, not blended together. These are minutely described. The detection of the three membranes is very rapidly effected by the application of concentrated potash. After the transformation of the contents is terminated and the formation of the two inner membranes completed, the germination of the spore commences by a growth of the internal cell, formed by the inmost membrane. The increasing size of the internal cell first causes the yellow (median) membrane to break across in an irregular crack, and, after a further growth of the germinating cell, the outer colourless membrane tears in a similar manner. This succession of the bursting of the outer coats of the spore is caused by the structure of the spore and the unyielding rigidity of the middle coloured coat. The internal cell, bursting forth from the coats, grows in the course of a few days into a longish cell, which soon presents septa, and becomes a many-celled filament, which resembles the parent both in the number of spiral bands and in dimensions Even in the unicellular condition, one end of the cell is elongated in a tubular form. The green spiral bands do not extend into this always unbranched, radical extremity, and, its further growth being restricted, it remains fixed from an early epoch, at *that* stage of development which it has attained in the young, few-celled plant, while the opposite end of the spore is capable of unlimited elongation, by uninterrupted growth, and repeated formation of septa.

"The end of the young plant, no matter whether it was the radical extremity or the growing summit, remained sticking in the burst coats long after the emergence of the other end, and the envelopes were not thrown completely off until a late period, and then either accidentally or, as mostly occurred, by the young plant rising from the bottom of the water, where the germination took place. I never saw the liberated young plant become attached to anything by its radical extremity, and this corresponds to the ordinary floating condition of the *Spirogyræ*. But I cannot decide whether or not the *Spirogyræ* become fixed to anything by their root-cell at a later stage than that to which I was able to trace the young plants. It is probable, however, that those *Spirogyræ* which are found adherent in their natural stations use their root-cell as the organ of attachment."

In *Sphæroplea annulina* the resting spores are red spherical bodies formed of two hyaline membranes, the interior of which is intimately connected with its plastic contents, whilst the exterior is loose and elegantly plaited. These plaits, or folds, are so arranged that they meet at their two poles; often, however, they are very irregular in shape and direction, especially in the larger spores. In germination, according to Cohn,* they undergo several modifications. They become granular and change to a dull

* Cohn, in *Annales des Sciences Naturelles*, 1856, p. 187; and *Annals of Natural History*, xviii. (1856), p. 81.

brown red, and a more transparent circle appears in their centre. Frequently the red matter changes to green before the germination, and this change is gradual, proceeding from the circumference to the centre. At length the whole of the plastic contents divides into two, then into four or eight bodies, which burst the double envelope, and disperse in the water, as so many zoospores.

"The zoospores are of an elegant shape, but this is not more uniform than their size or colour. Usually they are globular or shortly cylindrical bodies, from $\frac{1}{190}$ to $\frac{1}{150}$ of a line long, of a beautiful cinnabar or carmine red, and furnished at one of their ends with a small colourless head bearing two long cilia. Some of them are larger, pyriform or fusiform, and the result probably of the undivided contents of a resting spore. Some of the zoospores are two-coloured—red towards the beak, and green throughout the other part, or the two colours are variously disposed, the colourless head or beak, and the two cilia are invariably very distinct. The zoospores exhibit a slow jerking movement during several hours. This movement is often interrupted for several hours, when the whirling suddenly recommences. When the zoospores break through the integument within which they are formed, they are not enveloped in cellulose, but already during their period of activity they begin to invest themselves with a thin elastic pellicle. At the time of their germination this envelope

thickens and lengthens in the form of a spindle, the two ends soon tapering off into long tails, whilst even the enlarging body of the zoospore itself separates farther and farther apart. The contents of this germ-cell, at first homogeneous and finally granular, change during this first growth. What is left of the red oil is quickly transformed into chlorophyl, and the plantlet assumes a uniform green colour. Nevertheless one may perceive from the beginning a number of vacuoles, or limpid, colourless droplets, in the midst of the protoplasm with which they are filled, and between them the chlorophyl collects in rings more or less distinct from each other. Soon large grains of starch appear in these collections of green matter, so that the plantlet combines all the characteristics of an adult cellule of the *Sphæroplea*, even before it has exceeded a thirteenth of a line in length. The terminal tails have been observed after the plantlet was more than half a line long. Growth takes place in the middle, by the successive division of the older rings."

The macrospores of *Hormiscia zonata* are of a thick short pear-shape, furnished with four cilia. After a time they come to rest, and, fixing themselves by the ciliated end, lose their cilia and develop a membrane; in this condition they seem to acquire the functions of a spore, without the intervention of fecundation. The fixed end develops into a root-like colourless organ of attachment; the free end growing into a club-

shaped plantlet, through the cell dividing into two by a cross partition, and each of these again in two, and so further. So also microzoospores remaining behind in the mother-cell, unable to copulate and pass through their stages after the normal manner, are capable of germinating within the mother-cell, and developing into independent plants.

CHAPTER XI.

SPONTANEOUS MOVEMENTS.

INTERMINABLE discussions have been carried on, with practically very feeble results, as to the causes of spontaneous movements in algæ. We have advisedly omitted Diatoms from this work, as an isolated group which could better be studied by themselves, but the movements of Diatoms have been one of the most fertile themes of discussion. Some savants were led to the conclusion that they must be animals; others maintained them as plants.* The Desmids, also, another isolated and excluded group of fresh-water algæ, have been fertile in discussion. Still amongst the remainder there are known instances of spontaneous motion, which have been constituted puzzles for the curious. The movements of the ciliated zoospore long held to be infusorial is a case in point, whilst certain amœboid structures and amœboid movements have led to a wavering of faith in the continued and persistent vegetable nature of algæ, under all circum-

* Meneghini on the Animal Nature of the *Diatomeæ* (Ray Society), 1853.

stances and conditions. The *Oscillarieæ*, with their peculiar and oscillating movements, have been subjected to scrutiny, and have not wholly escaped condemnation on the ground of this erratic tendency. Without assuming any special inspiration to explain these phenomena and set the question at rest for ever, it may be permitted to allude to some of them, as presenting interesting problems still remaining open for illustration and solution.

Active motile cells are so common amongst algæ that they scarce need description. It is true that they have been honoured with many names, such as active gonidia, zoogonidia, zoospores, etc., etc., but in the main they are minute corpuscles, endued with active movement, caused or accelerated by the action of one, two, or more of vibratile cilia; what they may ultimately become in part determines the name they shall bear. In many cases they are produced in immense numbers, and swarm out of the cells in which they originated. They may have been produced without any known act of fecundation, or they may have had a sexual origin. In themselves they may be objective or passive, male or female, but externally there is very little essential difference between them. They are single cells, more or less globose or elongated, bearing cilia at one extremity and capable of spontaneous motion. When locomotion was thought to be an attribute of animal life, these little bodies were held to be animals, and supposed parasites.

Now that locomotion is not believed to be confined to animals, these corpuscles are reckoned amongst the phases of vegetable organisms. With objects so minute it is difficult to investigate so as to be able to give a satisfactory answer to the question how the motion is produced. That it is caused by the rapid movements of the cilia, no one has called in question, but what is the power which operates upon the cilia has not yet been determined, and wherein does the source of motion differ from the same source in animals is unanswered. There is no absolute reason why the motive power should be different, in zoospores, to what it is in infusoria of the same dimensions and simplicity of structure. This is not a problem which is readily determinable.

The movements of such compound bodies as *Volvox*, *Pandorina*, *Eudorina*, and *Gonium* have been regarded as mysteries in the past, when microscopes were too imperfect to resolve them; but no longer are they relegated to the animal kingdom on account of their spontaneous movements, since these are dependent upon the impulse of the individual ciliated zoospores of which the colonies are composed. "The combined action of the pairs of cilia in which the gonidia terminate is the actuating power whence proceed both the rotatory and the progressive movement of *Volvox*, and these are both in a definite direction. If an imaginary axis be drawn through the sphere, the progressive motion being, so to speak, from the north to the south

pole of that axis, the rotatory motion is usually from west to east, though not always, being occasionally reversed for a few seconds; but for the greater part of the time it is regularly in the direction indicated." * In *Pandorina*, the individual groups are at first motionless, and the mother plant loses its cilia during the formation of the young ones; the entire group is at first quiescent. But afterwards the young sexual plants, like the neuter ones, produce upon each of their cells two cilia, which commence their motion as soon as the enveloping mucus admits of it, and thus ultimately the entire group assumes a state of active rotation. In *Gonium*, and also in *Stephanosphæra*, the colonies rotate, each on its axis perpendicular to the plane in which the primordial cells are arranged, and move actively in space, by the aid of cilia, two of which proceed from each of the primordial cells, and pierce the hyaline envelope.

To the novice nothing will appear more remarkable in the movements of algæ than the behaviour of the gonidia and antheridia in acts of fecundation. If certain species of *Œdogonium* are selected for illustration, these movements will seem so near akin to animal instinct as to occasion surprise. The selected species will be one of those in which dwarf males are produced from certain privileged cells of the filament which bears the oogonium, or female cell. The oogonium is more or less oval and inflated, and

* Wills on *Volvox* in *Midland Naturalist*, September, 1880.

encloses the oospore which requires to be fertilized. To assist in this process the upper portion of the oogonium splits round and opens, like a lid, or operculum; or else there is a pore or opening in the side wall, for the admission of the male element. In due time some short and specialized cell of the same filament produces in its interior an active zoospore, which escapes by rupture of the cell-wall. This escaped zoospore (called androspore) floats freely in the water, but soon attaches itself by the ciliated end either upon, or closely beside, the unfertilized oogonium, and in that position undergoes a further development into a dwarf male plant, having the form of an inverted flask, seated upon a more or less elongated stem, the apex opening by a lid or cap when mature. In the upper portion of this dwarf male spermatozoids are developed, and these at length escape through the opening at the top, and, swarming around the oogonium, enter it by the pore, or the raised operculum, to fertilize the oospore. In all these movements nothing seems to transpire by accident. The androspore attaches itself in a convenient position for the resulting male to fertilize the oospore, and, when the spermatozoids are expelled, this action takes place in close proximity to the opening in the oospore.

In this same genus, *Œdogonium*, there are other species, in which the androspores, which result in the production of dwarf males, are not developed from

special cells of the same filament which bears the oogonium, but upon separate male filaments which only produce androspores. In such case the escaped active zoospores, or androspores, have to seek out for female filaments, and select upon them, when found, an eligible position for development into dwarf males, so that the escaping spermatozoids shall be in close proximity to the unfertilized oospore. This power of selection seems indisputable, as we do not find the dwarf males established upon male filaments, or on sterile portions of female filaments, where their energies would be expended in vain, and their functions unfulfilled.

Of less interest, because less remarkable, are the movements of the ciliated zoospores, or spermatozoids, in *Sphœroplea,* which are produced in large numbers within the filaments, and ultimately escape into the surrounding water. These rod-shaped bodies have a somewhat expanded posterior extremity, which is often flattened, and a long narrow beak, armed with two cilia, at the other extremity. When discharged by rupture of the mother-cell, these active bodies become diffused, but soon assemble around the filaments enclosing unfertilized female zoospores. The walls of these cells are perforated, and the rod-shaped corpuscles may soon be seen struggling to enter the little orifices, with the beak foremost. Sometimes three or four may be seen struggling to enter the same orifice. The more slender corpuscles make their

way, at the first attempt, in a remarkable manner, swimming in wide curves, from the water, through the hole into the cavity of the cell, and the act of fecundation is accomplished.

Certainly one of the most singular of experiences in the life history of fresh-water algæ has been the discovery that, under certain conditions, they assume the form and habit of an *Amœba.* It is well known that the organism which goes by the name of *Amœba* is recognized as an animal, very low in the scale, it is true, but still an animal, and a rhizopod, without any special organs, but capable of slow locomotion, undergoing constant change of form, and conducting itself like a simple animal. At first it seemed almost incredible that, under any conditions, algæ should be metamorphosed into such a body as should in itself be scarcely distinguishable from an *Amœba,* yet the evidence is so strong as to leave no ground for doubt. Not only simulating *Amœba,* but in some cases a closely related rhizopod, well known to microscopists as *Actinophrys.* We will, however, proceed with the facts.

The first authority is Dr. Braxton Hicks, and his observations relate to *Volvox.* He says, "The first example in which I observed motion in the cell was at an early period, before the young *Volvox* is fully grown, at the time when the future zoospores first appear, enclosed in cells, the final product of segmentation. These zoospore-containing cells, by contact with

their neighbours, are rendered multiangular, and they include about twenty or thirty hexagonal young zoospores, in close contact, and which are of many colours. When these cells are detached they become round, and they have a curious power of changing shape, like an infusorial *Proteus*, protruding the wall first at one side and then at the other, into which protrusions the contents run. The other and more striking instance, however, was visible in the zoospores themselves at an advanced age, when some of them enlarge and become irregular in outline. Some disappear; some break up and disperse within the *Volvox;* some undergo a process of subdivision, producing a group of from two to forty green drops, arranged so that their apices, with cilia, point externally; while others enlarge to two or three times their natural size, having many nuclei within, and variously coloured. When this cell, probably by the solution of the outer mucilaginous coat, becomes free, it also possesses the power of moving precisely as does a true *Amœba*." Setting aside the suggestion that they must be animals, because in some phase of their existence they possess a self-moving endoplast, he proceeds to give his own interpretation, "That the protoplasmic contents, when deprived of their confining envelope of cellulose, possess, in common with sarcode, under certain circumstances, a power of spontaneous motion in the manner of an *Amœba*." *

* Hinks on *Volvox globator*, in *Quarterly Journal of Microscopical Science* (1860), p. 100.

Subsequently the same author confirmed his previous observations, and detailed fresh instances, in which he had seen the zoospores of *Volvox* taking the amœboid form, and possessing the power of protruding and retracting, in various parts, portions of the primordial utricle, exactly and to the full extent of a true *Amœba*. By this power they glide along the inner surface of the sphere, among the unchanged zoospores, and when they come in contact with one, they bend themselves around it in the manner of the *Amœba*.*

In a long and elaborate communication on *Stephanosphœria pluvialis*, Mr. W. Archer describes the development of amœboid bodies in that species, confirming in a remarkable manner the observations of Dr. Braxton Hicks. "I was very greatly astonished," he writes, "to find the slide to a considerable extent crowded by a number of what appeared to me to be *Amœbæ* of some undescribed species, and these in active movement, gliding about and crossing each other in every direction. These were certainly not to be seen when I last looked at the slide, and the phenomenon was, beyond measure, puzzling. I therefore rigidly examined them. It will readily be believed that my astonishment was beyond measure great upon shortly, beyond all question, identifying these vigorously active *Amœba*-like bodies with the just previously quiescent primordial cells of the *Stephanosphœria*—nay more, in watching the transformation

* Also in *Quarterly Journal of Microscopical Science* (1862), p. 97.

of the latter themselves into the creeping amœboid bodies, putting a parasitic development wholly out of the question; it will readily be believed, I say, that my astonishment was beyond measure great in actually witnessing with my own eyes this, at first sight, sufficiently startling phenomenon. What! a plant, an undoubted true chlorophyl-containing, cellulose-bounded alga, become metamorphosed into an animal! For my part, indeed, even after witnessing the wonderful change now mentioned, I could not acquiesce in such an assumption; and, so far as I can see, in my humble judgment, those who might be disposed thus to understand it would greatly misinterpret the phenomenon." * We need not detail all the process of transformation, or reproduce the valuable remarks which go to make up this long and most interesting communication, but accept the facts, as above stated.

We have yet another witness for the conversion into amœboid forms in *Chlamydococcus pluvialis*, as observed by Mr. Charters White. He says, "My impression, derivable from an examination of many *Amœbæ*, is that they are the results of changes from the protococcal state, that they are vegetable; but of course this phase of the subject remains for future investigation. It appears to me that the structureless envelope becomes the homogeneous part of the *Amœba*,

* On *Stephanosphæria pluvialis*, by W. Archer, in *Quarterly Journal of Microscopical Science* (1865), p. 125.

while the granular centre becomes the granular *Amœba*. This conclusion is derivable from, and is the result of, the collation of many observations made since last spring, and ought not to be deemed beyond the bounds of probability, inasmuch as some of the former writers on these subjects mention the rhizopodous development of the contents of *Euglena* into granuliferous *Amœba*." *

It only remains to cite another authority, and in this instance it relates to the development of forms related to or simulating the kindred rhizopod *Actinophrys*. Whether the development is of the same kind as those above enumerated may be open to doubt, but the phenomenon is, in any case, of considerable interest. This development took place in the cells of *Spirogyra crassa* in the following manner:—" Under certain circumstances the cell of the *Spirogyra* apparently dies, the chlorophyl becomes yellow, and the protoplasm divides into portions of different sizes, each of which encloses more or less of the chlorophyl. These portions travel about the cell under a rhizopodous form; the chlorophyl within them turns brown; the portions of the protoplasm then become actinophorous, then more radiated, and finally assume the figure of *Actinophrys*. The radii are now withdrawn, while the pellicle in which they were encased is retracted, and hardened into setæ with the rest of the pellicle,

* On *Protococcus pluvialis*, by T. C. White, in *Journal of Quekett Microscopical Club* (1879), p. 46.

which now becomes a lifeless, transparent cyst. Another more delicate cyst is secreted within this, and the remains of the protoplasm within all having separated itself from the chlorophyl, divides up into a group of monociliated monads, which sooner or later find their way through the cysts into the cell of the *Spirogyra;* while the latter by this time having passed far into dissolution, they thus easily escape into the water.

"At first it did not appear plain why the portions of protoplasm enclosed the chlorophyl, but afterwards it was found that this was for the purpose of abstracting the starch which accompanies the latter, since in some cases where the grains of starch were numerous the chlorophyl was not included.

"This was the process when the cells of *Spirogyra* were not pregnant with starch, as they are just before conjugating. When these changes took place at this period they were somewhat different, insomuch as the whole of the contents of the two conjugating cells become united into one mass, and, having assumed a globular form, remain in this state until the chlorophyl has become more or less brown. After this the protoplasm reappears at the circumference of the mass in two forms, viz. in portions which leave the mass altogether, after the manner of rhizopods, and in the form of tubular extensions, which maintain their connection with the mass throughout. In both instances the protoplasm is without chlorophyl, but

charged with oil globules, and both forms make their way to the confines of the *Spirogyra* cell, which they ultimately pierce, develop their contents, and discharge them in the following manner:—

"On reaching the cell-wall, each form puts forth a minute papillary eminence, which, having passed through the wall, expands into a large sac, or bursts at the apex. Following the isolated form first, this then gradually drags four-fifths or more of its bulk through this opening, sometimes so much as only to leave a little papillary eminence in it, which then makes the portion of protoplasm look as if it were entering instead of escaping from the *Spirogyra* cell. The internal contents of this protoplasm then become more defined and granular, the granules assume a spherical form respectively, they evince a power of locomotion, and the originally flexible pellicle, having become a stiffened cyst, with a more delicate one within, assumes a slightly conical form, which, giving way by a circular aperture at the apex, allows the granules to pass into the water, when they are seen to be monociliated monads, each consisting, apparently, of a film of protoplasm expanded over an oil globule, and bearing a single cilium. The contents of the tubular form, on the other hand, undergo the same changes, but the tube becomes dilated into a pyriform shape, within the *Spirogyra* cell; and when the monads are ready to lead an independent existence, the end of the papillary eminence, which has been projected some

little distance beyond the cell-wall into the water, gives way, and thus they also escape."

After some further details and observations, the writer adds that "whenever a mass of filaments of *Spirogyra* underwent these transformations, the latter were invariably followed by a numerous development of *Actinophrys sol* of all sizes, to the exclusion at first of almost all other animalcules; and, coupling this with the undistinguishable form from *Actinophrys sol* assumed by the monads developed by these transformations, he saw no other more reasonable conclusion to come to than that they were one and the same, and therefore that one source at least of *Actinophrys sol* was the protoplasm of *Spirogyra*." * In plain words, he thinks that from the protoplasm of a vegetable alga the animal rhizopod becomes eliminated—a conclusion with which we are not prepared to concur.

Under the designation of abnormal spore-formation, Braun seems to allude to the phenomena we have described; for he says, "The character of these abnormal cells is most varied and changeable. Especially remarkable is the recurrence of globular, resting, spore-like cells (in old *Closteria*), as also the appearance of active infusorioid structures, which occur not unfrequently in the interior of decaying cells of green fresh-water algæ (*Œdogonium*, *Spirogyra*), and are distinguished from normal swarming cells by their irregular form, varying size, slower motion, and mostly

* H. J. Carter in *Annals of Natural History*, xix. (1857), p. 260.

brownish-yellow contents, succeeded by hyaline, finely granular mucilage. Abnormal structures of this kind have doubtless often been confounded with the normal reproductive cells of the algæ. The future will certainly unfold many interesting phenomena in this hitherto little-worked field." *

That well-known algologist, Mr. Archer, of Dublin, has some pertinent remarks on a phenomenon which he observed in connection with *Botryococcus Braunii*. More than once, when a single group, or family, of this alga, from gatherings kept for some time in the house, had turned up under a low power of the microscope, he had been to some extent deceived by the way in which it resembled some radiolarian rhizopod. The mucous matrix containing the families of cells seems not unfrequently to give off rather long filiform prolongations, which stand out more or less radiantly, looking not unlike pseudopodia, and these are undoubted rhizopods containing chlorophyl. It might, indeed, be a good example of two objects with no affinity in any respect to each other, still superficially stimulating one another. †

The oscillation of the filaments in the *Oscillariœ* is a fact so prominent and remarkable that it gave origin to the name by which this family is known. It is forty-five years since Hassall wrote of them in terms which can hardly be changed by subsequent

* Braun on Rejuvenescence (Ray Society), p. 281.

† Cooke, "Fresh-Water Algæ," p. 17.

knowledge. He says that the majority of the species are distinguished "by a peculiar oscillation, with regard to which I can myself perceive nothing extraordinary, although the phenomenon is certainly peculiar to this family—nothing indicative, as most suppose, of a sensitive or animal life. The explanation to be given of this oscillation of the filaments I consider to be partly of an external, and entirely of a physical character. It has been stated that the filaments of very many species, and, indeed, of all those which present the phenomenon of oscillation, are remarkable for their straightness or rectitude, which is due to a certain degree of elasticity belonging to them, and which leads to the effort on their part, whenever, as on being placed for observation on the field of the microscope must be the case, they are bent or put out of a straight line, to recover that position which is natural to them. This elastic property of the filaments, currents almost imperceptible in the liquid in which they are immersed, and perhaps unequal attractions amongst the filaments themselves, are causes amply sufficient to explain any motion which I have ever witnessed, and which motion I cannot help thinking to have been misunderstood, and exaggerated to such an extent, as to throw around these plants an unnecessary degree of mystery." *

Professor Schnetzler had not practically got much

* Hassall's "British Fresh-Water Algæ" (1845), vol. i. p. 244.

further than this in 1835, when he gave, as the results of his investigations into the movements of *Oscillaria,* the division of those movements into six different kinds: (1) Of rotation round the axis of the filament or its segments; (2) creeping or gliding over a solid substratum; (3) a free movement of translation in the fluid; (4) the rotation or flexion of the filament; (5) sharp tremblings or concussions; and (6) radiating arrangement of the entangled filaments. This writer considers that simple osmose is not sufficient to explain all these various movements, but that they must be due, in some way at present unexplained, to the protoplasm. Everything which increases or retards the vital energy of the protoplasm increases or retards respectively the intensity of the movements of the filaments.* It must be confessed that, whether attributed to external influences and elasticity, or to internal energy of the protoplasm, the explanation has yet to be given of the causes, and their mode of operation, of the oscillation of the filaments of *Oscillaria* (Fig. 99).

* *Arch. Sci. Phys. et Nat.*, xiv. (1885), p. 160.

CHAPTER XII.

NOTABLE PHENOMENA.

THERE are a few phenomena which partake of the mysterious, or at least are remarkable, to such an extent as to claim a little notice in a work of this kind. Some superstitious regard attached to certain of these phenomena when their causes were absolutely unknown, and, even now, there are many who are content to wonder at the manifestation, and do not seek behind them for their elucidation.

"BREAKING OF THE MERES" is a phrase which represents certain phenomena in still inland waters which the uneducated marvel at because they cannot comprehend. Much speculation has been indulged in as to its cause, but the true interpretation seems to have been reached by a small committee of a local society, which was appointed to investigate the meres of Shropshire. The report states that "An interesting phenomenon occurs at certain seasons of the year in this (Ellesmere) and some of the other meres, which the people of the neighbourhood are accustomed to call 'breaking of the water,' or 'breaking of the

mere.' To a stranger these terms are somewhat misleading, as they appear to suggest a violent agitation of the water, or its bursting through its banks, whereas the phenomenon resembles the breaking of wort in the process of brewing, causing a discoloration of the water, rendering it unfit for consumption, and spoiling the fisherman's sport. In its normal condition the water is pure and limpid, perfectly suitable for domestic purposes, but when it breaks it becomes turbid from the formation of small dark-green bodies, in countless thousands, which not only float as a scum on the surface, but abound throughout the whole of the water. The change is so apparent that it cannot escape the notice of the most careless observer. On examining the floating matter of Ellesmere, the green bodies composing it are found to be rather smaller than a turnip seed, spherical in form, and of the deep green colour familiar to us in the rust of copper. Their specific gravity must be nearly the same as that of the water, which will account for their rapid dissemination throughout it when disturbed, and rising to the surface when at rest. This mere abounds in fish, and is much frequented in the proper season by anglers, but as soon as the breaking begins all sport invariably ceases, and the fish become torpid, refuse the bait, and sulk at the bottom. Whether this curious effect upon them is caused by some injurious gases generated at the time, or by the minute green bodies already mentioned

entering their gills and impeding respiration, is a question not yet determined.

"Various popular explanations have been given of this breaking, the more generally accepted one being that it results from the seeds of aquatic plants, growing on the margin of the mere, falling into the water; and there is some probability on the face of this explanation, because it generally occurs in the autumn, when plants begin to drop their seeds, and the green bodies somewhat resemble a minute seed. In 1878 the late Rev. W. Leighton pointed out that the real cause was the rapid germination of a minute plant classed amongst the algæ, and formerly known as *Conferva echinata*, but which, he intimated, should, according to modern classification, be called *Rivularia articulata.*"

Proceeding to a microscopical examination of the water, the following may be regarded as a summary of results obtained by this committee:—"It is necessary to remark that the phenomenon called 'breaking' must be distinguished from a turbid or muddy state of the water, produced by heavy rains washing down vegetable fragments and earth. If we examine water under the microscope changed in its appearance by this latter cause, we do not find one or two small vegetable organisms pervading the whole body of water, imparting to it their own peculiar colour, as in true 'breaking.' Nor must we confound with it an occasional and partial occurrence of algæ in small

quantities, for at any time during the year interesting species of these minute plants can be found, by diligent searching, in nearly every gently running stream, quiet pool, and mere. It can be most readily detected by the uniform dark-green colour of the water, or by the floating scum in the quiet bays on the leeward shore; but in such cases it is best to take up a small portion in a white glass bottle, and look through it with a pocket lens, when well-defined forms will be detected, though too small to admit of their structure being seen. A good microscope will at once show the myriads of beautiful green bodies—true plants—which are present. To convey some idea of their number, I took a common pin, put the head of it in water collected in Newton Mere, and thus obtained a small drop, and on placing this drop under a microscope I could clearly count 300 individual plants. I must leave it to the reader to calculate how many must be present to colour the water of a mere 115 acres in area." *

The different species of algæ found in Shropshire meres causing, or contributing, to the "breaking" were *Rivularia echinata* (*articulata*), *Anabæna Hassallii*, *Cœlosphærium Kutzingianum*, *Anabæna Ralfsii*, and *Aphanizomenon flos-aquæ* (Fig. 96).

It must not be inferred that this "breaking of the water" is confined to Shropshire, for a similar pheno-

* "The Breaking of the Shropshire Meres," by W. Phillips, F.L.S., in *Transactions of Shropshire Natural History Society*.

menon was recorded many years ago, by Professor Dickie, in Scotland, and two of the same species of algæ were concerned in its production. "For some years," he says, "excursions were made with the students of my botanical class to a loch on the estate of Parkhill, about four miles north-west from Aberdeen. The sheet of water in question is about a quarter of a mile in its greatest length; on almost all sides it is surrounded by extensive deposits of peat, with a soluble matter of which a great proportion of the water passing into the loch is impregnated. The locality was generally visited in the beginning of July; nothing peculiar had ever been observed till the autumn of 1846, when my attention was arrested by a peculiar appearance of the water, especially near the edge, but extending also some distance into the loch. Numerous minute bodies with a spherical outline, and varying in size from one-twenty-fourth to one-twelfth of an inch in diameter, were seen floating at different depths, and giving the water a peculiar appearance. In some places they were very densely congregated, especially in small creeks at the edge of the loch. A quantity was collected by filtration through a piece of cloth, and on examination by the microscope, there could be no doubt that the production was of a vegetable nature, and a species of *Rivularia;* one, however, unknown to me. Specimens were sent to the Rev. M. J. Berkeley, who informed me that the plant was *Rivularia echinata* of

the English Botany. Along with it, but in very small quantity, I also found another plant, *Aphanizomenon flos-aquæ*.

"In the first week of July, 1847, the same species were observed similarly associated, but the *Aphanizomenon* was now more plentiful, without, however, any apparent corresponding diminution in the quantity of the *Rivularia*.

"In July, 1848, it was observed that the *Rivularia* was as rare as the *Aphanizomenon* had been in 1846; to the latter, consequently, the water of the loch now owed its colour, which was a very dull green; the colour, however, becomes brighter when the plant is dried. In neither of the seasons mentioned was it in my power to make any observations on the colour of the loch earlier or later than the date above-mentioned, consequently nothing can be added respecting the comparative development of the two plants at other periods of the season. Other two lochs in the vicinity did not contain the plants alluded to." *

It is not at all improbable that the *Oscillaria* (*œrugescens*) mentioned by Professor Drummond as giving colour to a lake in Ireland may have been associated with some such a phenomenon. The professor commences by stating that "Glas-lough" signifies "green lake," an appellation given to it from time immemorial on account of the hue of

* "The Botanist's Guide to Aberdeen," etc., by G. Dickie, A.M., M.D. Aberdeen (1860), p. 310.

its waters, which exhibit a green tinge, equal to, or exceeding in intensity, that of the sea, though it is not at all times equally striking. "From the accounts I received, the green colour is evident in the lough throughout the year, and if I may judge from my own observations, every drop of it is impregnated with the oscillatory filaments. When a little of the water is lifted in the hand it seems perfectly transparent, and it appears equally clear at the edges of the lake, but at a depth of two feet the bottom is indistinguishable, and the water presents a sort of feculent opacity, accompanied by a dull, dirty, greenish hue. On lifting some of this in a glass, it seems at first sight quite transparent, but on holding it up to the light innumerable minute flocculi are seen floating through every part of it, and producing a mottled cloudiness throughout the whole. At first I could only find the plant diffused through the water, but at length I discovered a wet ditch extending from the lake into an adjoining field, and there it appeared swimming on the surface in large masses several inches in thickness, and above a foot and a half in length. These seemed evidently to be produced by an agglomeration of the filaments floated in from the lake, matted together at the surface, and increased in growth. The surface of these masses, where dried by the contact of the air, was of a bright bluish verdigris hue, while the parts immersed in the water were of a dull opaque green.

"On examining specimens in the microscope, I sometimes observed their motions to be very vivid, and in other instances little or no motion could be perceived. They were extremely minute, their transverse striæ very numerous, and at distances of about half a diameter from each other. The filaments in the conglomerated masses appeared to me to be many inches long, and running parallel together; the broken fragments dispersed through the lake cross each other in all directions." *

These phenomena are evidently not confined to our own islands, for Professor Cohn refers to something very similar, which is known in Germany as "Water-blossom." "Though the appearance has often been observed and examined," he says, "very little is known of the causes from which it originates. Within the course of a few hours an alga so densely covers a vast extent of the surface of the water, that it imparts to it a distinct colour, green, brown, or red; sooner or later it disappears, either periodically, or altogether. The only reason for this that can be assigned, apart from the extraordinary increase of the respective species, is the sudden change of their specific gravity, which causes them to rise suddenly from the bottom of the water, where they are developed in vast numbers, to the surface, and as suddenly to sink down again." As a specific instance, he alludes to the Leba, near the Prussian frontier. "This Leba is a true moor

* *Annals of Natural History* (1838), i. p. 1.

river; its banks are quite flat, the bed is nothing but moor and swamp, which gives way under one's feet. Whenever the river is about two feet deep, the water takes a brown colour, which prevents people from seeing to the bottom. On July 19, 1877, the river appeared quite green, from a vast quantity of minute spherical bodies which floated on its surface, and even ordinary people were struck by it. The phenomenon, which was first noticed towards noon, lasted for about five hours, and had totally disappeared in the evening. The next morning there was nothing to be seen, but at noon there was again a large quantity, whilst there were very few towards night. It was similar on the third day, but since then the minute spherical bodies have entirely disappeared from the Leba." *

Undoubtedly this "breaking of the meres" is not the unmitigated evil which is attributed to it by disappointed anglers, but has some moral, some good service, perhaps by clearing off the carbonic acid gas produced by decay of organic matter, at any rate by clearing and sweetening the water; perhaps also, not a little, in furnishing a supply of food to minute animal organisms; at any rate, somehow, the natural working of some natural law.

Red Snow was regarded with something of superstition from the period of its discovery down to recent times, when its true character was revealed. Various speculations had been indulged in, even by the scien-

* Cohn on *Rivularia fluitans*, in "Hedwigia," xvii. (1878), p. 1.

tific, as to whether it was a lichen, or a fungus, or even an infusorial animal. Finally it was determined to be a fresh-water alga, to which the name now applied is *Chlamydococcus nivalis.*

It is believed that De Saussure first noticed the red snow, in 1760, on Mount Breven, in Switzerland, and subsequently so frequently amongst the Alps, that he was surprised that it should have escaped notice by all previous travellers. Ramond found it in the Pyrenees, and Sommerfeldt in Norway. In 1818 an Italian journal contains an account of the fall of red snow in the Italian Alps and on the Apennines. In March, 1808, the whole country around Cadore, Belluno, and Feltri was covered in one night, to the depth of twenty centimetres, it is said, with a rose-coloured snow. A pure white snow fell before and afterwards, so that the coloured snow formed an intermediate stratum. A like phenomenon occurred at the same time on the mountains of Veltelin, Brescia, Krain, and Tyrol. A similar one occurred at Tolmezzo, in the Friaul, between the 5th and 6th of March, 1803, and a more remarkable one still, in the night, between the 14th and 15th of March, 1813, in Calabria, Abruzzo, Tuscany, and Bologna, consequently along the whole chain of the Apennines.*

Captain Ross saw mountains in Baffin's Bay which were covered by red snow, eight miles long. The snow was found to penetrate in some places to a

* "Memoir on the Red Snow," by C. A. Agardh.

depth of ten or twelve feet, and seemed to have existed long in the same state.

The early opinion prevalent was that the red snow fell from the sky, that it invariably fell during the night, and of course nobody ever saw it fall.

Like other algæ, moisture seems essential to its production, and hitherto this plant has not been found in places where it was debarred from this pabulum at some period of its growth. But once formed, it seems to possess the power of remaining stationary, and, perhaps, of reviving after an unlimited period. In the Arctic region it was discovered on snow, on rocks, on decayed mosses, and on the bare soil. In Scotland its locality is curious. The island of Lismore, in which it is found, is very low, ten miles in length by only one or two in breadth, and resting on a limestone rock, of a slate-blue colour. "It occurs," says Carmichael, "in abundance on the borders of the lakes of Lismore, spreading over the decayed reeds, leaves, etc., at the water's edge, but in greater perfection on the calcareous rocks within the reach of occasional inundation; and, what is rather remarkable, it seems to thrive equally well, whether immersed or exposed to the dry atmosphere. It is to be found, more or less, at all seasons of the year."

Dr. Greville examined some of the Lismore specimens and some from the Arctic regions, with the following results: "I had them immersed in water for a period of three weeks, but did not succeed in tracing

any appearance that was not developed equally well in the course of a few hours. In every instance I found no difficulty in detecting a gelatinous substratum, various in thickness (sometimes exceeding the diameter of the globules), colourless, diffuse, without any defined border. Upon this gelatine rests a vast number of minute globules, the colour of fine garnets, exactly spherical, nearly opaque, yet very brilliant, for the most part nearly equal in size; the smaller ones generally surrounded with a white pellucid limb, like the capsules of *Ceramium roseum;* and this limb gradually becoming less as the globules enlarge, at last entirely disappearing. In the full-sized globules, a favourable light shows the existence of internal granules, which make the surface to appear reticulated. When mature they burst, and the internal granules escape, to the number of six or eight, or more, and the membrane only of the globule is left behind, buoyant and colourless. The granules are globose, and escape from the globules one by one, or by several at once, adhering together, though I never could observe the least voluntary motion among any of these bodies."*

We need not enter into details in this place of the true character and metamorphoses of the red snow alga, which probably does not differ in all essential particulars from the life history of that allied species

* "Scottish Cryptogamic Flora," by Dr. R. K. Greville, vol. iv. No. 231.

which was so long known under the name of *Protococcus pluvialis,* but now denominated *Chlamydococcus pluvialis.* An exhaustive memoir has been published of this latter, by Professor Cohn, and finds notice in our chapter on "Alternation of generations." There are, indeed, some algologists who contend that the red snow is, at most, only a variety of the more common *Chlamydococcus pluvialis,* and, if that be the case, what is true of the one, will, as far as physiological details are concerned, be true of the other. In the active stages of these species the causes will be recognized wherefore some writers, in the past, have been doubtful whether "red snow" was an alga or an infusorian. Even Agardh did not seem to be fully convinced on this point, which now scarcely admits of doubt.

In the year 1878, Brun noticed on the sacred mountain near the city of Ouessin, in Morocco, a so-called "rain of blood," which he found to result from a quantity of minute shining flakes, which adhered closely to the rocks, and presented an extraordinary resemblance to drops of blood. These were found to be a young undeveloped condition of *Chlamydococcus pluvialis,* mixed with organic remains and fine sand. He suggested that they had been brought by a strong south-west wind from the Sahara, where the *Chlamydococcus* is assumed to be extremely abundant.*

Of the occurrence of red snow in Hertfordshire little

* *Bullet. Soc. Belg. Micr.* v. (1880), p. 55.

can be said, except to refer to the communication in which the circumstance is narrated.* It is not impossible that it should occur in such a locality, but there is a little confusion in the narrative. What is meant by *Protococcus* is not sufficiently clear, and the inference that some condition of *Euglena* caused the red appearance serves in no way to elucidate the mystery.

GORY DEW.—This is one of the names which has been applied to an alga, by no means uncommon, to which the superstitious in past ages ascribed singular attributes. Drayton writes that "In the plain, near Hastings, where the Norman William, after his victory, found King Harold slain, he built Battle Abbey, which at last, as divers other monasteries, grew to a town enough populous. Thereabout is a place which, after rain, always looks red, which some have attributed to a very bloody sweat of the earth, as crying to Heaven for vengeance of so great a slaughter." The substance itself is common in the lower part of damp walls, in cellars, dairies, and outhouses, on the ground, gravel walks, and hard-trodden paths, and is most conspicuous after rain. It forms broad patches of a deep blood-red or purple colour, with a shining surface, as if blood or red wine had been poured upon the ground. Examined by the microscope, it consists of an agglomeration of minute globose cells, filled with granular matter. Its

* "Red Snow in Herts," by R. B. Croft, in *Transactions of Herts Natural History Society*, vol. i. p. 5 (July, 1881).

present name, for it has had many, is *Porphyridium cruentum* (Fig. 7).

The appearance of this organism has doubtless contributed at times to verify the vulgar belief in the occurrence of showers of blood, in the form of hail, snow, or dew. In dry weather it loses its bright colour and becomes blackened, but when moist it certainly resembles coagulated blood, which often appears in patches on the floor of wet conservatories and greenhouses. How many monkish legends may have been indebted to this phenomenon for support it is impossible to say, for it lent itself readily to such purposes, and must often have caused the superstitious to shudder, being ignorant of its real nature. In this respect its honours may be divided with the next species.

Blood Rain.—This organism forms blood-red spots on bread, rice, potatoes, and even on meat, and at the time of Ehrenberg was held to be a minute animal, or rather a colony of minute animals. Afterwards it came to be regarded as an alga, and bore the name of *Palmella prodigiosa*. More recently still it had been relegated to that mysterious little group of obscure fungi, called the *Schizomycetes*, where it rests at present under the name of *Micrococcus prodigiosus*. Perhaps, for the latter reason, no mention should have been made of it here, but as opinions have been, and possibly still are, divided as to its claims to be considered an alga or a fungus, a brief reference is

advisable. About 1886 an epidemic on the Continent was traced to this source. Pieces of cooked meat presented a singular carmine-red coloration, and stained vividly the fingers or linen with which they came in contact. These phenomena prevailed regularly for a period of three months. Food cooked overnight was found the next morning covered with red patches, and it then underwent rapid alteration. Coincident with a sudden and considerable fall in the temperature, the epidemic ceased, and has not reappeared.* Berkeley has also stated that "In the hot days of July, 1853, provisions which were cooked in the evening were in some cases the next morning covered with this production. The only instance of similarly rapid development is that of yeast globules, and it is there probably that we must look for the true solution of the question as to its real nature." And again: "The rapidity with which it spreads over meat, boiled vegetables, or even decaying agarics is quite astonishing, making them appear as if spotted with arterial blood; and what increases the illusion is, that there are little detached specks, exactly as if they had been squirted in jets from a small artery. The particles of which the substance is composed have an active molecular motion, but the morphosis of the production has not yet been properly observed, and till that is the case it will be impossible to assign its place rightly in the vegetable world. Its resemblance to the

* *Pharmaceutical Journal*, xvii. (January 29, 1887), p. 610.

gelatinous specks which occur on mouldy paste, or raw meat in an incipient state of decomposition, satisfy me that it is not properly an alga." * Mr. H. O. Stephens, on the other hand, contends that it is an algoid production. After narrating its history,† he says, "I observed at table the under surface of a half-round of boiled salt beef, cooked the day before, to be specked with several bright carmine-coloured spots, as if the dish in which the meat was placed had contained minute portions of red-currant jelly. On examination the next day, the spots had spread into patches of a vivid carmine-red stratum of two or more inches in length.

"With a simple lens the plant appears to consist of a gelatinous substratum of a paler red, bearing an upper layer of a vivid red hue, having an uneven or papillate surface. The microscope shows this stratum to consist of generally globose cells immersed in or connected by mucilaginous or gelatinous matter. The cells vary in size, and contain red endochrome. As far as I can observe, they consist of a single cell-membrane, and contain a nucleus. Treated with sulpho-iodine, they become blue. In my judgment, this plant is a *Palmella* closely allied to *P. cruenta*, but certainly distinct, the cells or granules of the latter differing from it not only in their colour but size." The memoir also contains observations on the great vitality of this

* Berkeley, "Introduction to Cryptogamic Botany" (1857), p. 114.

† *Annals and Magazine of Natural History* (1853), p. 409.

species, and other subjects connected therewith, to which the student is referred.

Ehrenberg remarked of another alga, which is terrestrial in its habits, and known as *Sphæroplea annulina*, that it covers large tracts about Berlin with a red coating, and hence may have given rise to traditions of "blood rain." At Breslau, where Professor Cohn saw it at the end of October, it occurred in a potato field which had been laid under water by the overflow of the Oder. It covered the field on the retreat of the water in an almost uninterrupted felt, of a beautiful red-lead or vermilion colour on the smooth upper surface, and green on the under side. The red colour depended on the spores with which the filaments were completely filled up. This, however, is a less likely source of the traditions of "blood rain" than the more minute species which appear as stains, or blood-red blotches, upon the ground and other objects.

CHAPTER XIII.

THE DUAL HYPOTHESIS.

There is one hypothesis, which has made some stir in the world, in which green algæ are implicated, and it would be expected that a work of this kind should not pass it over in absolute silence. It will not be necessary to recapitulate the voluminous controversy which has now being going on for some years, but simply to state the theory, and the objections urged against it. Shortly expressed, the contention is that the large group of vegetable organisms which have been known as lichens are not independent or autonomous plants at all, but merely a combination of fungus and alga. This theory originated with Schwendener, possibly based on a suggestion of De Bary, and has been kept alive by the Germans down to the present.

The paragraph which is believed to contain, in a compressed form, the whole contention of the theorists, is to the following effect:—"As the result of my researches, all these growths (lichens) are not simple plants, not individuals, in the ordinary sense of the

word; they are rather colonies, which consist of hundreds and thousands of individuals, of which, however, one alone plays the master, whilst the rest in perpetual captivity prepare the nutriment for themselves and their master. This master is a fungus, of the class Ascomycetes, a parasite which is accustomed to live upon other's work; its slaves are green algæ, which it has sought out, or indeed caught hold of, and compelled into its service. It surrounds them, as a spider its prey, with a fibrous net of narrow meshes, which is gradually converted into an impenetrable covering; but whilst the spider sucks its prey and leaves it dead, the fungus incites the algæ found in its net to more rapid activity, nay, to more vigorous increase." * It has never been challenged, that the following is an accurate statement of the case. The two great points sought to be established are these: that what we call lichens are compound organisms, not simple, independent vegetable entities; and that this compound organism consists of unicellular algæ, with a fungus parasitic upon them. The coloured gonidia which are found in the substance, or thallus, of lichens are the supposed algæ, and the cellular structure, which surrounds, encloses, and imprisons the gonidia, is the parasitic fungus, which is parasitic on something infinitely smaller than itself, and which is entirely and absolutely isolated from all external

* Schwendener, "Die Algentypen der Flechtengonidien" (1869), p. 3.

influences. The theorists therefore maintain that lichens are identical with fungi, with the addition of certain extraneous bodies, called "gonidia," which are truly microscopic algæ.

Whether lichens are autonomous plants, or whether, independently of their gonidia, they are identical with fungi, are not questions to be discussed here, and we have elsewhere given our conclusions on these points.* All that we are concerned to inquire is, whether the so-called "gonidia" of lichens are green algæ. A very important result was obtained by Dr. Minks, when he confirmed and established the fact that the gonidia decidedly have their origin in the hypha and cortical cells, but he proves from his experiments—which have been checked by other cryptogamists—that the microgonidia, which are transformed into gonidia, exist in the hypha, rhizines, cortical cells, paraphyses, young thecæ, and even in the spores and spermatia, that is to say, in all the vegetative and reproductive cells. The transformation of the microgonidia into gonidia can easily be seen under the thin cortical layer, and in those parts of the bark which are contiguous to the medulla.

Are gonidia a part of the lichen-structure, or are they appropriated green algæ? This is the only point in which the hypothesis enters into the scope of our work. It is well known that the thalli of lichens enclose within them peculiar cellules, forming a sub-

* "The Dual Lichen Hypothesis" in *Grevillea* (March, 1879).

cortical layer, which are subglobose, of a greenish colour, and to these the name of gonidia has been given. They frequently burst through, and appear on the surface in the form of powdery masses. The lichenologist believes, and as he thinks upon good grounds, that they form part of the plant itself. One says, "They may be regarded as intermediate in function between the vegetative and reproductive cell, assuming the offices and partaking of the characters of both." Tulasne considered them to be parts of the lichen structure, performing important functions. The theorists contend, on the other hand, that they are no part of the plant, but that they are a form of algæ, upon which the residue of the lichen is parasitic.

It is argued that they are free cells, resembling in size, form, and colour certain low forms of unicellular algæ, and hence, as they are out of place in lichens, they must be unicellular algæ. Any one who has had any experience amongst the low forms of vegetable life, in which the organism consists of a single cell, are exceedingly well aware that it is almost an impossibility, from the observation of these cells, to arrive at any satisfactory conclusion as to what they are, and what their ultimate development may be. Let them compare, if they please, what are known to be the earliest stages of mosses and algæ with the gonidia of lichens, and draw up characteristic diagnoses, if they can. All are globose cells, containing a greenish protoplasm, and about equal in size

By what occult power can the theorists distinguish that which, it is admitted, they cannot describe? The only safe method by which these low forms can be determined is by watching their development. In their simple condition of cells, they are no more than mere buds, the ultimate form of which only the rash or foolish would predicate.

If the gonidia of lichens are true algæ, it is insufficient to state that they so closely resemble algæ that they might be mistaken for such; there must be some undoubted evidence produced that they are algæ in fact, and not in appearance.

But if, on the contrary, the experience of practical lichenologists is all in favour of the opinion that the gonidia are truly parts of the lichen structure, that they belong essentially to the lichen, all speculation should be at an end. Dr. Nylander, the prince of lichenologists, has written, "I have adduced that the gonidia and gonimia of lichens constitute a normal organic system necessary, and of the greatest physiological importance, so that around them we behold the growing (or vegetative) life chiefly promoted and active." And again, he says, "The absurdity of such an hypothesis is evident from the very consideration that it cannot be the case that an organ (gonidia) should at the same time be a parasite on the body of which it exercises vital functions."

It can be clearly demonstrated that the gonidia are developed within the substance of the lichen itself in

a determinate and uniform manner, that, instead of being altogether foreign to the lichen, they are generated within it, and hence (according to the hypothesis) the parasite produces from its own substance the host upon which it is parasitic.

It has been disputed whether the microgonidia of Dr. Minks have anything whatever to do with the production of gonidia, and it may be added that whether true or false makes no difference to the ultimate conclusion whether the gonidia themselves are an integral part of lichen structure or not.

There is, undoubtedly, a remarkable coincidence in the structure of a *Nostoc* (Fig. 92) amongst algæ, and a *Collema* amongst lichens. This resemblance probably first led to the insinuation of relationship. In its early days the theorists got but little further than *Nostoc* and *Collema*, but they soon became reckless. No one would attempt to deny that the *Collemaceæ* are a sort of outside group of lichens; they are classified by themselves, and tacked on as an appendage to the true lichens, as if they were a kind of pseudolichen. Perhaps with less prejudice and less of theory a more disinterested inquiry into any relationship between *Nostoc* and *Collema* would have resulted in far greater advantage to science than all the volumes of Schwendenerian controversy.

It is a common mistake, repeated over and over again, under varied conditions and circumstances, to confound analogy with affinity; and even to assume

identity where there is only analogy. "In a scientific inquiry a fallacy, great or small, is always of importance, and is sure to be, in the long run, constantly productive of mischievous, if not fatal results." It is undoubtedly a fallacy to assume that things which are only analogous are identical, as if there were no real difference between analogy and identity. In the present instance no more decided evidence need be given than in the case of the gonidia. It has been deemed unnecessary to demonstrate that they are algæ, but simply on the faith of their analogy has identity been assumed. The interests of truth demand that fallacies should be encountered, and not accepted on the faith of any authority whatever, be that authority ever so great, or ever so highly esteemed amongst men.

Text-books are teaching, and will be teaching, one after another, that this hallucination and some others are accepted—in Germany—and therefore must be true. It is often the case that persons are most positive about the very things of which they know the least. We may ourselves be in error, but in this case we err in company with all the most celebrated lichenologists of the day—Nylander, Krempelhuber, Th. Fries, Koerber, Archangeli, Crombie, Weddel, Franck, and Müller. Hence this chapter is scarcely necessary, there being no true green alga concerned in the ordinary life-history of lichens; or, if so concerned, the fact has not yet been satisfactorily demonstrated.

CHAPTER XIV

CLASSIFICATION.

It is a well-known practice, in all branches of natural history, to group together all the various objects which constitute each separate branch, in a systematic manner for convenience of study, and in order that the different objects, whether called species or varieties, may be quoted, or referred to under some distinctive appellation, so that something like accuracy may be arrived at. Whatever this classification, or arrangement, may be, it is to a greater or less extent artificial, and is only a means to an end. However perfect it may seem to be when constructed, or modified, depends upon its accordance with the total of knowledge available at the time of construction, but it cannot long remain perfect in detail, because knowledge is progressive, whilst systems are fixed, and are constantly in need of modification in order to keep pace with the accumulation of fact. There are some who affect to despise system or classification altogether, quite forgetting that there could be no science without it, and there are others, probably, who think that

science consists solely in classification. As it is folly to think of science without system, so is it equally absurd to mistake classification for science, whereas it is simply a necessary appendage to science.

Without, therefore, desiring to claim for classification a position greater than its merits, we would briefly indicate some of the features of the classification of algæ, and especially of the fresh-water species, in order that the arrangement hereafter followed may be somewhat intelligible. It will serve no useful purpose to refer back to old and crude methods, antecedent to that adopted by Professor Harvey in "Phycologia Britannica," to which that of Lindley's "Vegetable Kingdom" was similar, with an alteration of names. The principal divisions of the whole mass of algæ were four: DIATOMACEÆ, with a siliceous skeleton, and three other groups, viz. the CHLOROSPERMS, with the seeds or spores *green*; RHODOSPERMS, with the spores *red*; and MELANOSPERMS, with the spores *olive*. This purely artificial method was employed for a long time, even whilst it was acknowledged to be unsatisfactory, because it appeared to be simple and easy, and practically answered the purpose. Lindley proposed, in addition to the *Diatomaceæ*, the three orders of *Confervaceæ*, almost equal to the *Chlorosperms*; the *Fucaceæ*, nearly equivalent to the *Melanosperms* and the *Ceramiaceæ*, being about the same as the *Rhodosperms*.

Strong objections were sometimes urged against the

method adopted by Professor Harvey, and these found expression in Berkeley's "Introduction to Cryptogamic Botany," in the following words:—"The difficulties are the most glaring in the *Chlorosperms,* which comprise a considerable number of species which have not green fruit in any stage of growth; or, at least, not as a primitive stage, for the red spores of the *Rhodosperms* sometimes become green in decay. The contrary effect takes place in some *Chlorosperms,* where the green assumes a dark red, but not rosy tinge, probably by the same process which changes the natural green of leaves into autumnal red." And, after some other objections, too technical for reference here, he proceeds to adopt the method proposed by Professor Harvey.

It was this same arrangement, as far as the primary groups are concerned, with one modification, which was adopted in Cooke's "Fresh-Water Algæ," and consequently we have retained it here. The modification was the division into two groups of the green algæ, as *Chlorophyllophyceæ,* with the contents chlorophyl green; and *Phycochromophyceæ* with the contents bluish green. There is not the least doubt that such an arrangement as we have adopted will soon have to be abandoned for something better, but this will not alter the arrangement practically a great deal, except as regards the primary groups.

Some most elaborate schemes have been proposed—on paper—for the reconstruction of the classification of algæ, but, like paper constitutions, not a few of

them are impracticable. When those who believe in systems, as the *ultima thule,* have discussed and decided upon the best and most philosophical method to replace the old ones, and the new is found to be useful, and practicable to facilitate study, it will not then be very difficult to rearrange the smaller groups under some other system, like the shuffling of a pack of cards.

Practically the bulk of the fresh-water species are green algæ. The few *Rhodosperms* may be called by that name, or, if preferable, *Florideæ.* It matters little; the names will be altered, but the things they represent will remain the same. Whether the chlorophyl-green algæ are really the highest, is of but little importance, except perhaps to rabid evolutionists. They may stand at the top, or the bottom, of any scheme, and yet their position be of no practical consequence. The classification of the green algæ will, doubtless, be much simplified and improved when all the polymorphic forms are run in, and instead of our meeting with one stage, or condition, under one name, a more complex stage under another, and a still more developed condition under a third or a fourth, we shall have all the phases of the life history, well determined and arranged, under a single name.

Without attempting to dogmatize upon the necessity or advisability of excluding certain forms of algæ from the green series, and calling them Protophytes, this is an article of faith with some constructors of paper

systems, and it would be simply heresy in their eyes to doubt its wisdom. If it simplifies classification, that will certainly be a point in its favour, but multiplication of obscure, or ill-defined, or even of too finely drawn distinctions, often leads to confusion rather than to clearness.

The most pretentious of philosophical systems has of late been fairly placed before the public, and the principles on which it is based have thus been laid down by one of its authors. Too little importance has, he considers, hitherto been attached to degeneration or retrogression, which may be exhibited in the partial or complete suppression of either the reproductive or the vegetative organs. He traces all the various forms of vegetable life to three lines of descent, represented by three distinct kinds of cell-contents—colourless, blue green, and pure green. The first appears to originate in the Bacteria or Schizomycetes, from which are derived the whole group of fungi. The second primordial type consists of unicellular organisms, in which the cell-contents are composed of a pale, watery, blue-green endochrome, diffused through the protoplasm, without distinct chlorophyl grains, starch grains, or nucleus—the *Chroococcaceæ*, the simplest form of the *Phycochromaceæ*, or *Cyanophyceæ*, which attain their highest development in the *Nostochineæ*, including the *Oscillariaceæ*, *Rivulariaceæ*, *Scytonemaceæ*, and *Nostocaceæ*. To them are probably related the *Diatomaceæ*, which the author regards as

a simple form of life, probably not nearly connected with the Conjugatæ.

The third series, or *Chlorophyllophyceæ,* is the only one which has developed into the higher forms of vegetable life. It is characterized from the outset by the cells possessing a nucleus, starch grains, pure chlorophyl, and, in certain states, a true cell-wall of cellulose. The lowest family, the *Protococcaceæ,* exhibit further development in two directions—the perfection and differentiation of the individual cells, and the association of cells into colonies, or cœnobes. The latter tendency leads to the *Sorastreæ, Pandorineæ,* and finally to the *Volvocineæ.* The further differentiation of the individual cell has advanced one stage in the *Eremobiæ* or *Characiaceæ,* from which are derived the *Multinucleatæ,* comprising the *Siphonocladaceæ* and *Siphoneæ.* The striving after a higher development by the elaboration of a single cell culminates in *Vaucheria,* or in such forms as *Acetabularia.* Cell-division is already well displayed in the *Confervoideæ* isogamæ, including the *Chroolepidæ, Ulotrichaceæ, Confervaceæ,* and *Pithophoraceæ.* From them evolution appears to have taken place in three different lines:—(1) The *Conjugatæ,* including the *Zygnemaceæ, Mesocarpeæ,* and *Desmidieæ,* which evidently came to an abrupt conclusion; (2) the *Phæosporeæ,* which led through the *Cutleriaceæ,* and *Dictyoteæ,* to the *Fucaceæ,* the highest type of "oogamous" reproduction, consisting in the impregnation of a com-

paratively large oosphere by a number of minute antherozoids; the *Syngeneticæ* being regarded as a retrogressive offshoot from the *Phæosporeæ;* and (3) the *Confervoideæ* heterogamæ, including the *Sphæropleaceæ, Œdogoniaceæ,* and *Coleochætaceæ,* from which latter family the *Pediastreæ* are probably derived by retrogression. The *Coleochætaceæ* lead up directly to the highest type of structure attained by Thallophytes, the *Florideæ,* from the highest form of which we have probably several retrogressive branches, viz. the *Nemalieæ,* the *Lemaneaceæ,* and the *Bangiaceæ.* The author suggests that the *Ulvaceæ* may possibly be derived from the *Bangiaceæ* by further retrogression.*

After this lucid (?) explanation of a philosophical system, presumably written by the author himself, it is hardly assuming too much that our readers will be satisfied, for the present at least, with a less philosophical and evolutionary method, and permit us to proceed with our enumeration upon antique lines.

* A. W. Bennett, in *Journal Linnean Society*, Botany, xxiv. p. 49, and *Journal of Royal Microscopical Society* (1887), p. 786.

ARRANGEMENT OF THE

BRITISH SPECIES OF FRESH-WATER ALGÆ.

THE old artificial arrangement of Algæ comprised five classes—

I. CHLOROPHYLLOPHYCEÆ. Contents chlorophyl green.

II. PHYCOCHROMOPHYCEÆ. Contents bluish green.

III. MELANOPHYCEÆ. Contents olive or blackish.

IV. RHODOPHYCEÆ. Contents red or violet.

V. DIATOMOPHYCEÆ. With a siliceous skeleton.

Classes III. and V. may be excluded here.

Class I. CHLOROPHYLLOPHYCEÆ.

Cell-contents mostly chlorophyl green, sometimes crimson or brown.

ORDER I. *COCCOPHYCEÆ.*

Unicellular. Cells single, or associated in families, tegument involute or naked, destitute of branches.

Family I. PALMELLACEÆ.

Cells solitary, or in families, vegetating by cell-division, propagating by active gonidia.

Genus 1. EREMOSPHÆRA. *De Bary.* (1858.)

Cells single, rather large, free swimming, spherical, with a hyaline border. Cell-contents green. Multiplication by division into 2 or 4 or more sister cells (Fig. 1).

Sp. 1. Eremosphæra viridis. (*De Bary.*) *Cooke, Algæ, t.* 1.

Cells globose, large, of a beautiful grass green.
In boggy ditches.

Genus 2. PLEUROCOCCUS. *Meneg.* (1842.)

Cells gregarious, globose, or angular; single or associated in small families. Cell-contents green, or oily red. Multiplication by division in alternate directions. Propagation by gonidia. Aquatic or aerial (Fig. 2).

* *Species green.*

2. Pleurococcus vulgaris. (*Meneg.*) *Cooke, Algæ,* 3, *t.* 2, *f.* 1.

Cells variable, simple, binate, or quaternate, or 32, associated in families, aggregated in a crustaceous, powdery, bright green stratum. Cells 4–6μ; families 18μ and more.
On trunks of trees, moist walls, etc. Common everywhere.

3. Pleurococcus angulosus. (*Corda.*) *Cooke, Algæ,* 4, *t.* 2, *f.* 2.

Cells single, or 2–4, associated (64) in families; deep green, in a greenish rather gelatinous stratum. Cell-membrane thick. Cells 7–13μ diam.
On stems and leaves of aquatic plants.

4. **Pleurococcus mucosus.** (*Rabh.*) *Cooke, Algæ,* 4, *t.* 2, *f.* 3.

Cells very small, variable, single, and 4–16 associated in families, globose, scattered, or aggregated in a gelatinous stratum. Cell-membrane very thin, hyaline. Cells $2\frac{1}{2}$–3μ diam.

On naked ground.

5. **Pleurococcus Beigelli.** (*Küch. and Rabh.*) *Cooke, Algæ,* 5, *t.* 2, *f.* 4.

Very small, pale greenish, aggregated in numerous globose families, encircling the hair. Cell-contents very finely granular. Sporangia containing 12–20 gonidia. Cells 6–9μ diam.

On human hair used as "chignons." (A doubtful species.)

** *Species red or brownish.*

6. **Pleurococcus miniatus.** (*Kutz.*) *Cooke, Algæ,* 6, *t.* 2, *f.* 5.

Cells variable, globose, usually single, rarely 2–4 in a family, seated on a broadly effused red stratum. Cell-membrane hyaline; contents oleaginous, orange. Cells $3\frac{1}{2}$–15μ diam.

On the walls of conservatories.

7. **Pleurococcus vestitus.** *Reinsch, Alg. Flor.* 56.

Cells solitary, rarely associated in small families, orange. Cell-membrane rather thick, densely clad with minute hairs. Cells 12–22μ diam.

In ditches.

8. **Pleurococcus bituminosus.** (*Bory.*) *Kutz. Tab. t. f.* 5.

Cells small, rounded angular, greenish brown, 4–8 associated in families, forming a pitchy-looking stratum. Cell-membrane hyaline, (indistinctly lamellose). Cells 3μ diam.; families 10–20μ.

On cellar walls.

Genus 3. **GLÆOCYSTIS.** *Nägeli.* (1849.)

Cells globose or oblong, either single, or 2–4–8 associated in globose families. Common and special integu-

ments gelatinous, *lamellose.* Division in alternate directions. Propagation by zoogonidia (Fig. 4).

* *Species more or less green.*

9. **Glæocystis ampla.** (*Kutz.*) *Cooke, Algæ, p.* 6, *t.* 3, *f.* 1.

Thallus gelatinous, rounded, lobed, dirty green; cells subglobose, 2–4–6 (rarely 8) associated in families. Cell-membrane colourless, distinctly concentrically stratose; contents green. Cells 9–12μ diam.

Fixed to submerged plants.

10. **Glæocystis vesiculosa.** (*Näg.*) *Cooke, Algæ,* 7, *t.* 3 *f.* 2.

Thallus gelatinous, green; cells small, globose, 64, and more, associated in families. Cell-membrane hyaline, lamellose; contents green. Cells $4\frac{1}{2}$–$7\frac{1}{2}\mu$; families 36μ diam.

On wood and stones in stagnant water.

11. **Glæocystis rupestris.** (*Lyngb.*) *Cooke, Algæ,* 7, *t.* 8, *f.* 1.

Thallus more or less expanded, dirty green, gelatinous; cells globose, associated in families. Cell-membrane distinctly lamellose; contents green. Sporangia globose, containing from 4–12 gonidia. Cells $3\frac{1}{2}$–5μ; families 60μ diam.

On rocks, moist walls, and damp earth.

12. **Glæocystis botryoides.** (*Kutz.*) *Cooke, Algæ,* 8, *t.* 3, *f.* 3.

Thallus gelatinous, green; cells minute, globose or oblong, in small families. Cell-membrane indistinctly lamellose; contents green. Cells 2–4μ; families 10–18μ diam.

On submerged or constantly wet wood.

** *Species fresh coloured, becoming reddish.*

13. **Glæocystis Paroliniana.** (*Meneg.*) *Cooke, Algæ,* 8, *t.* 3. *f.* 5.

Thallus crustaceous, horny when dry, about a line thick, flesh colour; cells small, spherical, 2–4–8 in families. Cell-membrane very broad, distinctly concentrically

lamellose; contents becoming yellowish. Cells $3\frac{1}{2}$–5μ; families 18–22μ diam.

On rocks constantly wet.

14. **Glæocystis adnata.** (*Huds.*) *Cooke, Algæ*, 8, *t.* 3, *f.* 4.

Thallus broadly expanded, gelatinous, firm, yellow brown; cells globose or oblong. Contents brownish green or brown; cell-membrane lamellose. Cells 8–13μ diam.

On chalk cliffs, about high-water mark, etc.

Genus 4. UROCOCCUS. *Hassall.* (1845.)

Cells large, globose or oblong, reddish or blood red; tegument thick, gelatinous, concentrically lamellose. Stem thick, gelatinous, often ringed, or annulate (Fig. 5).

* *Stem annulate.*

15. **Urococcus Hookerianus.** (*Hass.*) *Cooke, Algæ*, 9, *t.* 4, *f.* 2.

Cells globose or elliptic, variable, blood red; stem more or less elongated, often divided, densely ringed. Cells 13–60μ diam.

On chalk cliffs.

16. **Urococcus insignis.** (*Hass.*) *Cooke, Algæ*, 9, *t.* 4, *f.* 2.

Cells large, globose, blood red; stem abbreviated, remotely annulate.

On rocks.

** *Stem exannulate.*

17. **Urococcus Allmanni.** (*Hass.*) *Cooke, Algæ*, 9, *t.* 4, *f.* 2.

Cells elliptical, blood red; stem short, rather club-shaped, colourless, smooth.

In springs at Knaresborough.

18. **Urococcus cryptophilus.** (*Hass.*) *Cooke, Algæ*, 9, *t. f.* 4.

Cells small, oval, rarely globose. Cell-membrane very large, confluent with the short ringless stem.

On stalactites lining a cavern.

Genus 5. SCHIZOCHLAMYS. *Braun.* (1849.)

Cells globose, single, or 2–4 associated in families. Cell-membrane lamellose, dividing in 2–4 equal parts, sometime adhering. Division in one or two directions (Fig. 3).

19. **Schizochlamys gelatinosa.** (*Br.*) *Cooke, Algæ*, 11, *t.* 3, *f.* 6.

Cells globose; contents green, granulose. Cells 10–13μ diam.

In peaty swamps, moor pools, and boggy ditches.

Genus 6. PALMELLA. *Lyngb.* (1819.)

Cells globose, oval or oblong, surrounded by a more or less thick integument, generally soon confluent into a firm or soft jelly; thallus shapeless. Division of the cells alternately in all directions (Fig. 6).

* *Mostly green.*

20. **Palmella mucosa.** (*Kutz.*) *Cooke, Algæ, p.* 11, *t.* 5, *f.* 1.

Thallus expanded, gelatinous, deformed, olivaceous green; cells large, nearly equal, pale green. Cell-membrane very thin. Cells 7–13μ diam.

On stones in streams.

21. **Palmella hyalina.** (*Breb.*) *Cooke, Algæ, p.* 11, *t.* 5, *f.* 3.

Thallus gelatinous, irregularly expanded, green; cells very minute, crowded. Cell-membrane very soon diffluent. Cells 1μ diam.

In stagnant water and bogs.

** *Reddish or orange.*

22. **Palmella miniata,** *var.* **aequalis.** (*Näg.*) *Cooke, Algæ, p.* 12, *t.* 5, *f.* 2.

Thallus expanded, soft, brick red; cells nearly equal. Cell-membrane somewhat thick, colourless, indistinctly striate; contents orange, sometimes greenish. Cells 12–14μ diam.

On wet rocks, moist ground, etc.

22*. **Palmella prodigiosa.** (*Mont.*) *Cooke, Algæ*, 12, *t.* 5, *f.* 5.

Is claimed as a Schizomycete (Fungus). See *Grove, Synop.* p. 7, as *Micrococcus prodigiosus.*

GENUS 7. **PORPHYRIDIUM.** *Näg.* (1849.)

Thallus between gelatinous and membranaceous, somewhat incrusting, composed of globose or many-sided cells. Multiplication by division in all directions (Fig. 7).

23. **Porphyridium cruentum.** (*Näg.*) *Cooke, Algæ, t.* 5, *f.* 6.

Thallus dark purplish red, gelatinous; cells angular or rounded, 7–9μ diam.

On naked ground, moist walls, etc.

GENUS 8. **BOTRYDINA.** *Breb.* (1839.)

Cells oblong or rounded, involved in a very thick, gelatinous integument, in large families, often very numerous, enclosed in a mother-cell, which constitutes a subglobose thallus (Fig. 19).

24. **Botrydina vulgaris.** (*Breb.*, *Cooke, Algæ, p.* 14, *t. xi. f.* 3.

Thallus minute, rarely larger than the head of a pin, globose, green. Thallus $\frac{1}{500}$ to $\frac{1}{10}$ mm.; cells 2–4μ.

On moist ground, trunks, moss, etc.

GENUS 9. **PALMODICTYON.** *Kutz.* (1845.)

Cells oval or globose, with a very thick gelatinous integument, united into a filiform thallus, which anastomoses in various ways. Cell-division simple or double. Propagation by zoogonidia (Fig. 11).

25. **Palmodictyon viride.** (*Kutz.*) *Cooke, Algæ*, 15, *t.* 8, *f.* 2.

Thallus mucous, irregularly reticulate, thickness of a hair, greenish; cells biserial, with a thick membrane. Cells, without membrane, 7½–9μ; with membrane, 25–40μ.

In ditches, canals, etc., attached to twigs, etc.

GENUS 10. **TETRASPORA.** *Link.* (1810.)

Thallus gelatinous, membranous or submembranous, at first a short sac, afterwards expanded; cells globose or angular, more or less distant, associated in a single stratum into large families. Cell-membrane thick, rapidly diffluent. Division in two directions (Fig. 8).

26. **Tetraspora bullosa.** (*Ag.*) *Cooke, Algæ, p.* 16, *t.* 6, *f.* 7.

Thallus membranaceous, saccate, obovate, an inch to a palm long, dark green, more or less warted; cells nearly spherical, geminate, or quaternate, crowded. Cells 8–12μ diam.

In stagnant pools and ditches of fresh water.

27. **Tetraspora gelatinosa.** (*Vauch.*) *Cooke, Algæ,* 16, *t.* 6, *f.* 2.

Thallus vesiculose, clavate, gelatinous, unequally expanded, and irregularly torn, pallid, sometimes dirty green, often incrusted with lime; cells variable, globose, single or geminate, or quaternate, and somewhat crowded; contents green. Cells 3–4μ diam.

In pools and ditches.

28. **Tetraspora lubrica.** (*Roth.*) *Cooke, Algæ,* 6, *t.* 6, *f.* 3.

Thallus elongated, tubular, erect, an inch to a palm long, 1–4 lines thick, splitting, sinuous, between gelatinous and membranous, yellow green; cells globose, green. Cell-membrane very thin. Cells 8–10μ diam.

In ditches.

29. **Tetraspora flava.** (*Hass.*) *Cooke, Algæ, t.* 6, *f.* 4.

Thallus yellow when dry; cells small, quaternate.

In rocky rivulets.

GENUS 11. **BOTRYOCOCCUS.** *Kutz.* (1849.)

Thallus botryoid (or like a bunch of grapes), irregularly lobed, mucous, involved in a thin membrane; cells ovoid

or elliptic, united in families, densely packed in a thin integument (Fig. 10).

30. **Botryococcus Braunii.** (*Kutz.*) *Cooke, Algæ*, 17, *t.* 7, *f.* 2.

Small, free swimming, green, at length becoming pallid, or reddish brown. Cells 10–12μ diam.

In moor pools.

GENUS 12. APIOCYSTIS. *Näg.* (1849.)

Thallus small, vesicular, fixed by a stem-like base; cells globose, scattered, or sometimes 8, disposed in a circle. Cell-membrane thick, dissolving into gelatin, cells dividing alternately in all directions. Propagation by globose motile gonidia (Fig. 9).

31. **Apiocystis Brauniana.** (*Näg.*) *Cooke, Algæ, p.* 18, *t.* 7, *f.* 1.

Thallus pear-shaped, pallid green, the cavity filled up by gelatinous matter, in which are imbedded the gonidia, at first few, increasing in number with age as far as 1600. Frond $\frac{4}{10}$–1 mm. high; cells $7\frac{1}{2}$–11μ diam.

In fresh-water ditches.

GENUS 13. RHAPHIDIUM. *Kutz.* (1845.)

Cells fusiform or cylindrical, generally cuspidate or acuminate at the ends, straight or curved, single, geminate, or fasciculately aggregate, rarely two laterally united at the end, other cells free. Cell-membrane thin; contents green. Division in one direction (Fig. 12).

32. **Rhaphidium aciculare.** (*Braun.*) *Cooke, Algæ*, 19, *t.* 8, *f.* 3.

Very slender, 15 to 20 times as long as broad, yellow green, often single, acicular, acutely cuspidate at each end, straight, or slightly curved, or somewhat lunate. 80μ long.

In pools.

33. **Rhaphidium falcatum.** (*Corda.*) *Cooke, Algæ*, 19, *t.* 8, *f.* 4.

Fusiform, slender, acutely cuspidate at each extremity, curved or semilunar, 4–16 congregated in fascicles. 30–40μ long.

In pools.

34. **Rhaphidium duplex.** (*Kutz.*) *Cooke, Algæ*, 20, *t.* 8, *f.* 5.

Fusiform, slender, slightly sigmoid, single, or 2–3–4 laterally connected at the poles, otherwise free. 30μ long.

In pools.

Genus 14. DICTYOSPHÆRIUM. *Näg.* (1849.)

Cells elliptic, with a thick mucous investment, combined into free-swimming hollow globular families, one always at the end of delicate threads, which proceed from the central point of the family, becoming repeatedly branched towards the periphery. Division in all directions (Fig. 13).

35. **Dictyosphærium Ehrenbergianum.** (*Näg.*) *Cooke, Algæ*, 20, *t.* 9, *f.* 1.

Families aggregated in a globular or broadly elliptical figure; cells elliptic, very minute, about one-third as broad as long. Cells 4 × 7μ.

Amongst *Confervæ.*

36. **Dictyosphærium reniforme.** (*Buln.*) *Cooke, Algæ*, 21, *t.* 9, *f.* 2.

Families aggregated in an irregular form; cells uniform, nearly twice as broad as long. Cells 6–10μ × 10–20μ.

In mountain pools.

Genus 15. DACTYLOCOCCUS. *Nageli.*

Cells oblong or fusiform, free swimming, 2–8 in families at length separating. Division in one direction (Fig. 17).

37. **Dactylococcus Debaryanus.** (*Reinsch.*) *Cooke, Algæ, t.* 129, *f.* 3.

Cells elliptic-oval, attenuated into a hyaline pedicle. Cell-contents green. Cells, $35\mu \times 16\mu$.

Parasitic on *Entomostraca.*

GENUS 16. HORMOSPORA. *Breb.* (1840.)

Thallus tubular, gelatinous, swimming free; cells oblong, green, arranged in simple longitudinal series (families) either remote or more or less united at the poles. Cell-membrane thick, contained within the broad gelatinous tube, which is either simple or branched (Fig. 14).

Tubes simple.

38. **Hormospora mutabilis.** (*Breb.*) *Cooke, Algæ*, 21, *t.* 10, *f.* 1.

Tubes intricate, more or less broad; cells twice as long as broad, broadly rounded at each end. Cell-membrane very thin. Cells $11–17\mu$; diameter of tube 43μ.

In boggy pools.

38*. **Hormospora transversalis.** (*Breb.*) *Cooke, Algæ, p.* 22, *t.* 10, *f.* 3.

Tubes slimy, equal or undulate; cells ovate-oblong or fusiform, disposed transversely in a moniliform series; contents granular. Diameter of tube $75–120\mu$.

In bogs.

** *Tubes branched.*

39. **Hormospora ramosa.** (*Thwaites.*) *Cooke, Algæ*, 22, *t.* 10, *f.* 2.

Tubes broad, gelatinous, irregularly branched; cells oval or nearly cylindrical, obtuse at the ends, either remote or connected, twice as long as broad; contents green, with green plates radiating from the centre.

In brackish water, attached to *Cladophora.*

GENUS 17. **HYDRURUS.** *Agardh.* (1824.)

Thallus adnate, gelatinous, tubular, elongated (2–4–12 inches long), sometimes variously divided; surface naked, or densely covered with delicate fibres, at times fasciculate. Cells globose, then elongated, arranged in longitudinal families. Cell-membrane thick, cells dividing in one direction. Propagation by agile gonidia (Fig. 15).

40. **Hydrurus penicellatus.** (*Ag.*) *Cooke, Algæ*, 25.

Thallus rather cartilaginous, olivaceous, of variable thickness, simple and naked below, divided above, and villous with dense fibrils; internal cells elliptical, or somewhat lanceolate. Cell-membrane thin, scarcely visible.

In rivulets.

var. **Ducluzelii.** (*Rabh.*) *Cooke, Algæ*, 25, *t.* 10, *f.* 4.

Thallus from an inch to a foot long, oftentimes sparingly branched, plumose with very dense fibrils. Cells 6–$9\frac{1}{2}\mu$.

In Alpine rivulets, on stones, rocks, etc.

GENUS 18. **NEPHROCYTIUM.** *Nägeli.* (1849.)

Cells oblong, kidney-shaped, 2–4–8–16 associated in free-swimming families, surrounded by an ample oval or kidney-shaped membrane (Fig. 16).

41. **Nephrocytium Agardhianum.** (*Näg.*) *Cooke, Algæ*, 26, *t.* 11, *f.* 1.

Cells pale green, 4 to 6 times as long as broad, spirally arranged, in families of 4–8 cells. Cell-membrane thin; length 2 to 3 times the breadth. Cells $35 \times 10\mu$.

In ditches, bogs, etc.

42. **Nephrocytium Nægelii.** (*Grun.*) *Cooke, Algæ*, 26, *t.* 11, *f.* 2.

Cells dark green, granular, twice as long as broad, irregularly disposed; families usually composed of 16 cells. Cell-membrane thick. Cells $40–45 \times 12–15\mu$.

In ditches, bogs, etc.

Genus 19. OOCYSTIS. *Nägeli.* (1855.)

Cells oblong, chlorophyllous, either solitary or binate, quaternate, or octonate; contained at first within an ample mother-cell, at length free.

43. **Oocystis gigas.** (*Archer.*) *Cooke, Algæ,* 26.

Mother-cell broadly elliptic, almost subglobose, large; family usually consisting of two cells. Mother-cell 60–70 × 50–60μ.

In pools.

44. **Oocystis setigera.** *Archer, Quart. Journ. Micr. Sci.*, 1877, *p.* 194.

Species undescribed.

Genus 20. DIMORPHOCOCCUS. *Braun.* (1849.)

Cells united in fours, on very short branches, dissimilar, the two intermediate contiguous oblique, obtuse ovate; the two lateral opposite and separate from each other, lunate; families free swimming, in botryoid clusters.

45. **Dimorphococcus lunatus.** (*Br.*) *Cooke, Algæ,* 27.

Green. Apices of the cells hyaline. Cells, longitudinal diam., 10–20μ.

In pools.

Genus 21. MISCHOCOCCUS. *Nägeli.* (1849.)

Thallus dichotomously branched; cells globose, terminal, geminate or quaternate. Division of cells in one direction. Propagation by zoogonidia (Fig. 18).

46. **Mischococcus confervicola.** (*Näg.*) *Cooke, Algæ,* 28, *t.* 11, *f.* 4.

Cells globose, even, geminate, ternate, or quaternate, on the tips of the branches, bright green; stem hyaline, often swollen at the angles. Cells 5–9μ diam.

Attached to filamentous algæ, in ditches.

Family II. PROTOCOCCACEÆ.

Unicellular, without terminal growth, or ramification. Single, or in families. Cells either indefinitely increasing in number (then forming *families*) or of a definite number (then forming a *cœnobium*). Propagation by gonidia of two kinds—the one larger, *macrogonidia;* the other smaller, *microgonidia.*

Sub-Family 1. Protococceæ.

Cells sphæroid, segregate; cell-membrane thin, hyaline, without integument, swimming free, or, when not growing in water, forming a thin pulverulent stratum. Contents at first green, or reddish.

Genus 22. **PROTOCOCCUS.** *Ag.* (1824.)

Same as above. Propagation by mobile gonidia (Fig. 20).

47. **Protococcus viridis.** (*Ag.*) *Cooke, Algæ, t.* 12, *f.* 1.

Cells small, segregate, accumulated in a broadly expanded stratum, yellowish green, either pulverulent, or, in moist weather, somewhat gelatinous. Cells $2\frac{1}{2}$–4μ.

On the trunks of trees and damp walls.

Sub-Family 2. Chlorococcaceæ.

Cells sphæroid, single and free, or more often accumulated in strata, or little clusters. Propagation by zoospores.

Genus 23. **CHLOROCOCCUM.** *Fries.* (1825.)

Cells subglobose, single or in clusters (Fig. 21).

† *Tegument thin.*

48. **Chlorococcum humicolum.** (*Näg.*) *Cooke, Algæ, t.* 12, *f.* 5.

Stratum effused, dark green, pulverulent; cells globose, variable in size, united in families, involved in a common tegument. Contents pale green, at length dark green. Cells 17μ.

On naked ground.

49. **Chlorococcum frustulosum.** (*Carm.*) *Cooke, Algæ, t.* 12, *f.* 2.

Thallus effused, pulverulent, green; cells globose, in families, involved in a broad hyaline envelope. Cells 4–7μ; families 40μ.

On moist rocks.

50. **Chlorococcum murorum.** (*Grev.*) *Cooke, Algæ, t.* 12, *f.* 4.

Thallus crustaceous, yellow green; cells subglobose, with a rather thick envelope. Cell-contents verdigris green. Cells 16–20$\mu \times 10\mu$ with membrane.

On walls.

†† *Tegument thick.*

51. **Chlorococcum gigas.** (*Grun.*) *Cooke, Algæ, t.* 12, *f.* 3

Stratum thin, green, mucous; cells globose, large, either single or associated in small families, always involved in a broad, distinctly lamellose hyaline tegument. Cells 12–17μ diam. without membrane.

In pools, on walls and glass windows.

Sub-Family 3. POLYEDRIEÆ.

Cells single, segregate, free swimming, compressed, 3–4–8 angled; angles sometimes radially elongated, entire or bifid, oblong-elliptic laterally, rounded at the ends. Cell-membrane thin.

GENUS 24. **POLYEDRIUM.** *Näg.* (1849.)

Characters the same as above for the sub-family.

A. *Angles entire.*

52. **Polyedrium gigas.** (*Wittr.*) *Cooke, Algæ, t.* 13, *f.* 1.

Cells irregularly pentahedrical (rarely hexahedrical), angles obtuse, sides concave. Maximum diameter, 64–75μ : minimum, 35–45μ.

In standing pools.

53. **Polyedrium tetraedricum.** (*Näg.*) *Cooke, Algæ, t.* 13, *f.* 3.

Cells regularly tetrahedrical; angles obtuse, mucronate Cells 15–30μ diam. (Fig. 29).

In pools.

B. *Angles radiato-elongated.*

54. **Polyedrium longispinum.** (*Perty.*) *Cooke, Algæ, t.* 13, *f.* 2.

Quadri-radiate, radii thin, elongated, scarcely thickened into a body in the centre. Length of arms 30–50μ (Fig. 23).

In pools.

C. *Angles lobed.*

55. **Polyedrium enorme.** (*Ralfs.*) *Cooke, Algæ, t.* 13, *f.* 4.

Cells irregularly tetrahedrical, angles produced, hyaline, deeply bilobed, sometimes repeatedly, with the lobes mucronate. Cells 25–40μ.

In pools.

Sub-Family 4. SCENEDESMEÆ.

Cells elliptic, oblong, or cylindrical; cell-membrane thin. Cells 2–4–16, joined in a series, or forming a cœnobium. Propagation by division, whence arise gonidia, which unite into a cœnobium within the mother-cell.

GENUS 25. SCENEDESMUS. *Meyen.* (1829).

Cells polymorphous, equal or unequal at the ends, often produced into a spine-like horn. Family of 2–8 oblong,

fusiform, or elliptic cells, in a single or double row; propagating by repeated segmentation, into one or more brood families (Fig. 24).

A. *Cells unarmed.*

56. **Scenedesmus obtusus.** (*Meyen.*) *Cooke, Algæ, t.* 13, *f.* 5.

Cells oblong or ovate, obtuse at the poles, 4–6–8 loosely connected in a simple series, or joined obliquely, 3 to 5 times as long as broad. Cells $5\frac{1}{2}$–7μ.

In boggy pools.

57. **Scenedesmus acutus.** (*Meyen.*) *Cooke, Algæ, t.* 13, *f.* 6 *a.*

Cells fusiform or ovate-fusiform, acute at each extremity, 2–4–6–8 united in a series, either single and straight, or double and irregularly alternate; 3 to 6 times as long as broad. Cells 25–35 × 3μ.

In pools and boggy places.

var. b. **obliquus.** (*Rabh.*) *Cooke, Algæ, t.* 13, *f.* 6 *c.*

Cells elliptic, fusiform, arranged in two generally oblique series, the outer cell of each not in contact with any of those in the other series.

var. c. **dimorphus.** *Cooke, Algæ, t.* 13, *f.* 6 *b.*

Cells acute, 4–8 placed evenly in a single row, inner cells fusiform, outer lunate.

58. **Scenedesmus attenuatus.** (*Breb.*) *Cooke, Algæ, t.* 13, *f.* 7.

Cells fusiform, 2–4–8 joined in a single or double series, all somewhat curved, usually ventricose, cuspidate at each extremity, the apices bearing a hyaline globule. Cells 25–35 × 2μ.

B. *Cells armed.*

59. **Scenedesmus quadricauda.** (*Breb.*) *Cooke, Algæ, t.* 13, *f.* 8.

Cells oblong-cylindrical, extremities rounded, 2–4–8 narrowly united, in a single or double series, all straight;

outer cells armed at each extremity with a recurved spine. Cells $8\frac{1}{2}$–10 × 2μ.

In standing water.

Sub-Family 5. Hydrodictyeæ.

Individual cells oblong-cylindrical, united into a reticulated saccate cœnobium, some producing *macrogonidia*, which join themselves into a cœnobium within the mother-cell, others producing *microgonidia*, which are ciliate.

Genus 26. **HYDRODICTYON.** *Roth.* (1800.)

Characters the same as in the sub-family (Fig. 22).

60. **Hydrodictyon utriculatum.** (*Roth.*) *Cooke, Algæ, t.* 14, *f.* 1.

Size of the families (net) variable; also of the cells (forming the meshes) and the gonidia, according to circumstances.

In clear water.

Sub-Family 6. Ophiocytieæ.

Cells cylindrical, at first short, then elongated, either variously curved and contorted, one or other pole attenuated into a thin, short stem, free swimming; or straight or more or less curved, collected in an umbel with a simple stem, or forming a composite umbel. Cell-contents green. Propagation by gonidia.

Genus 27. **OPHIOCYTIUM.** *Näg.* (1849.)

Cells cylindrical, short, then elongated, variously curved, sometimes circinate, attenuated at one extremity; free swimming. Propagation by division and formation of gonidia (Fig. 25).

61. **Ophiocytium cochleare.** (*Br.*) *Cooke, Algæ, t.* 14, *f.* 2.

Slender, pale green, often very long, filiform, variously curved, circinate, or more or less loosely spirally involved; stem short, spine-like, acute or truncate; contents homogeneous. Cells $5–7\frac{1}{2}\mu$ diam.; length variable.

In pools, mixed with other algæ.

GENUS 28. **SCIADIUM.** *Braun.* (1855).

Thallus (solitary) adnate, unicellular; cell elongated, cylindrical, straight, attenuated into a slender stem. Gonidia about 8, from division of cell-contents, at length protruding from the ruptured apex, retained at the mouth and extending in the form of an umbel, each individual becoming a cylindrical cell like the mother-cell. Process repeated to a third or fourth generation, forming a composite umbel. Ultimate cells producing zoogonidia (Fig. 26).

62. **Sciadium arbuscula.** (*Braun.*) *Cooke, Algæ, t.* 15.

Umbellate. Cells straight (rarely falcate), obtuse at the apex; stem about as long as the diameter of the cells. Cells $3\frac{1}{2}–7\mu$ diam.

Attached to confervoid algæ and aquatic plants.

Sub-Family 7. PEDIASTREÆ.

Cœnobium discoid, plane.

GENUS 29. **PEDIASTRUM.** *Meyen.* (1829.)

Cœnobium plane, frond-like, discoid, or stellate, free swimming, formed of cells mostly in a single stratum, continuous, or with the cells here and there interrupted, perforate or clathrate. Cells polygonal, central entire,

those of periphery entire or two-lobed. Cell-contents green (Fig. 27).

SECTION 3. *DIACTINIUM.*

Cells of periphery emarginate or bilobate, lobes entire.

63. **Pediastrum selenæa.** (*Kutz.*) *Cooke, Algæ, t.* 16, *f.* 9.

Cœnobium orbicular, entire, formed of 8–16 (rarely 31) cells. Cells of periphery narrow, lunate, acutely lobed; cells of disc slightly excised, central one 5-angled; substance firm, rather thick. Cœnobium 28–85μ diam.

In bogs, moor pools, etc.

64. **Pediastrum angulosum.** (*Ehr.*) *Cooke, Algæ, t.* 16, *f.* 10.

Cœnobium orbicular, oblong, or subreniform, continuous, composed of 8–16–32–64 cells. Cells angular, those of the periphery truncate at the base and dilated upwards, notched in the middle; lobes obliquely truncate, outer angle shortly apiculate, inner one ending in a short horn. Central cells 5–6 angled, marked with a small transverse oblong pallid spot. Cœnobium 12μ diam.; cells 19μ diam.

In bogs.

65. **Pediastrum Boryanum.** (*Turp.*) *Cooke, Algæ, t.* 16, *f.* 11.

Cœnobium obicular, oblong, or elliptic, continuous, bright green, composed of 4–8–16–32–64 (rarely 128) cells. Cells of periphery more or less deeply emarginate, or two-lobed; lobes horn-like, sometimes a little thickened. Central cells very closely concrete, 4–6 angled; membrane punctate. Cells 20μ transverse diam.

In boggy pools.

var. B. **granulatum.** (*Kutz.*) *Cooke, Algæ, t.* 16, *f.* 12.

Cells as in the preceding, but all the cells and the horns distinctly granulated.

In the same localities.

66. **Pediastrum bidentulum.** (*Br.*) *Cooke, Algæ, t.* 17, *f.* 1.

Cœnobium orbicular or oblong, continuous, deep green, sometimes bluish green, composed of 16–32 cells. Cells of periphery 2-lobed to the middle, lobes straight, produced into a truncate, bidentate horn. Central cells 4–5 angled, slightly repand in front.

In boggy pools.

67. **Pediastrum compactum.** *Bennett, Journ. R. M. S.*, 1886, *p.* 5.

Oval, regular periphery of 32 lunate cells with 2 divergent horns. Inner cells polygonal, in 2–4 rows. Cœnobium, with a gelatinous envelope, 90–160μ long; cells 6μ long.

In bog pools.

68. **Pediastrum constrictum.** (*Hass.*) *Cooke, Algæ, t.* 17, *f.* 2.

Cœnobium orbicular, bright green, continuous, smooth (?), composed of 16–32 cells. Cells of periphery 2-lobed, sinus narrow, lobes unequal, now and then constricted at the base, produced into an obtuse, rather thick horn. Central cells polygonal, repand in front.

In standing water.

69. **Pediastrum gracile.** (*Br.*) *Cooke, Algæ, t.* 17, *f.* 3.

Cells quaternate, closely joined in a circle, centre open, rarely closed; cells deeply 2-lobed, lobes ovate, produced into a long divergent, acuminate horn.

In pools.

70. **Pediastrum pertusum.** (*Kutz.*) *Cooke, Algæ, t.* 17, *f.* 4.

Cœnobium orbicular, pierced with lacunæ, composed of as many as 64 cells. Cells of periphery loosely connected at the base, bilobed almost to the middle; lobes straight, produced into a hyaline horn. Central cells more or less quadrangular, emarginate in front, with 2 paler spots. Perfect cells 16–22μ transverse diam.

In pools.

var. b. **clathratum.** (*Br.*) *Cooke, Algæ, t.* 17, *f.* 5.

Disc pierced with larger openings; central cells deeply notched and bilobate.

var. c. **brachylobum.** (*Braun.*) *Cooke, Algæ, t.* 17, *f.* 6.

Cells larger, those of the periphery emarginate or triangularly notched, shortly 2-lobed; horns very short, truncate, or almost obsolete. Cells of the disc perforated with smaller openings.

SECTION 4. *TETRACTINUM. Braun.*

Cells of periphery emarginate or bilobate; lobes emarginate, bidentate, or bifid.

71. **Pediastrum Ehrenbergii.** (*Br.*) *Cooke, Algæ, t.* 18, *f.* 1 *a, c.*

Cœnobium orbicular or oblong, of 8–16 cells, or quadrate, of 4 cells, wedge-shaped, deeply lobed and arranged in the form of a cross. Cells of periphery cuneate, truncate at the base, deeply bilobate; sinus narrow, lobes obliquely truncate, notched, interior angles twice as long, all acute, or shortly appendiculate. Central cells yellow-green, polygonal, one side repand or deeply notched.

In pools and boggy places. Not uncommon.

var. a. **truncatum.** (*Braun.*) *Cooke, Algæ, t.* 18, *f.* 1 *b.*

Lobes truncate.

var. b. **excisum.** (*Braun.*) *Cooke, Algæ, t.* 18, *f.* 1 *d, e.*

Lobes slightly notched, emarginate.

var. c. **cuspidatum.** (*Braun.*) *Cooke, Algæ, t.* 18, *f.* 1 *g, h.*

Lobes deeply notched, evidently bidentate or bicuspidate.

In stagnant water, throughout Europe generally.

72. **Pediastrum rotula.** (*Ehr.*) *Cooke, Algæ, t.* 18, *f.* 2.

Cœnobium orbicular or oblong, cells variable, 4–8–16–32, pierced with openings, bright green, even. Cells of

periphery truncate at the base, more or less dilated upwards, deeply bifid, sinus acute, lobes straight, narrow, bidentate, teeth erect or divergent, somewhat bent ; cells of the centre usually polygonal, repand, or notched, containing a single paler spot.

In pools, etc., throughout Europe.

Sub-Family 8. SORASTREÆ.

Cells polygonal, often shortly horned, associated in a hollow cœnobium. Cell-membrane thin ; cell-contents green. Propagation by gonidia, simultaneous or after division, united into a cœnobium within the mother-cell, escaping by rupture of the membrane.

GENUS 30. **CŒLASTRUM.** *Näg.* (1849.)

Cœnobium globose, hollow within, formed of a single stratum of cells, reticulately pierced (Fig. 31).

73. **Cœlastrum sphæricum.** (*Näg.*) *Cooke, Algæ, t.* 19, *f.* 2.

Cœnobium globose or subglobose, composed of 4–8–16 or a larger number of cells, perforated, areolæ 3–4–5–6 angled. Cells rounded ; outer angles somewhat conical, obtusely rounded at the apex ; interstices 5–6 angled. Cœnobium 4–8 mm. diam. ; cells 21–23μ.

In boggy places.

74. **Cœlastrum cambricum.** *Archer, Micro. Journ.*, 1868, *p.* 65.

Cells rounded on the exterior margin, each bearing a single truncate tubercular process.

In pools.

75. **Cœlastrum microsporum.** (*Näg.*) *Braun, Alg. Unic., p.* 70.

Cells 8–16 or 32, exactly spherical, containing a single globule ; interstices small. Cœnobium ·4 mm. diam. ; cells 9μ diam.

In bogs and pools.

GENUS 31. STAURÓGENIA. *Kutz.*

Cœnobium cubical, hollow within, formed of 4–8–16 quadrate or sub-quadrate cells. Propagation by quiescent gonidia, produced after the subdivision of the cell-contents (Fig. 28).

76. **Staurogenia rectangularis.** (*Braun.*) *Cooke, Algæ, t.* 18, *f.* 3.

Cells oblong-oval, 4–16–64, associated in tabular families, almost twice as long as broad; angles obtusely rounded. Cells $7\frac{1}{2} \times 4\mu$.

In pools.

GENUS 32. SORASTRUM. *Kutz.* (1845.)

Cœnobium globose, solid within, free swimming, formed of 4–8–16–32 compressed wedge-shaped cells, which are sinuate, emarginate, or bifid at the apex, and radiately disposed. Propagation unknown (Fig. 30).

77. **Sorastrum spinulosum.** (*Näg.*) *Cooke, Algæ, t.* 19, *f.* 1.

Cœnobium spinulose. Cells wedge-shaped; apex slightly emarginate; angles obtusely rounded, bi-spinulose. Cœnobium to 40μ diam.

In stagnant water.

GENUS 33. SELENASTRUM. *Reinsch.*

Cells semilunate, joined together by the middle of the convex margin, in families of 4–8, regularly disposed. Propagation unknown (Fig. 32).

78. **Selenastrum Bibraianum.** (*Reinsch.*) *Cooke, Algæ, t.* 19, *f.* 3.

Cells semilunate, with the cusps either expanded or curved inwards; minor families constituted of 4 cells in pairs, major families of these combined in more or less spherical masses. Cells $16–23 \times 5–8\mu$; minor families $23–31\mu$ diam.

In moor pools.

Sub-Family 9. Characieæ.

Cells always innate, often distinctly stipitate, variable in form. Cell-membrane delicate, growing thicker with age; cell-contents bright green. Propagation by repeated division of the contents, resulting in more or less numerous biciliate zoogonidia.

Genus 34. CHARACIUM. *Braun.* (1847.)

Cells oblong, ovate, pyriform, fusiform, rarely acicular or subglobose, attenuated at the base in a hyaline stem. Cell-contents green. Zoogonidia succeeding division of the contents, occupying the whole of the cell, at length escaping by a lateral (rarely terminal) rupture, oblong, with two vibratile cilia (Fig. 34).

79. **Characium Sieboldi.** (*Br.*) *Cooke, Algæ, t.* 20, *f.* 9.

Cells erect, equal, at first nearly lanceolate, then pyriform or obovate, 2–3–4 times longer than broad, apex obtuse or broadly rounded; stem short, hyaline, base attenuated, truncate. Contents green at first, with one starch granule, afterwards several. Cells 22–26μ diam.

In clear water, attached to filiform algæ.

80. **Characium ornithocephalum.** (*Br.*) *Cooke, Algæ, t.* 19, *f.* 5.

Cells unequal, incurved, distinctly stipitate, afterwards one side swollen, semilunate, apex produced into a straight or inclined beak; stem elongated, slender, base sometimes discoid. Cell-contents bright green, with a central or lateral starch granule. Cells 25–33μ long, without stem, half as wide, or more.

In pools.

81. **Characium tenue.** (*Herm.*) *Cooke, Algæ, t.* 19, *f.* 4.

Cells erect, narrowly lanceolate, 6 times as long as broad, attenuated towards each extremity, somewhat ros-

trate, and hyaline above; stem short, slender, not dilated at the base. Contents homogeneous, bright green. Cells 3–6μ diam.

Attached to filamentous algæ.

Genus 35. **HYDRIANUM.** *Rabh.* (1864.)

Cells as in *Characium*, but cell-contents at first homogeneous, afterwards contracted into a dark green ovoid corpuscle, from which, by oblique division, 2–4–8 biciliate zoogonidia are produced (Fig. 33).

82. **Hydrianum heteromorphum.** (*Reinsch.*) *Cooke, Algæ, t.* 19, *f.* 6.

Cells at first globose-elliptical, attenuated below into a thin hyaline stem. Contents granular, then contracted in preparation for formation of the gonidia; zoogonidia elongated, escaping at the broadly opened apex. Cells, unopened, 8–9μ broad.

Attached to filamentous algæ.

Genus 36. **CODIOLUM.** *Braun.* (1852.)

Cells at first obovate, becoming clavate, or nearly cylindrical, densely aggregated in tufts; base attenuated into a stem. Cell-contents green. Propagation by zoogonidia, and by resting-spores.

83. **Codiolum gregarium.** (*Br.*) *Cooke, Algæ, t.* xx. *f.* 1–8.

Cells elongated, subclavate, green, many times longer than the diameter; apex rounded. Cells 30μ diam.

On maritime rocks. Also in the drip of fresh water.

Family III. VOLVOCINEÆ.

Cœnobia mobile, globose, subglobose, or quadrangular and flattened, produced from agile biciliate green cells,

with a double contractile vesicle. Common tegument of the cœnobium hyaline, more or less ample.

Propagation sexual or asexual.

Genus 37. **CHLAMYDOCOCCUS.** *Br.* (1849.)

Cells globose or subglobose (4–8 joined in a very fugitive cœnobium). Cell-membrane thickish, firm; cell-contents granular, brownish red or vermilion, in certain stages changing into green. Macrogonidia 2–4–8 rounded, with very long cilia, involved in a very ample, hyaline tegument. Microgonidia much smaller, numerous, biciliate, moving actively within the mother-cell, and escaping (Fig. 37) by rupture.

84. **Chlamydococcus pluvialis.** (*Br.*) *Cooke, Algæ, t.* xxi. *f.* 1.

Cells subglobose, very variable in size, brownish red, changing in some conditions to green. Cells 7–35μ.

On rocks, stones, etc., in hollows filled with rain-water.

85. **Chlamydococcus nivalis.** (*Br.*) *Cooke, Algæ, t.* 21, *f.* 2.

Cells globose, red, at first with a hyaline border, which is the thickened epispore; this gradually disappears with age. Cells 10–30μ.

On snow and wet rocks, etc.

Genus 38. **CHLAMYDOMONAS.** *Ehrb.* (1833.)

Macrogonidia ovate or oblong, green, involved in a rather narrow hyaline tegument; frontal extremity very obtuse, or somewhat truncate, with a contractile vacuole, and two cilia; posterior extremity with a large vesicle. Microgonidia arising from repeated division of the contents of the macrogonidia, oblong or ovate, numerous, pale green or yellow, becoming brownish. Tranquil oospores globose, red or brownish (Fig. 38).

86. **Chlamydomonas pulvisculus.** (*Ehr.*) *Cooke, Algæ, t.* 21, *f.* 3.

Macrogonidia ovate, twice as long as broad, or nearly; deep green, with a bright red lateral spot. Diam. $6\frac{1}{2}$–13μ.

In stagnant water.

Genus 39. VOLVOX. *Linn.* (1758.)

Cœnobium spherical, continually rotating and moving, looking like a hollow globe, composed of very numerous cells arranged on the periphery at regular distances, connected by the matrical gelatin; furnished with a red lateral spot, two contractile vacuoles, and two long exserted cilia, all circumscribed with a common hyaline vesicle. Propagation sexual or non-sexual (Fig. 36).

87. **Volvox globator.** (*Linn.*) *Cooke, Algæ, t.* 22, 23, 24.

Larger cœnobia, with very numerous cells (12,000), always with daughter-cœnobia enclosed within the mother, evolved without sexuality; fructification diœcious; the male cœnobia nourishing numerous red fascicles of spermatozoa; the female cœnobia originating 20–40 sexual cells, which after fecundation are resolved into as many red globose oospores, surrounded by a hyaline stellate epispore. Cœnobium as much as 1 mm. diam.

In clear pools, ponds, etc.

88. **Volvox minor.** (*Stein.*) *Cooke, Algæ, t.* 25.

Cœnobia and the number of cells smaller; the number of daughter-cœnobia evolved without sexuality within the mother, 1–9; fructification sexual, monœcious; many male cells, changing into bundles of spermatozoa; 5–10 female cells in the same cœnobium, after fecundation, evolved into as many oospores, surrounded by a smooth epispore.

In similar places to the preceding.

Genus 40. EUDORINA. *Ehrb.* (1831.)

Cœnobium oval, involved in a common tegument. Cells green, globose (16–32), enclosed within a single membrane,

bearing vibratile cilia, often with a red spot, distributed around the hyaline sphere at equal distances apart. Asexual propagation in all the cœnobia, the cells of which are divided into 16–32 parts, and soon evolved into new cœnobia. Sexual propagation in all the cœnobia (Fig. 39).

89. **Eudorina elegans.** (*Ehrb.*) *Cooke, Algæ, t.* 26.

Cœnobia oval. Cells usually 32, globose, either scattered or quaternate, eight at each pole, distributed in three parallel circles, at equal distances from each other, around the periphery of the cœnobium. Cœnobium 40–150μ long; cells 18–22μ diam.

In standing water.

Genus 41. PANDORINA. *Ehrb.* (1830.)

Cœnobium globose, or subglobose, invested by a broad colourless hyaline tegument. Cells green, globose (16, 32, or 64), included within a single rather thick membrane, bearing two vibrating cilia, with or without a red spot, aggregated in a botryoid manner. Propagation the same as in *Eudorina* (Fig. 41).

90. **Pandorina morum.** (*Ehr.*) *Cooke, Algæ, t.* 27, *f.* 2.

Cœnobium globose. Cells green, 16–32, arranged about the periphery. In the forms which produce the resting-spores, the cells are crowded together in the centre. Resting-spores, after becoming encysted, bright red. Cœnobium 200μ.

In standing water.

Genus 42. GONIUM. *Müller.* (1873.)

Cœnobium quadrangular, tabular, angles rounded, formed from a single flat stratum of cells, girt by a broad hyaline plano-convex tegument. Cells 16 (central 4,

peripherical 12), polygonal, bright green. Propagation by division (Fig. 40).

91. **Gonium pectorale.** (*Mull.*) *Cooke, Algæ, t.* 27, *f.* 1.

Cœnobium flattened, quadrangular, composed of 16 green cells, furnished with vibratile cilia. Cœnobium from 50μ; cells 10 × 7μ.

In stagnant water.

Genus 43. STEPHANOSPHÆRA. *Cohn.* (1852.)

Cœnobium throughout its whole life rotating and moving, composed of eight green cells, bearing two vibratile cilia, disposed at equal distances around a circle, enclosed in a common colourless hyaline, globose vesicle. Propagation both by macrogonidia and by microgonidia (Fig. 42).

92. **Stephanosphæra pluvialis.** (*Cohn.*) *Cooke, Algæ, t.* 28.

Cells globose, elliptic or fusiform, often at each extremity spreading out in mucous rays. Cœnobium 26–52μ; cells 6–12μ diam.

In hollows of rocks, and in pools after rain.

ORDER II. *ZYGOPHYCEÆ.*

Unicellular or multicellular, with terminal vegetation, destitute of true ramification. Cells single, or segregate, or geminate, or united in a series. Chlorophyl-mass for the most part distributed in plates or bands, including one or more starch granules. Multiplication by division in one direction. Propagation by zygospores resulting from the conjugation of two cells.

Family I. DESMIDIEÆ.

Unicellular. Excluded from this volume as a special study.

Family II. ZYGNEMACEÆ.

Multicellular. Cells cylindrical; fructiferous cells more or less inflated, all closely joined in filamentous families, forming an articulated simple thread, with a central cytioblast involved in radiating protoplasm. Cell-walls lamellose. Chlorophyl-mass effused, or of a definite form, often forming a spiral band. Propagation by zygospores, resulting from conjugation.

Sub-Family 1. Zygnemeæ.

Zygospore undivided, and mostly contracted, passing into the resting condition, afterwards developing into a germ-cell, divided into a basal cell and a thread-cell, capable of division.

Genus 44. **ZYGNEMA.** *Kutz.* (1843.)

Cells with two axile many-rayed chlorophyl bodies near the central cell nucleus, with a starch granule, or filled with dense granular contents, surrounding two starch granules lying near the centre. Zygospore in the middle space between the united pairing cells, or in one or other of the conjugating cells (Figs. 43, 44).

A. *Zygospores produced in conjugating canal.*

93. **Zygnema pectinatum.** (*Ag.*) *Cooke, Algæ, t.* 29, *f.* 1.

Sterile cells 1 to 2 times as long as broad. Zygospores globose or broadly elliptic, dark olive, scrobiculate, formed

in the canal of conjugation. Cells 30–35μ diam.; zygospore 40μ diam.

In still waters.

94. **Zygnema Ralfsii.** (*Kutz.*) *Cooke, Algæ, t.* 29, *f.* 2.

Sterile cells $2\frac{1}{2}$ to 3 (rarely 4) times as long as broad. Zygospore compressed ellipsoid, twice as long as broad, produced in the inflated conjunctive canal; sporoderm even. Cells 16–17μ diam.; zygospores 25 × 15μ.

In pools and streams.

95. **Zygnema parvulum.** (*Kutz.*) *Cooke, Algæ, t.* 29, *f*, 2.

Sterile cells 4 to 6 times as long as broad. Zygospore globose, produced in the conjunctive canal. Cells 20–22μ diam.; zygospores about equal.

In standing pools.

B. *Zygospores produced in one or other of the conjugating cells.*

96. **Zygnema cruciatum.** (*Vauch.*) *Cooke, Algæ, t.* 30, *f.* 1.

Sterile cells equal, or twice as long as broad. Zygospore spherical, formed in one or other of two conjoined cells; membrane brown and scrobiculate. Cells 28μ broad; zygospores 40μ diam.

In ditches, pools, etc.

97. **Zygnema stellinum.** (*Vauch.*) *Cooke, Algæ, t.* 30, *f.* 2.

Sterile cells $1\frac{1}{2}$ to 3 times longer than broad. Zygospore broadly ovoid, formed in one or other of the conjoined cells; membrane brown, scrobiculate. Sporiferous cells commonly longer than the zygospore. Cells 22μ diam.; zygospore 40 × 30μ.

In pools and ditches.

98. **Zygnema Vaucherii.** (*Ag.*) *Cooke, Algæ, t.* 30, *f.* 3.

Sterile cells $2\frac{1}{2}$ or 3 to 5 times as long as broad. Zygospores subglobose or broadly elliptic, produced in one or

other of the conjugating cells, which is usually more or less inflated; sporoderm delicately punctate. Cells 10–22μ diam.; zygospore, according to the varieties.
In ditches, ponds, etc.

var. a. **tenue.** *Rabh., Alg. Eur.* iii. *p.* 250.
Sterile cells 19–22μ, 1 to 3 times as long.

var. b. **subtile.** (*Rabh.*) *Cooke, Algæ, t.* 30, *f.* 4.
Sterile cells 15–19μ, 2 to 4 times as long.

var. c. **stagnale.** (*Kirsch.*) *Cooke, Algæ, t.* 30, *f.* 5.
Sterile cells 10μ, 3 to 4 times as long.

99. **Zygnema anomalum.** (*Hass.*) *Cooke, Algæ, t.* 31, *f.* 1.

Sterile cells equal, or nearly twice as long as broad; cytioderm thick, lamellose. Zygospore globose, olivaceous (sporoderm distinctly punctate?). Cells 25μ diam., with mucous sheath about double; zygospore 26μ diam.
In boggy pools.

100. **Zygnema leiospermum.** (*De Bary.*) *Cooke, Algæ, t.* 31, *f.* 2.

Sterile cells equal in length and breadth, or sometimes twice as long. Zygospore globose or broadly oval, formed in one of two conjugating cells; membrane brown, even. Sporiferous cells a little swollen. Cells 22μ diam.; zygospore 23–30μ.
In ditches filled after rain.

101. **Zygnema insigne.** (*Kutz.*) *Cooke, Algæ, t.* 31, *f.* 3.

Sterile cells equal, or twice as long as broad. Copulation scalariform or lateral; zygospore globose or slightly oval; membrane brown, even. Cells 26–30μ diam.; zygospore 26 × 30μ, or globose 30μ.
In streams and ditches.

Genus 45. **SPIROGYRA.** *Link.* (1820.)

Cells with one to several chlorophyl bands, usually spirally winding to the right. Copulation ladder-like or

lateral. Zygospores always within the wall of one of the united cells. Copulating cells similar to the sterile ones, or swollen (Fig. 45).

SECTION 1. Cells not replicate at the ends.

A. *Chlorophyl bands numerous (rarely two).*

102. **Spirogyra crassa.** (*Kutz.*) *Cooke, Algæ, t.* 32, *f.* 1.

Sterile cells with the extremities truncate, equal or twice as long as broad; chlorophyl bands 3 or more, making $\frac{1}{2}$ to $1\frac{1}{2}$ turns. Zygospores broadly and obtusely oval; membrane even. Sporiferous cells persistent, not swollen. Cells 150μ diam.; zygospore $160 \times 120\mu$.
In ponds, etc. Fruiting in summer.

103. **Spirogyra jugalis.** (*Dillw.*) *Cooke, Algæ, t.* 32, *f.* 2.

Sterile cells with the ends truncate, and commonly equal or double the length of the diameter; chlorophyl bands 4 to 5, making 1 to 2 turns. Zygospore elliptical; membrane even. Sporiferous cells not swollen. Sterile cells 90–100μ diam; zygospores 130–140×85–90μ.
In clear ponds, etc. Fruiting at Midsummer.

104. **Spirogyra nitida.** (*Dillw.*) *Cooke, Algæ, t.* 33, *f.* 1.

Sterile cells with the ends truncate, and usually 2 to 4 times as long as broad; chlorophyl bands about 4, making 1 to 4 turns of the spiral. Spores elliptic ovoid (almost almond shaped), $1\frac{1}{2}$ times as long as broad; membrane even. Sporiferous cells persistent. Sterile cells 70–90μ; zygospore 110–160×60–70μ.
In ponds.

105. **Spirogyra orthospira.** (*Näg.*) *Cooke, Algæ, t.* 33, *f.* 2.

Sterile cells with the extremities truncate, and from $2\frac{1}{2}$ to 4 to 10 times as long as broad; chlorophyl bands 3 to 4 to 5 (rarely 7), sometimes erect, sometimes forming a very lax spiral. Spores orbicular, flattened; membrane even.

Sporiferous cells scarcely swollen, $2\frac{1}{2}$ to 4 times as long as the diameter. Cells 50–65μ diam.; zygospore 70 × 48μ.
In pools. Fruiting in autumn.

106. **Spirogyra orbicularis.** (*Hassall.*) *Cooke, Algæ, t.* 34, *f.* 1.

Sterile cells with the end truncate, about equal in length to breadth; chlorophyl bands 5 to 7, making $\frac{1}{2}$ to 1 turn. Zygospores orbicular, flattened; membrane punctate. Sporiferous cells not inflated. Cells 110–140μ diam.; zygospores 100μ diam.
In ponds, etc. Fruiting in autumn.

107. **Spirogyra bellis.** (*Hassall.*) *Cooke, Algæ, t.* 34, *f.* 2.

Sterile cells with the end truncate, and usually $1\frac{1}{2}$ times (rarely 3 times) as long as broad; chlorophyl bands 5 to 6, making $\frac{1}{2}$ to 1 turn, or nearly erect. Spores orbicular, depressed, with the membrane punctate or porose, chestnut colour. Sporiferous cells persistent, swollen. Cells 70–80μ; zygospores 70–80μ diam.
In ponds. Fruiting in August.

B. *Chlorophyl bands single or double* (*rarely ternate*).

108. **Spirogyra porticalis.** (*Vauch.*) *Cooke, Algæ, t.* 35.

Sterile cells with the extremities truncate, 2 to 4 times longer than the diameter; chlorophyl bands single or binate, rarely ternate. Spores obtuse, ovoid, $1\frac{1}{2}$ times longer than the diameter; membrane even, chestnut colour. Sporiferous cells equal to the length of the spore, or twice as long, more or less turgid. Cells 32–50μ diam.; spores 80 × 48–50μ.
In ditches, etc. Fruiting in spring.

var. α. **quinina.** *Cooke, Algæ, t.* 35, *f.* 1.

Chlorophyl bands usually single.

var. β. **decimina.** *Cooke, Algæ, t.* 35, *f.* 2.

Chlorophyl bands usually 2, sometimes 3. Cells 34–40μ., 2 to 4 times as long.

var. γ. **rivularis.** (*Hass.*) *Cooke, Algæ, t.* 35, *f.* 3.

Cells 32–36μ, 5 to 10 times as long.

C. *Chlorophyl bands single.*

109. **Spirogyra condensata.** (*Vauch.*) *Cooke, Algæ, t.* 36, *f.* 1.

Sterile cells with the extremities truncate, and commonly 1 to 3½ longer than the diameter; chlorophyl bands single, rarely 2, making 1½ to 2 turns of the spiral. Spores broadly obtuse, ovoid, or subspherical; membrane even, chestnut colour. Sporiferous cells turgid, and usually shorter than the spores. Cells 40μ diam.; zygospores 35–40μ diam.

In pools. Fruiting in spring.

110. **Spirogyra velata.** (*Nordst.*) *Cooke, Algæ, t.* 130, *f.* 1.

Sterile cells with the ends truncate, 3 to 4 times as long as broad; chlorophyl band single, making 1½ to 2½ turns. Spores elongated-oval, 1½ to 3 times as long as broad. Epispore thick, of 4 membranes; the second hyaline and scrobiculate; the third coloured. Sporiferous cells a little swollen or not at all, shorter, or a little longer than the spores. Cells 35–40μ; zygospores 60–85 × 35–45μ.

In ditches.

111. **Spirogyra longata.** (*Vauch.*) *Cooke, Algæ, t.* 36, *f.* 2.

Sterile cells with the ends truncate, 3 to 8 times as long as broad; chlorophyl bands single or rarely 2, making 1½ to 6 turns of a spiral. Spore 1½ to 2 times as long as broad; membrane even, chestnut colour. Sporiferous cells swollen and usually longer than the spore. Cells ·24–·30μ diam.; zygospores 40–70 × 30μ.

In pools and ditches.

var. α. **communis.** *Cooke, Algæ, t.* 36, *f.* 2 *e.*

Sterile cells 3 to 8 times as long as broad.

var. β. **turpis.** *Cooke, Algæ, t.* 36, *f.* 2 *f.*

Sterile cells abbreviated.

112. **Spirogyra flavescens.** (*Hass.*) *Cleve.*

Sterile cells with the ends truncate, $2\frac{1}{2}$ to 5 times longer than broad; chlorophyl bands single. Spores attenuated, twice as long as broad; membrane even, chestnut colour. Sporiferous cells swollen, and usually longer than the spores. Cells 20μ diam.; zygospore $50 \times 24\mu$.

Boggy pools on heaths, etc.

form a. **gracilis.** *Cooke, Algæ, t.* 37, *f.* 1.

Zygospore about 30μ diam.

form b. **flavescens.** *Cooke, Algæ, t.* 37, *f.* 2.

Zygospore about 20μ diam.

form c. **parva.** *Cooke, Algæ, t.* 37, *f.* 3.

Zygospore about 10μ diam.

Section 2. Cells replicate at the ends.

A. *Chlorophyl bands usually two or more.*

113. **Spirogyra insignis.** (*Hass.*) *Cooke, Algæ, t.* 38, *f.* 1.

Sterile cells with the extremities replicate, $4\frac{1}{2}$ to 5 (rarely 6) times as long as broad; chlorophyl band 2 to 3, lax, with 1 to 2 turns of spiral, or nearly erect. Spores ovate-elliptic, twice as long as broad; membrane even. Sporiferous cells slightly swollen. Cells $30–35\mu$; zygospore $40–50\mu$, 2 to 3 times as long.

In streams.

114. **Spirogya calospora.** (*Cleve.*) *Cooke, Algæ, t.* 38, *f.* 2.

Sterile cells with the extremities replicate, 6 to 12 times as long as broad; chlorophyl bands 1 to 3, making $2\frac{1}{2}$ to 7 turns. Spores elongate, obtuse ovoid, $1\frac{1}{2}$ to 2 times as long as broad; membrane yellow, scrobiculate. Sporiferous cells scarcely turgid.

form a **major.**

Diameter of threads 50μ. Bands 2 to 3.

form β **minor.**

Diameter of threads 32μ. Band single. Zygospore 78–96 × 45μ

In bogs and moor pools.

B. *Chlorophyl bands single.*

115. **Spirogyra quadrata.** (*Hass.*) *Cooke, Algæ, t.* 39, *f.* 1.

Sterile cells 3 to 9 times as long as broad. Fertile cells turgid, quadrate. Zygospore elliptical. Sporoderm brown. Cells 24 to 27μ; zygospore 42–48μ diam., 1½ to 2 times as long.

In pools.

116. **Spirogyra Weberi.** (*Kutz.*) *Cooke, Algæ, t.* 39, *f.* 2.

Sterile cells with the extremities replicate, 7 to 12 times as long as the diameter; chlorophyl bands single, 3 to 8 turns of the spiral. Spores ovoid, scarce broader than the sterile threads; membrane even, chestnut, twice as long as broad. Sporiferous cells scarcely turgid. Spores: (α) 72 × 34μ; (β) 68 × 34μ.

form α. **inæqualis.**

Diameter of thread 30μ. Sporiferous cells scarcely longer than the spores.

form β. **subventricosum.**

Diam. of thread 26μ. Sporiferous cells 2 to 4 longer than the spores.

In ditches. Fruiting in summer.

117. **Spirogyra tenuissima.** (*Hass.*) *Cooke, Algæ, t.* 39, *f.* 3.

Sterile cells with the extremities replicate, 5 to 15 times as long as the diameter; chlorophyl bands single, making 3 to 6 turns of the spiral. Spores broader than the sterile cells, elongated ovoid, twice as long as the diameter; membrane even and chestnut colour. Sporiferous cells turgid. Spore 55–58 × 24–30μ.

form α. **tenuissima.**

Sterile cells 12–15μ diam., 8 to 16 times as long as broad. Sporiferous cells 2 to 3 times as long as the spores.

form β. **inflata.**

Sterile cells 17–20μ diam., 5 to 10 times as long as broad. Sporiferous cells scarcely longer than the spores.

In pools.

Genus 46. SIROGONIUM. *Kutz.* (1843.)

Cells with parietal longitudinal chlorophyl bands. Fructifying cells bending knee-like towards each other and growing together, united at the point of adnation; receiving-cells barrel-shaped; giving-cells short, cylindrical. Zygospore (elliptic) in the receiving cell-wall (Fig. 46).

118. **Sirogonium sticticum.** (*Kutz.*) *Cooke, Algæ, t.* 40, *f.* 1.

Sterile cells 2 to 5 times as long as broad. Zygospore broadly elliptical, spore-coat double. Sporiferous cells swollen, abbreviated. Cells 40 to 50μ, 2 to 5 times as long; zygospore 42 × 75μ.

In ponds and ditches and moor pools.

Genus 47. ZYGOGONIUM. *Kutz.* (1843.)

Cells cylindrical or barrel-shaped, with a compact cell-wall. On each side an irregular chlorophyl-body, each furnished with a starch granule, both often confluent in an axile string. Connection of the copulating threads ladder-like. The protuberances of the two contiguous threads that receive the chlorophyl-contents are bounded by partitions into fructifying cells, which then coalesce into a not-contracted zygospore (Fig. 47).

119. **Zygogonium ericetorum.** (*De Bary.*) *Cooke, Algæ, t.* 40, *f.* 2.

Sterile cells $1\frac{1}{2}$ to 2 times as long as broad. Zygospores subglobose or oblong. Sporoderm rather thick, even. Cells 13–18μ diam.; zygospore 13 × 25 mm.

var. a. **terrestris.**

Growing on the ground on heaths.

var. b. **aquaticum.** *Cooke, Algæ, t.* 40, *f.* 3.

In pools, bogs, etc.

Doubtful Species.

120. **Zygogonium gracile.** (*Berk.*) *Cooke, Algæ, t.* 40, *f.* 4.

Sterile cells about 5 times as long as broad, of a pale or yellowish green colour. Zygospore unknown. Cells 14–16μ diam.

Face of a dripping rock.

GENUS 48. MOUGEOTIA. *De Bary.* (1858.)

Cells with axile chlorophyl-plates. Copulation ladder-like. Zygospore drawn together in the swollen, bladdery, persisting middle space (Fig. 48).

121. **Mougeotia glyptosperma.** (*De Bary.*) *Cooke, Algæ, t.* 41, *f.* 2.

Sterile cells 7 to 12 times as long as broad. Zygospores large, oval, with a thick, firm, yellow-brown epispore. Sporiferous cells elongated. Cells 10–15μ, 6 to 10 times as long; zygospore 16 × 35μ.

122. **Mougeotia lævis.** (*Archer.*) *Cooke, Algæ, t.* 41, *f.* 2.

Sterile cells twice as long as broad. Zygospores broadly elliptic or oval. Epispore thick, brown. Sporiferous cells sometimes elongated. Cells 20–25μ; zygospore about 45 × 36μ.

In ditches and pools.

Sub-Family 2. MESOCARPEÆ.

Cells cylindrical, united in threads, with axile plates of chlorophyl. Zygospore the shape of the mother-cells; not contracted, separating by three to five partitions into a central firm-walled resting-spore, and two or four lateral decaying cells.

GENUS 49. **MESOCARPUS.** *Hass.* (1845.)

Spore spherical or oval, between two cylindrical, straight or slightly inbent lateral cells. (*a*) Copulation ladder-like, threads free, or with one end attached; (*b*) copulation lateral between two neighbouring cells of a thread, rarely ladder-like. Sterile cells often with a knee-like bend, and intergrown at the bend with similar cells of another thread (Figs. 49, 50).

† *Spore membrane scrobiculate or punctate.*

123. **Mesocarpus nummuloides.** (*Hass.*) *Cooke, Algæ, t.* 41, *f.* 3.

Sterile cells 7 to 14 times as long as broad. Zygospore spherical, or broadly ovoid; membrane brown, scrobiculate. Cells 15μ diam.; zygospore $44 \times 34\mu$.

In ditches. Fruiting in September.

124. **Mesocarpus depressus.** (*Hass.*) *Cooke, Algæ, t.* 41, *f.* 4.

Sterile cells 7 to 12 times as long as broad. Zypospore elliptical, compressed; membrane brown, punctate. Cells 7–15μ diam.

var. B. **ovalis.** (*Rabh.*) *Cooke, Algæ, t.* 41, *f.* 5.

In boggy waters.

†† *Spore membrane smooth.*

125. **Mesocarpus parvulus.** (*Hass.*) *Cooke, Algæ, t.* 42, *f.* 3.

Sterile cells 5 to 12 times as long as broad. Zygospore spherical; membrane even, commonly twice the diameter of the threads. Cells 10μ; zygospore 20–24μ.

var. B. **angustus.** (*Hass.*) *Cooke, Algæ, t.* 42, *f.* 4.

126. **Mesocarpus scalaris.** (*Hass.*) *Cooke, Algæ, t.* 42, *f.* 1.

Sterile cells 2 to 4 times as long as broad. Zygospore spherical or broadly ovoid; membrane brown, *even*, about equal in diameter to the threads. Cells 34μ diam.; zygospore 34μ diam.

In boggy pools, etc.

127. **Mesocarpus recurvus.** (*Hass.*) *Cooke, Algæ, t.* 42, *f.* 2.

Sterile cells 5 to 10 times as long as broad. Zygospore globose. Sporoderm brown, even. Cells 12–18μ.

In ditches.

128. **Mesocarpus? neaumensis.** *Bennett, Journ. R.M.S.*, 1886, *p.* 15.

Sterile cells with the endochrome in a single axile plate. Conjugation lateral. Zygospores oval, 90μ × 40μ; sterile cells 25μ long, 20–25μ broad.

In a duck-pond.

Sub-Genus PLEUROCARPUS. *Braun.*

129. **Mesocarpus pleurocarpus.** (*De Bary.*) *Cooke, Algæ, t.* 43, *f.* 1.

Sterile cells 2 to 3 times as long as broad. Zygospores subglobose, brown, even. Cells 25–30μ.

In moor pools, etc.

GENUS 50. **STAUROSPERMUM.** *Kutz.* (1843.)

Spores 4-cornered, between the truncated corners of 4 sessile lateral cells (cells of all the species up to 20 times longer than broad) (Figs. 51, 52).

† *Sporoderm porose.*

130. **Staurospermum quadratum.** (*Hass.*) *Cooke, Algæ, t.* 43, *f.* 2.

Sterile cells 10 to 20 times longer than broad. Epispore quadrangular, with the angles truncate, not replicate; sides straight, covered with large pores (about 50 on the longer side). Cells 15–20μ; zygospore 40–44μ.

In ponds, ditches, etc.

†† *Sporoderm verrucose.*

131. **Staurospermum gracillimum.** (*Hass.*) *Cooke, Algæ, t.* 43, *f.* 3.

Sterile cells 8 to 15 times as long as broad, pale yellowish green. Zygospore quadrate; the sides deeply sinuate; angles retuse. Sporoderm verrucose. Cells 6–8μ; zygospore 20μ diam.

In bogs and moor pools.

132. **Staurospermum capucinum.** (*Kutz.*) *Cooke, Algæ, t.* 44, *f.* 1.

Sterile cells 6 to 14 times as long as broad. Zygospore quadrate; angles obtuse or truncate; sides often deeply sinuate. Sporoderm even, 15 × 20μ; zygospore 50 × 40μ.

In ditches and ponds.

133. **Staurospermum viride.** (*Kutz.*) *Cooke, Algæ, t.* 44, *f.* 2.

Sterile cells 10 to 20 times as long as broad. Epispore quadrangular; angles truncate and replicate; sides concave, smooth. Cells 8μ; zygospore 25μ.

In ditches.

Sub-Family 3. GONATONEMÆ.

Cells cylindrical, much elongated, united in threads, with axile plates of chlorophyl. Agamospores produced without conjugation in cells continuous with, and partitioned from the mother-cells.

GENUS 51. **GONATONEMA.** *Wittrock.* (1878.)

Spores (agamospores, not carpospores) without conjugation, formed by biseptation of the mother-cells, which

latter are bent angularly, and alternately, at the point of fructification (Fig. 53).

134. **Gonatonema notabile.** (*Hass.*) *Cooke, Algæ, t. 44, f. 3.*

Sterile cells 8 to 10 times as long as broad, sometimes longer. Zygospore, front view cylindrical, side view bent so as to be convex on one side, concave on the other, truncate at the ends, same diameter as the vegetative cells. Cells 12–15μ.

In fields.

ORDER III. *SIPHOPHYCEÆ.*

Unicellular, or, when fruiting, bicellular. Cells utricle-shaped, often branched; branches with terminal vegetation, at length shut off by a septum, some containing oospores, others antheridia. Propagation by free cells, zoogonidia, or oospores. Aquatic or terrestrial.

FAMILY I. BOTRYDIACEÆ.

Terrestrial, unicellular. Cell globose, then pyriform; base divided into hyaline radicles. Cell-contents modified into resting-spores. Spore-contents in germination modified into sexual zoospores.

GENUS 52. **BOTRYDIUM.** (*Wallr.*)

Same as above (Fig. 54).

135. **Botrydium granulatum.** (*Linn.*) *Cooke, Algæ, t. 65.*

Gregarious, often aggregated, rarely confluent. Cells globose, pyriform, size of a poppy seed or mustard seed, or larger, leek-green, pulverulent.

On the ground in swampy places.

FAMILY II. VAUCHERIACEÆ.

Monœcious, rarely diœcious, cespitose, unicellular, or bicellular. Thallus more or less branched, vegetation terminal. Propagation sexual or non-sexual. Oogonium lateral, sessile, or stipitate. Antheridia lateral, sessile. Spermatozoids oblong.

GENUS 53. **VAUCHERIA.** (*D. Cand.*)

Characters same as above (Fig. 55).

SECTION A. **Tubuligeræ.** Antheridia little or scarcely bent.

136. **Vaucheria dichotoma.** (*Lyngb.*) *Cooke, Algæ, t.* 46, *f.* 21.

Loosely cæspitose, dirty green. Thallus very thick, remotely dichotomous. Oogonia sessile, globose, or ovoid, single. Oospores with a triple membrane, spotted with brown. Antheridia single, erect, on the same or on different threads. Oogonia $\frac{1}{10}$ mm. diam.; threads $\frac{1}{5}$ mm. diam.

In ditches, and in brackish water.

137. **Vaucheria aversa.** (*Hass.*) *Cooke, Algæ, t.* 47, *f.* 1.

Loosely cæspitose, sparingly branched. Fructification similar to *V. sericea*, but thallus much thicker. Oogonia larger, now and then somewhat pedicellate. Oospores much smaller.

In ditches.

138. **Vaucheria sericea.** (*Lyngb.*) *Cooke, Algæ, t.* 47, *f.* 4.

Tufts densely interwoven, dirty green; thallus thin, loosely branched. Oogonia 2 to 6 in a series, oblique, rostellate, sessile or shortly pedicellate. Antheridia cylindrical, horizontally deflexed. Spermatozoids oblong. Oogonia $\frac{1}{10}$ mm.

In ditches, etc.

SECTION B. **Corniculatæ.** Antheridia bent, or hooked, on short lateral branches.

139. **Vaucheria Dillwynii.** (*Ag.*) *Cooke, Algæ, t.* 47, *f.* 9, 10.

Terrestrial, forming a thin dark-green stratum. Oogonia globose, or ellipsoid, rostrate, sessile, single or in pairs membrane punctate. Oospores spotted. Sporoderm thick, stratose. Antheridia bag-shaped.

On the ground in damp shady places.

140. **Vaucheria sessilis.** (*Vauch.*) *Cooke, Algæ, t.* 46.

Loosely intricate, pale or dull green. Thallus sparingly branched. Oogonia 2 to 3, approximate, rarely single, ovate, oblique, rostrate. Antheridia intermediate, short, straight, and subulate, or elongated and incurved. Oospores punctate. Oospores and threads 70μ diam.

In ditches or on the ground.

var. **cæspitosa.** (*Vauch.*) *Cooke, Algæ, t.* 48, *f.* 3.

Oogonia usually in pairs, ovate, opposite. Antheridia intermediate, generally short, circinate.

On the margin of streams.

var. **ornithocephala.** (*Hass.*)

Oogonia solitary, or in pairs, oval-oblong, obliquely rostrate, beaks truncate. Antheridia cylindrical-subulate.

In stagnant or slow-flowing water.

var. **repens.** (*Hass.*) *Cooke, Algæ, t.* 48, *f.* 4.

Terrestrial. Oogonia single, sessile, oblong or ovate, mouth lateral, truncate. Antheridia solitary, erect or curved, scarcely longer than the oogonium.

On the naked ground.

141. **Vaucheria geminata.** (*Vauch.*) *Cooke, Algæ, t.* 48, *f.* 6–9.

Dense dull green tufts. Thallus dichotomous. Oogonia 2 (rarely 1 to 3), ovate, opposite, pedunculate. Antheridia

intermediate, subulate, recurved. Oospore spotted. Sporoderm colourless, stratose, 110–120 × 180–190μ.

In ponds and ditches.

var. **racemosa.** (*Grev.*) *Cooke, Algæ, t.* 49, *f.* 4.

Oogonia shortly pedunculate, 3 to 5, or more, aggregated in a corymbose manner. Antheridia single, scarcely longer than the oogonia. Oospore 60–80 × 75–80μ.

In ditches.

142. **Vaucheria hamata.** (*Vauch.*) *Cooke, Algæ, t.* 48, *f.* 10–13.

Aquatic or terrestrial. Thallus vaguely branched. Oogonia usually single, ovate, seated on a short segment of the divided stem, the other segment forming the antheridium.

In ditches.

143. **Vaucheria terrestris.** (*Lyngb.*) *Cooke, Algæ, t.* 49, *f.* 1, 2.

Densely interwoven in a bright green stratum. Oogonia usually single, pedunculate, attached at the back of the curved antheridia. Oospores with a colourless inflated sporoderm.

On damp clay soil.

SECTION C. **Piloboloideæ.** Antheridia bordering immediately on the boundary cell.

144. **Vaucheria sphœrospora.** (*Nordst.*) *Grevillea*, XIV. *p.* 57.

Loosely cæspitose. Antheridia at tips of the branches, tumid, a little incurved, acuminate, furnished at the apex with 2 (rarely 4) conical processes, connected with the side or base of the oogonium by means of a short cell without chlorophyl. Oogonium globose. Threads 26–60μ; oogonia 104–136μ; oospore 88–120μ.

On mud of Thames at low water.

ORDER IV. *NEMATOPHYCEÆ.*

Multicellular, membranaceous or filamentous, with or without branches. Vegetation either terminal, forming an articulate thread, or afterwards lateral, forming a membranaceous thallus of a single stratum. Cell-multiplication by repeated division in one or two directions. Propagation by oospores or zoogonidia.

FAMILY I. ULVACEÆ.

Thallus membranaceous or foliaceous, rarely crustaceous, formed of one stratum of cells. Propagation by zoogonidia, arising from a repeated division of the contents. Zoogonidia oblong, with two or four cilia.

Sub-Family 1. PRASIOLEÆ.

Thallus expanded and foliaceous, rarely crustaceous.

GENUS 54. **PRASIOLA.** *Ag.*

Thallus membranaceous, foliaceous, ascending or erect, more or less crispate, composed of angular cells, distributed in plane areas; base sometimes loosely fibrillose (Fig. 56).

145. **Prasiola crispa.** (*Kutz.*) *Cooke, Algæ, t.* 50, *f.* 1, 2.

Tufts more or less dense, dark green, soft and elastic. Thallus plicate crisped, of variable form and size, often bullate. Cells in distinct areolas, or confluent, quadrate, or quadrangular; angles more or less obtusely rounded. Cells 5–9μ diam., or 8–13 × 3–5μ.

On damp ground, rocks, etc.

146. **Prasiola furfuracea.** (*Menegh.*) *Cooke, Algæ, t.* 50, *f.* 5–7.

Forming a furfuraceous stratum, more or less expanded, dark green. Thallus about a line long and broad, dilated from the short stem-like base into a fan-like lamina; margin slightly undulate and repand, often emarginate at the apex or lobed. Cells angular, in quadrate or almost quadrate areolas. Cells 14–16 × 4–6μ.

On damp walls and rocks.

147. **Prasiola stipitata.** (*Suhr.*) *Cooke, Algæ, t.* 50, *f.* 8–11.

Stratum cæspitose, expanded, dark green. Thallus variable, commonly 1 to 2 lines long; dilated upwards from a stem-like base, often truncate at the apex; margin slightly repand. Cells in the stem-like base in series, in the upper part in small regular areolas. Cells 5–7μ.

On rocks by the sea, etc.

148. **Prasiola calophylla.** (*Spreng.*) *Cooke, Algæ, t.* 50, *f.* 3, 4.

Cæspitose, dark green, crispate. Thallus 2 to 4 lines long, narrow, linear, rather circinate, attenuated at the base into a stem, truncate at the apex, now and then crenate. Cells large, arranged in longitudinal series. Cells 4–5 × 2–4μ.

On damp stones, rocks, etc.

Sub-Family 2. ULVEÆ.

Thallus membranaceous, vesiculose, or tubulose.

GENUS 55. **ENTEROMORPHA.** *Link.* (1820.)

Thallus membranaceous, tubular or bladdery, fixed at the base; composed of one stratum of cells, sometimes branched. Propagation by zoogonidia (Fig. 57).

149. **Enteromorpha intestinalis.** (*Linn.*) *Cooke, Algæ, t.* 51, *f.* 1–5.

Fronds simple, elongated, variable in form and size, usually becoming more or less inflated, obtuse above, attenuated at the base, pale green. Cells 3–5–6 angled. Cells 12–20μ diam.

In ditches, chiefly brackish.

Genus 56. MONOSTROMA. *Thur.* (1854.)

Frond plane or saccate, simple, or torn, or lobate, composed of one stratum of cells. Cells somewhat rounded, immersed in a homogeneous membrane (Fig. 58).

150. **Monostroma laceratum.** (*Thur.*) *Cooke, Algæ, t.* 51, *f.* 6, 7.

Thallus membranaceous, thin and flaccid, pallid green, rugose; margin plane, or crisped (40–50μ thick). Cells rounded, twin, ternate, or quaternate, disposed loosely in the intercellular substance, in transverse section of the thallus oval (17–23μ).

In brackish water.

151. **Monostroma Wittrockii.** (*Born.*) *Cooke, Algæ, t.* 51, *f.* 8–12.

Thallus membranaceous, gelatinous, bright green (18 mill.), oblong, pedicellate, at first saccate, then open at the summit, margin becoming regularly lobed. Adult plant sessile, attached by a part of its surface, when mature (8 cent. diam.), the lobes plicate, elongated and rounded. Cells angular, subquaternate, in section of thallus rounded.

In salt or brackish water.

Family II. SPHÆROPLEACEÆ.

Threads simple, with terminal vegetation, very long, articulations cylindrical, by spurious septa multilocular. Chlorophyllose mass distributed in annular bands. Pro-

pagation by oospores, after sexual fecundation, enclosed in a stellate sporoderm.

GENUS 57. **SPHÆROPLEA.** *Ag.* (1824.)

Characters the same as above (Fig. 59).

152. **Sphæroplea annulina.** (*Roth.*) *Cooke, Algæ, t.* 52.

Green, yellowish, brick-red, or scarlet. Cells 8 to 10 or 20 times as long as broad, with 20 to 30 chlorophyllose rings in each cell. Spores at length densely seriate, rarely disposed irregularly, at first green, afterwards olive-brown, and then red. Threads 36–70μ diam.; oospore 18–30μ.

In quarries, pits, or inundated fields.

GENUS 58. **CYLINDROCAPSA.** *Reinsch.* (1867.)

Cells spherical or ellipsoid; membrane thick, either with a three or fourfold tegument, or naked; cells associated in a linear series, enclosed in a cylindrical hyaline gelatinous tube; cells dividing transversely, Cell-contents green, granular (Fig. 60).

153. **Cylindrocapsa involuta.** (*Reinsch.*) *Cooke, Algæ, t.* 9, *f.* 3.

Cells ellipsoid, ultimately involved in a fourfold tegument, which is expanded at the poles. Cells 23–30μ diam.

In pools, etc.

FAMILY III. CONFERVACEÆ.

Threads articulate, either simple or branched, vegetation terminal. Articulations more or less elongated, rarely abbreviated, cylindrical, rarely swollen. Cell-membrane sometimes lamellose. Vegetation by repeated division in one direction. Propagation by zoogonidia.

GENUS 59. **MICROSPORA.** *Thur.* (1851.)

Articulate thread simple. Chlorophyllose mass at first parietal, afterwards contracted in the centre. All articulations fertile. Propagation by zoogonidia, arising from a division of the cell-contents, escaping by rupture of the cell (Fig. 61).

154. **Microspora fugacissima.** (*Ag.*) *Cooke, Algæ, t.* 53, *f.* 1.

Pale green or yellowish green. Articulations before division 4 to 5 times as long as their diameter, after division about 2 to $2\frac{1}{2}$ times as long, not constricted at the joints. Cells $8\frac{1}{2}$–10μ diam.

In ditches.

155. **Microspora vulgaris.** (*Rabh.*) *Cooke, Algæ, t.* 53, *f.* 2.

Bright green. Articulations 2 to $3\frac{1}{2}$ times as long as the diameter. Threads 12μ diam.

In ditches and pools.

156. **Microspora floccosa.** (*Ag.*) *Cooke, Algæ, t.* 53, *f.* 3.

Articulations about twice as long as broad, after division equal, or a little shorter, slightly constricted at the joints. Threads 8–10 or 15μ diam.

In stagnant water.

GENUS 60. **CONFERVA.** (*Linn.*)

Articulate threads simple, joints cylindrical. Chlorophyllose mass homogeneous. Vegetation by division Fig. 62).

57. **Conferva fontinalis.** (*Berk.*) *Cooke, Algæ, t.* 53, *f.* 6, 7.

Bright green, attached. Articulations 6 to 10 times as long as the diameter, slightly swollen, a little constricted at the joints. Cell-membrane rather thick, homogeneous; when heated with sulphuric acid, swelling and distinctly lamellose. Threads 16–18μ diam.

Attached to grass, etc., in ditches.

158. **Conferva tenerrima.** (*Kutz.*) *Cooke, Algæ, t.* 53, *f.* 5.

Usually pale green. Articulations $1\frac{1}{2}$–3 times as long as the diameter. Threads $3\frac{1}{2}$–5μ diam.

In fresh water, often mixed with other algæ.

159. **Conferva bombycina.** (*Ag.*) *Cooke, Algæ, t.* 53, *f.* 4.

Yellowish green or green, soft, silky. Articulations oblong-cylindrical, slightly constricted at the joints, before division three times as long as the diameter, collapsing alternately when dry. Threads 6–12μ diam.

In ditches, pools, etc., common.

GENUS 61. **CHÆTOMORPHA.** *Kutz.* (1845.)

Articulate thread simple, nearly equal, fixed by a discoid base. Lower articulations always short; before division equal or half as long again as broad; after division shorter. Upper articulations elongated. Cell-membrane thick; cell-contents green. Propagation by zoogonidia (Fig. 63).

160. **Chætomorpha litorea.** (*Harv.*) *Cooke, Algæ, t.* 54, *f.* 1.

Rigid, green, crispate. Articulations, before division, $1\frac{1}{2}$ times as long as broad, here and there swollen in pairs, and discoloured. Threads 160μ diam.

In estuaries.

161. **Chætomorpha linum.** (*Roth.*) *Cooke, Algæ, t.* 54, *f.* 2-4.

Rather rigid, dark green, or yellowish green. Lower articulations equal or almost equal in length to their diameter. Upper articulations, before division, two or three times as long as the diameter, or even four times, here and there swollen. Cell-membrane of the lower articulations thick, distinctly lamellose; the upper ones thinner and indistinctly lamellose, contracted at the joints. Threads ·25 mm. thick.

In brackish and salt water.

162. **Chætomorpha sutoria.** (*Berk.*) *Cooke, Algæ, t.* 54, *f.* 5.

Dark green, crispate, rather rigid, interwoven in lax tufts. Articulations one and a half times as long as broad, after division shorter than the diameter. Cell-membrane thick, distinctly lamellose. Threads 100–120μ diam.

In brackish ditches, estuaries, and salt water.

163. **Chætomorpha implexa.** (*Dill.*) *Cooke, Algæ, t.* 54, *f.* 6.

Yellowish green, crispate, interwoven in lax tufts, rather rigid. Articulations twice as long as broad. Cell-membrane rather thick, indistinctly lamellose. Threads 40–60μ diam.

In brackish water.

Genus 62. RHIZOCLONIUM. *Kutz.*

Articulate thread as in *Conferva*, distinctly contorted, forming by prolification of the cells short root-like processes (Fig. 64).

164. **Rhizoclonium Casparyi.** (*Harv.*) *Cooke, Algæ, t.* 54, *f.* 7.

Threads elongated, slender, decumbent, yellow green, stratified, interwoven, curved and angular, emitting short root-like branches at the angles. Joints 2 to 6 times longer than broad, with narrow dissepiments. Threads 18–25μ diam.

In brackish water.

165. **Rhizoclonium flavicans.** (*Jurg.*) *Cooke, Algæ, t.* 54, *f.* 8.

Threads soft, simple, extremely fine, matted, somewhat crisped, at first pale green, at length distinctly jointed. Articulations one and a half as long as broad, dotted; interstices pellucid. Threads 18μ diam.

At the mouths of rivers, and salt marshes.

165*. **Rhizoclonium geminatum.** *Benn. Roy. Micr. Journ.*, 1890, *t.* 1, *f.* 6, 7.

Cells $20 \times 12\frac{1}{2}\mu$.

Genus 63. CLADOPHORA. *Kutz.* (1843.)

Articulate thread variously branched. Cell-membrane usually thick, lamellose; cell-contents parietal. Propagation by zoogonidia, furnished with 2 or 4 vibratile cilia (Fig. 65).

166. **Cladophora fracta.** (*Dillw.*) *Cooke, Algæ, t.* 55, *f.* 1, 2.

Branches sparse, divaricate, the lower laterally inserted. Cell-contents of the branches not spiral. Fertile cells often in the middle of the branches or basal. Threads 100μ diam.

In fresh or brackish water.

167. **Cladophora crispata.** (*Roth.*) *Cooke, Algæ, t.* 55, *f.* 3, 4.

Less coloured than the preceding, now and then dark green, sometimes colourless. Branches and branchlets remote, sometimes secund; insertion apical, articulations collapsing. Cell-contents disposed in a lax spiral. Cell-membrane delicately plicate-striate. Primary branches 22μ thick; ultimate branches less than half that diameter; main thread 120μ diam.

In pools.

168. **Cladophora glomerata.** (*Linn.*) *Cooke, Algæ, t.* 56, *f.* 1–4.

Branches in the upper part of the primary thread and branchlets of the second and third order usually fasciculate or penicellate. Cell-contents of the larger cells applied in a net-like or spiral manner to the walls. Fructiferous cells always terminal, with the lower cells sterile. Primary and secondary branches to 60μ diam., 3 to 6 times as long.

In clear streams and rivulets, usually attached to stones.

169. **Cladophora flavescens.** (*Ag.*) *Cooke, Algæ, t.* 55, *f.* 5–7.

Pale yellowish, 6 inches long, very much branched, fasciculate in a plumose manner. Branches patent; ultimate branchlets often rather clavate, patent or incurved.

Cell-membrane often distinctly plicate; cell-contents distributed in a reticulate manner. Diameter of branches 70–80μ, 6 to 12 times as long.

In ditches or pools of brackish or fresh water.

170. **Cladophora canalicularis.** (*Roth.*) *Cooke, Algæ, t.* 56, *f.* 5.

Dichotomously or trichotomously branched. Branches connate at the base, often fasciculately branched above, as in *C. glomerata*. Fructiferous cells terminal. Cell-membrane often thick, now and then swollen; cell-contents arranged in very lax spirals. Lower branches 70–180μ, 4 to 8 times as long.

In ditches, pools, and other standing water.

171. **Cladophora ægagropila.** (*Linn.*) *Cooke, Algæ, t.* 56, *f.* 6.

Dark green, threads rigid, very much branched, radiating from a common centre, at length agglomerated into a very dense, spongy globe. Ramuli erect, often quite obtuse. Articulations sometimes incrassated upwards. Cell-contents not in spirals. Cell-membrane now and then thickened. Branches 40–70μ diam., 2 to 4 or even 12 times as long.

var. **Brownii.** (*Dillw.*)

On stones in streams, etc.

Family IV. PITHOPHORACEÆ.

Cladophora-like algæ, consisting of cells formed by bipartition of the terminal cell, the thallus having two distinct parts—the cauloid and rhizoid part. Spores neutral, quiescent, generally cask-shaped, single.

Genus 64. PITHOPHORA. *Wittr.* (1877.)

Character the same as that of the family given above (Fig. 66).

172. **Pithophora Kewensis.** (*Wittr.*) *Cooke, Algæ, t.* 56, *f.* 8-11.

Principal filament of the cauloid part of the thallus 59μ thick, with solitary branches. Spores single, partly enclosed, partly terminal. Enclosed spores cask-shaped, 80μ thick and 200μ long; terminal spores cask-shaped, upper end conical, top somewhat rounded, 38μ thick and 219μ long. The rhizoid part unicellular.

In tank, Water-lily House, Kew Gardens.

FAMILY V. ŒDOGONIACEÆ.

Monœcious or diœcious. Filaments articulated, either simple or branched. Basal cell obovate-clavate, mostly lobately divided, or ending in a disc. Propagation by zoospores, or by oospores after sexual fecundation. Oogonia single or in a chain (2–5), with a single oospore in each, becoming reddish brown when mature, and dividing into (mostly 4) zoospores. Male plants, dwarf, attached to the female plants, or elongated and similar to the female filaments. Spermatozoids produced in abbreviated special cells.

GENUS 65. **ŒDOGONIUM.** *Link.* (1820.)

Articulated filament simple. Cells marked with transverse striæ at one extremity. Terminal cell sometimes setiform. Either monœcious or diœcious; when diœcious the male plants either dwarf—produced from short cells of the female plants—or elongated and independent. Propagation by asexual zoospores, and by oospores sexually fertilized (Fig. 67).

SECTION 1. Monœcious species.

A. *Oogonia always destitute of median processes.*

a. Oospores globose or subglobose.

173. **Œdogonium Petri.** (*Wittr.*) *Cooke, Algæ, t.* 68, *f.* 1.

Oogonia single, very rarely binate, pear-shaped globose, pore a little above the middle. Oospores rather depressed globose, almost filling the oogonium. Spermogonia 1–2 celled, hypogynous or epigynous. Spermatozoids single (?), terminal cell obtuse. Cells 6–7μ, 5 to 7 times as long; oospore 20–23 × 17–19μ.

In pools, etc., Ireland.

174. **Œdogonium cryptoporum.** (*Wittr.*) *Cooke, Algæ, p.* 153.

Oogonia single, elliptic, or rather depressedly globose, opening by a median pore, almost filling the oogonium Spermogonia 2–7 celled, scattered. Spermatozoids single (?). Cells 7–9μ, 4 to 6 times as long; oospore 22–23 × 19–21μ.

var. β. **vulgare.** (*Wittr.*) *Cooke, Algæ, t.* 68, *f.* 2.

Oogonia 2–5, continuous or single. Spermogonia 1–4 celled, sub-epigynous or hypogynous, or scattered. Cells 5–8μ, 3 to 5 times as long; oospore 16–22 × 13–18μ.

In pools and ditches.

175. **Œdogonium curvum.** (*Prings.*) *Cooke, Algæ, t.* 58, *f.* 3.

Oogonia 2–7 continuous, or single, depressedly globose, opening by a median pore. Oospores depressedly globose, filling the oogonium. Spermogonia 3 or many celled, in the upper part of the filament. Spermatozoids single; upper part of thread arcuate, or spirally twisted. Cells 5–10μ, 1½ to 4 times as long; oospore 20–23 × 16–19μ

In pools, etc , Ireland.

176. **Œdogonium cymatosporum.** (*Wittr. & Nord.*) *Cooke, Algæ, t.* 58, *f.* 4.

Oogonia single, rarely binate, rather depressedly globose, opening by a pore at the middle, nearly filling the oogonium.

Membrane of oospore scrobiculate, pits deep and dense. Spermogonia 1–4 celled. Spermatozoids single. Cells 8–10μ, 4 to 7 times as long; oospore 22–31 × 19–27μ.

In pools and ditches.

177. **Œdogonium minus.** (*Wittr.*) *Cooke, Algæ, t.* 58, *f.* 5.

Oogonia single, depressedly globose, splitting round in the middle, opening by a median pore. Oospores depressedly globose, nearly filling the oogonium. Spermogonia 1–10 celled. Spermatozoids single. Vegetative cells slightly capitate; membrane of vegetative cells and oogonia spirally punctate. Cells 9–13μ, 3 to 6 times as long; oospore 30–42 × 26–36μ.

In pools, etc., Ireland.

178. **Œdogonium vernale.** (*Hass.*) *Cooke, Algæ, t.* 58, *f.* 6.

Oogonia single, obversely egg-shaped or globose, opening with an operculum; fissure narrow. Oospores globose, not filling the oogonium. Spermogonia bicellular, somewhat epigynous. Cells 10–16μ, 4½ to 6 times as long; oospore 34–38 × 34–39μ.

In pools and ditches.

179. **Œdogonium crispum.** (*Hass.*) *Cooke, Algæ, t.* 58, *f.* 7.

Oogonia single, obversely egg-shaped or globose, opening with an operculum; fissure narrow. Oospores nearly globose, not filling the oogonium. Spermogonia 2–5 celled, hypogynous, or sub-epigynous. Spermatozoids binate; terminal cell obtuse. Cells 12–18μ, 2 to 4½ times as long; oospore 33–46 × 34–46μ.

In pools and ditches.

180. **Œdogonium Vaucherii.** (*Le Clerc.*) *Cooke, Algæ, t.* 58, *f.* 8.

Oogonia single, obversely egg-shaped, or globose, or nearly globose, pore above the middle. Oospores globose, not completely filling the oogonium. Spermogonia 2–4 celled, sub-epigynous or hypogynous. Spermatozoids binate. Cells 20–30μ, 1½–4 times as long; oospores 35–50 × 35–52μ.

In pools and ditches.

181. **Œdogonium urbicum.** (*Wittr.*) *Cooke, Algæ, t.* 59, *f.* 1.

Oogonia single, ellipsoid; pore above the middle. Oospores globose, not filling the oogonium. Spermogonia usually 2-celled. Spermatozoids binate; supporting cells destitute of chlorophyl. Cells 16μ, $2\frac{1}{2}$ to 6 times as long; oospore 33–45 × 33–45μ.

In pools, etc., Ireland.

b. Oospores ellipsoid or egg-shaped.

182. **Œdogonium paludosum.** (*Hass.*) *Cooke, Algæ, t.* 59, *f.* 2.

Oogonia single, ellipsoid; pore above the middle. Oospores ellipsoid, filling the oogonium (membrane, when mature, longitudinally costate ?). Spermogonia 1–8 celled, scattered, usually in the upper portion of the filament. Spermatozoids binate, often born with an oblique division. Cells 15–20μ, 3 to 7 times as long; oospore 36–45 × 54–63μ.

In pools and ditches.

B. *Oogonia furnished with verticellate median processes.*

a. Oospores subglobose.

183. **Œdogonium Itzigsohnii.** (*De Bary.*) *Cooke, Algæ, t.* 59, *f.* 3.

Oogonia single, ellipsoid; median processes 7–10, obtusely conical; oogonia splitting below the middle, opening by a pore in the fissure; viewed from above stellate, with 7–10 rays, the depressions between the rays deep and rounded. Oospores globose, not filling the oogonium. Spermogonia 1–2 celled; terminal cell obtuse or apiculate. Cells 8–10μ, 3 to 6 times as long; oospore 22–23 × 22–23μ.

In pools, etc., Ireland, Scotland.

b. Oospores subellipsoid.

184. **Œdogonium excisum.** (*Wittr. & Lund.*) *Cooke, Algæ, t.* 59, *f.* 4.

Oogonia single, biconically oblong; median processes 9, rounded, small; oogonia deeply cut round; vertical view

orbicular, margin slightly undulated. Oospores ellipsoid, as if constricted in the middle, not filling the oogonium. Spermogonia 1–2 celled, sub-epigynous or hypogynous; terminal cell obtuse; upper part of the filament curved. Cells $3\frac{1}{2}$–5μ, 5 to 6 times as long; oospore 9–12×15–18μ.
In pools, etc., Ireland.

185. **Œdogonium Archerianum.** *Cooke, Algæ*, p. 157.

Monœcious. Oospore elliptic, its wall marked by somewhat coarse longitudinal striæ, not filling the cavity of the much larger and elliptic oogonium. Aperture of the oogonium very high up, close to the annular striæ of the caps.
In pools, etc., Ireland.

Section II. Diœcious species.

A. *Dwarf males unicellular.*

a. Oogonia furnished with verticellate median processes.

186. **Œdogonium platygynum.** (*Wittr.*) *Cooke, Algæ, t.* 59, *f.* 5.

Gynandrosporous. Oogonia single (rarely binate), depressedly obverse egg-shaped; median processes 7–12, rounded; oogonia cut round below the middle; pore in the fissure; vertical view orbicular; margin sinate, with 7–12 (usually 8) depressions. Oospores rather depressedly globose, nearly filling the oogonium. Androsporangia 1–3 celled; terminal cell obtuse. Dwarf males obverse egg-shaped, small, seated on the oogonia. Cells 6–10μ, 2 to 5 times as long; oospores 17–24×15–20μ; dwarf males $4\frac{1}{2}$–$5 \times 8\frac{1}{2}$–$9\frac{1}{2}\mu$.
In pools, etc., Ireland.

b. Oogonia destitute of median processes.

a. Oospores globose or subglobose.

187. **Œdogonium Rothii.** (*Le Clerc.*) *Cooke, Algæ, t.* 59, *f.* 6.

Gynandrosporous. Oogonia single, or 2–6 continuous, globose, or rather depressedly globose; pore at the middle.

Oospores rather depressedly globose, almost filling the oogonia. Androsporangia 2–4 celled, sub-hypogynous. Dwarf males obversely egg-shaped, seated on the oogonia. Cells 6–8μ, 3 to 8 times as long; oogonia 20–21 × 16–19μ.
In pools and ditches.

188. **Œdogonium Areschougii.** (*Wittr.*) *Cooke, Algæ, t.* 59, *f.* 7.

Gynandrosporous. Oogonia 2–6, continuous or single, rather depressedly globose, broadly cut round in the middle; pore in the fissure. Oospore exactly globose, not filling the oogonium. Androsporangia 1–6 celled; terminal cell obtuse. Dwarf males obversely egg-shaped, seated on the oogonia. Cells 8–12μ, 4 to 6 times as long; oospore 22–24 × 22–24μ; dwarf males 6–7 × 14–15μ.
In pools, etc., Ireland.

189. **Œdogonium pluviale.** (*Nordst.*) *Cooke, Algæ, t.* 59, *f.* 8.

Idio-androsporous. Oogonia simple, rarely 2–3 continuous, obversely egg-shaped, nearly globose, opening by a terminal operculum. Oospores nearly globose, almost filling the oogonium; terminal cell obtuse; filaments bearing the androsporangia a little slenderer than the female filaments. Androsporangia 6–10 celled. Dwarf males broadly obverse egg-shaped, seated on the oogonia. Cells 18–28μ, equal to three times as long; oospore 32–37 × 31–40μ; dwarf males 10 × 15μ.

190. **Œdogonium undulatum.** (*Breb.*) *Cooke, Algæ, t.* 59, *f.* 9.

Oogonia single or twin, ellipsoid-globose, or nearly globose; pore below the middle. Oospore ellipsoid-globose or nearly globose, nearly filling the oogonia; vegetative cells four times undulatingly constricted; terminal cell obtuse; dwarf males obconical, seated on the supporting cells. Cells 15–17μ, 3 to 5 times as long; oospores 46–50 × 48–60μ; dwarf males 9–10μ long.
In pools, etc., Scotland.

191. **Œdogonium Reinschii.** (*Roy MSS.*) *Cooke, Algæ, t.* 57, *f.* 23.

Mr. Roy has announced that the *Cymatonema* figured by Reinsch (*Contrib. t.* 6, *f.* 7) has been found in Scotland,

and is a genuine *Œdogonium*, but no further details have transpired, and we know nothing of the fructification.

B. *Dwarf males bicellular, spermogonia internal.*

192. **Œdogonium depressum.** (*Prings.*) *Cooke, Algæ, t.* 60, *f.* 1.

Gynandrosporous. Oogonia single, depressedly globose; pore at the middle. Oospores depressedly globose, not filling the oogonia. Androsporangia 2-celled. Dwarf males oblong, obversely egg-shaped, one-third shorter than the oogonia on which they are seated. Cells 8–9μ, 3 to 6 times as long; oogonia 28 × 26μ; oospores 23 × 17μ.
In pools, etc., Scotland.

C. *Dwarf males bi-multicellular, spermogonia external.*

* Oospores with smooth membrane.

a. Oospores globose or subglobose.

193. **Œdogonium flavescens.** (*Hass.*) *Cooke, Algæ, t.* 60, *f.* 2.

Idio-androsporous. Oogonia single, egg-shaped globose; pore a little above the middle. Oospores globose, not filling the oogonia. Androsporangia 1–9 celled. Dwarf males a little curved, seated on the supporting cell. Spermogonia 1 (or 2?) celled. Cells 18–21μ by 4½ to 6 times as long; oospore 45–49 × 45–49μ.
In pools and ditches.

194. **Œdogonium Braunii.** (*Kutz.*) *Cooke, Algæ, t.* 60, *f.* 3.

Gynandrosporous. Oogonia single, ellipsoid, globose; pore at the middle. Oospores globose, not filling the oogonia. Androsporangia 1–2 celled. Dwarf males a little curved, seated about the oogonium. Spermogonia 1-celled. Cells 13–15μ, 2 to 4 times as long; oospore 27–29 × 27–29μ.
In pools, etc.

195. **Œdogonium macrandum.** (*Wittr.*) *Cooke, Algæ, t.* 60, *f.* 4.

Oogonia single or twin (rarely 3), obversely egg-shaped or globosely egg-shaped, opening by an operculum,

with a very narrow fissure. Oospores globose or egg-shaped, not filling the oogonia; terminal cell shortly apiculate. Dwarf males much curved, seated on the oogonia. Spermogonia many (to 7) celled. Cells 15–16μ, 3 to 5 times as long; oospores 31–34 × 33–39μ.

In pools and ditches.

196. **Œdogonium crassiusculum.** (*Wittr.*) *Cooke, Algæ, t.* 60, *f.* 5.

Gynandrosporous. Oogonia single or twin, globose egg-shaped or nearly globose; pore above the middle. Oospores ellipsoid-globose or globose; membrane very thick, almost filling the oogonia. Androsporangia 2–5 celled. Dwarf males nearly straight, seated on or about the supporting cells. Spermogonia 1 (?) celled. Cells 27–30μ, $3\frac{1}{2}$ to 5 times as long; oospores 51–57 × 52–63μ.

In pools and ditches.

b. Oospores ellipsoid or egg-shaped.

197. **Œdogonium Borisianum.** (*Le Clerc.*) *Cooke, Algæ, t.* 60, *f.* 6.

Gynandrosporous. Oogonia single or twin, obversely egg-shaped; pore above the middle. Oospores obversely egg-shaped, almost filling the oogonia; supporting cells swollen. Androsporangia 2 (?) celled; terminal cell obtuse. Dwarf males a little curved, seated on the supporting cells. Spermogonia unicellular. Cells 15–21μ, 3 to 5 times as long; supporting cells twice as long; oospores 40–44 × 51–54μ.

In pools and ditches.

198. **Œdogonium concatenatum.** (*Hass.*) *Cooke, Algæ, t.* 61, *f.* 1.

Gynandrosporous. Oogonia 2–6 continuous, or single, egg-shaped, or quadrangularly ellipsoid; pore above the middle. Oospores filling the oogonia. Sporoderm delicately porose; supporting cell swollen. Androsporangia 2–4 celled; terminal cell obtuse. Dwarf males curved, seated on the supporting cells. Spermogonia 2–4 celled. Cells

25–40μ, 3 to 10 times as long; supporting cells 2½ times as long; oospores 65–76 × 87–95μ.

In pools and ditches.

199. **Œdogonium acrosporum.** (*De Bary.*) *Cooke, Algæ, t.* 61, *f.* 2.

Idio-androsporous. Oogonia solitary, terminal, ellipsoid, opening by a small apical deciduous operculum. Oospore filling the oogonia; membrane longitudinally costate. Supporting cells often swollen; terminal cells obtuse. Dwarf males curved, seated on the supporting cells. Spermogonia 1–2 celled. Cells 10–14μ, 2 to 7 times as long; supporting cells 2 to 3 times as long; oogonia 30–35 × 45–51μ.

In pools and ditches.

200. **Œdogonium ciliatum.** (*Hass.*) *Cooke, Algæ, t.* 61, *f.* 3.

Gynandrosporous. Oogonia 2–7, continuous or single, egg-shaped, opening by an operculum, with a broad fissure. Oospores egg-shaped, nearly filling the oogonia. Androsporangia 2–8 celled; terminal cell setiform. Dwarf males curved, seated on the oogonium. Spermogonia unicellular. Cells 15–23μ, 2½ to 4 times as long; oospore 40–46 × 47–57μ.

In pools and ditches.

** Membrane of oospore echinulate. Oospores globose.

201. **Œdogonium Cleveanum.** (*Wittr.*) *Cooke, Algæ, t.* 62, *f.* 1.

Gynandrosporous. Oogonia single, subglobose; pore below the middle. Oospores almost filling the oogonium, globose, spinulose; spines conical, spirally disposed. Androsporangia 4–6 celled. Dwarf males a little curved, seated on the supporting cell. Spermogonia unicellular. Cells 18–26μ, 3 to 7 times as long; oospores 49–57 × 51–59μ; spines 4μ long.

In pools and ditches, Ireland.

202. **Œdogonium echinospermum.** (*Br.*) *Cooke, Algæ, t.* 62, *f.* 2.

Gynandrosporous, or idio-androsporous. Oogonia single, ellipsoid-globose, or nearly globose; pore at the middle.

Oospore almost filling the oogonia, globose, echinulate; spines awl-shaped. Androsporangia 2–5 celled. Dwarf males a little curved, seated on the supporting cells. Spermogonia unicellular. Cells 18–3μ, $2\frac{1}{2}$ to $4\frac{1}{2}$ times as long; oospore 38–47 × 38–49μ; spines 3μ long.

In pools and ditches.

SUB-SECTION II. Diœcious, with elongated male plants.

a. Oogonia not, or scarcely, swollen.

203. **Œdogonium capillare.** (*Linn.*) *Cooke, Algæ, t.* 62, *f.* 3.

Oogonia single, not swollen, cylindrical; pore above the middle. Oospores globose or cylindrical-globose, not filling the oogonia. Male plants the same, or almost the thickness of the female plants. Spermogonia 1–4 celled, alternate with the vegetative cells. Spermatozoids binate. Cells 35–55μ, equal or twice as long; oospore 30–52 × 39–63μ.

In pools and ditches.

204. **Œdogonium capilliforme.** (*Kutz.*) *Cooke, Algæ, t.* 129, *f.* 4.

Oogonia single, a little swollen, obversely egg-shaped, with a superior pore. Oospores ellipsoid-globose or cylindrically globose, not filling the oogonia. Male plants more slender than the females. Spermogonia 2–10 celled, alternating with the vegetative cells; terminal cell obtuse. Cells of female 30–34μ, $1\frac{1}{4}$ to 3 times as long; of male 24–28 mm., $1\frac{1}{2}$ times as long; oospore 37–45 × 40–50μ.

In pools and ditches.

b. Oospores manifestly swollen.

aa. Oospores globose, or nearly so.

205. **Œdogonium calcareum.** (*Cleve.*) *Cooke, Algæ, t.* 62, *f.* 4.

Oogonia single (very rarely twin), depressedly globose; pore at the middle. Oospores filling the oogonia. Male plants the same, or almost the same, thickness as the female. Spermogonia 2–5 celled. Spermatozoids single (?). Cells 11–14μ, 2 to 4 times as long; oospore 26–28 × 20–21μ.

In pools and ditches.

206. **Œdogonium cardiacum.** (*Hass.*) *Cooke, Algæ, t.* 62, *f.* 5.

Oogonia single, between heart-shaped and globose; pore a little above the middle. Oospores globose, not filling the oogonia. Male plants slenderer than the female. Spermogonia 2–10 celled. Spermatozoids binate; terminal cells obtuse. Cells: fem. 18–30μ, 2–7 times as long; male 15–25μ, 2 to 6 times as long; oospore 42–60 × 42–60μ.
In pools and ditches.

207. **Œdogonium carbonicum.** (*Wittr.*) *Cooke, Algæ, t.* 63, *f.* 1.

Oogonia single or twin, obversely egg-shaped—or ovate—globose; pore above the middle. Oospores nearly globose, scarce filling the oogonia. Male plants slenderer than the female. Spermogonia 2–5 celled. Spermatozoids binate; terminal cell obtuse. Cells: fem. 16–30μ, 3 to 6 times as long; male 14–16 mm., 3 to 6 times as long; oospore 42–50 × 46–56μ.
In pools and ditches.

208. **Œdogonium Pringsheimii.** (*Cramer.*) *Cooke, Algæ, t.* 63, *f.* 2.

Oogonia single or 2–6 continuous, somewhat egg-shaped globose, opening by an operculum, with a very narrow fissure. Oospores globose, not filling the oogonia. Male plants slenderer than the female. Spermogonia 2–10 celled, alternate with the vegetative cells in the upper part of the filament; terminal cell obtuse or rarely shortly apiculate. Cells: fem. 12–20μ, 2 to 4 times as long; male 11–16 mm. 2 to 4 times as long; oospore 28–35 × 28–34μ.
In pools and ditches.

209. **Œdogonium punctato-striatum.** (*De Bary.*) *Cooke, Algæ, t.* 63, *f.* 3.

Oogonia single, depressedly globose, manifestly splitting round in the middle; pore in the fissure. Oospore depressedly globose, nearly filling the oogonia. Male plants slenderer than the female. Spermogonia 3–7 celled. Spermatozoids single. Membrane of the vegetative cells and oogonia spirally punctate; basal cell depressedly globose; membrane vertically plicate. Cells: fem 18–22μ, 2 to

6 times as large; male 16–19μ, 2 to 6 times as long; oospore 44–51 × 35–43μ.

In pools and ditches, Ireland.

bb. Oospores ellipsoid or egg-shaped.

210. **Œdogonium Boscii.** (*Le Clerc.*) *Cooke, Algæ, t.* 63, *f.* 4.

Oogonia single, rarely twin, oblong-ellipsoid; pore above the middle. Oospores ellipsoid, by no means filling the oogonia, longitudinally costate. Male plants the same, or nearly the thickness of the female. Spermogonia 3–6 celled. Spermatozoids binate; terminal cell slenderer and somewhat hyaline. Cells 14–20μ, 4 to 6 times as long; oospore 36–40 × 60–65μ.

In pools, etc.

211. **Œdogonium tumidulum.** (*Kutz.*) *Cooke, Algæ, t.* 63, *f.* 5.

Oogonia single, ellipsoid egg-shaped; pore above the middle, almost filling the oogonium. Male plants a little slenderer than the female. Spermogonia 6–45 celled. Spermatozoids binate. Cells: fem. 18–25μ, 3½ to 5 times as long; male 15–18μ, 4 times as long; oospore 49–54 × 61–68μ.

In pools and ditches, Ireland.

212. **Œdogonium Landsboroughii.** (*Hass.*) *Cooke, Algæ, t.* 64, *f.* 1.

Oogonia single, rarely twin, obversely egg-shaped; pore above the middle. Oospores obversely egg-shaped, filling the oogonia (or rarely ellipsoid and not filling the oogonia). Male plants slenderer than the female. Spermogonia 5–25 celled. Spermatozoids binate, with a vertical division; terminal cell obtuse. Cells: fem. 33–36μ, 4 to 6 times as long; male 31–33μ, 4 to 6 times as long; oospore 57–70 × 75–100μ.

In pools and ditches.

var. β. **gemelliparum.** (*Prings.*) *Cooke, Algæ, t.* 64, *f.* 2.

Smaller than the typical form. Oogonia egg-shaped. Oospores filling the oogonia; terminal cell very long,

somewhat hyaline. Cells: fem. 20–27μ, 3 to 5 or 8 times as long; oospore 49–51 × 65–69μ.

In pools and ditches, Ireland.

213. **Œdogonium rivulare.** (*Le Clerc.*) *Cooke, Algæ, t.* 64, *f.* 3.

Oogonia single, or 2–7 continuous, obversely egg-shaped; pore above the middle. Oospores obversely egg-shaped, rarely ellipsoid or nearly globose, not filling the oogonia. Male plants slenderer than the female. Spermogonia 3–9 celled. Spermatozoids binate. Cells: fem. 40–45 mm., 3 to 8 times as long; male 30–36μ, 4 times as long; oospore 55–70 × 65–100μ.

In pools and ditches, Scotland.

SUB-SECTION 3. Species of which fructification imperfectly known.

a. Oospores globose or subglobose

214. **Œdogonium delicatulum.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 7.

Pallid. Basal cell scarcely lobed at the base, affixed. Cells cylindrical. Oogonia subglobose, inflated, a little extended at either pole. Oospore perfectly globose. Cells 5–6μ, 3 times as long; oospores 12–14μ.

In pools, etc., Deeside (Scotland).

215. **Œdogonium tenellum.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 6.

Basal cell 2 to 3 lobed, at first fixed; terminal joint obtuse. Cells cylindrical or rather clavate. Oogonia very much inflated. Oospore globose, bright orange. Cells 9–11μ, 4 to 8 times as long; oospore 16–18μ.

In pools, etc., Deeside (Scotland).

216. **Œdogonium hexagonum.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 8.

Oogonia almost globose. Oospores globose, rufous-brown, not filling the oogonia. Basal cell bifurcate; terminal cell often setigerous. Cells 11–13μ, 2 to 4 times as long; oospore 16μ.

In pools, etc., Deeside (Scotland).

217. **Œdogonium Londinense.** (*Wittr.*) *Cooke, Algæ, t.* 65, *f.* 4.

Monœcious (?) Oogonia twin or single, globose, cut round (circumscissile) in the middle, pore seated in the fissure. Oospores globose, almost filling the oogonia. Spermogonia (or androsporangia ?) 1–2 celled, hypogynous. Cells 10–15μ, $1\frac{1}{2}$ to 5 times as long ; oospore 27–32 × 27–32μ.

In pools, etc.

218. **Œdogonium fasciatum.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 2.

Oogonia somewhat globose. Oospores globose, rufous-brown, almost filling the oogonia. Basal cell usually bilobate ; terminal cell obtuse. Cells 28–30μ, twice as long ; oospore 30–32μ.

In pools, etc., Deeside (Scotland).

219. **Œdogonium capillaceum.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 3.

Dark green. Basal cell attenuated downwards, bifid ; terminal point obtuse. Cells sub-cylindrical. Oogonia broadly elliptical, 2–4 often contiguous, opening by a lateral pore. Oospore nearly globose, rufous-brown when matured, loosely involved in the oogonium. Cells 20–25μ, $1\frac{1}{2}$ to 3 times as long ; oospore 30–32μ.

In pools, etc., Deeside (Scotland).

220. **Œdogonium Hutchinsiæ.** (*Wittr.*) *Cooke, Algæ, t.* 65, *f.* 1.

Oogonia single, rather depressedly to somewhat egg-shaped, globose ; pore above the middle. Oospores filling the oogonium ; epispore punctate with little warts ; supporting cells swollen. Cells 30–35μ, 4 to 6 times as long ; oospores 60–73 × 55–72μ ; supporting cells 2 to 4 times as long.

In pools, etc., Ireland.

221. **Œdogonium princeps.** (*Hass.*) *Cooke, Algæ, t.* 65, *f.* 2.

Oogonia single, somewhat egg-shaped globose ; pore above the middle. Oospores globose, not distinctly filling the oogonium. Cells 37–45μ, $1\frac{1}{4}$ to $2\frac{1}{4}$ times as long ; oospore 58–66 × 60–65μ.

In pools and ditches.

b. Oospores subelliptic or oval.

222. **Œdogonium longatum.** (*Kutz.*) *Cooke, Algæ, t.* 64, *f.* 4.

Oogonia single (often solitary, terminal), rarely 2–3 continuous, ellipsoid, opening by an operculum, with a narrow fissure. Oospores globosely ellipsoid, scarcely filling the oogonium; terminal cell obtuse. Cells 5–6μ, 2 to 3 times as long; oospores 15–16 × 17–18μ.

In pools and ditches.

223. **Œdogonium vesicatum.** (*Lyngb.*) *Cooke, Algæ, t.* 65, *f.* 5.

Oogonia single, ellipsoid, globose, opening by an operculum, with a narrow fissure. Oospores ellipsoid-globose, almost filling the oogonium. Cells 17–21μ, 1¼ to 3 times as long; oospore 37–38 × 41–42μ.

In pools, etc., Scotland.

224. **Œdogonium grande.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 4.

Oogonia oval-elliptic, nearly twice as long as broad. Oospores oval-elliptic, entirely filling the oogonia. Basal cell contracted towards the base, then dilated and discoid; terminal cell obtuse. Cells 25–35μ, 3 to 4 or 5 times as long; oospore 90 × 65μ.

In pools, etc., Scotland.

225. **Œdogonium giganteum.** (*Kutz.*) *Cooke, Algæ, t.* 65, *f.* 3.

Oogonia single, a little swollen, cylindrically egg-shaped; pore above the middle. Oospores cylindrically ellipsoid, nearly filling the oogonia (or flask-shaped and filling the oogonia). Epispore delicately scrobiculate; supporting cells rather swollen. Cells 30–24μ, 2 to 4½ times as long; supporting cells 1½ to 1¾ times as long; oospore 54–65 × 75–103μ.

In pools, etc.

226. **Œdogonium crassum.** (*Hass.*) *Cooke, Algæ, t.* 66, *f.* 1.

Oogonia single (rarely twin), obversely egg-shaped ellipsoid, a little swollen; pore above the middle. Oospores

ellipsoid, not filling the oogonia. Cells 33–55μ, 2 to 5 times as long; oospore 60–66 × 80–110μ.

In pools, etc.

227. **Œdogonium subsetaceum.** (*Kutz.*) *Cooke, Algæ, t.* 66, *f.* 5.

Basal cell dilated and discoid at the base, rather lobed; terminal joint obtuse. Oospores broadly oval, golden red, closely involved in the oogonium. Cells 40–52μ, equal or twice as long; oospore 60 × 50μ.

In pools, etc., Deeside (Scotland).

Genus 66. BULBOCHŒTE. *Ag.* (1817.)

Filaments articulated, branched, joints thickened upwards, at or about the apex bearing setæ, straight, hyaline, bulbous at the base. Cell-membrane usually punctate. Oogonia opening by a lateral pore above the middle. Mature oospore red. Monœcious or diœcious. Reproduction sexual, as in *Œdogonium* (Fig. 68).

Section 1. Oogonia globose or subglobose; diœcious.

B. *Dwarf males bicellular.*

228. **Bulbochœte intermedia.** (*De Bary.*) *Cooke, Algæ, t.* 67, *f.* 1.

Oogonia depressedly globose, seated beneath the androsporangia; dissepiment of supporting cell in the middle. Epispore delicately crenulate. Androsporangia 1–2 celled, epigynous, rarely scattered. Dwarf males seated on the oogonia. Stem slightly curved. Cells 17–19μ, 1½ to 3 times as long; oogonia 40–48 × 31–40μ; dwarf males 9–10 × 24–26μ.

In ditches, etc.

229. **Bulbochœte polyandra.** (*Cleve.*) *Cooke, Algæ, t.* 67, *f.* 2.

Idio-androsporous. Oogonia sub-depressedly globose, seated beneath terminal setæ or vegetative cells; dissepiment of supporting cell above, or about the middle. Epispore delicately crenulate or nearly even. Andro-

sporangia 4–10 celled. Dwarf males seated on the oogonia. Stem a little curved. Cells 15–20μ, 3 to 5 times as long; oogonia 35–46 × 32–38μ; dwarf males 8–9 × 23μ.
In ditches, etc.

230. **Bulbochœte Brebissonii.** (*Kutz.*) *Cooke, Algæ, t.* 67, *f.* 3.

Oogonia obcordate-globose, truncate below, erect, seated beneath terminal setæ or androsporangia; dissepiment of supporting cell low. Epispore delicately crenulate. Androsporangia 2–3 celled, scattered or epigynous. Dwarf males seated on the oogonia, rarely around it. Stem straight, or nearly so. Cells 17–20μ by 3 to 4½ times as long; oogonia 42–50 × 37–45μ; dwarf males 10–12 × 28–33μ.
In pools, etc.

231. **Bulbochœte setigera.** (*Ag.*) *Cooke, Algæ, t.* 68, *f.* 1.

Oogonia depressedly globose, seated beneath terminal setæ, or androsporangia. Membrane of the oogonium after fertilization thickened; dissepiment of supporting cell a little above the middle. Epispore granulated. Androsporangia bicellular. Dwarf males upon or about the oogonia. Stem straight. Cells 25–28μ, 2½ to 5 times as long; oogonia 75–80 × 60–65μ; dwarf males, 12–13 × 34–36μ.
In pools and ditches.

232. **Bulbochœte gigantea.** (*Prings.*) *Cooke, Algæ, t.* 68, *f.* 4.

Idio-androsporous (?) Oogonia obcordate-globose, seated beneath terminal setæ, rarely beneath vegetative cells; dissepiment of supporting cell at or a little above the middle. Epispore verrucose. Dwarf males a little longer than the oogonia, and seated upon it. Stem twice as long as the spermogonium, arcuate. Cells 24–27μ, by 2 to 3 times as long; oogonia 62–66 × 51–58μ; stem of dwarf males 11–12 × 40–45μ.
In pools and ditches.

Section 2. Oogonia ellipsoid or subellipsoid.

Sub-Section 1. Species monœcious.

233. **Bulbochœte mirabilis.** (*Wittr.*) *Cooke, Algæ, t.* 68, *f.* 2.

Oogonia ellipsoid, or rather oblong-ellipsoid, patent, or rarely erect, seated beneath terminal setæ or vegetative cells. Spermogonia 2–4 celled, erect (rarely patent), subepigynous, or scattered. Cells 16–20μ, $1\frac{1}{4}$ to $1\frac{3}{4}$ times as long; oogonia 27–35 × 46–56μ.

In pools and ditches.

Sub-Section 2. Species diœcious.

234. **Bulbochœte pygmœa.** (*Wittr.*) *Cooke, Algæ, t.* 68, *f.* 5.

Oogonia ellipsoid, patent, seated beneath terminal setæ or vegetative cells, in longitudinal section rather quadrangular. Androsporangia scattered. Dwarf males seated about the oogonia. (Filament at first short, and curved.) Cells 12–15μ × a third part shorter or equal; oogonia 23–25 × 34–40μ.

In ditches, etc.

235. **Bulbochœte insignis.** (*Prings.*) *Cooke, Algæ, t.* 67, *f.* 4.

Oogonia ellipsoid, patent or erect, seated beneath androsporangia or terminal setæ. Epispore delicately transversely striate. Androsporangia epigynous, or rarely scattered. Dwarf males seated about or upon the oogonia. Cells 20–25μ, $2\frac{1}{2}$ to $4\frac{1}{2}$ times as long; oogonia 46–50 × 70–100μ; stem of dwarf males 17–19 × 29–31μ.

In pools, etc., Ireland.

236. **Bulbochœte rectangularis.** (*Wittr.*) *Cooke, Algæ, t.* 67, *f.* 3.

Oogonia ellipsoid, patent, or rarely erect, seated beneath terminal setæ, or androsporangia, or vegetative cells. Androsporangia scattered or epigynous. Vegetative cells somewhat rectangular in longitudinal section. Branches few and very long. Dwarf males seated about or upon

the oogonia. Cells 19–23μ, $1\frac{1}{4}$ to 2 times as long; oogonia 30–39 × 48–55μ; stem of dwarf males 15–18 × 22–27μ.

In pools, etc., Ireland.

SECTION 3. Species of which fructification imperfectly known.

237. **Bulbochœte gracilis.** (*Prings.*) *Cooke, Algæ, t.* 66, *f.* 9.

Monœcious (?). Oogonia oblong-ellipsoid, patent or rarely erect, with vegetative cells above; supporting cells without dissepiment (?). Cells 13–14μ, $1\frac{1}{4}$ to $1\frac{1}{2}$ times as long; oogonia 21–24 × 49–54μ.

In pools, etc., Ireland.

FAMILY VI. ULOTRICHEÆ.

Aquatic or terrestrial, green or yellowish green. Threads very shortly articulate, simple, very rarely dividing into single branches, free, now and then laterally connate in bands. Primitive cells always many times longer than their diameter; after repeated division equal, or shorter; all fertile. Cell-membrane sometimes very thick, and distinctly lamellose. Cell-contents at first effused, after division transmuted into gonidia. Gonidia of two kinds, produced within the cells of the threads, emitted either by a poriform opening, or by the breaking up of the mother-cell.

GENUS 67. HORMISCIA. *Ares.* (1866.)

Articulate thread fixed by the basal cell, attenuated downwards; simple, or now and then emitting branchlets. Cells abbreviated, with a thick cell-membrane, often lamellose. Cell-contents green. Propagation by macrogonidia and microgonidia (Fig. 69).

238. **Hormiscia moniliformis.** (*Kutz.*) *Cooke, Algæ, t.* 70, *f.* 1.

Pale green, more or less crispate. Cells equal or a little shorter than their diameter. Cell-membrane thick, colourless, somewhat lamellose, more or less constricted at the septa. Cells 11–14μ diam.

In swamps, amongst *Sphagnum*, etc.

239. **Hormiscia zonata.** (*Web. & M.*) *Cooke, Algæ, t.* 69.

More or less bright green, mucous, 2 or 3 feet long, often less, either floating or interwoven. Sterile cells equal, or half their diameter; fructiferous cells usually a little longer than broad. Cell-membrane thick, slightly constricted at the septa. Cells 12–40μ; macrozoospores 12–18 × 10–12μ; microzoospores 5–10 × 4–7μ.

In ditches, ponds, swamps, etc.

240. **Hormiscia æqualis.** (*Kutz.*) *Cooke, Algæ, p.* 180.

Yellowish green. Cells equal, or a little longer than their diameter. Cell-membrane rather thick.

var. **catenæformis.** (*Kutz.*) *Cooke, Algæ, t.* 70, *f.* 2.

Rather thicker than in the typical form. Cells a little longer than their diameter. Cell-membrane thick, striate, manifestly constricted at the septa. Cells 12–18μ diam.

In ditches and streams, attached to aquatic plants.

241. **Hormiscia speciosa.** (*Carm.*) *Cooke, Algæ, t.* 70, *f.* 3.

Dark green, 1–2 inches long. Threads often crispate. Cells 2 to 4 times shorter than their diameter; fructiferous cells subglobose. Cells 43–48μ diam.

In brackish and fresh water.

242. **Hormiscia bicolor.** (*Eng. Bot.*) *Cooke, Algæ, t.* 70, *f.* 7.

Bright green. Tufts very long, 1 foot or more. Articulations 2 to 3 times shorter than their diameter, pectinate. Cell-membrane thick, distinctly lamellose. Cells 5μ diam.

In fresh water.

GENUS 68. **ULOTHRIX.** *Kutz.* (1845.)

Threads articulate, simple. Articulations short, sometimes shorter than their diameter, rarely a little longer. Cell-membrane thin, very rarely lamellose. Cell-contents effused, green (Fig. 70).

243. **Ulothrix variabilis.** (*Kutz.*) *Cooke, Algæ, t.* 70, *f.* 4.

Pale green. Cells equal, or a little longer than their diameter, rarely twice as long. Cell-contents at first always contracted in a quadrate manner. Cells 5–7μ.

In ditches and slow streams.

244. **Ulothrix tenerrima.** (*Kutz.*) *Cooke, Algæ, t.* 70, *f.* 5.

Pale green or yellowish green, lubricous. Cells mostly equal in length and diameter, now and then a little shorter. Cells 7–10μ.

In ditches, turbaries, etc.

245. **Ulothrix tenuis.** (*Kutz.*) *Cooke, Algæ, t.* 70, *f.* 6.

Dark green, attached, from $\frac{1}{2}$ to 2 or 3 inches long, mucous. Cells equal, or 2 to 4 times shorter than their diameter. Cell-membrane thin, homogeneous. Cells 17–26μ.

In ditches and streamlets.

246. **Ulothrix (Hormidium) radicans.** (*Kutz.*) *Cooke, Algæ, t.* 71, *f.* 1.

Yellowish green, rather rigid, densely interwoven in a soft velvety green stratum. Cells either nearly equal or 2 to 3 times shorter than their diameter. Cells $7\frac{1}{2}$–$9\frac{1}{2}\mu$.

On the naked ground, rocks, walls, etc.

247. **Ulothrix (Hormidium) parietina.** (*Vauch.*) *Cooke, Algæ, t.* 71, *f.* 2.

Bright yellowish green, flexuous and interwoven. Cells half as long as broad. Cell-membrane thin, hyaline, homogeneous. Cells 9–16μ

On walls, trunks, etc.

Genus 69. SCHIZOGONIUM. *Kutz.* (1843.)

Threads as in *Ulothrix*, or in many places laterally connate, or by cellular division in two directions forming narrow flat bands, which are more or less crispate (Fig. 73).

248. **Schizogonium murale.** (*Kutz.*) *Cooke, Algæ, t.* 71, *f.* 3.

Dark green, forming a broadly expanded soft velvety stratum. Threads sometimes free, here and there 2 or 3 united. Cells 2 to 4 times shorter than their diameter, pectinate, often crowded, sometimes interrupted. Cell-membrane rather thick, colourless, slightly undulated and constricted. Cells 15–18μ.

On moist walls and naked ground.

Family VII. CHROOLEPIDEÆ.

Aerial algæ, coloured golden yellow, etc., when dry often becoming greenish grey; more or less fragrant. Threads articulate, branched. Cell-membrane thick, firm, collected in minute tufts, or densely interwoven in a tomentose stratum. Cell-contents oily, red, orange, or yellow brown. Propagation by zoogonidia, produced in proper cells. Zoogonidia oblong-oval, with two vibratile cilia.

Genus 70. CHROOLEPUS. *Ag.* (1824.)

Characters the same as given above for the family (Fig. 72).

249. **Chroolepus aureus.** (*Linn.*) *Cooke, Algæ, t.* 72, *f.* 1.

Golden red or orange. Threads either collected in small tufts, or spreading in a soft silky stratum, sometimes intricate and very much branched. Cells as long, or 2

to 3 times as long as their diameter. Cells 10–12μ diam.; zoosporangium 20–30μ.

On walls, rocks, chips, bark, etc.

250. **Chroolepus odoratus.** (*Lyngb.*) *Cooke, Algæ, t.* 72, *f*. 2.

Stratum thin, rather tomentose, rufous-tawny (when dry, cinereous). Threads and branches abbreviated, erect, parallel, flexuously curved, torulose. Cells equal, or twice as long as their diameter. Cells 20–25μ diam.

On the bark of various trees.

251. **Chroolepus Iolithus.** (*Linn.*) *Cooke, Algæ, t.* 72, *f*. 4.

Stratum thin, or a line thick, reddish orange, glaucous or dirty greenish when dry. Threads and branches elongated, rather dichotomous, variously curved, ascending. Cells $1\frac{1}{2}$ or 3 times as long as their diameter, in the upper portion of the branches reaching to double that proportion. Cells 25–40μ diam.; zoosporangium 50μ diam.

On rocks, in moist places.

252. **Chroolepus ilicicolus.** (*Eng. Bot.*) *Cooke, Algæ, t.* 72, *f*. 5.

Filaments erect, alternately branched, forming tufts of a permanent tawny yellow. Cells nearly as long as broad, about 30μ diam.

On holly bark.

253. **Chroolepus umbrinum.** (*Kutz.*) *Cooke, Algæ, t.* 130, *f*. 2.

Stratum thin, crustaceous, rather pulverulent, reddish brown, growing pale when dead. Threads and branches abbreviated, torulose. Joints nearly as long as broad, broadly elliptic or subglobose. Cells 20μ diam.

On the bark of beech and oak.

254. **Chroolepus lichenicolus.** (*Ag.*) *Cooke, Algæ, t.* 72, *f*. 3.

Tufts red orange. Threads erect, tufted, alternately branched, rigid. Cells slightly tumid, as long as broad. Cells 12μ diam.; zoosporangium about 15μ diam.

On lichens and old trees.

Family VIII. CHÆTOPHORACEÆ.

Aquatic, rarely terrestrial, monœcious or diœcious. Articulate filaments, often dichotomously, not rarely fasciculately branched, accumulated in tufts, nestling in a fluid or gelatinous mucus, or constituting a filamentose, rarely a somewhat foliaceous thallus. Propagation by oospores after sexual fecundation, or by zoogonidia.

Genus 71. **MICROTHAMNION.** *Näg.* (1849.)

Articulate filament dichotomously or trichotomously branched, straight, with the terminal cell obtuse, or nearly so, afterwards swollen, forming a sporangium. Cell-contents effused. Propagation by zoogonidia (Fig. 71).

255. **Microthamnion vexator.** *Cooke, Algæ, t.* 73, *f.* 1.

Filaments erect, very slender, dichotomously branched, more or less growing in tufts. Cells cylindrical, longer than broad, not at all constricted at the joints. Dissepiments scarcely visible. Cell-membrane thin, pellucid. Cells about 3μ diam.

Attached to aquatic plants in clear springs, etc.

Genus 72. **STIGEOCLONIUM.** *Kutz.* (1843.)

Articulate threads branched. Branches scattered, rarely approximate in a fasciculate manner, acute at the apex, sometimes attenuated into a colourless bristle; at times extended very long, at other times furnished with shortly subulate branches. Cell-membrane very thin. Cell-contents with the chlorophyl arranged in transverse bands. Propagation by oospores or zoogonidia, each zoospore with four vibratile cilia (Fig. 75).

256. **Stigeoclonium thermale.** (*Braun.*) *Cooke, Algæ, t.* 73, *f.* 2.

Bright green, branched in a fasciculate manner, creeping at the base. Branches attenuated upwards to the cuspidate apex. Branchlets for the most part alternate, rather remote, nearly erect, setiform. Joints variable, at the base of the filaments equal or twice as long as the diameter, in the upper part of the branchlets 3 to 5 times as long as the diameter. Chlorophyl bands broad, sometimes effused. Cells 12μ.

In thermal springs, etc.

257. **Stigeoclonium tenue.** (*Ag.*) *Cooke, Algæ, t.* 73, *f.* 3.

Bright green, lubricous. Filaments a little branched. Branches nearly simple. Cells equal, or 2 to 3 times as long as their diameter, more or less constricted. Chlorophyl bands narrow. Branchlets scattered, shortened, nearly erect, subulate. Cells at the base longer than broad, abbreviated towards the apex. Cells 10μ diam.

In streams and ditches.

258. **Stigeoclonium protensum.** (*Dillw.*) *Cooke, Algæ, t.* 74, *f.* 1.

Pale green, cœspitose, slender. Filaments and branches long drawn out. Cells almost cylindrical, equal or twice as long as their diameter; terminal cell extended into a colourless bristle. Branches usually scattered, rarely in pairs, with the extremities cuspidate, piliferous. Cells 15μ diam.

In slow streams.

259. **Stigeoclonium nanum.** (*Dillw.*) *Cooke, Algæ, t.* 74, *f.* 2.

Filaments alternately branched. Branches abbreviated, a little attenuated upwards, obtuse, not piliferous. Cells equal or a little shorter than their diameter, in the upper part equal. Cells 8μ diam.

In streams.

260. **Stigeoclonium fastigiatum.** (*Ralfs.*) *Cooke, Algæ, t.* 74, *f.* 3.

Pale green, small. Thread very much branched, fastigiate, radiately disposed, mucous. Upper branches alternate, fastigiate, moniliform, somewhat pinnate, a little spreading, extended at the apex in a long bristle. Cells of the filament three times as long as broad; of the branches, equal or twice as long, swollen, constricted at the joints. Cells 12μ diam.

Attached to aquatic plants.

GENUS 73. **DRAPARNALDIA.** *Ag.* (1824.)

Articulate thread simply branched, formed of large cells, for the most part hyaline, with a broad chlorophyllose band; more or less densely furnished with penicellate fasciculate branchlets, alternate or opposite, composed of smaller fertile cells. Terminal cells hyaline and more or less elongated into a bristle. Propagation by resting spores or zoogonidia (Fig. 74).

261. **Draparnaldia glomerata.** (*Ag.*) *Cooke, Algæ, t.* 75, *f.* 1.

Filaments and primary branches colourless, or nearly so. Lower cells equal, or a little shorter than their diameter, distinctly constricted at the joints. Chlorophyllose bands narrow, pale green. Primary branches spreading at right angles, sometimes opposite; fascicles of the branches crowded, alternate or opposite, densely branched, obtuse, oval. Cells of main thread 35μ; of fascicles 8μ.

In clear pools or slow streams.

262. **Draparnaldia plumosa.** (*Vauch.*) *Cooke, Algæ, t.* 76, *f.* 1.

Threads and primary branches hyaline. Cells equal or shorter than their diameter, scarcely constricted at the joints. Chlorophyllose bands narrow, bright green. Lower cells of the branches equal, or almost twice as long as their diameter; upper cells cylindrical, attenuated, 2 to 5 times as long as broad, sometimes not piliferous. Fascicles of the

branches densely branched, elongated, with an acutely lanceolate outline, erect, somewhat appressed. Cells of main thread 45μ; of fascicles 8μ.

In slow streams or pools.

GENUS 74. **CHÆTOPHORA.** *Schrank.* (1789.)

Articulate filaments, with the primary branches radiately disposed, composed of elongated vegetative cells, with chlorophyl bands; divided upwards into numerous branchlets, which are shortly articulated, the ultimate joint attenuated, scarcely lengthened into a thread. Ultimate branchlets in fascicles, involved in a firm gelatinous mass, of a globose, expanded, or variously lobed form. Propagation as in the preceding (Fig. 84).

263. **Chætophora pisiformis.** (*Roth.*) *Cooke, Algæ, t.* 77, *f.* 1.

Thallus globose, about the size of a pea, often smaller (now and then as large as a cherry), bright green, even, shining, sometimes aggregated, not rarely confluent. Cells 6–9μ; of branches 6μ.

On submerged plants.

264. **Chætophora tuberculosa.** (*Roth.*) *Cooke, Algæ, t.* 78, *f.* 1.

Thallus subglobose, the size of a cherry, bright or pale green. Surface tuberculose, elastic. Fascicles of branches very dense. Lower articulations cylindrical; the upper swollen. Extremities cuspidate, sharp pointed, rarely hair-like. Cells 9–12μ; of branches 8–10μ.

In clear water.

265. **Chætophora elegans.** (*Roth.*) *Cooke, Algæ, t.* 77, *f.* 2.

Thallus the size of a pea or a cherry, pale green. Surface even, elastic, soft, now and then becoming hard. Fascicles of branches lax, rather flaccid. Extremities shortly cuspidate, often terminating in a hair. Cells 7–9μ; of branches 5–7μ.

In clear water, attached to submerged plants.

266. **Chætophora endivæfolia.** (*Ag.*) *Cooke, Algæ, t.* 78, *f.* 2.

Thallus linear, flattened, ½–1 inch, bright green, dichotomously laciniate. Threads and primary branches mostly colourless, here and there with green zones, parallel. Fascicles of branches lateral, more or less dense. Spreading articulations more or less swollen, nearly equal in length and diameter, constricted at the joints. Cell-contents effused. Cells 10–15μ; of branches 8–11μ.

In ditches, etc.

GENUS 75. COLEOCHÆTE. *Breb.* (1844.)

Articulated filaments branched, either united in a pulvinule, or little cushion, or expanded in a flat, somewhat disc-shaped thallus. Cells oblong, more or less dilated in front, sometimes bearing from the back or upper surface a hyaline bristle, sheathed at its base. Propagation by oospores and by zoogonidia (Fig. 85).

267. **Coleochæte soluta.** (*Prings.*) *Cooke, Algæ, t.* 78, *f.* 3.

Threads radiating from a common centre, furcately branched, of equal length, closely packed side by side, prostrate, but not connate, forming an orbicular disc. Cells 1½ to 3 times as long as broad. Oogonia placed before the terminal cells, globose, corticate. Cells 25μ.

Attached to aquatic plants.

268. **Coleochæte scutata.** (*Breb.*) *Cooke, Algæ, t.* 79.

Filaments and their branches radiating from the centre, very densely connate in one stratum, forming a kind of parenchymatous orbicular disc. Cells quadrangular, nearly equal or twice as long. Oogonia subglobose, peripherical, corticate above, naked below. Cells 20–22μ.

On aquatic plants.

269. **Coleochæte orbicularis.** (*Prings.*) *Cooke, Algæ, t.* 80, *f.* 1.

Disc orbicular, parenchymatous, formed from one stratum of cells, bright green. Cells oblong-quadrangular when

old, by pressure becoming often polygonal, usually twice as long as broad. Oogonia oval, peripherical, mostly naked. Cells 12–17μ.

On aquatic plants.

Genus 76. **APHANOCHÆTE.** *Braun.* (1847.)

Articulate threads prostrate, somewhat creeping, sometimes united in an irregular stratum. Branches decumbent or ascending. Cells bearing on their apex or back often a long bristle which has no sheath at the base. Propagation by zoogonidia (Fig. 83).

270. **Aphanochæte repens.** (*Braun.*) *Cooke, Algæ, t.* 80, *f.* 3.

Filaments and branches procumbent, adpressed. Cells slightly swollen, of equal diameter in both directions, supporting an indistinctly articulated bristle. Cells 5–10μ.

On *Cladophora flavescens*, and other algæ.

271. **Aphanochæte hystrix.** (*Thw.*) *Cooke, Algæ, t.* 80, *f.* 2.

Filaments and their branches radiating, procumbent, adpressed, more or less connate in a pale green irregular discoid thallus. Cells somewhat cylindrical, produced at the apex into a long bristle, which is not articulated. Cells 10μ diam.

On aquatic plants in brackish ditches.

The family Chytridieæ are too uncertain to be included here. They are parasitic, and, as some contend, more allied to fungi than algæ.

Class II. PHYCOCHROMOPHYCEÆ.

One or many celled, living in water, or enclosed in a maternal jelly when out of it, mostly in families formed from successive generations of cells. Cell-contents brown, olivaceous, or fuscous. Propagation by division and by immovable gonidia.

ORDER I. *CYSTIPHORÆ.*

Unicellular. Cells spherical, oblong, or cylindrical, enclosed in a tegument, associated in families surrounded by a universal tegument, immersed in a more or less firm mucilage. Division in one, two, or three directions alternately. Propagation by quiescent gonidia.

FAMILY I. CHROOCOCCACEÆ.

Thallus mucous or gelatinous, amorphous, enclosing cells and families irregularly disposed.

GENUS 77. **CHROOCOCCUS.** *Nägeli.* (1849.)

Cells globose or more or less angular, solitary or associated in families, free. Cell-membrane thin, often confluent in a more or less firm jelly; cell-contents verdigris or pallid blue-green. Propagation by division alternately in three directions (Fig. 77).

272. **Chroococcus cohærens.** (*Näg.*) *Cooke, Algæ, t.* 83, *f.* 1.

Cells oblong, twin, or in fours, with a distinct hyaline ellipsoid tegument. Cell-membrane thin; cell-contents

blue-green. Cells 3–6μ diam.; families of 2–4 individuals.

On damp walls and flower-pots.

273. **Chroococcus turgidus.** (*Näg.*) *Cooke, Algæ, t.* 83, *f.* 2.

Cells spherical, or more or less angular, single, 2, 3 or 4 (rarely 8), associated in families; tegument thick, usually lamellose. Cell-membrane thin; cell-contents bright verdigris green, at length brownish. Cells 13–25μ diam.; families of 2–4.

In swampy places and on moist rocks.

GENUS 78. **GLŒOCAPSA.** *Kutz.* (1843.)

Cells spherical, either single or associated in families, the single cell included in a vesiculiform tegument, dividing into two daughter-cells; the whole surrounded by the tegument of the mother-cell. Cell-membrane thick, equalling in diameter the cavity of the cell, mostly lamellated; cell-contents æruginous, bluish green, steel-blue, reddish, yellowish, fuscous, etc. Division of the cells in three directions (Fig. 78).

274. **Glœocapsa coracina.** (*Kutz.*) *Cooke, Algæ, t.* 83, *f.* 3.

Thallus crustaceous, very black, lubricous. Single cells spherical, small; tegument very pale violet, distinctly lamellose. Cell-contents homogeneous, blue-green. Cells 3–4; with envelope, 6–14μ; families 9–75μ diam.

On rocks, and on boggy ground amongst moss.

275. **Glœocapsa atrata.** (*Kutz.*) *Cooke, Algæ, t.* 83, *f.* 4.

Thallus crustaceous, mucous, black. Cells spherical, small; tegument very thick, hyaline, 2 or 3 times broader than the central cell. Cell-contents pale verdigris green, rather granulated. Cells $3\frac{1}{2}$–$4\frac{1}{2}\mu$; with envelope, 14μ; families 10–80μ.

On rocks in mountain regions.

276. **Glœocapsa livida.** (*Carm.*) *Cooke, Algæ, t.* 83, *f.* 5.

Thallus mucous, rounded lobate, broadly expanded, hyaline, dingy green, or olive brownish. Cells very minute; tegument pale bluish, hyaline. Cell-contents solid, dark blue-green. Cells 3–6μ; with envelope, 6–7μ; families 16–50μ.

On naked ground, or amongst moss and lichens.

277. **Glœocapsa caldariorum.** (*Rabh.*) *Cooke, Algæ, t.* 83, *f.* 6.

Thallus irregular, thick, gelatinous, pale yellowish. Cells solitary, globose; tegument spherical or elliptic, colourless, lamellose. Cell-contents pale blue-green. Cells 3–6μ; with envelope, 19–40μ.

On walls, flower-pots, glass, etc., in conservatories and greenhouses.

278. **Glœocapsa polydermatica.** (*Kutz.*) *Cooke, Algæ, t.* 83, *f.* 7.

Thallus gelatinous, more or less compact, dirty green, becoming brownish. Cells small, spherical; tegument very thick, lamellose. Cell-contents verdigris green. Cells 3–4½μ; with envelope, 23μ; families 50μ.

On moist rocks.

279. **Glœocapsa quaternata.** (*Kutz.*) *Cooke, Algæ, t.* 83, *f.* 8.

Thallus mucous, effused, dirty green, then reddish brown. Cells usually spherical, single or 2 to 4 (rarely 6–8) in families; tegument narrow, lamellose, rounded or oblong. Cell-contents verdigris green. Cells 3–4½μ; with envelope, 7–11μ; families 11–22μ.

On rocks or moist ground (Scotland).

280. **Glœocapsa arenaria.** (*Hass.*) *Cooke, Algæ, t.* 84, *f.* 1.

Thallus mucous, somewhat olive-coloured. Cells large, spherical; tegument thick, almost spherical, lamellose. Cell-contents verdigris green, then brownish. Cells 3½–5μ; with envelope, 6–14μ; families 40μ.

In springs and thermal waters.

281. **Glœocapsa æruginosa.** (*Carm.*) *Cooke, Algæ, t.* 84, *f.* 2.

Thallus crustaceous, glaucous green. Cells small, spherical; tegument thick, indistinctly lamellose, externally not rarely angular. Cell-contents verdigris green. Cells 2–3μ; with envelope, $4\frac{1}{2}$–9μ; families 16–50μ.

On limestone and other rocks.

282. **Glœocapsa magma.** (*Breb.*) *Cooke, Algæ, t.* 84, *f.* 3.

Thallus grumous, rather crustaceous, purple brown, blackish when dry. Cells spherical; tegument lamellose, intense purple or coppery-brown, external stratum very broad, paler. Cell-contents verdigris green, then brownish. Cells $4\frac{1}{2}$–7μ; with envelope, 6–12μ.

On moist rocks.

283. **Glœocapsa rupicola.** (*Kutz.*) *Cooke, Algæ, t.* 84, *f.* 4.

Thallus black, then brown, crustaceous, thin. Cells small, spherical; tegument narrow, not lamellose, fuscous, then rusty-brown, for the most part in fours, rarely in twos; outer tegument broad, very pale, enclosing numerous smaller families. Cell-contents pale verdigris green, or rusty brown. Cells $3\frac{1}{2}$–5μ; families 70μ.

On rocks amongst moss (Scotland).

284. **Glœocapsa sanguinea.** (*Ag.*) *Cooke, Algæ, t.* 85, *f.* 1.

Thallus effused, gelatinous, thin, blood red, or thicker, and then becoming blackish brown. Cells spherical; tegument intense blood red, not lamellose, the extreme outer colourless or nearly so, very broad, globose or angular. Cell-contents verdigris green. Cells with envelope 4–9μ; families to 140μ.

On rocks.

285. **Glœocapsa Ralfsiana.** (*Harv.*) *Cooke, Algæ, t.* 85, *f.* 2.

Thallus gelatinous, dark purple brown. Cells spherical; tegument very thick, opaque, and intense purple, the outer very broad, usually angular, almost colourless, enclosing smaller families of 2, 4, 6, 8. Cell-contents pale

verdigris green. Cells with envelope 10–17μ; small families 22–40μ; large families to 170μ.

Amongst moss and lichens.

286. **Glœocapsa Shuttleworthiana.** (*Kutz.*) *Cooke, Algæ, t.* 85, *f.* 3.

Thallus gelatinous, compact, dark rufous brown. Cells small, spherical; tegument very thick, many times broader than the central cell, globose, intense orange red, the outer pale orange, or colourless. Cell-contents pale verdigris green. Cells with envelope $7\frac{1}{2}$–13μ; families 35μ.

On moist rocks and amongst moss.

287. **Glœocapsa rupestris.** (*Kutz.*) *Cooke, Algæ, t.* 84, *f.* 5.

Thallus dark brown, crustaceous, rather hard. Cells spherical; tegument very thick, lamellose, yellow or golden brown, the outer permanent, yellowish. Cell-contents verdigris green. Cells with envelope 6–9μ; families 15–75μ.

On rocks.

Genus 79. APHANOCAPSA. *Näg.* (1849.)

Cells spherical, with a thick, soft, colourless tegument, confluent in a homogeneous mucous stratum. Cell-division as in *Glœocapsa* (Fig. 79).

288. **Aphanocapsa virescens.** (*Hass.*) *Cooke, Algæ, t.* 86, *f.* 1.

Thallus gelatinous, more or less expanded, dirty green or olive, becoming brownish. Cells pale bluish green, solitary or in pairs; tegument scarcely visible. Cell-contents homogeneous. Cells about $5\frac{1}{2}\mu$.

On stones, rocks, etc.

289. **Aphanocapsa rivularis.** (*Carm.*) *Cooke, Algæ, t.* 86, *f.* 2.

Thallus hemispherical, gelatinous, tuberculose, often confluent, æruginous green, becoming brownish when dry. Cells spherical, single or in pairs; tegument very thick, not

lamellose. Cell-contents bluish green. Cells about 5–6μ diam.

On rocks and stones inundated, in mountain streams.

290. **Aphanocapsa Grevillei.** (*Hass.*) *Cooke, Algæ, t.* 86, *f.* 3.

Thallus gelatinous, globose, densely aggregated, more or less confluent, dirty green, olive to brownish when dry. Cells spherical or elliptic, single or in pairs, in a homogeneous jelly; tegument diffluent. Cell-contents blue-green. Cells $3\frac{1}{2}$–6μ diam.

On damp heaths and moors.

291. **Aphanocapsa depressa.** (*Hass.*) *Cooke, Algæ, t.* 86, *f.* 4.

Thallus somewhat hemispherical, depressed, gelatinous, green. Cells spherical or irregular, variable in size. Cells $2\frac{1}{2}$–3μ.

On an old pump, constantly moistened.

Genus 80. **MICROCYSTIS.** *Kutz.* (1833.)

Cells spherical, numerous, densely aggregated, enclosed in a very thin globose mother-vesicle, forming solid families, singly, or several, surrounded by a universal tegument. Cell-division in three directions alternately (Fig. 80).

292. **Microcystis protogenita.** (*Bias.*) *Cooke, Algæ, t.* 86, *f.* 5.

Thallus membranaceous, thin, green. Families small, angular from mutual pressure. Cells small, spherical. Cell-contents granular, pale blue-green. Families 20μ; cells 15–20μ.

In water long standing, stagnant ditches.

293. **Microcystis marginata.** (*Meneg.*) *Cooke, Algæ, t.* 86, *f.* 6.

Thallus spherical, flattened, or orbicular and lens-shaped, sometimes confluent, pale green, colourless at the margin. Cells minute. Cell-contents blue-green. Cells 3–4μ; families 30μ.

In ditches, free swimming.

GENUS 81. **CLATHROCYSTIS.** *Henfrey.* (1856.)

Frond gelatinous, at first solid, then saccate, ultimately clathrate, composed of a colourless matrix, in which are imbedded innumerable minute cells, which multiply by division within the frond (Fig. 81).

294. **Clathrocystis æruginosa.** (*Henf.*) *Cooke, Algæ, t.* 86, *f.* 7.

Fronds floating in vast strata on fresh-water pools, forming a bright green scum, presenting to the naked eye a finely granular appearance; when dried, appearing like a crust of verdigris. Cells minute. Fronds 30–130μ; cells $2\frac{1}{2}$–$3\frac{1}{2}\mu$.

On fresh-water lakes.

GENUS 82. **CŒLOSPHÆRIUM.** *Näg.* (1849.)

Thallus globose, small, hollow, composed of small cells, which are associated in families at the periphery, immersed in a mucous stratum. Increase by division of the cells in all directions (Fig. 82).

295. **Cœlosphærium Kutzingianum.** (*Näg.*) *Cooke, Algæ, t.* 87, *f.* 1.

Families spherical. Cells subglobose, geminate, or quaternate, loosely disposed. Cell-contents blue-green, delicately granulose. Cells 2–5μ; families 60μ and more.

In ponds, meres, etc.

GENUS 83. **GOMPHOSPHÆRIA.** *Kutz.* (1836.)

Cells wedge-shaped, peripherical, 2–4–8 associated in radiating families, nestling in jelly, covered with a tegument, and forming a solid globose free-swimming thallus. Cells dividing alternately in three divisions (Fig. 86).

296. **Gomphosphæria aponina.** (*Kutz.*) *Cooke, Algæ, t.* 87, *f.* 2.

Thallus blue-green, often becoming pale; tegument colourless, rather thick and somewhat lamellose. Central

cells smaller. Cell-contents verdigris or pale blue-green. Cells 4μ diam. to 10μ long; families 50μ.

In ditches.

Genus 84. MERISMOPEDIA. *Meyen.* (1839.)

Cells globose, at the time of division oblong, rather thick; teguments confluent, 4–8–16–32–64–128 associated in tabular families of a single stratum, forming a quadrate, plane, free-swimming thallus (Fig. 87).

297. **Merismopedia violacea.** (*Kutz.*) *Cooke, Algæ, t.* 87, *f.* 3.

Thallus mucous, colourless, or nearly so, indefinite. Families small, composed of 4–32 remote very minute cells. Cell-contents homogeneous, violet. Cells 1–1½μ; families 15μ.

In ponds, ditches, etc., amongst other algæ.

298. **Merismopedia glauca.** (*Nag.*) *Cooke, Algæ, t.* 87, *f.* 4.

Thallus more or less limited, glaucous green, margin slightly sinulately crenate. Families composed of 16–48–64 (rarely more) oval or globose cells. Cell-contents pale blue-green. Cells 3–5μ; families 40–50μ.

In stagnant water.

299. **Merismopedia punctata.** (*Meyen.*) *Cooke, Algæ, t.* 87, *f.* 5.

Thallus less limited, almost colourless, for the most part composed of 4–64 remote cells. Cell-contents pale blue-green. Cells 3½μ; families 60μ.

In stagnant water.

300. **Merismopedia (?) paludosa.** *Bennett, Journ. R.M.S.,* 1886, *p.* 4.

Family of 8 cells. Cells square in outline, with rounded corners, each divided in four. Length of family 50μ, breadth 25μ; cells 12½μ.

In bog pools.

GENUS 85. TETRAPEDIA. *Reinsch.* (1867.)

Cells compressed, quadrangular or triangular, equilateral, becoming subdivided into quadrate or cuneate segments, or rounded lobes, either by deep incisions, or wide angular sinuses (Fig. 88).

301. **Tetrapedia Crux-Michaeli.** (*Reinsch.*) *Cooke, Algæ, t.* 87, *f.* 8.

Cells quadrate, lateral margins with two shallow concavities, producing an obtuse-angled central prominence, deeply incised at the angles; incisions diagonal, rectilineal, deep, slightly expanding upwards, dividing the cell into four cuneate segments; in side view lanceolate; ends acute. Cells 8–12μ diam.

In running water, Ireland.

302. **Tetrapedia Reinschiana.** (*Archer.*) *Cooke, Algæ, t.* 87, *f.* 9.

Cells quadrangular, two opposite margins excavated by a wide triangular sinus, the upper margins of the segments very slightly concave at the middle; in side view oblong, constricted at the middle; ends rounded. Largest cell $7\frac{1}{2}$–10μ diam.

In moor pools, co. Dublin and Wicklow.

303. **Tetrapedia setigera.** (*Archer.*) *Cooke, Algæ, t.* 87, *f.* 10.

Cells triangular, 3-lobed, rounded at the ends, and each terminated by a very delicate straight bristle; in side view oblong, somewhat inflated at the middle at each side; ends round, each tipped by the bristle. Cells, without bristles, 6–$7\frac{1}{2}\mu$; including bristles, 16–20μ.

In moor pools, co. Dublin and Wicklow.

GENUS 86. SYNECHOCOCCUS. *Näg.* (1849.)

Cells oblong, usually single, sometimes 2–4 connected in a series constituting a family. Cell-membrane thin; cell-contents blue-green, now and then yellow or pale orange. Division in one direction only.

304. **Synechococcus crassus.** (*Archer.*) *Cooke, Algæ, p.* 217.

Cells broadly elliptic, about one-half longer than broad. Cell-wall very thin.

In shallow pools, Bray's Head, Ireland.

GENUS 87. GLŒOTHECE. *Näg.* (1849.)

Cells cylindrical-oblong, rounded at the ends; division transversal, in one direction. Other characters as in *Glœocapsa*. Tegument very thick, lamellose (Fig. 89).

305. **Glœothece cystifera.** (*Hass.*) *Cooke, Algæ, t.* 88, *f.* 1.

Cells oblong-cylindrical, 2–4 associated in families; involved in a special universal tegument which is globose or oval, $1\frac{1}{2}$ to 3 times as long as broad. Cell-contents verdigris green. Cells 4–5μ; with tegument, 8–12μ; families 25–45μ.

On rocks.

306. **Glœothece granosa.** (*Rabh.*) *Cooke, Algæ, t.* 88, *f.* 2.

Thallus compact-gelatinous, blue-green. Cells oblong, twice as long as broad, usually 2–4 associated in families; tegument very broad, many times exceeding the central cell, distinctly lamellose, colourless. Cell-contents pallid blue-green. Cells 14–18μ diam.

On mosses in swamps.

GENUS 88. APHANOTHECE. *Näg.* (1849.)

Differing from *Glœothece* in all the teguments being usually confluent. Cells oblong or subcylindrical. Cell-contents now and then green, and then with difficulty distinguished from *Palmella* (Fig. 90).

307. **Aphanothece prasina.** (*Br.*) *Cooke, Algæ, t.* 88, *f.* 3.

Thallus gelatinous, more or less globose, tuberculose, the size of a cherry, bright leek-green, sometimes confluent, and then lobed. Cells oblong or ovoid, 1 to 2 times longer

than broad, after division spherical; tegument none. Cell contents verdigris green. Cells 5–6 × 8–11μ.

In ditches and stagnant ponds.

308. **Aphanothece stagnina.** (*Spr.*) *Cooke, Algæ, t.* 88, *f.* 4.

Thallus gelatinous, oblong or elliptical, from the size of a pea to that of a cherry, pale verdigris green. Cells oblong-oval, always smaller than in *A. prasina*, half to once longer than broad; tegument none. Cell-contents pallid verdigris green. Cells 3–5 × 5–8μ.

In stagnant water.

Genus 89. HOMALOCOCCUS. *Kutz.* (1863.)

Thallus globose, gelatinous. Internal cells irregularly united in a plane, oblong body, immersed in the gelatinous thallus (Fig. 21).

309. **Homalococcus Hassallii.** (*Kutz.*) *Cooke, Algæ, t.* 88, *f.* 5.

Thallus globose, soft, green, of the size of a pea or a hazel-nut. Cells rounded or somewhat angular. Cells 6–7μ diam.

In stagnant water.

ORDER II. *NEMATOGENÆ.*

Multicellular. Cells forming a filament, usually included in a tubular sheath. Filaments (*Trichomes*) either simple or branched.

Tribe 1. NOSTOCHINEÆ.

Trichomes simple or branched. Apex obtuse or acute, naked or enclosed in a sheath. Reproduction by fragments of the trichome (*hormogones*), which are endowed with motion after separating from the mother-plant.

Sub-tribe I. Psilonemeæ. *Filaments not attenuated into a hair-like extremity.*

Family I. NOSTOCEÆ.

Trichomes furnished with heterocysts, involved in a very copious gelatin, which is collected into a variously expanded thallus, or rarely with the mucilage quickly dissolved.

Genus 90. **NOSTOC.** *Vauch.* (1803.)

Thallus gelatinous or membranaceous, definite, globose, or variously expanded. Trichomes flexuously curved, irregularly interlaced, now and then vaginate; joints globose or elliptical. Heterocysts terminal or intercalated. Spores equal to the heterocysts, or a little larger, green, becoming bluish, olivaceous, or yellowish brown (Fig. 92).

I. Intricata. *Aquatic. Fronds soft, gelatinous, often floating.*

310. **Nostoc Linckia.** (*Roth.*) *Cooke, Algæ, t.* 89, *f.* 1–11.

Fronds lobed, multipartite, free swimming, as large as a walnut; lobes elongated and anastomosing, æruginous green, at length becoming brownish. Trichomes flexuous; joints short and close, spherical; sheaths uncoloured, very refractive. Heterocysts slightly oblong. Spores subglobose or oval. Joints $3\frac{1}{2}\mu$; heterocysts $5–6\mu$ diam.; spores (in form *intricatum*), subglobose, $6\frac{1}{2} \times 9\mu$.

In ditches (slightly brackish).

311. **Nostoc piscinale.** (*Kutz.*) *Cooke, Algæ, t.* 89, *f.* 12–15.

Fronds attached or free swimming, bullate and tuberculate, verdigris green, rarely rufescent, becoming olivaceous by age. Trichomes loosely interwoven; joints equal in diameter, rather distant. Spores subglobose. Joints $3\frac{1}{2}–4\mu$; heterocysts 6μ; spores, $7 \times 8\mu$.

In ditches.

312. **Nostoc carneum.** (*Ag.*) *Cooke, Algæ, t.* 90, *f.* 1–3.

Frond indefinitely expanded, bullate and undulate, flesh coloured, rufescent or purplish. Trichomes loosely interwoven; joints equal; sheath none, indistinct, or uncoloured. Spores oval. Joints $3\frac{1}{2}$–4μ; heterocysts 6μ diam.; spores $6 \times 9\mu$.

On rocks.

II. Gelatinosa. *Fronds soft and gelatinous, adherent; joints of trichome cylindrically elongated in the young filaments.*

313. **Nostoc spongiæforme.** (*Ag.*) *Cooke, Algæ, t.* 90, *f.* 4.

Frond at first subglobose, then expanded, becoming rather firm, pale æruginous or olive green; surface tuberculated. Trichomes composed of two sorts of joints, one cylindrical, the other cask-shaped or compressed spherical. Heterocysts globose. Spores smooth, oblong. Joints 4μ; heterocysts 7–8μ; spores 6–7 $\times$ 10–12μ.

In wet or inundated places.

314. **Nostoc ellipsosporum.** (*Desm.*) *Cooke, Algæ, t.* 90, *f.* 8–11.

Terrestrial. Frond plane, gelatinous, rufous brown. Trichomes densely interwoven, pale æruginous green; joints cylindrically elongated, loosely connected; sheaths broad, homogeneous. Heterocysts elongated, elliptical. Spores oblong, smooth. Joints 4μ; heterocysts 6–7μ; spores 6 $\times$ 6–8 $\times$ 19μ.

On the ground amongst moss.

III. Humifusa. *Terrestrial. Fronds globose, then confluent, forming gelatinous patches adhering by their lower face.*

315. **Nostoc muscorum.** (*Ag.*) *Cooke, Algæ, t.* 90, *f.* 12–18.

Dark green, foliaceous, tuberculate, opaque. Trichomes diffused, irregularly interwoven, pale æruginous green; sheaths confluent. Heterocysts spherical, usually intercalated. Spores oval. Joints $3\frac{1}{2}\mu$; heterocysts 5μ; spores $6 \times 10\mu$.

On calcareous rocks, and the mosses that cover them.

316. **Nostoc humifusum.** (*Carm.*) *Cooke, Algæ, t.* 91, *f.* 1–3.

Small, at first globose or subglobose, size of a peppercorn, olive, then brownish, shining opaque when dry. Trichomes olive, slender, vertically folded; sheaths well defined. Heterocysts globose. Spores oval. Joints $2\frac{1}{2}\mu$; heterocysts 3μ; spores $4 \times 6\mu$.

On mosses and on walls in greenhouses, etc.

IV. COMMUNIA. *Terrestrial. Fronds at first globose, then tongue-shaped, plane or irregular.*

317. **Nostoc commune.** (*Vauch.*) *Cooke, Algæ, t.* 91, *f.* 4–7.

Adult frond sub-orbicular, folded, undulating, entire or lobed, often perforated, olive, yellowish brown, or becoming brownish. Trichomes flexuous, loosely interwoven, pale blue-green; joints spherical, compressed, uniform. Heterocysts globose. Joints $4\frac{1}{2}$–6 (usually 5) μ; heterocysts 7μ.

On wet ground.

V. SPHÆRICA. *Fronds globose or subglobose, limited by a firm and resisting periderm.*

318. **Nostoc sphæricum.** (*Vauch.*) *Cooke, Algæ, t.* 91, *f.* 8–11.

Firm, spherical, about the size of a pea, gregarious, olive or bluish green, or brownish, with a firm brownish or colourless periderm. Trichomes compact, densely interwoven at the periphery; joints cask-shaped, or compressed spherical, close together, uniform. Heterocysts subglobose. Spores oval, with a thick tegument, smooth. Joints 4–5μ; heterocysts 6μ; spores $5 \times 7\mu$.

In springs and mountain rivulets.

319. **Nostoc rupestre.** (*Kutz.*) *Cooke, Algæ, t.* 91, *f.* 12–15.

Soft, globose, olive, becoming brownish, often forming an irregular crust. Trichomes much spaced out, of unequal size; joints nearly spherical; sheaths often coloured, contrasting with the generally uncoloured jelly. Spores oval, with a smooth tegument. Joints 5–8μ; heterocysts 7μ.

On rocks, overrunning mosses, etc.

320. **Nostoc macrosporum.** (*Meneg.*) *Cooke, Algæ, t.* 92, *f.* 1–3.

Very small, punctiform, æruginous green, or brownish olive. Trichomes large, bluish green, or brownish; joints cylindrical, a little constricted at their junction; sheaths broad, brownish or yellowish brown. Heterocysts globose. Spores globose, with a smooth tegument. Joints 8–9μ; heterocysts 9–10μ.

On rocks among moss.

321. **Nostoc cæruleum.** (*Lyngb.*) *Cooke, Algæ, t.* 92, *f.* 4–6.

Small, globose or subglobose ($\frac{1}{2}$ to 4 lines), fixed or free swimming, usually gregarious, blue or greenish blue. Trichomes dissimilar, unequal; joints of two forms, the one (young) elongated, the other larger, nearly spherical, sometimes filled with opaque granules. Joints 4–7μ; heterocysts 8μ.

On mosses and submerged plants.

322. **Nostoc pruniforme.** (*Ag.*) *Cooke, Algæ, t.* 92, *f.* 7–9.

The size of a pea to that of a damson, olive or dark æruginous green, when old becoming blackish brown, with a coriaceous periderm, and watery within. Trichomes loosely interwoven; joints subglobose, compressed, closely connected. Heterocysts globose, usually terminal. Joints 4–5μ; heterocysts 6–7μ.

In fresh-water pools, rivulets, etc.

VI. Verrucosa. *Aquatic. Fronds rounded or discoid, then hollow, with a tough periderm.*

323. **Nostoc verrucosum.** (*Vauch.*) *Cooke, Algæ, t.* 92, *f.* 10–17.

Subglobose or nodulose, warted, brownish green, tolerably soft, with a firm and tough periderm. Trichomes slender, somewhat compact, spaced out, and a little flexuous at the centre, more compact and distorted at the periphery, where they are often deprived of sheaths; joints subglobose, closely connected. Heterocysts spherical. Joints 3–3$\frac{1}{2}\mu$; heterocysts 6μ; spores 5–7μ.

In streams, attached to stones.

GENUS 91. ANABÆNA. *Bory.* (1823.)

Trichomes moniliform, without sheaths, composed of subglobose cells, some of which are changed into spores, usually brown. Heterocysts intercalated in the trichomes. Spores originating in cells not adjoining the heterocysts (Fig. 93).

324. **Anabæna flos-aquæ.** (*Kutz.*) *Cooke, Algæ, t.* 93, *f.* 1.

Free swimming, membranaceous, blue-green. Trichomes curved, often circinate; joints spherical, or elliptic or quadrate. Heterocysts intercalated, elliptical. Spores globose. Cells $4\frac{1}{2}$–6μ; heterocysts 12–14μ long; spores 8–10μ.

var. **circinalis.** (*Kirch.*) *Cooke, Algæ, t.* 93, *f.* 1 *c.*

Trichomes more circinate, and joints rather larger. Cells 7–10μ; spores 12–14μ diam.

In ponds, moor pools, etc.

325. **Anabæna variabilis.** (*Kutz.*) *Cooke, Algæ, t.* 93, *f.* 2.

Gelatinous, submembranaceous, deep blue-green. Trichomes slightly curved, verdigris green; joints globose or elliptic, compressed subcylindrical, 1 to $1\frac{1}{2}$ times longer than broad. Heterocysts intercalated, paler. Spores seriate, ellipsoid, tawny, with a rather thick membrane. Cells $3\frac{1}{2}$–4μ; heterocysts 7μ; spores $8 \times 12\mu$.

In ditches.

326. **Anabæna Hassallii.** (*Nord. and Wittr.*) *Cooke, Algæ, t.* 93, *f.* 3.

Trichomes equal, curved, often circinate, interwoven in a thin blue-green stratum; joints globose or compressed. Heterocysts spherical, intercalated without order. Spores oblong cylindrical, single or in pairs, distinctly curved, dark blue-green, $1\frac{1}{2}$ to $2\frac{1}{2}$ times as long as broad. Cells 8μ; heterocysts 9–10μ; spores $12 \times 25\mu$.

In ditches with *Confervæ*, and floating on lakes.

327. **Anabæna Ralfsii.** (*Kutz.*) *Cooke, Algæ, t.* 94, *f.* 1.

Forming strata of a velvety dark green colour, sometimes verging towards verdigris green. Trichomes moniliform; joints spherical. Heterocysts elliptical. Spores elliptic or cylindrical, 1 or 2 in each series not contiguous to the heterocysts. Cells 4μ diam; heterocysts 5–6 × 8μ; spores 8–10 × 22–30μ.

In bogs and rivulets.

328. **Anabæna Smithii.** (*Thw.*) *Cooke, Algæ, t.* 93, *f.* 7.

Trichomes straight, with a definite gelatinous sheath; joints subspherical, compressed, about as long as wide. Heterocysts subspherical, half as wide again as the joints; puncta very distinct. Spores cylindrical, unequal; ends rounded and somewhat truncate. Cells 4–6μ diam.; heterocysts 8–9 × 9–13μ; spores 9–12 × 20–40μ.

In boggy pools with other algæ.

329. **Anabæna oscillarioides.** (*Bory.*) *Cooke, Algæ, t.* 93, *f.* 6.

Forming a bluish-green stratum. Trichomes elongated flexuous; joints subquadrate. Heterocysts barrel-shaped or elliptic. Spores oval, catenate, somewhat larger than the cells. Cells 4–5 × 4–6μ; heterocysts 6–8 × 7–9μ; spores 7–8 × 8–12μ.

In brackish ditches.

330. **Anabæna Thwaitesii.** (*Ralfs.*) *Cooke, Algæ, t.* 93, *f.* 5.

Trichomes moniliform, straight or nearly so; joints quadrate. Heterocysts oblong subquadrate, hardly exceeding the joints in diameter. Spores numerous, cylindrical, with truncate ends, variable in length. Cells 6–7μ; heterocysts 8 × 10μ; spores 10–12 × 25–30μ.

In fresh-water pools and brackish ditches.

Uncertain Species.

331. **Anabæna inæqualis.** (*Ralfs.*) *Cooke, Algæ, t.* 93, *f.* 4.

Forming extensive strata of a deep green colour. Trichomes stout, moniliform elongated, joints distinct,

at first quadrate, finally orbicular, with granular contents. Heterocysts globose, broader than the ordinary joints, occurring at short intervals. Spores 3 to 4 times longer than broad, with truncate ends, in chains of 2 to 5.

In boggy pools.

GENUS 92. APHANIZOMENON. *Morren.* (1839.)

Thallus membranaceous, free swimming, blue, or becoming olive. Trichomes a little attenuated towards the apex, agglutinated densely in fascicles; joints cylindrical, very closely connected, nearly colourless and delicately granular. Spores cylindrical, rounded at the ends, pale blue, or somewhat olive. Exospore thin, quite smooth (Fig. 96).

332. **Aphanizomenon flos-aquæ.** (*Ralfs.*) *Cooke, Algæ, t.* 94, *f.* 1.

Floating, forming a pale or dark blue-green stratum. Trichomes very thin, nearly straight, aggregated in membranaceous flakes, distinctly or indistinctly articulated, very pale blue or colourless; joints cylindrical, about as long as broad, slightly granular. Spores more or less cylindrical, 6 to 12 times as long as broad, granular. Cells 3–4μ diam.; spores 5×30–40μ.

In ditches, ponds, and meres.

GENUS 93. SPHÆROZYGA. (*Ag.*) *Ralfs.* (1850.)

Trichomes involved in an amorphous mucilage, rarely vaginate, agglutinated in an indefinite gelatinous stratum; joints spherical, elliptical or oblong, transversely compressed and often quadrangular. Heterocysts intercalated, binary, or solitary. Spores originating in cells placed on each side of the heterocysts (Fig. 95).

333. **Sphærozyga Carmichaeli.** (*Harv.*) *Cooke, Algæ, t.* 94, *f.* 3.

Stratum thin, of a dark or bluish green colour when recent, but opaque and glaucous when dry. Trichomes moniliform, with tapering extremities; joints distinct,

somewhat quadrate. Heterocysts spherical. Spores oblong. Cells $3\frac{1}{2}$–$4\frac{1}{2}\mu$; heterocysts 6μ diam.; spores $8–10 \times 18–25\mu$.

On damp soil in salt marshes, in brackish ditches, etc.

334. **Sphærozyga Broomei.** (*Thwaites.*) *Cooke, Algæ, t.* 94, *f.* 4.

Stratum bluish or yellowish green. Trichomes moniliform; joints subspherical. Heterocysts smooth, subquadrate, rather longer than wide. Spores numerous, elliptical, twice as long as wide, not much exceeding in width the joints, commencing to be formed on either side next to the heterocysts. Cells 4μ; heterocysts $5 \times 6\mu$; spores $8 \times 16\mu$.

On dead leaves of *Myriophyllum* in a brackish ditch.

Species imperfectly known.

335. **Sphærozyga Berkeleyana.** (*Thwaites.*) *Cooke, Algæ, t.* 94, *f.* 9.

Young trichomes, one or several together in a mucous sheath; joints spherical, compressed. Heterocysts spheroidal, slightly compressed. Spores usually 2 on each side of the heterocysts, large, twice the width of the joints, oblong, half as long again as wide, becoming brown when mature. Cells $6–7\mu$; spores $12 \times 15\mu$.

Amongst *Cladophora fracta* in a brackish ditch.

336. **Sphærozyga Jacobi.** (*Ralfs.*) *Cooke, Algæ, t.* 94, *f.* 5.

Forming thick bluish-green gelatinous masses, from which the filaments issue in long rays. Trichomes elongated, ends attenuated; joints quadrate, then globose, the terminal one longer than broad, and usually conical. Heterocysts spherical, larger than the joints. Spores oblong or cylindrical, 1 or 2 on each side of the heterocysts. Cells about 5μ; spores $8 \times 20–25\mu$.

In streams, pools, etc.

337. **Sphærozyga Mooreana.** (*Ralfs.*) *Cooke, Algæ, t.* 94, *f.* 6.

Trichomes scattered; joints minute, somewhat orbicular. Heterocysts minute, barrel-shaped, much narrower than

the spores. Spores very turgid, often nearly orbicular or broadly elliptical, much larger than the joints or heterocysts. Cells about $3\frac{1}{2}$–4μ; spores about 8 × 12–15μ.
Mixed with other algæ.

338. **Sphærozyga leptosperma.** (*Ralfs.*) *Cooke, Algæ, t.* 94, *f.* 8.

Forming large gelatinous masses, deep green to pale yellowish green. Trichomes elongated, not constricted; joints longer than broad, separated by transverse dissepiments, often so obscure that they can hardly be detected. Heterocysts at first barrel-shaped, finally elliptic. Spores cylindrical, 4 to 6 times longer than broad, truncate, slightly broader than the ordinary joints. Cells 4μ diam.; spores about 7 × 20–30μ.
In ditches and pools.

339. **Sphærozyga elastica.** (*Ralfs.*) *Cooke, Algæ, t.* 94, *f.* 7.

Stratum deep bluish green. Trichomes elongated, constricted; joints about equal in length and breadth, but when dividing they lengthen. Heterocysts at first barrel-shaped, then elliptic. Spores cylindrical, 4 to 8 times longer than broad; ends at first truncate, but rounded after separation. Cells about 5μ; spores 8 × 25μ.
In bogs.

GENUS 94. **CYLINDROSPERMUM.** (*Kutz.*) *Ralfs.* (1850.)

Heterocysts terminal, single. Other characters as in *Sphærozyga*. Spores originating in cells placed just below the heterocysts (Fig. 94).

340. **Cylindrospermum macrospermum.** (*Kutz.*) *Cooke, Algæ, t.* 95, *f.* 1.

Trichomes curved or nearly straight, pale blue green, more or less interwoven; joints globose or elliptic, often mixed with others somewhat cylindrical, either homogeneous or granular. Heterocysts terminal, elliptical.

Spores oblong or cylindrical, green or yellowish brown, darker when mature, twice as long as broad. Cells 3–4μ; heterocysts rather longer; spores 14 × 25–30μ.

341. **Cylindrospermum catenatum.** (*Ralfs.*) *Cooke, Algæ, t.* 95, *f.* 2.

Stratum bluish green. Trichomes straight, or slightly flexuous, generally parallel, moniliform; joints spherical, minute. Heterocysts oval. Spores 2–8 in each series, at first spherical, then oval, but little broader than the heterocysts. Cells about 3μ; heterocysts a little longer; spores about 6 × 8μ.

In fresh water.

GENUS 95. NODULARIA. *Mertens.* (1822.)

Trichomes vaginate, with very closely compressed disc-shaped joints, collected in a gelatinous or membranaceous stratum. Heterocysts intercalated at regular intervals; joints nearly equal, transversely compressed. Spores fuscous, globose, slightly compressed (Fig. 97).

342. **Nodularia litorea.** (*Thw.*) *Cooke, Algæ, t.* 95, *f.* 3.

Scarcely gelatinous, forming a deep green fleecy covering. Trichomes of considerable diameter, nearly straight; joints blue green, very short and compressed, giving the filaments the appearance of an *Oscillaria*. Heterocysts pale reddish. Spores elliptical, at length deep brown. Trichome, without sheath, 12μ.

In muddy, brackish ditches.

343. **Nodularia Harveyana.** (*Thur.*) *Cooke, Algæ, t.* 95, *f.* 4.

Trichomes much curved, composed of cells nearly as long as broad. Heterocysts subquadrate, rather longer than wide, and of the same width as the joints. Spores spherical, almost twice the diameter of the joints. Trichomes 6½μ diam.

In brackish ditches.

FAMILY II. LYNGBYÆ.

Filaments without heterocysts, not setulose, single, and scattered, or numbers associated in bundles and enclosed in a common sheath. Joints shortly cylindrical, disc-shaped in section.

GENUS 96. SPIRULINA. *Link.* (1834.)

Trichomes articulated, spirally twisted, motile, nestling in a more or less liquid colourless matrical mucilage (Fig. 98).

344. Spirulina Jenneri. (*Kutz.*) *Cooke, Algæ, t.* 96, *f.* 1.

Trichomes more or less elongated, distinctly articulated, spirals lax, distant; joints equal in length to their diameter, or a little shorter. Cell-contents pale or bright blue green. Trichomes 7–8μ diam.

In stagnant water.

345. Spirulina oscillarioides. (*Turp.*) *Cooke, Algæ, p.* 246.

Solitary, or forming little green tufts, sometimes almost radiating. Trichomes more or less elongated, nearly erect, pale blue-green, twisted in lax or dense spirals, endowed with active motion. Trichomes $1\frac{1}{2}$–2μ diam.

var. b. **minutissima.** (*Rabh.*) *Cooke, Algæ, t.* 96, *f.* 3.

Trichomes abbreviated, more loosely spiral.

In fresh, brackish, or thermal waters.

346. Spirulina tenuissima. (*Kutz.*) *Cooke, Algæ, t.* 96, *f.* 2.

Forming a membranaceous, dark blue-green floating stratum. Trichomes very thin, flexuous, very densely spiral, endowed with active motion; joints very indistinct. Spirals 5μ diam.

In brackish ditches.

GENUS 97. **OSCILLARIA.** *Bosc.* (1800.)

Trichomes simple, articulate, rigid, straight, or a little curved, rarely circinate, brightly coloured (blue-green, steel-blue, violet, æruginous, etc.), motile, nestling in a matrical mucilage; joints disc-shaped in the front view, without a sheath distinct from the trichome (Fig. 99).

347. **Oscillaria tenerrima.** (*Kutz.*) *Cooke, Algæ, t.* 96, *f.* 4.

Solitary and scattered, or associated in fascicles. Trichomes straight, indistinctly articulate; joints equal in length to their diameter, or a little longer or shorter; ends somewhat acute, slightly inclined. Cell-contents pale blue-green or olive, homogeneous, or very finely granular. Threads 2–2½μ.

In ditches, amongst decaying vegetable matter.

348. **Oscillaria leptotricha.** (*Kutz.*) *Cooke, Algæ, t.* 96, *f.* 5.

Solitary, scattered, or collected in a very thin blue-green stratum. Trichomes very slender, slightly curved, indistinctly articulate; joints twice as long as broad, or after division equal, attenuated at the ends. Cell-contents pale blue-green, homogeneous, or finally granular. Threads 3μ diam.

In fresh or brackish ditches.

var. **splendida.** (*Grev.*) *Cooke, Algæ, t.* 96, *f.* 6.

Trichomes not exceeding 2μ diam.

In tubs of water in a stove.

349. **Oscillaria spiralis.** (*Carm.*) *Cooke, Algæ, t.* 98, *f.* 7.

Effused in a firm coriaceous glossy black stratum. Trichomes radiating, slender, long, flexuous, regularly twisted in spirals. Threads 3½–4μ diam.

On rocks by the seaside.

350. **Oscillaria rubiginosa.** (*Carm.*) *Cooke, Algæ, t.* 98, *f.* 6.

Stratum gelatinous, dark purple. Trichomes very thin, straight, indistinctly articulated, laid on a thin, compact, greenish substratum. Threads $4–4\frac{1}{2}\mu$ diam.

Rapid streams, and on stones at the bottom of rivers.

351. **Oscillaria subfusca.** (*Vauch.*) *Cooke, Algæ, t.* 96, *f.* 7

Forming a very thin greenish brown, then blackish stratum, shortly radiating. Trichomes equal, straight, curved at the apex; joints about equal in length to breadth; dissepiments distinctly granulate; apical point fimbriate. Cell-contents pale greenish steel-blue, granular. Threads $4\frac{1}{2}–6\mu$ diam.

Attached to wood, rocks, stones, etc., in streams.

352. **Oscillaria ærugescens.** (*Drumm.*) *Cooke, Algæ, t.* 98, *f.* 5.

Stratum of a fine deep green, highly gelatinous, when dried æruginous blue, and glossy. Trichomes very slender, opaque green, conglomerated in large masses, rarely floating, or broken into fragments and suspended like cloudy flocculi in the water; joints about half their diameter long. Trichomes 5μ diam.

In lakes and pools.

353. **Oscillaria tenuis.** (*Ag.*) *Cooke, Algæ, t.* 96, *f.* 8.

Forming a bright green or dark blue-green stratum, radiating. Trichomes straight, rather rigid; joints equal or half as long as broad, sometimes a little constricted and granulated; apex more or less attenuated, obtuse, curved or straight. Cell-contents pale watery blue. Threads $5–6\mu$ diam.

In ditches, swamps, inundated places.

354. **Oscillaria antliaria.** (*Jurgens.*) *Cooke, Algæ, t.* 97, *f.* 2.

Expanded in a gelatinous submembranaceous stratum, dark steel-blue. Trichomes rigid, straight, tranquil, or oscillating, curved at the attenuated apex; joints equal, or nearly equal (after division half as long); dissepiments

distinctly granular. Cell-contents pale steel-blue or blue-green, nearly homogeneous. Threads $4\frac{1}{2}$–$5\frac{1}{2}\mu$ diam.
Around pumps, cisterns, etc.

355. **Oscillaria muscorum.** (*Carm.*) *Cooke, Algæ, t.* 98, *f.* 8.

Stratum 3–4 inches, of a dark bluish-green colour, slightly lubricous, shortly radiating, creeping over mosses. Trichomes variously curved, pale blue-green; joints about equal in length to their diameter. Trichomes 6–7μ diam.
In rapid streams, on *Hypnum ruscifolium*, etc.

356. **Oscillaria subuliformis.** (*Thw.*) *Cooke, Algæ, t.* 98, *f.* 3.

Stratum of an intense æruginous green. Trichomes bright green, subuliform, gradually attenuated towards the apices, which are subacute and much curved; joints about three-fourths as long as broad, homogeneous. Trichomes 6–7μ diam.
In brackish ditches. Summer and autumn.

357. **Oscillaria limosa.** (*Ag.*) *Cooke, Algæ, t.* 97, *f.* 3.

Trichomes rigid, straight, actively oscillating, blue-green, interwoven in a thin mucilaginous radiating green stratum, distinctly articulate; joints nearly equal or a little longer than broad (shorter after division); dissepiments granulated; apex obtuse. Cell-contents pallid. Threads 8–10μ diam.

358. **Oscillaria irrigua.** (*Kutz.*) *Cooke, Algæ, t.* 97, *f.* 5.

Stratum thin, expanded, compact, dark steel-blue. Trichomes straight, flexile, pallid, then livid steel-blue, a little attenuated at the apex; joints equal in length to their diameter (after division half as long); dissepiments granulated; extreme apex broadly rounded. Threads $7\frac{1}{2}$–10μ.
On wet rocks, walls, or overrunning mosses.

359. **Oscillaria nigra.** (*Vauch.*) *Cooke, Algæ, t.* 97, *f.* 6.

Stratum somewhat membranaceous, often floating, steel-blue, or dark olive, nearly black, with radii of the same

colour. Trichomes straight or slightly flexuous, obtusely rounded at the apex, or attenuated, and sometimes bearded; joints equal in length to their diameter (after division one-half or one-third as long); dissepiments distinctly granulated. Cell-contents pale olive, finely granular. Threads 9–10μ diam.

In ditches and ponds.

360. **Oscillaria nigro-viridis.** (*Thwaites.*) *Cooke, Algæ, t.* 98, *f.* 2.

Stratum thin, of a dark olive-green, almost black, growing upon the mud, and subsequently floating in large masses. Trichomes pale dull green, with obtuse, distinctly curved, scarcely attenuated apices; joints indistinct, about half as long as broad. Cell-contents slightly granulose. Trichomes 12μ diam.

In brackish ditches.

361. **Oscillaria chalybea.** (*Mertens.*) *Cooke, Algæ, t.* 98, *f.* 1.

Floating. Stratum broadly expanded, with long radii, dark blue-green or steel-blue, shining. Trichomes pale steel-blue, slightly flexuous, a little attenuated at the apex; joints 3 or 4 times shorter than their diameter, a little contracted; apiculus slightly curved, obtusely rounded. Cell-contents pale steel-blue. Threads 8–10μ diam.

In still and stagnant water.

362. **Oscillaria princeps.** *Vauch., Conf., p.* 190.

Stratum mucous, bright æruginous green, or turning dark green, shining. Trichomes rigid, attenuated at the apex; joints one-fourth in length to their diameter; granules scattered or in transverse series. Cell-contents æruginous. Threads 30–45μ diam.

In fresh, or brackish, water.

363. **Oscillaria Frolichii.** (*Kutz.*) *Cooke, Algæ, t.* 97, *f.* 7.

Stratum dark steel-blue, or at first olive, then dark blue, radiating, opaque, shining. Trichomes nearly equal, straight; joints 2, 3, or 4 times shorter than their dia-

meter, with a double series of granular points at the junction; apiculus broadly rounded, straight, or declined. Cell-contents blue, homogeneous. Threads 15–18μ diam.

In ditches, pools, and boggy places.

364. **Oscillaria insignis.** (*Thwaites.*) *Cooke, Algæ, t.* 98, *f.* 4.

Stratum thin, covering decayed vegetable matter at the bottom of a ditch, with a dark-brown coating, becoming somewhat greenish in drying. Trichomes very large, rather brittle, their apices rounded, somewhat oblique, and furnished with numerous motionless cilia. Cell-contents distinctly granulose. Trichomes 18μ with sheath.

In a brackish ditch. November.

Doubtful Species.

365. **Oscillaria Dickiei.** (*Hass.*) *Cooke, Algæ, p.* 254.

Stratum pale chestnut-brown, gelatinous, shining. Trichomes of medium size, long, straight, fragile, with visible spaces between the joints.

Pools of fresh water near the sea.

366. **Oscillaria thermalis.** (*Hass.*) *Cooke, Algæ, p.* 254.

Trichomes straight, rigid, fragile, green. Divisions of the joints distinct, rather remote.

In warm water.

367. **Oscillaria virescens.** (*Hass.*) *Cooke, Algæ, p.* 254.

Stratum pale blue-green. Trichomes of medium size, pale yellowish green, with the joints rather distant, nearly equal in length to their diameter.

On the ground.

GENUS 98. **MICROCOLEUS.** *Desm.* (1823.)

Trichomes rigid, articulate, crowded together in bundles, enclosed in a common mucous sheath, either closed or open at the apex. Sheath ample, colourless, more or less lamellose, rarely indistinct (Fig. 100).

368. **Microcoleus gracilis.** (*Hass.*) *Cooke, Algæ, t.* 99, *f.* 1.

Effused broadly in a thin dark-green stratum. Trichomes pale blue-green, slightly curved, in fascicles densely contorted about the apex; joints 2 to 3 times longer than their diameter. Divisions paler, nearly hyaline, a little contracted about the apex. Special sheath narrow, very delicate; universal sheath very thick, lamellose. Trichomes $2\frac{1}{2}$–3μ; fascicles 90–120μ.

On salt marshes.

369. **Microcoleus chthonoplastes.** (*Thur.*) *Cooke, Algæ, t.* 100, *f.* 1.

Stratum thin, or rather compact, dingy æruginous green. Trichomes slightly flexuous, equal, twisted, in dense fascicles; joints nearly twice as long as their diameter, rather remote from each other, leaving a hyaline space between them; apiculus attenuated. Special sheath delicate; universal sheath narrow, scarcely lamellose. Trichomes $3\frac{1}{2}$–4μ; fascicles 30–35μ.

On the naked road, by roadsides, etc.

370. **Microcoleus terrestris.** (*Desm.*) *Cooke, Algæ, t.* 99, *f.* 2.

Stratum expanded, blue-green or olive, becoming brownish, membranaceous. Trichomes equal, in filiform fascicles, sometimes much elongated, extruding from the opening of a common sheath in a penicillate manner; joints equal in breadth and length; dissepiments granulated; apiculus acute, straight. Trichomes 5–6μ; fascicles 75–80μ diam.

On moist naked ground.

Genus 99. INACTIS. *Kutz.* (1843.)

Trichomes vaginate, indistinctly articulate, parallel and fastigiate, now and then dichotomous, very densely aggregated and agglutinated in a pulvinate thallus (Fig. 101).

371. **Inactis Cresswelli.** (*Thur.*) *Cooke, Algæ, t.* 100, *f.* 2.

Forming convex roundish or oval patches, which become confluent for several inches. Filaments hyaline, yellowish

or greenish olive, collected into dense rope-like branching bundles, which are fastigiate. Trichomes exceedingly slender, once or twice divided in a dichotomous manner. Trichomes $2\frac{1}{2}\mu$ diam.

Spreading over soft sandstone rocks.

372. **Inactis tinctoria.** (*Thur.*) *Cooke, Algæ, t.* 100, *f.* 3.

Fasciculate cespitose, dingy brown, becoming olive. Trichomes single, or many associated in one sheath; joints equal in length to their diameter, or a little longer. Sheaths broad, colourless, distinctly lamellose, even. Trichomes 2μ diam.

On aquatic plants.

Genus 100. **LYNGBYA.** *Ag. em Thuret.* (1876.)

Filaments enclosed singly in a sheath, simple, or only exceptionally exhibiting the beginning of ramification where the trichome issues from the side of the sheath, often combined in a membranaceous stratum (Fig. 102).

373. **Lyngbya æstuarii.** (*Lieb.*) *Cooke, Algæ, t.* 101, *f.* 1.

Trichomes rigid, flexuously curved, blue-green, granular, densely interwoven in dark blue-green tufts; joints 3 to 6 times shorter than their diameter, scarcely constricted. Sheaths pellucid, hyaline, becoming brownish, at first scarcely lamellose, at length when old becoming distinctly lamellose. Trichomes 25–30μ diam. without sheath.

In brackish water.

374. **Lyngbya littoralis.** (*Carm.*) *Cooke, Algæ, t.* 102, *f.* 1.

Stratum thin, blue-green, shortly radiating. Trichomes rigid, flexuous, vividly oscillating, equal; joints 4 to 5 times as broad as long, constricted at their junction and hyaline; dissepiments granulated; extreme apiculus straight, broadly rounded, paler. Cell-contents pale blue-green, very delicately granular. Threads 13–15μ diam.

In brackish water, and in rock pools by the shore.

375. **Lyngbya ochracea.** (*Thur.*) *Cooke, Algæ, t.* 102, *f.* 4.

Forming cloud-like floating fragile masses of an ochrey colour. Trichomes very slender, scattered; joints scarcely visible. Trichomes 2μ diam., including sheath.

In boggy pools.

376. **Lyngbya inundata.** (*Kutz.*) *Cooke, Algæ, t.* 102, *f.* 8.

Deep blue-green, with a whitish grumous membranaceous substratum. Trichomes curved rather rigid, pale blue-green, rarely fasciculate. Sheaths narrow; joints shorter than their diameter; dissepiments naked; extreme apex straight obtuse. Trichomes 4μ diam.

Margin of ditches, by moist roads, on flower-pots, etc.

377. **Lyngbya vulgaris.** (*Kirch.*) *Cooke, Algæ, t.* 102, *f.* 5.

Stratum thin, more or less expanded, mucilaginous, dark coloured, opaque or shining, rarely lamellose, and without a substratum being formed. Trichomes straight, rigid, distinctly vaginate; joints equal to their diameter or shorter; dissepiments delicately granulated; apex attenuated, somewhat curved, naked. Trichomes $4\frac{1}{2}$–$6\frac{1}{2}\mu$ with sheath.

On moist naked ground after rain.

378. **Lyngbya papyrina.** (*Kirch.*) *Cooke, Algæ, t.* 102, *f.* 7.

Forming a thin papery stratum, sometimes shortly radiating, with a pallid or brownish fibrillose substratum, formed from the interlaced empty sheaths. Trichomes equal; joints nearly equal or a little shorter than their diameter, granulated at their junction; apex obtuse, straight, naked. Trichomes 5–6μ diam.; with sheath, $7\frac{1}{2}$–9μ.

In streams, torrents, aqueducts, canals, etc.

379. **Lyngbya rupestris.** (*Ag.*) *Cooke, Algæ, t.* 101, *f.* 2.

Stratum compact, rather velvety, gelatinous, lamellose, very shortly radiating, bright blue-green or dark steel-blue, lower strata discoloured and fibrillose. Trichomes

rigid, rather flexuous, a little torulose towards the apex; joints equal in length and breadth, very finely punctate; dissepiments granulated; extreme apex paler, sometimes bearded. Trichomes 7–8μ diam.

On moist rocks where the water is constantly trickling, and in mountain streams.

380. **Lyngbya corium.** (*Ag.*) *Cooke, Algæ, t.* 102, *f.* 2.

Stratum toughly membranaceous, compact, brown, steel-blue or greenish, interwoven in a mucilaginous substratum. Trichomes straight or flexuous, rather rigid, olive or brown, then yellowish; joints not more than half as long as broad, transversely punctate, granulated; apex conically attenuated, bearded. Trichomes 7–8μ diam.

On the rocky bottom of alpine rivulets.

381. **Lyngbya turfosa.** (*Carm.*) *Cooke, Algæ, t.* 102, *f.* 3.

Forming a thick intensely green stratum, with a tough, slimy, ochre-coloured substratum. Trichomes slender, more or less curved, and mostly hyaline at the point; joints not more than half as long as broad, distinct. Trichomes 8μ diam.

On floating sods in old turf-pits.

382. **Lyngbya subfusca.** (*Ag.*) *Cooke, Algæ, t.* 101, *f.* 3.

Substratum velvety, fibrillose, tawny, becoming yellowish, forming a firm compact stratum, of a violet or steel-blue colour, changing to brownish. Trichomes rigid, straight; joints about half as long as broad, with a double row of points at the commissure; apex rather obtuse, naked. Trichomes 8μ diam. Thinner form, trichomes 6–7μ diam.

On stones in mountain streams.

Genus 101. **SYMPLOCA.** *Kutz.* (1843.)

Trichomes articulate, simple, or exhibiting the beginning of ramification, more or less vaginate, ascending from a prostrate base, agglutinated together in erect or

anastomosing fascicles, or wick-like bundles, more or less procumbent, coalescing, and often involved in gelatin (Fig. 103).

383. **Symploca lucifuga.** (*Harv.*) *Cooke, Algæ, t.* 103, *f.* 2.

Dark æruginous green. Fascicles about 2 lines high, approximate, subuliform; apex at length penicillate. Trichomes single or twin, æruginous; joints equal or a little longer than broad, distinctly granulated. Sheaths broad, pellucid, colourless, quite smooth. Trichomes $3\frac{1}{2}$–4μ diam.; including sheath, 10μ.

On pastures and heaths, on decayed alder trunk.

384. **Symploca Ralfsiana.** (*Kutz.*) *Cooke, Algæ, t.* 103, *f.* 1.

Steel-blue or olive becoming blackish. Fascicles as much as 1 inch high, densely aggregated, often coalescing, subuliform, straight. Trichomes pale blue-green or steel-blue, densely agglutinate, distinctly articulated; joints equal or a little longer than broad. Cell-contents granular. Sheaths broad, pellucid, homogeneous. Trichomes $8\frac{1}{2}$–4μ diam.

Overrunning mosses in shady sub-alpine situation.

Genus 102. PLECTONEMA. *Thur.* (1875.)

Filaments branched. Ramifications produced by the branching of the trichome outside of the sheath very irregular, and often geminate as in *Scytonema* (Fig. 105).

385. **Plectonema mirabile.** (*Thur.*) *Cooke, Algæ, t.* 104, *f.* 1.

Forming floccose tufts, blue-green, now and then turning brownish. Trichomes with pseudo-branches usually in pairs and parallel; joints shorter than their diameter, granular. Sheath narrow, colourless or yellowish, quite smooth. Filaments 21μ with sheath.

In small streams.

386. **Plectonema Kirchneri.** *Cooke, Grev.* XI., *p.* 75; *Algæ, t.* 104, *f.* 2.

At first attached, soon floating, and forming subglobose woolly tufts, of a dark bluish green, changing to olivaceous. Tufts from ½–1 inch in diameter. Trichomes radiating, with simple (rarely geminate) branches; joints ½ or ¼ as long as broad. Filaments 12–15μ diam. with sheath.

In ornamental water.

FAMILY III. SCYTONEMEÆ.

Filaments with lateral ramifications in which some of the cells change into heterocysts.

GENUS 103. **SCYTONEMA.** *Ag.* (1824.)

Sheath enclosing a single trichome, which emerges from the side of the sheath. Ramifications usually geminate, the two filaments given off at a right angle. Heterocysts scattered in the trichome (Fig. 106).

387. **Scytonema myochrous.** (*Ag.*) *Cooke, Algæ, t.* 105, *f.* 1.

Stratum thin, woolly, dark brown. Trichomes very thick, brown, slightly curved, ascending, blue-green within, reddish at the apex (5–6 terminal joints), distinctly articulate. Pseudo-branches flaccidly erect, about half the thickness of the trichomes. Sheath thick, distinctly lamellose, firm, yellow-brown; that of the branches paler. Heterocysts oblong or sub-cylindrical, colourless, about equal to the inner diameter of the trichomes. Cells 10μ diam.; with sheath, 30μ diam.

On moist rocks.

388. **Scytonema natans.** (*Breb.*) *Cooke, Algæ, t.* 105, *f.* 2.

Floccose tomentose, green, then brown or olive. Trichomes slender, becoming brownish, internally æruginous

green, distinctly articulate; joints nearly equal, granular. Pseudo-branches very slender, more or less distant, very shortly articulated. Sheaths firm, lamellose, yellow or brownish. Branches paler, indistinctly lamellose. Heterocysts interspersed, oblong or ovoid, pellucid. Threads, with sheath, 25μ; without sheath, 7μ.

In stagnant water.

389. **Scytonema cinereum.** (*Meneg.*) *Cooke, Algæ, t.* 106, *f.* 1.

At first pulvinate, cinereous green, then confluent, forming a more or less tomentose pulverulent stratum (becoming pale blue when dry), now and then violet or purplish. Trichomes very fragile, flexuose and curved, loosely interwoven, sparingly branching, indistinctly articulate, æruginous green; joints shorter than broad. Sheaths thick, golden brown, often encrusted with deposit of lime. Trichomes 8μ, including sheath.

On walls, stones, overrunning moss, etc.

390. **Scytonema interruptum.** (*Thw.*) *Cooke, Algæ, t.* 106, *f.* 2.

Intense blue-green, forming a stratum. Sheath furnished throughout with numerous branched and anastomosing rootlets. Trichomes distinctly annulate, interrupted heterocysts. Branches in pairs arising from the protruded trichome.

In wet heathy places, coating mosses, etc.

Genus 104. **PETALONEMA.** *Berk.* (1832.)

Trichomes enclosed in a very broad striate membranous sheath, which forms a transparent layer, resembling a hyaline wing (Fig. 104).

391. **Petalonema alatum.** (*Berk.*) *Cooke, Algæ, t.* 107, *f.* 1.

Forming a thin brown stratum. Trichomes small, a few lines only in length, winged, obtuse; each wing thrice the breadth of the filament, white, somewhat transparent, bright yellow next the filament, exhibiting a numerous series of transverse lines or folds. Endochrome

of the central thread greenish and septate. Trichomes 10μ; with sheath, from $50–120\mu$.

On rocks exposed to the trickling of water.

GENUS 105. **SYMPHYOSIPHON.** *Kutz.* (1843.)

Trichomes as in *Scytonema*. Filaments agglutinated in erect wick-like bundles (Fig. 107).

392. **Symphyosiphon Hoffmanni.** (*Kutz.*) *Cooke, Algæ, t.* 107, *f.* 2.

Terrestrial. Tufts small, ascending, dark brown. Trichomes simple, erect, loosely collected in pointed fascicles, internally pale æruginous green, sometimes interrupted; joints delicately granulose, inferior cylindrical, thin, superior thicker and more or less swollen. Sheath firm, broad, attenuated upwards, rarely acute, colourless, or yellowish towards the base. Heterocysts intercalated, globose, hyaline. Trichomes 10μ diam.; with sheath, $12–14\mu$.

On naked ground, overrunning mosses, etc.

GENUS 106. **TOLYPOTHRIX.** *Kutz.* (1843.)

Trichomes spuriously branched. Pseudo - branches spreading. Ramifications rarely geminate, oftener solitary, and originating near the heterocysts. One or several heterocysts placed directly above each branchlet (Fig. 108).

393. **Tolypothrix flaccida.** (*Kutz.*) *Cooke, Algæ, t.* 108, *f.* 1.

Cœspitose, dark blue-green. Trichomes and pseudo-branches elongated, flaccid, arising from a prostrate base, internally pale blue-green, interrupted or torulose, distinctly articulate; joints a little shorter than broad. Sheaths colourless, hyaline, rather broad. Heterocysts towards the base, subglobose or oblong, 2 or 3 together, colourless. Trichomes 10μ.

In pools, etc.

394. **Tolypothrix distorta.** (*Kutz.*) *Cooke, Algæ, t.* 108, *f.* 2.

Cœspitose floccose, bright blue-green, now and then pale. Trichomes and pseudo-branches loosely interwoven, internally blue-green, apparently continuous, or distinctly articulate; joints equal or a little shorter than their diameter. Sheaths broad, colourless, rarely pale yellow. Heterocysts at the base, or interjected, subglobose or oblong, often 2–3 together. Trichomes 12μ.

In swamps.

395. **Tolypothrix ægagropila.** (*Kutz.*) *Cooke, Algæ, t.* 109, *f.* 1.

Tufts an inch or more broad, somewhat rounded, bright blue-green or greenish olive. Trichomes and pseudo-branches loosely interwoven, internally pallid blue-green, continuous or distinctly articulate; joints equal or a little longer than their diameter. Sheaths narrow, hyaline, colourless. Heterocysts 2 or 3 (rarely more) in a series, oblong, hyaline. Trichomes 10–12μ.

In standing pools.

var. e. **pygmæa.** (*Kutz.*) *Cooke, Algæ, t.* 109, *f.* 2.

Tufts small, blue-green or brownish. Trichomes and pseudo-branches slender, very loosely interwoven; joints a little shorter than broad. Sheaths narrow, colourless or yellowish. Trichomes 7–8μ; with sheath, 10μ.

var. f. **muscicola.** (*Kutz.*)

Cœspitose, blue-green or brownish. Trichomes and pseudo-branches thicker, elongated, loosely intricate, distinctly articulated; joints a little shorter than broad. Sheaths very delicate. Trichomes 8–11μ.

On mosses, etc.

396. **Tolypothrix coactilis.** (*Kutz.*) *Cooke, Algæ, t.* 109, *f.* 3.

Fasciculate, cœspitose, green, then æruginous. Trichomes and pseudo-branches slender, internally pallid, æruginous, distinctly or indistinctly articulate, granulose; joints half their diameter in length. Sheaths very narrow, thin,

hyaline. Heterocysts oblong, twin or ternate, colourless. Trichomes 10μ; with sheath, a little more.

In ponds and lakes.

397. **Tolypothrix cirrhosa.** (*Carm.*) *Cooke, Algæ, t.* 108, *f.* 3.

Floating, cœspitose, olive or blue-green, becoming brownish. Trichomes nearly simple, rather stout, distinctly articulate, pallid blue-green; joints finely granular, $\frac{1}{2}$ or $\frac{1}{3}$ as long as broad. Sheaths narrow, indistinctly lamellose, smooth. Heterocysts scattered. Trichomes 12–14μ; with sheath, 20–25μ.

In mountain lakes.

Species of *Stigonema* and *Hapalosiphon* now generally included with lichens.

SPECIES FOR INQUIRY.

398. **Dasygloia amorpha.** (*Thwaites.*) *Cooke, Algæ, t.* 112, *f.* 1.

Gelatinous, amorphous. Sheaths of the trichomes thick, mucilaginous, cohering, slightly branched. Internal trichomes blue-green, slender, simple, septate.

In bogs.

399. **Petronema fruticulosum.** (*Thwaites.*) *Cooke, Algæ, t.* 112, *f.* 1.

Plants densely cœspitose, erect, branched. Branches free, with obtuse rounded apices, and each with a heterocyst at the base. Endochrome annulated, increasing in diameter towards the apices of the filaments. Fronds 200μ long; trichomes 4μ diam.

On rocks.

Sub-Tribe II. **TRICHOPHOREÆ.** *Filaments tapering at the top into a hyaline hair.*

Family IV. CALOTRICHEÆ.

Filaments free, or agglutinated into a definite thallus, terminating at the apex in a delicate hair-like extremity. Heterocysts scattered, or basal.

Genus 107. CALOTHRIX. *Ag.* (1824.)

Trichomes rather rigid, straight, attached, often fasciculate, growing in small tufts, or forming a turf of indefinite extent (Fig. 109).

400. **Calothrix Orsiniana.** (*Thur.*) *Cooke, Algæ, t.* 113, *f.* 1.

Stratum pulvinate, 2 lines in thickness, dark brown, lubricous, opaque. Trichomes elongated, branched, nearly equal, cuspidate at the apex or obtuse, distinctly articulate, here and there moniliform. Sheaths thick, lamellose, golden brown, apical portion dividing in fibrous lamellæ. Trichomes, with sheath, 10–12μ; without sheath, 4–6μ.

On rocks and submerged stones.

401. **Calothrix Dillwyni.** (*Hass.*) *Cooke, Algæ, t.* 113, *f.* 2.

Flaccid, bluish green or brown. Trichomes usually cohering in pairs. Sheaths inconspicuous, except towards the base; joints about half as long as their diameter. Heterocysts at the base of the branches, ovate or cordate. Trichomes 5–6μ; with sheaths, 8–10μ.

On mosses and moist rocks.

Species uncertain.

402. **Calothrix (?) Smithii.** (*Berk.*) *Cooke, Algæ, p.* 277.

Filaments red, creeping, branched, contained, with their ramifications, within a tough, more or less permanent sheath, which bursts irregularly. Endochrome annulated, very slender, green. Joints about as broad as long.

On moors.

Genus 108. RIVULARIA. *Roth.* (1824.)

Frond hemispherical or bladdery. Filaments agglutinated, radiating. Frond with a well-defined outline. Heterocysts basal. Ramifications produced by transverse division of the trichomes. Trichomes never producing any spores (Fig. 112).

403. **Rivularia echinata.** (*Eng. Bot.*) *Cooke, Algæ, t.* 114, *f.* 2.

Globose, minute, dark coloured, compact. Threads fastigiate, attenuated upwards to the apex, closely cohering, articulated. Heterocysts basal, globose. Sheaths very narrow, almost inconspicuous. Trichomes 7μ at base, 250μ long.

In lakes, ponds, etc.

404. **Rivularia calcarea.** (*Eng. Bot.*) *Cooke, Algæ, t.* 116, *f.* 3.

Hemispherical, confluent in a hard incrusting blue-green or brownish stratum, internally zoned of a darker green. Trichomes rather thick, pale blue-green, slightly flexuous, articulate, ending in a colourless hyaline point. Sheaths narrow, colourless or brownish at the base. Heterocysts globose. Lower joints of the trichomes equal in length to their diameter. Trichomes 6μ diam.

On rocks and stones in streams.

405. **Rivularia dura.** (*Kutz.*) *Cooke, Algæ, t.* 115, *f.* 2.

Size of a mustard seed, rather hard, dark bluish green, becoming brownish or blackish. Trichomes æruginous, variable, some thin and inarticulate, others thicker, articulate and torulose, all with distinct sheaths, lengthened into a colourless flexuous thread; lower joints as long as broad, or nearly so; upper ones longer, all granulated. Sheath colourless or yellowish. Heterocysts rounded, oblong. Trichomes 3–9μ diam. at the base.

Attached to aquatic plants, especially *Chara.*

406. **Rivularia granulifera.** (*Carm.*) *Cooke, Algæ, t.* 115, *f.* 1.

Frond large, convex, becoming hollow underneath, fleshy, lubricous, brownish olive, often including strong particles. Trichomes 6μ diam. at the base.

On cliffs exposed to the trickling of water.

Species uncertain.

407. **Rivularia botryoides.** (*Carm.*) *Cooke, Algæ, p.* 280.

Fronds minute, aggregated, roundish, wrinkled, ferruginous, cartilaginous. Trichomes dichotomous. Size not stated.

In streamlets, attached to rocks and stones.

408. **Rivularia crustacea.** (*Carm.*) *Cooke, Algæ, p.* 280.

Crust very thin, widely spreading. Filaments attenuated at the base, fastigiately branched above the middle, olive green.

On rocks exposed to the spray of cascades.

Genus 109. ISACTIS. *Thur.* (1875.)

Similar to *Rivularia*, from which it differs in the frond being flattened, and in the filaments being erect and parallel, and not radiating (Fig. 110).

409. **Isactis plana.** (*Thur.*) *Cooke, Algæ, t.* 114, *f.* 1.

Frond crustaceous, plane, suborbicular or confluent, from 1 inch to 2 feet, dull green, darker in the centre, lubricous, gelatinous. Trichomes erect, parallel. Sheaths hyaline. Trichomes 8μ diam.

Parasitic on *Enteromorpha* and other algæ.

Genus 110. GLOIOTRICHIA. *Ag.* (1842.)

Trichomes pseudo-ramose, vaginate. Sheaths broad, often saccate at the base, transversely plicate. Spores originating in the lower part of the trichome (Fig. 111).

410. **Gloiotrichia natans.** (*Thur.*) *Cooke, Algæ, t.* 116, *f.* 1.

Globose or angular, tuberculose, variable, green, becoming brownish. Trichomes straight, torulose, flexuous and hyaline above; lower joints more or less compressed. Sheath broad, here and there constricted, colourless or yellowish. Spores oblong, cylindrical. Heterocysts subglobose. Trichomes 10–12μ at base; with sheath, 30μ diam.; spores 18μ diam., several times as long.

In ditches, ponds, etc.

411. **Gloiotrichia pisum.** (*Thur.*) *Cooke, Algæ, t.* 116, *f.* 2.

Size and form of a pea or a cherry, soft, even, dark olive-green or brownish. Trichomes elongated; the lower part blue-green, distinctly articulated, the upper part setiform, colourless, and indistinctly articulated. Lower joints about equal in length and breadth, here and there somewhat swollen. Heterocysts globose or subglobose. Trichomes 10–12μ diam. at base; spores 10–12μ diam., of variable length.

In ponds, ditches, etc., adhering to aquatic plants.

Class III. RHODOPHYCEÆ (or Florideæ.)

Multicellular, with terminal vegetation. Cell-contents for the most part reddish, rarely otherwise coloured. Reproductive organs of three kinds, very often disposed in different plants, viz. (1) Male organs, or antheridia; (2) Female organs, or cystocarps; and (3) Tetrasporangia.

Family I. PORPHYRACEÆ.

Thallus mucous-membranaceous, formed from a single stratum of cells, chiefly purplish. Vegetation by division of cells. Propagation by tetraspores.

Genus 111. **BANGIA.** *Lyngb.* (1819.)

Thallus filamentous, simple or branched, for the most part purplish, lubricose, formed from a single series of cells. Cell-membrane thick, colourless, sometimes lamellose. Multiplication by division of the cell-contents (Fig. 113).

412. **Bangia atro-purpurea.** (*Dillw.*) *Cooke, Algæ, t.* 117, *f.* 1.

Forming lax purple tufts. Threads abbreviated, scarcely exceeding 1 inch long, simple, varying in thickness. Joints nearly equal in length to diameter, or one-third as long, more or less constricted. Filaments 30–60μ diam.; cells 10μ long.

Attached to wood and stones in streams.

Family II. HILDENBRANDTIACEÆ.

Thallus crustaceous, formed of many strata of cells, at first smooth, then punctate. Cells very minute, rounded, arranged in vertical series. Conceptacles opening with a broad pore. Tetrasporangia pyriform.

Genus 112. **HILDENBRANDTIA.** *Nardo.*

Character as in the family (Fig. 118).

413. **Hildenbrandtia rivularis.** *Ag.*

Crustaceous, rosy red. Cells oblong, rounded. Cells $3\frac{1}{2}$–4μ thick, equal or twice as long.

Incrusting stones, etc., in mountain streams.

Family III. CHANTRANSIACEÆ.

Forming dwarf pulvinate tufts, purplish violet or steel-blue. Thallus filamentous. Threads articulate, branched,

straight, naked, fasciculately branched above; joints cylindrical. Propagation by immovable spores formed at the tips of the branchlets. Tetraspores rare.

GENUS 113. CHANTRANSIA. *Fries.* (1825.)

The same characters as given above (Fig. 114).

414. **Chantransia violacea.** (*Kutz.*) *Cooke, Algæ, t.* 118, *f.* 1.

Tufts bright violet, scarcely exceeding 1 line broad, pulvinately rounded. Threads straight. Branches becoming erect, radiately disposed; joints 3 to 6 times as long as broad, the apical joints rather obtuse. Cells 8–9μ diam.

Parasitic on *Lemanea*, *Cladophora*, and aquatic mosses.

415. **Chantransia Hermanni.** (*Roth.*) *Cooke, Algæ, t.* 118, *f.* 2.

Cœspitose, pale rosy-purple, 3 lines long. Threads and branches whip-like, straight. Branchlets spreading, then ascending; joints 3 to 6 times as long as broad, the final joints cuspidate, or rarely piliferous. Cells 9–20μ diam.

On aquatic plants in streams.

416. **Chantransia chalybea.** (*Lyngb.*) *Cooke, Algæ, t.* 119, *f.* 3.

Cœspitose, steel-blue, about 1 inch long. Threads radiately disposed, adpressed. Branches straight; joints 3 to 6 times as long as broad. Spores collected in a racemose manner on lateral branchlets. Cells 10–11μ diam.

Rivulets, waterfalls, and on water-wheels.

417. **Chantransia pygmæa.** (*Kutz.*) *Cooke, Algæ, t.* 119, *f.* 2.

Tufts rounded, about 1 line in diameter, dingy greenish, becoming reddish, violet, or steel-blue when dry. Threads proceeding from a common centre, branched upwards in a somewhat fasciculate manner. Branches erect, parallel, rather adpressed; joints 2 to 3 times as long as broad, apical joints obtuse. Fascicles lateral or terminal. Cells 11–14μ diam.

In streams and springs.

418. **Chantransia investiens.** (*Lenormand.*) *Cooke, Algæ, t.* 119, *f.* 1.

Parasitic, rose-red, much branched. Joints many times longer than broad. Spores solitary or in pairs, lateral and terminal, clavate or obovate. Cells 6μ diam.

On *Batrachospermum moniliforme* and *B. atrum.*

Species uncertain.

419. **Chantransia scotica.** (*Kutz.*) *Cooke, Algæ, t.* 117, *f.* 2.

Cœspitose, about 1 inch long, steel-blue. Threads sparingly branched. Branches rather elongated, and, as well as the branchlets, somewhat divergent; joints 2 to 3 times as long as broad. Cells about 9–10μ diam.

On old immersed wood.

420. **Chantransia compacta.** (*Ralfs.*) *Cooke, Algæ, p.* 286.

Plant minute, hemispherical, inky-green, firm. Filaments much branched; joints twice as long as broad. Branches erecto-patent.

On aquatic plants.

Family IV. BATRACHOSPERMEÆ.

Diœcious. Thallus filamentous, articulate, branched, violet or violet-purple or bluish-green, covered with mucus. Primary filament of a single central series of cells, either furnished with densely conglobate tufts of verticillate fascicles of branches, or everywhere densely covered with simple or forked branches. Vegetation terminal.

Genus 114. BATRACHOSPERMUM. *Roth.* (1800.)

Thallus moniliform, composed of a simple series of medullary cells, and a cortical accessory parallel series, clothed with subglobosely clustered fascicles of branches (Fig. 115).

421. **Batrachospermum moniliforme.** (*Roth.*) *Cooke, Algæ, t.* 120.

From 1 inch to 1 foot in length, clothed with a more or less gelatinous mucus, violet-brownish, reddish brown, purple, or bluish green, profusely branched. Joints of the branches similar, oblong or clavate, outer ones sometimes setigerous. Internodes naked, or furnished with scattered accessory branches. Cellules 20–22 × 10μ.

In streams and ditches.

var. **setigerum.** (*Rabh.*) *Cooke, Algæ, p.* 288.

The extremities of the moniliform branchlets attenuated into a long setiform thread. Cell 20–24 × 10μ.

var. **pulcherrimum.** (*Bory.*) *Cooke, Algæ, t.* 121.

About 4 inches long, violet or purple, the gelatinous investment less developed. Branches elongated. Whorls rather distant, globose, with the apices of the branchlets almost confluent. Interstitial spaces nearly naked. Cellules 18 × 13–12μ.

var. **proliferum.** (*Kutz.*) *Cooke, Algæ, t.* 122.

Stem and primary branches densely set with short accessory branchlets. Cellules 18 × 10μ diam.

var. **confusum.** (*Hass.*) *Cooke, Algæ, t.* 123.

For the most part bright violet, 2–3–4 inches long, and similarly expanded, densely involved in a gelatinous mucus. Whorls approximate, with numerous interstitial branches irregularly disposed. Cellules 20–22 × 10μ.

var. **Boltoni.** *Cooke, Algæ, t.* 124.

This variety differs in the large size and very globose form of the joints of the whorls. The apices are very often setiform. Cellules 25 × 20, or 22 × 18μ.

var. **stagnale.** (*Ag.*) *Cooke, Algæ, p.* 290.

One or two inches long, blue or steel-blue. Whorls of the stem confluent, of the branches distant.

var. **alpestre.** (*Shuttleworth.*) *Hass., Algæ, t.* 14, *f.* 2.

Frond black, very mucous, much branched, alternately forming very obtuse angles with the principal filaments. Whorls of the stem spherical, distinct, but approximate. Branches compressed.

var. **helmintosum.** (*Bory.*) *Cooke, Algæ, p.* 291

Filaments branched, pyramidal, naked below. Branches simple, subpinnate, acute. Whorls contiguous, compressed.

var. **bambusinum.** (*Bory.*) *Cooke, Algæ, p.* 291.

Filaments sparingly branched. Branches simple. Cells much elongated. Whorls minute, distant.

422. **Batrachospermum vagum.** (*Roth.*) *Cooke, Algæ, t.* 125.

Vaguely branched, 1–3 inches long, brownish or bluish green. Inferior internodes covered with a dense mass of branchlets; the superior naked, or nearly so. Apical joints of the branchlets attenuated into a long bristle. Cellules $25 \times 12\mu$.

var. **keratophytum.** (*Bory.*) *Ann. Mus., t.* 31, *f.* 2.

Beautiful blue-green, thin, very much branched, dichotomous, with the black setaceous base naked. Branches all equal, slender, thin; apex slightly incrassated. Whorls distinct. Cellules clavate, about $30 \times 15\mu$.

423. **Batrachospermum atrum.** (*Harv.*) *Cooke, Algæ, t.* 126, *f.* 1.

Violet-coloured when moist, dark brown, almost black when dry, vaguely and much branched, reaching 2 inches. Whorls abbreviated, distant. Interstitial branchlets very short, 1 or 2 celled. Cellules 12μ diam.

In streams and ditches.

var. **Dillenii.** (*Bory.*) *Cooke, Algæ, t.* 126, *f.* 2.

Filaments dark brown, very thin. Lower nodes remote, the interstices beset very densely with prominent cells; upper nodes crowded. Branchlets very short, consisting of 3–4 cellules. Extreme apical nodes confluent. Cellules 12μ diam.

GENUS 115. **THOREA.** *Bory.* (1808.)

Thallus filamentose, attenuated, branched, purple-brown, villose, mucous, with a solid central medullary stratum, surrounded by dichotomously divided branchlets (Fig. 116).

424. **Thorea ramosissima.** (*Bory.*) *Cooke, Algæ, t.* 127.

From a hand's-breadth to 1 to 2 feet, very much branched, about the thickness of a horsehair, dark-green, of a beautiful purple-violet when dry. Ramelli spreading horizontally, long and short alternating, articulate. Joints 1 to 3 times as long as broad, or twice that length.

Attached to wood, etc.

FAMILY V. LEMANEACEÆ.

Fluviatile. Thallus developed from a confervoid prothallic filament, setaceous, almost simple, hollow, nodose, having an internal and a cortical layer of cells. Polyspores numerous, collected in branched moniliform series, germinating without fertilization.

GENUS 116. **LEMANEA.** *Bory.* (1808.)

The same characters as above (Fig. 117).

425. **Lemanea fluviatilis.** (*Ag.*) *Cooke, Algæ, t.* 128, *f.* 1.

Simple, or sparingly branched, 3–4 inches long, straight. Nodules rather remote, with about 3 verticillate papillæ. Spores $40 \times 25\mu$.

Attached to stones, wood, etc., in streams.

426. **Lemanea torulosa.** (*Roth.*) *Cooke, Algæ, t.* 128, *f.* 2.

Nearly simple, for the most part bent like a bow, 1–2 inches long. Nodules approximate. Papillæ flattened, sometimes confluent or almost obsolete. Spores 40×22–30μ.

In streams.

ADDENDA.

THE following species have been recently recorded; too late for insertion in their proper places.

GENUS 4 *bis*. **TROCHISCIA.** (*Kutz.*) *De Toni*, *Syll.*, 693.

Cells globose or subglobose. Membrane thick, warted, or spinulose. *Acanthococcus* Lagerh.

Trochiscia hirta. *De Toni*, *Sylloge.*

Entered at page 193 as *Pleurococcus vestitus*, Reinsch.

Trochiscia insignis. *Reinsch*, *t.* xii., *f.* 22.

Large. Cells solitary, globose. Membrane of the cells thick, lamellose, equal to one-fifth of the diameter of the cell, volvate, plicate at the periphery. 68–84μ diam.

In bogs.

Trochiscia anglica. *Bennett*, *Journ. R. M. S.* (1890.)

Cells irregularly sphæroid. Spines long, slender, hyaline, curved. Cell-contents bright green, granulate. Cells 65–95μ diam.

In bogs.

GENUS 5 *bis*. **CAPSULOCOCCUS.** *Bennett.* (1888.)

Cells green, globose, solitary, or 2–8 in families. Tegument lamellose, firm or rather gelatinous, subglobose or ovoid, cup-shaped at the apex, brown.

Capsulococcus crateriformis. *Bennett, Journ. R. M. S.*, 1888, *t.* 1, *f.* 6–8.

Cells large, bright green, usually solitary, globose or sub-ellipsoid, or formed from 2–8 smaller cells. Tegument more or less dingy brown, lamellose, becoming rather hard. Cells 20–25μ diam.

In bogs.

70*. **Pediastrum integrum.** *Näg., Einz. Alg., t.* v., *f.* 4.

Cœnobium composed of 4–8–16–32 cells, irregularly disposed. Cells polygonal suborbicular, broadly rounded at the periphery or obtusely angular, with two stout horns, generally abbreviated into warts, or sometimes absent. Membrane firm, reddish when old. Cœnobium 125 × 100μ; cells 20–28μ diam.

In bogs.

73*. **Cœlastrum cubicum.** *Näg., Einz. Alg.* 13, *t.* iv., *f.* 14.

Cœnobium rounded or cubical, composed of 8–50 cells. Cells sub-hexagonal, produced into 3 short hyaline appendages. Areolæ regular, 3–4–5 sided. Cœnobium 20–62μ; cells 18μ diam.

In bogs.

97*. **Zygnema peliosporum.** *Wittr., Bot. Not.*, 1868.

Sterile cells equal, or 2–3 times longer than broad. Zygospore formed in one of the conjugating cells. Membrane scrobiculate, dark violet. Cells 24μ diam.; zygospore 33μ diam.

In swamps.

164*. **Rhizoclonium geminatum.** *Bennett, Journ. R. M. S.*, 1890, *f.* 6–7.

Filaments long, slender, curving and interlaced. Cell-walls thin. From the filaments short root-like processes, filled with green endochrome, sometimes solitary, often geminate. Forming a flocculent scum. Cells 20 × $12\frac{1}{2}\mu$.

In pools, etc.

309*. **Aphanothece microscopica.** *Näg., Einz. Alg., t.* 1, *H.*

Thallus small, gelatinous, amorphous, indefinite. Cells oblong-cylindrical, nestling in mucus, without visible tegument. Cell-contents æruginous.

In swamps.

369*. **Schizothrix anglica.** *Bennett, Journ. R. M. S.*, 1890, *f.* 2.

Trichomes very long and slender, unbranched, 2 or more enclosed in a common mucilaginous sheath. Sheath 6–10 times as broad as the trichomes, pale yellow, diffluent, somewhat lamellose. Trichomes 5μ diam.

In bog pools.

GLOSSARY.

ACHROMATIC, colourless.

ACICULAR, needle-shaped.

ACUMINATE, tapering to a point.

ÆRUGINOUS, of the colour of verdigris—blue-green.

AGAMO - HYPNOSPORES, neutrally formed resting-spores.

AGAMOSPORES, spore formed neutrally without fecundation.

AGAMOSPOROUS, bearing spores without fecundation.

ALTERNATE, two organs so placed as not to be opposite to each other.

AMÆBOID, resembling an Amœba.

AMORPHOUS, without definite form.

AMYLACEOUS, resembling starch.

ANASTOMOSE, the opening of one vessel into another, applied to threads or tubes which become confluent, and form an irregular network.

ANDROGONIDIA, peculiar zoogonidia produced by female plants from which male plants are developed.

ANDROSPORANGIUM, sporangium enclosing spores of male plants, or androspores.

ANDROSPORE, a special kind of zoospores produced in cells, which originate the dwarf males in *Œdogonium*.

ANTHERIDIA, certain reproductive organs supposed to be analogous to anthers, or fecundative.

APICULUS, ending with a short point.

ARCUATE, bent like a bow.

AREOLA, an angular space with an elevated margin.

ARTICULATE, composed of joints.

BILOBATE, having two lobes.

BINATE, in pairs.

BOTRYOID, collected in clusters like a bunch of grapes.

BULLATE, blistered or puckered.

CAPILLARY, thread-like, resembling a hair.

CARPOSPORE, spores produced (by conjugation) in a sporocarpium.

CARTILAGINOUS, hard and tough like cartilage.

CAULOID, resembling, or analogous to, a stem.

CHLOROPHYL, the green colouring matter of leaves, and other green parts of plants.

CHLOROPHYLLOSE, resembling chlorophyl green.

CILIATE, furnished, or fringed, with hairs.

CILIUM, CILIA, hair or bristle placed marginally.

CIRCINATE, curled round, like the young frond of ferns.

CIRCUMSCISSILE, cut round transversely.

CLATHRATE, latticed, or perforated like a window.

CŒNOBIUM, a community of a definite number of individuals united in one body.

CŒSPITOSE, growing in tufts, after the manner of turf strictly, with many stems from one root.

CONCENTRICALLY, in rings, with a common centre.

CORDATE, heart-shaped.

CORIACEOUS, of a leathery consistence.

CORYMBOSE, resembling the inflorescence called a corymb.

CRENATE, notched or scolloped.

CRUSTACEOUS, hard and brittle, or forming a crust.

CUNEATE, shaped like a wedge.

CUSPIDATE, tapering gradually to a sharp stiff point.

CYTIOBLAST, a cell-germ.

CYTIODERM, cell-membrane.

CYTIOPLASMA, cell-contents.

DECUSSATE, in pairs, alternately crossing.

DEHISCENCE, splitting into regular parts.

DIAPHANOUS, nearly transparent.

DICHOTOMOUS, forked equally.

DIFFLUENT, readily dissolving.

DIŒCIOUS, DIOICOUS, when the male organs are borne on one plant and the female on another.

DISSEPIMENT, a partition or division.

ENCYSTED, enclosed in a cyst or bladder.

ENDOCHROME, cell-contents, colouring matter of cells.

ENDOPHYTAL, growing within plants.

ENDOSMOSE, the inward current established between fluids of different densities when separated by a membrane.

ENDOSPORIUM, ENDOSPORE, the inner coating of a spore.

EPIGYNOUS, seated upon the female organ.

EPIPHYTAL, growing upon plants.

EPISPORE, the outer integument of a spore.

EPIZOIC, growing upon animals.

EXOSPORIUM, EXOSPORE, the outer membrane of the coat of a spore.

FASCICLE, a bundle.

FASCICULATE, in bundles from a common point.

FILAMENTOSE, composed of threads, thread-like.

FOLIACEOUS, resembling a leaf.

FURFURACEOUS, mealy, or resembling meal.

GEMINATE, produced in pairs.

GENUFLEXUOUS, bent angularly like a knee-joint.

GONIDIA, propagative bodies of small size not produced directly or indirectly by any act of fertilization.

GONOSPHERE, a ball-like agglomeration of spores.

GYNANDROSPOROUS, bearing male and female spores.

HAMATE, hook-shaped, resembling a hook.

HETEROCYST, intercalated cells of a

special character differing from their neighbours.

HETEROGENEOUS, unlike, or dissimilar in kind.

HEXAHEDRICAL, having six sides.

HOMOGENEOUS, of the same kind, consisting of elements of a like nature.

HORMOGONE, special reproductive bodies, composed of a chain of cells.

HYALINE, transparent, resembling glass.

HYPNOSPORANGIUM, HYPNOSPORANGE, sporangium enclosing hypnospores.

HYPNOSPORE, spores which repose some time before germinating = "resting-spores."

HYPOGYNOUS, seated beneath the female organ.

IDIO-ANDROSPORES, neuter individuals, producing androspores (in *Œdogonium*).

INTERCALATED, interspersed, placed between others.

INTERCELLULAR, between the cells.

INTERSTITIAL, placed between.

ISOLATED, detached, placed by itself.

ISOSPORE, applied to spores which are all of one size, or kind, in the same plant.

LACUNA, a depression, cavity, or intercellular space.

LAMELLÆ, thin plates or membranes parallel to each other.

LAMELLOSE, formed of layers or plates superimposed.

LUBRICOUS, slippery.

LUNATE, crescent-shaped.

MACRANDROUS, having elongated male plants.

MACROGONIDIA, large gonidia.

MATRICAL, belonging to the matrix.

MESOPHYLLIC, in the middle of a leaf or frond.

MESOSPORIUM, MESOSPORE, the middle membrane of the coat of a spore.

METAGENESIS, a kind of alternation of generations.

MICROGONIDIA, small gonidia.

MICROPYLE, the aperture in the skin of a seed which was the foramen in the ovule, a little scar.

MOBILE, movable.

MONILIFORM, necklace-shaped, contracted at regular intervals.

MONOICOUS, MONŒCIOUS, with male and female organs on the same plant.

MULTICELLULAR, composed of many cells.

MULTILOCULAR, containing many cells or cavities.

MULTI-PARTITE, divided into many parts.

NANANDROUS, having short or dwarf male plants.

NODULOSE, knotted, or with swollen joints.

NUCLEUS, the central germ around which a cell is formed, small spherical bodies contained within spores or other cells.

OBCORDATE, inversely heart-shaped.

OCTONATE, eight together.

OLEAGINOUS, oily, or resembling oil.

OOGONIUM, a kind of ovarian sac containing spores which, when liberated, are called oospores.

OOSPORE, spores produced in an ovarian sac.

Operculum, the lid or cover of a capsule.

Parenchyma, compressed or hexagonal cellular tissue.

Parenchymatous, resembling the cellular tissue termed "parenchyma."

Parietal, growing by, or to, the wall.

Parthenogenesis, production of fertile seeds without sexual impregnation.

Parthenogonidia, gonidia produced without fecundation.

Patent, spreading.

Pectinate, pinnatifid, with narrow close segments, like the tooth of a comb.

Pedicellate, having a foot, or stem.

Pentahedrical, having five sides.

Pericarpium, covering or tegument of fruit.

Periderm, Peridermic, the enclosing membrane.

Peripheral, the outer portion of a circle.

Piliferous, bearing hairs, hairy.

Plicate, folded, or plaited.

Plumose, feathery, or like a feather.

Polymorphism, Polymorphic, having many forms.

Primordial, original, existing from the beginning.

Prothallus, the false thallus first formed on germination of a spore.

Pseudo-branches, false branches, or resembling branches.

Pseudo-ramose, having false branches.

Pyriform, pear-shaped.

Quadri-radiate, with four radii, or rays.

Quaternate, arranged in fours.

Ramulus, a small or secondary branch.

Reniform, kidney-shaped.

Replicate, folded back.

Resting-spore, a spore which becomes quiescent, or rests for a period, more or less long, before germination.

Rhizoid, resembling, or analogous to, a root.

Rostrate, terminating with a beak.

Saccate, in the form of a bag.

Scalariform, barred or crossed like the steps of a ladder.

Scrobiculate, marked with little pits or depressions.

Scutate, buckler-shaped.

Segmentation, dividing into segments.

Segregate, to separate from others, or set apart.

Semi-, prefix signifying "half."

Septum, a partition or division.

Sigmoid, shaped like the letter S.

Sinus, a depression or notch.

Spermatozoa, Spermatozoids, thread-like bodies possessed of motion, supposed to have fecundative power.

Sporangium, Sporangia, a spore-case, having spores produced within it.

Sporiferous, bearing spores.

Sporocarpium, covering or capsule enclosing spores or carpospores.

Sporoderm, the coating or covering of a spore.

Sporules, minute spore-like bodies.

Stratose, arranged in layers or strata.

Stratum, a layer or extended bed.

STRIÆ, parallel lines or shallow grooves.

SUB-, a common prefix indicating "almost" or "nearly."

SUBULATE, shaped like an awl.

TANGENTIAL, in the direction of a tangent, touching a straight line on the arc of a circle.

TEGUMENT, a covering or membrane.

TERETE, cylindrical, tapering like the trunk of a tree.

TETRAHEDRICAL, having four sides.

TETRASPORES, certain spores produced in fours.

THALLUS, an expansion somewhat resembling a leaf.

TORULOSE, almost synonymous with moniliform.

TRICHOGONIA, the female reproductive organs in Batrachosperms.

TRICHOME, the thread or filament of filamentous algæ.

TRICHOTOMOUS, dividing in threes.

TRUNCATE, terminating very abruptly.

TUBERCULATE, covered with warts or tubercles.

UNICELLULAR, literally composed of one cell.

VACUOLE, drops which are seen in the interior of the protoplasm of cells.

VAGINA, VAGINATE, a sheath, sheathing.

VERRUCOSE, covered with warts.

VERTICILLATE, arranged in whorls.

VESICLE, a bladder-like cavity.

VIBRATILE, that moves to and fro, or vibrates.

ZOOGONIDIA, gonidia endowed with active motion.

ZOOSPORANGIUM, ZOOSPORANGE, sporangium enclosing zoospores.

ZOOSPORES, locomotive spores.

ZYGOSPORE, a spore resulting from conjugation.

EXPLANATION OF FIGURES.

1. Eremosphæra viridis.
2. Pleurococcus angulosus.
3. Schizochlamys gelatinosa.
4. Glœocystis ampla.
5. Urococcus Hookerianus.
6. Palmella mucosa.
7. Porphyridium cruentum.
8. Tetraspora gelatinosa.
9. Apiocystis Brauniana.
10. Botryococcus Braunii.
11. Palmodictyon viride.
12. Raphidium falcatum.
13. Dictyosphærium reniforme.
14. Hormospora ramosa.
15. Hydrurus penicillatus.
16. Nephrocytium Naegelii.
17. Dactylococcus De Baryanus.
18. Mischococcus confervicola.
19. Botrydina vulgaris.
20. Protococcus viridis.
21. Chlorococcum gigas.
22. Hydrodictyon utriculatum.
23. Polyedrium longispinum.
24. Scenedesmus quadricauda.
25. Ophiocytium cochleare.
26. Sciadium arbuscula
27. Pediastrum Boryanum.
28. Staurogenia rectangularis.
29. Polyedrium tetrahedricum.
30. Sorastrum spinulosum.
31. Cœlastrum sphæricum.
32. Selenastrum Bibraianum.
33. Hydrianum heteromorphum.
34. Characium ornithocephalum.
35. Codiolum gregarium.
36. Volvox globator.
37. Chlamydococcus pluvialis.
38. Chlamydomonas pulvisculus.
39. Eudorina elegans.
40. Gonium pectorale.
41. Pandorina morum.
42. Stephanosphæra pluvialis.
43. Zygnema pectinatum.
44. Zygnema subtile.
45. Spirogyra longata.
46. Sirogonium sticticum.
47. Zygogonium ericetorum.
48. Mongeotia lævis.
49. Mesocarpus recurvus.
50. Mesocarpus depressus.
51. Staurospermum gracillimum.
52. Staurospermum viride.
53. Gonatonema subtile.
54. Botrydium granulatum.
55. Vaucheria sessilis.
56. Prasiola calophylla.
57. Enteromorpha intestinalis.
58. Monostroma Wittrockii.

59. Sphæroplea annulina.
60. Cylindrocapsa involuta.
61. Microspora fugacissima.
62. Conferva fontinalis.
63. Chætomorpha sutoria.
64. Rhizoclonium Casparyi.
65. Cladophora flavescens.
66. Pithophora Kewensis.
67. Œdogonium ciliatum.
68. Bulbochæte gracilis.
69. Hormiscia zonata.
70. Ulothrix tenuis.
71. Microthamnion vexator.
72. Chroolepus aureus.
73. Schizogonium murale.
74. Draparnaldia glomerata.
75. Stigeoclonium tenue.
76. Young plants of Hormiscia.
77. Chroococcus turgidus.
78. Glœocapsa rupestris.
79. Aphanocapsa virescens.
80. Microcystis protogenita.
81. Clathrocystis æruginosa.
82. Cælosphærium Kutzingianum.
83. Aphanochæte repens.
84. Chætophora elegans.
85. Coleochæte soluta.
86. Gomphosphæria aponina.
87. Merismopædia glauca.
88. Tetrapedia crux michaeli.
89. Glœothece granosa.
90. Aphanothece stagnina.
91. Homalococcus Hassallii.
92. Nostoc verrucosum.
93. Anabæna flos-aquæ.
94. Cylindrospermum macrospermum.
95. Sphærozyga Broomei.
96. Aphanizomenon flos-aquæ.
97. Nodularia litorea.
98. Spirulina Jenneri.
99. Oscillaria tenuis.
100. Microcoleus chthonoplastes.
101. Inactis tinctoria.
102. Lyngbya æstuarii.
103. Symploca Ralfsiana.
104. Petalonema alatum.
105. Plectonema Kirchneri.
106. Scytonema natans.
107. Symphyosiphon Hoffmanni.
108. Tolypothrix ægagropila.
109. Calothrix Dillwynii.
110. Isactis plana.
111. Glœotrichia natans.
112. Rivularia dura.
113. Bangia atropurpurea.
114. Chantransia Hermanni.
115. Batrachospermum moniliforme.
116. Thorea ramosissima.
117. Lemanea torulosa.
118. Hildenbrandtia rivularis.

INDEX TO INTRODUCTION.

INDEX TO GENERA.

THE END.

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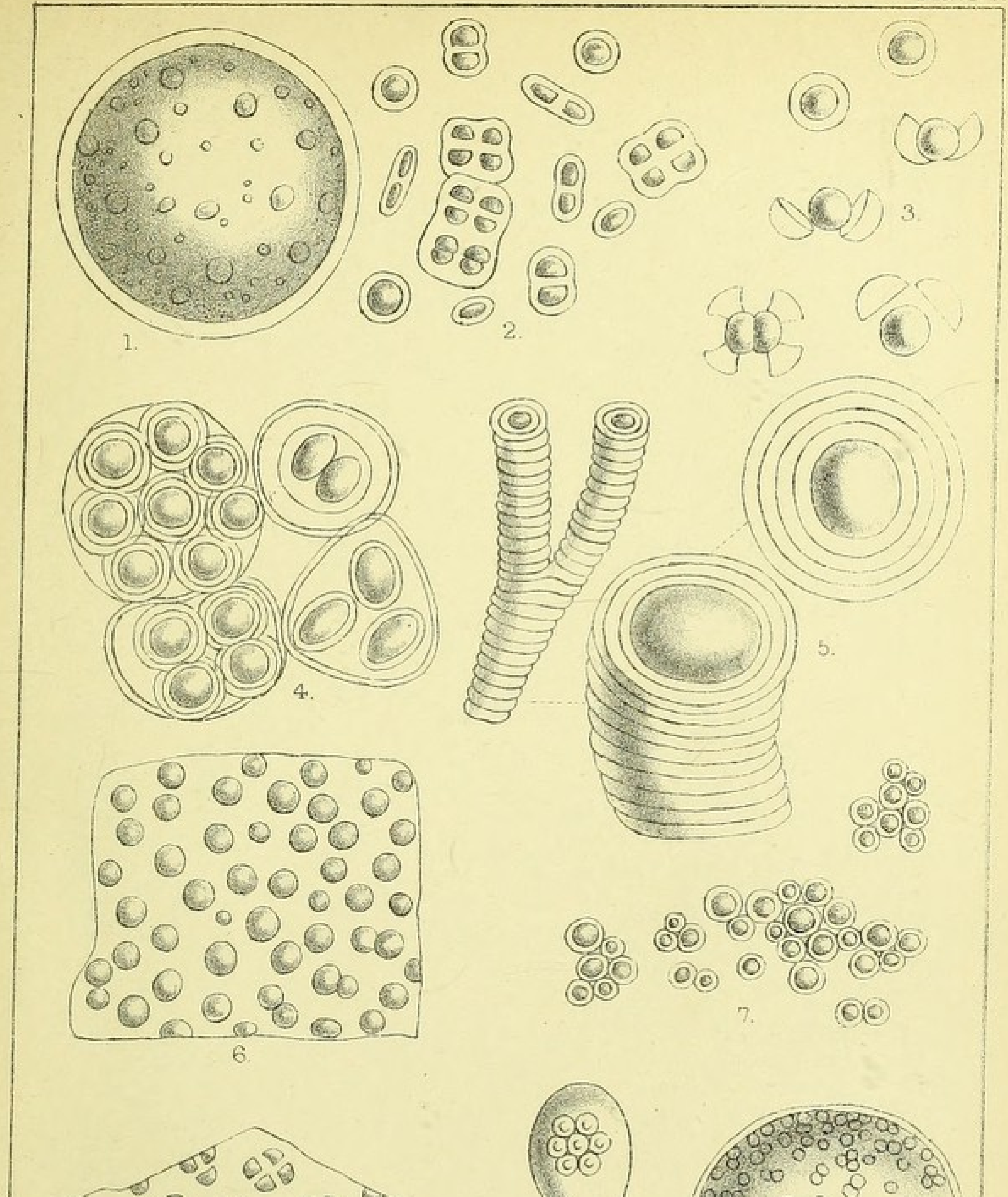

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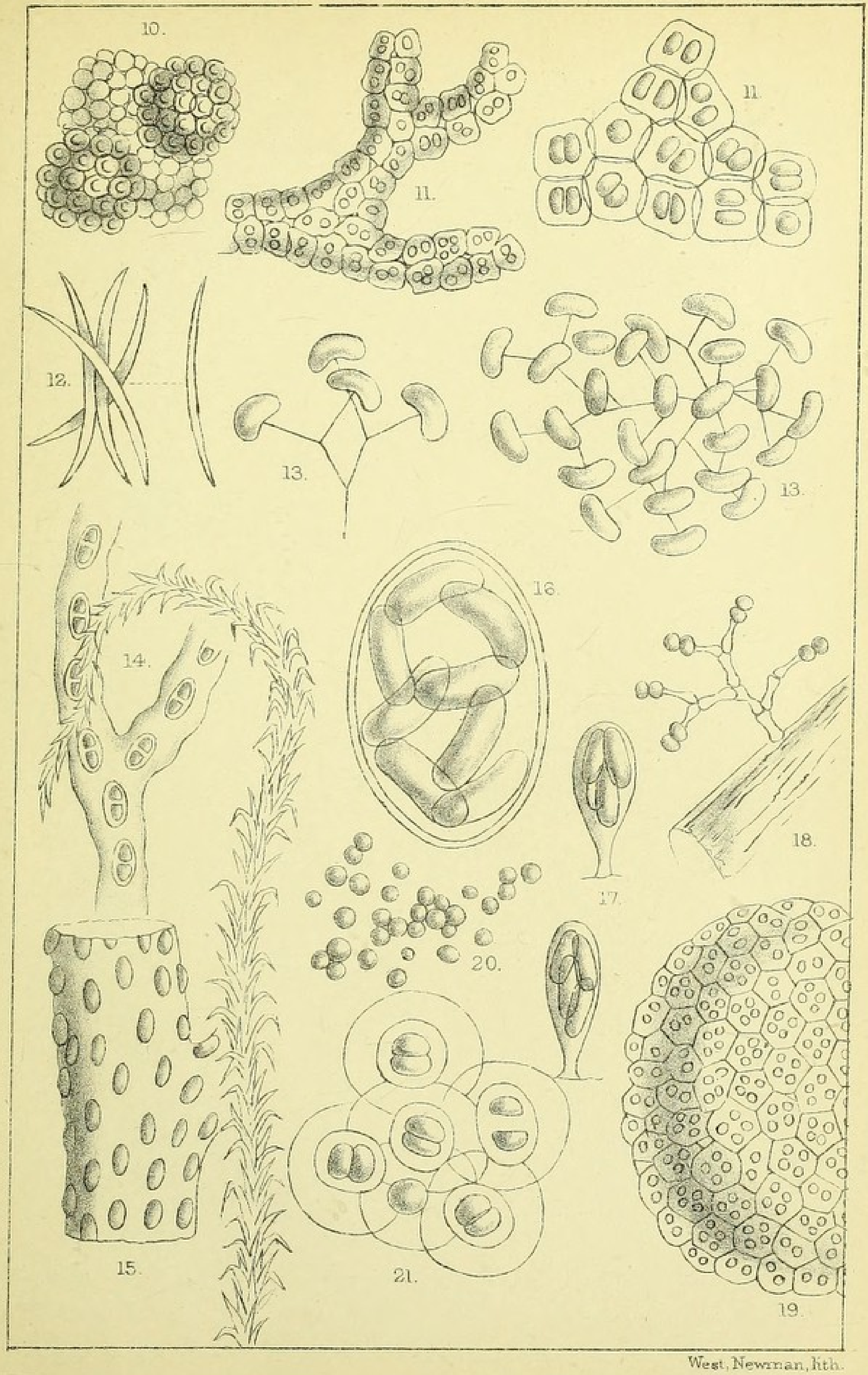

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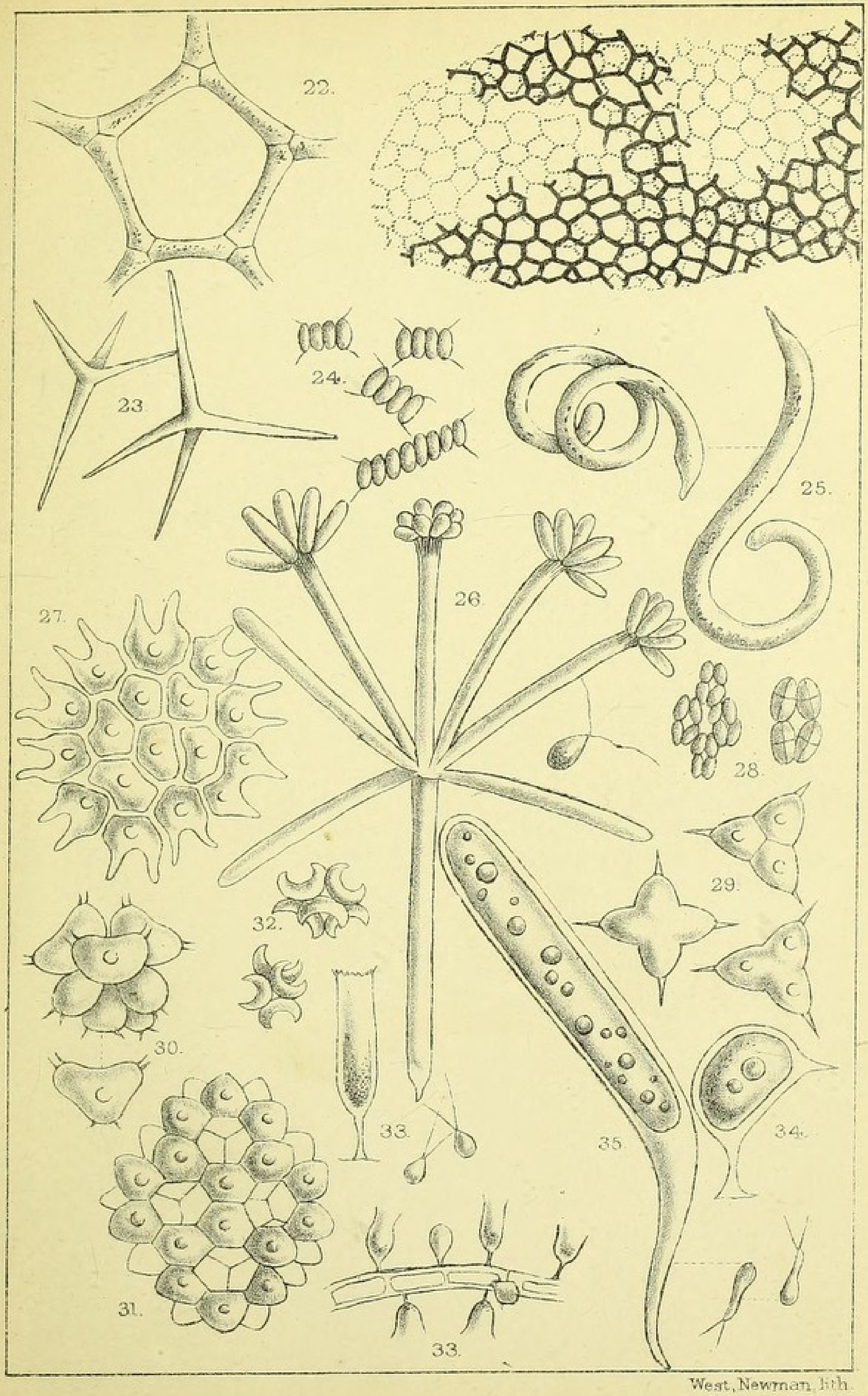

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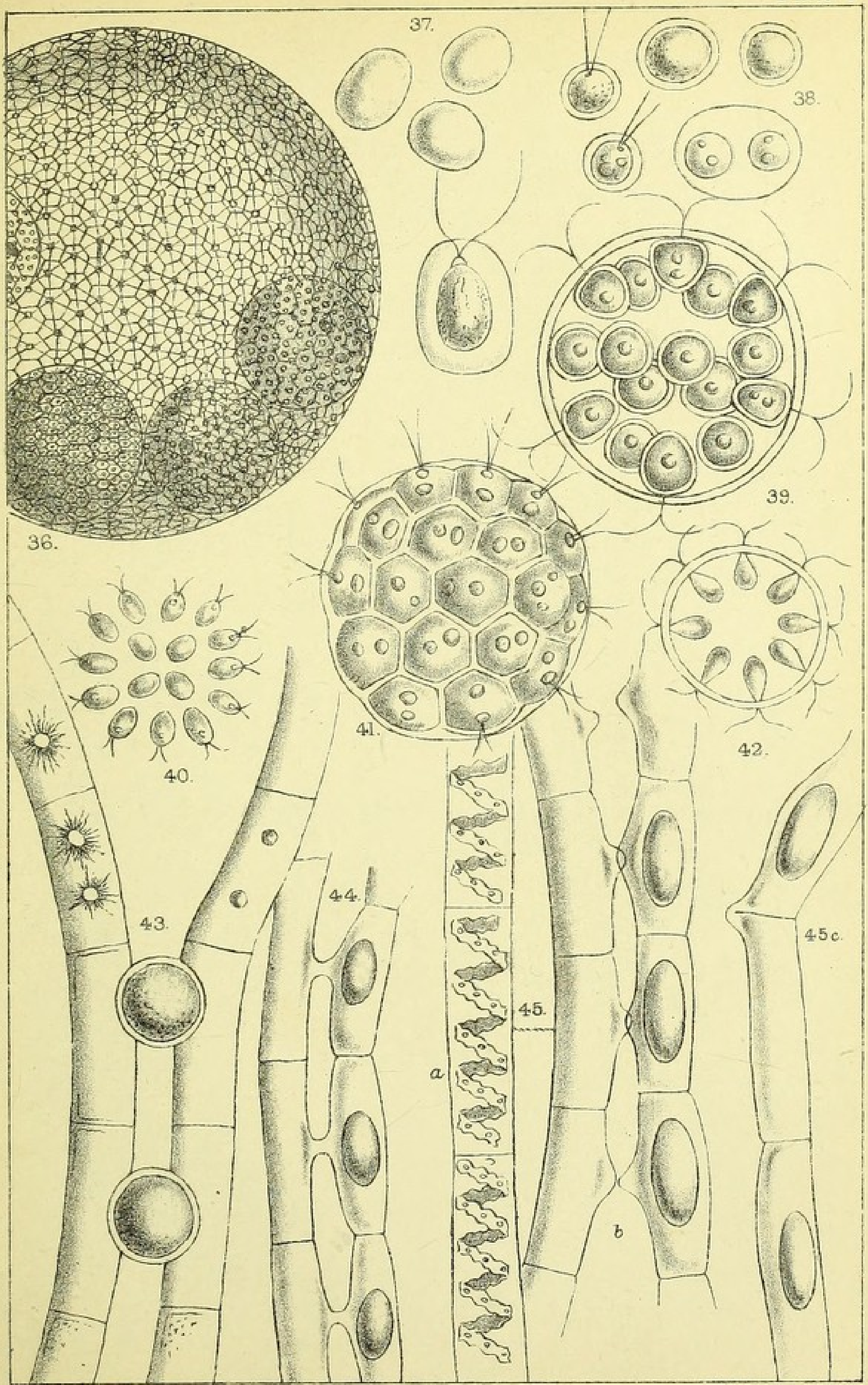

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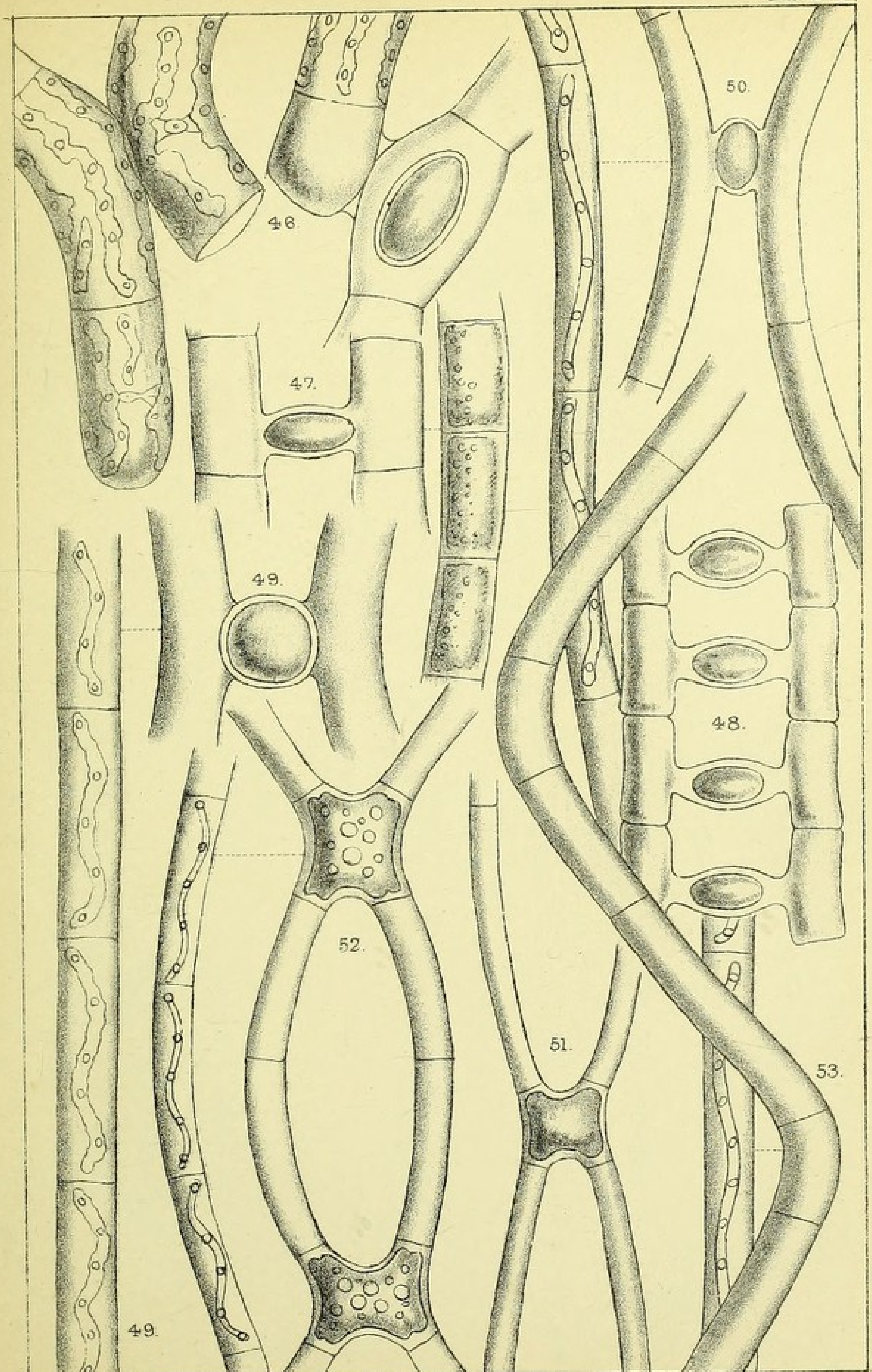

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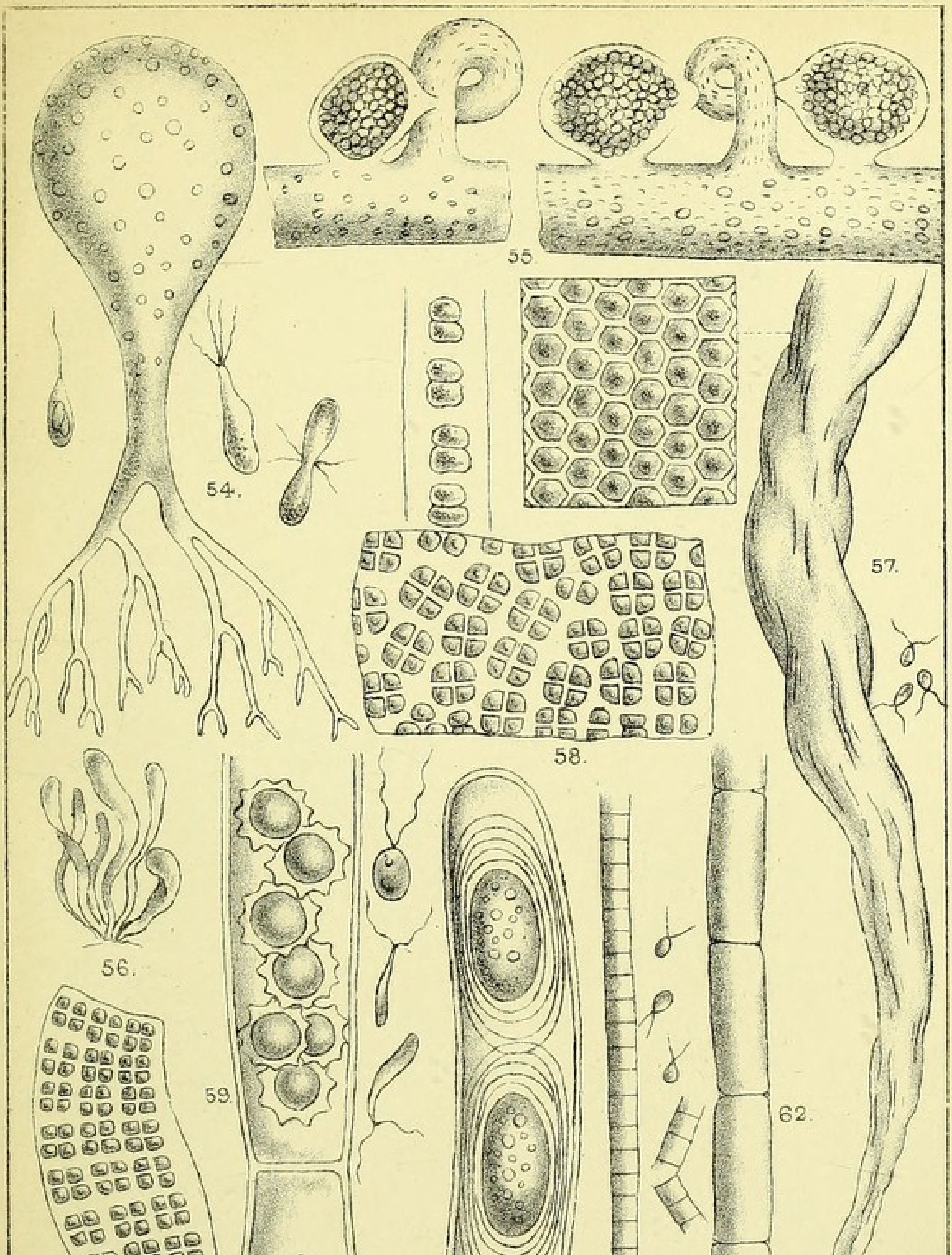

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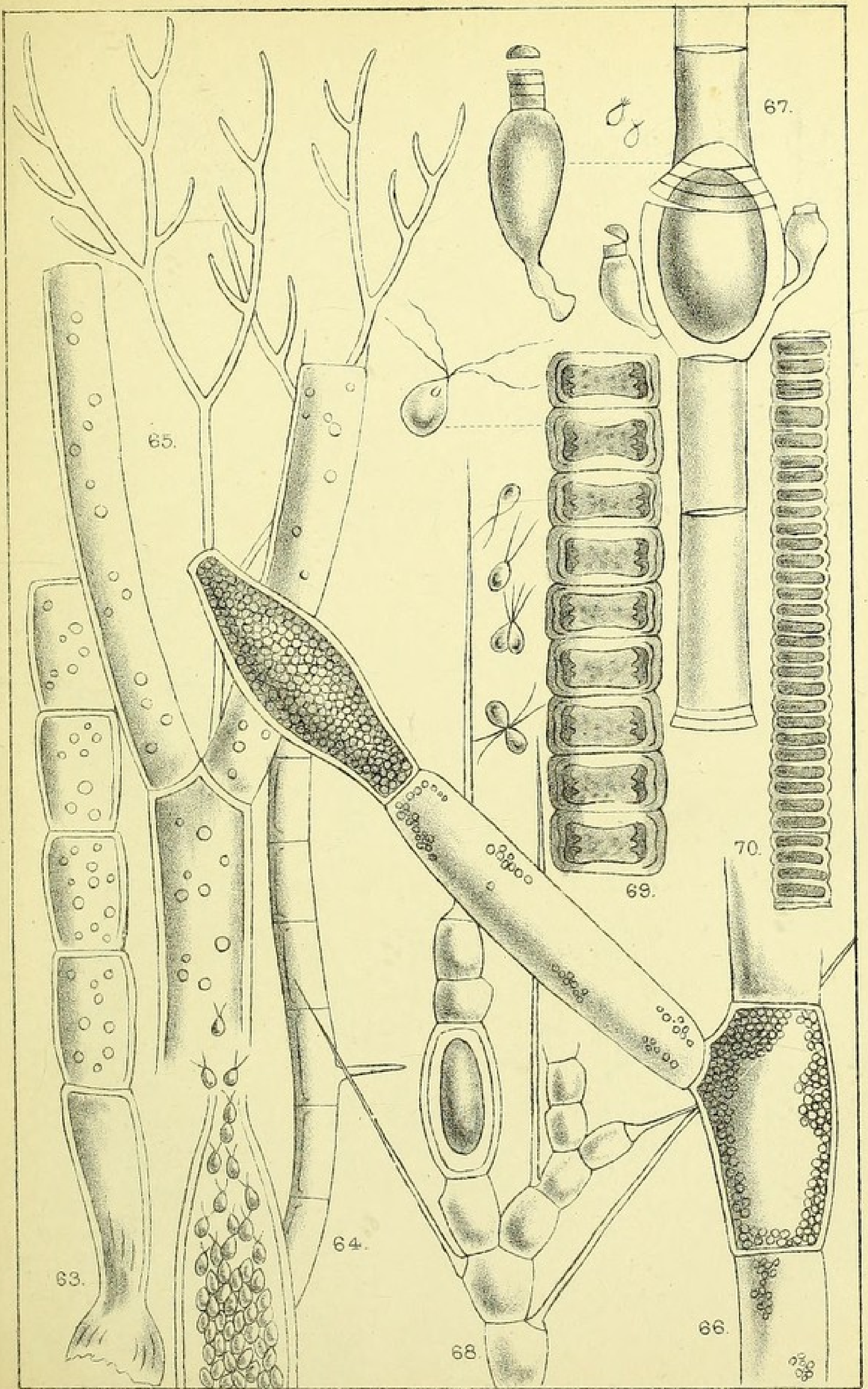

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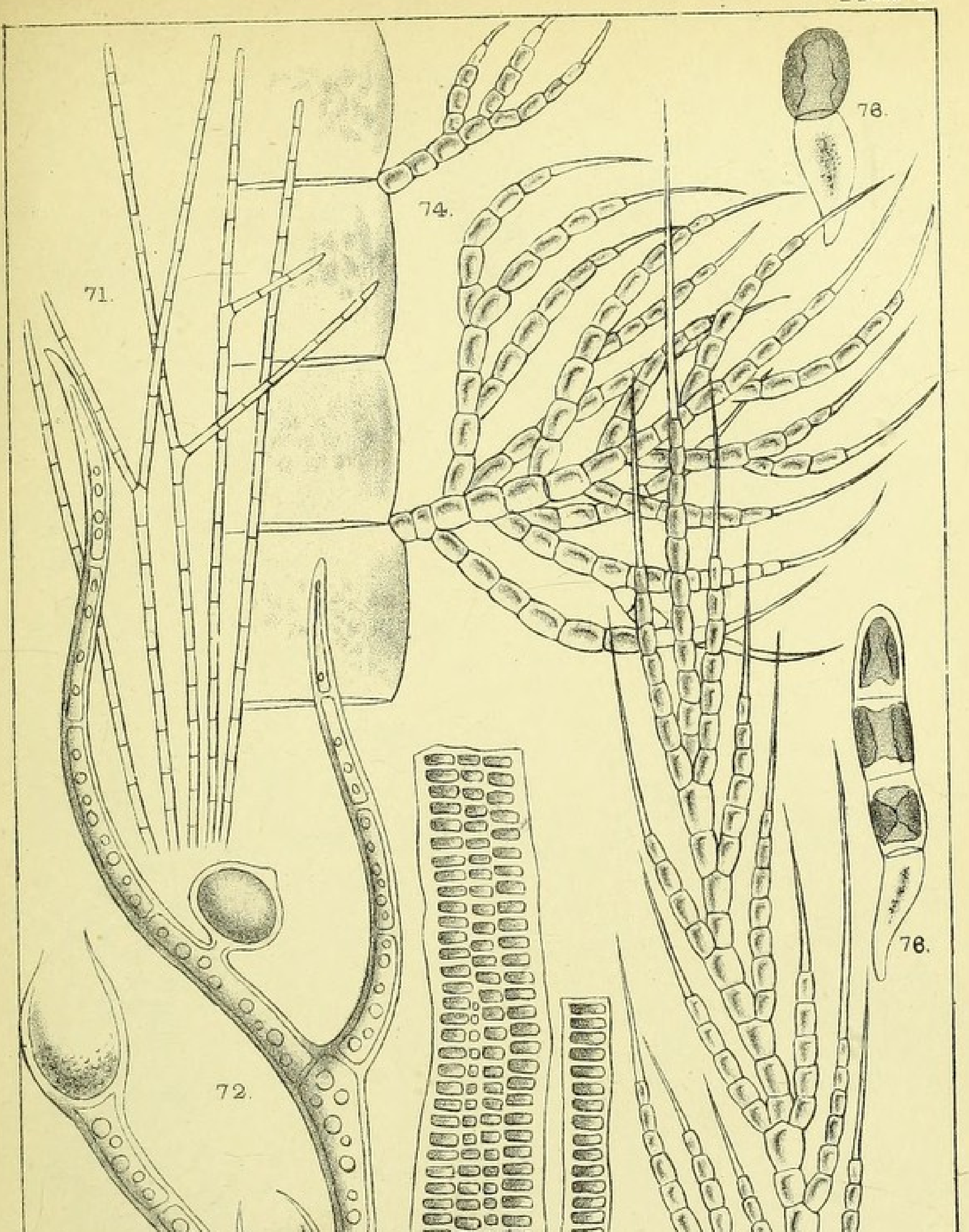

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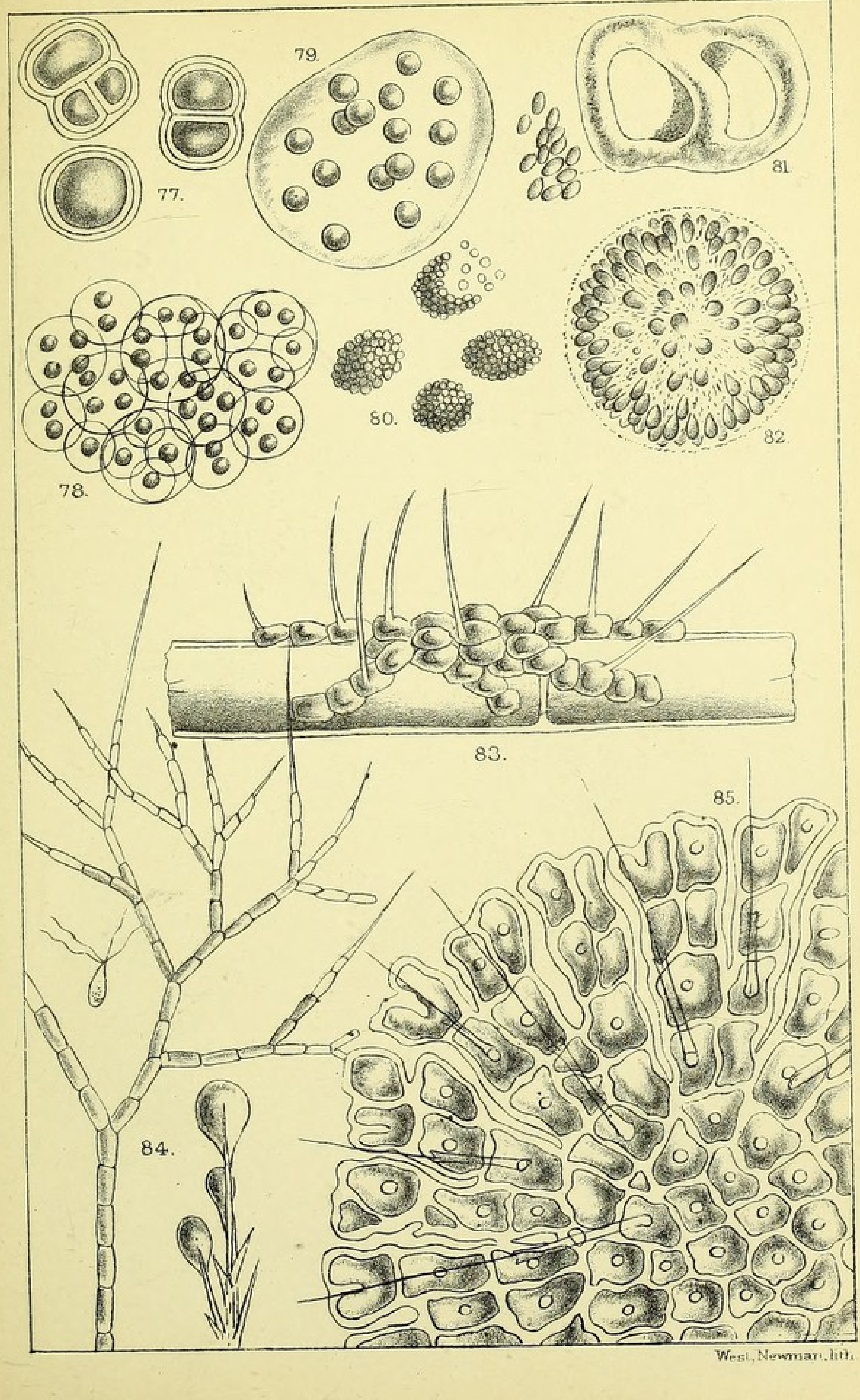

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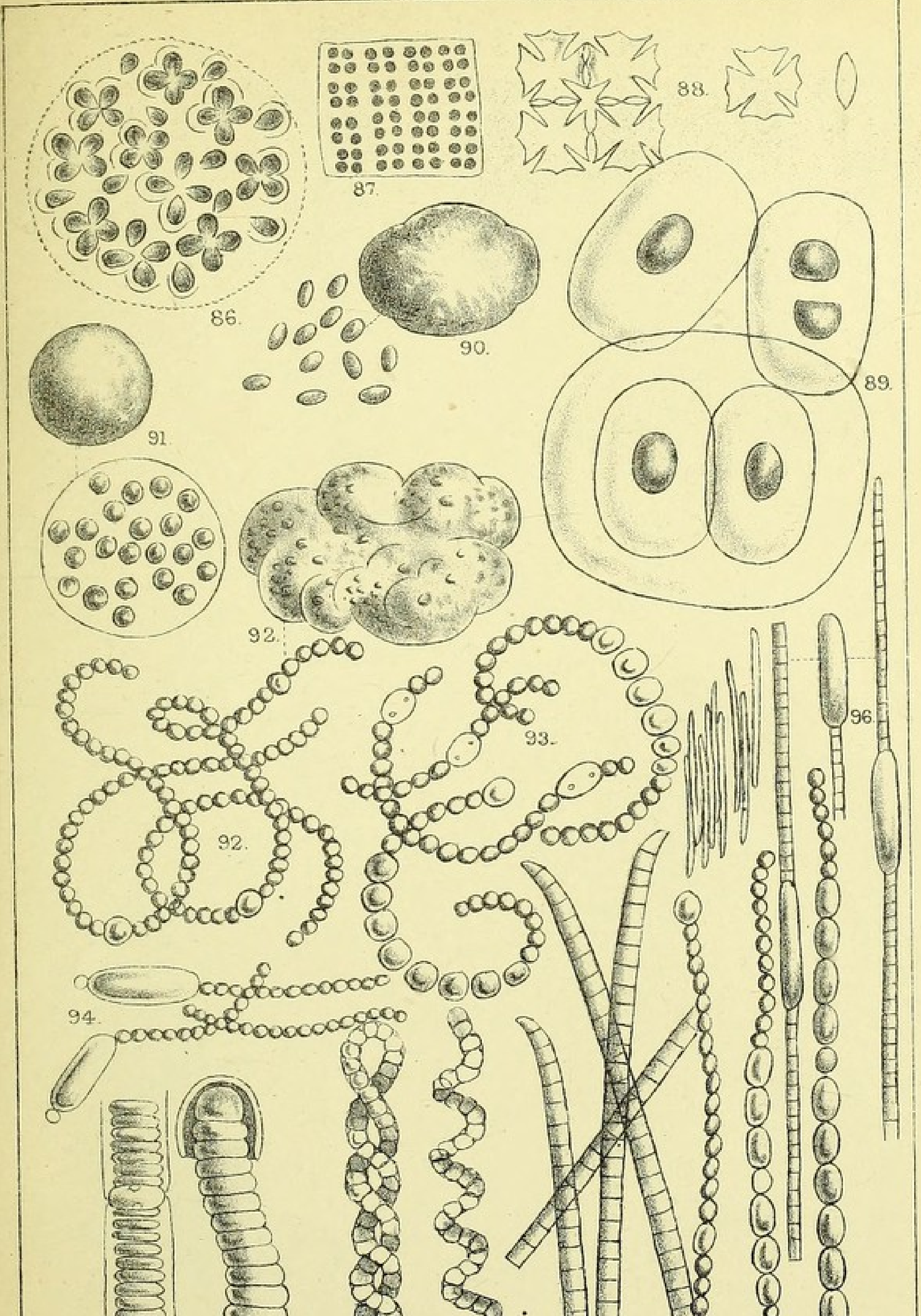

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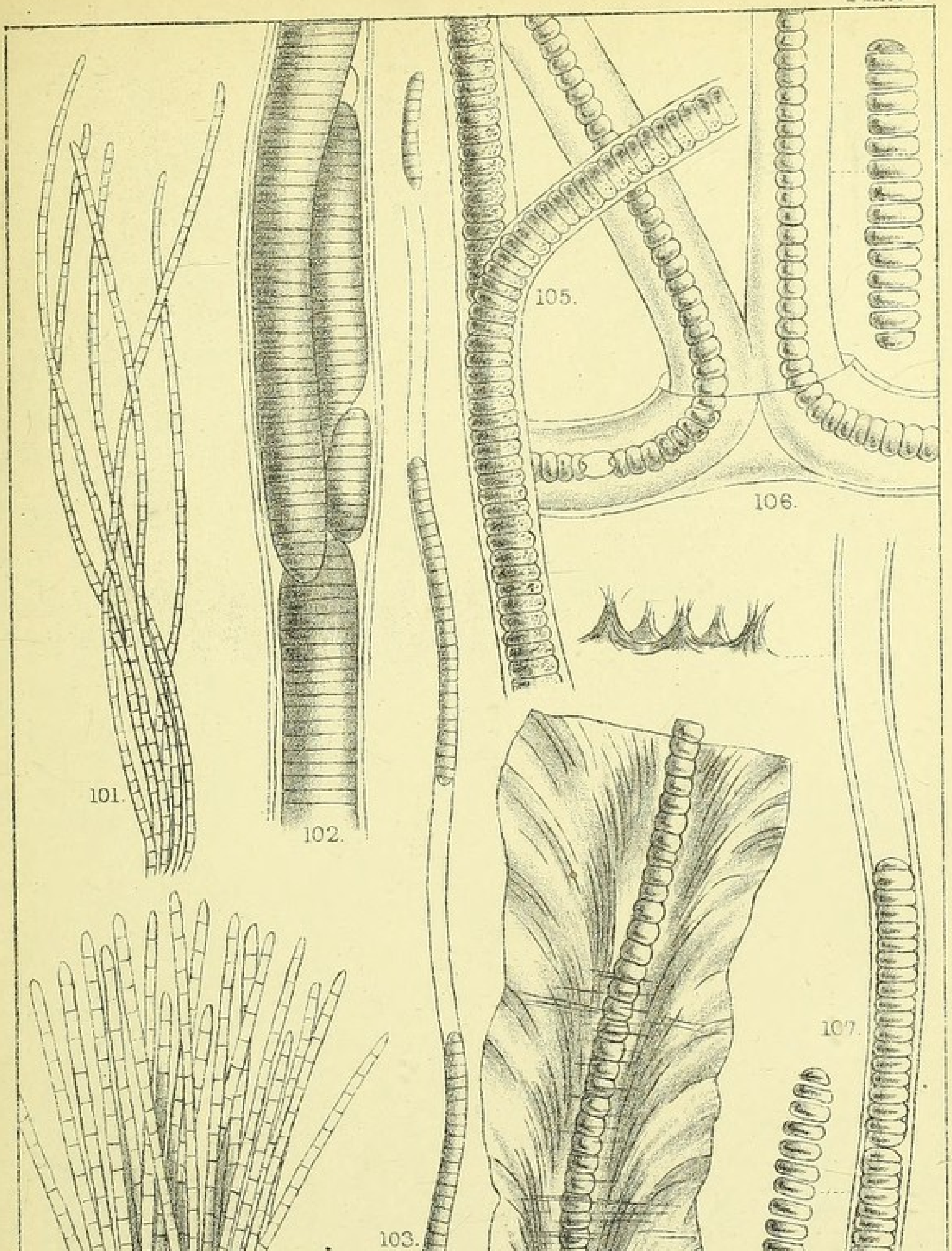

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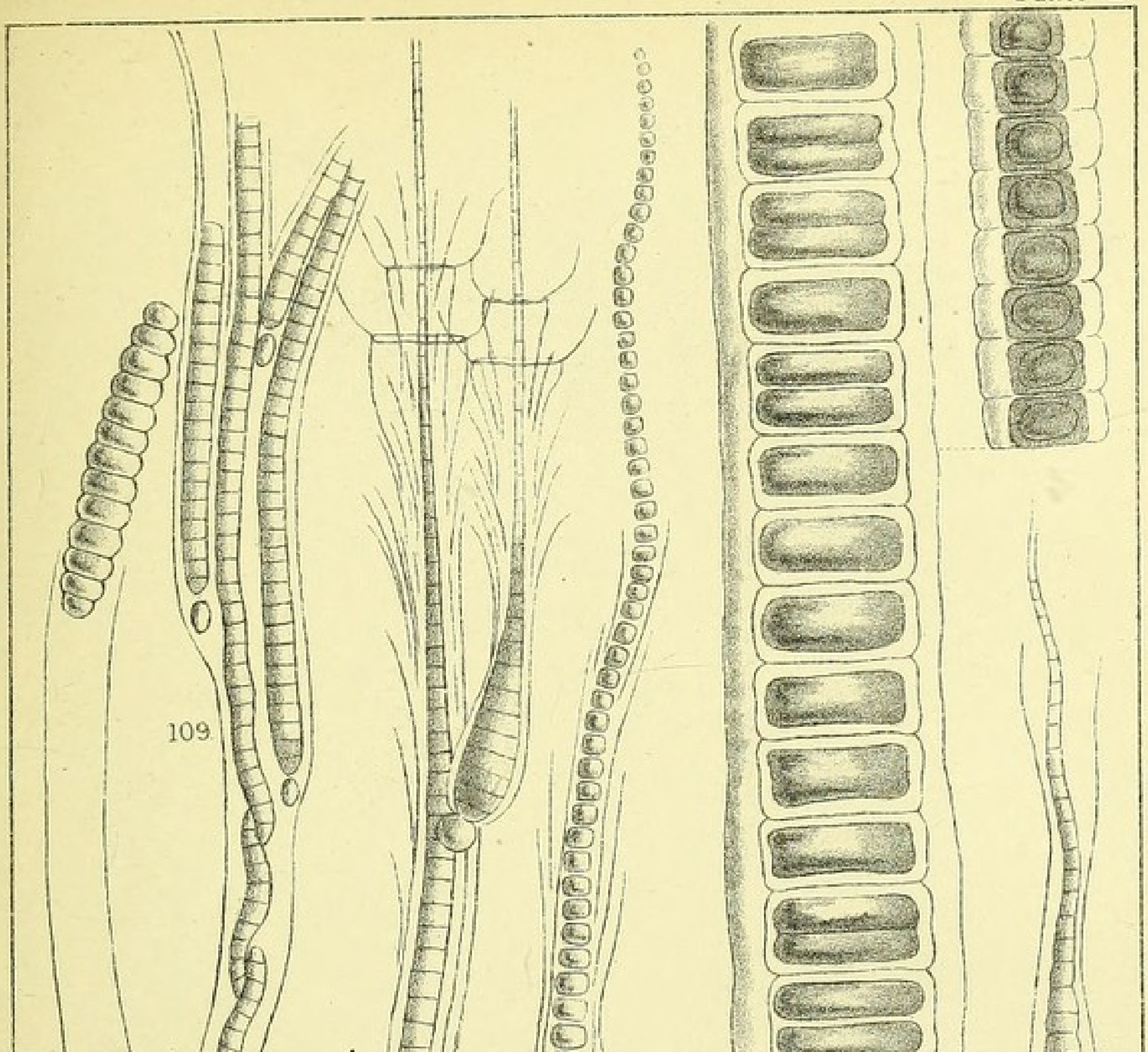

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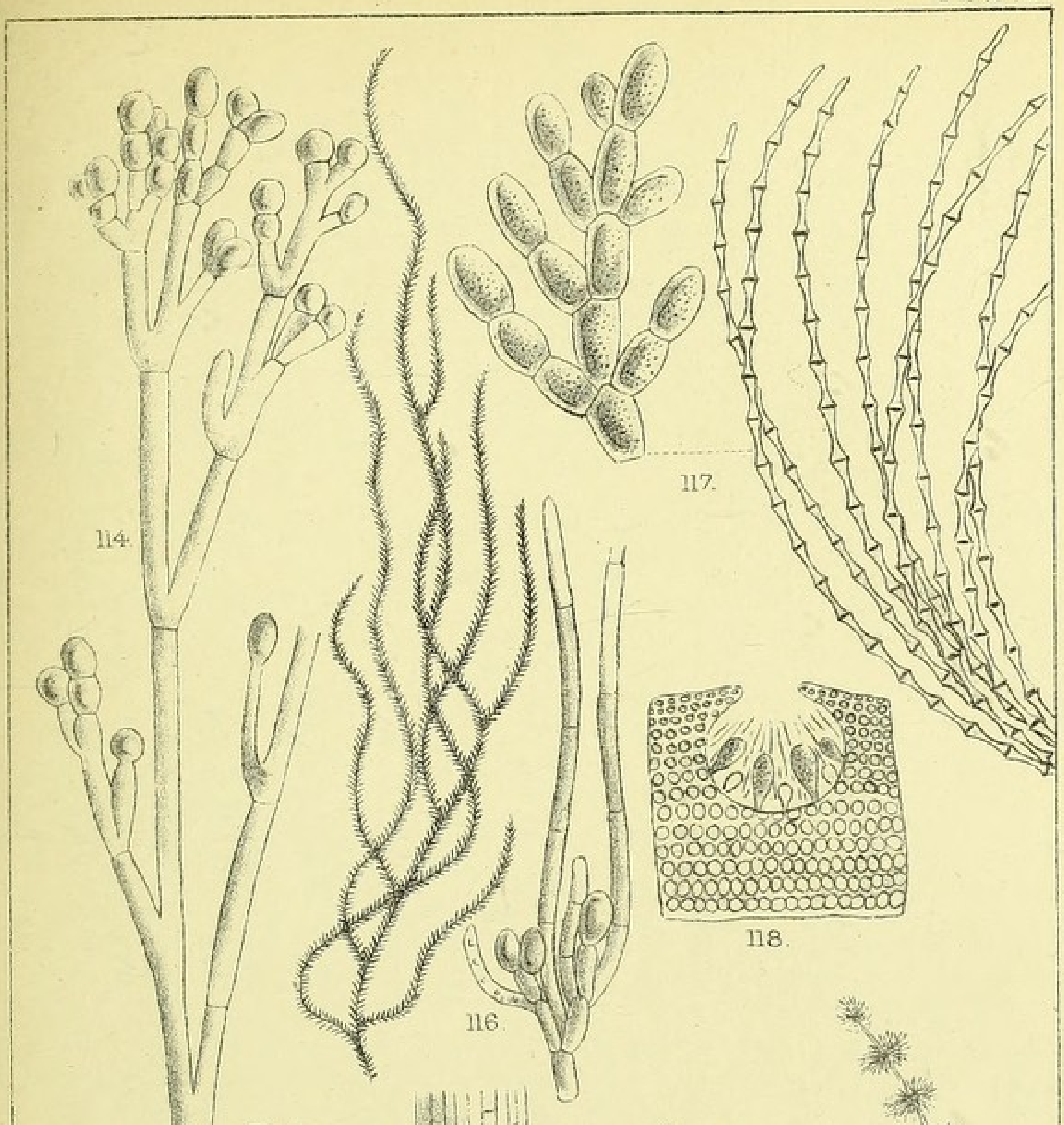
Plate 13.



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