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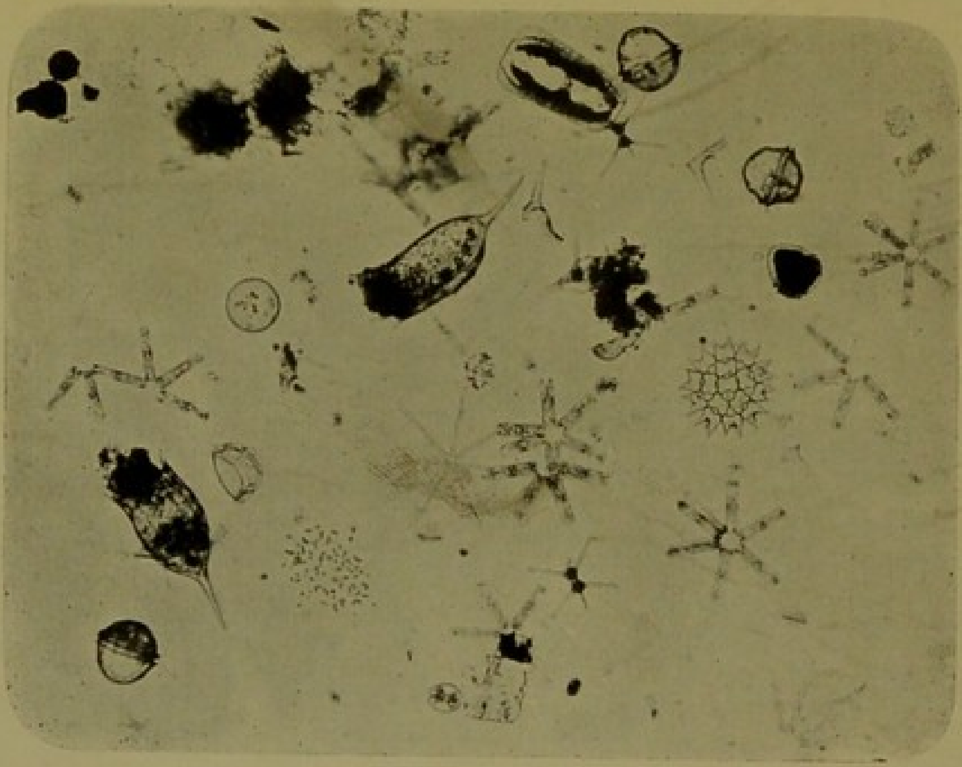

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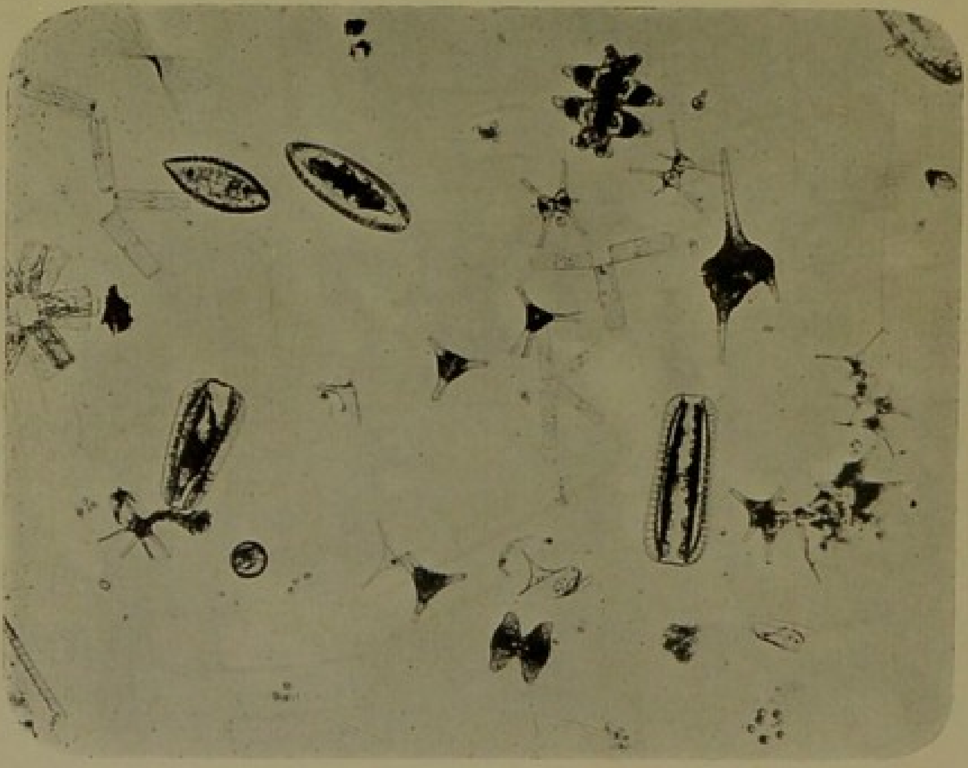

Plankton from Loch Ruar, Sutherland (×100).

A TREATISE
ON THE
BRITISH FRESHWATER ALGÆ

BY

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PREFACE.

THE object of the present volume is to give the student a concise account of the structure, habits and life-histories of Freshwater Algæ, and also to enable him to place within the prescribed limits of a genus any Alga he may find in the fresh waters of the British Islands.

Although it may seem incongruous to treat of *freshwater* Algæ apart from marine ones, there are many excuses for the production of a special treatise on the freshwater forms. Few genera of Algæ, and still fewer species, exist both in salt and fresh water, and the vast majority of marine Algæ are very different in nature from those inhabiting fresh water.

The need for a book of this kind is very great, owing to the rapid strides made in the investigation of this class of plants during the last twenty years. To identify even many of the commonest of freshwater Algæ one has at present to be fully conversant with most of the recent phycological literature, and I have endeavoured in this volume to give a general account of those facts concerning the British species which will be of most assistance to a diligent student.

Many facts and suggestions concerning the life-histories, development, and relationships of freshwater Algæ are here brought forward for the first time, and with few exceptions the figures are original, pains having been taken to state as far as possible the localities from which the specimens were collected. The figures are careful and accurate drawings to scale, and they are in no way diagrammatic. A few stages in the life-histories of various Algæ, and certain figures showing structural peculiarities, have been copied from the original drawings of other authors, but in each case this has been specially mentioned.

The magnifications given under the figures are far from uniform, but this is no great disadvantage, as a knowledge of the relative sizes of these plants is very soon acquired, and 'size' is of no generic and little specific value.

Accurate measurements are given of the most abundant and widely distributed species.

It was originally my intention to add a chapter on the Peridinieæ, but after further consideration I have for two reasons excluded them. Lack of space would have compelled me to have given a very indifferent account of them, and I also prefer to regard them as a group quite distinct from the Algæ. Most zoologists claim these organisms as Dinoflagellates, and the Peridinieæ of this country are sufficiently numerous and important to require separate treatment.

Similar remarks apply to the Characeæ. They are best regarded as distinct from the Algæ, as their vegetative organs exhibit far more differentiation than the vegetative structures of any of the freshwater Algæ, and their sexual reproduction is of a distinctly higher type.

In some instances I have quoted freely from previous publications of my own, sometimes with slight alterations.

The work was undertaken at the request of Mr A. E. Shipley, to whom I tender my best thanks for assistance and advice during its publication. I have also to thank Mr Edwin Wilson for the care he has expended in reproducing the drawings.

I take this opportunity to remark that a good systematic text-book of British Freshwater Algæ, with descriptions of all the known species, remarks on their affinities, and if possible, with figures, is at the present time very urgently needed. There is, in fact, no single book, or set of accessible books, by means of which a student can hope to accurately identify one-third of the freshwater Algæ he may find in a single day's ramble through a reasonably productive part of the country. I venture to state that this is the only branch of systematic botany in which such a state of affairs exists.

The reason for it is not far to seek. It is one result of the general neglect of systematic botany (especially Cryptogamic) in the botanical laboratories of this country. Every encouragement has been given, and is given, to students to take up physiological botany or to investigate the morphology of such plants as exhibit sufficiently striking peculiarities to arrest the attention even of a casual observer; but what encouragement is given to a student who wishes to take up the systematics of any group of plants? The answer is found in the 'Bibliography' of every work on systematic botany.

Although the work of the systematist is indispensable to a laboratory worthy of the name, there is undoubtedly in many quarters a lack of appreciation of systematic work, because it is at the same time the most laborious and the most vexatious of any form of biological investigation. It is becoming more and more difficult every day to conduct systematic investigation away from the special libraries indispensable to every well-equipped laboratory, and unless a slight encouragement is given to the laboratory student to take up some branch of systematic botany this department of botanical science will be left largely in the hands of the foreigner.

One cannot emphasize too much the importance of a sound knowledge of the geographical distribution of some of the more lowly types of Cryptogams, particularly of the Desmidiaceæ. Such a knowledge, which can only be acquired by the patient labours of the systematist, will throw much light on one of the most interesting of all problems concerned with the later phases of the earth's history, namely, the land-connections of previous periods.

The frontispiece consists of a reproduction of two photomicrographs to show some of the characters of the freshwater plankton. One is a photograph of some material collected from Loch Ruar, Sutherland, by Mr J. Murray, of the Scottish Lake Survey (Pullar Trust). The other represents plankton of a somewhat different nature from Lough Neagh, Ireland.

G. S. WEST.

CIRENCESTER,
April 7th, 1904.

ERRATA.

Page 3, line 19, *for* Glaucocystidæ *read* Glaucocystideæ.
,, 14, last line, *after* Zygnemaceæ *insert* a semicolon.
,, 165, line 12, *for E. ansatum* Ehrenb. *read E. ansatum* Ralfs.
,, 304, line 1, *for* **Cymatopleura** Turpin, 1827, *read* **Cymatopleura** W. Sm., 1851.
,, 358 (Index), *for* Dabarya *read* Debarya.

TABLE OF CONTENTS.

INTRODUCTION.

ALGÆ.

Class 1. RHODOPHYCEÆ, p. **34**.

Class 4. HETEROKONTÆ, p. **248**.

Class 5. BACILLARIEÆ, p. **260**.

Class 6. MYXOPHYCEÆ, p. **306**.

INTRODUCTION.

One of the earliest attempts to bring together all that was then known concerning British Freshwater Algæ was Dillwyn's 'British Confervæ,' which appeared in 1809, and hardly any further advance was made in Britain until the appearance in 1845 of Hassal's 'History of British Freshwater Algæ.' About this time two very important works were commenced on the continent, one being Kützing's 'Tabulæ Phycologicæ,' the first part of which appeared in 1846, and the other Rabenhorst's 'Flora Europæa Algarum,' issued from 1864–68. Ralfs' 'British Desmids' appeared in 1848, and for the next thirty years Henfrey, Hicks and Archer were almost the sole contributors to the literature of British Freshwater Algæ, the publications of Archer being very numerous and most valuable.

From 1882–84 Cooke issued his 'British Freshwater Algæ' and in 1887 Wolle's 'Freshwater Algæ of the United States' appeared. Since the publication of these two books more actual work has been accomplished in the investigation of freshwater Algæ than at any previous period, particularly by continental investigators, amongst whom may be mentioned Wille, Wittrock, Nordstedt, Bornet, Thuret, Lagerheim, Klebs, Hansgirg, Schmidle, Chodat, Borge, Boergesen, Lemmermann, and others. In Britain, Marquand, Bennett, and Roy have done systematic work in certain districts, and, in conjunction with my father, I have myself spent much time in the investigation of the Algæ of many parts of the British Islands. During this later period of approximately twenty years many new phases have been discovered in the life-histories of Algæ, and much has been found out with regard to their habits and mode of life. In addition, a great deal has been accomplished in clearing up the synonymy of these plants, so that taking into consideration all these circumstances, it is now doubtful if thirty per cent. of the British freshwater Algæ could be identified with certainty from Cooke's book; and Wolle's American publication would be of little or no assistance. The relationships and affinities of the Algæ described in these publications, and in many cases their life-histories also, are now much better known. This has resulted in great changes in their classification.

At the time Cooke's book was published it was expected by many that during the next few years the groups of the Protococcaceæ and Chroococcaceæ would have disappeared, and statements were made by certain authors advocating great polymorphism in Algæ, evidence being brought forward to prove that many of the more lowly forms were obviously stages in the development of higher forms. I have elsewhere pointed out[1] that these statements were based upon very inadequate observations and that more evidence is yet required concerning the life-histories of some of the lowly types before any definite statements can be formulated as to their systematic position. Again, because a few observers have at different times suggested and attempted to show that these lowly types are only developmental stages, that constitutes no reason why, when their life-histories are unknown, they should be neglected and left out of consideration. Yet, that is largely the case in Wolle's 'Freshwater Algæ of the United States.'

Blackman[2] in advocating the primitive nature of the genus *Chlamydomonas*, also remarks that "this specific constancy of the most primitive type is in strong opposition to the idea of wide polymorphism brought forward by Hansgirg, Chodat, and Borzi, which associates different genera, and even members of different families, in the life-history of one individual." No one would doubt for a moment the existence of considerable polymorphism in most groups of the Algæ, but it is certainly on a more reasonable scale than was at one time advocated.

The classification I have adopted is thoroughly explained in the next chapter and the reasons for so arranging these plants are stated in full.

With regard to the terminology, I have for the most part followed that used by Vines in his 'Text-book of Botany[3].'

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[1] G. S. West, 'Algafl. of Cambridgeshire,' Journ. Bot. 1899, pp. 52—53.

[2] F. F. Blackman, 'The Primitive Algæ and the Flagellata,' Ann. Bot. xiv, 1900, p. 660.

[3] S. H. Vines, 'A Students' Text-book of Botany,' London, 1895.

Exception may be taken to the rejection of Cohn's group of the Schizophyta, which was instituted to include the Schizomycetes (or Bacteria) and the Schizophyceæ (or Blue-green Algæ). These two series of plants undoubtedly present a similarity in their method of multiplication by simple cell-fission, but it must be remembered that most unicellular and colonial Algæ habitually multiply in this manner, and although the Bacteria stand near in this respect to some of the less differentiated Blue-green Algæ, there are many reasons for not including the two series of organisms in the same group. The Blue-green Algæ possess chlorophyll and phycocyanin disposed within the cells in the manner of a primitive chromatophore, and are thus capable of carbon-assimilation; whereas in the Bacteria this is not the case. A ciliated motile condition is only known to occur in about two blue-green organisms, whereas that is the normal condition in most of the Bacteria; and the spore-formation, with very few exceptions, is quite different in the two groups. The Myxophyceæ are also of a much higher type of organization than the Bacteria, possessing a primitive nucleus (which in the Glaucocystidæ has become a true cell-nucleus) and a cell-wall composed partly (and in the case of certain cells, entirely) of cellulose. Moreover, the habits and mode of life of most of them are totally different from those exhibited by the Bacteria.

In this volume the Blue-green Algæ are placed in the class Myxophyceæ (Stizenberger, 1860)[1], which is an earlier name than Phycochromophyceæ (Rabenhorst, 1864) or Cyanophyceæ (Sachs, 1874), the limits of which were carefully and exactly made out by Stizenberger. It is the name under which the Blue-green Algæ have been placed by systematists for many years past, but for some unaccountable reason it has not up to the present been even mentioned in general text-books on botany.

OCCURRENCE, COLLECTION, AND PRESERVATION OF FRESHWATER ALGÆ.

Algæ are universal in their occurrence, no moist situation being without some type of Alga. They are found on damp earth, rocks, walls, palings, tree-trunks, in rain-tubs, etc.; they are met with in all kinds of running water, from the torrent, waterfall and cataract

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[1] Stizenberger in Rabenhorst's Algen Sachsens systematisch geordnet, 1860, p. 17.

to the slowest river. They are most abundant, however, in still waters, occurring in quantity in pools, ditches and lakes.

They occur either floating at the surface, being simply immersed in the water, or attached to submerged stones, or to larger aquatic plants as epiphytes, etc. The larger Algæ are often conspicuous as green slimy masses forming a surface coat to ponds, ditches, etc., or attached as large green masses to the rocks and stones of rivers. Rocks over which the water is constantly dripping possess at times quite a characteristic Alga-flora, and many of the more uncommon Algæ are found in such situations. If such rocks present vertical wet faces, they are often covered with thick leathery patches, or gelatinous masses, which exhibit a great variety of colour. This material is always of interest and usually consists of a mixture of plants belonging to the blue-green Algæ or Myxophyceæ.

Some Algæ have acquired a symbiotic relationship with other plants, and even with animals. One species of *Anabœna* lives symbiotically with the aquatic Lycopod *Azolla*, and another with the Hepatic *Blasia*, and some Algæ belonging to the genus *Chlorella* are connected symbiotically with such animals as *Hydra viridis* and certain small species of *Amœba, Paramecium, Ophrydium*, etc. Again, there is the Lichen, which is a compound organism consisting of a Fungus associated symbiotically with Algæ of the genera *Pleurococcus, Trentepohlia, Cephaleuros, Nostoc, Stigonema, Scytonema*, etc. The genus *Foreliella* has a symbiotic relationship to the freshwater mussel (*Anodonta*) and several other Algæ are similarly related to sponges.

Many of the most beautiful Algæ are exceedingly minute and occur in quantity in situations which are not at first obvious, and which are only found by experience. They occur embedded in a thin mucus surrounding the stems and leaves of submerged plants, such as *Utricularia, Myriophyllum, Nymphœa, Nuphar, Potamogeton, Scirpus fluitans, Isoëtes*, etc. Many of the submerged mosses, such as *Sphagnum contortum, S. plumosum, Amblystegium scorpioides, A. falcatum, A. exannulatum, A. glaucum, Fontinalis antipyretica, Jungermannia inflata, Nardia emarginata*, etc., are often richly covered with these minute Algæ.

Numerous minute Algæ occur along with an abundance of the Peridinieæ and Copepoda scattered through the surface waters of lakes, rivers, and other large bodies of fresh water, and constitute a large proportion of the *Freshwater Plankton*. The animal and vegetable organisms occurring in the plankton form the food of most of the smaller aquatic animals, and so, indirectly, form the basis of the food-material of lacustrine and river fishes. Little is known concerning the food-value of the freshwater plankton, but statistics of this nature have been very carefully compiled with regard to the Baltic Sea. Brandt[1] states that the chemical composition of the plankton of this sea in autumn and winter is intermediate between that of "rich pasturage" and green lupines. The proportion of fat is greater than in land products used as fodder, but in spring the great abundance of Diatoms causes such a great increase in the amount of ash as to preclude direct comparison with land plants. Many of the Algæ found in the plankton are more or less characteristic, some of them being largely and others entirely surface organisms. The majority of them belong to the Palmellaceæ, Protococcaceæ, Volvocaceæ, Desmidiaceæ and Bacillarieæ. Most of the Desmids of the plankton possess very long spines or processes which terminate in spines, and in those species which normally possess long spines the latter are of greater length when the plants occur in the plankton than when found in other situations. Some of the Protococcaceæ and Diatoms have also acquired long spines. The assumption of this spined condition is to be correlated with their free-floating existence and their consequent need for greater protection against those animals of the plankton which feed on Algæ[2].

Algæ exist under very varied conditions of temperature. In temperate and arctic climates many of them can survive prolonged freezing even when in the ordinary vegetative condition. It is quite possible to melt out from the ice numerous healthy Algæ which have suffered in no way from their exposure to such a low temperature. In the arctic and antarctic regions, in the Alps and in the Andes, there is a snow-flora, consisting principally of Algæ which pass their entire existence on the snow and ice. This collection of Algæ, which is known as the 'Cryoplankton,' consists of a few forms which are more or less universal in such situations[3].

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[1] Brandt in Wissensch. Meeresuntersuchungen, N. Folge, Bd iii, Heft 2, 1898; *consult also* American Naturalist, xxxii, Dec. 1898.

[2] West & G. S. West, 'Scott. Freshw. Plankton,' Journ. Linn. Soc. Bot. xxxv, Nov. 1903, p. 554.

[3] The most interesting of these Algæ are *Sphærella nivalis* Sommerfeldt (the Red Snow plant) and a Desmid, *Ancylonema Nordenskiöldii*, first discovered by Berggren in the snows of Greenland, and afterwards by Lagerheim in the Andes and by Chodat on Mont Blanc.

Algæ also occur in warm streams, and the vegetation of hot-springs consists exclusively of Algæ. They can exist in hot water and hot vapour up to a temperature of 94·5° C. (200° F.)[1]. It is worthy of note that the Algæ which occur at very high altitudes, and which therefore exist at relatively low temperatures, and those which inhabit the hottest springs, are, with few exceptions, species of Myxophyceæ and Bacillarieæ.

Some Algæ become encrusted with carbonate of lime or with silica, and play no small part in the formation of the deposits which are generally found in the neighbourhood of hot-springs.

The comparative richness of any district in freshwater Algæ depends very largely on its physical geography and on the geological formations. Mountainous tracts are more prolific than flat districts, even though many of the larger Algæ are absent from them. Most of the larger filamentous Algæ and an abundance of the commoner unicellular forms are found in low-lying quiet waters, but in mountainous areas the filamentous forms are chiefly representatives of the Myxophyceæ and Conjugatæ, the presence of numerous species of the genus *Mougeotia* being a marked feature of such districts, and the unicellular forms are greatly increased by the addition of numerous Desmids. If the mountains consist of the Older Palæozoic rocks, of Pre-Cambrian rocks, or of rocks of Igneous origin, there is a surprising numerical increase, not merely of species but also of individuals; and in comparison, a mountainous district of carboniferous limestone or other formation is distinctly poor. Thus, the English Lake District, Wales, and certain parts of Scotland and Ireland yield a much greater variety of Algæ than any other parts of the British Isles. The poorest area of all is the fen district in the east of England.

The most prolific localities in the British Islands, and perhaps in the whole of Europe, for freshwater Algæ are the small tarns and peat-bogs which lie in the hollows of the Lewisian gneiss of north-west Scotland. The plankton of the larger lakes of this area is also much richer in the Desmidiaceæ than any which has been described from elsewhere.

Most of the unicellular Algæ and some of the filamentous ones, unless specially protected as in many Desmids, are readily taken

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[1] W. H. Brewer in Amer. Journ. Science, ser. 2, xli. These Algæ were unicells, filamentous Algæ having been observed up to a temperature of 85° C. (185° F.); G. S. West in Journ. Bot. 1902, p. 241.

as food by Amœbæ, Turbellarians, Oligochætes, Tardigrades and Crustacea. The tadpoles of the common frog feed almost exclusively on the larger filamentous Algæ, and Bles has recently shown that the larvæ of that most remarkable African frog, *Xenopus lœvis,* feed exclusively on the lower Algæ[1]. A considerable proportion of the food of freshwater Lamellibranchs also consists of living and decaying Algæ.

For the collection of freshwater Algæ a plentiful supply of small wide-mouthed tubes or bottles will be found most useful. Small quantities of the larger, strictly aquatic Algæ should be put into these tubes, care being taken not to overstock the tube. A small tuft of the Alga with plenty of water is best, and the tube should not be filled more than three-quarters full. The reason for this is obvious, as rapid decomposition accompanies overcrowding, and it frequently happens that collections cannot be examined for many hours after they have been made, or under certain circumstances even for a day or two.

To collect the minute Algæ that occur attached to larger water plants, the latter should be removed from the water with as little mud as possible, the superfluous water allowed to drain away for a few minutes, and they should then be gently squeezed over a wide-mouthed bottle, the issuing water being collected in the bottle. In the sediment which settles to the bottom of the water in the bottle will be found numerous unicellular and other small Algæ. Sometimes a hundred or even two hundred species may be obtained from a small quantity of such material. The Algæ of the plankton are collected from the surface layers of water by means of silken tow-nets.

If it is desired to keep the plants living for some time they should be placed in wide-mouthed jars with an abundance of water, and not exposed to too strong light. Sterile species of the Zygnemaceæ and Œdogoniaceæ will often become fertile under these conditions.

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[1] There can be little doubt that a portion of the food of *Ceratodus*, the Australian mud-fish, consists of Algæ. An examination of the intestine of this fish (for which I must express my indebtedness to Prof. Howes), revealed masses of sticks, twigs, leaves, fragments of Hepatics, etc., all of which would have been taken in by the fish from the muddy bottom of the water in which it lived. This material would be mostly in a dead condition before being swallowed and it seems to suffer little change in its passage through the gut; but a microscopical examination shows amongst it the decomposed remains of many kinds of Algæ, including thousands of the empty valves of Diatoms.

Algæ should always be examined in the living state whenever possible, as some of them are more easily determined when alive. Many of the Desmidiaceæ and Bacillarieæ, however, especially those with characteristic surface markings, can only be determined with precision from the dead empty cells or semicells.

In preserving Algæ for future examination several fluids may be used. In studying the structure of the cell-contents a 2—4 $^{\circ}/_{\circ}$ formalin solution is best for subsequent staining, etc. This is almost equalled by a dilute solution of picric acid. But if only the cell-outlines and the structure of the cell-wall are required then there is no better preservative than a 4 $^{\circ}/_{\circ}$ solution of potassium acetate (containing a trace of copper acetate). An equal volume of this solution added to the water in which the Algæ are living is quite sufficient. A very instructive paper has been published by Pfeiffer R. v. Wellheim[1] on the methods of preparation, staining, etc., of algæ, in which chromacetic acid is largely recommended for preserving them. Certain reagents such as a solution of iodine, methylene blue, hæmatoxylin, ammonia-carmine, etc., are almost essential to all students of Algæ. A 2 $^{\circ}/_{\circ}$ cocaine solution is also very useful for the observation of the cilia of motile forms.

Some Algæ can be preserved by drying, either on paper or on slips of mica, but they are always better for purposes of future examination when preserved in a fluid medium than when dried. The only Algæ that preserve well by drying are the Myxophyceæ. These Algæ on soaking out again in water almost regain their original freshness, and, moreover, retain their original bright colours.

Algæ are best mounted in the fluid in which they have been preserved, and the best varnish with which to seal them up is gold-size. Everyone who has had any experience of fluid mounts, however, knows quite well that if his specimens keep for a long time it is due more to good fortune than to any other cause. Many fluid mounts, even the best ones, frequently begin to dry up by the formation of air-bubbles in the centre of the slide, which gradually extend towards the periphery. The only explanation of this is the porous nature of the thin coverslip.

In examining Algæ, in following out their life-history, and in

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[1] F. Pfeiffer R. v. Wellheim, 'Präparation der Süsswasseralgen,' in Pringsheim's Jahrbüch. für wissensch. Botan. Bd xxvi, Heft 4, Berlin, 1894.

identifying them, they should always be carefully drawn to scale with the help of a Camera Lucida. This is the surest way of obtaining accurate measurements of the plants, and also much the best way of impressing on the memory their diagnostic features. Great attention should be paid by all students of Algæ to their cytological characters,—the structure of the cell-wall, the disposition of the protoplasmic cell-contents, the form and structure of the chromatophores, the presence or absence of pyrenoids, etc. It is the absence of any definite information on these points that renders many books on Algæ almost useless. No student can acquire erroneous ideas of such common genera as *Ulothrix*, *Tribonema* (*Conferva*), *Microspora*, and others, if he has once realized their fundamental cytological characters.

CULTIVATION OF ALGÆ.

It is often desirable to cultivate Algæ in order to investigate their life-history and polymorphism. Under cultivation an Alga is often under abnormal conditions, and as a result, it sometimes develops strange forms which are quite unknown in the natural state of the plant. Careful observation of these cultures frequently affords good evidence towards the elucidation of the phylogenetic relationships of Algæ. Cultures can be made at various temperatures, in water, in sugar solutions of various strengths, or if necessary under damp conditions only. Cultures are most frequently made in solutions of a nutritive character, but sometimes good results are obtained in pure water or in weak saline solutions. A medium containing gelose is very favourable for making pure cultures of the lower Algæ[1]. Klebs and others have emphasized the usefulness of cultures on gelatine, agar-agar, and other solid media, and cultivation experiments on damp porcelain plates are frequently a success. The temperature necessary to obtain the best cultures varies with different types of Algæ, but 20° C. is a good average temperature.

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[1] Chodat and Grintzesco in Arch. Sci. Phys. et Nat. x, 1900, p. 386.

ALGÆ.

ALGÆ are Thallophytes of a simple or complex structure, and are of a green, yellow-green, blue-green, red or brown colour. Most of them live entirely submerged in water and the major portion of them inhabit the sea. They are found floating freely at the surface, attached to stones, or as in a large number of the freshwater forms, adhering in gelatinous masses to the submerged portions of more highly organised aquatic plants. A few prefer damp situations in which they do not become immersed at all, or only periodically become covered with water.

They are mainly distinguished from the Fungi by the presence of chlorophyll and consequently by their mode of life. Even in the red, brown, and blue-green Algæ chlorophyll is present, but the green colour is masked by the presence of other colouring-matters. As the colouring-matter is usually the same throughout large groups of these plants which agree in other characters, particularly in the method of reproduction, they are classified as follows:—

Class 1. *Rhodophyceæ* (or the Red Algæ), containing a reddish colouring-matter known as phycoerythrin. Mostly marine.

Class 2. *Phæophyceæ* (or the Brown Algæ), containing a brown colouring-matter known as phycophæin. Mostly marine.

Class 3. *Chlorophyceæ* (or the Green Algæ), containing only the green colouring-matter known as chlorophyll. Very largely freshwater plants. The stored product of assimilation is in almost all cases starch.

Class 4. *Heterokontæ* (or the Yellow-green Algæ), containing a large proportion of a yellow pigment known as xanthophyll. The stored product of assimilation is a fatty substance. Freshwater.

Class 5. *Bacillarieæ* (or the Diatoms), containing a brown colouring-matter diatomin, which much resembles the phycophæin of the brown Algæ. Universal both in fresh and salt water.

Class 6. *Myxophyceæ* (or the Blue-green Algæ), containing a blue colouring-matter known as phycocyanin. The stored product of assimilation is most probably glycogen. Mostly freshwater.

By far the greater part of the vegetation of the sea consists of marine Algæ, and with few exceptions these marine forms are of quite a different nature from the freshwater ones. It is only with freshwater Algæ that this volume is concerned.

Certain Algæ are known in a fossil state. These are mostly Diatoms, the siliceous valves of which are eminently suited for fossilization, and a few others in which the thallus was encrusted with carbonate of lime. The majority of other Algæ are of much too fragile and delicate a nature to become fossilized, and most of the records of such fossil Algæ are of very doubtful value.

Freshwater Algæ exhibit a variety of types of structure. Some of them are *unicellular*, each plant consisting of a single protoplasmic unit or energid (i.e. a mass of protoplasm containing a single nucleus) surrounded and enclosed by a definite cell-wall (e.g. Desmidiaceæ, Bacillarieæ, and many Protococcoideæ); others are *unseptate* or *cœnocytic* plants composed of an aggregate of protoplasmic units enclosed within a common cell-wall (e.g. Siphoneæ, *Hydrodictyon*); others are *incompletely septate* plants, each segment containing a number of protoplasmic units within a cell-wall, the septation of the plant going on independently of the divisions of the nuclei (e.g. Cladophorales); others are *multicellular* or *completely septate* plants, each segment containing one protoplasmic unit (e.g. Zygnemaceæ, Chætophorales, etc.).

Many of the unicellular forms are solitary cells, but others occur as *colonies*, in which the individual cells are more or less loosely held together in a common mucilaginous envelope, which is either secreted by the protoplasm of the cells or is derived from the cell-walls. This mucilaginous sheath is present in most of the unicellular and filamentous freshwater Algæ, and sometimes attains a huge development. Its nature was well investigated by Hauptfleisch[1] and more recently by Schröder[2].

The multicellular forms consist of closely connected cells forming a *thallus*, which exhibits a great variety of form. It may be spherical (e.g. *Cœlastrum*), filamentous (e.g. *Spirogyra*, *Ulothrix*, etc.), or a flattened expansion (e.g. some species of *Coleochæte*, *Protoderma*). Sometimes the thallus is differentiated into a "root" and a thalloid "shoot" (e.g. *Botrydium*, *Rhizoclonium*, *Œdogonium*, *Spirogyra*, etc.[3]), but the "root" is in all cases merely an organ of attachment and is more correctly called a *hapteron*.

The cell-wall always consists largely of cellulose, and is sometimes delicate, sometimes of considerable thickness and strength, being cuticularized or even silicified, but it is rarely, if ever, lignified. It often becomes gelatinous in its outer layers.

The principal colouring-matter of the cell is usually arranged in definite parts of the protoplasm known as *chromatophores*. A single cell may contain one or many chromatophores. If the chromatophores contain the green colouring-matter *chlorophyll*, they are known as *chloroplastids* (or *chloroplasts*); if they contain some other colouring-matter they are termed *chromoplastids* (or *chromoplasts*). Plastids are present in all groups of Algæ, but those present in the Myxophyceæ are of a very primitive character. Chromatophores, particularly chloroplasts, often contain *pyrenoids*, which consist of colourless masses of proteid substance. The central mass of the pyrenoid is a proteid substance of crystalloidal character which bears a great resemblance to an aleuron grain. It is sometimes angular, sometimes rounded, or it may be quite irregular in its outward form, and is often surrounded by an amylaceous envelope or coat of starch. The latter sometimes becomes lobed and penetrates into the chromatophore to such an extent that its existence appears doubtful. In *Spirogyra* the envelope of amylaceous material round each central mass (or pyrenocrystal) is in the form of a number of grains of starch. On

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[1] Hauptfleisch, 'Zellmembran und Hüllgallerte der Desmidiaceen,' Mitteil. aus d. Naturwiss. Vereine f. Neuvorpommern und Rügen, 1888.

[2] Schröder, 'Untersuchungen über Gallertbildungen der Algen,' Verhand. des Naturhist.-Med. Vereins zu Heidelberg, Bd vii, Heft 2, 1902.

[3] Borge, 'Ueber die Rhizoidenbildung,' Upsala nya Tidnings Akteb. Tr. 1894; West and G. S. West in Ann. Bot. vol. xii, March 1898.

the division of a cell the pyrenoids usually divide equally. Sometimes a pyrenoid in a well-nourished cell multiplies by division without any division of the cell or the cell-nucleus. In a badly nourished cell, the amylaceous portion first disappears and then the crystalloidal part. The pyrenoid is thus a store of reserve food-material, and it may arise quite spontaneously without the previous existence of pyrenoids in the cell.

Almost all Algæ are holophytes; that is to say, they are themselves able to elaborate organic material from the mineral and other inorganic substances found in the water, or in some instances, in the atmosphere, in which they exist. The chlorophyll found in the chromatophores of the cells arrests certain rays of light, the energy of which is utilized by the living protoplasm for the construction of organic substance from the inorganic materials taken up.

Algæ absorb a relatively large amount of mineral food substances, particularly nitrates, from the water in which they live. It has been assumed that the presence of nitrates in abundance is necessary for the prolific growth of Algæ, but it is certainly true that these plants occur in quantity in water which is relatively poor in nitrates. Whipple and Parker[1] state, as a result of experiments on the occurrence of small chlorophyll-bearing organisms in the waters of lakes, that the presence or absence of carbonic acid is one of the fundamental factors which influence the growth of Algæ.

The tropical Algæ of the genera *Phyllosiphon* and *Cephaleuros* are partial parasites, and a few have already been mentioned as symbiotic with other plants or even with animals.

The growth of the thallus may be apical or intercalary. In many Algæ it is by the repeated division of a single apical cell, or by a series of marginal cells, as in the expanded thallus of *Coleochæte*. In many of the filamentous Algæ with intercalary growth all the cells of the thallus are meristematic and undergo division (e.g. Zygnemaceæ, Ulotrichaceæ).

Vegetative multiplication occurs in the unicellular forms by ordinary cell-division or fission, and in many of these plants it is the only method of increase. The division may take place in one direction only (e.g. *Aphanothece, Glœothece, Stichococcus*), in two directions in one plane (e.g. *Tetraspora, Merismopedia*), or in all directions of space (e.g. *Glœocystis, Glœocapsa*, and many others).

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[1] Whipple and Parker, in Trans. Amer. Micr. Soc. May 1902.

In the Desmidiaceæ, in which the cells generally exhibit a more or less deep median constriction, division is only in one direction, and it is brought about by the development of two new half-cells (or semicells) between the old halves. So that each of the individuals formed after one division consists of an old and a new half-cell. In many unicells the division is accomplished by the formation of daughter-cells within the mother-cell. The daughter-cells are rejuvenized and metamorphosed portions of the original mother-cell and are enclosed in the old wall of the mother-cell. Sometimes the daughter-cells are set free by the bursting of the wall of the mother-cell, but it often happens that the old wall of the mother-cell swells up and remains as an outer, wider coat to the daughter-cells. Successive generations of cells are produced in the same manner inside the enlarged walls of the mother-cells until quite a colony is formed inside the swollen cell-wall of the original mother-cell (e.g. many Protococcoideæ and Chroococcaceæ). In many types of lower Algæ there is no definite line to be drawn between this so-called free cell-formation and the ordinary vegetative division[1]. In certain of the Protococcaceæ two or four daughter-cells arise in a mother-cell, and at the time of their escape from the parent-cell they possess the exact form and external peculiarities of the parent; these have been termed *autospores*.

Increase of cells occurs in the filamentous Algæ by new divisions, the septa being always transverse to the length. In the Œdogoniaceæ the method of cell-division is somewhat specialized and a description of it is given under the family.

On injury to the filamentous cœnocytic Algæ septa usually appear cutting off the injured part. The injured portion soon dies away, and if it happens to be in the median part of a filament, two filaments are thus set free. This occurs frequently in *Vaucheria*, and if the injuries to one filament are numerous, all the injured parts are sometimes cut off, the intermediate uninjured portions developing into new filaments on being set free.

The *reproduction* of freshwater Algæ is brought about in a great variety of ways, most of the plants exhibiting both an asexual and a sexual mode of reproduction.

Asexual reproduction.—In some cases special non-motile cells develop into *cysts* or unicellular gemmæ (e.g. Zygnemaceæ

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[1] Chodat in Ann. Bot. 1897, p. 102.

they are also specially cut off in the Vaucheriaceæ), and in the filamentous Myxophyceæ *hormogones* or multicellular gemmæ are formed. Sometimes single non-motile cells are produced, which have been termed by Wille *akinetes* when they are formed without rejuvenescence and *aplanospores* when formed by rejuvenescence (e.g. Chætophorales, Confervales, Conjugatæ). Many of these non-motile asexual spores, which may be either akinetes or aplanospores, rest for considerable periods before germination and are known as *hypnospores* (or sometimes as *hypnocysts*). Asexual reproductive organs are known as *gonidangia* when borne on the gametophyte generation and *sporangia* when borne on the sporophyte. A sporangium (or a gonidangium) as a rule gives origin to a number of *spores* (or *gonidia*), but in *Vaucheria*, *Œdogonium*, and some of the Ulotrichaceæ only one gonidium is formed in the gonidangium.

Very often the gonidia consist of motile cells which receive the name of *zoogonidia* (or *zoospores*). One of the most frequent methods of asexual reproduction is by means of zoogonidia, which are found in all groups of freshwater Algæ except the Conjugatæ (the largest order of the Chlorophyceæ), the Myxophyceæ, and the Bacillarieæ (or Diatoms). Zoogonidia are small masses of protoplasm formed singly by the rejuvenescence of the entire contents of a cell, or more frequently in numbers by free cell-formation. They are not possessed of a cellulose wall, but are furnished with one (?), two, four, or many cilia, with one or more chromatophores, and often with one or two contractile vacuoles. The cilia are usually disposed towards one end or one side of the zoogonidium and their rapid vibratile movements cause it to swim quickly through the water. A red or brown pigment-spot is very often present. After a time the zoogonidium comes to rest, the cilia disappear, the protoplasm secretes a cellulose wall, and the zoogonidium develops into a new plant.

Sexual reproduction.—Reproduction by the union of male and female elements, or gametes, is fairly general throughout the Algæ, but it is entirely absent in the Myxophyceæ, in some of the unicellular Protococcoideæ, and in the Syngeneticæ. Sometimes the gametes are clearly differentiated into male and female elements, but in other cases sexual differences are scarcely appreciable. The following is a summary of the sexual methods of reproduction met with in the freshwater Algæ:—

I. *Sexual reproduction by isogamous gametes* (*isogametes*), or precisely similar sexual cells which undergo the process of *conjugation.*

- *a.* Gametes ciliated, known as *planogametes* or *zoogametes,* set free, and on conjugation forming a *zygospore* (or *zygote*) (e.g. Ulotrichaceæ, Ulvaceæ, Trentepohliaceæ, *Pandorina*).
- *b.* Gametes not ciliated, known as *aplanogametes.*
    - i. Conjugation forming a zygospore which after a period of rest develops directly into a new gametophyte (e.g. Bacillarieæ and Desmidiaceæ, in which the gametes are set free; Zygnemeæ, in which the gametes are not set free).
    - ii. Conjugation forming a zygospore which immediately develops a rudimentary sporophyte with one spore (e.g. Mesocarpeæ).

II. *Sexual reproduction by heterogamous gametes* (*heterogametes*), or clearly differentiated sexual cells which undergo the process of *fertilization.*

- *a.* Oogamous heterogamy:—The female organ is an *oogonium* containing an *oosphere.* The male organ is an *antheridium* in which are developed motile, ciliated *antherozoids* (or *spermatozoids*). The result of fertilization is the production of an *oospore* (e.g. Vaucheriaceæ, Œdogoniales, certain of the Chætophorales and Cladophorales, and some of the Volvocaceæ).
- *b.* Carpogamous heterogamy:—The female organ is a *procarp* (consisting of *carpogonium* and *trichogyne*) with no specially differentiated female cell. The male cells are non-ciliated *spermatia* (or *pollinoids*). Fertilization results in the development of a *cystocarp* (or *sporocarp*) with contained spores known as *carpospores* (e.g. Rhodophyceæ).

The *sexual organs* of those Algæ with similar sexual cells are termed *gametangia.* If the Algæ are unicellular then the cell itself becomes the gametangium (e.g. Desmidiaceæ, Bacillarieæ), and in the multicellular and cœnocytic forms the ordinary vegetative cells become the gametangia (e.g. Zygnemaceæ, Chætophorales, *Hydrodictyon*). In the whole of the Conjugatæ the gametangium gives origin to only one *aplanogamete*, but in other Algæ it is more usual for several gametes to arise from one gametangium. *Planogametes*, such as are found in the Ulotrichaceæ, are pear-shaped bodies with the chromatophores more or less confined towards the broader end, the narrower end being colourless. Two cilia are inserted at or near the narrow, colourless end, and a red pigment-spot is frequently present. They exhibit active movements for a longer or shorter period of time and finally conjugate, each pair coming into contact by their colourless poles.

In those Algæ with dissimilar sexual cells the *female organ* consists either of a single cell or a cœnocyte known as the *oogonium*, which is usually more or less spherical (e.g. Œdogoniaceæ), sometimes attenuated into a beak (e.g. *Vaucheria*), or produced at the apex into a long, narrow tube, the *trichogyne* (e.g. Coleochætaceæ). An oogonium usually contains a single female cell or *oosphere* (e.g. Vaucheriaceæ, Œdogoniaceæ), but sometimes there are many oospheres present (e.g. Sphæropleaceæ). An oosphere is generally a spherical cell containing chromatophores, and often with a clear, colourless area at one side known as the *receptive spot*. It is at this spot that the antherozoid enters during the process of fertilization. In the Rhodophyceæ the female organ is usually a multicellular structure (in the freshwater Red Algæ it is unicellular) termed a *procarp*, which is divisible into two portions, a *carpogonium* and a *trichogyne*.

The *male organ* is known as the *antheridium*. It is usually unicellular, but in *Œdogonium* it may consist of one or of many cells. Each antheridial cell often gives rise to quite a number of male cells (*spermatozoids* or *antherozoids*), but in the Œdogoniaceæ it gives rise to two, and in the Coleochætaceæ and most of the Rhodophyceæ to only one. Antherozoids frequently resemble the asexual zoogonidia, but are usually smaller. They are commonly pear-shaped, but may be elongate and almost rod-like. They possess two cilia which are generally inserted at the pointed end, but laterally in *Volvox*, *Vaucheria*, etc., and in *Œdogonium* there is quite a tuft of cilia at the narrower end. They are as a rule faintly coloured and often possess a red pigment-spot.

Sexual organs have not been observed in many of the Protococcoideæ and in the Syngeneticæ, and are apparently entirely absent from the whole class of the Myxophyceæ.

Many Algæ exhibit an *alternation of generations* in their life-history. In those forms in which neither asexual nor sexual reproduction is known this alternation of generations is, of course, absent. Other Algæ exhibit slight indications of an alternation of generations. Thus, in a large number of the Chlorophyceæ, the sporophyte generation is represented by the zygospore. This zygospore can be described as a unicellular sporangium which often gives rise to two or four zoospores. Each zoospore, on coming to rest, germinates and produces the gametophyte generation. In the Mesocarpeæ the isogamous gametes conjugate in a connecting-tube between the gametangia, and the zygospore immediately produces a rudimentary sporocarp consisting of a variable number of cells, one cell of which is the carpospore. This is the sporophyte generation. The carpospore, after a period of rest, germinates and gives rise to the new gametophyte generation. In the Rhodophyceæ there is a well-marked alternation of generations.

In the Algæ the gametophyte is the important generation; in fact, the '*plant*' is the gametophyte; but as one proceeds higher in the scale of vegetable life there is a great reduction of the gametophyte accompanied by a corresponding increase in the development of the sporophyte, until in the Phanerogams the sporophyte becomes the '*plant*' and the gametophyte is parasitic on it.

POLYMORPHISM.

Polymorphism occurs in most families of Algæ. All those Algæ which exhibit an alternation of generations are polymorphic, and some species appear to possess several different vegetative forms. It is very doubtful, however, if polymorphism occurs in Algæ to the extraordinary extent advocated by some authors. Sirodot has proved the occurrence of several types of structure in the genera *Batrachospermum* and *Lemanea*, and it is fairly evident that the plants at one time described under the genera *Prasiola*, *Schizogonium* and *Hormidium* are different vegetative forms of one genus. Polymorphism is well illustrated in *Botrydium*, and numerous striking instances could be mentioned of other Algæ in which it occurs, notably in the common genus *Pleurococcus*.

Hansgirg, and following in his footsteps Wolle, have endeavoured to prove (on insufficient evidence) the existence of extraordinary polymorphism in Algæ, relegating most of the unicellular Algæ as mere stages in the growth of higher forms. It is necessary, however, to remark that a great many loose statements have been made on this subject, statements which are supported by no direct or conclusive evidence. Most of the remarks have been based upon the fact of the occurrence together, in one matrix, of various stages of different plants, and to the assumed identity of certain normally unicellular plants with unicellular stages in the life-history of higher organisms. Undoubtedly in the case of the Myxophyceæ many different forms are met with in one gelatinous matrix, and these are of the most confusing nature. Many of the higher blue-green Algæ do certainly pass through stages which resemble very much some of the so-called unicellular species, but there is equally no doubt that careful observation frequently proves that this is a resemblance and not an identity. In some instances it may be quite true that a blue-green form which has been accepted as a species in the past is really a stage in the development of another form, but that does not necessarily prove that every blue-green Alga exhibits wide polymorphism and that every form met with is only one stage in some complex life-history. Similarly, in the Chlorophyceæ, polymorphism is frequent, but because species of *Chætophora* or *Myxonema* (*Stigeoclonium*) at one period of their existence regularly and normally break up into '*Palmella*-like' forms, it does not follow that every aggregate of unicells such as *Glœocystis*, *Palmella*, etc., is merely a stage in the development of *Chætophora*, *Myxonema*, or some other allied plant. The observation of the polymorphism of higher and lower types of Algæ, both in nature and under cultivation, is, however, the surest and best way to discover their affinities, and in many cases furnishes direct evidence as to the phylogeny of the plants in question. Thus, the fact that *Myxonema* assumes under certain conditions a '*Palmella*-state,' much resembling species of the genus *Palmella* but in no way specifically related to them, is one of the primary reasons for regarding *Myxonema* (and therefore the Chætophoraceæ) as having been derived from the Palmellaceæ.

Without question many of the Algæ referred to the order Protococcoideæ have a much more direct relationship with filamentous green Algæ, particularly with the Chætophorales, than is indicated by their present systematic position. As an instance, the genus *Stichococcus*, described by Nägeli as a unicell, undoubtedly belongs to the family Ulotrichaceæ and is connected by many intermediate stages with species of Kützing's genus *Glœotila*, and even with species of the genus *Ulothrix*. This was first definitely shown by Gay[1] and afterwards emphasized by Klercker[2]. But, although in some instances this is the case, and various genera of the group 'Protococcoideæ' have to be transferred to other groups to which they more rightly belong, many forms still have to remain in the old group 'Protococcoideæ' until more is known concerning their life-histories and affinities. For instance, it has been asserted that species of the genus *Tetraëdron* Kütz. 1845 (= *Polyedrium* Näg. 1849) are merely stages in the development of *Pediastrum*, but this is now known to be erroneous[3], and that even if certain forms are developed in the life-cycle of *Pediastrum* which much resemble species of *Tetraëdron*, yet the latter genus is quite distinct and has a life-history of its own. It is, however, most probable that *Pediastrum* has been evolved from Algæ of the nature of *Tetraëdron*, and one of the connecting links has been discovered in a genus recently described by Lagerheim under the name of *Euastropsis*.

As another example of erroneous conclusions arrived at from insufficient evidence, there is the case of the genus *Chantransia*. The discovery by Sirodot[4] of the 'protonema-stage' of *Batrachospermum* was regarded by many people as a sufficient proof that species of *Chantransia* were merely asexual forms of *Batrachospermum*. This was entirely due to the mistake of confounding the sporophytic shoots of *Batrachospermum* (and *Lemanea*) with certain true species of *Chantransia* which they much resembled. Murray[5], in commenting upon this, says that to speak of the "*Chantransia*-forms" of these genera "means no more than if the protonema of a moss were to be called its '*Conferva*-form' or the prothallus of a fern its 'Liverwort-form.' These growths of *Lemanea* and *Batrachospermum* have nothing to do with the valid generic type *Chantransia*."

In conclusion, it seems well established that the higher types of Algæ have originated by gradual evolution from the more lowly

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[1] Gay, 'Recherches sur le développement et la classification de quelques Algues Vertes,' Paris, 1891.

[2] Klercker, 'Ueber zwei Wasserformen von Stichococcus,' Flora, 1896.

[3] Cfr Lagerheim in Tromsö Museums Aarshefter, 17. 1894.

[4] Sirodot, 'Sur le développement des Algues d'eau douce du genre Batrachospermum,' Paris, 1875.

[5] G. Murray, 'An Introduction to the Study of Seaweeds,' London, 1895, p. 208.

types, but the fact must not be overlooked that these lowly types, although they may have undergone many modifications, still persist, and great care should be taken not to confound them with those stages in the life-histories of the higher types which present so many resemblances to them.

THE PHYLOGENY AND CLASSIFICATION OF THE FRESHWATER ALGÆ.

The researches and discoveries of the last few years have certainly thrown much light on the affinities of many genera and families of Algæ, and constitute a very great advance in our knowledge of the phylogenetic relationships of these plants. It is by no means an easy task to give even a mere outline of the suggestions which have at different times been put forward as to the evolution of freshwater Algæ, but one derives great assistance from two recently published papers, one by Chodat[1] and the other by Blackman[2], containing not only a summary of much of the work bearing on this difficult problem of phylogeny, but putting forward some well-founded suggestions as to the same.

In the succeeding brief account of the evolution of freshwater Algæ I have followed very largely the suggestions of Borzi, Blackman, Bohlin and others, with certain alterations based upon my own experience[3].

Taking first the Chlorophyceæ or green Algæ, which a few years ago were in a chaotic condition, we find that this chaos has been greatly reduced to order and that the affinities of many of these plants have been clearly demonstrated. The four groups of the Confervoideæ, Conjugatæ, Siphoneæ and Protococcoideæ, into which the green Algæ have been usually classified, must be considerably modified in view of recent researches. The Conjugatæ and the Siphoneæ will remain as distinct and natural orders of the green Algæ, the former chiefly by reason of their reproduction and the latter on account of their cœnocytic structure, but the Confervoideæ and Protococcoideæ were unquestionably unnatural

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[1] Chodat, 'On the Polymorphism of Green Algæ and the Principles of their Evolution,' Ann. Bot. xi, 1897.

[2] F. F. Blackman, 'The Primitive Algæ and the Flagellata. An Account of Modern Work bearing on the Evolution of the Algæ,' Ann. Bot. xiv, 1900.

[3] In 'Lectures on the Evolution of Plants' by D. H. Campbell (Macmillan Company, New York, 1889), there is a chapter on Algæ (pp. 48—79) with a scheme of evolution (p. 79), but the latter appears to be largely based upon erroneous conceptions of the relationships of these plants.

groups which could no longer be tolerated in the sense in which they were originally proposed.

Chodat, from observations on the lower green Algæ, both in a state of nature and in cultures, traces the principal groups of the Chlorophyceæ back to the Palmellaceæ, one of the lowly families of the order Protococcoideæ. He recognizes three important tendencies which rule the lower green Algæ:—(1) the zoospore-condition, the other two conditions being only transient; (2) the sporangium-condition or unicellular motionless stage, the other conditions being realized accidentally; (3) the Tetraspora-stage, where non-motile cells are connected by regular cell-walls at right angles.

Blackman follows somewhat on these lines, but he considers, along with others, that all the tendencies of the lower Algæ have had an origin in the motile unicellular Chlamydomonads. Among the families of lower Algæ constituting the group of the Protococcoideæ, he observes three divergent vegetative tendencies:—(1) a Volvocine tendency towards the aggregation of motile vegetative cells into gradually larger and more specialized motile true cœnobia; (2) a Tetrasporine tendency towards the formation of aggregations by the juxtaposition of the products of septate vegetative cell-division to form non-motile organisms of increasing definiteness and solidarity; (3) an Endosphærine tendency towards the reduction of the vegetative division and septate cell-formation to a minimum. The simplest forms which exhibit any one of these three tendencies seem clearly to diverge from species of the genus *Chlamydomonas,* and these motile organisms must be regarded as the real primitive form of green plant and the foundation stone, so to speak, of the vegetable kingdom. Of late much work has been done at the genus *Chlamydomonas* by Goroschankin, Francé, Dill, Klebs, and Wille, and now the genus is brought into still more prominence. It has been found to contain some twenty-nine species which are remarkable for the constancy of their cytological characters. Unfavourable conditions produce in this genus the '*Palmella*-condition.' This is the beginning of a vegetative non-motile existence such as predominates in the Palmellaceæ. In the latter family the cells at intervals in their life-history escape from their walls, develop cilia, and return to the motile state as zoogonidia. Blackman remarks that the "formation of zoospores is then nothing but reversion to an ancestral type of vegetative existence for a biological advantage, and all the vegetative existence of the higher Algæ is phylogenetically a new intercalation into the life-history of the motile Chlamydomonad which is permanently in the zoospore condition, though walled, and in which zoospore-formation and vegetative cell-division are one and indistinguishably the same thing."

Chlamydomonas itself has had an origin from the Protomastigina—one of the five subdivisions of the Flagellata proposed by Klebs—and two instances of the connecting forms are found in the organisms known as *Polyblepharis* Dang. and *Chlorogonium* Ehrenb. Many of these lowly Flagellates are green, but others are colourless saprophytic organisms, and in some either a saprophytic or holophytic nutrition may be carried on, depending on whether the organism is well fed or not[1]. In the same way that green organisms occur among the Flagellates so do colourless forms occur among the lower Algæ. One species of *Chlamydomonas* —*Chl. hyalina*—is always colourless and saprophytic, and Dangeard's researches into *Polytoma* have likewise shown that the small group of organisms of which *Polytoma uvella* Ehrenb. is the best known representative should perhaps be regarded as a saprophytic sub-family of the Volvocaceæ which have probably evolved from a green organism of the Chlamydomonad-type. The various Flagellates such as *Euglena* and others belonging to the Euglenoidina, have given origin to no organisms of preponderating plant-characters.

The Volvocine tendency in the Chlamydomonad-type has caused the evolution of a series of organisms of gradually increasing complexity, which constitute the Volvocaceæ. These are genera which practically consist of cœnobia of cells of the Chlamydomonad-type. The genus *Gonium* is perhaps very little removed from *Chlamydomonas* except in the possession of a four-celled or sixteen-celled colony. The highest development reached is the *Volvox*-colony, in which there are highly developed oospheres and antheridia. Between the isogamous *Chlamydomonas* or isogamous *Gonium* and the highly differentiated heterogamous condition of *Volvox*, there are two intermediate stages in *Pandorina* and *Eudorina*.

The Tetrasporine tendency in the Chlamydomonad-type first resulted in the production of a series of forms in which vegetative

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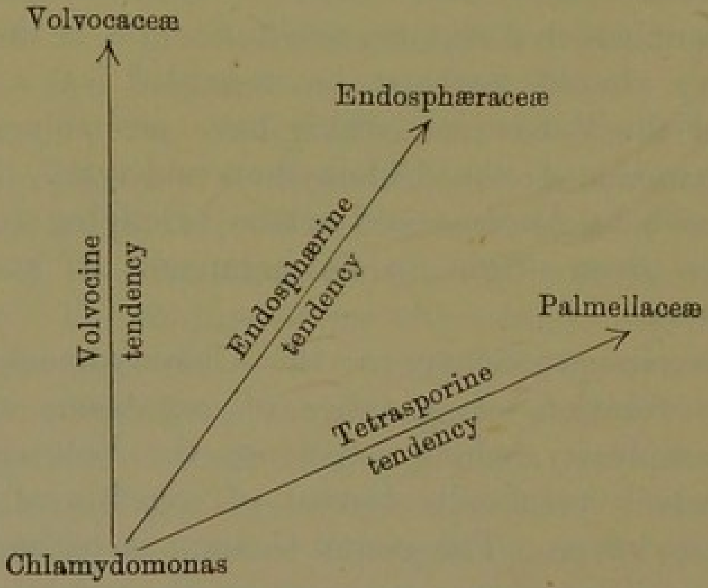
[1] Zumstein in Pringsheim's Jahrbüch. für. wiss. Botan. xxiv, 1899.

cell-division gradually replaced the formation of zoogonidia as the chief method of multiplication. The first group of Algæ evolved in this direction was the lowly family of the Palmellaceæ, in which the cells are grouped together either in all directions of space as in *Palmella,* or regularly disposed in one plane as in *Tetraspora.* The cells are enveloped in a general mucous envelope formed by the confluence of the special gelatinous cell-walls, and in every stage the cells on leaving the envelope are capable of swarming as zoogonidia. It is to this family of the Palmellaceæ that we must look for the origin of most of the other families of green Algæ.

The Endosphærine tendency in the Chlamydomonad-type has given rise to certain plants in which vegetative cell-division is absent, the multiplication of individuals taking place only by the formation of zoogonidia or gametes. These plants belong to the family Endosphæraceæ and are almost strictly unicellular.

So far, then, the phylogeny of the green Algæ can be illustrated by the following simple diagram:—



The Volvocine tendency has resulted in no higher development than the *Volvox*-colony, but a very reasonable suggestion has been made by Blackman as to the origin of the Siphoneæ by a further development of the Endosphærine tendency and formation of a thallus, which, although essentially cœnocytic, is structurally unicellular and lacks the solidity acquired by septate cell-division. He remarks that "nothing appears to have been evolved from it of higher status than an Alga. While the Tetrasporine tendency has given rise to all the higher green plants, the Endosphærine has only succeeded in producing the elaborate but puny mockery of them which we find in *Caulerpa*."

It is now necessary to trace the further developments from the Palmellaceæ, which family was the first result of the influence of the Tetrasporine tendency on the Chlamydomonad-type.

The Protococcaceæ is a group which has been gradually evolved from the Palmellaceæ by the direct production of the unicellular motionless stage with a firm cell-wall as the principal state of the plant, the zoogonidia and the *Tetraspora*-stage being only transient conditions in the life-history, and often absent. In the lower forms of this family the cells are globose with firm cell-walls, and all their reproductive processes show a marked tendency to transform the motile elements into resting spores. In some of the other forms of the family the cells exhibit great variety of form (e.g. *Oocystis*, *Nephrocytium*, *Kirchneriella*, *Chodatella*, etc.), and reproduction is largely by a type of spore termed by Chodat an *autospore*. Such spores are usually produced in fours inside the mother-cell, and at the moment of their liberation they possess the exact form and external peculiarities of the mother-cell. Sometimes the autospores are quite free after their liberation (e.g. *Lagerheimia*, *Oocystis*), but at other times they are surrounded by a gelatinous envelope (e.g. *Kirchneriella*, *Nephrocytium*). When the autospores are united together in a colony at the time of their expulsion an *auto-colony* is produced. Such is the usual method of multiplication of *Scenedesmus*. Forms of the nature of *Cœlastrum* and *Sorastrum* have originated from the lower Protococcaceæ with autospores, the latter being grouped together into a globular auto-colony.

The position of the two genera *Pediastrum* and *Hydrodictyon* is still very doubtful. I am inclined to agree with Chodat that the resemblance is due to convergence rather than to a common origin. In *Pediastrum* the swarming stage is outside the mother-cell and the new cœnobium arises by the apposition of motile zoogonidia. In *Hydrodictyon* the new cœnobium also arises by the apposition of zoogonidia which have become quiescent, but is formed inside the mother-cell. Both genera consist of cœnobia of cœnocytes, and for the present they are best kept in the separate sub-families of the Pediastreæ and Hydrodictyeæ.

Among the Chætophorales it is clear that the Ulotrichaceæ have had a direct origin from the Palmellaceæ through such forms as *Stichococcus*, *Hormospora*, *Radiofilum*, *Glœotila* and *Geminella*, forms in which simple loosely connected series of cells occur embedded in a gelatinous envelope.

The Chætophoraceæ are further specialized forms of the Ulotrichaceæ, which are distinguished mainly by their branched habit. The polymorphism exhibited by the Chætophoraceæ, and the development of zoogonidia and formation of resting-spores, also indicate a close connection with the Palmellaceæ, but probably through the Ulotrichaceæ. Chodat considers the genus *Pleurococcus* as one type of the Chætophoraceæ which has been reduced owing to its existence as a lichen-gonidium, but this is a statement I cannot agree with.

The Ulvales and the Schizogoniales are parallel groups, each of which has probably had a separate origin from the Protococcoideæ. The Ulvaceæ, especially such forms as *Monostroma* and *Ulva*, have most likely originated from Palmellaceous Algæ of the nature of *Tetraspora*.

The genus *Microspora* is difficult to relegate to its proper place in a classificatory scheme. It is the sole representative of the family Microsporaceæ and its characters mark it off sharply from other green Algæ. It may have originated from some aberrant form of the Ulotrichaceæ, but its affinities are at present doubtful. It is possible that the forms placed in the genus *Rhizoclonium* have originated from *Microspora*, and by a further specialization the genus *Cladophora* has been produced. The Cladophoraceæ (and therefore the Pithophoraceæ) may thus have had an origin from the Microsporaceæ. Bohlin[1] has recently transferred the Cladophoraceæ to the order Siphoneæ owing to the cœnocytic nature of the segments of the thallus, but the validity of such a change is a question of opinion. Owing to the many points of resemblance between *Hydrodictyon* and *Cladophora*, the former genus may possibly be a degenerate form of the Cladophoraceæ. Since 1897[2] I have regarded the Cladophoraceæ as a distinct family of Chlorophyceæ, in close proximity to the Siphoneæ and far removed from the Ulotrichaceæ, yet I hardly see the justification for its inclusion in the Siphoneæ. I think it better to place the Cladophoraceæ and Pithophoraceæ, along with the Sphæropleaceæ, in a separate order, the Cladophorales.

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[1] Bohlin, 'Utkast till de Gröna Algernas och Arkegoniaternas Fylogeni,' Akad. Afhandl. Upsala, 1901.

[2] W. & G. S. West in Journ. Roy. Micr. Soc. 1897, p. 475.

Luther and Bohlin have recently advocated considerable changes in the classification of the Green Algæ, most of which have been rendered necessary by the abolition of the old artificial group of the 'Confervoideæ.' I agree with Bohlin in the establishment of the order 'Microsporales,' even though it appears to be giving undue prominence to a small group of more or less insignificant Algæ, because species of the genus *Microspora* are referable to no other order of green Algæ. Likewise, the Œdogoniaceæ require placing in a separate order because of their anomalous characters.

Several of the recent students of freshwater Algæ have attempted to show that all the main groups of the Chlorophyceæ have had a separate origin from unicellular, motile, ciliated or flagellated ancestors. This is no doubt a very helpful idea, but like many other such ideas it can easily be carried too far. It appears most probable that certain groups of green Algæ have had a direct origin from ciliated or flagellated unicells, but that in itself is no proof that other groups have had a similar origin. There is not a shadow of evidence in support of the direct and individual origin of the Microsporaceæ, the Conjugatæ, the Vaucheriaceæ, the Œdogoniaceæ or the Cladophorales; in fact, there is every reason to suppose that some at least of these groups have originated from previously existing filamentous forms.

The origin of the Conjugatæ seems very uncertain. Blackman, in his scheme of evolution[1], and Bohlin[2] have both suggested an origin from the unicellular motile Chlamydomonad-type, and therefore directly from the Flagellata. To my mind this shows a lack of experience of the Conjugatæ as a whole, and particularly of the family Desmidiaceæ. Whatever the true origin of the Conjugatæ it cannot have been direct from Flagellate forms. Presumably the first Conjugates which would arise from such motile unicells would be themselves unicells, or loose aggregates of cells. Now, such is exactly the condition found in the Desmidiaceæ; but it has been clearly shown[3] that the Desmidiaceæ is unquestionably a family of Conjugates derived by retrogression from filamentous ancestors, and therefore, they cannot by any possible means have had a direct origin from unicellular motile organisms.

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[1] Blackman, l.c. p. 684.

[2] Bohlin, l.c. p. 22.

[3] W. & G. S. West in Ann. Bot. xii, 1898, p. 55; G. S. West in Journ. Linn. Soc. Bot. xxxiv, 1899, pp. 409—415.

It appears more probable that the early Conjugates were filamentous forms and that they originated from some other order of green Algæ, coming to an abrupt conclusion soon afterwards. Nothing higher was evolved from them, but the group of the Desmidiaceæ became sharply marked off from the rest of the Conjugates owing to great specialization. The specializing tendency was in the direction of a remarkable increase in the complexity of morphological characters, and this was accompanied by degeneration of sexual differences.

Perhaps there may be an affinity between certain of the Conjugates and the genus *Microspora*, as the resemblance between such species as *Microspora Löfgrenii* Nordst.[1] and *Zygnema pachydermum* West[2] is most striking; the cell-walls are thick and exhibit the same structure, and in both plants precisely similar aplanospores are formed in identically the same manner.

It is now necessary to consider a group of Algæ for which Borzi[3] proposed the name of the 'Confervales.' In this order he included a number of Algæ which had previously been scattered amongst various groups of the Chlorophyceæ. The characters of the group are based upon the structure of the cell, which contains parietal discoidal chromatophores of a yellowish-green colour and without pyrenoids. Even the zoogonidia possess discoidal chromatophores of a yellowish-green colour and two unequal cilia (sometimes one?). The plants may be unicellular, cœnocytic or multicellular, and include amongst others the following genera:—*Ophiocytium*, *Characiopsis*, *Chlorothecium*, *Mischococcus*, *Tribonema* (*Conferva*), *Botrydiopsis* and *Botrydium*. Bohlin[4] in 1897 conclusively demonstrated, by an exhaustive study of the structure of the cell-wall, the close affinity which exists between the genera *Ophiocytium* and *Tribonema* (*Conferva*); and, in addition, in the earlier stages of development these two genera, one of which is unicellular and the other multicellular, much resemble each other[5]. The order Confervales is subdivided into three families:—(1) Tribonemaceæ, which includes *Tribonema* (*Conferva*), *Ophiocytium*,

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[1] Nordstedt in Botaniska Notiser, 1882, p. 55; W. & G. S. West in Journ. Bot. Febr. 1897, p. 34.

[2] West in Journ. Linn. Soc. Bot. xxx, 1894, p. 266, t. xiii, f. 1—16.

[3] Borzi in Boll. della Soc. ital. dei Microscop. i, 1889.

[4] Bohlin in Bihang till K. Sv. Vet.-Akad. Handl. 1897, Bd xxiii, no. 3.

[5] Bohlin l.c. t. ii, f. 47, 51, 52, 54—56; Wille in Öfvers. af K. Vet.-Akad. Förh. 1881, no. 8, t. ix, f. 15, 17, 18, 21—26; G. S. West in Journ. Bot. Mar. 1899, p. 106, t. 394, f. 18—22.

Bumilleria, Botrydiopsis, Chlorobotrys; (2) *Chlorotheciaçeæ*, which includes *Mischococcus, Peroniella, Stipitococcus, Characiopsis, Chlorothecium*; (3) Botrydiaceæ, including *Botrydium*. Now, amongst the Flagellate organisms there exists a genus described as *Vacuolaria* by Cienkowski[1], which possesses yellow-green discoidal chromatophores without pyrenoids; and this organism, as in the case of the Chlamydomonad-type, may very possibly be the starting point of the Confervales. Lagerheim discovered another organism in 1897 which was further worked out by Bohlin[2] and named *Chloramœba*. It is of a similar type to *Vacuolaria* with discoidal chromatophores of a yellow-green colour, but more strictly a Flagellate. Great interest is likewise attached to the discovery by Luther[3] in 1898 of yet another similar organism which he named *Chlorosaccus*. This organism has certain resemblances to *Tetraspora*, but is of a yellow-green colour with several parietal disc-like chromatophores, and seems to connect *Chloramœba* and *Vacuolaria* with the direct line of descent of the Confervales. Luther proposed to remove all these forms out of the Chlorophyceæ and suggested the name '*Heterokontæ*' as a class equal with that of the Chlorophyceæ, and to include the Algal series 'Confervales' and the corresponding Flagellate group 'Chloromonadina' (or Chloromonadales). This class seems a very natural one and differs from the Chlorophyceæ in certain cytological characters, such as the abundant presence of xanthophyll and the presence of a fatty substance as the stored product of carbon-assimilation.

Bohlin has recently suggested that the Vaucheriaceæ should be included with the 'Confervales' and 'Chloromonadales' as one of the orders of the Heterokontæ, with the name 'Vaucheriales.' There are, however, wide differences in structure between the Vaucheriaceæ and the Confervales, not to mention the absence of the yellow pigment and the highly differentiated sexual reproduction present in the former; neither is there any evidence that the plants of these orders are in any way phylogenetically related; therefore, for the present, I prefer to retain the Vaucheriaceæ in the order Siphoneæ of the Green Algæ.

The origin of the Phæophyceæ, or Brown Algæ, from brown

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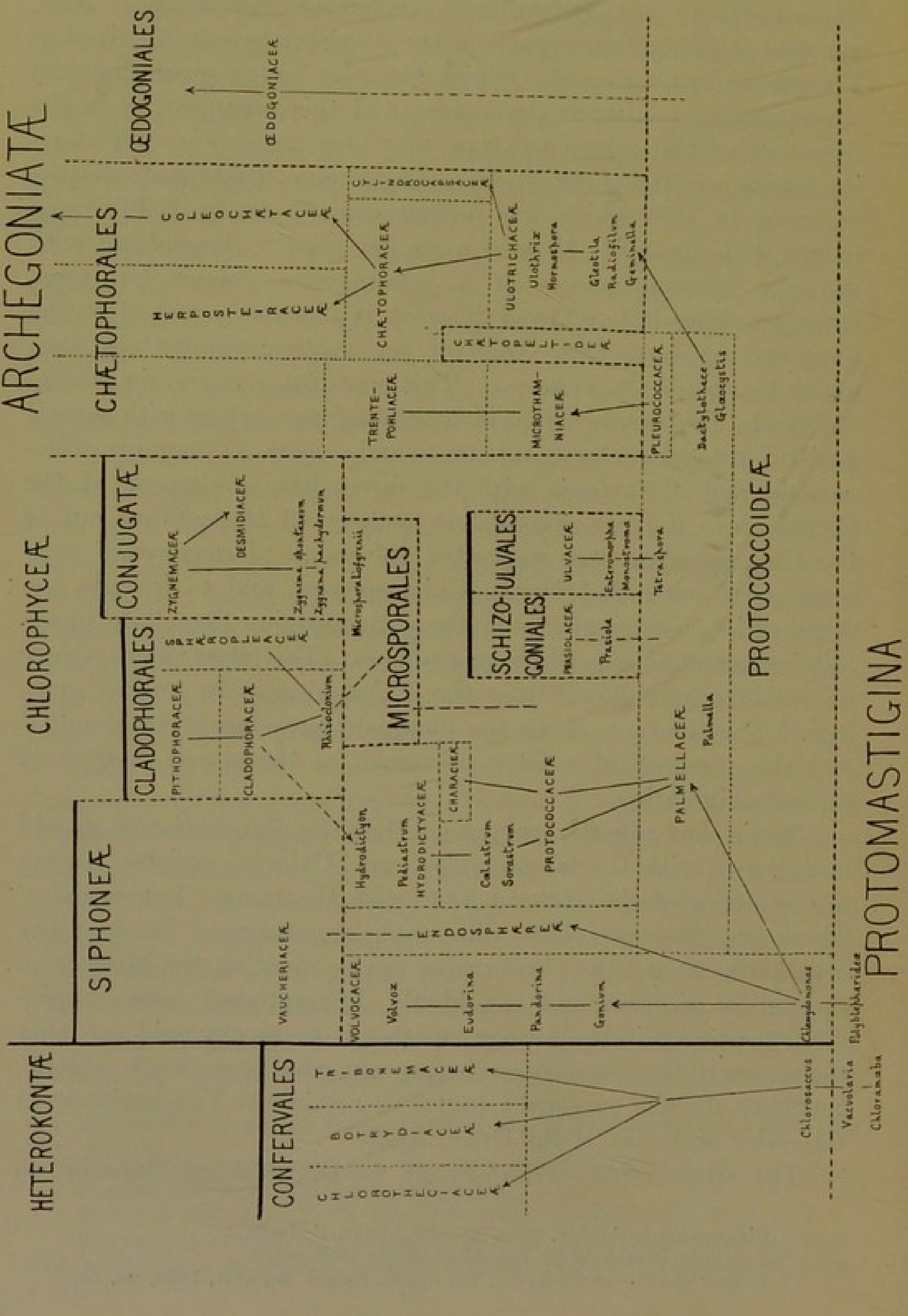
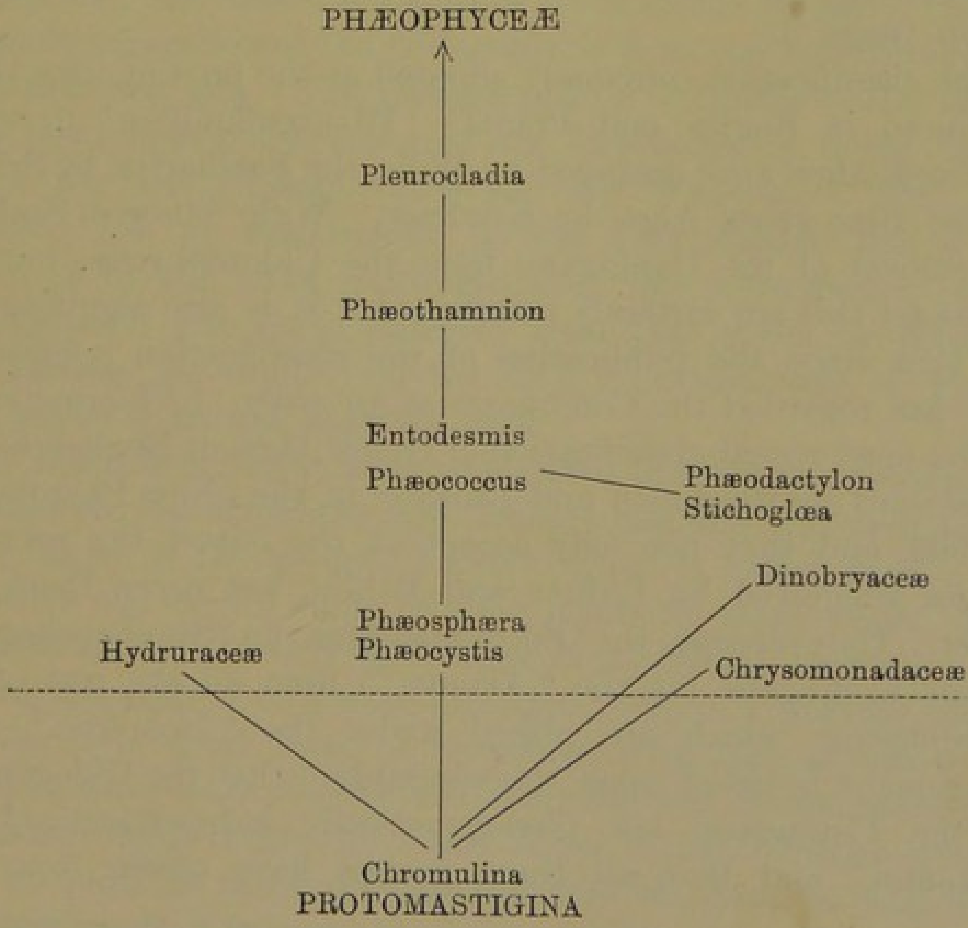
[1] Cienkowski in Archiv. für Mikroscop. Anat. vi, 1867.

[2] Bohlin in Öfvers. af K. Vet.-Akad. Förh. 1897, no. 9.

[3] Luther in Bihang till K. Sv. Vet.-Akad. Handl. Bd xxiv, 1898, no. 13.


ARCHEGONIATÆ
CHLOROPHYCEÆ
HETEROKONTÆ
PROTOMASTIGINA
ŒDOGONIALES
ŒDOGONIACEÆ
CHÆTOPHORALES
COLEOCHÆTACEÆ
HERPOSTEIRACEÆ
CHÆTOPHORACEÆ
ULOTRICHACEÆ
Ulothrix
Hormospora
Gleotila
Radiofilum
Geminella
CHÆTOPELTIDEÆ
TRENTEPOHLIACEÆ
MICROTHAMNIACEÆ
PLEUROCOCCACEÆ
Dactylothece
Glœocystis
CONJUGATÆ
ZYGNEMACEÆ
DESMIDIACEÆ
Zygnema spontaneum
Zygnema pachydermum
MICROSPORALES
Microspora löfgrenii
ULVALES
ULVACEÆ
Enteromorpha
Monostroma
Tetraspora
SCHIZOGONIALES
PRASIOLACEÆ
Prasiola
PROTOCOCCOIDEÆ
CLADOPHORALES
SPHÆROPLEACEÆ
PITHOPHORACEÆ
CLADOPHORACEÆ
Rhizoclonium
SIPHONEÆ
VAUCHERIACEÆ
Hydrodictyon
Pediastrum
HYDRODICTYACEÆ
CHARACIEÆ
Cœlastrum
Sorastrum
PROTOCOCCACEÆ
PALMELLACEÆ
Palmella
ENDOSPHÆREÆ
VOLVOCACEÆ
Volvox
Eudorina
Pandorina
Gonium
Chlamydomonas
Polyblepharideæ
CONFERVALES
TRIBONEMACEÆ
BOTRYDIACEÆ
CHLOROTHECIACEÆ
Chlorosaccus
Vacuolaria
Chloramœba

Flagellate organisms seems quite as reasonable as in the parallel case of the Green Algæ. During recent years many genera of primitive brown Algæ have been discovered, most of which appear to be intermediate forms between the higher brown Flagellates and the simpler types of filamentous brown Algæ. The majority of these primitive brown Algæ inhabit fresh water, but few of them have up to the present been observed in Britain. The Flagellate organism suggested as the possible starting point for this series is *Chromulina* Cienk.[1], and the ascending series of forms include *Phæocystis* Lagerh., *Phæosphæra* West & G. S. West, *Phæococcus* Borzi, *Entodesmis* Borzi, *Phæothamnion* Lagerh. and *Pleurocladia* A. Br. Divergences along other lines from *Chromulina* may have given rise to the Hydruraceæ, the Chrysomonadinaceæ and the Dinobryaceæ. *Phæodactylon* Bohlin and *Stichoglœa* Chodat may have a relationship with the *Phæococcus*-type of brown Alga.



The origin of the Bacillarieæ is still extremely doubtful, and no reasonable suggestions have yet been put forward as to their

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[1] Cf. Lagerheim in Öfvers. af K. Vet.-Akad. Förh. 1896, no. 4, p. 288.

line of descent. They are regarded by some as a group of the Phæophyceæ, but are better considered as a distinct class. It may be that there is a much more direct relationship between the Bacillarieæ and the Flagellate Peridinieæ than is at first apparent.

The origin of the large class Rhodophyceæ is still very uncertain, although quite recently a marine Flagellate with the chromatophores of the Rhodophyceæ has been discovered by Karsten[1]. As there are so few freshwater representatives of this large class of Algæ, a discussion as to their origin would here be out of place.

So little is known concerning the Myxophyceæ and their life-histories that any attempt to give an account of their origin and evolution would be mostly a matter of conjecture. It is interesting to note, however, the existence of blue-green motile organisms such as *Cryptoglena* Ehrenb. and *Chroomonas* Hansg.[2] Reasons for retaining the word 'Myxophyceæ' are stated in the Introduction (page 3).

The classification commonly adopted at the present time is the one found in Engler and Prantl's 'Pflanzenfamilien,' in which the Green Algæ were arranged by Wille, the Bacillarieæ by Schütt, and the Blue-green Algæ by Kirchner. Wille followed Sachs in the removal of the Conjugatæ from the Chlorophyceæ, but the reasons for this are certainly insufficient. It is also significant to note that since the publication of the classification referred to, Wille has regarded the Conjugatæ as an order of Chlorophyceæ[3].

The most recent classification of Green Algæ in English is that put forward by Blackman and Tansley[4] in the 'New Phytologist' for 1902, and they not only accept at the outset the principal changes suggested by Luther and Bohlin, but carry them still further. They separate the Œdogoniales (as the "Stephanokontæ") and the Conjugatæ (as the "Akontæ") from all the rest of the Chlorophyceæ, which are placed under the "Isokontæ." This arrangement is based upon the assumption that the Œdogoniales and the Conjugatæ are phylogenetically independent of the "Isokontæ," and that all three groups have arisen from the

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[1] Karsten in Wissensch. Meeresuntersuchungen, Kiel, Bd iii, Heft 2, 1898.

[2] Hansgirg, 'Noch einmal über die Phykochromaceen-Schwärmer,' Bot. Centralbl. Bd xxiv, 1885.

[3] Wille, 'Algologische Notizen VII, VIII,' Nyt Magazin f. Naturvidensk., B. 39, H. 1, Kristiania, 1901.

[4] F. F. Blackman and A. G. Tansley, 'A Revision of the Classification of the Green Algæ,' The New Phytologist, 1902.

Flagellata. Be it remembered, however, that there is no direct evidence in support of the view that the Œdogoniales and Conjugatæ are phylogenetically independent of the rest of the Chlorophyceæ. Indeed, with regard to the Conjugatæ all the known facts concerning them tend to show that they, at least, have not had a *direct* origin from Flagellate ancestors. I have for many years made a special study of the Conjugatæ, including a particularly detailed investigation of the Desmidiaceæ, the family around which all the interest of this idea is centred; and I can say most emphatically that all the facts concerning these plants with which I am acquainted, far from supporting the idea of a Flagellate ancestry, tend to prove conclusively that this beautiful family of Conjugates has originated from filamentous ancestors.

The separation of the Conjugatæ from the rest of the Chlorophyceæ is therefore to my mind based upon an erroneous supposition, and there is likewise no evidence to show that the complete separation of the Œdogoniales from the rest of the green Algæ is a just one. The Heterokontæ is obviously a very natural class, but I have not transferred the Vaucheriaceæ to the Heterokontæ nor the Cladophoraceæ to the Siphoneæ. The genus *Prasiola* has no relationship to the Ulotrichaceæ and I have placed it in the order Schizogoniales. My arrangement of the Conjugatæ is also quite different from that given by Blackman and Tansley, particularly in the family Desmidiaceæ, of which I have given a natural classification.

In those facts lie the main differences between the classification put forward by Blackman and Tansley and the one used for the green Algæ in the present volume, which is based upon a very extensive and careful study of these plants for many years. There will also be found many differences in the genera themselves and in their disposition, as I have arranged them in a manner which I consider to be much more in accordance with their affinities. For example, the genera *Radiofilum* Schmidle and *Hormospora* Bréb. are undoubtedly feebly developed forms of the Ulotrichaceæ and have no place in the Protococcaceæ; and the same is true of the genera *Glœotila* Kütz. and *Stichococcus* Näg. *Dactylothece* Lagerh. is an elongated *Glœocystis*-like genus and has no relationship with either *Dimorphococcus* A. Br. or *Scenedesmus* Meyen; and many other instances could be quoted.

Class 1. RHODOPHYCEÆ (or Florideæ).

THIS class comprises the Algæ usually known as the Red Seaweeds. They exhibit a variety of colours from bright red and purple to dark brownish-reds, brownish-green, blue-green and black. Very few of the genera are freshwater forms.

The *thallus* is multicellular, very diverse in form, and consists of simple or branched cell-filaments which may be merely held in close proximity by mucilaginous material, or bound together by a tough intercellular substance, giving the thallus a parenchymatous appearance. The branching of the cell-filaments is very varied, the plants exhibiting many types of branching. The filaments increase in length by the repeated divisions of an apical cell. The cells are all protoplasmically continuous through pits in the transverse or cross-walls of the filaments. Each cell may contain one well differentiated nucleus, or more rarely the thallus may consist largely of cœnocytes. The chromatophores are distinct and the chlorophyll is masked by either a red colouring-matter—*phycoerythrin*, or a blue colouring-matter—*phycocyanin*. Sometimes pyrenoids are present.

Asexual reproduction takes place by motionless spores known as *tetraspores* (or tetragonidia), which are generally bright red, and have neither cilia nor cell-wall. They are produced in a tetrasporangium (or tetragonidangium), usually in variously arranged groups of four. This is the most common form of reproduction. Zoogonidia are absent from the entire class.

Sexual reproduction by male and female cells is wanting in some, but present in others. The female organ is a *procarp* which consists of a single cell containing a cell-nucleus, the *carpogonium,* drawn out into an attenuated, hair-like process called the *trichogyne.* The latter is homologous with the receptive spot of the oosphere of the green Algæ. The male organ is an *antheridium* of variable form which gives origin to large numbers of male cells. Each male cell opens at the apex and sets free a rounded, nucleated mass of protoplasm, without a cell-wall and without cilia, known as a *spermatium* (or pollinoid). Fertilization takes place by the attachment of the spermatium to the apex of the trichogyne and the union of their contents. As the nucleus of the spermatium disappears, it travels down the trichogyne and unites with that of the carpogonium, this fusion having been observed by Osterhaut in *Batrachospermum Boryanum*[1].

The result of the fertilization of the carpogonium is the development of a fructification known as a *cystocarp* (or sporocarp), and the different groups of the Rhodophyceæ are characterized by the method of formation of this fructification. Sometimes the cystocarp is developed directly from the carpogonium; but, frequently, the fertilizing influence is handed on to other cells in the neighbourhood of the carpogonium, and conjugation occurs between outgrowths of the fertilized carpogonium (known as *ooblastema filaments*) and certain auxiliary cells, the final result in all cases being the development of the cystocarp and the production of *carpospores*. Whatever be the method of formation of the cystocarp, the carpospores are always developed on a tuft of filaments which spring from fertilized cells and which are known as *gonimoblasts*.

The class is subdivided into four orders:—

Order I. *Nemalionaceæ*. This order includes four families, of which the Lemaneaceæ is exclusively freshwater, and the Helminthocladieæ includes several freshwater genera.

Order II. *Cryptonemiaceæ*. One family of this order, the Squamariaceæ, contains a genus of which there are several freshwater species.

Order III. *Gigartinaceæ*. Exclusively marine.

Order IV. *Rhodymeniaceæ*. Exclusively marine.

In addition to the four orders just enumerated, another group of Algæ known as the *Bangiaceæ* is often included in the Rhodophyceæ, but the systematic position of this group is very uncertain.

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[1] Osterhaut in Flora, lxxxvii, 1900.

The main argument for its inclusion in the Rhodophyceæ is derived from the red colour of the chromatophores, whereas the intercalary growth of the thallus and the absence of the pits between the thallus-cells are points against its inclusion among the Red Algæ. The so-called tetraspores of the Bangiaceæ are somewhat remarkable, the whole of the contents of a thallus-cell going to form one unciliated, amœbiform spore. The sexual process is also of a very reduced type, far removed even from that of the simplest red Alga. The genus *Bangia*, which is a simple filamentous form, occurs on the shores of the British Islands and in the estuaries of the rivers, but it is not exactly a freshwater Alga.

Order I. NEMALIONACEÆ.

The fertilized carpogonium gives origin directly to the gonimoblasts, which are developed in tufts.

Family 1. **HELMINTHOCLADIEÆ.**

The thallus is filamentous, simple or branched, with the secondary axes often arranged in whorls. The main axis may consist of a single row of cells, or of a central cell-filament surrounded by a cortical ring of smaller cell-filaments. The gonimoblast is a short tuft of cell-filaments and the terminal cells usually form the carpospores. When the terminal cell has shed its carpospore, the supporting cell grows through into the old cell-wall and produces a new spore-forming cell. There is no definite wall to the cystocarp.

Genus **Batrachospermum** Roth, 1797. This is an exclusively freshwater genus with a wide distribution in temperate and tropical climates. Most of the species prefer deep water in which there is a slight current, but more rarely they are found attached to stones in fast streams. They scarcely ever occur in stagnant water, but are found frequently in bogs, usually at a point where a spring rises. The thallus, which is of a blue-green colour and enveloped in a thick coat of mucus, is remarkable for the great beauty and symmetry of its branching; sometimes it reaches a length of 16—20 cms. The plants are generally attached to stones or wood by a number of thick old shoots; these send off numerous primary axes which float freely in the water. The primary axis consists of a central filament of cells which grows by

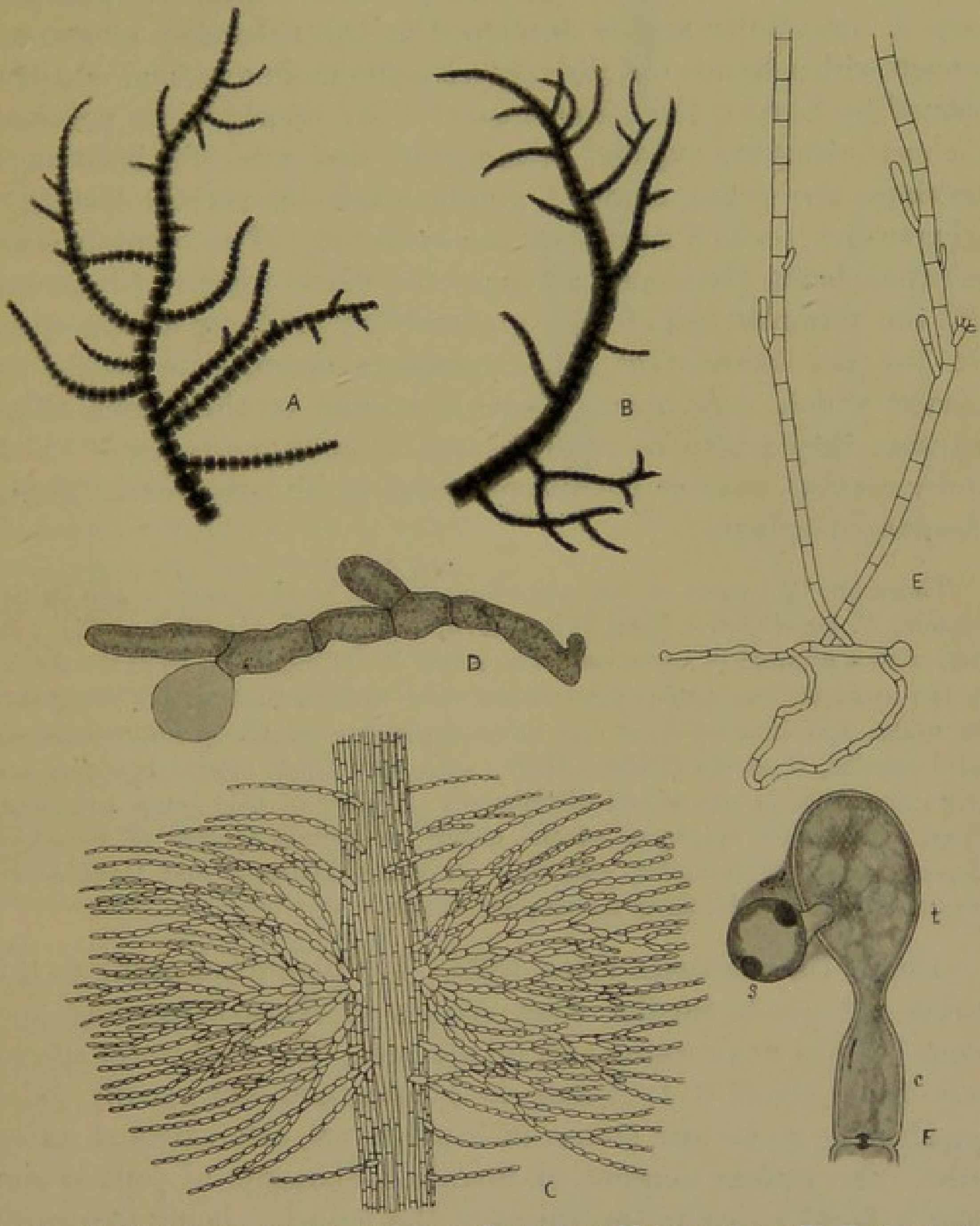

Fig. 1. A, *Batrachospermum moniliforme* Roth, from Malham Cove, W. Yorks. (× 2); B—C, *Batrachospermum vagum* (Roth) Ag., from Thursley Common, Surrey; B (× 2); C, single node with lateral branches, more highly magnified. D, germinating spore. E, protonemal growth. F, Female organ and fertilization; *s*, spermatium; *c*, carpogonium; *t*, trichogyne. (D, E, and F after Schmidle.)

means of a hemispherical apical cell. The cells of this central filament become swollen at each end, a dense whorl of branches being produced at each swelling (or node). From the basal cells of the branches secondary branches grow downwards over the main axis, forming a cortical ring of cell-filaments (sometimes termed the pseudocortex). The apical cells of the lateral branches are frequently produced out into long hairs or bristles. The procarp is unicellular and is developed at the extremity of a small branch which stands out directly from the main axis, and which is termed by Sirodot the 'female axis.' The carpogonium possesses a short, straight, exposed trichogyne[1], and after fertilization it develops the dense mass of gonimoblasts (frequently termed a 'glomerulus') which constitute the cystocarp. The cystocarps are external, being developed amongst the dense whorls of branches, and the terminal cell of each gonimoblast produces a carpospore. On the development of the carpospores sporophytic shoots are formed which very much resemble species of the genus *Chantransia*; they are to be regarded as a kind of 'protonema,' which, under certain suitable conditions, develops into the sexual *Batrachospermum*-plant.

There are two more or less abundant species of the genus in the British Islands, *B. moniliforme* Roth (Fig. 1 A) and *B. vagum* (Roth) Ag. (Fig. 1 B), each with a number of varieties. The latter is distinguished from the former by the more or less uniform development of the lateral branches along both the nodes and internodes of the inferior portions of the primary axis. A third species, *B. atrum* (Dillw.) Harv., with very short lateral branches and long internodes, is less widely distributed. Species of this genus commonly afford a home for epiphytes of the nature of certain species of *Calothrix*, *Hapalosiphon*, *Ammatoidea*, etc., and numerous Diatoms and Desmids are frequently present in their enveloping mucus.

Genus **Chantransia** Fries, 1825. The plants belonging to this genus are much smaller than species of *Batrachospermum* and occur both in fresh water and in the sea. The freshwater species vary from about 3 to 7 mm. in length, and are usually found attached to rocks and stones in rapid rivers, cataracts and waterfalls. The thallus consists of branched filaments of cells arising from a basal stratum, the apices of the branches being frequently much attenuated and almost piliferous. In colour the plants are all shades of red, purple and blue. There is an entire absence of the mucous coat which is so conspicuous a feature of *Batrachospermum*. It was thought for some time that all the species of

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[1] Schmidle, 'Einiges über die Befruchtung, Keimung, und Haarinsertion von Batrachospermum,' Bot. Zeitung, Heft 7, 1899.

Chantransia were merely non-sexual stages of *Batrachospermum*, and that under brighter conditions of light they underwent a metamorphosis, giving rise to the sexual stage or *Batrachospermum.* The carpospores of the latter genus develop a protonema-like growth which bears great resemblance to species of *Chantransia*, and many of these growths, both of *Batrachospermum* and *Lemanea*, have been erroneously described as species of that genus; but, at the same time, these have nothing to do with the valid genus *Chantransia*. The sexual reproduction of *Chantransia* has only been fully worked out in one species—*Ch. corymbifera* Thur. On the fertilization of the carpogonium it develops numerous gonimoblasts upwardly and on one side. There is thus formed a naked corymbose cystocarp, the terminal cells of the gonimoblasts producing the carpospores. The antheridia are likewise developed in clusters. Asexual reproduction occurs by tetraspores and also by other spores which remain undivided and are known as 'monospores.' These, on germination, divide into four cells in one plane, giving rise to the basal stratum from which the branched filaments spring.

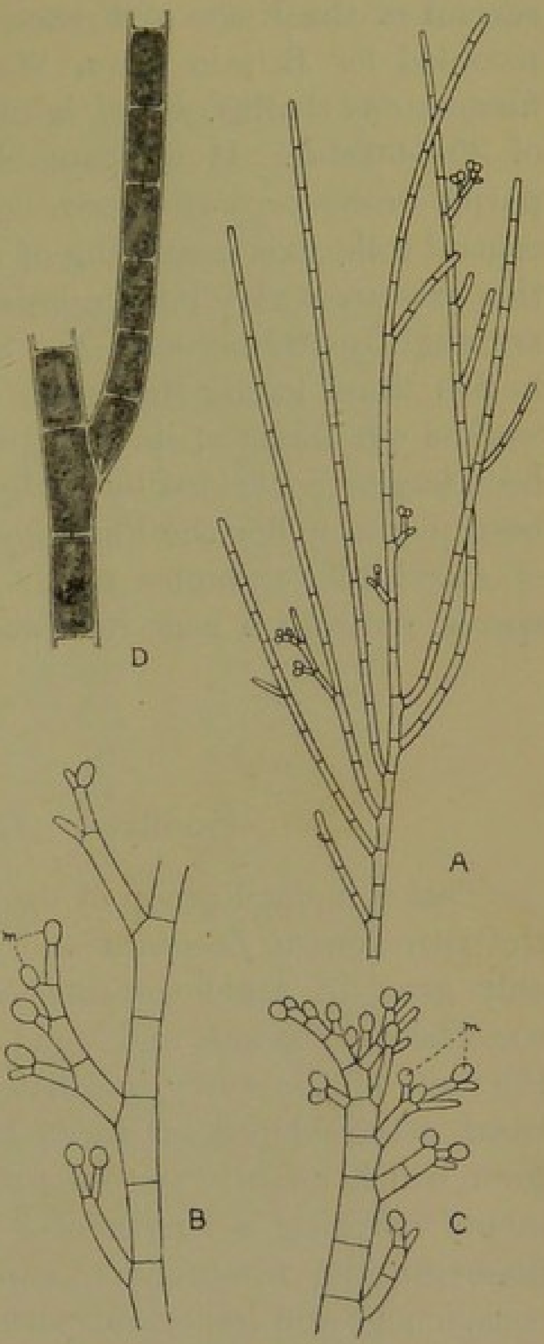

Fig. 2. A, *Chantransia pygmæa* Kütz., from Penyghent, W. Yorks. (× 100). B and C, branches of the same with 'monospores' (*m*) (× 300). D, *Ch. scotica* Kütz., from Cornwall; a small portion of the thallus showing the pits in the transverse walls (× 400).

There are some seven or eight British freshwater species of the genus, of which *Ch. pygmæa* Kütz. (fig. 2 A—C) and *Ch. violacea* Kütz. are perhaps the most frequent.

Genus **Thorea** Bory, 1808. This is a rare genus with only one species—*Th. ramosissima* Bory—which, although found in several of the rivers of France and Germany, has only once been recorded for Britain (from Walton-on-Thames). It has a round filamentous thallus, which is much branched and reaches a length of 30—60 cms. It is about the thickness of a horse-hair, of a purple-brown or dark brown colour, and very mucous. There is a central solid axis consisting of filaments of cells, and arising from this axis are a very large number of short compact branches, which are slightly attenuated. The cells of the branches are from two to five times longer than their diameter. Schmidle[1] has recently worked out much of its structure and fructification, and this has been largely confirmed by Hedgcock and Hunter[2]. This genus has been placed under the Phæophyceæ, but the pigment, the presence of starch-like granules in the cells, and the naked non-motile spores, indicate a near relationship with certain of the Florideæ.

Family 2. LEMANEACEÆ.

This is a small group of exclusively freshwater Algæ including the two genera *Lemanea* and *Sacheria*. They are plants which only grow in rapid torrents, occurring attached to the rocks of waterfalls, to stones and wood in mill-sluices, etc., always where the force of the water is greatest. The thallus is composed of a basal, attached portion, termed by Sirodot[3] a "système radicant," from which arise cæspitose tufts of erect, branched, simple filaments reaching a length of 3—8 mm. From portions of these filaments the fructiferous branches arise. These are the most conspicuous and important parts of the plant, in most species the vegetative portion dying away after their production, and in a short time they become fixed by organs of attachment of their own. Each species is thus represented by two distinct sets of individuals, the one vegetative and the other reproductive.

The fructiferous branches are elongated, thread-like portions

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[1] Schmidle, 'Untersuchungen über Thorea ramosissima Bory,' Hedwigia, Bd xxxv, 1896.

[2] G. G. Hedgcock and A. A. Hunter in Botan. Gazette, xxxviii, 1899.

[3] Sirodot, 'Étude anatomique, organogénique, et physiologique de la Fam. des Lemanéacées,' Ann. Sci. Nat. Bot. tom. xvi, Paris, 1872.

of the thallus, of a cartilaginous consistency, and hang freely in the rapid torrent. They are of an olive-green or greenish-black colour and grow to a length of 15—18 cms. At short, more or less regular intervals along their whole length are distinct swellings or nodes, and each nodulose thread is built up of an axial

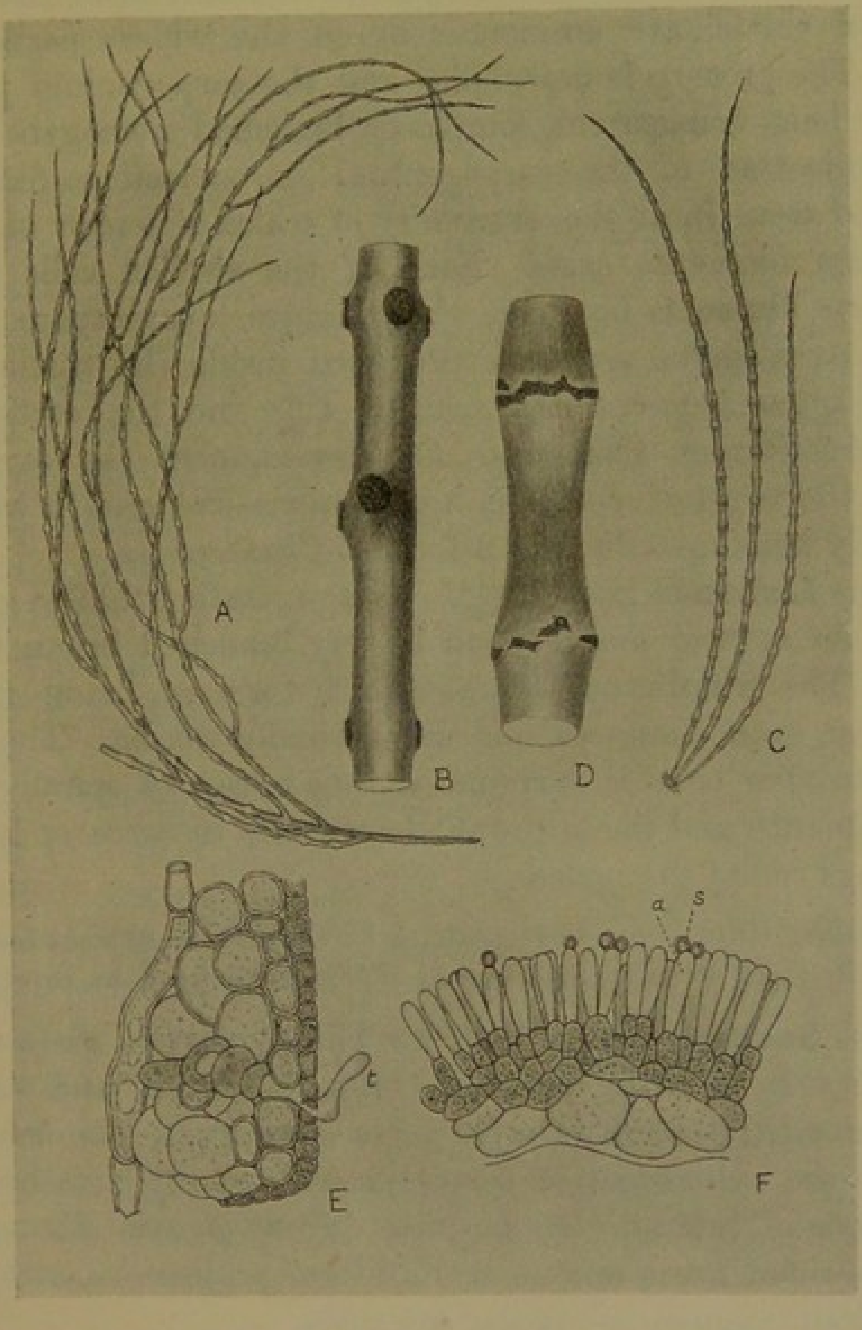

Fig. 3. A, *Sacheria mamillosa* Sirodot (nat. size), from R. Wharfe, W. Yorks. B, portion slightly magnified showing antheridial areas. C, *Lemanea torulosa* Kütz. (nat. size). D, portion slightly magnified showing antheridial areas. E, *Sacheria fucina* (Bory) Sirodot, longitudinal section of fructiferous filament showing female organ; *t*, trichogyne. F, *Lemanea catenata* Kütz., transverse section of fructiferous filaments showing antheridia; *a*, antheridial cell; *s*, spermatium. (D, E, and F after Sirodot.)

row of tubular cells surrounded by rows of smaller cortical cells, growth taking place in all cases by an apical cell. The only known method of reproduction is a sexual one. The antheridia are short, cylindrical cells developed on the exterior of the thallus, either on verticillate eminences or on the widest parts of the nodes. The procarp is unicellular and the carpogonium possesses a rather long, transparent, simple or branched trichogyne. After the fertilization of the carpogonium an ooblastema-filament is developed from it, at the extremity of which a bunch of jointed, moniliform filaments arise. Each of the swollen cells of these moniliform filaments becomes, when mature, a carpospore.

The carpospores are thus produced inside the thallus, filling up the space between the central axis and the cortical cells of the fructiferous filaments. On development the carpospores produce the vegetative thallus, a protonema-like growth which has frequently been mistaken for a form of *Chantransia*.

Genus **Lemanea** Bory, 1808. The vegetative thallus generally persists for several months, and is very branched but never piliferous. The fructiferous filaments are torulose, being regularly inflated at even distances, and are normally simple. The central axis of tubular cells is surrounded by a series of spirally twisted axial filaments, and the antheridial areas are in more or less complete rings round the nodes.

L. torulosa Kütz.; em. Sirodot (fig. 3 C, D), and *L. parvula* Sirodot, are found in the rapid streams and torrents of certain parts of the British Isles.

Genus **Sacheria** Sirodot, 1872. The vegetative thallus is very fugacious. It is little branched, often piliferous, and exists for about a month (generally December or January). The fructiferous filaments are cylindrical or setaceous and usually branched. The central axis of tubular cells is quite devoid of axial filaments and the antheridial areas are on mamilliform projections, arranged in a verticillate manner at regular intervals.

Species of this genus are much more frequent than species of *Lemanea*. Three species of the genus are widely distributed in the British Isles,—*S. fluviatilis* (Ag.) Sirod. (syn. *Lemanea fluviatilis* Ag.), *S. fucina* (Bory) Sirod., and *S. mamillosa* Sirod. (fig. 3 A, B), the last-mentioned one being the most abundant. It appears that *S. mamillosa* may sometimes occur in still water, as I have recently examined specimens of this species collected by Mr J. Murray from the west side of Loch Ness, Inverness. It must be remembered, however, that Loch Ness is a large body of water forming part of the Caledonian Canal, and probably numerous currents exist in it.

Order II. CRYPTONEMIACEÆ.

The fertilized carpogonium sends out a long, branched ooblastema-filament, the terminal cells of each branch conjugating with an auxiliary cell. From the latter the gonimoblasts arise.

Family 1. **SQUAMARIACEÆ.**

This family consists of a small group of marine, or rarely freshwater Algæ, which are minute, flat, gelatinous or membranous expansions, commonly encrusting stones, shells, or larger Algæ. The thallus usually consists of dense, vertically arranged cell-filaments. Tetrasporangia are formed in various ways, and often give the surface of the thallus quite a verruculate appearance. The sexual organs are developed in cavities or 'conceptacles' in the upper surface of the thallus. After the fertilization of the carpogonia these 'conceptacles' contain numerous cystocarps.

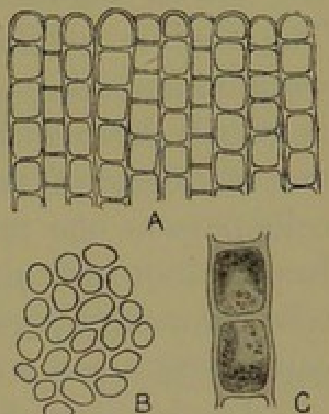

Fig. 4. *Hildenbrandtia rivularis* (Liebm.) J. Ag., from Shipley Glen, W. Yorks. A, section of thallus. B, surface view (×400). C, two cells showing the chromatophores (×800).

Genus **Hildenbrandtia** Nardo, 1845. This genus consists of a crustaceous expanded thallus, of a blood-red, dark red, rose, or brown colour, firmly adhering to rocks and stones on the sea-shore or in rivers and streams. The thallus is composed of compact, vertically arranged cell-filaments, with subcubical or oblong cells. The cell-walls are colourless and strong.

There is only one British freshwater species—*H. rivularis* (Liebm.) J. Ag. (fig. 4)—which occurs as dark red patches on rocks and stones in streams and dripping places.

Class 2. PHÆOPHYCEÆ (or Fucoideæ).

Almost all the Algæ of this class are marine and are known as the Brown Seaweeds. They are often termed the Melanophyceæ. The thallus exhibits great diversity of form; in some it is a simple filament, in others a flat expansion of cells, and in others it is greatly differentiated. The most highly organized of all seaweeds are members of this class of the brown Algæ. The vegetative cells possess one nucleus, and the chromatophores have a distinct brown tinge owing to the presence of *phycophæin* and *phycoxanthin* (the compound pigment being known as phæophyll). The former can be extracted with water and the latter by means of alcohol.

Asexual reproduction is by motile cells or zoogonidia.

Sexual reproduction is either by isogamous or heterogamous gametes, the conjugation of the gametes or the fertilization of the oospheres taking place in all cases outside the plant. The zygospore or the oospore always germinates directly. The motile reproductive cells, whether zoogonidia or gametes, invariably possess two cilia, inserted laterally, and in their movements one cilium is carried in a forward direction and one in a backward direction.

The class is divided into a number of orders of which only one——the *Syngeneticæ*—is freshwater.

Order I. SYNGENETICÆ.

The plants included in this order, which is sometimes termed the 'Phæozoosporinæ,' are exclusively freshwater. They are Algæ of little note or importance, and may be either solitary or colonial unicells, multicellular, free-swimming or motionless. The cells are often naked, but at other times are surrounded by a mucilaginous cell-wall. In some of the multicellular forms the cells are only loosely held in position by a copious mucilaginous envelope. There is one cell-nucleus and one or more pulsating vacuoles. The chromatophores, which are of a yellow or pale brown colour, may be solitary and excentric, or sometimes two in a cell, and pyrenoids are occasionally present. Vegetative multiplication occurs by simple cell-fission and asexual reproduction takes place by means of zoogonidia.

The following seven families are the most important:—

Fam. *Hydruraceæ.* *Hydrurus* Ag.
Fam. *Cryptomonadinaceæ.* *Cryptomonas* Ehrenb.
Fam. *Chrysomonadinaceæ.* *Syncrypta* Ehrenb. *Synura* Ehrenb. *Uroglena* Ehrenb.
Fam. *Dinobryaceæ.* *Dinobryon* Ehrenb.
Fam. *Phæocapsaceæ.* *Phæocystis* Lagerh. *Phæococcus* Borzi. *Phæosphæra* West & G. S. West. *Stichoglœa* Chodat. *Phæschizochlamys* Lemm. *Phæodactylon* Bohlin.
Fam. *Choristocarpaceæ.* *Pleurocladia* A. Br.
Fam. *Phæothamniaceæ.* *Phæothamnion* Lagerh.

Only four of the above families are known to be represented in Britain, but probably all the others will be found in more or less abundance if searched for. Many of the plants of this order are plankton-forms, and the families Cryptomonadinaceæ, Chrysomonadinaceæ and Dinobryaceæ are truly flagellate in character.

Family 1. **HYDRURACEÆ.**

The plants are attached, branched, and consist of a colony of unicells. The cells are at first spherical but afterwards become almost spindle-shaped, and are embedded in large masses of mucilage. They have one chromatophore and are destitute of a cell-wall. Asexual reproduction takes place by zoogonidia which are tetrahedric in form and possess one cilium[1]. They are only produced in the branches, two or four from each cell, and they germinate directly. After having come to rest, the zoogonidia attach themselves by the clear apex (at which point the cilium was inserted) and secrete a stalk-like mass of mucilage. This cell is the beginning of a new colony which is developed subsequently by its repeated divisions. Certain of the peripheral cells take on apical growth and produce branches. Resting spores (akinetes) have also been observed by Lagerheim.

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[1] Cfr Lagerheim in Ber. Deutsch. Bot. Gesell. 1888, p. 80, fig. xylogr. 1—3.

Genus **Hydrurus** Ag., 1824. The plants are branched colonies of unicellular units embedded in a tough, cylindrical mucilage. They vary from about 5 to 30 cms. in length and are of an olive green colour. The whole colony is simple below but branched above, often cut up into fine penicillate divisions, and covered with small villous projections giving it a plumose appearance. The entire structure behaves almost as a multicellular plant, growth in length being entirely dependent on single apical cells, and the branching is usually monopodial. The cells are commonly ellipsoidal and are more densely crowded in the small branches than in the main stems and branches. Afterwards the cells elongate and become arranged more or less in longitudinal groups.

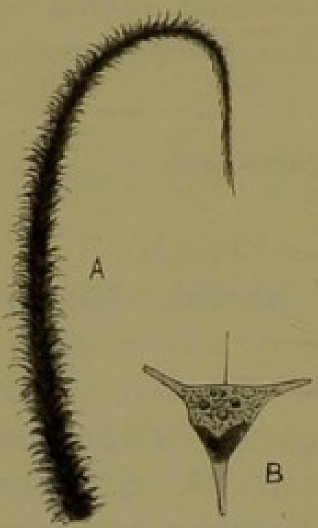

Fig. 5. *Hydrurus fœtidus* (Vill.) Kirchn. A, nat. size. B, zoogonidium (after Lagerheim).

H. fœtidus (Vill.) Kirchn. is found attached to stones and rocks in mountain streams. It is a sticky plant and gives off an offensive odour when alive. It is common in Central Europe and in the Arctic regions when the snows melt in the spring, but in the British Islands it is of very rare occurrence, being known only from Yorkshire and Scotland.

Family 2. CHRYSOMONADINACEÆ.

These are unicellular or colonial organisms which in the free condition are motile. Each individual consists of an oval or elongated cell, with either one or two cilia and either one or two brownish-green chromatophores. A red pigment spot is generally visible. The cells increase by longitudinal division.

Genus **Synura** Ehrenb., 1838. This is a small, globose, free-swimming colony, formed of a variable number (from 10 to 50) of ovoid or ellipsoid, biciliated individuals. They are arranged close together in a radial manner, and each individual possesses two chromatophores and at the hinder end two pulsating vacuoles.

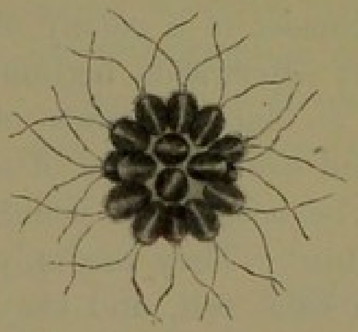

Fig. 6. *Synura Uvella* Ehrenb. Single colony (×400), from Eldwick, W. Yorks.

Synura Uvella Ehrenb. (fig. 6) is commonly found in small ditches and pools, particularly if they are of rain-water. Pure collections of it can be frequently obtained in the early summer.

Genus **Syncrypta** Ehrenb., 1838. This is a motile colony similar in appearance to *Synura* but invested with a mucilaginous coat through which the cilia protrude.

Syncrypta Volvox Ehrenb. is an abundant organism which bears great resemblance to *Synura Uvella*.

Genus **Uroglena** Ehrenb., 1838. In this colonial form the cells are of the same nature as those of *Synura*, but the central portion of the colony is a hollow space filled with mucilage, and the ciliated cells are arranged round the periphery.

Uroglena Volvox Ehrenb. is found in similar situations to those mentioned for the two previous genera. It is, however, much less abundant.

Family 3. DINOBRYACEÆ.

The individuals are attached to the bottom of a cup-shaped receptacle, which is widely open above. They are contractile and possess two cilia of unequal length.

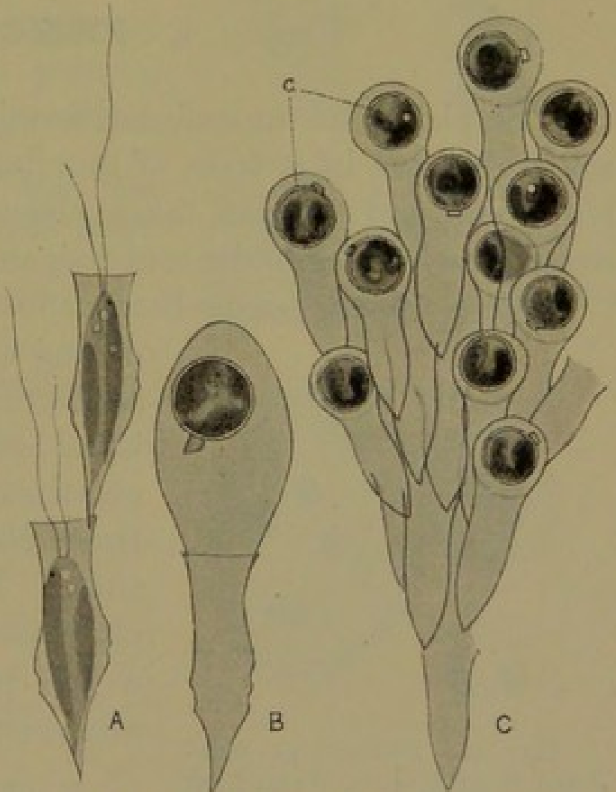

Fig. 7. A, *Dinobryon cylindricum* Imhof var. *divergens* Lemm.; two living examples from Eldwick, W. Yorks. (× 730). B, encysted condition of same. C, *Dinobryon Sertularia* Ehrenb., colony with individuals encysted, from Cornwall (× 410); *c*, cysts.

Genus **Dinobryon** Ehr., 1833. The cells are very delicate, of a somewhat changeable form, and are sensitive to stimuli. The lower end is attenuated into a stalk which is attached near the base of the open receptacle. There is one long cilium and one shorter secondary cilium. The chromatophores are two in number and of a yellow-brown colour. There is a pigment spot, two contractile vacuoles, and one cell-nucleus. The receptacle is campanulate or cylindrical, attenuated at its lower end into a straight or oblique point; it is hyaline or sometimes coloured yellow or brown with oxide of iron, and the margins may be smooth or undulate. The multiplication is by longitudinal division or by the formation of globose resting-cells (or cysts) which are furnished with a peculiar projecting process (fig. 7 B and C). The cells occur singly or joined into dense, spreading colonies. The daughter-cells effect a lodgement above the inner rim of the mother-receptacle and then secrete a similar receptacle for themselves. Senn[1] has written a good account of this genus, and Lemmermann[2] has published a monograph of it, discriminating between fourteen species.

Three species, *D. Sertularia* Ehrenb. (fig. 7 C), *D. sociale* Ehrenb. and *D. cylindricum* Imhof, and varieties of them, are abundant throughout the British Isles, the first-named one being the most widely distributed. Species of this genus are very abundant in the freshwater plankton, the colonies of each species exhibiting a characteristic type of branching. *D. protuberans* Lemm. and *D. elongatum* Imhof are generally distributed but not abundant.

Family 4. **PHÆOCAPSACEÆ.**

The plants are unicellular, forming colonies, the cells of which are embedded in a mass of mucilage. The cells are spherical or ellipsoidal and division takes place in all directions. The reproduction is by zoogonidia and zoogametes.

Genus **Phæococcus** Borzi, 1892[3]. The cells are ellipsoidal or oblong-ellipsoidal, 6—11 μ in diameter, and occur in twos, fours, eights or multiples of these numbers, in hyaline gelatinous integuments which sometimes show a delicate concentric structure. There are two yellow-brown chromatophores in each cell and usually a red pigment-spot. The zoogonidia are ovoid or subpyriform.

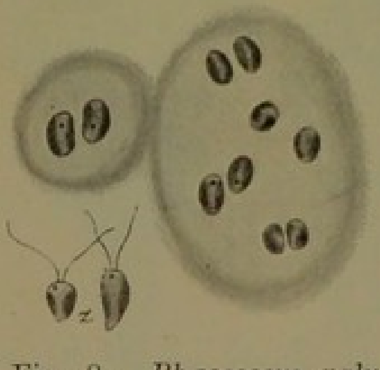

Fig. 8. *Phæococcus paludosus* West & G. S. West, from Eldwick, W. Yorks. (× 410). *z*, zoogonidia.

P. Clementi (Menegh.) Borzi has not been observed from Britain, but *P. paludosus* West & G. S. West occurs in moorland ditches.

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[1] Senn, 'Flagellata' in Engler and Prantl Natürl. Pflanzenfam. I Theil. Ia Abth.

[2] Lemmermann, in Berichte Deutsch. Botan. Gesellsch. 1900, Bd xviii, pp. 500—524, t. xvii u. xix.

[3] Borzi in Atti del Congr. Botan. Internaz. Genova, 1892, pp. 463—471, t. xviii.

Genus **Phæosphæra** West & G. S. West, 1902. The cells are large, exactly spherical, 14—17·5 μ in diameter, and are embedded in small aggregates in a cylindrical, gelatinous integument which is sparsely branched. One brown, parietal chromatophore with somewhat irregular margins is present in each cell.

P. gelatinosa West & G. S. West (fig. 9) is known from *Sphagnum*-bogs in Cornwall.

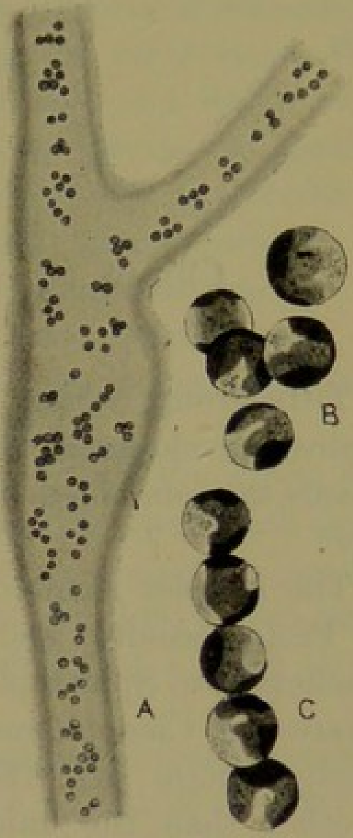

Fig. 9. *Phæosphæra gelatinosa* West & G. S. West. A, portion of colony (× 50). B and C, cells showing the solitary chromatophores (× 410). From Tremethick Moor, Cornwall.

Genus **Stichoglœa** Chodat, 1897[1]. The cells are small, oblong or subovoid in shape, and are associated to form a membranous, gelatinous thallus of small size. The thallus is generally variously lobed and the cells are often somewhat radiately disposed. The cell-walls are firm and each cell contains a parietal chromatophore destitute of a pyrenoid.

S. olivacea Chodat is known from the plankton of certain of the Scottish lakes. Length of cells 9—15 μ.

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[1] Chodat in Bull. L'Herb. Boiss. tom. v, no. 4, 1897, p. 302, t. 10, f. 8—12.

Class 3. CHLOROPHYCEÆ.

THIS group, which includes all the green Algæ, attains its greatest development in fresh water, and the number of species exceeds the combined total of the freshwater species of all other Algæ.

The simpler forms of green Algæ are unicellular (e.g. some of the Protococcoideæ and Desmidiaceæ), some are cœnocytic (e.g. Vaucheriaceæ, Sphæropleaceæ, Pediastreæ), some are incompletely septate (e.g. Cladophoraceæ), and others are multicellular or completely septate (e.g. Œdogoniales, Chætophorales, Zygnemaceæ). In other than the unicellular forms the thallus exhibits every degree of development from simple rounded cells to long, simple or branched filaments, flat expansions, or pulvinate masses of tissue. As a rule there is no differentiation of the ordinary vegetative cells, but in some there is a marked distinction between the vegetative and reproductive cells.

The *cell-protoplasm* (or *cytoplasm*) of the green Algæ consists of a lining layer or 'primordial utricle' which adheres closely to the cell-wall[1], and, in many Algæ, of additional anastomosing strands and threads traversing the interior of the cell. It contains numerous granules of variable size which behave differently with staining reagents. Evidence goes to prove that there is no definite protoplasmic continuity between the cells of multicellular green Algæ. A division of labour is rarely observed amongst this class of plants, and in the Conjugatæ the cells of most of the filamentous forms are under normal circumstances quite able to lead an independent existence. The *vacuoles* are much as in other plant-cells and they contain a fluid usually known as the cell-sap. In the Conjugatæ the cell-sap is occasionally coloured violet or purple owing to the

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[1] Cf. Chodat et Boubier, 'Sur la Plasmolyse et la membrane plasmique,' Journ. Bot. de Morot, Paris, 1898.

presence of a pigment termed by Lagerheim *phycoporphyrin*[1]. This violet colour occurs normally in *Ancylonema Nordenskioldii* Berggr., *Mesotænium violascens* De Bary, *M. purpureum* W. & G. S. West and *Mougeotia capucina* (Bory) Ag., and under exceptional circumstances it is found in various species of *Zygnema*, *Spirogyra* and Desmids. The Volvocaceæ and the zoogonidia and gametes of other green Algæ possess vibratile cilia, which are very variable in their length, number, disposition, and symmetry; and in certain of the same forms contractile vacuoles are present. In the genera *Tetraspora* and *Apiocystis* 'pseudocilia' are found, which do not possess any power of movement.

A single *nucleus* is present in the cells of all the green Algæ except the cœnocytic and incompletely septate forms, and during the formation of asexual non-motile spores, zoogonidia, or gametes, it undergoes divisions corresponding to the divisions of the protoplasm. In some green Algæ mitotic division of a more or less complex character has been observed[2].

The *cell-wall* is very variable and its structure is often difficult of observation. In the formation of a cell-wall such as after the quiescence of a zoogonidium, it is developed on the outer surface of the protoplasm as the result of more or less complex processes. The young cell-wall usually consists of *cellulose*, but sometimes equally of *pectose*. Under the action of strong acids or other hydrating reagents an ordinary thick cell-wall will swell up and show traces of lamination. Each lamina represents successive layers of growth in thickness and in most plants consists of a mixture of cellulose and pectose constituents in variable proportions. In the Chlorophyceæ these two constituents of the cell-wall are differentiated while the wall is very young. They exhibit considerable differences in their behaviour with reagents, the cellulose constituents giving a violet colour with chlor-zinc-iodine (Schulze's solution), whereas the pectose constituents do not. In many Algæ the pectose constituents of the cell-wall are in the form of gelatinous layers on the outside of inner layers of cellulose. This mucilaginous material stains readily with aniline dyes such

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[1] Lagerheim in Vidensk.-Selsk. Skrift., I mathem.-natur. Kl., Kristiania, 1895, no. 5.

[2] Observed in *Spirogyra* by Mitzkewitsch (Flora, lxxxv, 1898) and C. van Wisselingh (Bot. Zeitung, lvi, 1898; Flora, lxxxvii, 1900); in *Chlamydomonas* by Dangeard (Le Botaniste, vi, 1899); in *Closterium* by Klebahn; also in *Botrydium*, etc., etc.

as fuchsin, safranin, methylene-blue and gentian-violet. The outer layers often become thick coats of mucilage by the formation of series of pectose constituents which exhibit all stages between insolubility and complete solubility in water. It is not merely a hydration but a molecular change, and successive increments are often added by the gelatinization of other layers of the cell-wall. In some of the unicells the increase in thickness of the cell-wall due to gelatinization is only on one side and elongated colonies such as those of *Hormotila* are formed.

The gelatinous pectose compounds although sometimes forming a large proportion of the cell-wall, do not alternate with layers of cellulose, but there appears to be a continual exudation of them through the inner layers of cellulose, a mass of jelly being thus formed on the outside of the cellulose wall. This is best seen in some of the Protococcoideæ and Conjugatæ. The mucilage in which filaments of Algæ are so frequently embedded exhibits a distinct radiating fibrillar structure which is clearly brought out by various reagents. The radiating structure of the enveloping mucus has long been known in the Conjugatæ and has at times given rise, especially in the Desmidiaceæ, to grave morphological misconceptions.

The cell-walls of *Œdogonium* and other Algæ exhibit peculiarities of structure which will be described in their respective families.

Whatever the nature of the cell-wall one of its primary functions is the regulation of osmotic changes.

Hairs and bristles are developed by certain green Algæ belonging to the Coleochætaceæ, Herposteiraceæ, Œdogoniaceæ, Chætophoraceæ and Chætopeltidæ. They are of many kinds, from slender articulate branches such as the piliferous apices of *Chætophora*, to exceedingly fine inarticulate hairs such as the setæ of *Bulbochæte*, *Herposteiron*, *Chætosphæridium*, or *Conochæte*.

The thallus often develops special root-like organs of attachment or *haptera* (commonly termed *rhizoids*), but these are as a rule only found in the young plants, most of the older ones occurring as freely floating masses.

The *chromatophores* are usually distinct and in the forms with a filamentous or expanded thallus they are frequently characteristic of the different families or genera. They are of a bright green colour due to the presence of chlorophyll and are therefore *chloroplasts*. Sometimes they are very difficult to define, but at other times they stand out clearly, occupying only a relatively small portion of the cytoplasm. They may be solitary or very numerous, of infinite variety of form, central or parietal, and the edges may be entire or deeply incised. In some forms they are ribbon-like and wound spirally round the interior of the cell-wall (e.g. *Spirogyra*, *Genicularia*, and some species of *Spirotænia*), and in others they are central, spirally twisted masses (e.g. some species of *Spirotænia*). Sometimes they are reduced and very pale in colour, and in the rhizoids and terminal cells of the hairs of some green Algæ they are entirely wanting.

The chloroplasts of most green Algæ contain *pyrenoids* or proteid bodies which serve as a reserve of food-material. Much has been done towards the investigation of these bodies during the past few years and the presence or absence of pyrenoids has been regarded by some as a sufficient generic distinction. This is, however, attaching an importance to these proteid bodies which is scarcely borne out by facts. Although they frequently divide equally on the division of the cell, they also multiply without any cell-increase. They are likewise known to disappear during the development of certain species, and it has been clearly demonstrated that during certain stages of *Tetraspora*, *Sphærella* and *Eudorina* they can arise spontaneously. Moreover, forms of *Ankistrodesmus falcatus* (Corda) Ralfs containing pyrenoids are sometimes met with in the same collection as others which have no pyrenoids. Similarly, the chromatophores of *Debarya calospora* (Palla) W. & G. S. West may or may not contain pyrenoids[1]. Starvation causes a disappearance of pyrenoids and they frequently increase in numbers if the cell is well nourished. On the whole, there is little doubt that the presence or absence of pyrenoids depends largely upon external conditions and is a character to which a great deal too much importance has been attached in discriminating between the genera of green Algæ.

In the Chlorophyceæ the stored product of assimilation is almost invariably starch. Exceptions to this are found commonly in *Mesotænium* in the Desmidiaceæ and in the Vaucheriaceæ.

Cell-division generally takes place in all the cells of the thallus, but in a few instances there is a definite growing point which is usually an apical cell.

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[1] West & G. S. West in Ann. Bot. xx, March, 1898, p. 49; in Journ. Bot. Aug. 1900, p. 289.

Multiplication by cell-division occurs in many of the lower forms of the Protococcoideæ and in the Desmidiaceæ. In the Zygnemaceæ, and particularly in the smaller species of *Spirogyra*, the filaments often dissociate into solitary cells each of which then divides and forms a new filament.

Asexual reproduction by zoogonidia is general throughout the class, although there is a notable exception in the Conjugatæ, in which motile reproductive cells are entirely wanting. In many of the Chætophorales, Microsporales and Protococcoideæ reproduction takes place by non-motile spores which may be either akinetes or aplanospores. Asexual spores are also more rarely found in the Conjugatæ, having been observed in *Zygnema*, *Spirogyra*, and in a few Desmids, and they are formed normally in the rare genus *Gonatonema*.

Sexual reproduction occurs in most of the families of green Algæ, and may be either isogamous or heterogamous. In isogamous reproduction the sexual organs are gametangia, usually giving rise to planogametes which conjugate and produce a zygospore. In the Conjugatæ only aplanogametes are found. Many planogametes are generally produced from one gametangium, but only one aplanogamete. In heterogamous reproduction the sexual organs are oogonia and antheridia, and the gametes consist of oospheres and antherozoids. In all cases with the exception of *Herposteiron*, the oosphere remains *in situ* in the parent plant, being fertilized within the oogonium, and the result of fertilization is an oospore. The oogonia are always unicellular, and, except in *Cylindrocapsa* and some species of *Œdogonium*, so are the antheridia. Only one oosphere is produced in an oogonium, except in *Sphæroplea*, and one, two, or many antherozoids may arise from an antheridium.

The gametophyte is the principal generation, the sporophyte being generally represented by the sexually-produced spore. In *Coleochæte*, in *Œdogonium*, and in *Mougeotia* very rudimentary sporophyte generations consisting of several cells do exist.

Of all freshwater Algæ the Chlorophyceæ have the most varied habitats. They are found in every possible damp or wet situation and some are epiphytes, others endophytes, and a few are even parasites[1].

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[1] *Phyllosiphon Arisari* Kühn (in Sitzungsber. d. naturf. Ges. in Halle, 1878) is a parasitic Alga observed only on the leaves of *Arisarum vulgare* in Italy and the

Richter[1] and Comère[2] have conducted experiments with a view to ascertaining if certain of the freshwater Algæ, especially Chlorophyceæ, can exist in salt water. Richter states that the lower the organization of the Alga the better its power of adaptation, but Comère finds that only those Algæ with a robust structure and with large chloroplasts can successfully withstand immersion in salt water. Some species of *Œdogonium* and *Cladophora* can live in water containing 3·5 $^\circ/_\circ$ of sodium chloride, *Vaucheria sessilis* in water containing 2 $^\circ/_\circ$, and some of the large species of *Spirogyra* in water containing from 1·8—2 $^\circ/_\circ$. Richter affirms that *Œdogonium*, *Spirogyra*, or *Vaucheria* have less power of adaptation to life in salt water than *Stichococcus* or *Tetraspora*. In all cases the salinity of the water caused the cells to increase in size and when the concentration was high malformation of the cells invariably occurred. Starch at first disappeared from the cells, but reappeared when the adaptation was more complete. Notwithstanding the somewhat contradictory nature of these two sets of experiments, it appears that certain of the freshwater Chlorophyceæ can adapt themselves to an increasing salinity of the water in a manner comparable with the adaptation of a few forms of the green Algæ to a life in hot water[3].

The class Chlorophyceæ can be conveniently subdivided into nine orders, all of which are found abundantly in the British Islands.

Order I. *Œdogoniales.* Thallus filamentous, simple or branched. Cells uninucleate, with a large, parietal, anastomosing chloroplast containing one or several pyrenoids. Cell-division characterized by the intercalation of a new piece of cell-wall between the mother-cell and the distal end of the daughter-cell. Sexual reproduction by heterogamous gametes. Zoogonidia with an anterior circle of cilia. Exclusively freshwater.

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south of France; *P. maximus* Lagerh., *P. Philodendri* Lagerh. and *P. Alocasiæ* Lagerh. are parasites on the leaves of species of *Arisarum*, *Philodendrum* and *Alocasia* in Ecuador (*vide* Lagerheim in Nuova Notarisia, 1892, pp. 120—124). *Trichophilus* Weber is a genus of Algæ parasitic on the hairs of *Bradypus* (the Three-toed Sloth); another species has also been found on species of *Nenia* (*Clausilia*); cf. Lagerheim in Bericht. der Deutsch. Bot. Gesellsch. 1892, Bd x, Heft 8, pp. 514—517.

[1] Richter in Flora, lxxv, 1892.

[2] J. Comère in Nuova Notarisia, xiv, 1903, pp. 18—21.

[3] G. S. West in Journ. Bot. July, 1902, pp. 242—243.

Order II. *Chætophorales.* Thallus filamentous, sometimes simple, but more often branched. Cells uninucleate; chloroplasts parietal, generally single and with pyrenoids. Sexual reproduction either isogamous or heterogamous. Mostly freshwater.

Order III. *Ulvales.* Thallus expanded, membranous, parenchymatous, attached when young. Cells uninucleate; chloroplasts single, parietal, with one pyrenoid. Sexual reproduction isogamous. Mostly marine.

Order IV. *Schizogoniales.* Thallus filamentous, sometimes parenchymatous, or expanded by fusion of filaments in one plane. Chloroplast single, central and substellate, with one pyrenoid. Mostly subaërial.

Order V. *Microsporales.* Thallus filamentous, unbranched. Cells uninucleate, with a large, parietal, reticulated or band-like chloroplast, destitute of pyrenoids. Exclusively freshwater.

Order VI. *Cladophorales.* Thallus filamentous, simple or branched, incompletely septate. Segments large with numerous parietal chloroplasts each with a pyrenoid. Sexual reproduction isogamous or heterogamous. Marine or freshwater.

Order VII. *Siphoneæ.* Thallus filamentous and cœnocytic, unseptate, consisting of one large branched cell with many nuclei. Chloroplasts numerous, without pyrenoids. Sexual reproduction heterogamous. Mostly marine.

Order VIII. *Conjugatæ.* Thallus unicellular or filamentous. Cells uninucleate; chloroplasts single or several, usually large and of some definite shape, with pyrenoids. Sexual reproduction by isogamous aplanogametes. Exclusively freshwater.

Order IX. *Protococcoideæ.* Small unicellular, multicellular or colonial Algæ. Cells uninucleate or cœnocytic; chloroplasts very variable in form, size and disposition, with or without pyrenoids. Sexual reproduction of an isogamous or heterogamous character is known in some. Almost exclusively freshwater.

Order I. ŒDOGONIALES.

In this order the thallus consists of fixed, simple or branched filaments. The cells possess a single nucleus and the chloroplast is a parietal, more or less cylindrical, anastomosing mass of chlorophyll, containing one or more pyrenoids. The vegetative division, in which a curious interpolation of new pieces of cell-wall takes place, is peculiar to the order. The zoogonidia are also anomalous, being characterized by a circlet of numerous cilia round the anterior end. In the autumn, plants of this order frequently have their cells packed with starch. The sexual organs are well-differentiated oogonia and antheridia, and the sexual reproduction is greatly specialized. There is only one family which includes three genera, two of which are abundantly found in the British Islands.

Family 1. **ŒDOGONIACEÆ.**

This family is represented in the British Isles by numerous species of the two widely distributed genera *Œdogonium* and *Bulbochæte*. The young stages of these plants possess well-developed organs of attachment, but most of the species of *Œdogonium* float freely in the water when adult. The thallus is simple or branched and some of the cells exhibit a peculiar transverse striation at their upper extremities. This is particularly noticeable in the large species of *Œdogonium* and is the result of intercalary surface growth. Beneath one of the transverse cell-walls an annular cushion of cellulose is deposited, and after each division a circular split is formed in the cell-wall opposite this cushion, the two parts remaining very slightly separated by a new piece of cell-wall derived from the cushion of cellulose. The rings or cushions of cellulose were investigated by Hirn[1], who found that they consisted of a central mucilaginous mass, surrounded by a coating of cellulose formed as an inner cell-wall layer, which becomes intimately concrescent with the old membrane above and below the ring. After each division another slit is formed beneath and close to the first one, the process being repeated until the upper end of the cell frequently presents the appearance of having a number of 'caps' placed one over the other (figs. 13 B and C; 14 A), each 'cap' indicating a division of the mother-cell.

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[1] Hirn in Acta Soc. Scient. Fennicæ, xxvii, 1900.

Most of the cells in *Bulbochæte* are furnished with long tubular bristles and the terminal cell of the filament in one or two species of *Œdogonium* also ends in a long bristle (fig. 14 C).

There is one large chloroplast in each cell disposed in the form of a cylindrical net-work, a large proportion of it forming anastomosing cushions on the inner surface of the cell-wall. The pyrenoids vary from one to several according to the species, and sometimes the number varies in different cells of the same plant. There is usually one nucleus with a prominent nucleolus (fig. 10 J *n*), situated in a more or less central position. The nucleus occasionally divides without a corresponding division of the cell. Growth of the filaments takes place by the transverse division of any of the vegetative cells.

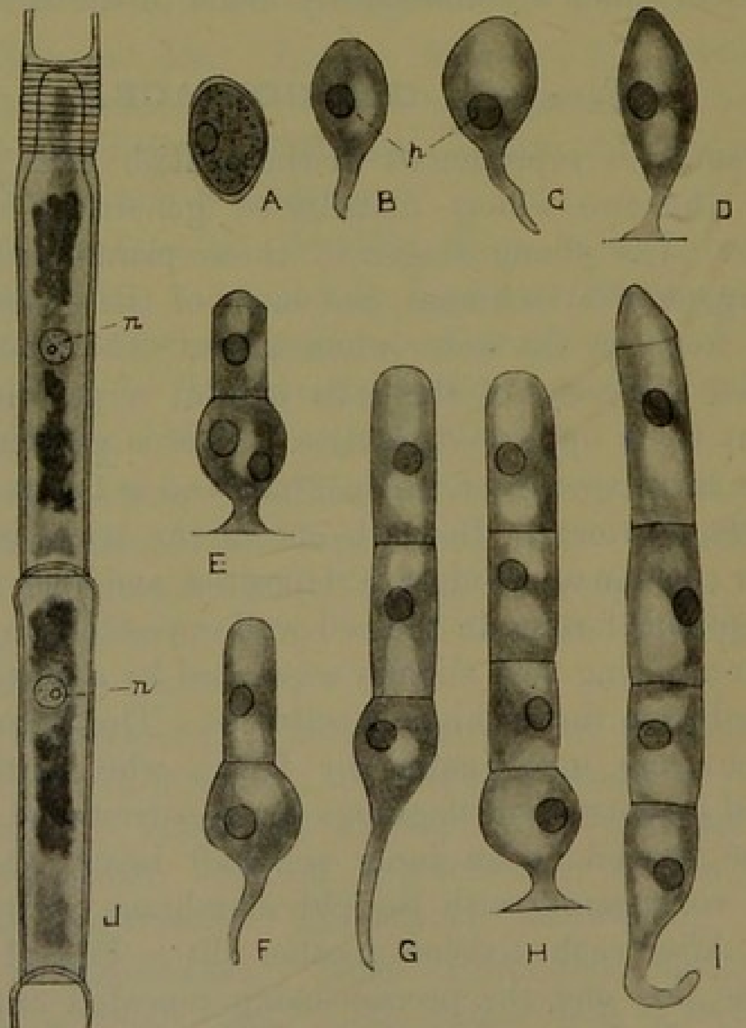

Fig. 10. A—I, *Œdogonium* sp., from Frizinghall, W. Yorkshire, showing stages of one type of development from a zoogonidium in which the basal cell does not become greatly swollen (×460). *p*, pyrenoid. J, *Œdogonium* sp., from Shipley Glen, W. Yorkshire, after treatment with Acetic Acid and Hæmatoxylin, showing nuclei (*n*), ×460.

Asexual reproduction takes place by means of zoogonidia, which are formed singly from ordinary vegetative cells. There is a rejuvenescence of the entire cell-contents, a large rounded mass being formed, which ultimately escapes. In *Œdogonium* this process may take place in any of the vegetative cells of the filament, whether terminal or not, and it sometimes occurs in a young plant consisting only of one cell. The cell-wall splits into two halves by a transverse slit near its upper extremity and the rounded mass of rejuvenized protoplasm makes its exit in a delicate hyaline vesicle. This mass assumes a pyriform shape and at the narrower end a small colourless protuberance is formed, round the base of which arises a circle of numerous cilia (fig. 11 *z*). This striking zoogonidium, which may or may not possess a red pigment spot, quickly swims away, the entire process lasting only a few minutes. On coming to rest it attaches itself by its anterior hyaline end, loses its cilia, and develops a cell-wall. This cell ultimately forms a new filament by transverse cell-division (fig. 10 E—I). The basal cell may be rounded and swollen or it may develop a hapteron or organ of attachment (fig. 10 A—D).

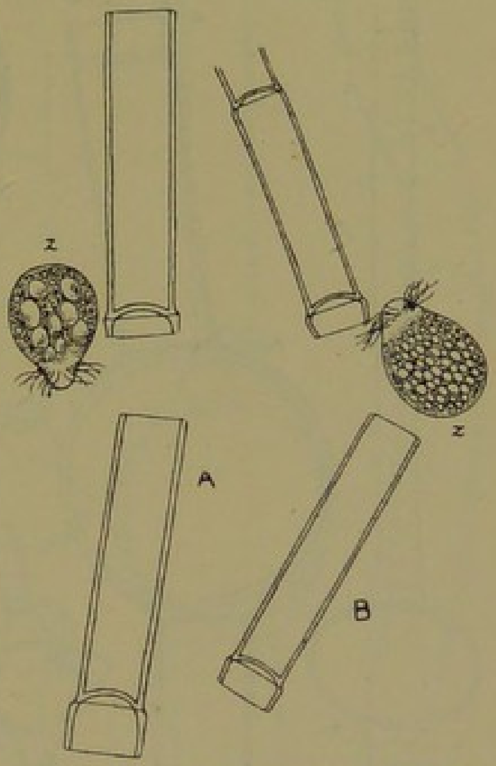

Fig. 11. The escape of the zoogonidium (*z*) from its zoogonidangium. A, *Œdogonium Boscii* (Le Cl.) Wittr., from near Senens, Cornwall. B, *Œ. Hirnii* Gutw., from Churchill, Donegal, Ireland (× 460).

Wille has observed resting-spores in some species of *Œdogonium*[1].

The sexual reproduction in this family of Algæ presents a greater specialization of the male and female organs than is found in any other family of the green Algæ. The oogonia may be developed from any of the ordinary vegetative cells, and most frequently arise from cells which exhibit intercalary surface growth at their upper extremities. They are usually spherical or ovoidal in form and occur singly or in series of from 2 to 10. The contents of each oogonium become rounded off, forming a single oosphere

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[1] *Vide* Bot. Centralbl. xvi, 1883.

which contains much chlorophyll. The antheridia may be developed in the same filament as the oogonia, as in the *monœcious* species (fig. 12), or they may arise in separate male filaments, as in the *diœcious* species (figs. 13 and 14). The antheridia are sometimes unicellular, consisting of a short cell rather narrower than the ordinary vegetative cell and containing less chlorophyll. More frequently, however, they consist of more than one cell, and occasionally of a dozen or more, the contents of each antheridial cell dividing into two masses each of which becomes an antherozoid. Rarely only one antherozoid is produced in an antheridial cell. The antherozoids are similar in form to the zoogonidia and are ciliated in the same way, but they are smaller and contain less chlorophyll.

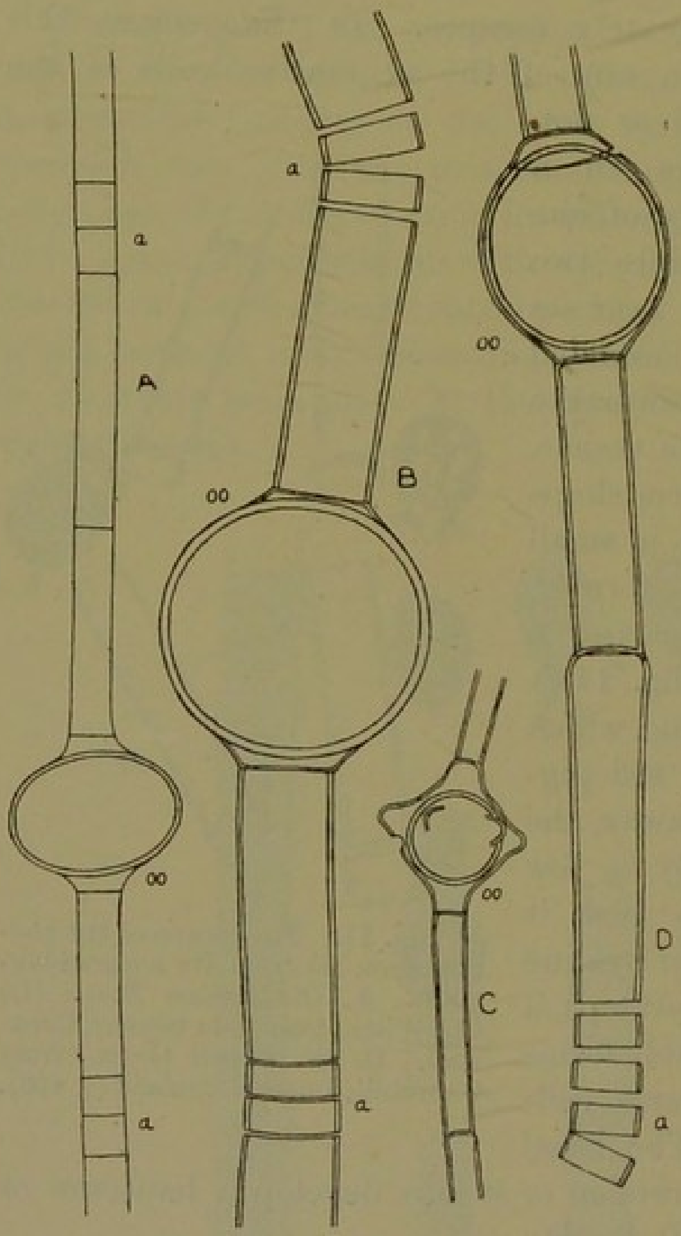

Fig. 12. Monœcious species of *Œdogonium*. A, a form of *Œ. obsoletum* Wittr., from near Goring, Oxfordshire. B, *Œ. zig-zag* Cleve var. *robustum* West & G. S. West, from Harefield, Middlesex. C, *Œ. Itzigsohnii* De Bary var. *minor* West, from the Orkney Is. D, *Œ. Ahlstrandii* Wittr., from Pilmoor, N. Yorkshire (×460). *oo*, oogonium; *a*, antheridium.

Diœcious species in which the male filaments are large and but little inferior in size to the female filaments are said to be *diœcious macrandrous* (fig. 13).

There is, however, another type of diœcious species in which the male plants are very small and are attached to the female plants; these are said to be *diœcious nannandrous* (fig. 14). This type requires a further description. Certain short cells are produced in the female filaments either singly or in chains, each cell being larger than the antheridial cells of the monœcious or diœcious macrandrous species, and known as an *androsporangium*. The androsporangium is usually produced in the neighbourhood of an oogonium and becomes the mother-cell of a motile ciliated spore known as an *androspore*, intermediate in size between an antherozoid and a zoogonidium. Each androspore swims about for a time and then attaches itself to the female plant, either actually on the oogonium or on some adjacent cell. It then surrounds itself with a cell-wall and grows into a very small male plant known as a 'dwarf-male' or a *nannandrium*. The dwarf-male usually consists of a basal vegetative cell which supports one or more antheridial cells, but occasionally it is reduced to one antheridial cell only. Two antherozoids arise in each antheridial cell as in the ordinary monœcious and diœcious species, and they are set free by the splitting off of a cap if there be only one antheridial cell, or by the general dismemberment of the antheridium if there are several antheridial cells.

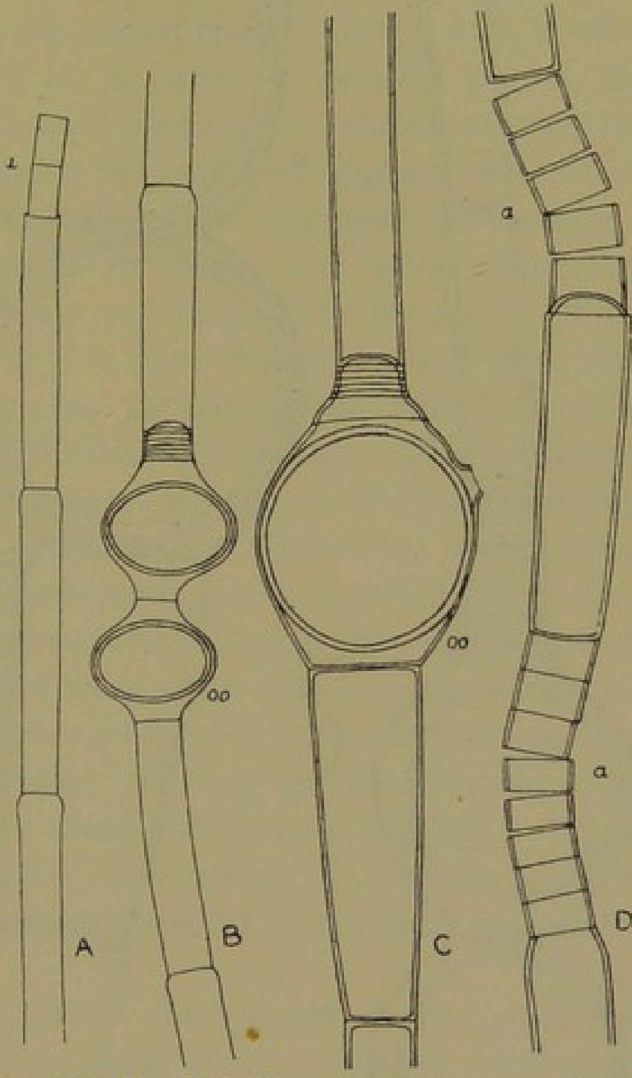

Fig. 13. Diœcious macrandrous species of *Œdogonium*. A, male plant of *Œ. rufescens* Wittr., from Scilly Is. B, female plant of same. C, female plant of *Œ. lautumniarum* Wittr., from Welsh Harp, Middlesex. D, male plant of same (× 460). *oo*, oogonium; *a*, antheridium.

When the oosphere is ready for fertilization a hyaline receptive spot appears in it at a point opposite that part of the wall of the oogonium which will open. The oogonium opens in many ways but the method of opening is constant for any one species. Sometimes a circular crack is formed, which may be median, superior, or inferior; sometimes a pore arises either in a superior or inferior

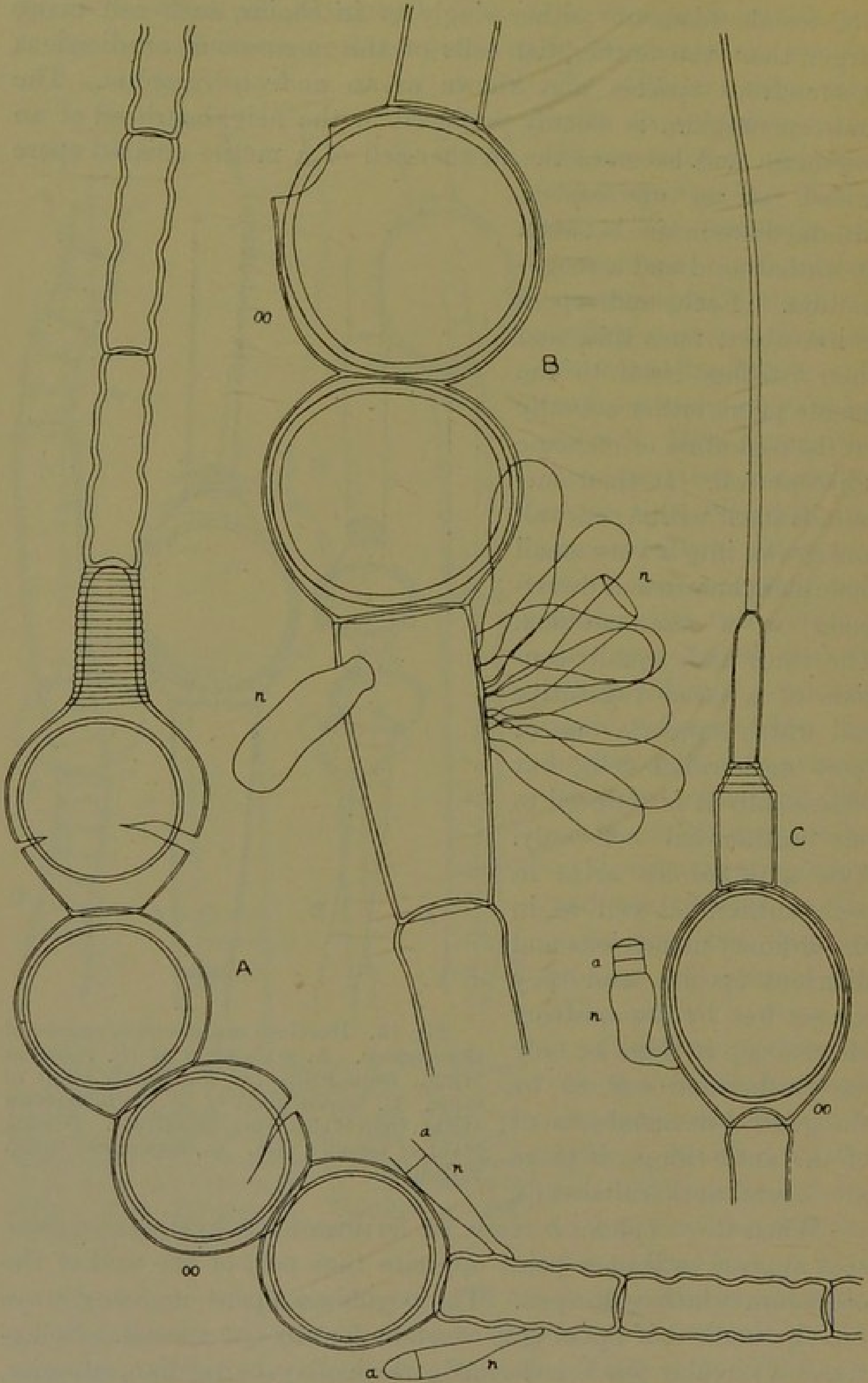

Fig. 14. Diœcious nannandrous species of *Œdogonium*. A, a form of *Œ. undulatum* (Bréb.) A. Br., from Pilmoor, N. Yorkshire. B, *Œ. cyathigerum* Wittr., from Rawcliffe Common, W. Yorkshire. C, *Œ. ciliatum* (Hass.) Pringsh., from near Senens, Cornwall (×460). *oo*, oogonium; *n*, nannandrium or dwarf-male; *a*, antheridium.

position; and at other times there is a distinct apical lid to the oogonium. An antherozoid finds its way through the opening into the oogonium, frequently having to accommodate itself to a passage much narrower than itself, and unites with the oosphere at the region of the receptive spot. After the fusion of the nuclei of the antherozoid and the oosphere the latter becomes the fertilized ovum or oospore, and it immediately surrounds itself with a cell-wall. The oospore then rests for a longer or shorter period, its chlorophyll disappears, its cell-wall increases in thickness, and its protoplasm becomes tinted with a red or brown pigment and filled with oil. On the decay of the walls of the oogonium the oospore is liberated and on germination its outer wall bursts and the contents, surrounded by a delicate membrane, are set free. With few exceptions a new plant is not immediately formed from the oospore, but the free cell-contents usually divide into four cells, each of which forms a rounded ciliated zoospore. The zoospores represent a rudimentary sporophyte generation, and after swarming for a while they come to rest and form new filaments. Sometimes the filaments formed from the zoospores are asexual and they give rise to several other asexual generations before forming a sexual plant. If the zoospores become fixed at once to some substratum, they form a hemispherical or spheroidal cell from a circular opening in which the new filament arises[1]. If they do not become fixed before germination haptera are usually developed (fig. 10 A—I).

The principal investigators of this family of Algæ have been Pringsheim and Wittrock, and quite recently it has been splendidly monographed by Hirn[2].

Genus **Œdogonium** Link, 1820. The plants of this genus are simple filaments with cylindrical cells usually slightly swollen at their upper extremities. The apical cell is generally terminated by an acutely conical cap or more rarely by an elongated bristle. The strong cell-walls and the swollen upper extremities of the cells, some of which possess the peculiar transverse striation, are characters which readily distinguish even sterile species of this genus from all other filamentous green Algæ. The adult plants usually occur floating in masses or they may remain attached to various water plants, and as the mucous covering on the exterior of the filaments is very slightly developed, they not only serve as

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[1] Scherffel in Ber. Deutsch. Bot. Ges. xix, 1901.

[2] Hirn in Acta Soc. Scient. Fennicæ, xxvii, 1900.

hosts for various epiphytes, but they do not feel so slimy as most filamentous green Algæ.

There are about 80 British species of this genus, exhibiting great variation in size and in the relative proportions of the cells. They are exceedingly abundant, particularly in quiet waters, and with one or two exceptions the species can only be accurately identified from fructiferous specimens. They are frequently found in the fructiferous condition in suitable localities, such as small ponds and ditches, and more commonly in the south of England and south-west of Ireland than in other parts of the British Islands. The smallest British species is *Œ. tapeinosporum* Wittr. (diam. of vegetative cells 2·7—5 μ), and the largest is *Œ. giganteum* Kütz. (diam. of vegetative cells 30—50 μ). *Œ. undulatum* (Bréb.) A. Br. (fig. 14 A) possesses very characteristic undulate

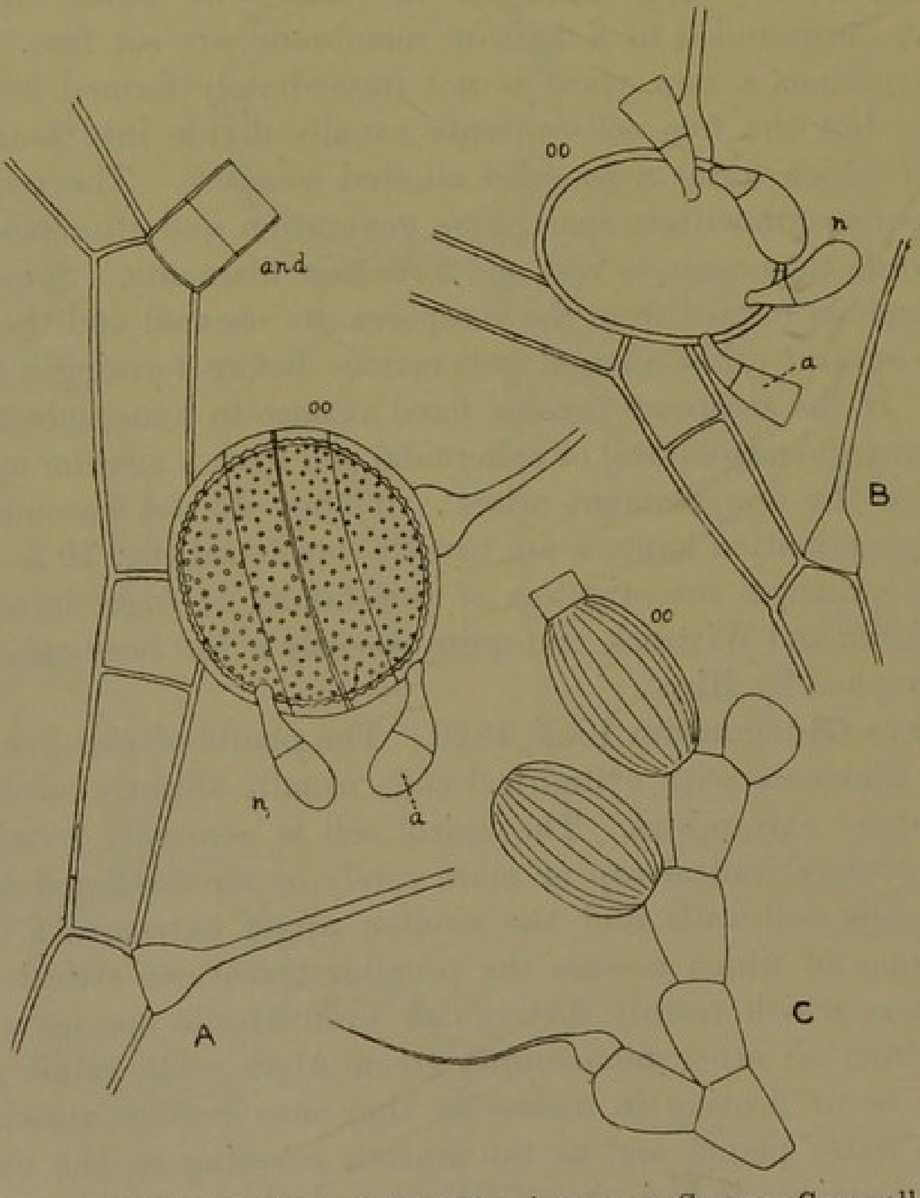

Fig. 15. A, *Bulbochæte subintermedia* Elfv., from near Senens, Cornwall. B, *B. Nordstedtii* Wittr., from near Glendoan, Donegal, Ireland. C, *B. nana* Wittr., from Goring, Oxfordshire (×495). *a*, antheridium; *and*, androsporangium; *n*, nannandrium; *oo*, oogonium.

vegetative cells, *Œ. punctato-striatum* De Bary has the entire filaments furnished with spirally arranged granules, and *Œ. acrosporum* De Bary possesses a remarkable terminal oogonium. The oospores are either globose, ellipsoidal or ovoidal, and the cell-wall may be smooth, ridged, spiny, punctate, scrobiculate or reticulate. Sometimes the oogonia are plicated as in *Œ. platygynum* Wittr., or they may possess a transversely disposed ring of conical projections as in *Œ. Itzigsohnii* De Bary (fig. 12 C). In some species the supporting cell of the oogonium is much swollen, as in *Œ. Borisianum* (Le Cl.) Wittr. and *Œ. lautumniarum* Wittr. (fig. 13 C and D).

Rather less than half the known species are diœcious nannandrous, and most of the remainder are monœcious.

Genus **Bulbochæte** Ag., 1817. The plants of this genus are branched and every branch usually terminates in a long hollow bristle with a swollen base. The vegetative cells widen upwards, most of them carrying a laterally placed bristle, and they do not reach the same relative length as those of *Œdogonium*. The oogonia are generally terminal on short lateral branches; and, with few exceptions, the supporting cell of the oogonium is divided by a transverse septum, the position of which is fairly constant for any one species. In the diœcious nannandrous species the androsporangia are commonly situated on the apices of the oogonia. The plants occur as branched tufts, more often fixed than in the preceding genus, and they possess a quantity of enveloping mucus, affording a home for numerous Diatoms and often Desmids.

There are about 14 British species, of which *B. nana* Wittr. (diam. of vegetative cells 10—15 μ; fig. 15 C) is the smallest and *B. gigantea* Pringsh. (diam. of vegetative cells 24—32 μ) the largest. No doubt many more species will be found if searched for, but in the greater part of the British Islands fructiferous specimens are relatively scarce. There is great variability in the form and size of the vegetative cells in the different species, and also in the comparative size and length of the bristles. The genus is not so abundant as *Œdogonium*, and all the species prefer very still waters.

Most of the species of this genus are diœcious nannandrous. Few species are monœcious, and diœcious macrandrous species are as yet unknown.

Order II. CHÆTOPHORALES.

In this order of green Algæ the thallus is filamentous, sometimes simple, but more frequently branched. The branches are generally attenuated and often piliferous. The cells possess one nucleus, and in all the families of the order, except the Trentepohliaceæ, there is a single parietal chloroplast with one or more pyrenoids.

Asexual reproduction takes place often by resting-spores, which may be either aplanospores or akinetes, and commonly by zoogonidia with two or four cilia. Sexual reproduction is brought about by isogamous planogametes with two cilia, or by well-differentiated heterogamous gametes.

This order has also received the name of the "Ulotrichales," but I prefer to accept Wille's name of the "Chætophorales" as five out of the seven families include branched Algæ.

Family 1. *Coleochætaceæ.* Flat expansions or pulvinate branched masses, epiphytic on the stems and leaves of submerged plants. Sexual reproduction heterogamous; plants monœcious or diœcious; oogonia with a trichogyne and one non-motile oosphere; fertilization within the oogonium and resulting in the formation of a cortical layer on the outer surface of the oogonium. Some of the cells of the thallus are furnished with fine bristles with basal sheaths.

Family 2. *Herposteiraceæ.* Filaments branched, creeping, epiphytic on submerged plants. Sexual reproduction heterogamous; plants monœcious; oospheres motile, fertilization taking place outside the oogonium. Cells with one or several long bristles, sometimes swollen at the base.

Family 3. *Ulotrichaceæ.* Filaments simple. Chloroplast single, parietal, with one or many pyrenoids. Sexual reproduction isogamous.

Family 4. *Cylindrocapsaceæ.* Filaments simple; cells with thick lamellose coats, usually arranged in a single series within a lamellose gelatinous sheath. Sexual reproduction heterogamous; plants monœcious; oogonia with one non-motile oosphere; fertilization within the oogonium.

Family 5. *Chætophoraceæ.* Filaments branched; branches attenuated into multicellular hair-like prolongations. Chloroplast single, parietal, with one or many pyrenoids. All the cells except those of the rhizoids and hairs are capable of producing zoogonidia or gametes. Sexual reproduction isogamous.

Family 6. *Microthamniaceæ.* Filaments branched; branches scarcely attenuated, not piliferous. Chloroplast single, parietal, with or without a single pyrenoid. Zoogonidia and gametes produced in special gonidangia. Sexual reproduction isogamous.

Family 7. *Trentepohliaceæ.* Thallus branched, terrestrial or arboreal. Chloroplasts several, parietal, without pyrenoids. Zoogonidia and gametes produced in special gonidangia. Sexual reproduction isogamous.

Family 1. **COLEOCHÆTACEÆ.**

The plants included in this small family have reached a higher stage of development than any other of the green Algæ, and have undoubtedly arisen from the Chætophoraceæ by further specialization. They form small discs or cushion-like masses, which are enveloped in mucilage and are attached to the stems and leaves of larger water-plants. In the commoner forms the thallus is more or less circular in outline and disc-like in form, consisting of a single layer of cells in one plane, which either form a compact parenchymatous layer, or are arranged in the form of branched filaments radiating from a central point. In other species the ramification is not confined to one plane, but numerous ascending branches are given off, the whole thallus sometimes having the appearance of a hemispherical cushion. The peripheral cells of the disc or the terminal cells of the branches are meristematic and the thallus grows by the formation of new radial and tangential cell-walls. The branching is in some species dichotomous, but in others it closely resembles that of *Chætophora* or *Myxonema.*

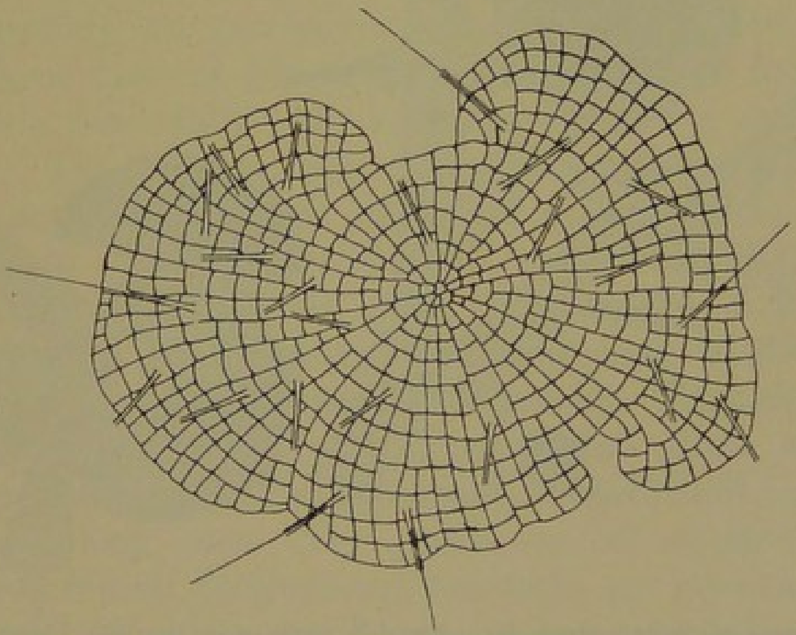

Fig. 16. *Coleochæte scutata* Bréb. (× 100), from Welsh Harp, Middlesex.

Some of the cells are furnished with a colourless bristle which is fixed at its base into a narrow sheath of considerable length.

Asexual reproduction takes place by means of large ovoidal zoogonidia (fig. 17 D), furnished with two long cilia and produced singly from the cells of the thallus, more particularly from the terminal cells of the branches. The zoogonidium escapes from the zoogonidangium either by a round orifice on the upper surface or by the dissolution of the extremity of the terminal cell.

Sexual reproduction is brought about by the fertilization of an oosphere by an antherozoid. The sexual organs are oogonia and antheridia. The oogonium is developed by a swelling of the terminal cell of a branch and it possesses on its upper surface a narrow trichogyne. An oosphere containing chlorophyll is produced within the oogonium, and just previous to fertilization the trichogyne opens at the apex and exudes a colourless drop of mucilage. The antheridia are flask-shaped cells which are developed from cells in the neighbourhood of the oogonium, or in diœcious species from cells of another thallus. Only one antherozoid is

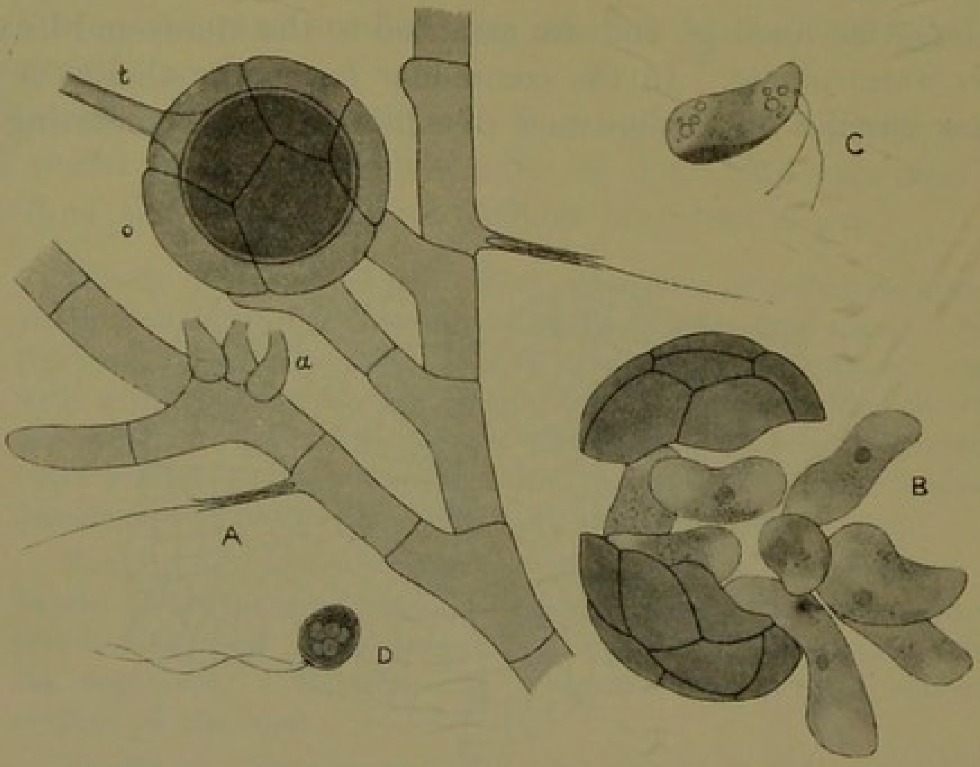

Fig. 17. *Coleochæte pulvinata* A. Br. A and B, from near Glenties, Donegal, Ireland; A, portion of thallus with sexual organs (× 460); *o*, oogonium; *t*, trichogyne; *a*, antheridia. B, ripe 'spermocarp' emitting the cells formed by the division of the oospore; each of these becomes a zoospore (× 460). C, zoospore (after Chodat). D, zoogonidium (after Pringsheim).

produced in an antheridium and it can only be distinguished from a zoogonidium by its smaller size. After fertilization the oospore surrounds itself with a cellulose wall and grows considerably in size. At the same time the oogonium becomes closely covered with a layer of cortical cells, produced by the proliferation of the supporting-cell and by the close application of the terminal cells of other branches. The fertilization and the formation of this cortical layer are said by Pringsheim to take place from May to July. The whole structure produced after fertilization, and which presents the appearance of a sphere supported on one or many filaments, has been termed a "spermocarp." The cortical cells often become dark brown or red in colour and lose their chlorophyllaceous contents. Usually this structure remains dormant through the winter, the maturation of the oospore taking place slowly. On germination the oospore divides into a number of cells and the cortical layer splits irregularly into two halves. The escaping spores (fig. 17 B), which become more or less irregular in outline, do not give rise directly to a new thallus, but each one becomes a zoospore with two cilia. The zoospore (fig. 17 C) gives rise to several rudimentary asexual generations which are propagated by zoospores, and finally to a sexual individual.

Genus **Coleochæte** Bréb., 1844. The thallus is filamentous, branched, erect or creeping, usually forming a flat pseudoparenchymatous plate with peripheral growth. The bristles, which are sparsely scattered over the upper surface of the thallus, are not always clearly visible, and they are characterized by the well-marked sheathing base. The plants are all epiphytes with a marked dorsiventral development, but there are no special organs of attachment. Each vegetative cell possesses a large nucleus and a single parietal chloroplast of irregular form, which contains one or two large pyrenoids. The plants occur attached to the submerged portions of various aquatic and marsh plants from which they are not easily removed.

C. scutata Bréb. and *C. soluta* Pringsh. are the most abundant species in Britain. The former possesses a compact, flat, parenchymatous thallus (fig. 16) and the latter a flat thallus composed of dichotomously branched filaments radiating in one plane from one or more central cells. The diameter of the thallus in each case scarcely exceeds 700—800 μ and the cells average about 10—23 μ in diameter. *C. orbicularis* Pringsh. possesses a flat, expanded, circular thallus which reaches a diameter of 4 mm., in which the filaments are very closely packed and the cells are rather small. *C. pulvinata* A. Br.

forms hemispherical cushions commonly 2—4 mm. in diameter, but occasionally greatly exceeding these dimensions. The filaments are erect and radiating and the cells are 1—3 times longer than their diameter, which is from 20—50 μ (fig. 17). This species is more frequently observed with sexual organs than any of the others. *C. irregularis* Pringsh. possesses a more or less parenchymatous thallus in which the branching is very irregular. All the species are readily eaten by pond-snails of the genera *Limnæa* and *Planorbis*.

Family 2. **HERPOSTEIRACEÆ.**

This is a small family including only the genus *Herposteiron*. The plants are epiphytic on larger Algæ and on other water-plants, and occur as short irregular filaments which are little branched. Most of the cells of the filament possess one or more bristle-like setæ or hairs, cut off from the cell which bears them by a basal septum. Chodat has found that in cultures the setæ are sometimes replaced by branches, showing the relationship between this genus and the Chætophoraceæ.

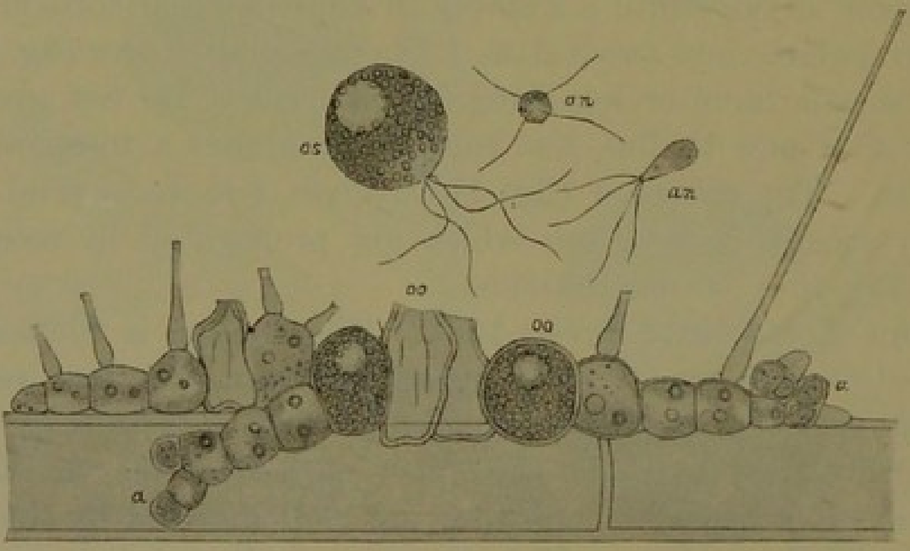

Fig. 18. *Herposteiron confervicola* Näg. (=*Aphanochæte repens* A. Br.). *oo*, oogonium; *os*, oosphere; *a*, antheridium; *an*, spermatozoid. (After Huber.)

Asexual reproduction takes place by zoogonidia, one to four being produced from the mother-cell, the wall of which ruptures and sets them free. They vary much in size, possess four cilia, and usually a red pigment-spot. On coming to rest they generally develop unilaterally into a new plant. Sometimes aplanospores are formed (fig. 19 C *a*).

The sexual reproduction of *Herposteiron* is of special interest. The oogonia are differentiated from certain of the central cells of the thallus which are devoid of bristles. These cells grow in size, assume a globular form, and become filled with starchy and oily material. One oosphere is produced, which is motile, having four cilia, and is expelled from the oogonium by the rupture of the upper portion of the wall. The antheridia are small cells usually developed at the ends of the filaments and branches; they are frequently colourless and are considerably smaller than the ordinary vegetative cells. One or two antherozoids are produced in an antheridium. These are pear-shaped bodies with four cilia and two pulsating vacuoles, and are much smaller than the zoogonidia. They escape into a hyaline vesicle which soon becomes diffluent and sets them free. The antherozoids move about very rapidly, but the movements of the oosphere are very feeble. The Herposteiraceæ is the only family of the Chætophorales in which the fertilization of the oosphere takes place outside the oogonium. Little is known concerning the development of the oospore.

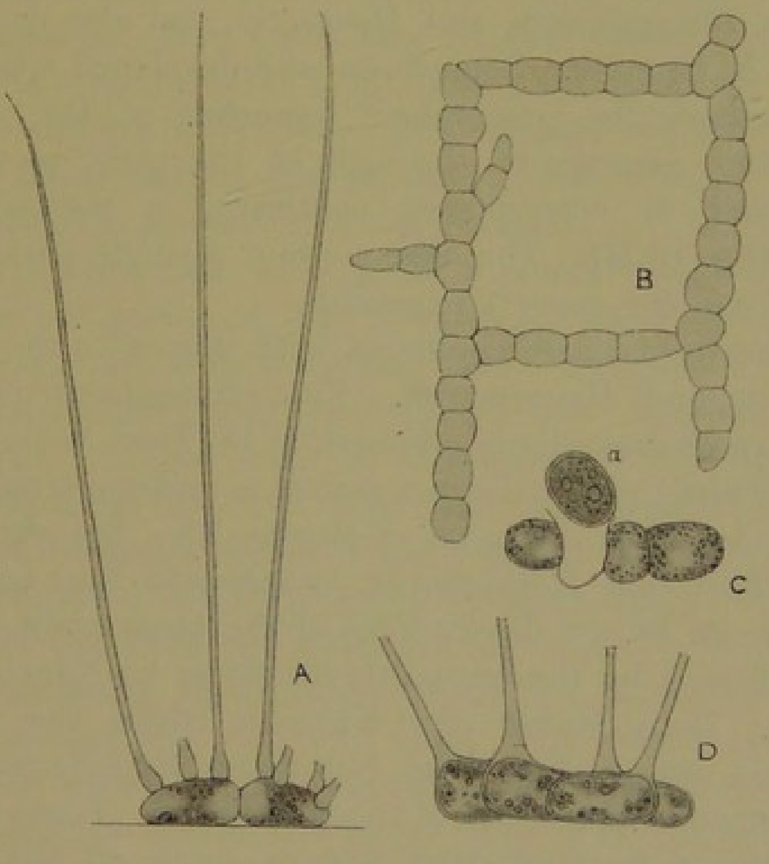

Fig. 19. A, *Herposteiron pilosissima* (Schmidle) nob., from Wimpole Park, Cambridgeshire. B—D, *H. confervicola* Näg.; B and C, from Bradford, W. Yorks.; D, from Richmond Park, Surrey (×450). *a*, aplanospore.

Genus **Herposteiron** Näg., 1849. [*Aphanochæte* A. Br., 1851; Berth., 1878; Huber, 1892.] The thallus is filamentous, creeping and branched, the terminal cells of the branches being rather smaller than the more central cells of the thallus. One or more erect bristles are attached to the dorsal surface of some or all of the cells. These bristles are single, attenuated, and very elongated cells, which have lost their protoplasmic contents and which never possess chloroplasts. They are somewhat fragile and are easily broken off near the base. The sexual organs, which are of very rare occurrence, have been described by Huber[1].

The plants occur as epiphytes on species of *Œdogonium*, *Cladophora*, *Rhizoclonium*, and *Mougeotia*, and also on the leaves of *Lemna*, *Elodea*, etc. Sometimes well-developed specimens are much branched, the procumbent branches of the Alga often following the contours of the cells of the plant to which it is attached, and in consequence exhibiting a marked reticular structure[2] (fig. 19 B). The cells contain a single parietal chloroplast with one (or more ?) pyrenoids.

There has been much confusion with regard to the two names *Aphanochæte* and *Herposteiron*. The arrangement proposed by Hansgirg, and subsequently adopted by De Toni, Wille and others (myself included), of two distinct genera is quite untenable. There can be no doubt in the mind of anyone who has studied these plants carefully that *Herposteiron confervicola* Näg. and *Aphanochæte repens* A. Br. are descriptions of the same plant, and this is amply confirmed by the authentic drawings by Nägeli published by Huber. Both Huber and Klebahn admit the identity of *Herposteiron* and *Aphanochæte*, but reject Nägeli's name on the ground of the incompleteness of the description. There is, however, far more reason for neglecting Braun's name on the ground of inaccuracy.

H. confervicola Näg. (=*Aphanochæte repens* A. Br.) is a species with oblong-ellipsoidal cells, each bearing a single bristle which is little swollen at the base and which is attached towards one end of the cell. It is not an uncommon species and is somewhat variable, two bristles being frequently attached to some of the cells of the thallus. (Figs. 18 and 19 B—D.) Another species, *H. pilosissima* (Schmidle) nob. (=*Aphanochæte pilosissima* Schmidle), is more abundant in some parts of the British Islands and is most probably identical with *H. polychæte* Hansg. The cells are more ellipsoidal and possess from one to four bristles, each bristle having a swollen base (fig. 19 A).

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[1] Huber in Bull. de la Soc. bot. de France, xli, 1892.

[2] G. S. West in Journ. Bot. Febr. 1899, p. 57.

Family 3. ULOTRICHACEÆ.

This family includes a few genera which are readily distinguished from other plants of the Chætophorales by their unbranched habit and by the structure of their cells. The thallus is a simple filament, consisting of cylindrical or doliform cells, as in *Ulothrix,* or of rounded cells arranged in a single series and enveloped in a thick mucous coat, as in *Hormospora* and *Radiofilum.* The cell-wall is always hyaline and colourless, but varies much in thickness. It is sometimes delicate, sometimes thick and lamellose, and sometimes the outer layers are diffluent. There is a single, parietal, plate-like chloroplast in each cell, with an entire or variously lobed margin, and containing one or many pyrenoids. A single nucleus is present in the cytoplasm.

Asexual reproduction takes place in several ways. Sometimes aplanospores are produced (fig. 20 D *a*; fig. 21 F *a*), or numbers of akinetes[1] are formed by the enlargement of certain cells and the gelatinization of the outer portions of their original cell-walls (fig. 21 E and I); these may be resting-spores (hypnospores) or they may germinate directly. Sometimes the thallus is multiplied by a general dismemberment of the filament into single cells or groups of cells, each cell or group developing into a new filament. Zoogonidia of two kinds are produced, often from different cells of the same filament; small microzoogonidia with two cilia and larger macrozoogonidia with four cilia. The microzoogonidia are produced from certain of the vegetative cells which have become microzoogonidangia and in the larger species of *Ulothrix,* such as *U. zonata,* 16 or 32 are produced from each gonidangium, but in *U. subtilis* only 2 or 4 are produced. Similarly 2, 4, or 8 macrozoogonidia are usually produced from a macrozoogonidangium, but in *U. subtilis* only one arises. It is occasionally observed that the entire contents of the cell are not used up in the formation of the macrozoogonidia (*vide* fig. 21 G). The zoogonidia germinate directly on coming to rest, sometimes even within the mother-cell, and the plants which arise by the germination of the macrozoogonidia are larger than those which arise from the microzoogonidia. This accounts for the variability in size of the filaments which is so often observed in a collection of any one

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[1] This was first shown by Wille in Bot. Centralbl. xi, 1882, p. 113.

species of *Ulothrix*. Occasionally the zoogonidia do not escape, but lose their cilia, become invested with a cell-wall, and form what is termed a "palmelloid condition" (fig. 20 F). The production of zoogonidia usually commences near the apex of a filament and progresses towards the base.

Sexual reproduction is by the conjugation of isogamous gametes, which are indistinguishable from the microzoogonidia. The gametes are biciliated and usually escape from the gametangia in the morning, conjugating in pairs with considerable rapidity. The resulting zygospore invests itself with a firm cell-wall and germinates after a more or less extended period of repose. On germination the contents break up into many zoospores each of which forms a new filament. The gametes frequently germinate directly without conjugation.

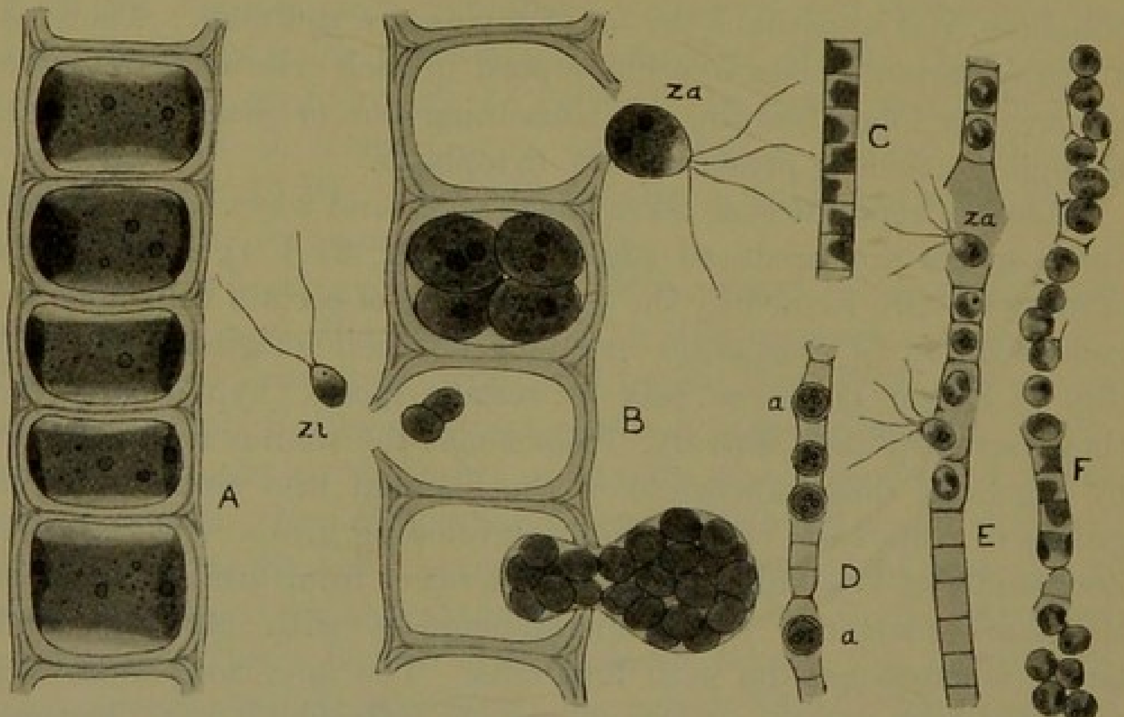

Fig. 20. A and B, *Ulothrix zonata* (Web. et Mohr.) Kütz., from near Meaux Abbey, E. Yorkshire (× 500). C—F, *U. subtilis* Kütz., from near Mullion, Cornwall (× 500); F shows the "palmelloid condition"; *a*, aplanospore; *za*, macrozoogonidium; *zi*, microzoogonidium.

The movements of the microzoogonidia and gametes are frequently very strange, one cilium being kept more or less rigid and its extreme apex used as a pivot, while the other cilium exhibits violent movements causing a rapid lateral oscillation of the body.

The British genera are best arranged as follows:—

- * Filaments thread-like, cells cylindrical with truncate apices.
  - † Filaments long and flexuose, attenuated towards base .... *Ulothrix.*
  - †† Filaments short, attenuated at both base and apex *Uronema.*
  - ††† Filaments of variable length; transverse walls very thick; cells in pairs .... *Binuclearia.*
- ** Filaments fragile, often moniliform, cells with rounded apices.
  - † Cells more or less cylindrical; plants with a resemblance to a fragmented *Ulothrix*; with no prominent mucous coat .... *Stichococcus.*
  - †† Cells cylindrical with hemispherical ends, or subglobose, often remote; with a prominent mucous envelope.
    - § Cells cylindrical.
      - ‡ Cells equidistant, often in close contact.
        - ⊙ Cells large, short .... *Hormospora.*
        - ⊙⊙ Cells minute, more elongate .... *Glœotila.*
      - ‡‡ Cells in pairs .... *Geminella.*
    - §§ Cells rounded .... *Radiofilum.*

The three genera *Hormospora*, *Glœotila* and *Geminella* are scarcely to be distinguished from each other. Perhaps it would be better to unite them under the name *Geminella*.

Genus **Ulothrix** Kütz., 1833. [*Hormiscia* in the sense used by Rabenhorst (1868), Hansgirg, and De Toni.] In this genus the filaments are simple, not attenuated at the apex, but frequently fixed at the base by a unicellular, simple or ramified 'rhizoid.' The cells are commonly cylindrical or sometimes swollen, and in the larger species the cell-wall is thick and evidently lamellose. The chloroplast is parietal with one or many pyrenoids, and varies much in its relative size.

The genus *Ulothrix* was established by Kützing[1] for the species *U. zonata* two years before Fries' description of *Hormiscia*[2]. Areschoug's[3] enlargement of the genus *Hormiscia* was based upon erroneous conceptions, as he included in it species having no affinity with each other. The original *Hormiscia* of Fries only included two Algæ previously known as "*Conferva penicilliformis* Roth" and "*Conferva Wormskioldii* Flor. Dan." These Algæ are commonly placed under the genus *Urospora* of Areschoug, but the

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[1] Kützing in Flora, 1833, xvi, p. 517.

[2] Fries in Flora Scand. 1835, p. 327.

[3] Areschoug in Acta Reg. Soc. Sci. Upsala, ser. III, vol. vi, no. 2, p. 12.

latter genus should undoubtedly be placed as a synonym of *Hormiscia* Fries.

The best known species of the genus is *U. zonata* (Web. et Mohr.) Kütz., (fig. 20 A and B), which is widely distributed all over the British Islands, occurring as bright green masses in streams, rivers, etc., more especially in the early spring. The cells vary from 15—70 μ in diameter and the cell-walls are very thick and lamellose. An abundant British species is *U. subtilis* Kütz.

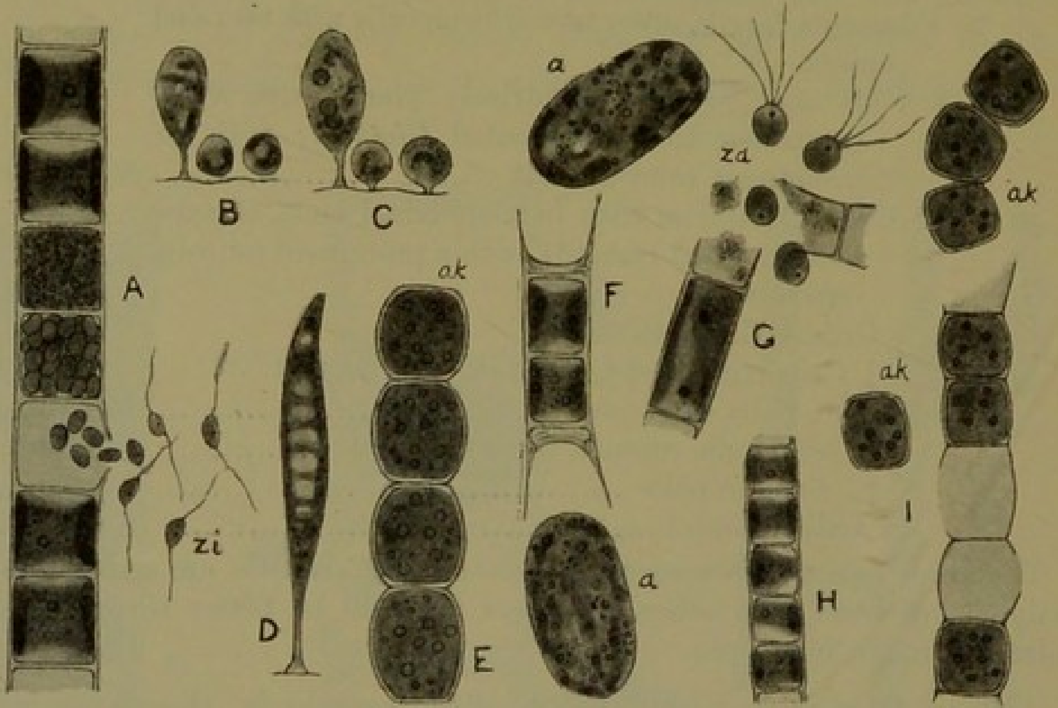

Fig. 21. A—F, *Ulothrix æqualis* Kütz.; A—D, from Putney Heath, Surrey; E and F, from Mitcham Common, Surrey; A, filament showing escape of microzoogonidia; B—D, germinating macrozoogonidia, C shows the same plants as B 48 hours afterwards, D is much further advanced; E, portion of filament of akinetes; F shows two aplanospores which have taken exactly 14 days to develop from ordinary vegetative cells. G, *U. æqualis* Kütz. var. *catæniformis* (Kütz.) Rabenh., from near Bradford, W. Yorkshire, showing escape of macrozoogonidia. H, *U. moniliformis* Kütz., from Wimbledon Common, Surrey; I, the same with akinetes. (All × 500.) *a*, aplanospore; *ak*, akinete; *za*, macrozoogonidium; *zi*, microzoogonidium.

(fig. 20 C—F), the cells of which are as long as broad and from 4—8 μ in diameter. A variety of this species—var. *variabilis* (Kütz.) Kirchn.—is probably the most abundant member of the genus, being generally distributed in the stagnant waters of ponds, ditches, troughs, rain-tubs, etc. It is a little thicker than *U. subtilis* and the cells are $1\frac{1}{4}$—$2\frac{1}{4}$ times longer than their diameter. *U. æqualis* Kütz. (fig. 21 A—F) and *U. moniliformis* Kütz. (fig. 21 H—I) are other well-known species.

Another Alga—*Schizomeris Leibleinii* Kütz.—which I have only once seen, from Stone Ghyll, Dodd Fell, N. Yorkshire, should perhaps be included here. I am doubtful as to the exact determination of the Yorkshire specimens, but they reminded one very much of a large *Ulothrix zonata*, attenuated both at the apex and the base, the latter being fixed to rocks and stones in the spray of a waterfall. Longitudinal division of the cells had occurred at intervals, so that the filaments often consisted of a double row of cells. Wolle seems to have observed the same plant from several parts of the United States (cf. Freshw. Alg. of U. S. t. cxxv).

Genus **Hormospora** Bréb., 1840. The filaments are simple and free-floating, rarely fixed by a mucous disc, and they consist of a single series of cells embedded in a thick, cylindrical, mucous investment. This outer gelatinous coat varies in its relative size, and is always hyaline and homogeneous. The cells are commonly oblong-cylindrical with broadly-rounded extremities, and they contain a single parietal chloroplast usually disposed as an equatorial band. One pyrenoid is generally present in each chloroplast, although rarely pyrenoids are quite absent. The genus is very closely allied to *Ulothrix*, but is distinguished by its thick gelatinous coat and by the constant separation of the cells after division. Cienkowski and others have regarded the genus as a mere state or condition of *Ulothrix*, but I think that is open to much doubt. The cell-wall is extremely thin and delicate, and the formation of zoogonidia has not been observed.

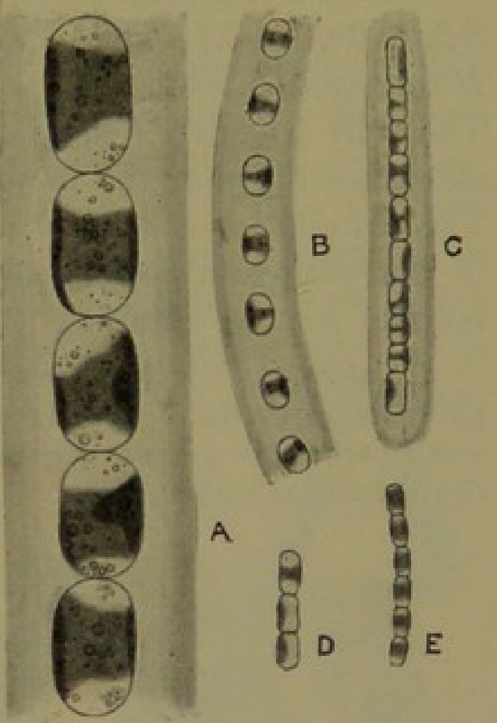

Fig. 22. A, *Hormospora mutabilis* Bréb., from near Mullion, Cornwall. B, *H. ordinata* West & G. S. West, from Cam Fell, W. Yorkshire. C—E, *Glœotila protogenita* Kütz., from Pilmoor, N. Yorkshire. (×440.)

The most frequent British species is *H. mutabilis* Bréb. (fig. 22 A), which occurs principally in bogs, especially amongst *Sphagnum*, and in such localities species of *Ulothrix* do not usually exist. The cells are 16—19 μ in diameter and 1½—1¾ times longer than broad. *H. ordinata* West & G. S. West (fig. 22 B) is a smaller and much rarer species with cells 5·8 μ in diameter. *H. plena* Bréb. is the only other British species.

Genus **Glœotila** Kutz., 1843. This is a genus of small Algæ intermediate in character between *Hormospora* and *Ulothrix*. The cells are very small, oblong or elliptical and more or less moniliform, but they are not so completely separated as those of *Hormospora*; they are arranged in a single series in a delicate mucous envelope, and each one contains a parietal chloroplast of small size which is disposed as in *Hormospora*. I have not observed any pyrenoids in the chloroplasts of this genus. Borzi[1] has recently described the formation of zoogonidia.

The cells of *G. protogenita* Kütz. (fig. 22 C—E), which is the typical species of the genus, only reach a diameter of 3—4·5 μ. The plants are very rare and occur in bogs or boggy pools.

Genus **Geminella** Turp., 1828[2]; Lagerh., 1883[3]. [?*Planctonema* Schmidle, 1903.] This genus is scarcely to be distinguished from *Hormospora* Bréb. except for the arrangement of the cells in pairs. The cells are fairly remote, are enveloped in a thick mucous coat, and after division the daughter-cells separate only very slightly. The chloroplast is exactly as in *Hormospora*. The cells of some of the filaments occasionally develop thick brown cell-walls and become resting akinetes.

G. interrupta Turpin (fig. 23 A—C) is the only known species and it is rarely found in the British Isles. The cells are 6·5—7 μ in diameter. It would perhaps be more correct to unite the genera *Geminella* and *Hormospora*, the former having priority.

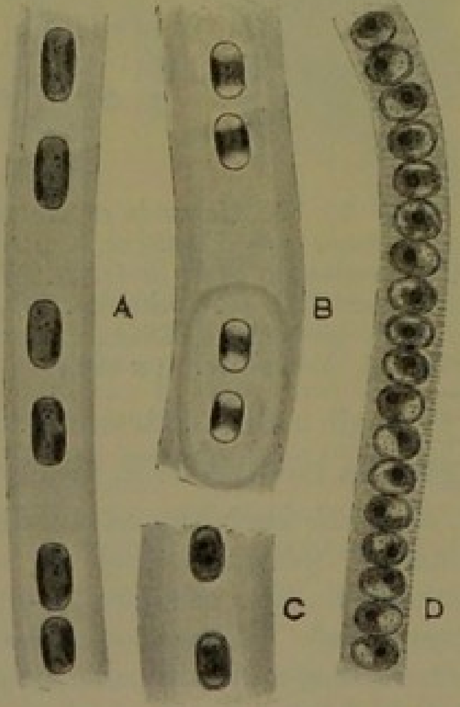

Fig. 23. A—C, *Geminella interrupta* Turp.; A and B, from near the Lizard, Cornwall (× 440); C, two resting akinetes from Glen Tummel, Perthshire, Scotland (× 350). D, *Radiofilum flavescens* G. S. West, from Wicken Fen, Cambridgeshire (× 440).

It is impossible to find any generic characters sufficient to separate *Planctonema* Schmidle from *Geminella* or *Glœotila*.

Genus **Radiofilum** Schmidle, 1894. The filaments are simple, sometimes short and fragile, sometimes long and flexuose, and they are enclosed in a considerable mucous sheath, which exhibits a more or less distinct radiating fibrillar structure. The cells are globose, ellipsoid, or sublenticular, free and distant or joined by a narrow hyaline bridge, always forming moniliform filaments after the manner of those of the Nostocaceæ. In each cell there is one chloroplast containing a single pyrenoid. In one species the cell-wall is composed of two

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[1] Borzi, 'Studi Algologici II.'

[2] Turpin in Mém. du Mus. d'hist. nat. 1828, tom. xvi, p. 329, t. 13, f. 24.

[3] Lagerh. in Öfvers. af K. Vet.-Akad. Förh. 1883, no. 2.

equal halves, but in others it is not. The cells multiply by division which is preceded by a division of the chloroplasts and pyrenoids.

The type species of the genus, *R. conjunctivum* Schmidle[1], has not been observed from Britain. *R. flavescens* G. S. West (fig. 23 D) is a larger species, with much longer flexuose filaments and broad elliptical cells; the diameter of the cells is 7·5—10·5 μ and the chromatophores are of a yellowish-green colour.

Genus **Stichococcus** Näg., 1849. [*Hormococcus* Chodat, 1902.] The filaments are entirely or very largely aërial, and are composed of cylindrical cells. They readily become disarticulated into fragments composed of a few cells, the extremities of the terminal cells being broadly rounded. There is one parietal chloroplast in each cell, plate-like or more or less irregular in form, and occupying as a rule only a portion of the cell-wall. A small pyrenoid is present in each. In some of the aquatic forms of *Stichococcus flaccidus* I have observed a fragmentation of the chloroplast (cf. fig. 24 B).

The plants are propagated by division of the cells and fragmentation of the filaments, by akinetes, and by zoogonidia. The latter are biciliated, have no pigment spot, and arise singly from cells which are undergoing rapid division.

This genus much resembles *Ulothrix*, but its adaptation to an aërial existence has caused a multiplication by disarticulation of the filaments and a reduction almost to a unicellular condition. This disarticulation often takes place first on one side and then on the other, giving a zig-zag appearance to the disarticulated filaments. Klebs has shown that it is facilitated either by too much or too little nourishment. The genus was well studied by Gay[2].

There appears to be no justification whatever for Chodat's name "*Hormococcus*."

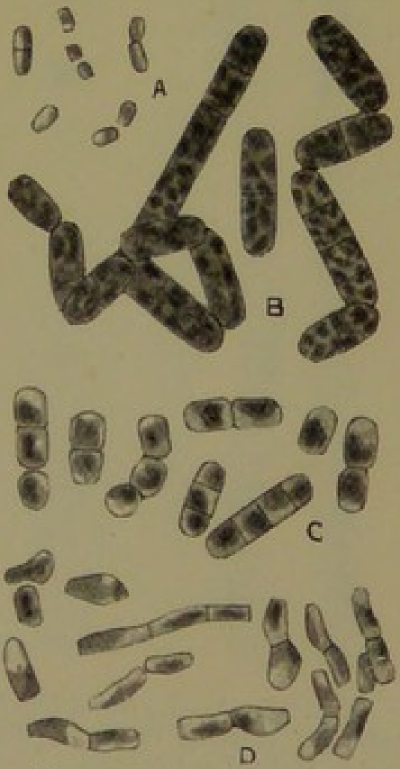

Fig. 24. A, *Stichococcus bacillaris* Näg., from Saltaire, W. Yorkshire. B, *S. flaccidus* (Kütz.) Gay, from Barnes Common, Surrey. C, *S. dissectus* Gay, from damp walls, London. D, *S. variabilis* West & G. S. West, from Bradford, W. Yorkshire (× 440).

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[1] Schmidle in Flora, 1894, Heft 1, p. 47, t. vii, f. 4, 5.

[2] Gay, 'Recherches sur le dével. et les classif. de quelques Algues Vertes,' Paris, 1891.

S. bacillaris Näg. (fig. 24 A) is an abundant species on damp earth, walls, palings, etc.; diam. of cells 2·7—3·8 μ. *S. flaccidus* (Kütz.) Gay (fig. 24 B) is a larger species frequent on wet stones and in rain-pools; diam. of cells 7—10·5 μ. *S. dissectus* Gay (fig. 24 C) is a closely allied species to *S. flaccidus*, or perhaps only a form of it. *S. variabilis* West & G. S. West (fig. 24 D) forms a thin green stratum on wet stones in the neighbourhood of waterfalls; the cells are very irregular in outward form and the chloroplast is often devoid of a pyrenoid or may even possess two; diameter of cells 3—6 μ.

Genus **Uronema** Lagerh., 1887[1]. The filaments are simple, relatively short, and destitute of a mucous coat; they consist of cylindrical cells, the apical cell being acuminate and the basal cell attenuate. The plants are fixed by a disc secreted by the basal cell. The chloroplast occupies a considerable area of the cell-wall and is parietal, containing two pyrenoids. The cell-wall is firm and thin.

The zoogonidia are produced singly or in pairs from each cell; they possess four cilia and a subapical pigment-spot. Sometimes the zoogonidia are arrested in their escape, the cilia are not developed, and an aplanospore is produced by the acquirement of a strong cell-wall.

The only species is *U. confervicolum* Lagerh. with filaments 4—6 μ in diameter and cells 2—3 times longer than broad. It is an exceedingly rare plant, distinguished from species of *Ulothrix* by its short filaments, by the attenuation of the apical and basal cells, by the chloroplast, and by the firm cell-walls. I have only met with it in abundance from the Orkney and Shetland Is.

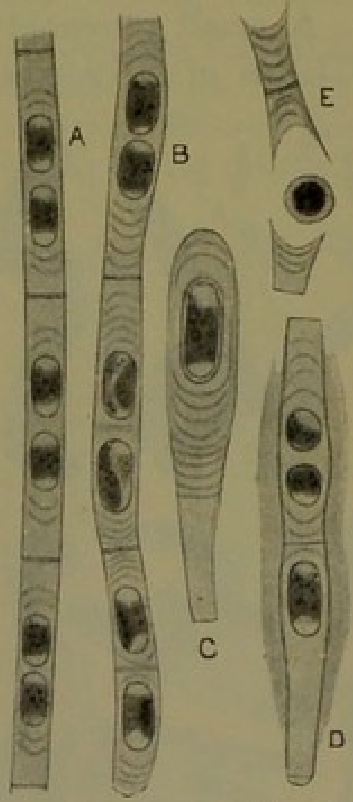

Fig. 25. A—E, *Binuclearia tatrana* Wittr., from Lewis, Outer Hebrides (× 440).

The genus *Rhaphidonema* Lagerh. (of which *R. nivale* is known from W. Yorks.) is a fungus.

Genus **Binuclearia** Wittr., 1886[2]. The filaments are simple and attached when young by a hapteron from the basal cell. The cells are cylindrical with firm, distinctly lamellose cell-walls, the transverse walls being unequal, a thin one and a very thick one alternating. The cells thus appear to be arranged in pairs. The

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[1] Lagerh. in Malpighia 1887, p. 518, t. xii, f. 1—10.

[2] Wittr. in Wittr. and Nordst. Alg. Exsic. 1886, no. 715. See also Schröder in Forschungsberichte aus der biol. Station zu Plön, Teil VI, 1898, p. 19—21.

chloroplast is single, parietal, and disposed as part of an equatorial band. Wittrock described the presence of two granule-like bodies of a nutritive character, which he termed "nuclei," situated one towards each end of the cell and outside the chloroplast. I have examined quantities of this plant and find those bodies commonly absent.

B. tatrana Wittr. (fig. 25 A—E) which has cells 6—9 μ in diameter, occurs in mountain lakes and bogs. It resembles certain stages of species of *Tribonema* (*Conferva*), and forms hypnospores (cfr fig. 25 E), but is more rightly placed in the Ulotrichaceæ on account of its parietal chloroplast. Sometimes the filaments become distinctly mucous.

Family 4. **CYLINDROCAPSACEÆ.**

This family includes only a few plants belonging to the genus *Cylindrocapsa* Reinsch. The thallus is filamentous and unbranched, and resembles very much that of certain of the Ulotrichaceæ. The cells are disposed in a single series, each one being surrounded by a lamellose, gelatinous cell-wall, and the entire filament is enclosed in a thick lamellose sheath. The cells resemble very much those of the genus *Hormospora* in their disposition and they may divide in the same manner as those of *Radiofilum*; they are often ovoid or subtriangular in shape and disposed in pairs at intervals along the filament. Each cell possesses a parietal chloroplast with a single pyrenoid, but it is often difficult to observe the nature of this chromatophore.

Asexual reproduction occurs by zoogonidia formed singly, or in twos or fours, from any of the cells of the filament. Each zoogonidium is rounded or oval in form, possesses two cilia, a red pigment-spot and two contractile vacuoles.

Sexual reproduction takes place by means of well differentiated male and female gametes. The male organs or antheridia are the result of the active division of certain vegetative cells, and are disposed in one, two, or four longitudinal series within the lamellose sheath. Two antherozoids are produced in each antheridial cell, similar in form to the zoogonidia, brownish red in colour, and with two short cilia. The oogonia are developed by an increase in size of the ordinary vegetative cells, each oogonium being large, ovoidal in shape, and with a thick lamellose wall. A single oosphere is present in each oogonium, which opens by a lateral pore to admit the antherozoids. On fertilization the oospore develops a brick-red colour and a thick cell-wall, but it does not fill the oogonium. The method of sexual reproduction was worked out by Cienkowski[1].

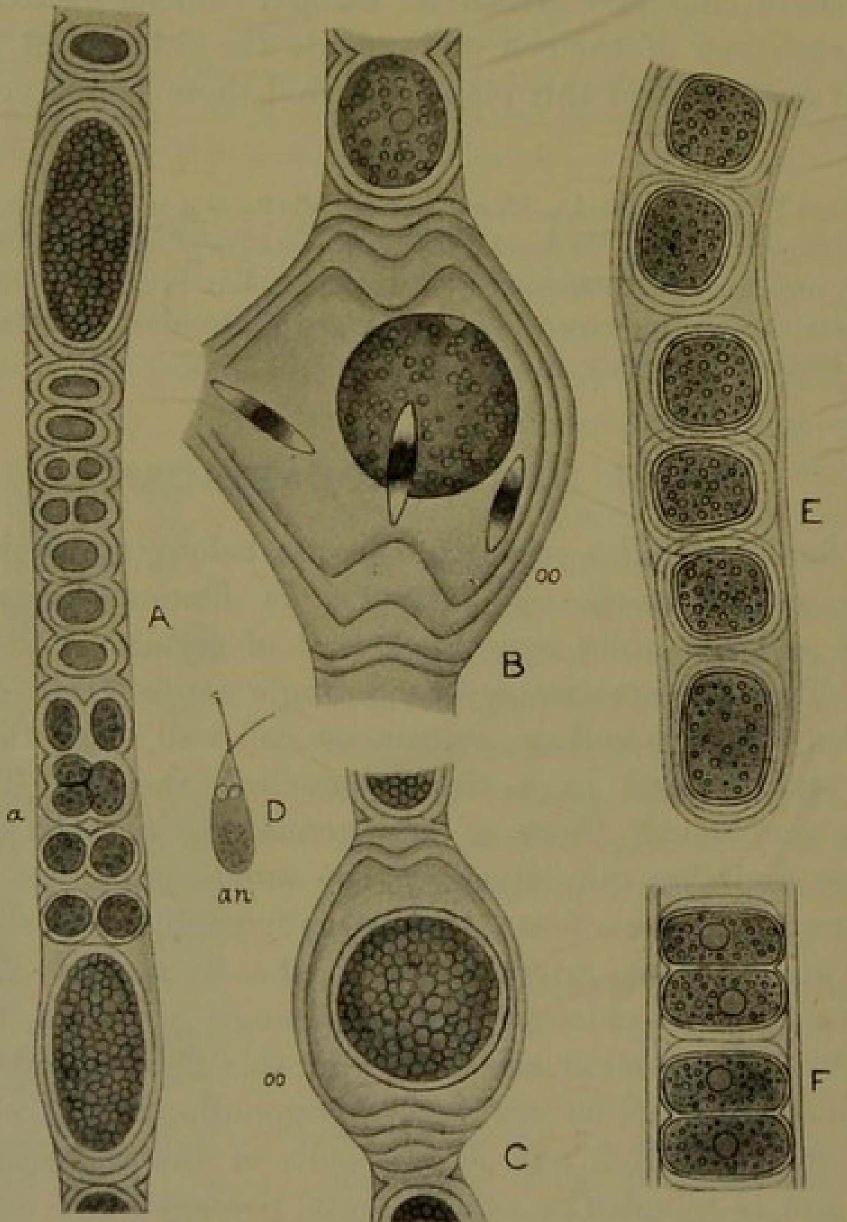

Fig. 26. A—D, *Cylindrocapsa involuta* Reinsch (×480). *a*, antheridium; *an*, antherozoid; *oo*, oogonium. (After Cienkowski.) E and F, *C. conferta* West, from Bowness, Westmoreland (×520).

Genus **Cylindrocapsa** Reinsch, 1867. The thallus consists of unbranched filaments of cells, each cell having a thick lamellose cell-wall. The filaments are encased in a thick lamellose sheath, and they greatly resemble certain of the more gelatinous stages

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[1] Cienkowski in Bull. de l'Acad. Imp. St Pétersbourg, tom. xxii, 1876, pp. 549—555, t. ii, f. 50—65.

met with in the Ulotrichaceæ; in fact, many authors place this genus in the Ulotrichaceæ.

Species of this genus are rarely met with in the British Isles. *C. involuta* Reinsch (which includes *C. nuda* Reinsch), the cells of which are 23—30 μ in diameter, is known from Ireland (fig. 26 A—C); *C. conferta* West (fig. 26 E and F) is known from the English Lake District, and *C. geminella* Wolle var. *minor* Hansg. has been observed from Yorkshire and Cambridgeshire.

Family 5. **CHÆTOPHORACEÆ.**

This family of the Chætophorales has undoubtedly arisen by a further specialization of the Ulotrichaceæ. The thallus is branched and the branches are attenuated, sometimes being produced into long multicellular hairs. As a rule the thallus is differentiated into a recumbent or creeping portion, attached to a substratum by rhizoids, and an erect, branched portion. The creeping portion presents a more or less moniliform or torulose appearance, is branched, and the cells are very similar to those of the Pleurococcaceæ. The cells of the erect portion of the thallus are elongated, more or less swollen, but not torulose, and the branching is most irregular, the terminal cells of the branches frequently forming long hyaline hairs.

There is a single chloroplast in each cell, consisting of a parietal, more or less irregular plate, containing one or more pyrenoids. In the attenuated cells towards the ends of the branches the chloroplast becomes reduced, and in the long, hyaline, terminal cells it is entirely absent.

Zoogonidia may be produced from all the cells of the thallus except those forming the rhizoids or the terminal hairs of the branches. The number which may arise from a single cell varies from 1 to 16, depending upon the age of the plant, the size of the cell, and other indeterminable causes. Both macrozoogonidia and microzoogonidia are produced, exhibiting a considerable range in size, and they possess either two or four cilia and a pigment spot. They rapidly come to rest, lose their cilia, and germinate directly.

On the direct germination of a zoogonidium the cilia are lost, a cell-wall arises, and increase in length takes place, one pole being greatly elongated to form a hyaline, rhizoid-like projection. Septa soon appear dividing the original long cell into several shorter ones, and if the adult plant be a strongly branched one, the branching soon becomes apparent. The zoogonidia in both *Chætophora* and *Myxonema* (*Stigeoclonium*) frequently congregate in masses on becoming quiescent and almost all germinate simultaneously (*vide* fig. 28 G). Palmelloid groups sometimes arise in *Myxonema* by the degeneration of some of the branches. Famintzin[1] and Fritsch[2] have observed these palmelloid cells germinate directly to form new plants, and Cienkowski[3] has seen them give rise to microzoogonidia, which latter form the young plants.

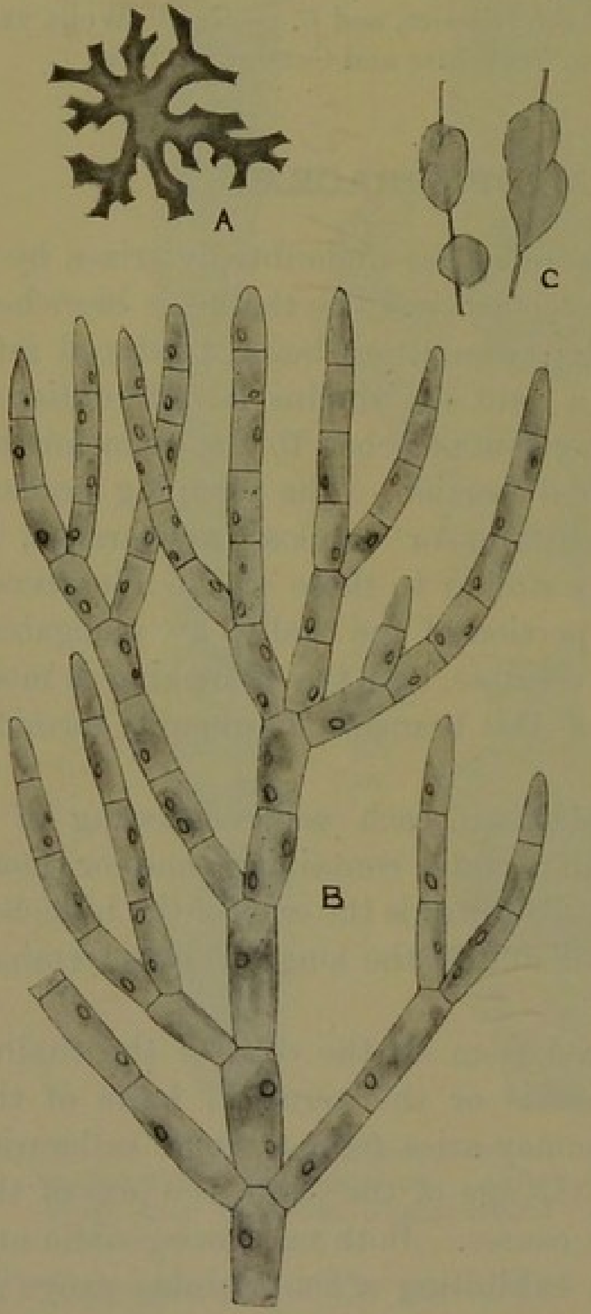

Fig. 27. A and B, *Chætophora incrassata* (Huds.) Hazen, from Scarborough Mere, N. Yorks.; A, nat. size; B, ×500. C, *Ch. elegans* (Roth) Ag., from Baildon, W. Yorks. (nat. size).

Akinetes (which are resting-cells or hypnocysts) are frequently produced in all the genera of this family. In this condition of the plant almost all the cells of a tuft of branches take part in spore-formation, one resting-spore being formed in each cell. The original cell-walls become hyaline or indistinct, causing the branches to exhibit a moniliform appearance. Each akinete is of a red-brown colour with a thick, asperulate cell-wall (fig. 29 D).

The gametes are small biciliated bodies, practically indistinguishable from the microzoogonidia except for the possession of only two cilia, and they conjugate in

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[1] Famintzin in Mélang. Biol. Bull. Acad. St Pétersbourg, tom. viii, 1871, p. 265.

[2] Fritsch in Beihefte zum Botanischen Centralblatt, 1903, Bd xiii, Heft 4, p. 384.

[3] Cienkowski in Botan. Zeitung, 1876, xxxiv.

pairs. The resultant zygospores usually undergo a short period of rest before germination.

Genus **Chætophora** Schrank, 1789. The thallus is gelatinous, macroscopic, of a tough consistency, and of some definite form. The filaments radiate out from a central point, those nearest the centre being little branched, but carrying at their apices dense clusters of corymbiform branches of a very bright green colour. The terminal cells of the branches are often prolonged into long hyaline hairs. The zoogonidia possess two or four cilia, and the hypnospores are brown, being generally developed from the terminal cells of the branches. Many of these plants, particularly certain species[1], have the power of extracting calcium carbonate from the water in which they live and so giving rise to incrustations of considerable thickness.

The most abundant species of the genus is *Ch. pisiformis* (Roth) Ag., an Alga which occurs as hemispherical, or almost spherical, dark green masses attached to submerged stones or to the submerged parts of plants. It is also often found attached to the shells of aquatic Gastropods. Its distinguishing features are the absence of terminal hairs and the slightly torulose character of cells of the branches; the cells of the primary filaments are 9—15 μ in diameter. The next most abundant species is *Ch. incrassata* (Hudson) Hazen [= *Ch. endivæfolia* Ag.; *Ch. Cornu Damæ* (Roth) Ag.], which possesses a tough, gelatinous, sub-dichotomously branched thallus, rather flat and of a darker green at the periphery than in the centre (fig. 27 A and B). The branched thallus bears much resemblance to the horns of a stag and in adult specimens is frequently found floating freely at the marshy margins of ponds and lakes, or even in bogs. *Ch. tuberculosa* (Roth) Ag. possesses a large cushion-shaped thallus from 2 to 4 (or even 5) cms. in diameter, occurring usually in marshes or in bogs. *Ch. elegans* (Roth) Ag. is a rarer species than the three previous ones and occurs as very pale-green masses, clinging to submerged stems and leaves of grasses, sedges, or mosses (fig. 27 C).

Genus **Myxonema** Fries, 1825. [*Stigeoclonium* Kütz., 1843.] The thallus is filamentous, branched, and usually devoid of the great mass of gelatinous material which is so conspicuous a feature of *Chætophora*. The branches are scattered, more or less isolated, and often very elongated, but they are rarely developed in dense fasciculate groups. The main branches bear other, shorter, lateral branches which are either acuminate or terminate in long hyaline hairs. There is usually a creeping portion of the thallus, attached to some substratum, but adult plants frequently float freely in

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[1] Forms of *Ch. incrassata* and *Ch. elegans* are often met with encrusted with lime. A form of the latter species was recently named by Tilden *Ch. calcarea*. *Vide* Tilden in Botan. Gazette, 1897, pp. 97—100, 102.

ponds and ditches. The macrozoogonidia and microzoogonidia possess two cilia in some species, but four in others[1], and they are produced singly or in numbers from almost all the cells of the thallus (fig. 28 B). The gametes are biciliated (fig. 28 C and F) and the zygospores are either smooth or stellate. Iwanoff states that the macrozoogonidia germinate directly, but that the microzoogonidia pass into a resting stage.

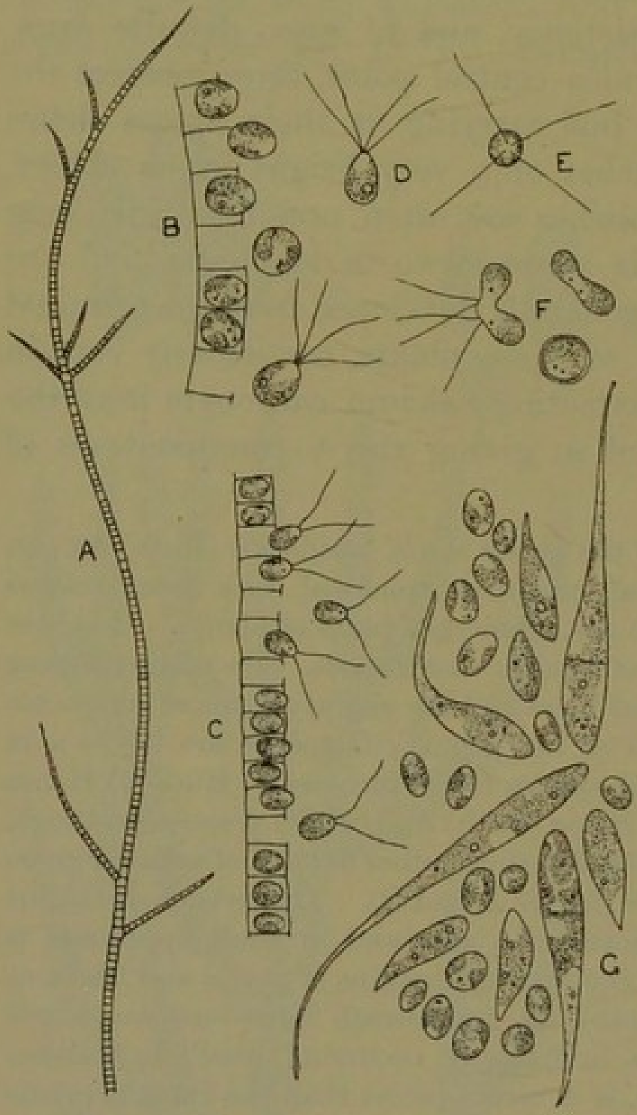

Fig. 28. *Myxonema tenue* (Ag.) Rabenh., from near the Lizard, Cornwall. A, part of thallus (× 100); B, escape of zoogonidia; C, escape of gametes; D and E, zoogonidia; F, conjugation of gametes; G, development of a cluster of zoogonidia (× 500).

Fritsch[2] has recently published some interesting observations on early stages of development of this genus. He finds the development of the basal portion to vary very much in different species and also to some extent within the limits of each species. He also concludes that certain plants described under the generic name *Herposteiron* are merely stages in the life-history of epiphytic "*Stigeoclonia*."

Hazen[3] has given full and conclusive evidence that *Myxonema* was well established before the publication of Kützing's genus *Stigeoclonium*, and sentimental reasons cannot therefore stand in the way of the abandonment of the generic name "*Stigeoclonium*."

There are several British species of this genus, of which the most frequent is *M. tenue* (Ag.) Rabenh. (fig. 28). *M. amœnum* (Kütz.) Hazen is also another widely distributed species.

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[1] Iwanoff in Bull. Soc. Imp. Nat. Moscou, 1899.

[2] Fritsch in Beihefte zum Botanischen Centralblatt, 1903, Bd xiii, Heft 4.

[3] Hazen in Memoirs Torr. Bot. Club, 1902, xi, no. 2, pp. 193—4.

Genus **Draparnaldia** Bory, 1808. The thallus is very gelatinous, and is differentiated into a principal filament and clusters of lateral branches. The cells of the main filament are large, more or less barrel-shaped, and are furnished with an equatorial, parietal chloroplast with toothed edges. The main lateral branches are alternate, opposite or verticillate, and are themselves very much branched, the apical cells frequently terminating in long hyaline hairs. From 1 to 4 zoogonidia arise in each cell of the lateral branches (fig. 29 C) and they are furnished with four cilia. They frequently escape through a hole in the cell-wall much smaller

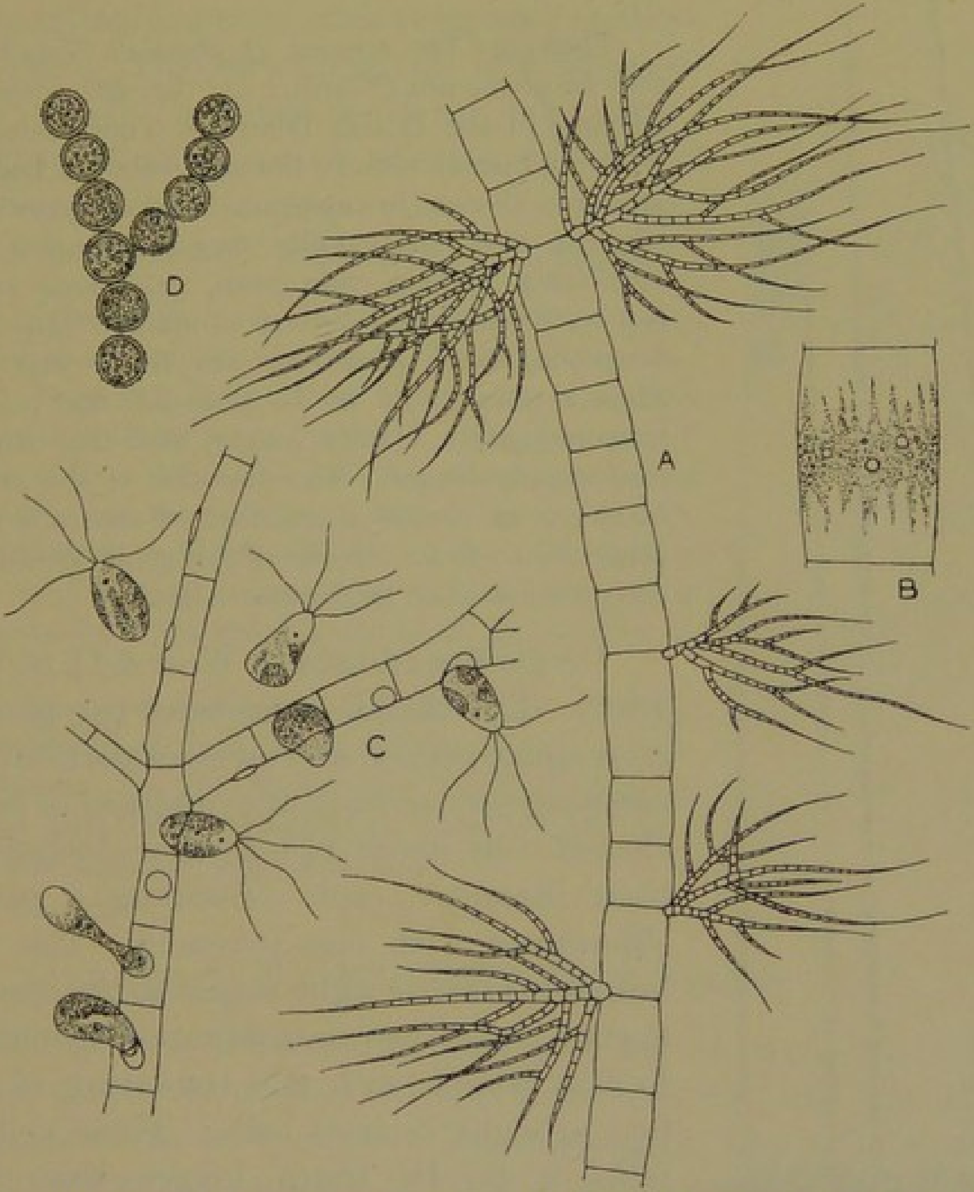

Fig. 29. *Draparnaldia glomerata* (Vauch.) Ag., from Tintagel, Cornwall. A, portion of thallus (× 100); B, single cell of main filament showing the chloroplast (× 220); C, part of branch showing escape of zoogonidia (× 500); D, hypnospores formed from cells of branches (× 500).

than their own diameter, and they pass through many different shapes in accommodating themselves to this small aperture. Usually all the cells of a single cluster of branches produce zoogonidia simultaneously, the entire performance occupying only a few minutes. Resting akinetes (hypnospores) are frequently produced from the cells of the branches.

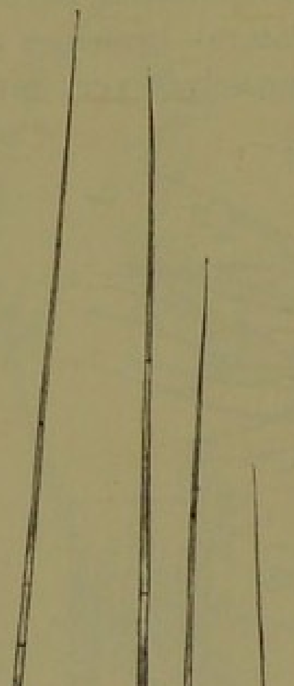

Fig. 30. *Pseudochæte gracilis* West & G. S. West, from near Coates, Gloucestershire (× 520).

There are two species, *D. plumosa* (Vauch.) Ag. and *D. glomerata* (Vauch.) Ag. (fig. 29), widely distributed in the British Islands. They prefer clear water and occur both in the still water of bogs and amongst stones in streams. When growing in streams they are usually found in quiet pools, stretching in long, pale-green, gelatinous strands (up to 20 cms.) from stone to stone. The lateral branches of *D. glomerata* are fewer and much shorter than those of *D. plumosa*, the cells are proportionately a little longer, and the hairs are also usually longer. The diameter of the primary filaments is 40—50 μ and that of the cells of the branches 5—10 μ. Species of this genus are amongst the prettiest of all freshwater Algæ.

Genus **Pseudochæte** West & G. S. West, 1902. The thallus consists of two portions, a creeping portion and an erect portion. The creeping part consists of cylindrical or barrel-shaped cells, about 1¼—2¼ times longer than their diameter, each containing a parietal chloroplast with one pyrenoid. The erect branches arise at right angles to the creeping portion; they are narrower and attenuated to fine points, each one consisting of from five to eight distinct cells. These cells are from 8 to 18 times longer than their diameter and each contains an elongated chloroplast, usually without a pyrenoid. Sometimes the terminal cells of the branches, or even the two terminal cells, contain no protoplasmic contents and therefore no chloroplast.

P. gracilis West & G. S. West (fig. 30) occurs as an epiphyte on aquatic plants. The diameter of the cells of the creeping filaments is 5·7—

7·7 μ and of the erect branches only 1·5—1·8 μ. The plants bear considerable resemblance to *Herposteiron* Näg. (*Aphanochæte* A. Br.) but differ in the possession of completely septate branches instead of simple empty bristles. The only other species of the genus is *P. crassisetum* West & G. S. West which has been found in Ceylon, but it is quite possible that this is merely a developmental stage of an epiphytic *Myxonema*.

Genus **Thamniochæte** Gay, 1893[1]. The plants of this genus are exceedingly minute, consisting only of three to six cells. They are epiphytic and the basal cell is usually modified to form a hapteron. The terminal cell possesses an elongated bristle or a short spine-like projection. The chloroplast is parietal and contains one pyrenoid.

Th. aculeata West & G. S. West is a rare plant occurring as an epiphyte in the thallus of *Glœotrichia natans*. It is only known from Connemara in Ireland and from the Hebrides in Scotland. The diameter of the cells is from 5·5—13 μ, and the terminal bristle is short and very sharp, arising below the apex of a swollen terminal cell (fig. 31 A and B). *Th. Huberi* Gay is epiphytic on a species of *Oscillatoria* and is only known from the neighbourhood of Montpellier in France.

This genus represents the simplest type of all the Chætophoraceæ—a type in which branching is practically absent. In *Th. Huberi* the terminal cells are attenuated and are furnished with hollow bristles or hairs exactly as in many of the more typical and complex Chætophoraceæ.

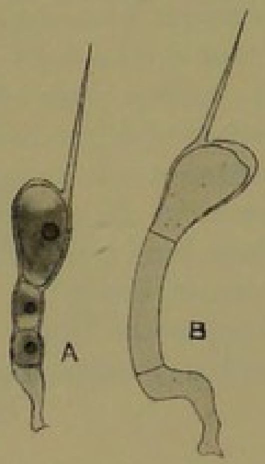

Fig. 31. *Thamniochæte aculeata* West & G. S. West. A, from near Balallan, Outer Hebrides; B, from Baheh Lough, Galway, Ireland (× 520).

Family 6. MICROTHAMNIACEÆ.

The thallus is filamentous, branched, and of small size. The branches are never attenuated into hairs and the cells are sometimes moniliform or torulose. The chloroplast is a parietal plate with one or many pyrenoids, or sometimes entirely without them.

The zoogonidia are only produced in special swollen cells of the thallus which are differentiated as zoogonidangia. Reproduction frequently takes place by akinetes.

It is a small family and bears considerable resemblance to the Chætophoraceæ, being distinguished by the absence of multicellular hairs and by the restricted origin of the zoogonidia. It

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[1] Gay in Bull. Soc. bot. France, tom. xl, 1893, p. clxxvii cum fig. xylogr. 2.

also resembles the Trentepohliaceæ but differs in the aquatic habit, smaller size, and in the nature of the chloroplasts.

Chodat includes the plants of this family in the Pleurococcaceæ, but they have unquestionably reached a higher stage of development than *Pleurococcus* or *Trochiscia*.

Genus **Microthamnion** Näg., 1849; Kirchn., 1878. The plants of this genus are at first fixed but afterwards they often float freely. The filaments are branched and the branches may be short or long. The cells are cylindrical, 3—7 times longer than their diameter, and the terminal cells of the branches are obtuse or

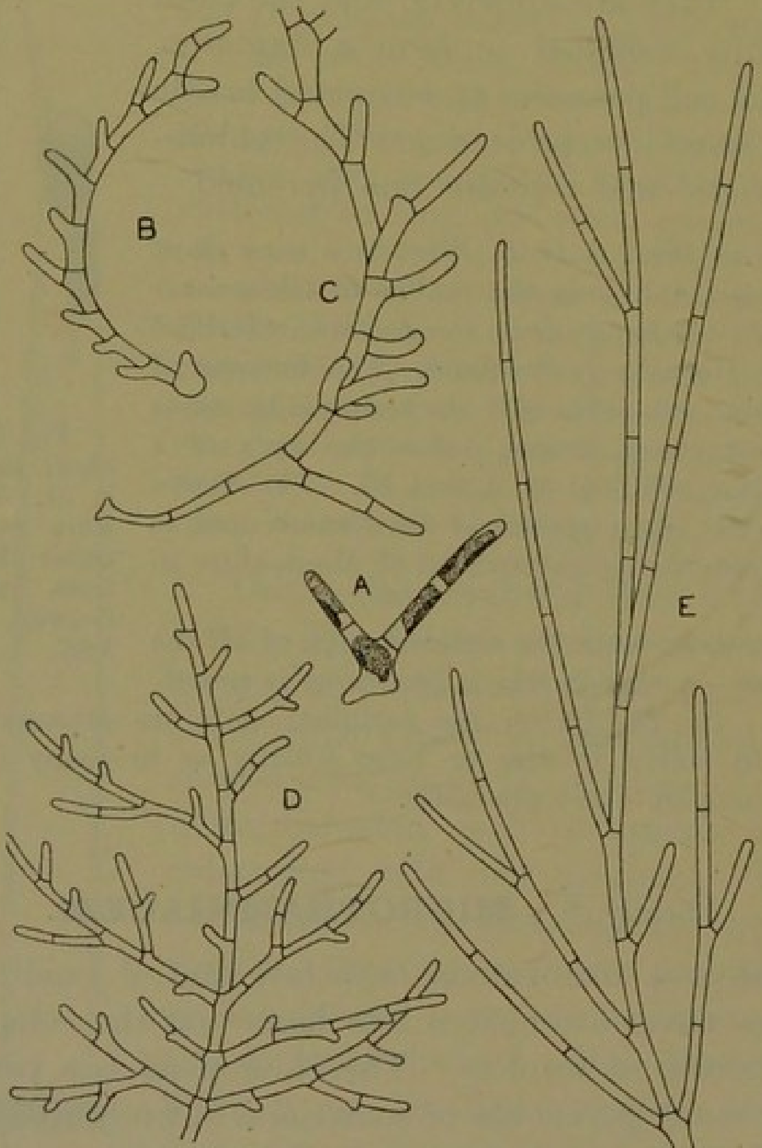

Fig. 32. A—D, *Microthamnion Kützingianum* Näg. A—C, young forms from Richmond Park, Surrey (× 500). D, portion of adult form from Horton-in-Ribblesdale, W. Yorks. (× 350). E, *M. strictissimum* Rabenh., from Blubberhouses, W. Yorks. (× 500).

acuminate. The branches all arise immediately below a transverse cell-wall, and at first appear as lateral outgrowths from the upper end of a cell. There is also a marked tendency for the branching to be unilateral. The parietal chloroplast is long, entire, and occupies about two-thirds of the inner wall of the cell; it contains no pyrenoids.

There are two species, *M. Kützingianum* Näg. and *M. strictissimum* Rabenh., 1863 [=*M. vexator* Cooke, 1882]. The former species (fig. 32 A—D) is much more abundant than the latter, and is most abundant in the early spring. It occurs in small pools and ditches, and likes peat. It is a small, much branched plant, with short branches of one to six cells, the diameter of the branches being 3—5 μ. *M. strictissimum* (fig. 32 E) is a larger plant with an erect thallus up to 4 mm. in height. The branches are much longer and more rigid, giving the plant a very different appearance from *M. Kützingianum*. The diameter of the cells is 4 μ. Fig. 32 E is drawn from one of the original specimens sent by W. B. Turner to M. C. Cooke when the latter described the plant as "*M. vexator*."

Genus **Gongrosira** Kütz., 1843 [inclus. *Pilinia* Kütz. (in part)]. The thallus is attached to a substratum by a mass of parenchymatous cells formed by a confluence of creeping branches. From this mass of cells, which may be one or many layers of cells in thickness, arise numerous, erect, branched filaments, varying in height from 0·04 to 2 mm. This dense, cushion-like mass of erect filaments is frequently incrusted with carbonate of lime, and sometimes forms quite a hard stratum. The cell-walls are often thick and distinctly lamellose. The chloroplast is a parietal plate with one or many pyrenoids, but it is usually difficult of observation. The cells generally present the appearance of being filled with a dense chlorophyllaceous mass, which has been proved to contain starch other than that present in the pyrenoids. The zoogonidia arise in terminal zoogonidangia which are generally flask-shaped. The akinetes are ordinary cells, generally of the recumbent portion of the thallus, which become detached and ultimately form new plants. The plants usually occur at the margins of ponds, lakes, or rivers, forming a tough green stratum on submerged stones or on the shells of aquatic Gastropods.

Species of this genus are rare in the British Islands, or perhaps they may have been overlooked. *G. viridis* Kütz. is a small species (thickness of prim. fil. 8—12 μ, of branches 4—8 μ; fig. 33 A—C) usually encrusted with lime. *G. stagnalis* (West) Schmidle is a larger species (thickness of prim. fil.

16—30 μ; fig. 33 D—F) occurring attached to the shells of *Limnæa peregra*. Schmidle has recently given a short systematic account of the genus[1].

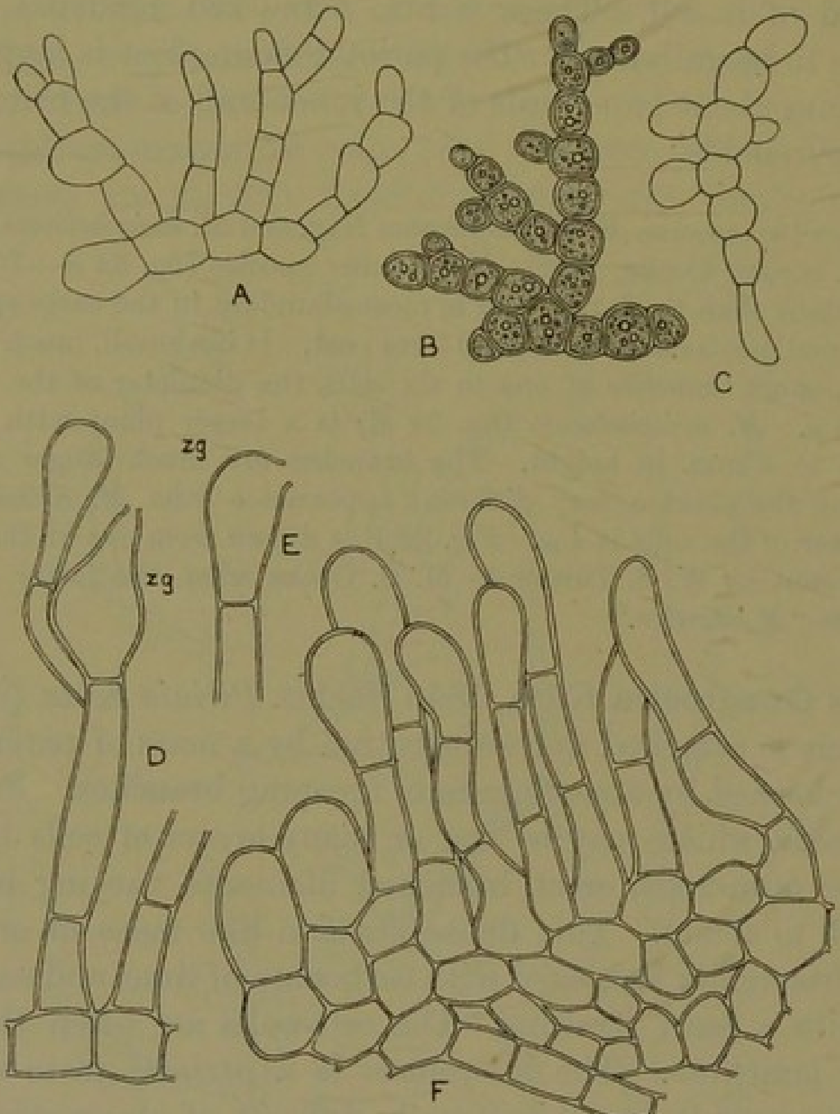

Fig. 33. A—C, *Gongrosira viridis* Kütz. (×500). A, from rocks, Lough Beg, Ireland; B and C, from rocks near Tremethick, Cornwall. D—F, *G. stagnalis* (West) Schmidle, from near Sutton, Cambridgeshire (×200). *zg*, zoogonidangium.

Genus **Leptosira** Borzi, 1883[2]. This genus is scarcely to be distinguished from *Gongrosira*. The plants are aquatic, forming very minute bright green cushions. The branches are torulose, the terminal cells being elliptical, doliform, or sometimes irregular in form. The cell-contents are pale yellow-green in colour and their structure is exceedingly difficult to observe. The zoogonidangia are intercalary and usually consist of the modified, older cells of the plant. The zoogonidia may germinate directly or they

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[1] Schmidle in Berichte Deutsch. Botan. Gesellsch. 1901, Bd xix.

[2] Borzi, 'Studi Algologici I,' Messina, 1883.

may conjugate in pairs and produce resting hypnospores. In the conjugation of the zoogonidia the ends which do not bear the cilia first fuse together.

L. Mediciana Borzi is a rare plant found amongst *Sphagnum* and *Utricularia* in bogs and boggy pools. It is only known from Yorkshire and Sicily. Diameter of cells up to 20 μ.

Family 7. **TRENTEPOHLIACEÆ.**

This family is only represented in the British Islands by a few species of the genus *Trentepohlia*. The thallus is aërial, filamentous and branched, generally occurring on rocks or on the bark of trees. The filaments may be very short and more or less creeping, or they may form erect tufts or closely matted cushions. The cells are sometimes cylindrical and sometimes moniliform or torulose, and the branches usually show a slight attenuation. The cell-walls are firm and frequently exhibit external sculptures. Brand[1] states that the longitudinal walls are lamellose, but the transverse walls are simple; and that the cellulose caps which are so frequently developed at the extremity of a branch, are the remains of dead, terminal zoogonidangia. This is certainly not true of some species, however. Each cell contains one nucleus and usually a number of disc-like, parietal chloroplasts without pyrenoids. The colour of these plants is usually some shade of brown, brownish-red, or orange-red, the chlorophyll being masked by the presence of a pigment known as hæmatochromin, which is frequently dissolved in a quantity of oil.

In the Trentepohliaceæ the zoogonidia are only produced in specially differentiated cells or zoogonidangia. This character, the absence of terminal hairs and the nature of the chloroplasts, are the principal distinctions between the Trentepohliaceæ and the Chætophoraceæ. The zoogonidangia are developed singly or in clusters, either terminating a branch and so arresting its development[2], or developed laterally on the branches, or more rarely in the axil of a branch. They are sessile or stalked, generally ellipsoid or ovoid in shape, and they open by means of a terminal or subterminal pore. The zoogonidia, which are of two sizes, are pear-shaped and furnished with two cilia. The smaller micro-zoogonidia have been observed to conjugate in pairs, but all are

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[1] F. Brand in Beihefte z. Bot. Centralbl. xii, 1902.

[2] The development is only arrested temporarily as the terminal cell or supporting cell often grows through the empty zoogonidangium.

capable of direct germination. Resting-spores or hypnospores are sometimes produced.

Wildeman[1] has shown the ease with which these plants repair injuries to the thallus.

Species of this genus are most abundant in damp tropical or subtropical climates, occurring profusely as epiphytes on the leaves and bark of trees. A few of them are constituents of certain tropical lichens.

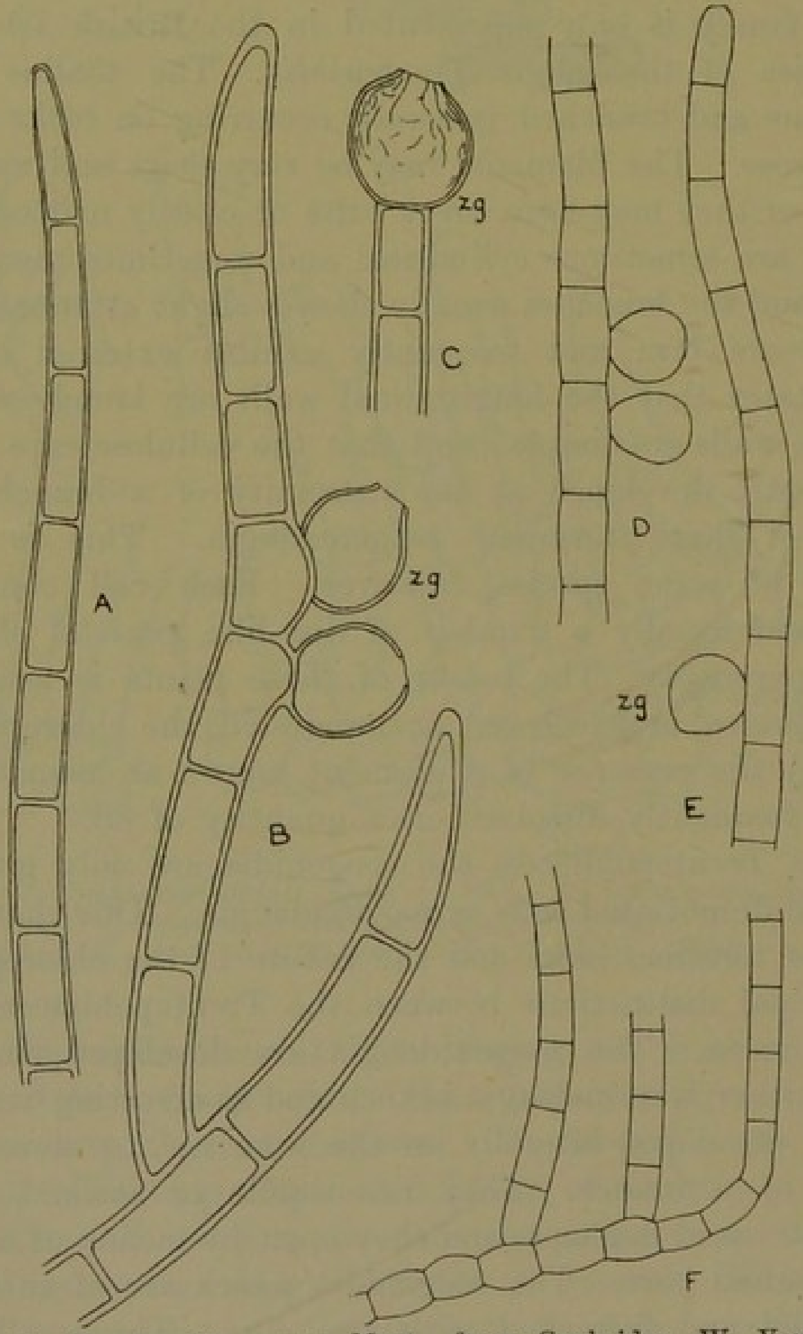

Fig. 34. A—C, *Trentepohlia aurea* Mart., from Cookridge, W. Yorks. (×500). D—F, *T. calamicola* (Zell.) De Toni, from trees near Lough Gartan, Donegal, Ireland (×500). *zg*, zoogonidangium.

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[1] Wildeman, in Mém. couronnés et autres Mém. Acad. roy. Belgique, 1899, tom. lviii.

Genus **Trentepohlia** Martins, 1817. [*Chroolepus* Ag., 1824.] The thallus is filamentous, simple or ramified. The branches are alternate, of the same diameter as the principal filaments, and do not terminate in a point or hair. The chloroplasts are numerous, discoidal, and without pyrenoids, but are generally masked by the presence of a red or orange-red oil which colours blue with iodine.

The most abundant species in the British Islands is *T. aurea* Mart., which occurs principally in hilly and mountainous districts, forming broad expanded sheets of a bright red or orange-red colour. It is chiefly found attached to rocks, particularly carboniferous limestone or silurian rocks, and generally on the windward side. The filaments are 10—20 μ in thickness (fig. 34 A—C). *T. odorata* (Ag.) Wittr [= *T. umbrina* (Kütz.) Bornet] and *T. calamicola* (Zeller) De Toni (thickness of filaments 7·5—10 μ; fig. 34 D—F) are much smaller British species of the genus.

Order III. ULVALES.

This order is mainly distinguished from the Chætophorales by the expanded, *parenchymatous* thallus, which is attached when young to a substratum by 'rhizoids.' The cells are uninucleate and they contain a single parietal chloroplast, often of considerable bulk and containing one pyrenoid.

Asexual reproduction takes place by zoogonidia and also by gemmation. Sexual reproduction is by isogamous planogametes with two cilia.

There is only one family which has few freshwater representatives.

Family 1. **ULVACEÆ.**

The Algæ belonging to this family are more often marine or brackish in habit than freshwater. They consist of flat, ribbon-shaped or expanded plates, or more rarely they exhibit a vesicular or intestiniform structure. These flat or tubular structures consist of one (*Monostroma*) or two (*Ulva*) layers of cells which may be somewhat scattered and rounded in form, in which case they are frequently arranged in groups of four, or they may be closely compact with polygonal outlines. The two genera *Monostroma* and *Enteromorpha* have freshwater representatives, and in each case the thallus consists of a single layer of cells, division only taking place in one plane. The cells are usually compact and arranged with their long axes at right angles to the plane of the thallus (fig. 35 D). Each cell contains a single nucleus and one large parietal chloroplast, often with deeply incised or lobed margins and containing a single pyrenoid. In *Monostroma bullosa* (Roth) Wittr. the cells are generally arranged in T-shaped groups of four.

Asexual reproduction takes place in *Ulva* by zoogonidia (sometimes termed megazoospores) with four cilia. These come to rest and germinate directly. *Monostroma* has been observed to reproduce itself asexually by budding off small flat portions from the surface of the thallus, each portion producing a new plant. Geddes[1] has observed a process of gemmation in *Enteromorpha.*

Sexual reproduction is brought about by the conjugation of isogamous gametes. Ordinary cells of the thallus become gametangia and give rise to eight (sometimes four or sixteen) planogametes, which are pear-shaped bodies, smaller than the zoogonidia, with a pigment spot and two long cilia. On conjugation the two gametes coalesce slowly and a "zygozoospore," or a rounded cell with two pigment spots and four cilia, is first formed; this loses its cilia and becomes a zygospore (fig. 35 J). The zygospore usually germinates directly, first forming a short filament of four cells, which soon produce a flat expansion by dividing in two directions in the same plane. According to Reinke the zygospore sometimes becomes a resting-spore or hypnocyst, which on germination divides into four and then eight cells arranged peripherally round a central cavity. By the increase of these peripheral cells a vesicular thallus is produced, which in most instances ultimately becomes a flattened expansion attached by a few rhizoids at its base.

Genus **Monostroma** Thur., 1854. The thallus in the adult plant is always a thin membranaceous plate. In its younger stages it is frequently vesiculose, opening out as it grows into a foliaceous plate, finally becoming free-floating. It consists of a single layer of rounded or more or less angular cells which are often disposed in groups of four. The zoogonidia possess either two or four cilia, and the gametes are biciliated and rather smaller in size.

Few species of the genus inhabit fresh water, the only British representatives being *M. bullosa* (Roth) Wittr. and *M. membranacea* West & G. S. West

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[1] Geddes in Trans. Roy. Soc. Edinburgh, 1881, p. 555.

(fig. 35, A—K). In the former species the cells are rounded, 6—12 μ in diameter, and arranged in fours, the two pairs often being disposed in a more or less T-shaped manner. In the latter species the cells are much more compact, angular, and 8—20 μ in diameter.

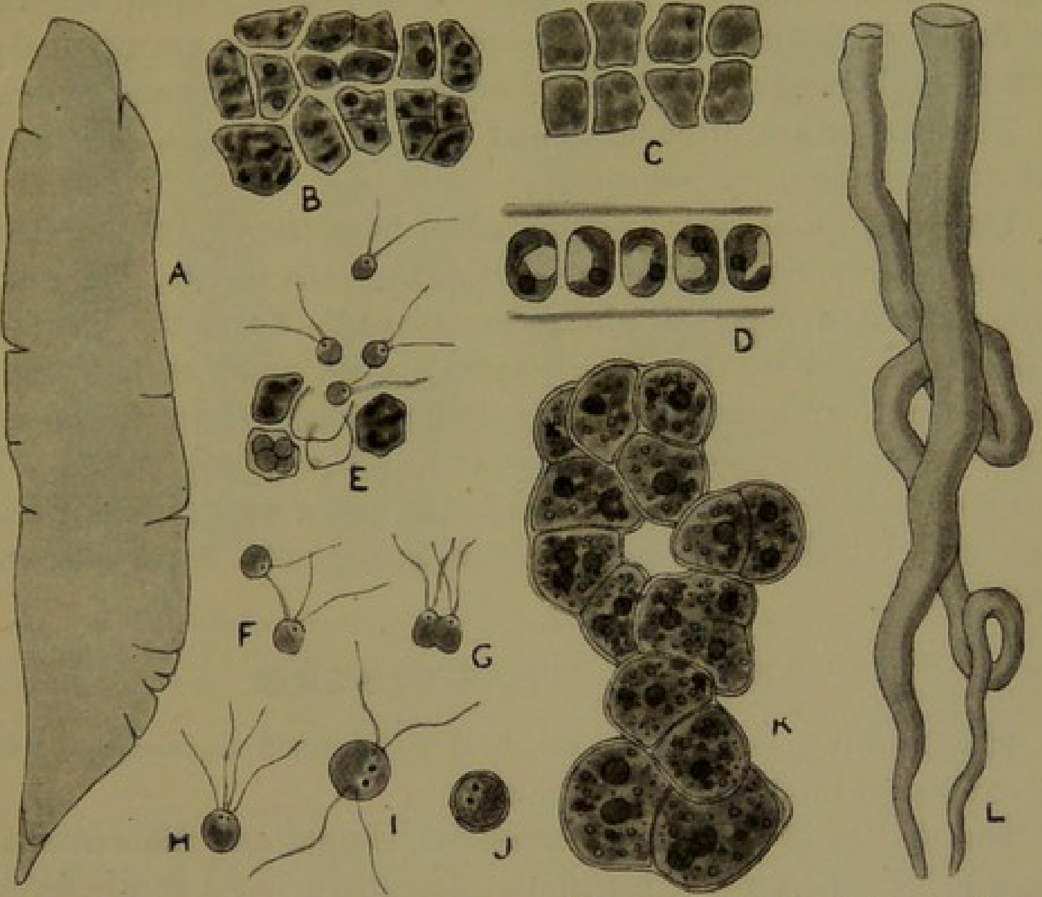

Fig. 35. A—K, *Monostroma membranacea* West & G. S. West, from Mitcham Common, Surrey. A, nat. size; B and C, portions of thallus showing cells; D, section of thallus; E, cells with escaping gametes (×566). F—J, conjugation of gametes (F—H, ×566; I and J, ×790). K, young plant developed from hypnospore (×566). L, *Enteromorpha intestinalis* (L.) Link, from Frizinghall, W. Yorkshire (nat. size).

Genus **Enteromorpha** Link, 1820. The thallus is elongated, tubular and intestiniform, sometimes reaching a considerable length. It is green, yellowish-green, or pale olive-green in colour, and consists of a single layer of rounded or polygonal cells, each with a parietal chloroplast.

The only freshwater species of the genus is *E. intestinalis* (L.) Link (fig. 35 L), an Alga which also occurs in brackish water and in the sea. It is widely distributed in the large drains and dykes in the east of England, and also occurs frequently in canals and ponds in other parts of the country.

Order IV. SCHIZOGONIALES.

The thallus is filamentous, sometimes (especially in young stages) parenchymatous, and often expanded into broad sheets by the fusion of the filaments in one plane. The cells are uninucleate with a single central, stellate chloroplast, containing one pyrenoid.

The plants are often attached by 'rhizoids' to a substratum, and are subaërial in habit.

The order is at once distinguished from the Chætophorales by its chloroplasts, and by the division of the cells in two, and often in three directions, especially in young plants. From the Ulvales it is distinguished by its chloroplasts, by the more or less regular longitudinal arrangement of the thallus-cells, and by the absence of the vesicular stage in the growth of the young plants. The plants of this order have most probably had a very different origin from the Ulvales, the resemblance being only a parallelism of modification.

Family 1. **PRASIOLACEÆ.**

This family has been established to include those Algæ which are embraced in the Schizogoniales.

The thallus is commonly terrestrial, simple and filamentous, or forming flat, creeping expansions. It consists of a single layer of cells produced largely by a fusion of the contiguous walls of cell-filaments. Each cell possesses a central, stellate chloroplast with one pyrenoid.

Asexual reproduction takes place by gemmation and by the formation of resting akinetes. Lagerheim has observed the production of 'tetraspores.'

Chodat regards the family as having analogies to the Bangiaceæ among the Rhodophyceæ, both on account of the production of tetraspores and the mode of growth.

Genus **Prasiola** Ag., 1821. [Inclus. *Schizogonium* Kütz. 1843, and *Hormidium* Kütz. 1843.] The genus occurs on moist earth, rocks, stones, old walls, trunks of trees, etc. The thallus is filamentous, consisting of one, two, or many series of cells, or foliaceous and expanded with the cells arranged more or less in groups of four. The cells of the ordinary filaments are broader than long and those of the flat expansions are quadrate or polygonal in form. The cell-wall is strong, rigid and hyaline. The single chloroplast is central, star-shaped, and contains one pyrenoid. Sometimes the thallus is fixed by rhizoids and sometimes not. In the broader, flat expansions the cell-walls are thick and confluent, and the cells have the appearance of being separated by considerable spaces. Reproduction is by a process of gemmation, by akinetes liberated at the margins of the thallus, and by tetraspores[1]. Gay and Chodat separate the genera *Schizogonium* and *Prasiola*, but I am inclined to agree with Wille[2] in uniting them under *Prasiola* Ag.

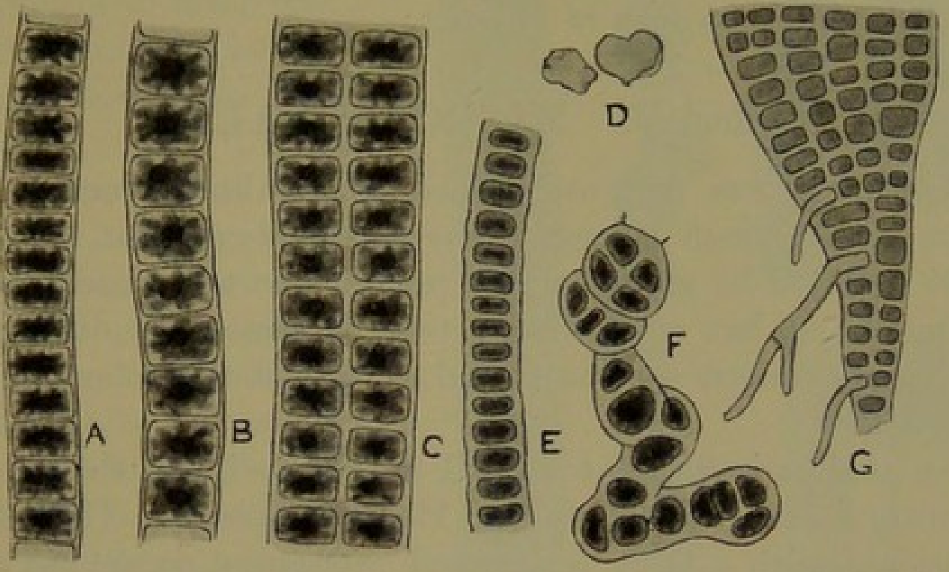

Fig. 36. A—C, *Prasiola parietina* (Vauch.) Wille, from Bradford, W. Yorkshire (×500). D—G, *Prasiola crispa* (Lightf.) Menegh.; D, examples from Bradford, W. Yorks. (nat. size); E, simple filament from Helvellyn, Westmoreland; F, portion of irregular filament from Wimbledon Common, Surrey (×500); G, basal portion of broader thallus, from Bradford, W. Yorks. (×400).

Wille and Börgesen[3] have each described some interesting marine forms of this genus in which the plants are more amply supplied with rhizoids. The expanded thallus of these forms does not reach such a large size as the thallus of the land forms.

Two species are abundant, *P. crispa* (Lightf.) Menegh. [which includes *Hormidium murale* Kütz.; *Schizogonium crispum* (L.) Gay; and *Ulothrix radicans* Kütz.], the cells of which are 7—14 μ in diameter (fig. 36 D—G), and *P. parietina* (Vauch.) Wille [which includes *Schizogonium murale* Kütz. and *Hormidium parietinum* Kütz.] with cells 9—18 μ in diameter (fig. 36

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[1] Lagerheim, 'Ueber die Fortpflanzung von Prasiola,' Ber. Deutsch. Botan. Gesellsch. 1892, Bd x, Heft 7.

[2] Wille, 'Studien über Chlorophyceen I-VII,' Vidensk. Skrifter, I math.-naturv. Klasse, 1900, no. 6, p. 13.

[3] Börgesen, 'Marine Alg. of the Faeröes,' Bot. of Faeröes, Part II, 1902.

A—C). These two species are widely distributed all over the British Islands, and they have a decided preference for the neighbourhood of towns, being found frequently under walls and as a green carpet between the paving-stones of quiet streets. They require little moisture and can withstand considerable desiccation. Associated with them are generally numerous *Rotifera vulgaris* and testaceous Rhizopods such as *Trinema acinus*. *Prasiola furfuracea* Menegh. is probably a form of *P. crispa*.

Order V. MICROSPORALES.

This order was first established by Bohlin to include those curious plants which belong to the genus *Microspora*. It seems at first sight to be giving undue prominence to a small group of aberrant Algæ, but at the same time it removes a difficulty, as these plants cannot well be placed in any of the other orders of green Algæ.

The thallus is filamentous and unbranched, and the cell-walls frequently become broken up into H-shaped pieces. The cells are uninucleate, with a large reticulated chloroplast occupying almost the entire inner surface of the cell-wall, and destitute of pyrenoids. The affinities of the order are very doubtful.

Family 1. **MICROSPORACEÆ.**

This small family includes only one genus. The thallus is filamentous and simple, and the cells are cylindrical. The cell-walls are composed of cellulose, are either homogeneous or more or less distinctly lamellose, and of a similar structure to those of *Tribonema* (*Conferva*), the cells often becoming disarticulated into H-shaped pieces. A single nucleus of considerable size is present in the centre of each cell. The chloroplast is disposed on the walls of the cell and may be band-like or sheet-like, covering more or less the entire cell-wall. It is usually areolated or reticulated, and really consists of a fusion of numerous cushion-like, chlorophyllaceous masses to form a stout areolated structure. There are no pyrenoids, but scattered granules of starch are often present.

Asexual reproduction takes place by the formation of aplanospores which become hypnospores (fig. 37 C and F); also by the production of biciliated or quadriciliated zoogonidia, one or two of which are found in a cell. Sometimes several small micro-zoogonidia are produced in a cell. The zoogonidia germinate directly.

Genus **Microspora** Thuret, 1850; em. Lagerh., 1888. The filaments are simple, consisting of cylindrical or slightly swollen cells. The cell-walls are firm, frequently distinctly lamellose, and sometimes dissociating into pieces which appear **H**-shaped in optical section, each piece consisting of a transverse wall and portions of the lateral walls of two adjacent cells. There is one cell-nucleus. The chloroplast is disposed on the cell-walls as a more or less reticulated mass. Globular hypnospores are produced, with thick walls, usually one in each cell.

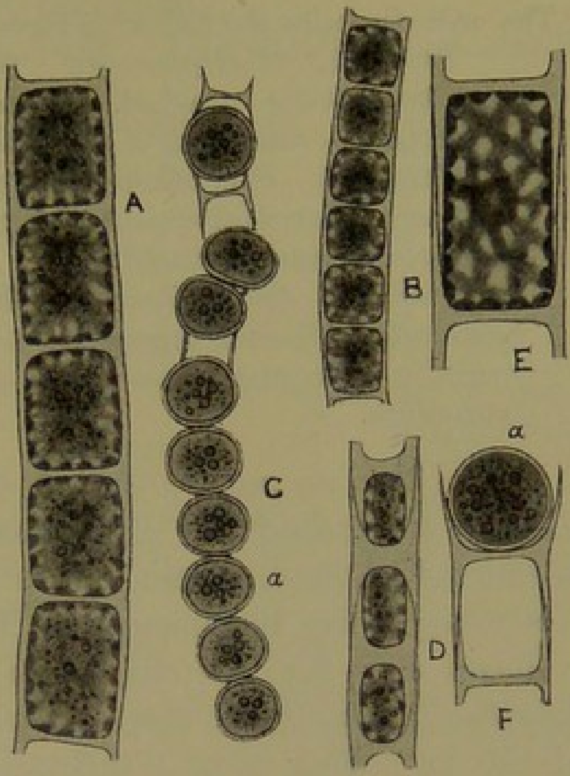

Fig. 37. A, *Microspora amœna* (Kütz.) Lagerh., from near Senens, Cornwall. B and C, *M. abbreviata* (Rabenh.) Lagerh.; B from Tremethick Moor and C from St Just, Cornwall. D, *M. pachyderma* (Wille) Lagerh., from near Land's End, Cornwall. E and F, forms of *M. amœna* (Kütz.) Lagerh.; E, from Shipley, W. Yorks., to show the chloroplast; F, from New Forest, Hants. *a*, aplanospores. (All × 520.) E is *M. amœna* var. *crassior* Hansg.

There are several widely distributed species of this genus in the British Islands. *M. floccosa* (Vauch.) Thur. and *M. amœna* (Kütz.) Lagerh. (fig. 37 A, E and F) are the most abundant and often occur in small ponds and horse-troughs. *M. abbreviata* (Rabenh.) Lagerh. (fig. 37 B and C) and *M. pachyderma* (Wille) Lagerh. (fig. 37 D) are not so frequent.

Order VI. CLADOPHORALES.

In this order are included three families of green Algæ which bear close relationship to the Siphoneæ and yet can scarcely be relegated to that order. The thallus is simple or branched and incompletely septate, each segment containing many nuclei and numerous parietal chloroplasts, the latter containing single pyrenoids.

Asexual reproduction takes place by biciliated or quadriciliated zoogonidia, by 'cysts,' or by special resting-spores (*Pithophora*);

and sexual reproduction is either by isogamous planogametes or by well-differentiated heterogamous gametes.

The order includes the following three families:—

Family 1. *Cladophoraceæ.* Thallus large, branched, incompletely septate, usually attached. Segments large with numerous small chloroplasts, each with a pyrenoid.

Family 2. *Pithophoraceæ.* Thallus similar to that of the Cladophoraceæ, but distinguished by the formation of barrel-shaped and fusiform asexual resting-spores.

Family 3. *Sphæropleaceæ.* Filaments simple, composed of elongated cœnocytes. Sexual reproduction heterogamous; plants monœcious; oogonia with many non-motile oospheres; fertilization within the oogonium.

Bohlin has recently proposed to transfer the families Cladophoraceæ (including the Pithophoraceæ) and Sphæropleaceæ to the order Siphoneæ, placing them next the Valoniaceæ. In this he is followed by Blackman and Tansley, but it yet remains to be shown how far this change is justified. The thallus of the Cladophorales is much more septate than that of the Siphoneæ and the branching is of a different nature.

Family 1. **CLADOPHORACEÆ.**

The thallus is large, filamentous and incompletely septate, each segment being a cœnocyte. The filaments usually have a basal organ of attachment, and in the genus *Cladophora* are much branched. The growth of the thallus is apical in *Cladophora* but intercalary in the other genera.

There are several nuclei in each segment of the thallus and either one reticulate, parietal chloroplast or a large number of separate chloroplasts, each with a pyrenoid.

Asexual reproduction takes place in *Cladophora* and *Chætomorpha* by zoogonidia which are produced in large numbers in the mother-cell and escape either by a terminal or lateral pore. 'Cysts' are also produced in *Rhizoclonium*, each one being a kind of large thick-walled akinete formed from a single segment.

An isogamous sexual reproduction occurs in *Cladophora*, the conjugation of the planogametes resulting in a zygospore which germinates directly without rest.

Very little, if any, mucus is secreted by these Algæ and they always feel rough and crisp. The absence of a mucous outer coat causes them to be frequently loaded with epiphytes. Very often the older filaments are thickly covered with Diatoms, particularly of the genera *Gomphonema* and *Cocconeis*.

Genus **Chætomorpha** Kütz., 1845. The filaments are simple, of more or less uniform thickness and fixed at the base, the lower segments being shorter than the upper ones. The segments are often slightly swollen and they are of considerable diameter. The cell-wall is thick, very firm and obviously lamellose.

Most of the species of this genus are truly marine or brackish in habit, but *Ch. sutoria* (Berk.) Rabenh. (fig. 38) is sometimes found in running water, in wells and horse-troughs, or in streams. Diameter of filaments 100—120 μ.

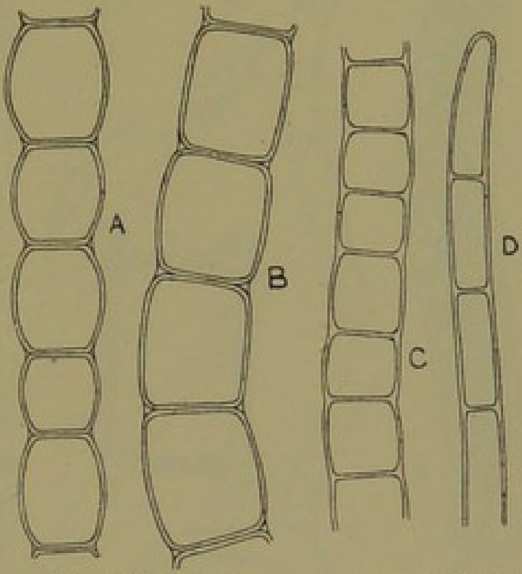

Fig. 38. *Chætomorpha sutoria* (Berk.) Rabenh., from Heaton, W. Yorks. (×100).

Genus **Rhizoclonium** Kütz., 1843. The filaments are of variable size, crisp, generally branched, and attached at the base by a branched hapteron. The branches are short, slightly attenuated, sometimes merely unicellular outgrowths, but more frequently consisting of several cells. The filaments are often bent at the point of origin of a branch. The cell-walls are firm, lamellose, and sometimes attain a considerable thickness. The number of nuclei present in each segment is variable and the chloroplast is in the form of a network containing several pyrenoids. The most recent account of the structure of this genus is by Wille[1], who confirms much that has been described by Gay[2]. Stockmeyer[3] has given a thoroughly good systematic account of the genus.

In the autumn the segments of the thallus are often packed with starch.

Species of this genus are marine, brackish, freshwater, or they may even occur on damp soil. The only freshwater British species is *R. hieroglyphicum* Kütz.; em. Stockm. [=*Conferva fontinalis* Berk.; *Microspora fontinalis* De

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[1] Wille, 'Studien über Chlorophyceen VII,' Vid.-Selsk. Skrifter. M.-N. Kl. Christiania, 1900.

[2] Gay, 'Recherches sur le dével. et la classif. de quelques Algues Vertes,' Paris, 1891.

[3] Stockmeyer, 'Über die Algengattung Rhizoclonium,' Verhandl. der k. k. Zool.-Bot. Gesellsch. in Wien, Jahr. 1890.

Toni] which possesses filaments 10—37 μ in diameter and segments 2—5 times longer than the diameter (fig. 39 A). The common form of this species possesses no branches whatever and occurs abundantly in ponds, ditches, drains, streams and cataracts all over the country, thriving well in water in which considerable putrefaction is taking place. The following varieties of it are widely distributed:—var. *Kochianum* (Kütz.) Stockm. [=*R. Kochianum* Kütz.; *R. flavicans* Rabenh.], var. *tortuosum* (Kütz.) Stockm. (fig. 39 B—E), and var. *riparium* (Harvey) Stockm.

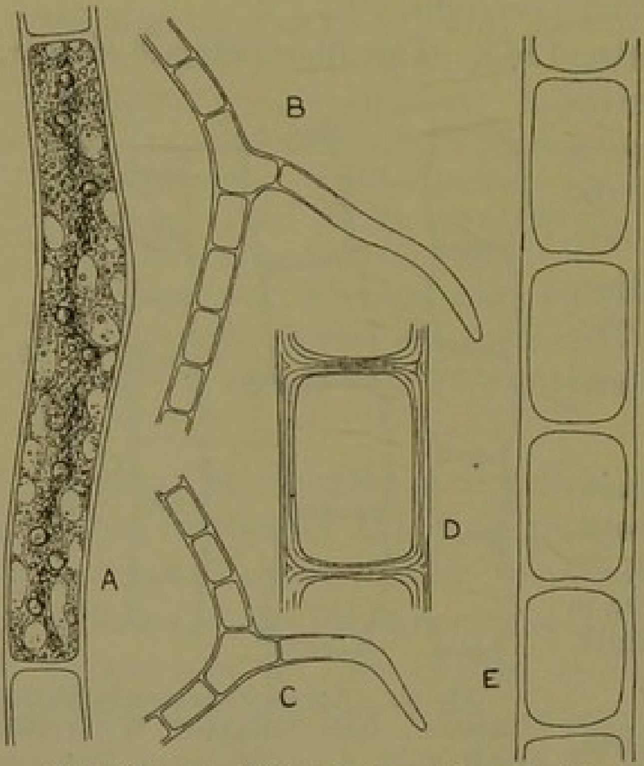

Fig. 39. A, *Rhizoclonium hieroglyphicum* Kütz., single cell showing chloroplast and pyrenoids, from Sheep's Green, Cambridge (× 500). B—E, *R. hieroglyphicum* Kütz. var. *tortuosum* (Kütz.) Stockm., from Heaton, W. Yorks.; B and C, × 100; D and E, × 500.

Genus **Cladophora** Kütz., 1843. This is the best known genus of the family and is widely distributed in salt and fresh waters. The thallus is branched, the type of branching varying with different species, and the segments are 6—12 (or even up to 20) times longer than their diameter. There are usually many nuclei in a segment, but they may be reduced to two or even one. The chloroplast is parietal and most commonly reticulate, but all intermediate stages are met with between an elongated reticulate cylinder and isolated plates[1]. There is one pyrenoid in each isolated plate or in each corresponding piece of the reticulum. The cell-wall consists of an inner and outer layer, and, according to Brand, of an 'outermost' layer which can be separated by acetic acid. The zoogonidia are very numerous and escape from the mother-cell through an opening formed by a complete absorption of the cell-wall. Nordhausen[2] regards the basal branching of the segments in a filament of *Cladophora* as a peculiar process, to which there is nothing strictly comparable in other Algæ. Brand states that the species with strong, primary, basal organs of attach-

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[1] Brand in Beitr. z. Bot. Centralbl. x, 1901.

[2] Nordhausen in Pringsheim's Jahrb. f. wiss. Bot. xxxv, 1900.

ment usually form zoogonidia, and that the free-floating species are usually propagated by resting-spores.

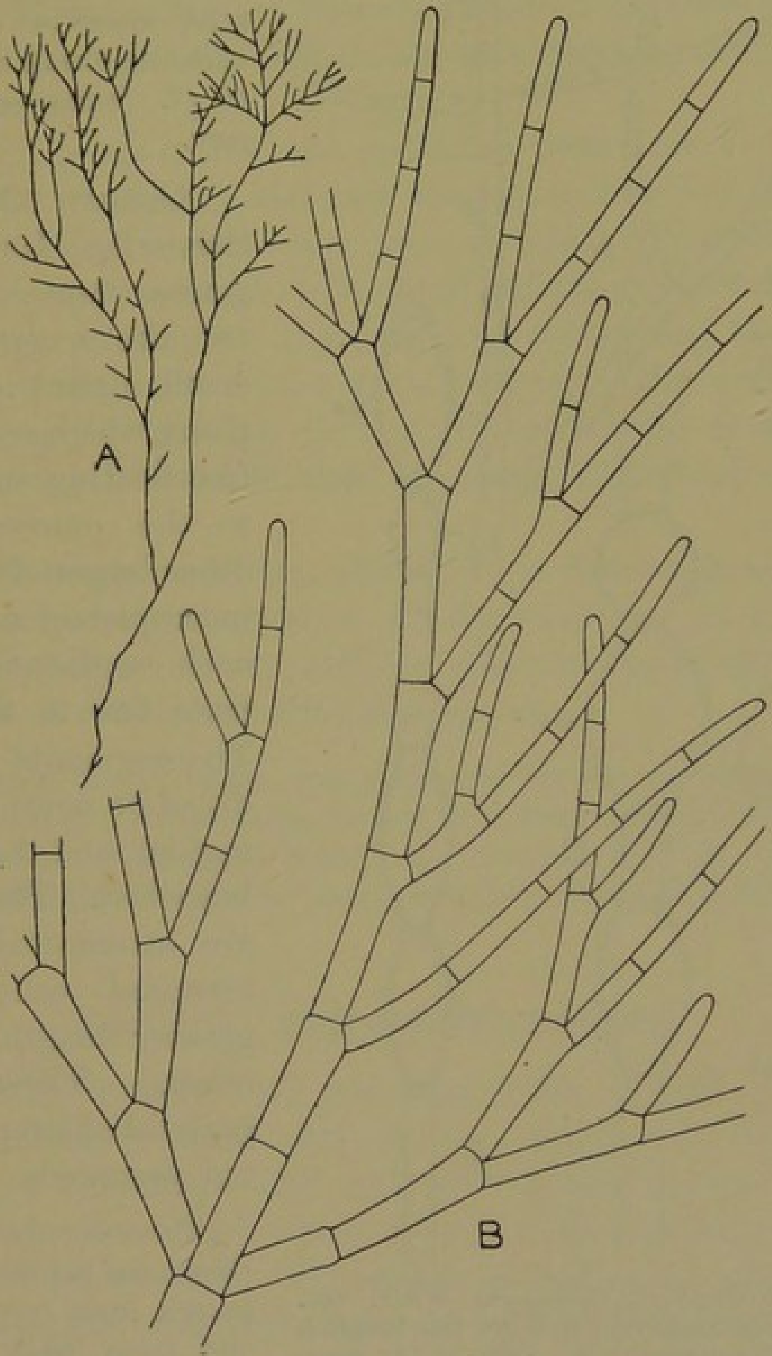

Fig. 40. *Cladophora glomerata* (L.) Kütz., from Shipley, W. Yorks. A, nat. size; B, ×85.

Most of the species of the genus are marine, but some five or six British freshwater species are known. *Cl. glomerata* (L.) Kütz. (fig. 40) is an abundant species, occurring as dark green masses attached to rocks and stones in streams and waterfalls. The branching is dense and the smaller branches are in tufts. *Cl. crispata* (Roth) Kütz. is another common species, usually occurring attached to stones. *Cl. flavescens* Ag. is a more slender species of a pale yellowish-green colour and frequently occurs floating freely in ponds and

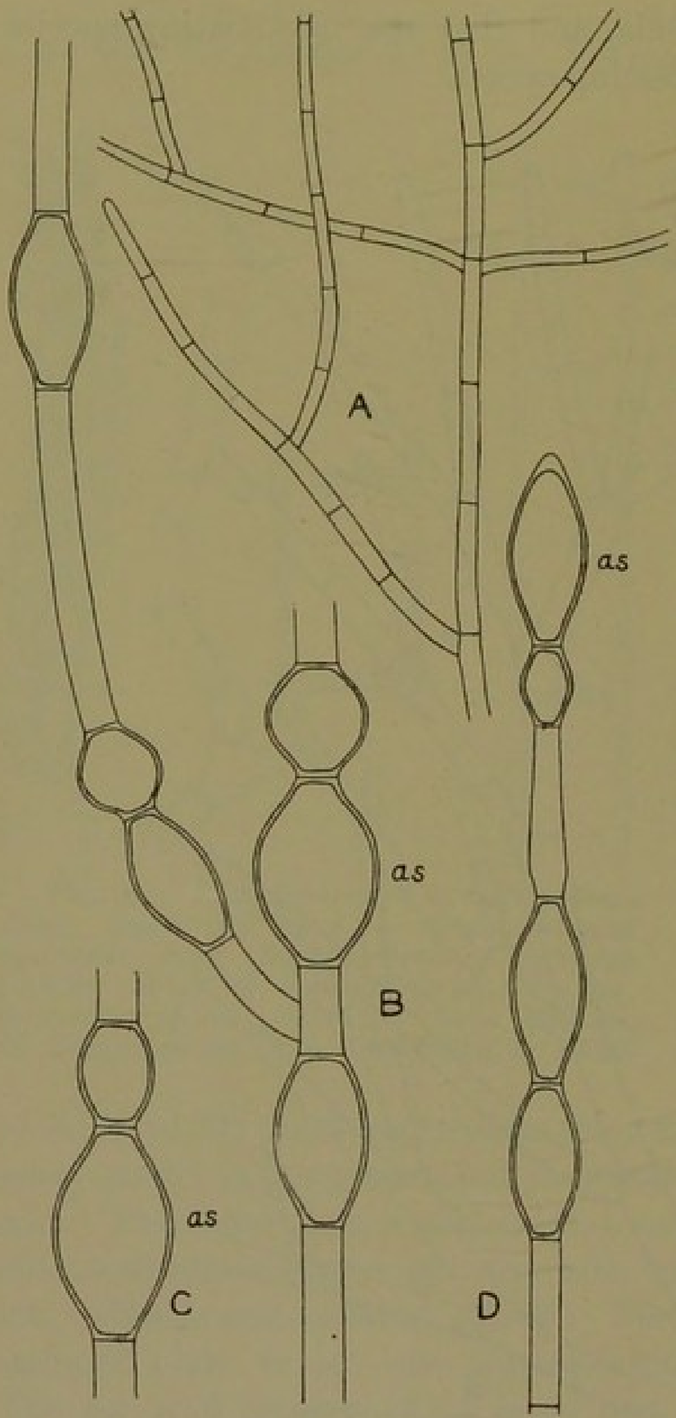

Fig. 41. *Pithophora Œdogonia* Wittr. var. *polyspora* Rendle and West f., from the Reddish Canal, near Manchester, A, × 65; B—D, fragments of thallus with asexual resting spores (*as*), × 100.

ditches. Brand[1] states that all the European species of *Cladophora* described by Rabenhorst, except the Ægagropilæ, must be regarded as varieties, forms, or conditions of *Cl. fracta* or *Cl. glomerata*.

Genus **Chætonella** Schmidle, 1901[2]. This genus was instituted for the reception of a small, almost microscopic plant, which occurs either free-floating or attached to the mucous coat of other larger Algæ. It is incompletely septate, and each segment possesses from two to five nuclei. The segments are cylindrical or more or less irregular, and the thallus is branched. The branches are attenuated and the terminal cells are of greater length than the others. There is one parietal chloroplast without pyrenoids.

There is only one species, *Ch. Goetzei* Schmidle, which is known from tropical Africa and from West Yorkshire. The filaments are 6—8 μ in thickness.

Family 2. PITHOPHORACEÆ.

The plants of this family very much resemble species of the genus *Cladophora*. The thallus is of exactly the same type and the

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[1] Brand in Bot. Centralbl. lxxix, 1899.

[2] Schmidle in Engler's Botan. Jahrbüch. Bd 30, Heft 2, 1901, p. 253, t. v, f. 1, 2.

growth is apical. The thallus is almost always branched, the branches arising a little below the top of their supporting cells, and it is attached below by well-developed haptera put out from a basal cell. It is doubtful if there is sufficient evidence to warrant the separation of the Pithophoraceæ as a distinct family from the Cladophoraceæ.

Asexual resting-spores are produced here and there in the thallus, either intercalary and cask-shaped, or terminal and ovoidal or fusiform. These spores, which were termed by Wittrock 'agamospores,' are richly filled with chlorophyll and the spore-wall increases considerably in thickness. Formation of spores may take place in all the cells of the cauloid part of the thallus. After a short period of rest the spores develop in opposite directions from the two apices. There is another method of asexual reproduction by 'prolific cells.'

Genus **Pithophora** Wittr., 1877. This striking genus of Algæ is almost exclusively tropical in its distribution. It is the only representative of the family, and few Algæ are more characteristic than a plant of *Pithophora* with ripe spores.

P. Œdogonia (Mont.) Wittr., var. *polyspora* Rendle and West f.[1] (fig. 41) may be regarded as a British Alga, having been found in the Reddish Canal, near Manchester. *P. Kewensis* Wittr. occurred in a tank in the water-lily house, Kew Gardens, but was most probably introduced from tropical S. America.

Family 3. **SPHÆROPLEACEÆ.**

This family includes only one Alga, which occurs in extensive masses on flooded plains and by the margins of lakes. The filaments are cylindrical and unbranched, and consist of single series of cœnocytes which reach an extraordinary length as compared with their breadth. The transverse cell-walls often become of great thickness, and each segment of the filament contains a considerable number of small nuclei. The chloroplasts, which are in the form of parietal rings, are very numerous and some of them contain pyrenoids.

The sexual organs are oogonia and antheridia, which may be formed without change of shape from any segment of the filament. Sometimes the oogonia and antheridia alternate in a filament, but

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[1] A. B. Rendle and W. West, junr., 'A New British Freshwater Alga,' Journ. Bot. July, 1899, pp. 289—291, t. 399.

more often they do not. A number of oospheres are developed in each oogonium, and a very large number of antherozoids arise by the breaking up of the red contents of an antheridium. The antherozoids are small, elongated bodies, provided with two long cilia, and they find their way into the oogonia through apertures in the transverse walls. After fertilization, which takes place within the oogonium, the oospores develop a thick verrucose cell-wall and the cell-contents become bright red in colour. The oospores generally hibernate within the oogonium, and this is the most striking condition of the Alga, which now consists of long filaments, most of the segments of which are filled with numerous, bright red, verrucose oospores.

On the germination of the oospore from two to eight zoospores are set free, representing the sporophyte generation, and each of these forms a new plant. The young plants are simple, fusiform cells, with each extremity attenuated to a very fine point.

Bohlin has suggested the transference of this family to the order Siphoneæ in close proximity to the family Valoniaceæ.

Genus **Sphæroplea** Ag., 1824. The thallus consists of unbranched filaments of cylindrical cœnocytes, which may only be as long as their diameter or up to ninety times longer. The filaments are 36—72 μ in diameter.

The only known species—*Sph. annulina* (Roth) Ag.—is not a British Alga. It occurs extensively on inundated portions of the plains of Europe, Asia and America, and is sometimes found in pits or quarries. It is questionable if there are any suitable localities for this plant in the British Islands. It sometimes occurs in Kew Gardens, having been introduced from abroad with various aquatic plants.

Order VII. SIPHONEÆ.

The order Siphoneæ embraces a large number of filamentous Algæ of many diverse forms. They are cœnocytic in character, the individuals being without septa, so that in reality each plant consists of a single large cœnocyte. They are mostly marine Algæ and some of them attain a considerable size. The thallus frequently becomes very complicated in character, but even then it consists of the interlaced branches of a single multinucleated cell. Nowhere else in the vegetable kingdom do such gigantic cells occur, and it is this extraordinary complication of a single cell which distinguishes the Siphoneæ from all other Algæ. Many of them have even reached a high stage of specialization, having developed organs analogous to the stem, leaf and root of higher plants. In the genus *Caulerpa* the cell is strengthened by trabeculæ which traverse the lumen of the cell from wall to wall.

Asexual reproduction takes place by proliferous shoots, by non-ciliated spores and by zoogonidia. In most of the Siphoneæ numerous zoogonidia arise in a zoogonidangium, but in *Vaucheria* only one large one is produced.

The plants are generally attached by strongly developed haptera.

The only family of the order which inhabits fresh waters is the Vaucheriaceæ, and it is also the only family in which well-differentiated sexual organs occur. The tropical family Phyllosiphonaceæ includes a number of Algæ which live as parasites on the leaves of Phanerogams.

Family 1. **VAUCHERIACEÆ.**

The thallus is an elongated filament consisting of a single large cœnocyte, and is sometimes branched. This unseptate filament increases in length by apical growth and is usually attached to a substratum by much branched haptera. In most members of the family the cell-wall is thin and relatively weak, easily collapsing even with careful manipulation. The protoplasm forms a thick lining layer on the interior of the wall of the filament and contains a large number of minute nuclei. The chloroplasts are very small and exceedingly numerous; they are oval, elliptical or subcircular in outline and are without pyrenoids. A considerable amount of oil is often present in the filaments, the oil-drops being always in connection with the chloroplasts. Fleissig[1] states that this oily material is a reserve substance, physiologically analogous to starch.

On the injury of the thallus septa usually appear cutting off the injured parts, the uninjured portions developing into new plants. (*vide* fig. 42 A and B.) These are the only instances of the occurrence of septa in the thallus except in connection with the reproductive organs.

Asexual reproduction takes place by the formation of zoogonidia. The extremity of a filament assumes a club-shaped form and becomes densely filled with protoplasm, after which a transverse

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[1] Fleissig, 'Ueber die phys. Bedeutung d. oelartigen Einschlüsse in d. *Vaucheria*,' Basel, 1900.

septum appears and cuts off the swollen end as a zoogonidangium. The contents of this gonidangium, which are of a rich green colour, gradually become rounded off, forming an oval zoogonidium of large size. The whole surface of the zoogonidium is usually clothed with numerous short cilia, arranged in pairs, and in the surface protoplasm under each pair there is a small nucleus. The entire structure contains one central cavity filled with cell-sap which is traversed by strands of protoplasm, and Schmitz has pointed out that it can be looked upon as an aggregate of zoogonidia with a great resemblance to certain of the more complex members of the Volvocaceæ. This compound zoogonidium escapes by an apical opening of much smaller diameter than itself and through which it pushes its way. Sometimes, owing to the rotatory movement of the cilia, the part first exuded becomes separated from the portion still left in the gonidangium and two zoogonidia are formed instead of one.

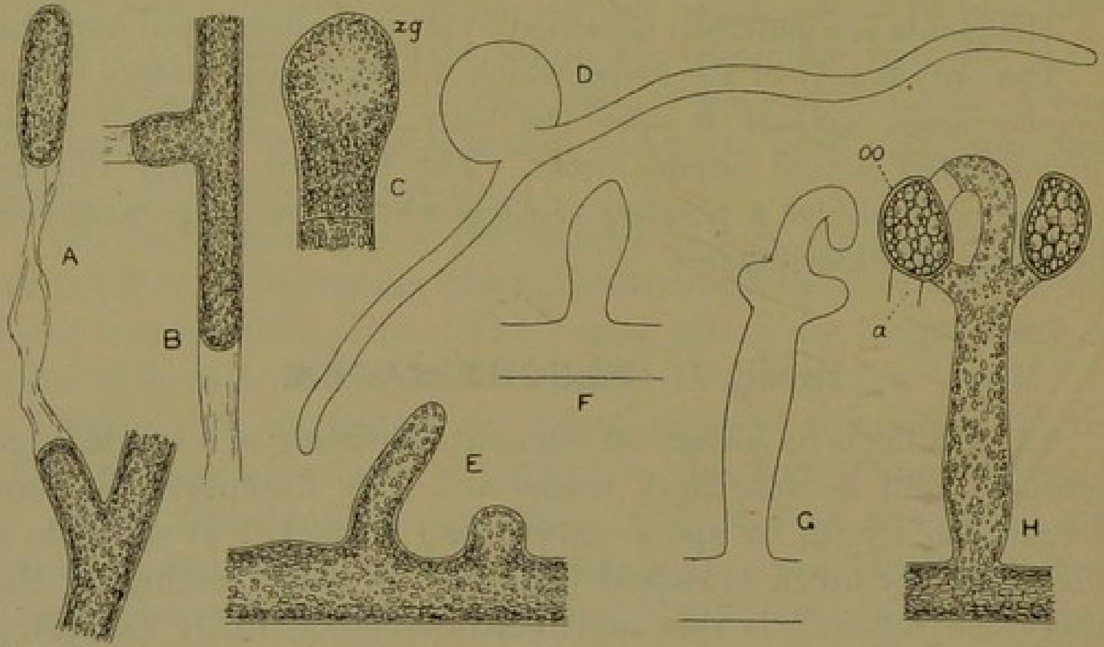

Fig. 42. A and B, portions of thallus of *Vaucheria* showing formation of septa on injury; A, *Vaucheria geminata* (Vauch.) D. C.; B, *V. sericea* Lyngb., from Harefield, Middlesex. C, apex of filament of *V. sessilis* (Vauch.) D. C., showing the zoogonidangium from which will escape a single zoogonidium. D, germination of the zoogonidium of *V. sericea*, from E. Yorkshire. E, *V. sessilis* from W. Yorkshire, showing developing oogonium (on right) and antheridium (on left). F—H, *V. geminata* (Vauch.) D. C., from Barnes Common, Surrey, showing development of sexual organs. (All × 75.) *a*, antheridium, *oo*, oogonium; *zg*, zoogonidangium.

The zoogonidia generally escape in the morning, that is to say, after the plants have been in the darkness for some time. They are sluggish in their movements and continue active for about fifteen minutes. On coming to rest the cilia are at once withdrawn and a cell-wall is developed. Klebs[1] states that zoogonidia can always be produced when filaments which have been kept moist for some days are soaked with water, or when they are removed from a dilute nutritive solution into pure water. The zoogonidia germinate almost immediately by the protrusion of one or more tube-like filaments, one at least of which attaches itself to the substratum by a colourless branched hapteron (or 'rhizoid').

Under unfavourable circumstances, particularly if the plants are liable to become dried up, asexual spores of another kind are sometimes developed. The end of a filament swells up into a more or less globular form and then a transverse wall appears and cuts this portion off. Such a spore may rest a considerable time before germination.

Sometimes, owing to drought, certain filaments break up into a number of distinct cœnocytes, each of which develops a thick cell-wall. These are of the nature of rudimentary gemmæ or *cysts*[2].

Sexual reproduction takes place by oogonia and antheridia, and amongst the Siphoneæ this family of Algæ stands alone in the possession of sharply differentiated sexual organs. These are developed at scattered intervals along the cylindrical filament. Except in the diœcious plants the antheridia and oogonia usually arise side by side on the same filament, or they are differentiated portions of a short lateral branch.

The oogonia usually arise as lateral outgrowths of the filament, or at the end of a very short branch, and they soon assume a more or less rounded or ovate form, being ultimately cut off by a septum at the base. The apex of the oogonium generally develops a rostrum or beak, which is usually turned to one side, either towards the antheridium or away from it. The protoplasm of the oogonium

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[1] Klebs, 'Die Bedingungen d. Fortpflanzung bei einigen Algen u. Pilzen,' Jena, 1896.

[2] Bennett and Murray in their 'Handbook of Cryptogamic Botany,' London, 1889, p. 284, in referring to this special type of asexual reproduction in *Vaucheria*, state that "in this condition it was formerly described as a distinct organism under the name of *Gongrosira*." Dr Scott, also, in his 'Introd. to Structural Botany, Part II,' London, 1897, remarks that "this is called the *Gongrosira* state, because specimens of *Vaucheria* in this condition used to be placed in a different genus under that name." These are most unfortunate statements, as *Gongrosira* is a well-established genus of the Chætophorales, which reproduces itself asexually by minute biciliated zoogonidia, and none of the plants of which approach in size even the smallest known species of *Vaucheria*.

contains a considerable amount of oil, numerous chloroplasts, and after the appearance of its basal wall, only one nucleus. That portion of the protoplasm towards the apex or beak becomes clear and free from chloroplasts, and is termed the receptive spot. The cell-contents now become rounded off, forming the ovum (or oosphere) and soon afterwards the wall of the oogonium opens at the extremity of the beak, a small quantity of mucilaginous protoplasm being exuded.

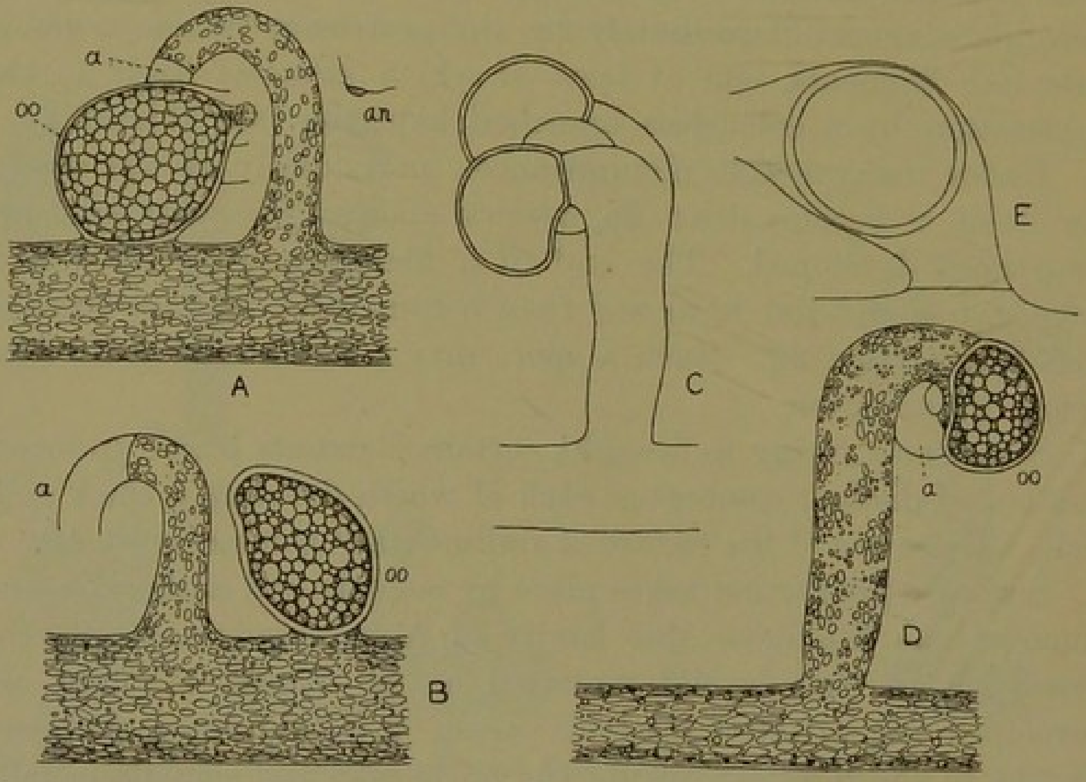

Fig. 43. A and B, *Vaucheria sessilis* (Vauch.) D. C.; A, from Esher West-end Common, Surrey; B, from Mitcham Common, Surrey. C and D, *V. hamata* (Vauch.) Lyngb., from Calverley, W. Yorks. E, oogonium and oospore of *V. sericea* Lyngb., from Beverley, E. Yorkshire. (A—D, ×200; E, ×320.) *a*, antheridium; *an*, antherozoid; *oo*, oogonium.

The antheridia develop simultaneously with the oogonia and generally in close proximity to them. (Fig. 42 E.) Each antheridium arises as a short cylindrical branch which usually becomes much curved on approaching maturity. (Fig. 43 A and B.) The terminal portion of this curved branch is cut off by a septum and becomes the actual antheridium. In some species, such as in the submarine *Vaucheria synandra*, a number of antheridia occur on a structure known as an "androphore." The protoplasm of each antheridium contains numerous chloroplasts and nuclei. The nuclei collect in the central portion of the antheridium and it is this part which breaks up into the antherozoids (or spermatozoids). The latter are extremely minute, each one consisting of a small amount of protoplasm surrounding a nucleus and possessing two cilia. The cilia are attached far apart and point in opposite directions. (Fig. 43 A, *an.*) The antherozoids swarm for a short time within the antheridium, which soon opens at the apex and sets them free. A certain amount of unused protoplasm is expelled with the antherozoids and another portion is left behind in the antheridium.

The antherozoids swarm near the opening of any oogonium they may happen to reach and frequently several of them enter the oogonium. One of them fuses with the oosphere at the region of the receptive spot and its nucleus travels through the protoplasm of the oosphere until it reaches the single nucleus of the latter. The male and female nuclei then unite and fertilization is effected.

The fertilized ovum or oospore now invests itself with a cell-wall of considerable thickness and undergoes a prolonged rest. The oospores can withstand a certain amount of desiccation, and on germination they give origin to a new plant without any alternation of generations.

Genus **Vaucheria** DC., 1803. This is a widely distributed genus of Algæ the filaments of which are interwoven to form compact, mat-like masses, either on damp earth, or in fresh or salt water. They most commonly occur in situations where they are subject to the splashing or trickling of water, although some habitually occur on damp ground or are entirely submerged. They are most abundant in the earlier months of the year. The filaments are coarse and thick, consisting of large cœnocytes, which sometimes reach 30 cms. in length, and their numerous chloroplasts give them a dark green colour. They are very sparsely branched, and some species rarely exhibit any branching except in connection with the formation of the sexual organs. Diœcious species of the genus exist, but in most others the antheridia and oogonia are developed in close approximation on the same filament. The filaments are sometimes subject to the attacks of the Rotifer *Notommata Werneckii*, which produces irregular gall-like swellings.

V. sessilis (Vauch.) DC. is perhaps the commonest species of the genus, being widely distributed in damp and wet situations in the neighbourhood of streams, cataracts and boggy springs; thickness of filaments 65—80 μ (figs. 42 C and E; 43 A and B). *V. geminata* (Vauch.) DC. also occurs in similar localities; thickness of filaments 78—90 μ (fig. 42 A, F—H). *V. terrestris* Lyngb., and *V. hamata* (Vauch.) Lyngb. (fig. 43 C and D), occur in profusion on damp ground, often forming thick mats on gravel paths and on the surface soil of damp flower-pots. *V. sericea* Lyngb., which is the smallest British species (thickness of fil. 48—55 μ; fig. 42 B and D, 43 E), and *V. aversa* Hass. usually occur entirely submerged in the waters of ditches and ponds. *V. dichotoma* (Lyngb.) Ag. is the largest British species (thickness of fil. 180—220 μ) and is diœcious. Some forms of it are truly marine, but others occur in brackish water.

Order VIII. CONJUGATÆ.

The order Conjugatæ is one of the best defined and most natural of the groups of the Chlorophyceæ. The thallus is unicellular in the Desmidiaceæ and the individuals exhibit great specialization of form. In the Zygnemaceæ, which is the only other family of the order, the plants are multicellular, consisting of unbranched filaments of cylindrical cells. These filaments are, however, fragile and often become dissociated into their individual cells. All the plants of this order, whether unicellular or multicellular, are remarkable for the great development of the gelatinous pectose constituents of the cell-wall. There appears to be a continual exudation of this gelatinous material, until, in some instances, it is of much greater bulk than the individual plant, and it frequently happens that the unicellular forms occur embedded in a mass of transparent jelly formed by the coalescence of their outer gelatinous coverings.

One of the most conspicuous features of the order is the presence of chloroplasts of large size and definite form. They vary in number from one to about eight or twelve in each cell and they exhibit great variety in form and symmetry. Each chloroplast contains one or more conspicuous pyrenoids. Boubier[1] has observed in species of *Spirogyra* and in *Mougeotia scalaris* Hass. what he terms 'compound pyrenoids.' These consist of an agglomeration of pyrenoid structures enclosed in a membrane and containing in the centre a pyrenocrystal.

Multiplication of the filamentous forms sometimes takes place by the fragmentation of the filaments, each cell undergoing rapid division and forming a new plant.

Asexual reproduction may be brought about in the Zygnemaceæ

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[1] Boubier in Bull. Herb. Boissier, vii, 1899.

by the formation of resting-cells with thick walls, which have received the name of 'cysts.' These are capable of surviving the winter. In both the Zygnemaceæ and Desmidiaceæ aplanospores are sometimes formed. Zoogonidia are entirely absent from this order of green Algæ.

Sexual reproduction takes place by the conjugation of isogamous gametes and the formation of a zygospore. As the gametes are devoid of cilia and therefore non-motile, they are known as aplanogametes. The ordinary vegetative cells become the gametangia, usually without change of form, and only one gamete arises from a gametangium, the entire cell-contents of which are generally utilized in its formation. In the Desmidiaceæ (with a solitary exception) the gametes are set free and conjugation takes place outside the gametangia, but in the Zygnemeæ the gametes unite either within one of the gametangia or within the connecting-tube which joins them. In these groups the zygospore after a period of rest forms a new gametophyte, but in the Mesocarpeæ the zygospore immediately forms a rudimentary sporophyte with one spore (a carpospore); the latter undergoes a long rest.

Much has been written concerning the sexuality of the Conjugatæ, and much of the evidence which has been brought forward of late years indicates that sexuality of a low type does exist. This sexuality is less marked in some Conjugates than in others, and least of all in the Desmidiaceæ. The cells in a filament of *Zygnema* or *Spirogyra* need not necessarily be considered as all of the same sex. It is quite possible that they have no sex until just prior to conjugation. There is no visible change on the conversion of an ordinary vegetative cell into a gametangium; the change is a physiological one which most probably takes place immediately antecedent to conjugation, and the formation of a male or a female gametangium may depend upon restricted local conditions. Taking this into consideration, it is no more surprising to see both male and female gametes produced from the cells of a single filament than to see a filament which gives origin to gametes of one sex only. It has been shown that a strictly filamentous condition is of no essential importance to the life of the Conjugate, and also that the functional activities of the cells of a filament are greatly increased during conjugation, even in those cells which take no part in the actual conjugation[1]. Thus, there is no reason why the physiological

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[1] West & G. S. West, 'Obs. on the Conj.,' Ann. Bot. xlv, 1898, pp. 30, 36, 37.

changes which take place in a filament on the conversion of its vegetative cells into gametangia—changes which are rendered manifest by a general increased activity—should not be so far modified at different parts of the same filament as to produce a differentiation of sex. This affords an explanation of the rare cases of "cross-conjugation" to be described later on, but at the same time there is no doubt that it is a general rule in the Zygnemeæ that the cells of any one filament all become of the same sex.

Little is known concerning the effect of temperature and climatic conditions on the methods of reproduction of the Conjugatæ. A high altitude, which is usually accompanied by a relatively low temperature, certainly favours the formation of 'cysts,' and an increase of temperature is in many cases an aid to conjugation. With regard to the British Islands, conjugating examples of the Zygnemaceæ are more frequently met with in low-lying areas than in upland districts, and most frequently in the western or south-western counties. Observations tend to prove that the Conjugatæ in their natural habitats withstand extremes of temperature very well, and that they are capable of adapting themselves to very different conditions from those under which they normally exist.

All plants of this order, whether unicellular or filamentous, are very slimy to the touch. This is due to the gelatinous nature of the outer layers of the cell-wall, and this character alone frequently enables the collector to distinguish Conjugates from most other filamentous green Algæ.

The order is subdivided into three families, of which one—the Temnogametaceæ—is only known from Equatorial Africa. The two British families are:—

Family 1. *Zygnemaceæ.* Thallus filamentous, consisting of a single series of cylindrical cells, each cell possessing one or several chloroplasts of definite form. Any cell may become a gametangium.

Family 2. *Desmidiaceæ.* Thallus unicellular; cells sometimes loosely, sometimes closely joined into simple filaments, *in most genera constricted into two equal and symmetrical halves.* Chloroplasts one or several in each cell, usually of definite form. Many of the plants of this family are remarkable for their beauty of form. Any cell may become a gametangium.

Family 1. **ZYGNEMACEÆ.**

This family of Conjugates has a world-wide distribution and includes some of the commonest and most striking of freshwater Algæ. The thallus is in every instance filamentous and consists of a single series of cylindrical cells forming an unbranched filament. Rare instances of branching are known, but the branches have been limited to short lateral outgrowths consisting only of a few cells; such outgrowths have been observed in the genera *Zygnema* and *Mougeotia*[1]. Similarly, longitudinal septa of an incomplete character have been observed in *Zygnema pachydermum* West, var. *confervoides* West[2]. Rhizoid-like organs of attachment or haptera are of frequent occurrence in young plants of *Spirogyra* and *Mougeotia*, but have not been noticed in any of the other genera of Zygnemaceæ. They are usually simple or branched outgrowths near the base of the filament, but in *Spirogyra* they may arise by the modification of a conjugating-tube which has been protruded by a cell some distance removed from those cells actually engaged in conjugation. This is yet another proof of the increased activity of the filament as a whole during conjugation.

The Zygnemaceæ is divided into three sub-families, of which the Pyxisporeæ is only known from tropical Africa. The two British sub-families are:—

Sub-family 1. *Mesocarpeæ.* Conjugation forming a zygospore which immediately develops a sporocarp of several cells, one of which is the spore (carpospore). The gametophyte is developed from this spore after a period of rest.

Sub-family 2. *Zygnemeæ.* Conjugation producing a zygospore which after a period of rest develops directly into a new gametophyte.

Sub-family I. MESOCARPEÆ.

The plants of this sub-family are the narrowest and most delicate of the filamentous Zygnemaceæ. There is a great variability in the diameter and relative length of the cells, and the cell-wall is relatively thin. The cells contain a single chloroplast, generally in the form of a thin axile plate, which may extend from end to end or only occupy the median portion of the cell. Each chloroplast contains several pyrenoids arranged in a single longitudinal series. The chloroplasts of adjacent cells usually lie in the same plane, so that a whole filament of cells may exhibit the full breadth of the chloroplasts or it may be in a position such that only the thin edge of the chloroplasts can be seen. The action of light causes a rotation of the plate-like chloroplasts of *Mougeotia*.

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[1] West & G. S. West in Ann. Bot. 1898, xlv, p. 32, t. iv, f. 17, 18, 19 and 41.

[2] West, 'Alg. from the W. Indies,' Journ. Linn. Soc. Bot. xxx, t. xiv, f. 5.

In diffused daylight they place themselves at right angles to the direction of the incident rays, but in strong sunlight the edge of the plate is directed towards the light. This has long been known to students of Algæ and special mention of it was made by Bennett. Quite recently this phenomenon, which is well exhibited by the chloroplasts of many green plants, has been further investigated and it has been shown that the chloroplast occupies on an average about 30 minutes in rotating through 90°.[1] Apart from the lining layer of protoplasm and the chloroplast, a considerable proportion of the cell-cavity is usually occupied by large fluid vacuoles.

Vegetative multiplication frequently occurs by the dissociation of a filament into its constituent cells, each of which forms a new plant by rapid cell-division.

Asexual reproduction takes place occasionally in *Mougeotia* by the formation of spores resembling aplanospores[2]. These spores are produced by the division of a vegetative cell and they may be regarded as carpospores formed from sporocarps (consisting of three cells) produced without conjugation, but possibly in consequence of the stimulus which has already caused conjugation to take place in a distant part of the filament. In the genus *Gonatonema* reproduction is solely by the formation of aplanospores, the whole of the contents of a single cell being generally, but not always, utilized in the formation of a spore. It has been noticed in the three best known species of *Gonatonema* (viz. *G. ventricosum* Wittr., *G. Boodlei* W. & G. S. West, and *G. tropicum* W. & G. S. West) that during the formation of the spore, and just before the rounding off of the protoplasmic mass, there is sometimes a more or less complete division of the cell-contents into two parts[3]. I have carefully studied the formation of aplanospores in this genus and this curious separation of the cell-contents into rudimentary gametes is by no means of frequent occurrence. It is most likely a slight retention of the last traces of ancestral sexual characters, the spores having arisen at one time by a process of conjugation.

Sexual reproduction of a low type takes place in *Mougeotia* by conjugation. This almost always occurs between the cells of different filaments which are lying side by side. Each cell puts

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[1] F. J. Lewis in Ann. Bot. xii, 1898.

[2] Wittrock, 'Om Gotl. och Ol. Sotv. Alg.,' Bihang till K. Sv. Vet.-Akad. Handl. Bd 1, no. 1, 1872, t. ii, f. 7 and 8.

[3] W. & G. S. West in Ann. Bot. 1898, xlv, p. 39, t. iv, f. 3; Trans. Roy. Irish Acad. xxxii, sect. B, 1902, p. 17, t. i, f. 5.

out a protuberance on the side towards the other filament, and this meets with a similar protuberance from one of the opposite cells. The ends of the protuberances fuse together and an open tube is formed placing the two conjugating cells in communication with each other. This is known as the *conjugating-tube.* During the development of the protuberances and their ultimate fusion the greater part of the protoplasmic contents of each cell, including the chloroplast, contracts away from the wall of the gametangium and passes into the conjugating-tube. There, a coalescence of the gametes takes place, resulting in the formation of a zygospore, which, although a compact mass situated in the conjugating-tube, is not at first cut off from the rest of the protoplasm left in the gametangia. Wittrock regards the entire H-shaped structure, consisting of the two gametangia and the conjugating-tube, as the zygospore. Cell-walls soon appear in this structure, indicating the formation of a rudimentary sporocarp, and they cut off a central fertile carpospore from the surrounding sterile cells (two, three, or four in number). Thus, the Mesocarpeæ afford an instance in the green Algæ of a sporophyte generation and a rudimentary 'alternation of generations.'

The method of spore-formation met with in *Mougeotia* differs materially from that which occurs in the Zygnemeæ. The spore is not formed by the development of a new cell-wall around the fused gametes, but by the appearance of partition walls which cut off some part of the H-shaped structure in which fusion of the gametes has taken place. Thus, the spore in the Mesocarpeæ can be regarded as a carpospore which is bounded partly by new walls and partly by the walls of the gametangia or the conjugating-tube.

The type of conjugation between the cells of distinct filaments is known as *scalariform conjugation.* In some cases conjugation occurs between adjacent cells of the same filament. This type is known as *lateral conjugation*, and although commonly met with in the Zygnemeæ, is very rarely observed in the Mesocarpeæ.

Irregularities are sometimes met with in the conjugation of *Mougeotia.* Cases have been observed in which the terminal cell of a filament has entered into conjugation through its free end, no conjugating-tube being developed, and rare instances occur in which three cells, each belonging to distinct filaments, have entered into conjugation. Equally rare are the hybrid examples in which conjugation has occurred between species of *Mougeotia* of different thickness. Two carpospores have been observed to be formed in one sporocarp of *Mougeotia capucina*; this is precisely analogous to the double spores met with in certain Desmids and in abnormal cases of *Spirogyra*.

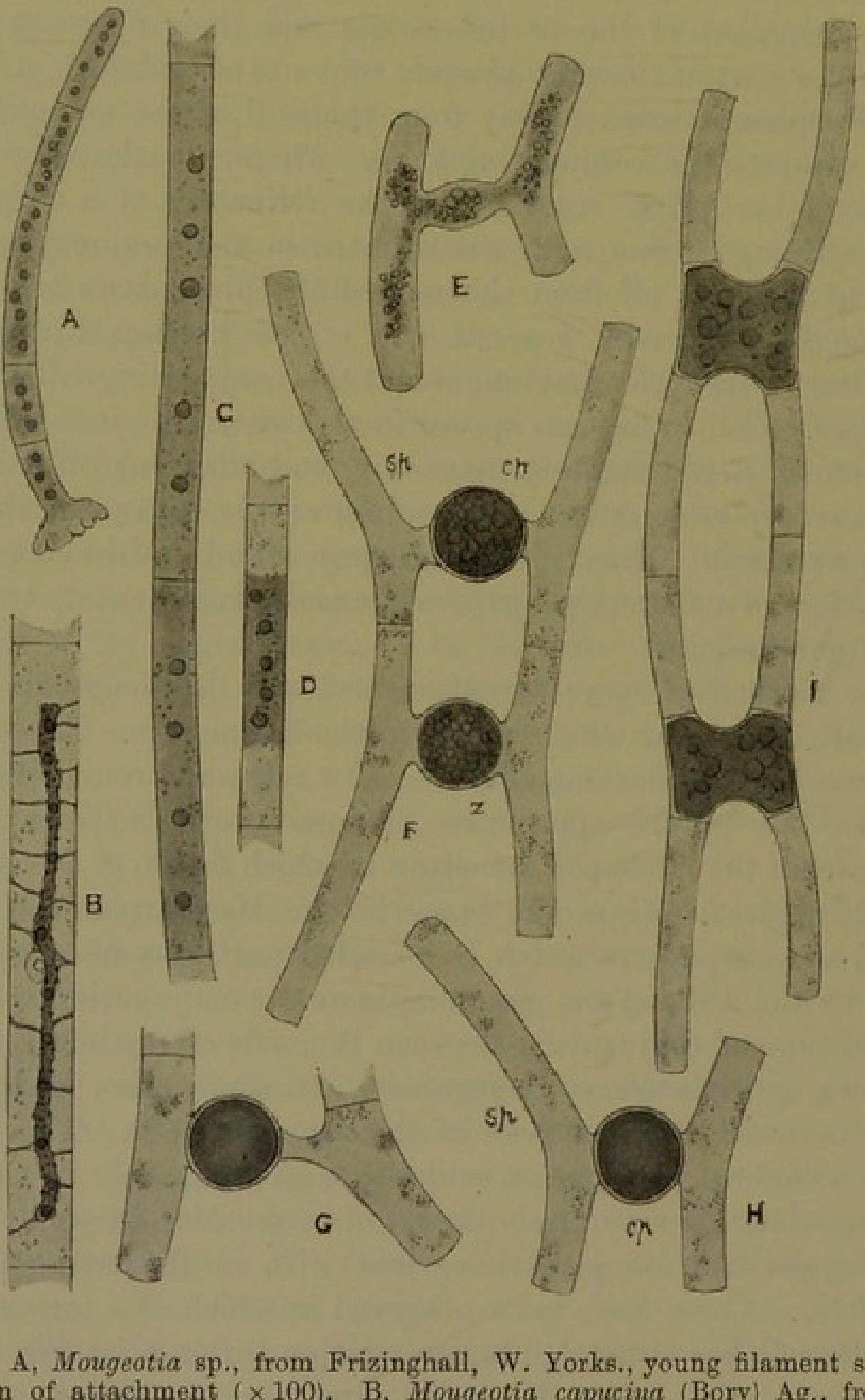

Fig. 44. A, *Mougeotia* sp., from Frizinghall, W. Yorks., young filament showing organ of attachment (×100). B, *Mougeotia capucina* (Bory) Ag., from the New Forest, Hants., showing edge of plate-like chloroplast (×430). C, *M. viridis* (Kütz.) Wittr. (×445). D—H, *M. parvula* Hass.; D—F, from Epping Forest, Essex; G and H, from near Settle, W. Yorks. (×445). I, *M. gracillima* (Hass.) Wittr., from Esher West-end Common, Surrey (×445). *cp*, carpospore; *sp*, sporocarp; *z*, zygospore (of Wittrock).

Indications of sexuality are to be found in the Mesocarpeæ, but they are much less marked than in the Zygnemeæ. The spores are often seen to be situated nearer to one gametangium and the conjugating-tube of that gametangium to be thicker and shorter than that of the other; hence the former may be looked upon as a female cell and the latter as a male cell. As these indications of sexuality are scarcely discernible and often absent, the Mesocarpeæ may be regarded as having lost almost all traces of differentiation of sex.

Genus **Mougeotia** Ag., 1824. [*Staurospermum* Kütz., 1843; *Mesocarpus* Hass., 1845; *Craterospermum* Braun, 1855; *Plagiospermum* Cleve, 1868.] The thallus consists of cylindrical unbranched filaments of elongated cells. The single chloroplast is disposed as an axile plate, extending from end to end of the cell or only occupying the median portion. The pyrenoids are numerous and usually arranged in a single series. In *M. capucina* the chloroplast sometimes assumes the form of an irregular axile rod, connected with the lining layer of protoplasm by fine colourless strands, and the vacuoles contain a purple cell-sap. In some species the carpospores are spherical, but in others they are quadrate and more or less flattened, with rounded or truncated angles. Species of this genus were at one time referred to various genera, such as *Mesocarpus, Staurospermum,* etc., according to the disposition of the sterile cells of the sporocarp and the form of the carpospores, but all the supposed generic differences have been found by Wittrock to be present in one and the same filament of *Mougeotia calcarea* Wittr. Throughout the entire genus there is great variability in the relative size of the carpospore and the sterile cells of the sporocarp.

In mountain tarns and lakes species of this genus are extremely abundant, and they flourish in the summer months in small pools on the mountains up to 3,000 ft. elevation. In these situations the plants rarely conjugate and they are kept alive through the winter largely by the formation of resting-cells or 'cysts,' which are of the same form as the ordinary vegetative cells. In the plankton of large lakes the filaments are often much twisted and coiled.

There are about 15 British species of the genus, of which *M. scalaris* Hass. (diameter of fil. 32—35 μ) is the largest and *M. elegantula* Wittr. (diameter of fil. 3·5—4·5 μ) is one of the smallest. The two most abundant species are

M. parvula Hass. (fig. 44 D—H) and *M. gracillima* (Hass.) Wittr. (fig. 44 I), which conjugate freely in all parts of the country and at all elevations up to 1,200 ft. *M. genuflexa* (Dillw.) Ag. is a frequent species in ditches and ponds. *M. gelatinosa* Wittr. is one of the rarest British species, being characterized by the curious gelatinous investment of the carpospore.

Genus **Gonatonema** Wittr., 1878. The thallus is similar in all respects to that of *Mougeotia*, but the reproduction is brought about solely by the formation of aplanospores, the filaments usually becoming genuflexed at the points of location of the spores. Each

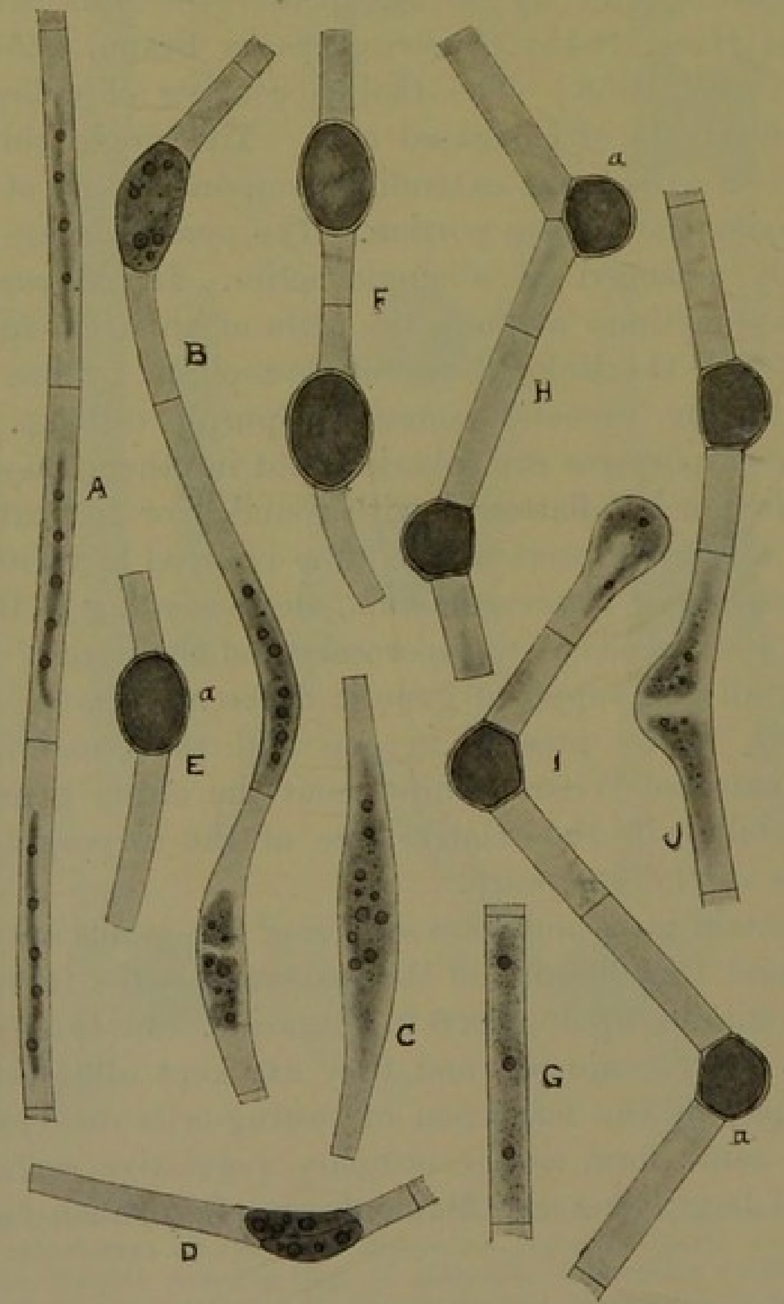

Fig. 45. A—F, *Gonatonema Boodlei* W. & G. S. West, from Mitcham Common, Surrey. G—J, *G. ventricosum* Wittr., from the river above Crolly Bridge, Donegal, Ireland. (All × 445.) *a*, aplanospore.

spore is formed by the rejuvenescence of the contents of the mother-cell, and there is a greater difference in size between the spores of species of this genus than can be accounted for by the difference in cubical capacity of the mother-cells.

Plants of this genus are of much rarer occurrence than those of *Mougeotia*; in fact, they are amongst the rarest of the Conjugatæ. *G. notabile* (Hass.) Wittr., with vegetative cells 12—15 μ in diameter, has not been seen since its discovery by Hassal in 1845. *G. ventricosum* Wittr. (fig. 45 G—J), with veg. cells 7·5—8·6 μ in diameter, is known from Ireland; and *G. Boodlei* W. & G. S. West (fig. 45 A—F), with veg. cells 5—5·5 μ in diameter, has been found in Surrey. The aplanospores of *G. ventricosum* are likewise considerably different from those of *G. Boodlei* and they are sometimes produced by the swelling of the free end of the terminal cell of a filament.

Sub-family II. ZYGNEMEÆ.

The plants of this sub-family consist of unbranched filaments of cells similar to those of the Mesocarpeæ, but usually of much larger size. There is a lining layer of protoplasm in each cell and the nucleus is situated in the central portion of the cell, embedded in a mass of protoplasm which is connected with the lining layer by numerous radiating strands. Gerassimoff[1] finds certain cells of *Spirogyra majuscula* to contain two ordinary nuclei or one compound nucleus. The chloroplasts, which contain prominent pyrenoids, are somewhat variable in form and disposition; in *Debarya* there is a single axile plate similar to that of *Mougeotia*; in *Zygnema* there are two star-shaped chloroplasts suspended in the middle line of the cell; and in *Spirogyra* the chlorophyll is arranged in one or more bands twisted spirally round the interior of the cell-wall. The chloroplasts of *Spirogyra* are very variable and special reference is made to this feature under the genus.

Vegetative multiplication takes place as in the Mesocarpeæ by the breaking up of a filament into its constituent cells, or into groups of cells, which then grow into new filaments.

Asexual reproduction sometimes takes place by the formation of aplanospores, which are produced from the contents of a single cell. They are more frequently found in *Zygnema* than in *Spirogyra*, and until the discovery of *Z. spontaneum* Nordst. in West Africa[2], the only known method of reproduction of this species was

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[1] Gerassimoff in Bull. Soc. Imp. Nat. Moscou, 1897.

[2] W. & G. S. West in Journ. Bot. Febr. 1897, p. 15.

an asexual one[1]. The aplanospores (or, as they are frequently termed, 'parthenospores') of *Zygnema* are generally globular and rather smaller than the zygospores, but those of *Spirogyra* are as a rule very similar in form to the zygospores. Klebs has stated that parthenogenetic resting-spores can be produced in filaments with long conjugating-tubes by placing them in a strong solution of sugar. *Spirogyra mirabilis* (Hass.) Petit is reproduced solely by spores resembling aplanospores, but produced by a degenerate form of conjugation[2]. Many of the upland forms of *Zygnema* habitually form solitary resting-cells or 'cysts' in order to survive the winter.

Sexual reproduction takes place by conjugation in all the genera of this sub-family. The usual type of conjugation is *scalariform*, between the cells of two distinct filaments. The conjugating-tube is formed exactly as in *Mougeotia*, and in all except species of the genus *Debarya* and certain species of *Zygnema* belonging to the section *Zygogonium*, the fusion of the gametes takes place in one of the gametangia. In the formation of a gamete the protoplasmic mass contracts away from the cell-wall, the chloroplast loses much of its original form, and the mass becomes of an ellipsoidal shape. The whole of this mass then glides gradually from its gametangium through the conjugating-tube into the opposite gametangium. The gametes may coalesce immediately on contact and before the one has completely passed through the conjugating-tube, or they may lie side by side in the gametangium before fusing. On the coalescence of the gametes and the fusion of their nuclei the mass generally assumes a spherical or ellipsoidal form, develops a thick cell-wall and is known as the *zygospore* (or *zygote*).

The cell in which the fusion of the gametes takes place and therefore the one in which the zygospore is formed, is known as the female cell, and the one which is emptied as the male cell; and that part of the conjugating-tube developed from the female

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[1] Nordst. 'Alg. et Char. Sandvic.' 1878, p. 17, t. 1, f. 23, 24.

[2] Petit in his 'Spirogyra des envir. de Paris,' p. 14, writes concerning *S. mirabilis*: "Cette très curieuse espèce ne conjugue pas et ne laisse voir aucun tube copulateur; à une certaine époque de la vie de la plante, les cellules renflent vers le milieu, l'endochrome se partage en deux parties qui se concentrent sous forme de globule aux deux extrémités de la cellule; il se forme ainsi une différentiation entre les parties de l'endochrome. Bientôt les deux globules se rapprochent vers la partie renflée de la cellule et finissent par se réunir en constituent ainsi la zygospore." This is a similar phenomenon to that which occasionally occurs in the formation of the aplanospores of *Gonatonema*. (Consult page 118.)

cell is usually thicker and shorter than the part developed from the male cell. The female cells frequently become much swollen after the fusion of the gametes.

On the examination of a large number of conjugated examples of either *Spirogyra* or *Zygnema* one feature must impress itself even on a casual observer, namely, that "the direction of conjugation is clearly governed by some physiological law, the movement of protoplasm between the two filaments almost invariably taking place in one direction only, so that one of the two conjugating filaments is entirely emptied, while the other is filled with zygosperms[1]." Thus, the cells of one filament usually become all of the same sex.

Two filaments are generally concerned in an example of scalariform conjugation, but three, four, five, six, or more, are occasionally seen (*vide* fig. 49 A). Such are mostly cases of polygamy or polyandry, and statistics seem to show that the former is the more frequent.

Lateral conjugation, or conjugation between adjoining cells of the same filament, is frequently observed, but it is much scarcer than scalariform conjugation and may be regarded as exceptional. It is more often met with in *Spirogyra* than in *Zygnema* and is especially frequent in some of the smaller species, such as *S. tenuissima* (Hass.) Kütz., *S. inflata* (Vauch.) Rabenh., and *S. varians* (Hass.) Kütz. *Cross-conjugation*, in which some cells of the filaments are male and others female, and therefore in which perfectly normal zygospores are found in both filaments, is exceedingly rare. In both lateral and cross-conjugation, as was mentioned in the general remarks under the order Conjugatæ, a differentiation of sex must take place amongst the cells of the same filament, some becoming male and others female.

Sometimes certain irregularities are met with in the conjugation, and these are no doubt largely due to the increased functional activity of all the cells of the filaments which is such a striking accompaniment to conjugation. Zygospores are occasionally observed which have been produced by the coalescence of three gametes, two male and one female[2], but attempts of this nature

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[1] Bennett and Murray, 'A Handbook of Cryptogamic Botany,' London, 1889, p. 266.

[2] West in Notarisia 1891, vi, t. xiii, f. 13; Borge in Bihang till K. Sv. Vet.-Akad. Handl. Bd 17, 1891, no. 2, t. i, f. 2; W. & G. S. West in Ann. Bot. xii, 1898, t. v, f. 66.

are usually abortive[1] (fig. 49 B). Gerassimoff has observed the conjugation of two female cells with one male cell and the formation of the zygospore by the coalescence of the protoplasm of the male cell with that of one of the female cells, a parthenospore being formed in the other female cell. In those plants of the Zygnemeæ in which the zygospore is formed in the conjugating-tube, conjugation between three cells entails the production of two zygospores, each of which is less than the normal size. Owing to sudden changes of local conditions it frequently happens that the conjugation has been brought to an abrupt termination before the proper formation of the zygospores has taken place. In such cases of interrupted conjugation the spores are apt to be very variable; sometimes the spore is not of its true form, and at other times one small one is formed in each gametangium or two small ones in the female gametangium[2]. The discovery by Gerassimoff of binucleated cells in the Zygnemeæ may perhaps afford an explanation of some of these irrregularities of conjugation. He states that in the conjugation of binucleated cells parthenospores were sometimes observed.

Rare instances of hybrids are known, in which conjugation, with the production of zygospores, has occurred between filaments of different species[3].

The ripe zygospores possess a thick wall of cellulose which is divisible into three coats, the outer one being cuticularized and the middle one usually exhibiting some form of sculptured markings. The contents of the zygospore often turn red in colour and develop a large amount of oily material. Sometimes the chloroplasts of the two gametes remain intact in the zygospore; sometimes those of the female remain intact and those of the male disintegrate; but it is quite a common thing for the chloroplasts to completely disintegrate before the fusion of the gametes. The zygospores undergo a period of rest, surviving the winter or even a period of drought, and they usually germinate after the conju-

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[1] W. & G. S. West, l. c. figs. 67 and 69; Schmula in Hedwigia, xxxviii, 1899. (c. fig.) Copeland states that in such a case the nucleus of the abortive male cell is situated against the wall opposite, remote from the conjugating-tube. (Cf. Bull. Torr. Bot. Club, xxix, 1902.)

[2] Rosenvinge in Öfvers. K. Vet.-Akad. Förh. 1883, no. 8, t. viii, f. 1—11; West in Notarisia 1891, vi, t. xiii, f. 27, 28; Hansgirg in Hedwigia 1888, t. x, f. 6; W. & G. S. West, l. c. t. v, f. 74—80.

[3] Cf. *Spirogyra maxima* var. *inæqualis* Wolle Freshw. Alg. u. s. t. cxxxviii, f. 5, 6; t. cxlii, f. 5, 6; W. & G. S. West, l. c. t. v, f. 70, 71.

gating filaments have entirely perished. In *Spirogyra* the two outer coats are ruptured, generally at one end of the spore, and the protoplasm is protruded as a filament clothed with the innermost cellulose wall. This filament becomes divided by a transverse septum, one cell becoming an organ of attachment and containing little or no chlorophyll, whereas the other cell increases in size, contains one or more chloroplasts, and by repeated divisions forms a filament. The distinction between base and apex is soon lost and the filament floats freely in the water. Organs of attachment have, however, been observed to be developed subsequently from older cells. In the germination of zygospores of *Zygnema* the distinction into base and apex is scarcely evident.

Certain of the zygospores of *Spirogyra velata* Nordst. have been observed to germinate immediately after their formation without the development of a thick cell-wall (fig. 49 E and F)[1].

Genus **Debarya** Wittr., 1872. [*Mougeotiopsis* Palla 1894.] The thallus consists of simple, cylindrical filaments, with or without a distinct constriction between the cells, and with a thin external mucous covering. There is one chloroplast in each cell, disposed as an axile plate similar to that of *Mougeotia*, and containing several pyrenoids. In rare instances pyrenoids are absent. The gametes are formed from the entire contents of the gametangium and conjugation takes place in the conjugating-tube, the mature zygospore occupying a position between the gametangia. The zygospores are very variable in character and there are considerable differences in the actual processes of conjugation, but in one curious fact all the species agree. A peculiar change comes over the empty gametangia as the zygospore is being formed; they become very clear and refractive, and sometimes a series of striations become visible parallel to the transverse walls. They have at this stage the appearance of solidity, most likely owing to the deposition of annular thickenings of cellulose inside the cell-wall on the receding of the protoplasm during conjugation. This feature is noticeable not only in living specimens, but also in old, preserved examples.

All the species of this genus are of rare occurrence. *D. glyptosperma* (De Bary) Wittr. is more widely distributed than the others; the cells are 9—15 μ in thickness and 6—15 times longer than the diameter; the conjugating-tubes

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[1] W. & G. S. West in Ann. Bot. xii, 1898, t. v, f. 84, 85.

are often very long and the zygospore is large and ellipsoidal, frequently with one or two mamillate protuberances at the poles; length of zygosp. 35—72 μ, breadth 16—40 μ (fig. 46 A). *D. lævis* (Kütz.) W. & G. S. West is a larger species with shorter cells, which are 20—26 μ in thickness and 2½—4 times longer than the diameter. The zypospore is ellipsoidal (44—50 μ × 29—36 μ) with a scrobiculate middle coat (fig. 46 C—E). *D. calospora* (Palla) W. & G. S. West is 11—13 μ in diameter; the zygospores are subglobose or ellipsoidal, 18—26 μ in diameter, and ornamented with large scrobiculations

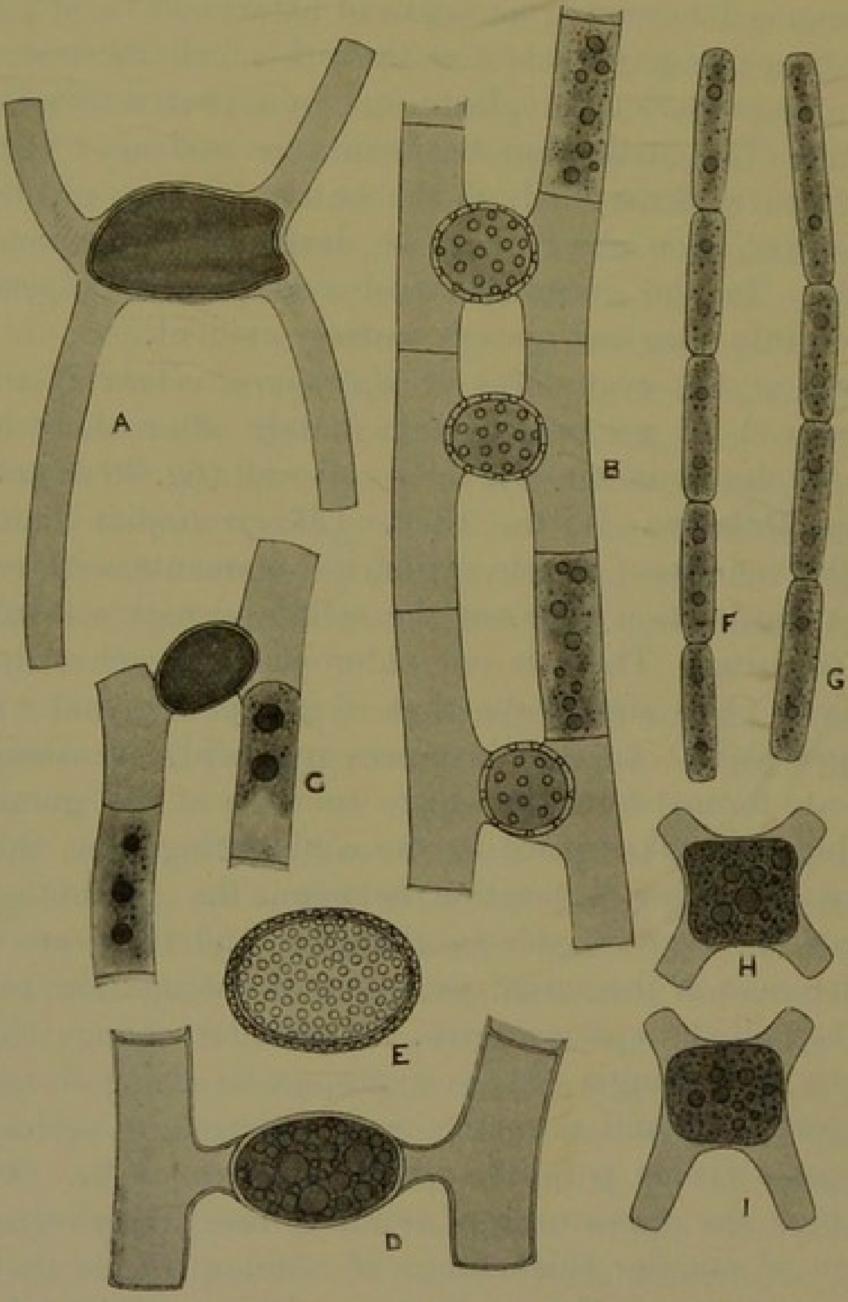

Fig. 46. A, *Debarya glyptosperma* (De Bary) Wittr., from Fairfield, Westmoreland (× 275). B, *D. calospora* (Palla) W. & G. S. West, from Pilmoor, N. Yorks. (× 430). C—E, *D. lævis* (Kütz.) W. & G. S. West, from Mitcham Common, Surrey; C, × 180; D, × 250; E, mature zygospore, × 430. F—I, *D. Desmidioides* W. & G. S. West, from near the Lizard, Cornwall (× 430).

(fig. 46 B). Palla[1] placed this species under a new genus of the Conjugatæ owing to the absence of pyrenoids in the plants he observed. More recently, however, precisely the same species has been discovered *with pyrenoids*, and as the latter are subject to much variability their presence or absence is of no generic value[2]. The most remarkable species of the genus is *D. Desmidioides* W. & G. S. West[3], which, up to the present time, has only been observed from Cornwall. The cells are short, only 2½—6½ times longer than the diameter and 7·7—8·6 μ in thickness (fig. 46 F—I). There is a most evident constriction between all the cells of the filaments, and the latter dissociate with the greatest ease into their individual cells, conjugation only occurring between the free, dissociated cells. This plant throws much light on the origin of the Desmidiaceæ.

Genus **Zygnema** Ag., 1824. [*Zygogonium* Kütz. 1843.] The filaments are simple, consisting of a single series of cylindrical cells placed end to end, and sometimes exhibiting a slight constriction at the points of junction. Each filament possesses an external mucous coat which is sometimes remarkable for its size and strength. There are two star-shaped chloroplasts suspended in the median line of each cell, each one containing a single large pyrenoid. Sometimes the chloroplasts are very indefinite, their form and disposition being difficult to make out. This is particularly the case in *Z. ericetorum* (Kütz.) Hansg., some forms of which greatly resemble species of *Microspora* or of *Rhizoclonium*. The coalescence of the gametes takes place either in one of the gametangia (the female) or in the conjugating-tube. Species in which the latter occurs were referred by Kützing to a separate genus—*Zygogonium*. The zygospores are globose or ellipsoid.

There are about a dozen British species of this genus, of which *Z. ericetorum* (Kütz.) Hansg. (fig. 47 C) is the most widely distributed. This species lives equally well in water or on damp heaths or peaty moors, and it frequently assumes a purple or violet colour owing to the formation of phycoporphyrin in the cell-sap. It is an Alga which fulfils an important function on some of the heaths and moors. In the drier and hotter periods of the year, thickly-matted sheets of *Z. ericetorum*, often many square feet in extent, are found covering wide patches of almost bare sand or peat, round such plants as *Drosera*, *Carices*, etc. These mats of *Zygnema* have great absorptive capacity, greedily taking up water, and in this way they regulate the moisture of the surface soil, the thriving of some of the smaller Phanerogams depending to a

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[1] E. Palla, 'Ueber eine neue, pyrenoidlose Art und Gattung der Conjugaten,' Berichte Deutsch. Bot. Gesellsch. xii, 1894, Heft 8, pp. 228—236, t. xviii.

[2] W. & G. S. West in Ann. Bot. xii, 1898, p. 49; in Journ. Bot. Aug. 1900, p. 289.

[3] W. & G. S. West in Journ. Bot. 1903, p. 7 (Sep.), t. 446, f. 1—9.

great extent on the presence of the *Zygnema*[1]. *Z. ericetorum* very rarely conjugates, and mature zygospores, which are found in the conjugating-tube, have only been observed on one or two occasions. The filaments are 15—22 μ in diameter and the cells often become irregularly thickened.

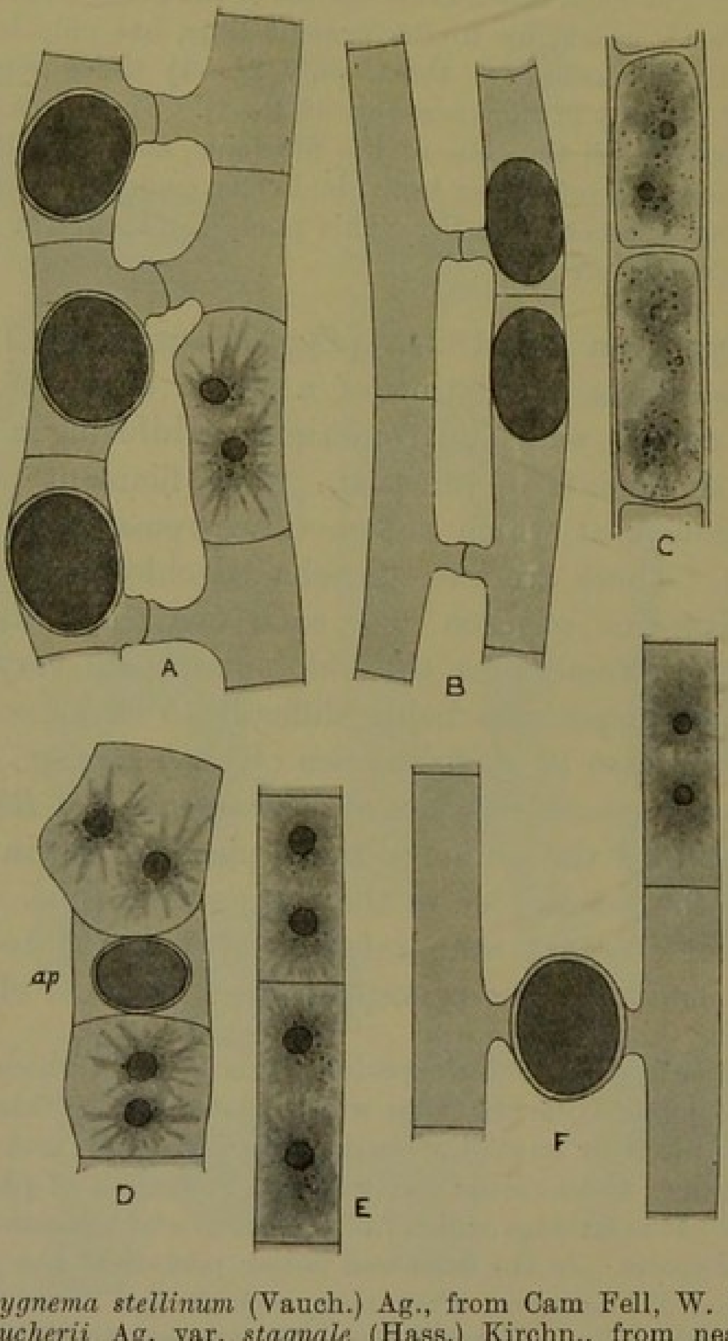

Fig. 47. A, *Zygnema stellinum* (Vauch.) Ag., from Cam Fell, W. Yorks. (×430). B, *Z. Vaucherii* Ag. var. *stagnale* (Hass.) Kirchn., from near the Lizard, Cornwall (×430). C, *Z. ericetorum* (Kütz.) Hansg., from Rombald's Moor, W. Yorks. (×415). D, *Z. leiospermum* De Bary, from Esher Common, Surrey (×430), a portion of a filament which was conjugating along the greater part of its length. E, *Z. insigne* (Hass.) Kütz., from Malham, W. Yorks. (×330). F, *Z. Ralfsii* (Hass.) De Bary, from Chippenham Fen, Cambridgeshire (×430). *ap*, aplanospore.

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[1] This phenomenon is much more evident in some parts of the tropics, and attention was first called to it by Welwitsch in the 'Journal of Travel and Natural History,' vol. i, 1868. In the damp sandy valley of the Cuanza River, in Angola, the Alga *Porphyrosiphon Notarisii* occurs in extensive sheets, closely spread like a

Z. pectinatum (Vauch.) Ag., *Z. cruciatum* (Vauch.) Ag. and *Z. insigne* (Hass.) Kütz. (fig. 47 E) are the three largest British species, usually occurring in ponds or in road-side ditches. The smallest form of the genus is *Z. Vaucherii* Ag. var. *stagnale* (Hass.) Kirchn. (fig. 47 B), the filaments of which reach a maximum thickness of 13 μ. *Z. anomalum* (Hass.) Cooke is a species largely confined to upland bogs and is remarkable for its wide mucous investment.

Genus **Spirogyra** Link, 1820. This is the best known and most abundant genus of Conjugatæ, and it has a distinct preference for low-lying, quiet waters, such as those of ponds and ditches. The filaments are quite simple and occur in bright green flocculent masses, often several feet in diameter. The cells are cylindrical and they exhibit great variability both with regard to their diameter and their relative length. The cell-wall is firm, with an outer mucous coat which renders the plants very slimy. In most species the transverse cell-walls are quite plane, but in some of the smaller species there is a curious annular ingrowth of cellulose at the ends of each cell (*vide* fig. 48 C). When this is present the cells are said to possess "replicate ends." It is a character which is constant for the species in which it is found, although the ingrowths are not

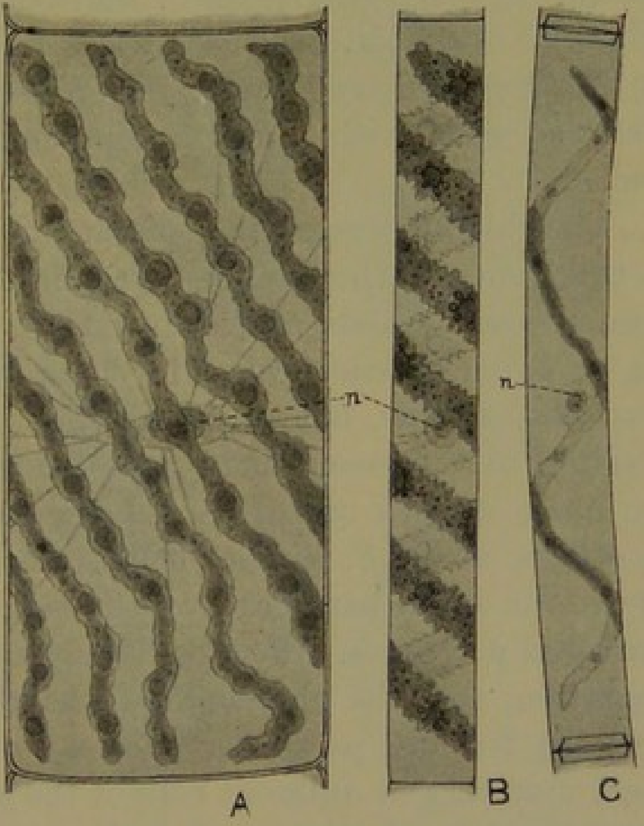

Fig. 48. A, *Spirogyra majuscula* Kütz., from Coates, Gloucestershire, single cell showing chloroplasts and nucleus (× 300). B, *Spirogyra* sp., from Coates, Gloucestershire (× 370). C, *S. tenuissima* (Hass.) Kütz., from Mitcham Common, Surrey (× 390). *n*, nucleus.

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net over the soil, intergrown with small herbaceous plants and shrubs. The mat-like sheets of the Alga eagerly absorb the atmospheric moisture during dewy nights, affording by this means a refreshing protection to the roots of many other and larger plants during the glowing heat of the following day. Welwitsch states that the growth and thriving of the numerous small phanerogamous plants in these places is conditional on the co-presence of the Alga. Cfr W. & G. S. West in Journ. Bot. 1897, p. 303.

necessarily present at the extremities of every cell in the filament. The nucleus is situated in the central portion of the cell and the protoplasm in which it is embedded is connected with the lining primordial utricle by numerous delicate strands. Many of these strands reach the lining protoplasm exactly opposite a pyrenoid, and as the starch formed during carbon-assimilation makes its appearance round the pyrenoids, this fact has been brought forward as a reason for supposing the nucleus to have a direct function in starch-formation. The nucleus is often clearly visible in living specimens, particularly of *S. majuscula* Kütz. and *S. pellucida* (Hass.) Kütz. Mitotic division has been observed in this nucleus by Mitzkewitsch and by C. van Wisselingh, and Gerassimoff has observed cells with either a compound nucleus or two ordinary nuclei.

The chloroplasts are the most striking feature of Algæ belonging to this genus. They are disposed in the primordial utricle in the form of spiral bands, and they vary in number from one to about six or seven in each cell. In some species they are coiled into very close spirals, but in others they are practically straight and longitudinal; in some, as in *S. neglecta* (Hass.) Kütz., their margins are quite smooth and there is a regular axile series of pyrenoids; in others, as in *S. nitida* (Dillw.) Link or *S. porticalis* (Vauch.) Cleve, the spiral bands are very broad, with serrated margins and scattered pyrenoids. Between these two extremes there is every gradation, and the character of the chloroplasts always remains constant for any particular species, even though the number of them may vary in different cells of the same filament. It has been ascertained by Kolkwitz[1] that the chloroplasts grow in length in the direction of the coils by both apical and intercalary growth; and therefore, as this is obliquely to the surface of the cell-wall, there is a gliding motion of the spiral bands through the primordial utricle.

The coalescence of the gametes takes place in all cases in the female gametangium, which often swells up to twice its normal size. The zygospores may be globular, ellipsoidal, cylindrical with obtuse ends, or they may more rarely assume the form of flattened discs; and the middle coat of the zygospore is frequently ornamented with distinctive markings.

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[1] Kolkwitz in Festschr. f. Swendener, 1899, pp. 271—287.

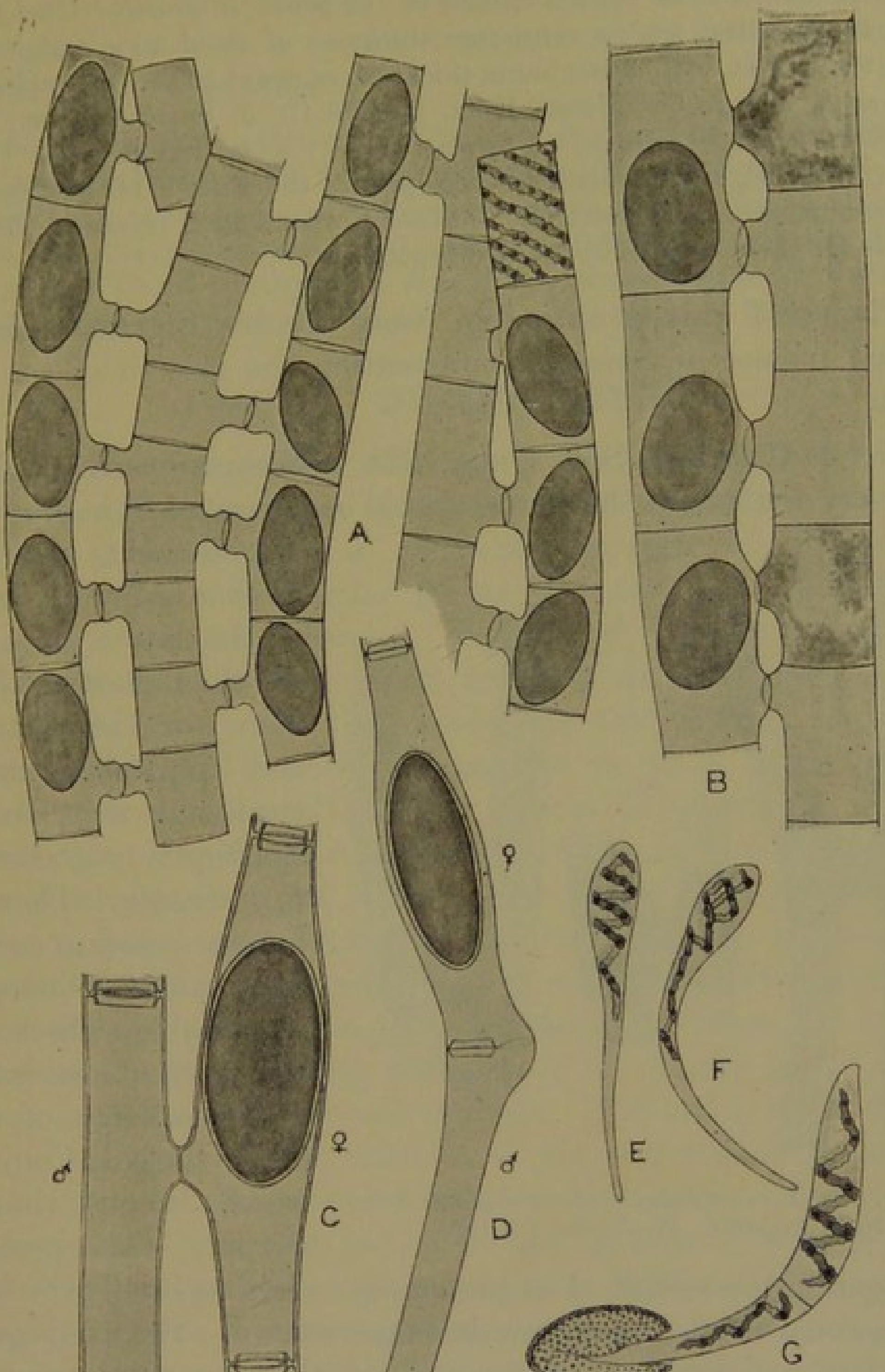

Fig. 49. A, *Spirogyra nitida* (Dillw.) Link, from near Morecambe, Lancashire; scalariform conjugation between six filaments (× 75). B, *S. setiformis* (Roth) Kütz., showing frustrated attempts at the conjugation of two male cells and one female cell (× 90). C, *S. Spréeiana* Rabenh., from near Esher, Surrey (× 390). D, *S. inflata* (Vauch.) Rabenh., from near Esher, Surrey; showing lateral conjugation (× 390). E and F, zygospores of *S. velata* Nordst., from Shipley Glen, W. Yorks., germinating immediately after their formation and before the differentiation of the wall of the zygospore (× 165). G, germination of zygospore of *S. velata* after normal period of rest (× 230).

There are about 24 British species of the genus, *S. gracilis* (Hass.) Kütz. being the smallest, with a minimum thickness of about 10 μ, and *S. crassa* Kütz. the largest, with a maximum thickness of about 150 μ. Several species, such as *S. tenuissima* (Hass.) Kütz. (fig. 48 C), *S. gracilis* (Hass.) Kütz., *S. communis* (Hass.) Kütz., *S. varians* (Hass.) Kütz. and *S. nitida* (Dillw.) Link (fig. 49 A), are abundant in every part of the British Islands except in the most mountainous districts. *S. velata* Nordst. and *S. calospora* Cleve are notable for their beautifully marked zygospores.

Plants of this genus often cause trouble in cress-beds, the matted masses of *Spirogyra* preventing the growth of the cress plants.

Genus **Choaspis** S. F. Gray, 1821. [*Sirogonium* Kütz., 1843.] It is very doubtful if this genus should be separated from *Spirogyra*. The filaments are similar to those of many species of the latter genus and the chloroplasts, although more or less straight and longitudinal, are not straighter than those of *Spirogyra majuscula* or *S. pellucida*. There are, however, certain constant distinctions. There is a remarkable absence of the external mucous coat, in consequence of which this is the only Conjugate which is not slimy or slippery. The process of conjugation is peculiar. The gametangia, more especially the female one, become swollen and sometimes genuflexed. The conjugating-tubes are not distinct, but the walls of the gametangia come into apposition and a perforation is formed at the point of contact. The chloroplasts also completely disintegrate, even before the gametes have receded from the walls of the gametangia. The coalescence of the gametes takes place in the female gametangium. Conjugation only appears to affect indiscriminately a few of the cells of the filament, and as these cells are usually shorter than the ordinary vegetative cells, they may perhaps be specially set apart as sexual cells, almost comparable to those which are specially cut

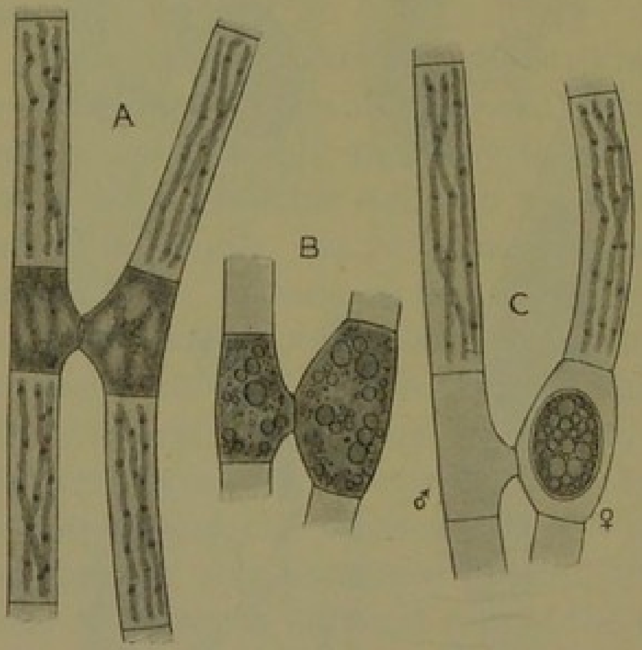

Fig. 50. A—C, *Choaspis stictica* (Eng. Bot.) O.K., from Ingleton, W. Yorks. (× 120).

off in the Temnogametaceæ. Gray's description of *Choaspis*[1] is a very good one and is twenty-two years previous to Kützing's description of *Sirogonium*.

Ch. stictica (Eng. Bot.) O. Kunze [= *Sirogonium sticticum* Kütz.] is the only British species (fig. 50 A—C). The cells are 2—6 times longer than their diameter (which is 40—50 μ), and there are several more or less longitudinal chloroplasts. The zygospores are ellipsoidal, about 75 μ in length and 42 μ in breadth. The plants usually occur attached to stones over which the water is running fairly fast; they are also said to occur in stagnant water.

Family 2. **DESMIDIACEÆ**.

The plants included in this family are remarkable for their great diversity of form and their wonderful symmetry. Indeed, the group includes some of the most beautiful of microscopic objects. They are unicellular plants and the major portion of them lead a solitary existence. Certain of them are, however, associated in colonies and others are more or less closely united into long filaments. They are essentially free-floating Algæ and frequently occur in enormous abundance in small ponds, in the quiet margins of lakes, and in other favourable localities.

Most Desmids exhibit a more or less distinct constriction into two perfectly symmetrical halves; each half is termed a *semicell* and the narrower part connecting the two semicells is known as the *isthmus*. The angle resulting on either side from the constriction or narrowing of the cell is known as the *sinus*.

One of the most striking features of the family is the extraordinary complexity of the cell-outlines. The cell is often deeply lobed or incised, and the exterior of the cell-wall is frequently covered with granules, spines, wart-like thickenings, or other protuberances, most of which have a definite pattern of arrangement. This firmer portion of the cell-wall consists chiefly of cellulose, and external to it are layers of gelatinous pectose compounds. The latter often form a thick mucilaginous coat completely surrounding the individual, or, as in the case of colonial forms, entirely enveloping the colony. It is by means of this mucilaginous envelope that Desmids adhere to other larger aquatic plants, and sometimes, when the conditions have been favourable for rapid multiplication, enormous numbers of individuals occur embedded in masses of jelly. Sometimes the mucus is very tough. In the genus *Spon-*

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[1] S. F. Gray, Arrang. Brit. Plants, 1821, vol. i, p. 299.

dylosium the cells are united into filaments by mucous threads passing between their apposed ends, and the filaments break much more readily across the isthmus of a cell than at the points of apical attachment.

The minute structure of the cell-wall was first studied by Klebs[1] who examined the nature of the gelatinous outer coat and also demonstrated the presence of pores in the cell-wall. Shortly afterwards Lütkemüller[2] described the pores in the cell-wall of *Closterium* and quite recently he has published a very important account of the structure of the cell-wall of Desmids[3].

In a few Desmids—those belonging to the Spirotænieæ—the cell-wall consists of a single layer of cellulose of homogeneous structure, but in the majority of Desmids it is composed of two well differentiated layers. The inner layer is structureless and consists of cellulose; the outer layer is stronger and thicker, consisting of a ground substance of cellulose through which pass numerous tube-like structures or 'pore-organs.' The latter are not composed of cellulose, and a small pore or canal runs through the middle of each one. The contents of these canals also traverse the inner layer of the cell-wall and often terminate on its inner surface in lens-shaped or bulbous swellings. From the outer end of the pore-organs there often arises a delicate flower-like or club-shaped structure through which the canal passes. More often this structure is entirely wanting or is replaced by a small perforated button or rod. In many of the larger Desmids there are numerous, smaller, thread-like pores between the larger canals and only traversing the outer layer of the cell-wall. Outside the differentiated parts of the cell-wall is the mass of gelatinous pectose compounds present in so many species, and which is secreted by the protoplasm and passed outwards through the pores. This outer gelatinous coat often exhibits a prismatic or fibrillar structure and is frequently the home of epiphytes or of numerous rod-shaped bacteria. The cell-wall sometimes contains a trace of silica.

With the exception of the lining primordial utricle the

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[1] Klebs, 'Ueber Bewegung und Schleimbildung der Desmidiaceen,' Biol. Centralbl. Bd v, 1885.

[2] Lütkemüller, 'Die Poren der Desmidiaceen Gatt. Closterium Nitzsch,' Oesterr. botan. Zeitschr. Bd 44, 1894.

[3] Lütkemüller, 'Die Zellmembran der Desmidiaceen,' Beiträge zur Biol. der Pflanzen, herausgegeben von F. Cohn, Bd viii, Breslau, 1902.

cytoplasm is variable in its general disposition, the variability depending largely on the nature and arrangement of the chloroplasts. In those Desmids with large, central chloroplasts, vacuoles may be absent or much reduced, and they are often confined to one at each extremity of the cell; in others with parietal chloroplasts large vacuoles are often present in the central portions of the cell. The general transparency of the cell-wall enables the circulation of the protoplasm to be seen extremely well, especially in the larger species. The nucleus is usually embedded in a small mass of protoplasm in the median part of the cell in the region of the isthmus, and in some genera is readily visible without the use of reagents. In the genera *Gonatozygon*, *Closterium* and *Pleurotænium,* and in certain species of the genus *Penium,* there is a well marked terminal vacuole at each extremity of the cell, containing one or many moving granules. These granules, which may be quite irregular in form or of some definite shape, exhibit rapid vibratory movements and have in the genus *Closterium* been shown to be minute crystals of gypsum. Their movements cease immediately on the death of the protoplasm.

If Desmids are kept living in small glass vessels for some time, and therefore under abnormal conditions, curious changes frequently occur in their protoplasm, resulting in the formation of large vacuoles which previously did not exist. These vacuoles generally contain numbers of minute moving corpuscles which are somewhat different in appearance from those normally present in the apical vacuoles of *Closterium.* As many as six large vacuoles can be noticed in a single semicell of *Pleurotænium coronatum* (Bréb.) Rabenh., each one being partially filled with an incessantly moving mass of minute corpuscles, which move freely in the vacuole and always collect towards its base. These corpuscles or granules are of a pale yellow colour and appear brown in a thin stratum; but when present in immense numbers they give the Desmid almost a black appearance. Under abnormal conditions these moving granules are developed in numerous genera, such as *Penium, Cosmarium, Euastrum, Micrasterias, Staurastrum, Arthrodesmus,* etc., and at the same time the cell-sap in the vacuoles often becomes coloured violet with phycoporphyrin, a pigment which occurs normally in the cell-sap of very few Desmids.

The form and disposition of the chloroplasts are conspicuous features of many Desmids. They may be situated in a central position in the cell or semicell, or they may take the form of parietal cushions or bands. In the cells of *Spirotænia*, *Mesotænium*, *Roya*, and in some forms of *Cosmocladium*, *Gonatozygon* and *Penium*, there is only one chloroplast, and the nucleus consequently occupies an asymmetrical position. The majority of Desmids possess two centrally disposed (axile) chloroplasts, symmetrically arranged, one in each semicell, but in *Pleurotænium* and a few species of *Cosmarium*, *Staurastrum* and *Xanthidium* there are a number of parietal, cushion-like chloroplasts in each semicell. The chloroplasts are very variable in character and disposition, and many intermediate conditions are noticed between truly axile and truly parietal masses of chlorophyll. There can be little doubt that the axile chloroplast was the original type and that the parietal condition has been secondarily acquired by certain Desmids. In those forms in which the cell is deeply lobed or incised the chloroplasts often closely follow the cell-outlines, being themselves symmetrically lobed. Pyrenoids are present in the chloroplasts of all Desmids. In most forms one or two pyrenoids are present in each semicell, but in the large flattened forms of *Euastrum* and *Micrasterias*, and in the elongated cells of *Closterium*, *Penium*, *Pleurotænium*, *Tetmemorus*, etc., the chloroplasts usually contain many pyrenoids. In certain species, such as *Spirotænia acuta* Hilse and *Penium subtile* W. & G. S. West, only a solitary pyrenoid occurs in each cell. In certain genera the pyrenoids are commonly subject to variation in number and disposition[1], but in other genera they are remarkably constant.

Under normal conditions Desmids frequently exhibit very active movements. Klebs described four phases of motion in certain elongated forms, all the movements being due to an exudation of mucilage, the nature and extent of which has been recently demonstrated in a few species by Schröder[2]. The net result is always a movement in the direction of the strongest light, the longest axis of the Desmid being placed in the direction of the incident rays of strong light and at right angles to those of feeble light.

Vegetative multiplication takes place by simple cell-division,

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[1] Lütkemüller, 'Beobacht. über die Chloroph. einig. Desmid.,' Oesterr. botan. Zeitschrift, xliii, 1893, no. 1; West & G. S. West, in Ann. Bot. xii, 1898, pp. 51, 52, t. iv, f. 30—36; G. S. West in Journ. Linn. Soc. Bot. xxxiv, 1899, pp. 399, 400.

[2] Schröder in Verhandl. d. Heidelb. Naturhist.-Med. Vereins, Bd vii, 1902.

each division occupying about a day in the smaller species and several days in the larger species. The first step in this cell-fission is an elongation of the isthmus, causing a slight separation of the two semicells. The elongated isthmus generally becomes swollen and soon shows signs of a constriction midway between the two semicells. By this time the nucleus has completely divided and shortly afterwards the constriction deepens, cutting the median portion into two young semicells, which usually remain in contact by their apices until they are practically full-grown. The ornamentation of the cell-wall gradually makes its appearance on the young semicells as they assume the normal size. At first they are

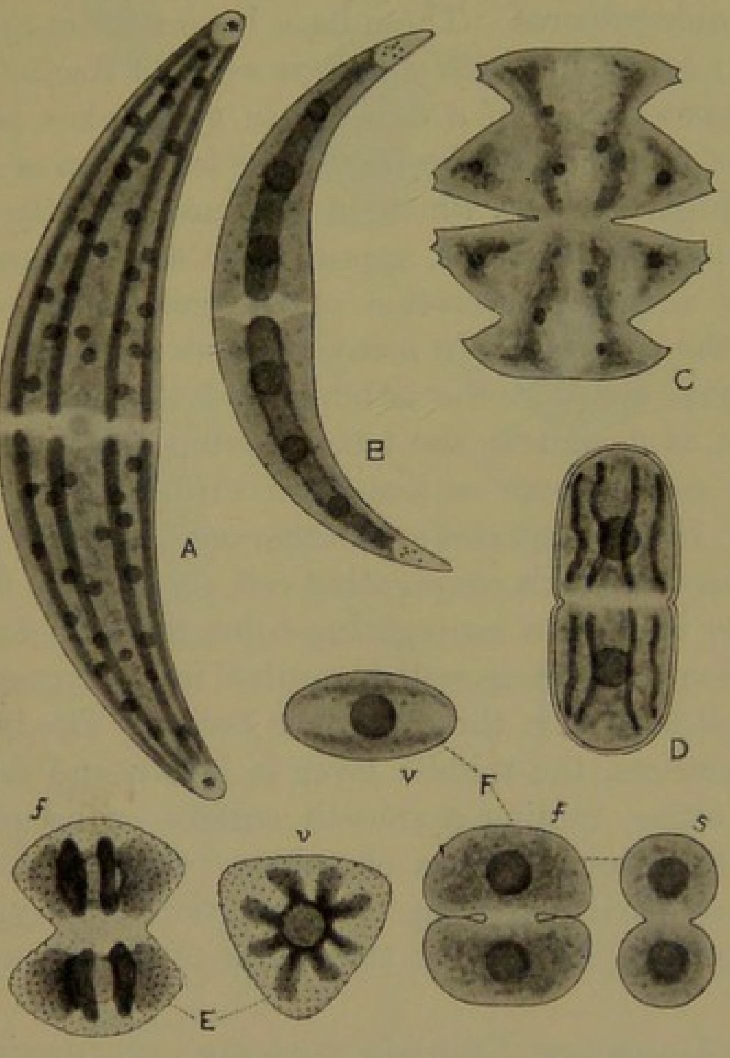

Fig. 51. A, *Closterium Ehrenbergii* Menegh., from Glyder Fawr, N. Wales (×184). B, *Cl. Leibleinii* Kütz., from near March, Cambs. (×334). C, *Micrasterias oscitans* Ralfs, var. *mucronata* (Dixon) Wille, from Kerry, Ireland (×184). D, *Penium cucurbitinum* Biss., from near St Just, Cornwall (×435). E, *Staurastrum Kjelmanni* Wille, from 2600 ft. on Glyder Fawr, N. Wales (×435). F, *Cosmarium Klebsii* Gutw. (a form), from near Ely, Cambs. (×435).

very pale in colour, but the chloroplasts are quickly developed and pyrenoids soon make their appearance. All Desmids which undergo normal cell-division at the region of the isthmus consist of one of the half-cells of the mother and a newly developed half, but in certain species of *Closterium* and *Penium* the cell may consist of portions of several generations.

Asexual reproduction takes place very occasionally by the formation of aplanospores. These have been seen in *Spondylosium nitens* (Wall.) Arch.[1] and in *Hyalotheca neglecta* Racib.[2]

Sexual reproduction of a degenerate type takes place by the conjugation of two individual cells and the formation of a zygospore. The two conjugating cells, which in the vast majority of Desmids are sexually indistinguishable, approximate and become enveloped in mucus by a further secretion of the gelatinous pectose constituents of the cell-wall. In many Desmids the semicells of each individual come apart at the isthmus and the entire contents of the cell issue as a gamete, the latter having the appearance of a protoplasmic vesicle more or less filled with an irregular mass of chlorophyll. In some species a protuberance of variable size arises from the isthmus of each conjugating cell, and on the fusion of the protuberances to form a conjugating-tube, the gametes issue into it. The union of the gametes results in a zygospore, which develops a cell-wall with three distinct layers. The inner layer is thin and colourless, the middle layer is brown and firm, and the outer layer either retains a smooth surface or becomes covered with variously arranged warts or spines. Sometimes more than two cells have participated in the formation of a zygospore, the latter having been formed by the union of three[3] or even four[4] gametes.

All the filamentous Desmids dissociate into their individual cells prior to normal conjugation, with the exception of certain species of the genus *Desmidium*, and the zygospores are formed *between* the conjugating cells in all Desmids except *Desmidium cylindricum* Grev. In this species the zygospore is formed within the female cell as in *Spirogyra* and *Zygnema*.

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[1] Wallich in Ann. Mag. Nat. Hist. ser. 3, vol. v, 1860, t. vii, f. 10, 11; Turner in Kongl. Sv. Vet.-Akad. Handl. Bd xxv, no. 5, t. xviii, f. 7, 8.

[2] W. & G. S. West in Ann. Bot. xii, 1898, t. iv, f. 23—27.

[3] West in Journ. Linn. Soc. Bot. xxix, t. xxiv, f. 5; W. & G. S. West in Journ. Roy. Micr. Soc. 1897, t. vi, f. 5.

[4] Turner, l. c. t. x, f. 16 *e*.

It frequently happens that conjugation takes place immediately after vegetative division and before the young semicells have arrived at maturity[1], and for any trace of sexuality to exist under such conditions, one must imagine that the physiological change from the vegetative to the reproductive cell occurs immediately antecedent to conjugation. Conjugation between adjacent cells of filamentous species (i.e. lateral conjugation) has been observed in

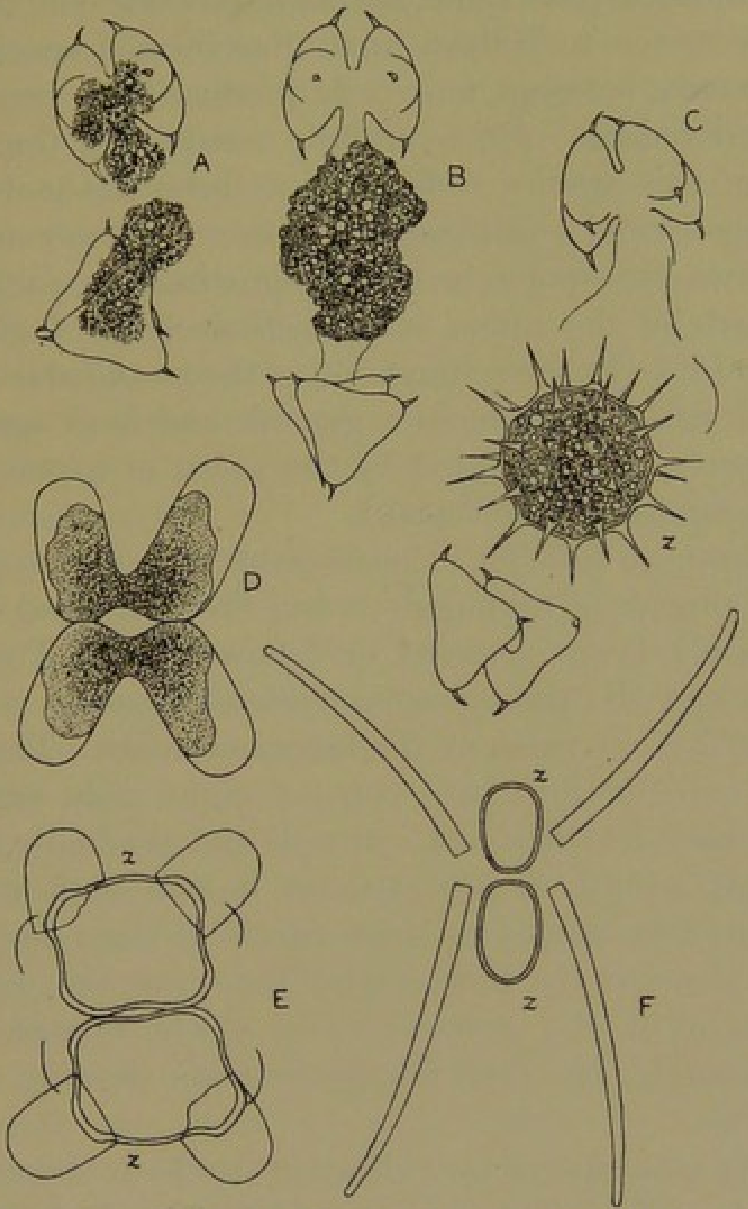

Fig. 52. A—C, *Staurastrum Dickiei* Ralfs; three stages in the conjugation, from the New Forest, Hants. (× 356). D and E, *Penium didymocarpum* Lund.; D, conjugation of four individuals just produced by division; E, completed conjugation showing the double zygospore; from near Balallan, Lewis, Outer Hebrides (× 464). F, *Closterium lineatum* Ehrenb., showing the double zygospore, from near Glenties, Donegal, Ireland (× 100). *z*, zygospore.

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[1] Archer in Quart. Journ. Micr. Sci. ii, p. 251; W. & G. S. West in Journ. Roy. Micr. Soc. 1896, p. 151.

the genera *Sphærozosma* and *Spondylosium*, but species of these genera conjugate normally only after dissociation of the filaments.

The four Desmids *Closterium lineatum* Ehrenb., *Cl. Ralfsii* Bréb. var. *hybridum* Rabenh., *Cylindrocystis diplospora* Lund. and *Penium didymocarpum* Lund. normally produce double zygospores, and I have reason to believe in the last-named species that conjugation occurs between four cells produced by two consecutive vegetative divisions. After carefully considering the conjugating examples of this species which I have been fortunate enough to obtain from several localities, I am forced to the conclusion that there are two zygospores in close approximation, each one having been formed by the union of a distinct pair of gametes (*vide* fig. 52 D and E). In the conjugation of the two *Closteria* mentioned above, each half-cell produces a gamete, and here again there are two zygospores each produced by the union of a pair of gametes, one from a semicell of each plant.

The zygospore rests for a considerable time before germination. The actual process of germination was first described by De Bary[1] and has rarely been observed or followed out. The two outer coats burst and the protoplasmic contents issue in a thin vesicle composed of an extension of the innermost coat. The contents of this vesicle divide into two, four, or eight cells, each of which becomes invested with a new cell-wall and gradually assumes the form of the adult. If the species is one with characteristic markings the first-formed cells are devoid of them, but on the first vegetative division the new semicells acquire the distinguishing ornamentation of the species. The newly formed individuals divide repeatedly, the first few generations showing a slight increase in size.

Only one true case of hybridization has been observed amongst the Desmids and in that case the development of the zygospore was not followed out[2]. All other recorded cases of hybrids are conjectural and most of them are obviously forms produced by ordinary vegetative division.

There are many strong reasons for regarding the Desmidiaceæ as a degenerate family of Conjugatæ which has originated by retrogression from filamentous ancestors. The degeneration has brought

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[1] De Bary, 'Untersuchungen über die Fam. der Conj.,' Leipzig, 1858.

[2] Archer in Quart. Journ. Micr. Sci. 1875, pp. 414, 415. This was a zygospore produced by the conjugation of two cells, one of which was *Euastrum Didelta* (Turp.) Ralfs and the other *Euastrum humerosum* Ralfs.

about a loss of the filamentous condition, accompanied by the development of specialized morphological characters[1], and this has gone on hand in hand with the loss of sexual differentiation of the conjugating cells. It has been previously mentioned that *Desmidium cylindricum* is the only known Desmid in which the zygospore is formed in one of the conjugating cells (presumably the female), and the occasional reversion to this type of conjugation in *Hyalotheca dissiliens*[2] goes far to prove that in all probability this was the ancestral type of conjugation in the Desmidiaceæ. Moreover, it is a type of conjugation which is represented at present by the Zygnemeæ, although amongst the Desmids its lingering remains are only found in *Desmidium cylindricum.* A few years ago I advocated a scheme of evolution of Desmids from ancestral filamentous forms by descent through the genus *Cylindrocystis*[3], and the recent discovery of that extraordinary member of the Zygnemeæ, *Debarya Desmidioides* W. & G. S. West[4], is of surpassing interest. This Conjugate fills up the link that was missing in the chain of evidence which goes to show that *Cylindrocystis* and *Mesotænium,* and following on that nearly all the other genera of Desmids, were most probably derived from filamentous ancestors. There is also a great tendency towards the secondary assumption of the filamentous condition. Not only has this resulted in the production of true filamentous genera such as *Spondylosium, Onychonema, Sphærozosma, Desmidium,* etc., which had their origin from unicellular forms, but this tendency reveals itself in certain species of genera which are normally unicellular. Thus, filamentous forms are occasionally met with of such species as *Cosmarium obliquum* Nordst.[5], *C. moniliforme* (Turp.) Ralfs, *C. Regnellii* Wille[6], *Euastrum binale* (Turp.) Ehrenb.[7] and *Staurastrum inconspicuum* Nordst.[8], not to mention certain of the tropical *Pleurotænia* and *Micrasterias foliacea* Bail., the latter being a true filamentous form of a typically unicellular genus with complex cell-outlines.

The Desmidiaceæ is at the present day the family of Conjugates

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[1] W. & G. S. West in Ann. Bot. xii, 1898, pp. 53, 55.

[2] Boldt in Bih. till Sv. Vet.-Akad. Handl. Bd xiii, no. 5, t. ii, f. 33; Joshua in Journ. Bot. xx, 1892.

[3] G. S. West in Journ. Linn. Soc. Bot. xxxiv, 1899, pp. 409—415.

[4] W. & G. S. West in Journ. Bot. 1903, p. 39, t. 446, f. 1—9.

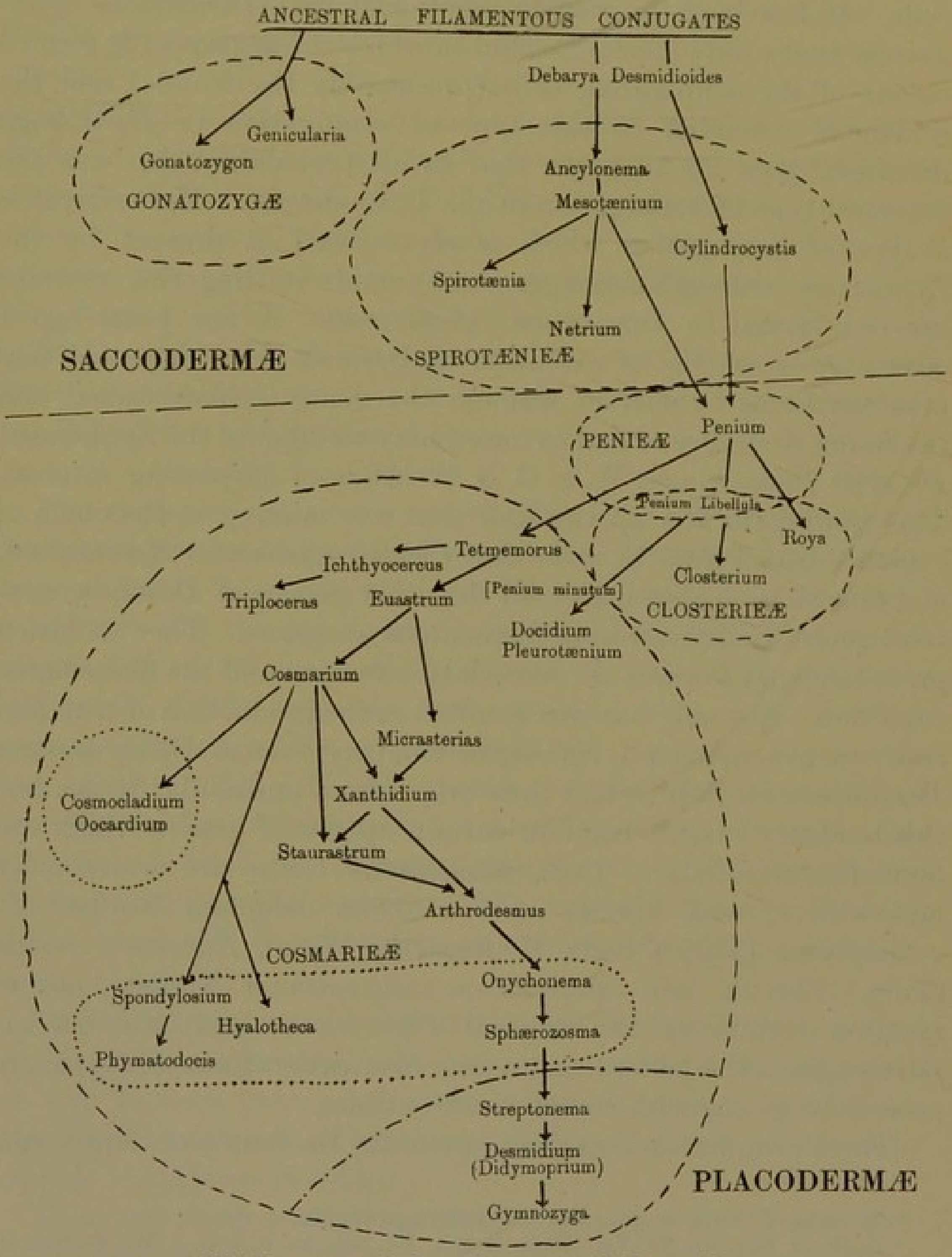
[5] Nordstedt in Acta Univers. Lund, ix, 1873, p. 23, t. i, f. 8.

[6] W. & G. S. West in Trans. Linn. Soc. Bot. ser. 2, v, t. xv, f. 20 *a′*.

[7] W. & G. S. West in Ann. Bot. xii, 1898, p. 30, t. iv, f. 38.

[8] Börgesen in Bot. of Faeröes, Part I, Copenhagen, 1901, p. 235, t. viii, f. 4.

which has attained a maximum state of specialization in the direction of an increase in the complexity of morphological characters, accompanied by degeneration of sexual differences.



Phylogeny of the Genera of Desmids.

There is little question that this complexity of outline, which is so frequently accompanied by a defensive armour of spines and spinous processes, has been acquired as a means of defence against the attacks of small aquatic animals. After the loss of the filamentous condition it became necessary for the solitary and unprotected individuals to acquire some other means of defence, and presumably the present morphological complexity is the result. It is a notable fact that those species which occur on wet rocks and in other localities in which Amœbæ, Oligochætes, Tardigrades, Crustacea, etc., are either absent or very scanty, especially at high elevations, usually possess a comparatively simple outline and are provided with a more or less abundant mucus; whereas those species occurring in deep bog-pools, in the plankton, and the quiet margins of deep lakes, in which localities such enemies abound, are generally possessed of a more complicated, and in many cases of a formidable, exterior. These characters acquired by the unicell are not only protective against the depredations of aquatic animals, but are also useful as anchors in the time of floods, and in their acquirement the Law of Symmetry has exercised its full influence, with the result that exquisite patterns have been produced which exhibit a symmetry far ahead of that shown by any other living vegetable organisms.

There are several thousand known species of Desmids, about one quarter of which are British, and almost all of them can be readily identified by their external morphological features. Some are cylindrical with rounded or attenuated apices; many of them are flattened and often disciform; and others are of a radiating character. To one who is not sufficiently versed in solid geometry there are few greater surprises than the extraordinary aspects presented by some of these plants. The majority of Desmids have three principal axes of symmetry at right angles to one another, and for this reason they require examining in three positions. The most important aspect is the *front view*, in which the plant is observed in that plane containing the two longest axes. The other important aspects are the *vertical view* and the *side* (or *lateral*) *view* (*vide* fig. 51 E and F).

Desmids are subject to considerable variation, but only within certain limits, and one of the most extraordinary facts relating to these plants is the constancy of the markings embellishing the exterior of the cell-wall. The following is a summary of the present state of our knowledge concerning the variation of Desmids[1]:—

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[1] G. S. West, 'On Variation in the Desmidieæ and its Bearing on their Classification,' Journ. Linn. Soc. Bot. xxxiv, 1899, p. 376.

(1) The structure of the cell-contents is one of the most constant features exhibited by a species; but this fact can be of little classificatory value owing to the very large number of species which possess the same structure and arrangement of the chromatophores.

(2) The outward form of the cell, as seen in front view, varies within certain limits, which are usually very small, but which may in exceptional cases (such as in pure cultures) be considerable. The form of the vertical view is, as a rule, a more constant feature than the form of the front view.

(3) The ornamentation (scrobiculations, granulations, spinulations, etc.) of the cell-wall is relatively constant, being always arranged according to a definite law, which is only transgressed by variations in one or more of the individual component groups which constitute the pattern of arrangement.

(4) The prolific growth and rapid division of immense numbers of Desmids have a tendency to produce variations from the typical forms.

(5) Changes in the conditions of environment cannot affect the characters of a species unless they act for long periods of time.

It is most unfortunate that so little is known concerning the geographical distribution of Desmids, as such a knowledge would probably be of much greater value than one would at first sight imagine. I have previously shown that the production of permanent variation in species of Desmids under natural conditions is much more difficult than is generally supposed[1]; also, that some of the prettily marked species are found in such widely separated localities as Ceylon, Java, Hong Kong and Queensland, identical in every respect and possessing precisely the same markings[2]. It is likewise most improbable that this result has been brought about by a parallelism of modification in the course of the evolution of these forms, owing to the occurrence of other species with a world-wide distribution and equally constant characters. The distribution of *Micrasterias foliacea* Bail. is sufficient to settle this point, as the plant in question is the most aberrant of all forms of the genus *Micrasterias*, having secondarily assumed a filamentous condition; and yet the plants found in North and South America, India, Burmah, Siam, China, Australia and New Zealand cannot be distinguished from one another. It should also be borne in

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[1] G. S. West, l. c. p. 371.

[2] W. & G. S. West in Trans. Linn. Soc. Bot. ser. 2, vol. vi, 1902, p. 124.

mind that the transference by natural means of living specimens of any Desmid from some of these countries to any of the others is an utter impossibility, desiccation, or in many cases even partial drying, being quickly followed by death, and submergence in sea-water is equally fatal[1]. Moreover, zygospores, which might possibly withstand the entailed vicissitudes if circumstances arose by which they could be transferred from one country to the other (such as by the long flight of a wading-bird), are so rarely found that distribution by their means across an expanse of ocean is almost impossible. There is but one conclusion to be arrived at from a consideration of these facts, namely, that such a species has been perpetuated by isolated communities which were derived originally from a common stock, and that the individuals of these communities have retained their original characters in an extraordinarily constant manner. Thus, it seems probable that a sound knowledge of the distribution of Desmids would shed much light on the subject of previous land-connections, and might perhaps afford more reliable evidence on this point than that afforded by the known distribution of any other plants or animals.

As a significant instance, it may be mentioned that several remarkably fine Desmids, such as *Staurastrum Ophiura* Lund., *St. Arctiscon* (Ehrenb.) Lund., *St. jaculiferum* West, *St. longispinum* (Bail.) Arch., *St. Cerastes* Lund., *St. Brasiliense* Nordst. var. *Lundellii* W. & G. S. West, *Micrasterias furcata* Ag., *M. conferta* Lund., *Pleurotænium nodosum* (Bail.) Lund., and others, are not uncommon in the eastern parts of N. America and that in Europe they are only abundant on the north-western shore districts of Ireland, Wales, Scotland, the Outer Hebrides, Scandinavia and Lapland. One of these species—*Staurastrum jaculiferum* West—is also known from the Shetland Is., the Faeröe Is. and Iceland.

Borge has examined a number of subfossil Desmids from the glacial clays of the Isle of Götland, and a few subfossil forms of existing species have also been noted from an ancient peat deposit near Filey in E. Yorkshire.

Desmids thrive best in soft water, and they are most numerous in peaty water which has a trace of acidity. With few exceptions they do not flourish in water containing carbonate of lime in solution, and no good collection of Desmids can be made in a purely limestone district in which the water is hard.

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[1] One Desmid has been described as inhabiting brackish water, viz.: *Cosmarium salinum* Hansg. in Oesterr. bot. Zeitschr. 1886, p. 335.

I have attempted to give a reasonable classification of the genera of Desmids based upon the evolutionary scheme previously mentioned[1] and upon the recent and sound observations of Lütkemüller[2]. It is very interesting to note that Lütkemüller's conclusions, which he arrived at chiefly from the study of the minute structure of the cell-wall, coincide almost entirely with the scheme I put forward in 1899, which was based upon a comprehensive study of the external morphological features of these plants.

The division of Desmids into filamentous forms and solitary forms, such as is adopted by many writers even at the present time, is no longer tenable; and such an arrangement as that given by Bessey[3], in which he places Desmids under the three tribes 'Desmidieæ,' 'Arthrodieæ' and 'Cosmarieæ,' is obviously one which is not based upon a careful study of the Desmids themselves and is therefore of no value.

Most Desmids would appear to have had an origin from the genera *Mesotænium* and *Cylindrocystis,* which were themselves derived by retrogression from ancestral filamentous Conjugates[4]. The genera *Gonatozygon* and *Genicularia* have so little in common with most other Desmids, and resemble so much some of the present existing filamentous Conjugates, that they must be regarded as having had a distinct origin from filamentous ancestors. They are however, more specialized than the genera *Spirotænia, Mesotænium* or *Cylindrocystis.*

The genus *Penium* is the most difficult to relegate to its proper place. In the sense in which this genus is generally regarded it undoubtedly contains many widely different plants, and therefore one hails with delight Lütkemüller's suggestion that the name *Netrium* be again brought forward as a distinct genus to include four species which obviously form a natural group. On the removal of these four plants from the genus, the remainder do not fit satisfactorily into any one place in the scheme of classification, and the difficulty lies in the fact that our knowledge of the plants

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[1] G. S. West in Journ. Linn. Soc. Bot. xxxiv, 1899.

[2] Lütkemüller in Beiträge zur Biol. der Pflanzen, herausgegeben von Dr F. Cohn, Bd viii, Breslau, 1902.

[3] Bessey in Trans. Amer. Micr. Soc. xxii, 1901.

[4] Had these genera originated directly from Flagellate forms, it is scarcely conceivable that the motile condition would not be frequently reverted to; in fact, it is reasonable to suppose that it would play a considerable part in the life-history of these Algæ. *Such is the case in all groups of Algæ with a direct Flagellate ancestry*; and the entire absence of motile forms of any description from the Desmidiaceæ lends strong support to the view put forward from other considerations, of the origin of this family of unicells by retrogression.

is too scanty to allow of splitting them up into a number of separate genera. One cannot see how, in the present state of our knowledge, such genera could be defined, and yet some of these plants are certainly not nearly related. The plant commonly known as *Penium minutum* (Ralfs) Cleve is the most puzzling of all.

I have accepted the two sub-families proposed by Lütkemüller and also his five tribes, but have placed the "Gonatozygæ" first and altered the definition of the "Penieæ" in order to include the heterogynous collection of Desmids embraced in the present genus *Penium*.

The following is a synopsis of all the known genera of Desmids, four of which (*Ichthyocercus*, *Triploceras*, *Phymatodocis* and *Streptonema*) are exclusively tropical and one (*Ancylonema*) is exclusively arctic.

Sub-family I. SACCODERMÆ.

Cell-wall unsegmented and without pores. Point of division of cells indefinite and unknown previous to the actual division. The young half of the cell is developed obliquely and its walls are absolutely continuous with the walls of the older half.

Tribe 1. **Gonatozygæ.** Cells elongate, cylindrical and unconstricted, forming loose filaments. Cell-wall with a differentiated outer layer of which the small roughnesses and spines form a part.

* Chloroplasts axile .... 1. *Gonatozygon.*
** Chloroplasts parietal and spirally twisted ... 2. *Genicularia.*

Tribe 2. **Spirotænieæ.** Cells solitary, relatively short and mostly unconstricted. Cell-wall a simple sac, without a differentiated outer layer. The cell becomes adult by periodical growth.

* One chloroplast in each cell.
† Chloroplast spirally twisted, axile or parietal 3. *Spirotænia.*
†† Chloroplast plane, axile.
§ Cells solitary .... 4. *Mesotænium.*
§§ Cells forming short filaments .... 5. *Ancylonema.*
** Two chloroplasts in each cell.
† Chloroplasts star-shaped, radiating from a central pyrenoid................................ 6. *Cylindrocystis.*
†† Chloroplasts ridged with longitudinal serrated ridges .... 7. *Netrium.*

Sub-family II. PLACODERMÆ.

Cell-wall segmented, with a differentiated outer layer. Cell-division follows a fixed type, with the interpolation of the younger halves between the old ones. The younger portions of the cell-wall are joined to the older portions by an oblique surface.

A. Point of division of cells variable or sometimes fixed (at the isthmus).

Tribe 3. **Penieæ.** Cells of moderate length, straight, cylindrical, sometimes with a slight median constriction. Cell-wall with or without pores. Point of division of cells often variable. The cell often arrives at maturity by periodical growth. 8. *Penium.*

Tribe 4. **Closterieæ.** Cells elongate, generally curved; symmetrical in one longitudinal plane only. Cell-wall commonly with pores. Points of division regularly placed in the middle region of the cell.

* Cells almost cylindrical, scarcely attenuated. Chloroplast single, without apical moving granules .... 9. *Roya.*

** Cells strongly attenuated towards each extremity. Two chloroplasts in each cell, with apical moving granules .... 10. *Closterium.*

B. Point of division of cells always fixed (at the isthmus).

Tribe 5. **Cosmarieæ.** Cells exhibit great variety of form, and the cell-wall consists of two thin, firm layers with pores. There is no periodical growth, the cell becoming adult immediately after division by the mature growth of the young semicell.

a. The point of division of the cell, where the new and old parts of the cell-wall are obliquely fitted together, remains plane during division. Solitary or colonial.

* After division the cells remain free and solitary.

† Cells elongated and cylindrical; constriction slight.

§ Apices of cells truncate or rounded.

‡ Base of semicells plicate............ 11. *Docidium.*

‡‡ Base of semicells plane............ 12. *Pleurotænium.*

§§ Apices of cells cleft, incision open or narrow.

‡ Cell-wall adorned with rings of furcate processes.................. 13. *Triploceras.*

‡‡ Cell-wall plane.

⊙ Apical incision widely open, each apical angle furnished with a spine .... 14. *Ichthyocercus.*

⊙⊙ Apical incision narrow ... 15. *Tetmemorus.*

†† Cells relatively short, commonly compressed or radiating, constriction usually deep.

§ Cells compressed (at right angles to the plane of the front view); from the vertical view fusiform or elliptical.

‡ Cells generally with an apical incision and a central protuberance, moderately lobed .... 16. *Euastrum.*

‡‡ Cells very compressed and deeply lobed or incised .... 17. *Micrasterias.*

‡‡‡ Cells with a more or less entire margin, often furnished with warts or spines.

⊙ Cells commonly with a central protuberance.
¶ Cell-wall smooth, granulate, verrucose, etc. Central protuberance present or absent...... 18. *Cosmarium.*
¶¶ Cell-wall with regularly arranged spines, commonly in pairs. Central protuberance always present............ 19. *Xanthidium.*
⊙ ⊙ Cells without a central protuberance; angles spinate 20. *Arthrodesmus.*
§§ Cells from the vertical view commonly radiating, triangular, quadrangular, or up to 11-radiate, rarely fusiform .... 21. *Staurastrum.*
** After division the cells remain attached to form colonies.
† Colonies spheroidal; cells not in contact, but joined by gelatinous bands.
§ Gelatinous bands narrow; few cells forming a microscopic colony ...... 22. *Cosmocladium.*
§§ Gelatinous bands very broad; many cells forming a macroscopic colony 23. *Oocardium.*
†† Colonies thread-like; cells attached by their apices to form long filaments.
§ Cells attached by special apical processes.
‡ Apical processes very short ...... 24. *Sphærozosma.*
‡‡ Apical processes long and overlapping the apices of the adjoining cells .... 25. *Onychonema.*
§§ Apices of cells plane and flat.
‡ Cells deeply constricted.
⊙ Cells in vertical view elliptical 26. *Spondylosium.*
⊙ ⊙ Cells in vertical view quadrangular with produced angles .... 27. *Phymatodocis.*
‡‡ Cells very slightly constricted... 28. *Hyalotheca.*

b. The point of division of the cell, where the new and old parts of the cell-wall are obliquely fitted together, develops a girdle-like thickening or ingrowth, which projects both ways into each of the old semicells during division. Cells attached to form thread-like colonies.

* Cells joined by special apical processes .... 29. *Streptonema.*
** Cells joined by their flat apices or by flattened apical projections.
† Cells short, in vertical view fusiform, triangular or quadrangular (rarely circular with produced angles) .... 30. *Desmidium.*
†† Cells elongate, cylindrical .... 31. *Gymnozyga.*

Sub-family I. SACCODERMÆ.

This is a very natural group of Desmids in which the cell-wall is unsegmented and destitute of pores. There is no line of demarcation between the newer semicell and the older semicell, the cell-wall being absolutely continuous. Division takes place at no fixed part of the cell (except in a few species of *Cylindrocystis*) and the young semicells are developed obliquely, gradually sliding away from one another as they reach maturity.

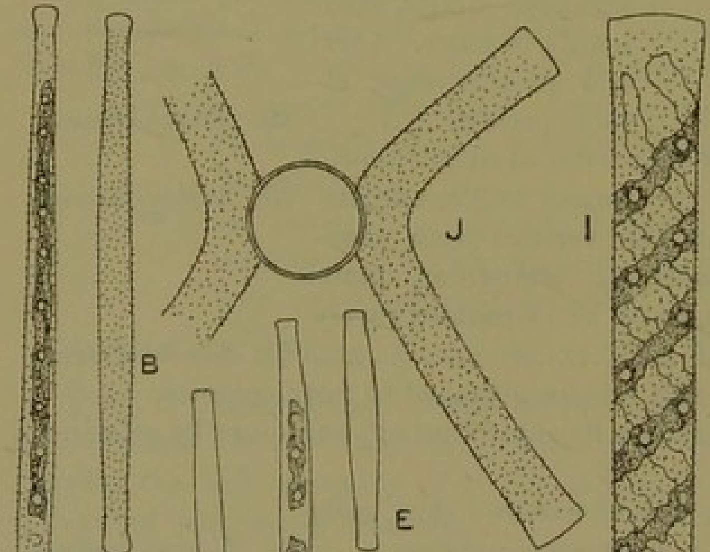

Fig. 53. A and B, *Gonatozygon Brébissonii* De Bary (×464); A, from Esher Common, Surrey; B, from Strensall, N. Yorks. C—E, *G. Brébissonii* var. *læve* (Hilse) W. & G. S. West, from Mickle Fell, N. Yorks. (×356). F and G, *G. Brébissonii* var. *minutum* W. & G. S. West, from Riccall Common, E. Yorks. (×464). H, zygospore of *G. monotænium* De Bary (×464). I and J, *Genicularia Spirotænia* De Bary, from near the Lizard, Cornwall; I, vegetative cell (×312); J, zygospore (×220).

Tribe 1. *Gonatozygeæ.*

This tribe only includes two genera which are considerably removed from other Desmids. The cells are long and cylindrical, and are joined by their apices into fragile filaments of variable length. The filaments easily break up, but this in no way interferes with the life of the individual cells. Conjugation only takes place between cells which have become free. The cell-wall is differentiated into two layers, the inner layer being hyaline and structureless, the minute prominences or small spines characteristic of most of the tribe forming a part of the outer layer.

Genus **Gonatozygon** De Bary, 1856. The cells are cylindrical or narrowly fusiform, 10—20 (rarely 40) times longer than the diameter, and without any constriction. The apices are occasionally subcapitate and always more or less truncate. The apical attachment of the cells is very slight, the least disturbance causing a general dissociation of the filament. The cell-wall is rarely smooth, being usually covered with minute, sharp prominences or short spines. There are generally two axile chloroplasts in each cell (rarely only one), each of which is rather narrow, undulated, sometimes twisted, and contains 4—16 equidistant pyrenoids. Occasionally an apical vacuole containing moving granules is present at each end of the cell, beyond the limit of the chloroplasts. On the formation of the zygospore the conjugating cells frequently become geniculate. The zygospore has a smooth outer coat.

There are five British species of the genus, of which *G. monotænium* De Bary [*G. Ralfsii* De Bary] and *G. Brebissonii* De Bary [? *Docidium asperum* Bréb.] (fig. 53 A and B) are the most abundant. Smooth varieties of both these species are known and *G. Kinahani* (Arch.) Rabenh., which is the largest species of the genus (length of cell 162—376 μ; breadth 11—14 μ), is always smooth. The smallest form is *G. Brébissonii* var. *minutum* W. & G. S. West (fig. 53 F and G), which has a length of 47·5—67·5 μ and a breadth of 4·2—7 μ.

Genus **Genicularia** De Bary, 1858. The cells are similar in form to those of *Gonatozygon*, being cylindrical, elongate, unconstricted and with truncate apices. The filaments are extremely fragile and the cells always become free previous to conjugation. The zygospore is globose and smooth, and the conjugating cells become geniculate. The cell-wall is rough on the exterior almost exactly like the cells of *Gonatozygon monotænium*. There may be two or three parietal chloroplasts in each cell, disposed as spiral bands or rarely somewhat irregular. Each chloroplast contains a number of pyrenoids. *Genicularia* is one of the rarest known genera of Desmids.

G. Spirotænia De Bary has only been found in the British Islands from Cornwall and the Shetland Is.; length of cells 200—400 μ, breadth 20—25 μ, diam. zygosp. 48—57 μ (fig. 53 I and J). *G. elegans* W. & G. S. West is a more slender species in which the chloroplasts form laxer spirals; length 303—427 μ, breadth 14—16·3 μ. It is only known from the plankton of Loch Fadaghoda, Lewis, and of Loch nan Eun, N. Uist, Outer Hebrides.

Tribe 2. *Spirotænieæ.*

In the British genera of this tribe the cells are solitary, relatively short and unconstricted (with the exception of a few species of *Cylindrocystis*). The cell-wall has no differentiated outer layer and is quite smooth. The individuals reach the adult condition by periodical growth, chiefly in length.

Genus **Spirotænia** Bréb., 1848. The cells are straight or very slightly curved, oblong-cylindrical or fusiform, and frequently enveloped in mucus. There is no median constriction and the apices of the cells may be rounded, truncate, subacute or very acute. There is only one chloroplast in each cell, which may be band-like and parietal, or axile and cristate, and is always spirally twisted to the left. The nucleus is generally asymmetrical, and the cell-wall is smooth and structureless. The genus is divided into two sections; in sect. 1, *Monotænieæ* Rabenh., the chloroplast is a parietal band spirally arranged round the inside of the cell-wall; in sect. 2, *Polytænieæ* Rabenh., the chloroplast is axile with a variable number of spirally twisted ridges. There may be one or many pyrenoids in the chloroplast.

There are fourteen British species of the genus, none of which is common. *S. condensata* Bréb. (fig. 54 A; length 150—270 μ, breadth 18—27 μ) is the largest and most widely distributed, and *S. closteridia* (Bréb.) Arch. is the smallest (length 13·5 μ, breadth 4·5—4·6 μ). They are all very delicate, with thin cell-walls, and most of them can only be identified with certainty from living specimens. The zygospores of few of them are known and they are rarely met with; the outer layer of the wall of the zygospore is usually ornamented. Most of the species occur in peat-bogs.

Genus **Mesotænium** Näg., 1849. The cells are cylindrical or subcylindrical, generally straight or slightly curved, and are without any trace of a median constriction. The apices are, as a rule, broadly rounded. The chloroplast, of which there is usually only one in a cell, is a flattened, axile plate extending from end to end of the cell, and there may be one or several pyrenoids. Sometimes there are two flattened chloroplasts. The cells often contain numerous globules of an oily nature.

There are ten British species of the genus, seven of which occur as mucilaginous masses amongst mosses and hepatics, generally on wet rocks. The largest of these is *M. De Greyi* Turn. (fig. 54 D; length 74—125 μ; breadth 15·5—30 μ) and the smallest is *M. macrococcum* (Kütz.) Roy & Biss. var. *micrococcum* (Kütz.) W. & G. S. West (length 13·5—15·3 μ; breadth

8·6 μ). *M. caldariorum* (Lagerh.) Hansg. is an attenuated species which occurs in greenhouses, forming a thin mucilaginous stratum on damp walls, etc. (length 27—46 μ; breadth 10·5—11·5 μ). *M. Endlicherianum* Näg. is the most frequent of the free-floating forms (length 25—27 μ; breadth 8·5—9·5 μ), and *M. purpureum* W. & G. S. West and *M. violascens* De Bary contain phycoporphyrin. The zygospores of species of this genus are generally polyhedral with thick brown walls.

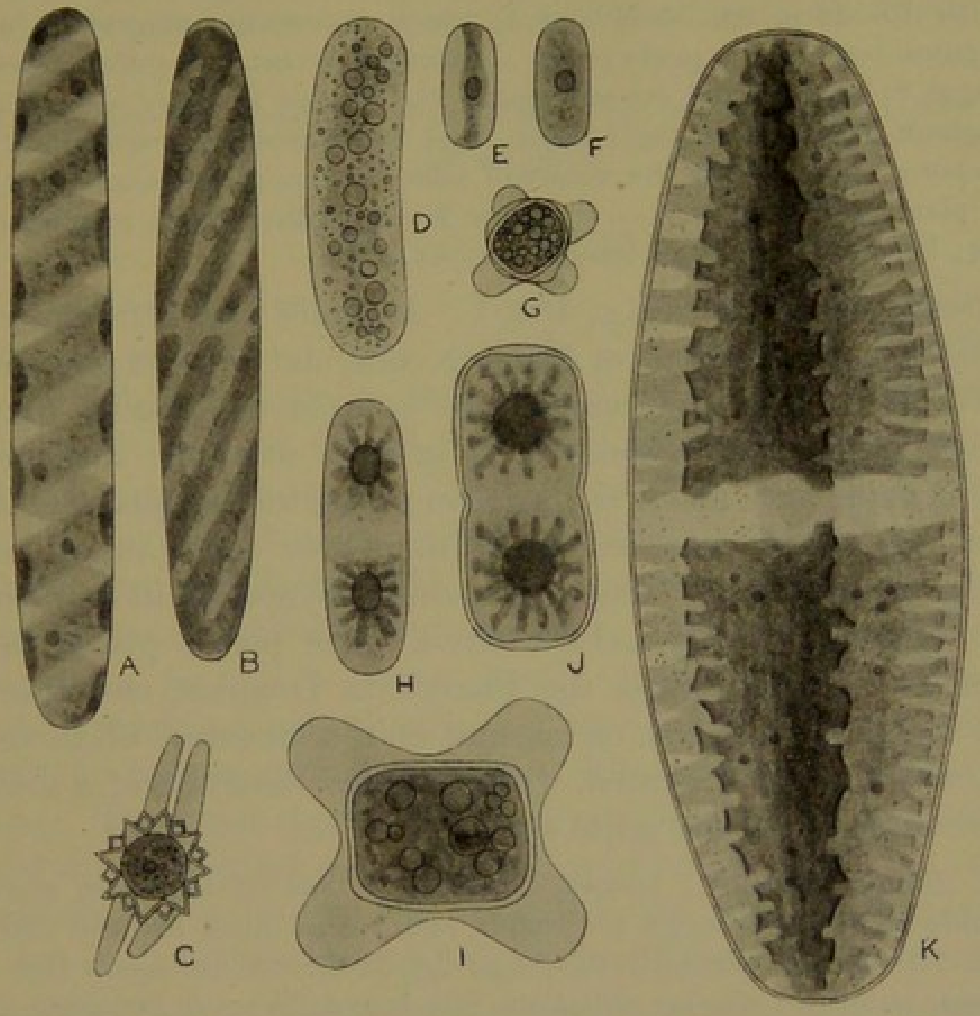

Fig. 54. A, *Spirotænia condensata* Bréb., from Rhiconich, Sutherland (×334), showing parietal chloroplast. B, *Sp. obscura* Ralfs, from Terrington, N. Yorks. (×435), showing the axile, cristate chloroplast. C, zygospore of *Sp. truncata* Arch. (×250, after Archer). D, *Mesotænium De Greyi* Turner, from near Settle, W. Yorks. (×435). E and F, *M. macrococcum* (Kütz.) Roy & Biss., from near Giggleswick, W. Yorks. (×334). G, zygospore of *M. chlamydosporum* De Bary, from Mayo, Ireland (×334). H and I, *Cylindrocystis Brébissonii* Menegh., from Helvellyn, Westmoreland; H, vegetative cell; I, zygospore (×435). J, *Cyl. diplospora* Lund., from Galway, Ireland (×435). K, *Netrium Digitus* (Ehrenb.) Itzigsh. & Rothe, from Moel Siabod, N. Wales (×435).

Genus **Cylindrocystis** Menegh., 1838. The cells are straight and cylindrical, averaging twice longer than the diameter, and they may or may not possess a slight median constriction. The apices of the cells are generally rounded or truncately rounded. There is a single axile, substellate chloroplast in each semicell and in the centre of each chloroplast is a large pyrenoid. The radiating prolongations of the chloroplast vary in number in the different species, and often become flattened against the interior of the cell-wall.

The most abundant species is *Cyl. Brébissonii* Menegh. (length 43—55 μ; breadth 15—18 μ, fig. 54 H and I) which occurs in quantity in upland Sphagnum-bogs and in peaty pools. It sometimes occurs in pure masses both amongst Sphagnum and on wet peat. *Cyl. crassa* De Bary also occurs in Sphagnum-bogs and amongst other Algæ and mosses on wet rocks. *Cyl. diplospora* Lund. prefers the waters of lakes and quiet pools, and is a much rarer plant; one form of it—var. *major* West—is the largest member of the genus; length 102—114 μ; breadth 48—54 μ.

Genus **Netrium** (Näg., 1849). A genus with straight, cylindrical, oblong-cylindrical or fusiform cells, and without any median constriction. The chloroplasts are two (in one species four) in number, one (in one species two) in each semicell; each chloroplast is axile with about six radiating longitudinal plates. These plates are deeply notched along their free edges in all except *Netrium interruptum*. There are several pyrenoids in each chloroplast, generally small and scattered. The plants placed in this genus are excluded from the Placoderm Desmids, and therefore from the genus *Penium*, on account of the structure of their cell-wall, which is unsegmented, without pores, destitute of a differentiated outer layer, and quite smooth.

N. Digitus (Ehrenb.) Itzigsh. & Rothe is one of the most abundant Desmids of elevated boggy moorlands and varies much in form and size; length 130—387 μ; breadth 40—82 μ; fig. 54 K. *N. oblongum* (De Bary) Lütkem. occurs in similar situations but is not quite so frequent; length 96—135 μ; breadth 32—33 μ. *N. interruptum* (Bréb.) Lütkem. is cylindrical with obtusely conical apices, and each chloroplast is transversely segmented, so that there are four chloroplasts in each cell arranged in an axile series. In this species the free edges of the plates are not notched; length 220—320 μ; breadth 37—64 μ.

Sub-family II. PLACODERMÆ.

This group includes the great majority of Desmids and is characterized by the segmented cell-wall with its differentiated outer layer. The cell-wall usually possesses pores, but this is not invariably the case. There is always a very distinct line of demarcation between the old and new semicells, the younger portions of the cell-wall not being continuous with the older portions, but joined to them by a narrow, oblique or bevelled surface. The cell-division is of a fixed type, taking place strictly in the manner of previous cell-divisions, and the younger semicells are interpolated between the older ones. The sub-family can be divided into two sections, one of which includes those Desmids in which cell-division does not always take place at a fixed point and those in which it does always take place at a fixed point known as the isthmus.

A. Point of division of cells variable or sometimes fixed at the isthmus.

Tribe 3. *Penieæ.*

This tribe only includes one genus, in which the cells are solitary, of moderate length, straight and generally cylindrical. Sometimes, but not always, there is a slight median constriction. The points of division are often variable, although the actual cell-division is of the same type. The cell-wall may be with or without pores, and the cell often grows periodically until it becomes adult.

Genus **Penium** Bréb., 1844. This genus is difficult to strictly define, as it undoubtedly contains many species which will ultimately have to find a resting-place elsewhere. The cells are straight, cylindrical, subcylindrical, ellipsoidal, or fusiform, and the apices may be rounded or truncate. The vertical view is always circular. The inner layer of the cell-wall is in many forms ornamented with striations, punctulations or granulations, but in others the cell-wall is quite smooth. There is one axile chloroplast in each semicell, with radiating longitudinal plates which have the free margin entire. The pyrenoids are one or many and uniseriate. Sometimes there is a prominent vacuole near each extremity of the cell containing moving granules.

There are about 27 British species of *Penium*, of which *P. Libellula* (Focke) Nordst. (length 250—354 μ; breadth 38—51 μ; fig. 55 D) is one of the largest and most striking. *P. margaritaceum* (Ehrenb.) Bréb., *P. Cylindrus* (Ehrenb.) Bréb. (fig. 55 A and B) and others, are granulated species, and *P. spirostriolatum* Barker (length 123—274 μ; breadth 23—26 μ; fig. 55 C) is a species with spiral striations on the cell-wall, which often anastomose or become broken up into dot-like thickenings. *P. polymorphum* Perty (length 55—58 μ; breadth 25—27 μ) is one of the most general of the upland, moorland species, and some of the smallest species of the genus are *P. inconspicuum* West (length 14·5—19 μ; breadth 5—5·7 μ), *P. minutissimum* Nordst. (length 12·2—13 μ; breadth

6·8—7·3 μ) and *P. suboctangulare* West (length 10·7—11·5 μ; breadth 6·8—7 μ; fig. 55 E). The cell-wall of many of the species is of a yellow or reddish-brown colour. *P. minutum* (Ralfs) Cleve is relatively the longest species of the genus, but should, perhaps, be relegated elsewhere.

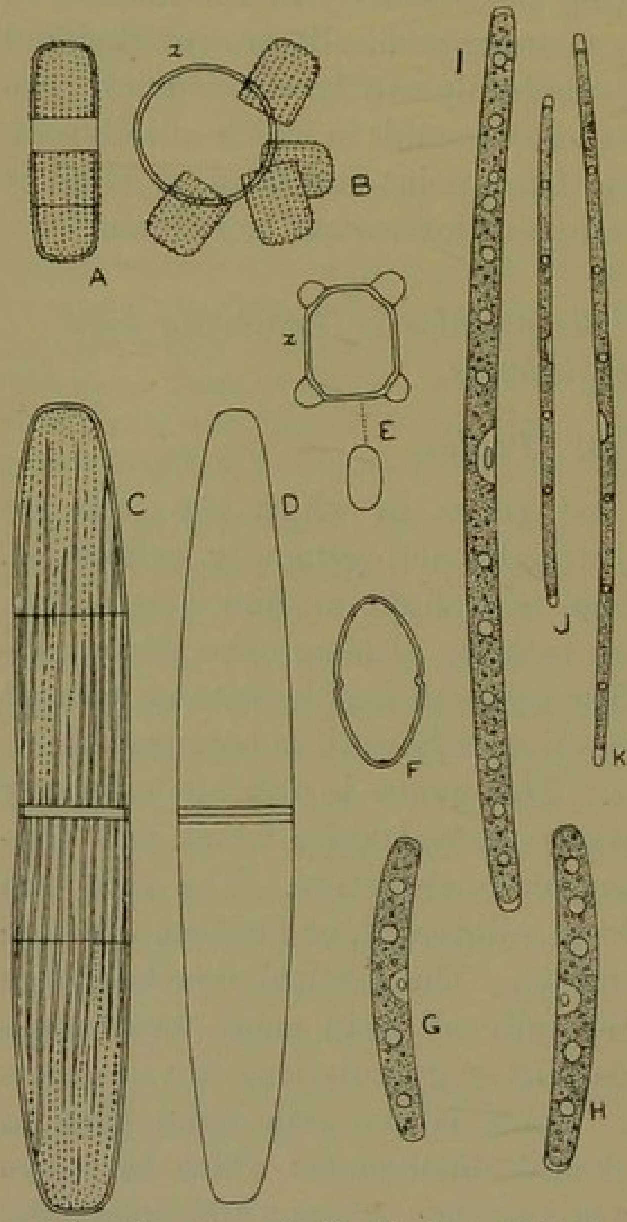

Fig. 55. A and B, *Penium Cylindrus* (Ehrenb.) Bréb.; A, from Loch Minnoch, Kirkcudbright; B, zygospore from Thursley Common, Surrey (×474). C, *P. spirostriolatum* Barker, from Kerry, Ireland (×474). D, *P. Libellula* (Focke) Nordst., from Bowness, Westmoreland (×200). E, *P. suboctangulare* West, with zygospore, from Killarney, Kerry, Ireland (×365). F, *P. curtum* Bréb., from Grimspound, Devonshire (×474). G and H, *Roya obtusa* (Bréb.) W. & G. S. West var. *montana* W. & G. S. West, from Baildon Moor, W. Yorks. (×570). I, *R. Cambrica* W. & G. S. West, from Llyn Ogwen, N. Wales (×474). J and K, *R. Pseudoclosterium* (Roy) W. & G. S. West, from Pilmoor, N. Yorks. (×474).

Tribe 4. *Closterieæ.*

The cells are elongate, generally curved, and usually attenuated towards each extremity. There is no trace of a median constriction and the plants are circular in transverse section. The points of division are always in the middle region of the cell and the cell-wall usually possesses pores. The cells are only symmetrical in *one* longitudinal plane.

Genus **Roya** West & G. S. West, 1896. This genus was named after the late Dr John Roy, who first pointed out the differences between those plants which are now included in it and species of *Closterium*. The cells are elongate, cylindrical, very slightly curved and scarcely attenuated towards the poles. There is only one chloroplast which occupies almost the entire cell-cavity. It extends to within a very short distance of each pole and its extremities are convex. In the median portion of the cell there is a slight lateral excavation in the chloroplast for the lodgement of the nucleus, which is thus asymmetrical. There are from four to thirteen pyrenoids in the chloroplast, arranged in a single series. The cell-wall is relatively thin and without pores.

The genus is readily distinguished from *Closterium* by the absence of any marked attenuation towards the apices and by the single chloroplast with convex extremities, the latter being in such close proximity to the ends of the cell that there is no room for an apical vacuole. The lateral position of the nucleus is also characteristic.

There are only three species of the genus, all of which occur in Britain. *R. obtusa* (Bréb.) W. & G. S. West (and its var. *montana*; fig. 55 G and H) is not an uncommon Desmid in mountainous districts; length 48—117 μ; breadth 5·5—12·5 μ. *R. Pseudoclosterium* (Roy) W. & G. S. West is a very narrow species of rare occurrence; length 98—192 μ; breadth 2·6—3 μ; fig. 55 J and K. *R. Cambrica* W. & G. S. West is only known from N. Wales; length 173—177 μ; breadth 6·2—6·7 μ; fig. 55 I.

Genus **Closterium** Nitzsch, 1817[1]. The cells are elongate, generally distinctly curved, and often markedly lunate or arcuate. In most cases they are strongly attenuated towards the poles, the latter being obtuse, truncate, rostrate, or drawn out into long needle-like points. In most of these plants the cell-wall possesses pores and in a large number of species it is striated, the striations being internal thickenings of the cell-wall running from pole to pole and disposed at regular intervals. The number and strength of the striations varies very much in different species of the genus. There are two chloroplasts, one in each semicell, and there may be one or many pyrenoids in each chloroplast. The extremities of the chloroplasts are concave and they do not reach the apices of the cell, thus affording room for prominent apical vacuoles which contain one or many moving granules of variable size and shape. In those species in which the apices are greatly produced the chloroplasts do not extend into the prolongations,

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[1] The name "*Arthrodia*" (Raf. in Desv. Journ. 1813, I, p. 235) cannot possibly be utilized as a generic name in place of *Closterium*. Rafinesque's diagnosis applies equally to *Ankistrodesmus*, *Penium*, *Docidium*, *Pleurotænium*, *Cylindrocystis*, and *Tetmemorus*. Nordstedt (in Hedwigia 1893, Heft 3, p. 148) has clearly pointed out that "*Arthrodia*" must always remain a "genus ignotum" and a "nomen delendum." The same author's remarks should also be consulted concerning "*Gyges* Ehrenb.," "*Helierella* Bory," "*Ursinella* Turpin," "*Prolifera* Vauch." and "*Conjugata* Vauch."

and the apical vacuoles are often correspondingly lengthened out. The chloroplasts are similar in form to those of the genus *Penium*, consisting of an axile mass with more or less distinct longitudinal ridges. In *Cl. acutum* Bréb. and several others there are no longitudinal ridges.

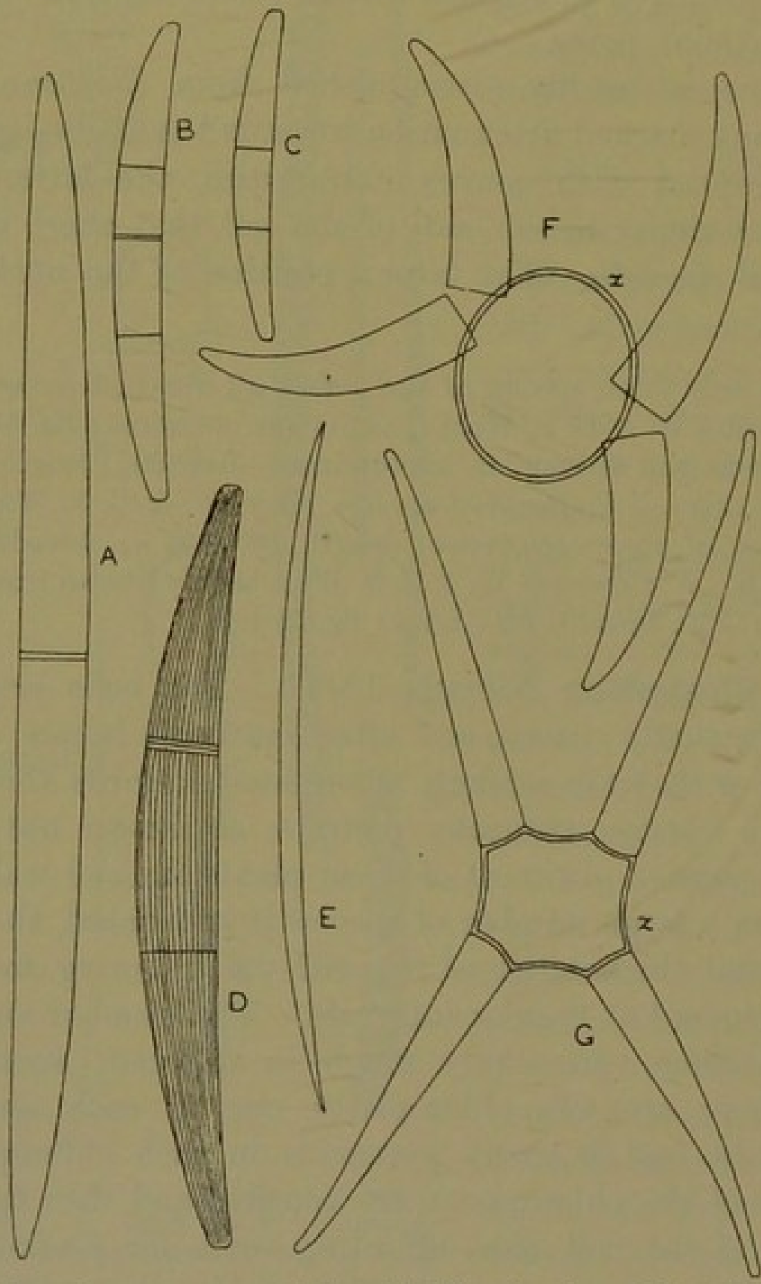

Fig. 56. A, *Closterium acerosum* (Schrank) Ehrenb., from Glen Shee, Perthshire (× 200). B—D, *Cl. striolatum* Ehrenb., from Frensham, Surrey; B and C, outlines, × 125; D, × 260. E, *Cl. acutum* Bréb., from Sligachan, Skye (× 474). F, *Cl. parvulum* Näg., zygospore, from Esher West-end Common, Surrey (× 474). G, *Cl. rostratum* Ehrenb. var. *brevirostratum* West, zygospore, from Wimbledon Common, Surrey (× 200).

The curvature of many of the species of this genus is very constant and may be utilized as a specific character. In stating the measurements of a species, the diameter across the middle of the cell should be given, the distance between the apices, and *the curvature of the outer margin expressed in degrees of arc.*

The zygospores are generally globose and smooth, but the spherical zygospore of *Cl. calosporum* Wittr. is furnished with conical papillations. The zygospores of certain species, such as *Cl. rostratum* Ehrenb. (fig. 56 G) and *Cl. Kützingii* Bréb., are flattened and quadrate with truncate angles; that of *Cl. Venus* Kütz. is also angular and sometimes twisted.

There are about 60 British species of the genus, of which *Cl. turgidum* Ehrenb. (length 476—940 μ; breadth 43—80 μ) is the largest and *Cl. pusillum* Hantzsch var. *monolithum* Wittr. (length 29·8—40·4 μ; breadth 7·5—8·6 μ) the smallest. *Cl. aciculare* Tuffen West and *C. pronum* Bréb. are the most elongate species of the genus, and certain forms of *Cl. acutum* Bréb. (fig. 56 E) are the narrowest. The commonest and most widely distributed species are *Cl. parvulum* Näg. (fig. 56 F), *Cl. Venus* Kütz., *Cl. Leibleinii* Kütz. (fig. 51 B), *Cl. moniliferum* (Bory) Ehrenb., *Cl. Ehrenbergii* Menegh. (fig. 51 A) and *Cl. acerosum* (Schrank) Ehrenb. *Cl. gracile* Bréb. is often abundant in Sphagnum bogs. The commonest striated species are *Cl. striolatum* Ehrenb. and *Cl. rostratum* Ehrenb.

Lütkemüller has divided the genus—and I think quite correctly—into two groups, the first one being characterized by the possession of an elongated median girdle, which is an intercalation of a cylindrical piece of cell-wall resulting from a growth to maturity subsequent to cell-division. The second group is characterized by the absence of this girdle, the two daughter-cells becoming adult immediately after cell-division.

B. Point of division of cells always fixed at the isthmus.

Tribe 5. *Cosmarieæ.*

The great majority of Desmids are included in this tribe and amongst them there is great diversity of form and size. They are solitary or filamentous, or grouped in spherical colonies, and most of them possess at least three planes of symmetry. The cell-wall consists of two thin, very firm layers, with pores, and is frequently ornamented with spines, warts and excrescences of all kinds. There is no periodical growth, the cell becoming adult immediately after division by the mature growth of the younger semicell.

Series a. The oblique junction of the new and old halves of the cell-wall (at the region of the isthmus) remains quite plane during division. The plants are solitary or colonial.

Genus **Docidium** Bréb., 1844; em. Lundell, 1871. The cells are comparatively small, elongate, straight and slightly constricted. They are subcylindrical with an inflation on each side of the constriction, or nodulose from pole to pole. The base of each semicell is plicated and there is a small basal granule under each plication. The basal plication of the semicells is the principal point of distinction between this genus and *Pleurotænium*. The apices of the cells are always truncate and smooth. There is a central chloroplast in each semicell, very irregular in form, and containing an axile row of pyrenoids. The zygospores are unknown.

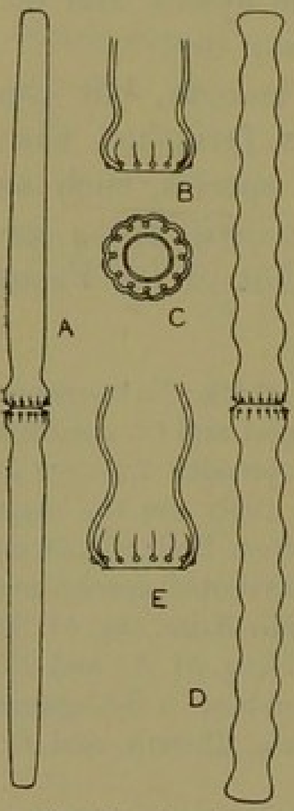

Fig. 57. A—C, *Docidium Baculum* Bréb., from Bowness, Westmoreland; A, × 315; B, base of semicell, × 630; C, basal view of semicell, × 630. D and E, *D. undulatum* Bail., from near Oughterard, Galway, Ireland; D, × 315; E, base of semicell, × 630.

There are three British species, of which *D. Baculum* Bréb. is the only one that is widely distributed, and even it is distinctly rare; length 167—262 μ; breadth at basal inflation of semicells 12—13 μ; fig. 57 A—C. *D. undulatum* Bail. is restricted to the western districts of Ireland and Scotland, and the semicells have a nodulose appearance caused by repeated shallow constrictions from base to apex; length 187—262 μ; breadth at basal inflation of semicells 13—16 μ; fig. 57 D and E.

Genus **Pleurotænium** Näg., 1849. The cells are elongate, straight, and slightly constricted. They are cylindrical, with or without inflations on either side of the constriction, or they may be nodulose along their entire length. They are slightly attenuated towards each pole and the apices are usually truncate, often being furnished with a ring of conical, tooth-like projections. There is no basal plication of the semicells. The chloroplasts are disposed as longitudinal, parietal bands, several in each semicell, and are furnished with a number of pyrenoids. Sometimes they become broken up into numerous parietal pieces, each containing a single pyrenoid. In most of the species the central portions of the cell contain large vacuoles and occasionally numerous moving granules are observed in the terminal or subterminal ones. These granules are of a yellow colour and black when seen in mass, differing in this respect from the moving granules normally present in the genus *Closterium*. They are produced mostly by pathological conditions. Zygospores of few species are known; they are globose and smooth.

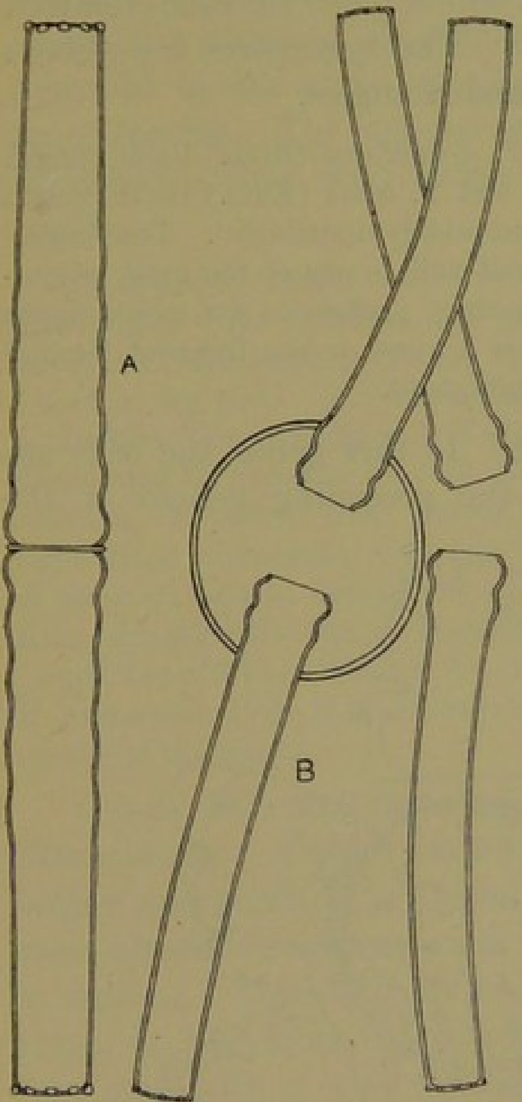

Fig. 58. A, *Pleurotænium coronatum* (Bréb.) Rabenh., from Helvellyn, Westmoreland (× 236). B, zygospore of *Pl. Ehrenbergii* (Bréb.) De Bary, from Thursley Common, Surrey (× 315).

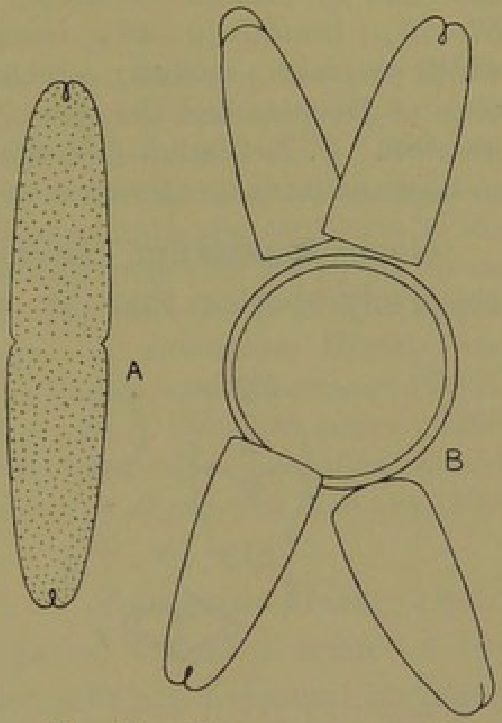

Fig. 59. *Tetmemorus granulatus* (Bréb) Ralfs, from Lough Anna, Donegal, Ireland. A, front view of cell; B, zygospore (× 315).

Species of this genus are much more abundant in the tropics than in temperate regions, and the tropical species frequently assume a secondary filamentous condition. Only nine species are known as British, of which *Pl. maximum* (Reinsch) Lund. is the largest, reaching a length of 852 μ and a diameter of 54 μ. The most abundant species is *Pl. Ehrenbergii* (Bréb.) De Bary; length 240—400 μ; breadth 18—24 μ; fig. 58 B. *Pl. Trabecula* (Ehrenb.) Näg. and *Pl. truncatum* (Bréb.) Näg. are each widely distributed. *Pl. nodosum* (Bail.) Lund. is the most striking species and is confined to the western districts of Wales, Ireland and Scotland.

Genus **Tetmemorus** Ralfs, 1844. This is a well-marked genus with straight cells of moderate length, slightly constricted in the middle and deeply cleft at each apex. The cells are usually attenuated towards each pole and the apical cleft or incision is tightly closed. There is a central chloroplast in each semicell with a single axile row of pyrenoids. The zygospores are globose and smooth, or subquadrate with rounded angles.

There are only four British species, *T. granulatus* (Bréb.) Ralfs (length 138—238 μ; breadth 30—45 μ; fig. 59) and *T. lævis* (Kütz.) Ralfs (length 57—76 μ; breadth 19—25 μ) being the most widely distributed. The former, which possesses a sparsely scrobiculated cell-wall, is one of the most ubiquitous of Desmids and the latter has a distinct preference for mountainous districts. *T. Brébissonii* (Menegh.) Ralfs is a more or less frequent Desmid in bogs and pools containing submerged Sphagnum.

Genus **Euastrum** Ehrenb., 1832. In this genus the cells are relatively shorter than in any of the preceding genera of the Cosmarieæ and they are always distinctly flattened. Seen from the front view they are elliptical, or narrowly elliptical, and they possess a median constriction of considerable depth. The lateral margins may be entire or lobed, and the apices are usually deeply notched. In the lobed species there is always an odd number of lobes to each semicell, the apical lobe (which bears the notch) being termed the 'polar lobe.' In the vertical and side views

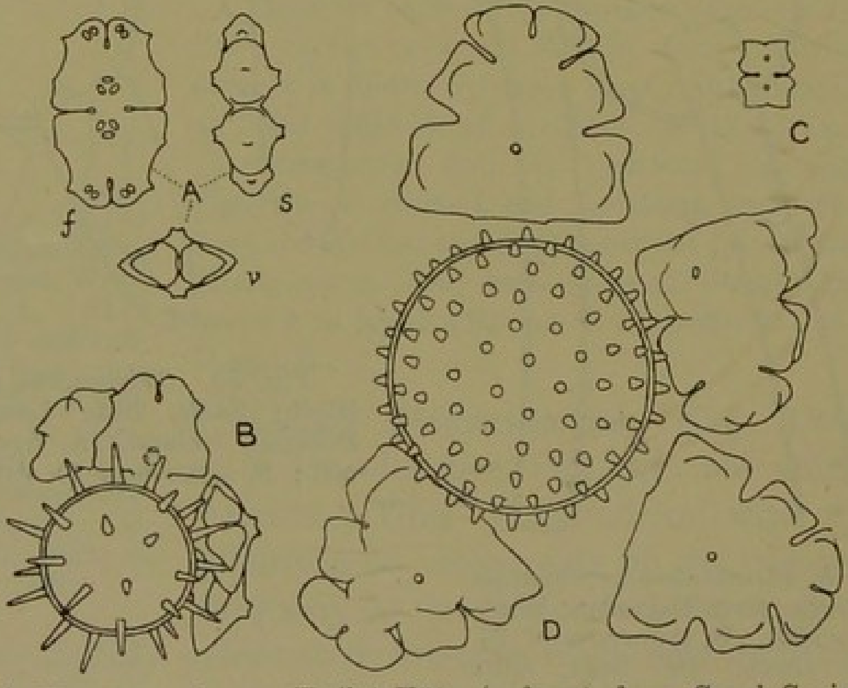

Fig. 60. A, *Euastrum elegans* (Bréb.) Kütz. (a form), from Capel Curig, N. Wales (×474). B, zygospore of *E. elegans*, from New Forest, Hants. (×474). C, *E. binale* (Turp.) Ehrenb., from Thursley Common, Surrey (×474). D, zygospore of *E. oblongum* (Grev.) Ralfs, from Pilmoor, N. Yorks. (×200). *f*, front view; *s*, side or lateral view; *v*, vertical view.

there is generally a well-marked protuberance in the middle of each side of the semicells. There is one axile chloroplast in each semicell, which is often very irregular; occasionally it possesses irregularly disposed, longitudinal plates. There is a single central pyrenoid in the small species and several scattered ones in the large species. The zygospores are globose or ellipsoid, and are furnished either with numerous simple spines or with conical papillæ.

There are 43 British species of the genus, about half of which are widely distributed. The smallest and perhaps the most abundant species of the genus is *E. binale* (Turp.) Ralfs; length 10—20 μ; breadth 9—16 μ; thickness 5·5—7 μ; fig. 60 C. *E. elegans* Bréb. (fig. 60 A and B), *E. ansatum* Ehrenb., *E. Didelta* (Turp.) Ralfs and *E. oblongum* (Grev.) Ralfs (fig. 60 D) are widely distributed all over the country, but in some districts they are by no means common. *E. insigne* Hass. (length 98—110 μ; breadth 49—60 μ) is an upland form found abundantly amongst Sphagnum. *E. verrucosum* Ehrenb. and *E. gemmatum* Bréb. are two of the prettiest species, and *E. crassum* (Bréb.) Kütz. (length 167—185 μ; breadth 87—97 μ) and *E. oblongum* (Grev.) Ralfs (length 144—167 μ; breadth 80—83 μ) are the largest species found in Britain. *E. pectinatum* Bréb. is more frequently found with zygospores than any other species of the genus.

Genus **Micrasterias** Ag., 1827. [*Holocystis* Hass., 1845; *Tetrachastrum* Dixon, 1859.] This genus contains some of the largest and prettiest of Desmids. The cells are flattened, in many cases almost disc-shaped, and they are circular or broadly elliptical in outline. The semicells are divided by deep incisions into either three or five lobes, of which the polar lobe may be entire or furnished with a wide excavation at the apex. The lateral lobes are sometimes narrow and attenuated, but more frequently they widen from the base outwards and are divided by incisions of variable depth into lobules. The flat surfaces of the cells are occasionally furnished with spines or wart-like projections, and in side or vertical view the cells are generally narrowly fusiform. There is a central, plate-like chloroplast in each semicell, often exhibiting irregular thickenings or ridges, and containing many scattered pyrenoids. The zygospores are globose and furnished with strong spines, simple or furcate at the apex.

There are 16 British species of the genus, none of which are really abundant, although *M. denticulata* Bréb. (length 205—350 μ; breadth 185—276 μ; fig. 61 C) and *M. truncata* (Corda) Bréb. (length 100—138 μ; breadth 90—129 μ; fig. 61 B) are widely distributed. *M. rotata* (Grev.) Ralfs (length 220—240 μ; breadth 195—220 μ) and *M. papillifera* Bréb. (length 135—145 μ;

breadth 115—145 μ) are not uncommon in permanent boggy pools and lakes, whilst *M. oscitans* Ralfs var. *mucronata* (Dixon) Wille and *M. Jenneri* Ralfs are frequently found in the Sphagnum-bogs of mountainous areas. *M. furcata* Ag., *M. Crux-Melitensis* (Ehrenb.) Hass. (fig. 61 A) and *M. pinnatifida* (Kütz.) Ralfs are amongst the rarest and most elegant species of the genus.

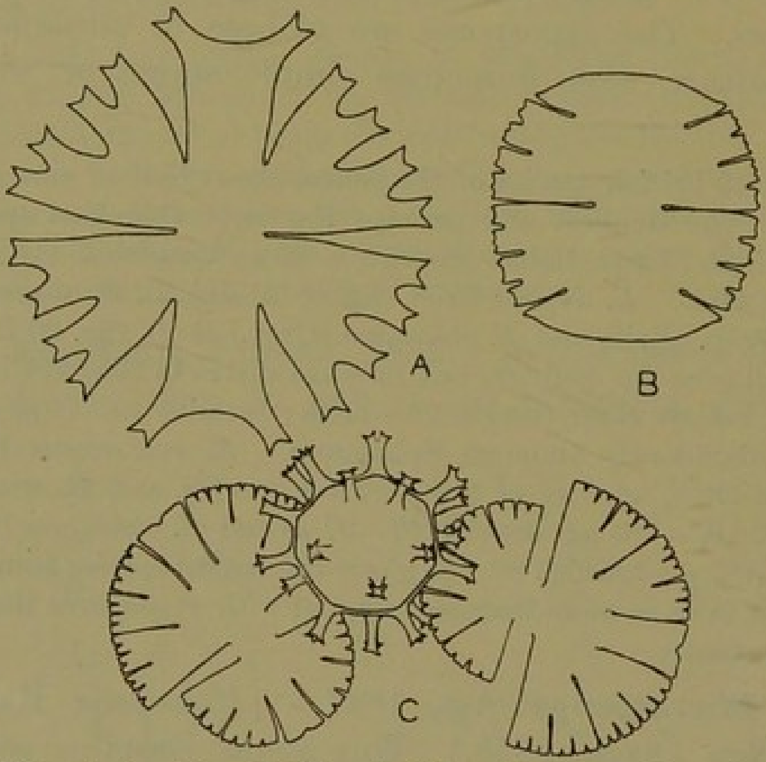

Fig. 61. A, *Micrasterias Crux-Melitensis* (Ehrenb.) Hass., from Bowness, Westmoreland (×365). B, *M. truncata* (Corda) Bréb., from Thursley Common, Surrey (×200). C, zygospore of *M. denticulata* Bréb., from Halgavor Moor, Cornwall (×110).

Genus **Cosmarium** Corda, 1834. [*Dysphinctium* Näg., 1849; *Calocylindrus* (Näg.) Kirchn., 1878; *Cosmaridium* Gay, 1884; *Pleurotæniopsis* (Lund.) Lagerh., 1887.] This is the largest genus of Desmids, embracing several hundreds of species, which although exhibiting many varied characters, all conform to a common type of structure. The cells are relatively short and the length is rarely more than one-and-a-half times the breadth. There is a median constriction of variable depth, in some cases very slight, but in others exceedingly deep. The semicells may be circular, elliptical, semicircular, ovate, pyramidate, or cuneiform in general outline, and the apex, which may be rounded or broadly truncate, possesses no apical notch. The cell-wall may be smooth, scrobiculate, granulate, verrucose, or clothed with minute spines, the ornamentation in almost all cases being arranged upon some definite plan. There is frequently a protuberance of some considerable size in the middle of each face of the semicell, so that the vertical view, which is elliptical in some species, may in others be furnished on each side with a more or less prominent swelling.

In the majority of species there is one central chloroplast in each semicell, possessing four somewhat curved longitudinal plates and either one or two large pyrenoids. In a few species there are several (from four to eight) parietal chloroplasts in each semicell, each containing one or more pyrenoids.

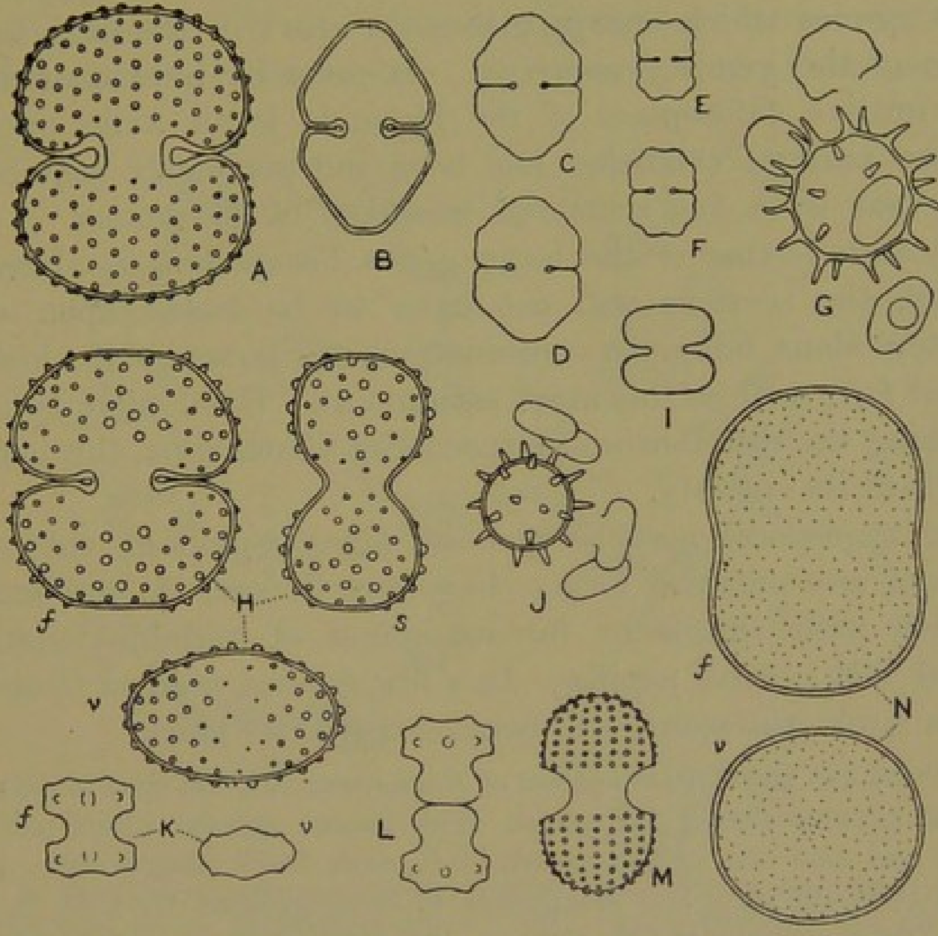

Fig. 62. A, *Cosmarium reniforme* (Ralfs) Arch. (a form), from Wicken Fen, Cambs. (×473). B, *C. granatum* Bréb., from Chippenham Fen, Cambs. (×473). C and D, *C. granatum* var. *subgranatum* Nordst., from Hornsey Mere, E. Yorks. (×473). E—G, *C. Meneghinii* Bréb.; E and F, from Hornsey Mere, E. Yorks.; G, zygospore of a form from Bowness, Westmoreland (×473). H, *C. præmorsum* Bréb., from Carrantuohill, Kerry, Ireland (×473). I and J, *C. bioculatum* Bréb.; I, from Roswell Pits, Cambs.; J, zygospore from Puttenham Common, Surrey (×473). K and L, forms of *C. Regnesii* Reinsch; L shows one stage of cell-division (×1170). M, *C. isthmium* West, from Harris, Outer Hebrides (×473). N, *C. pseudoconnatum* Nordst., from Capel Curig, N. Wales (×473). *f*, front view; *s*, side or lateral view; *v*, vertical view.

Some investigators of these plants have attempted to establish Nägeli's genus *Dysphinctium* (= *Calocylindrus* Kirchn.) in order to include certain species which are best left in the old genus

Cosmarium. The genus *Dysphinctium* can never be recognized in a sound system of classification, as opinion must always remain divided even upon many of the commonest forms that different authors have included in it. Its characters are too indefinite and artificial to be of any real systematic value. Similarly, *Pleurotæniopsis* can never be established as a genus, as it would be a small, polyphyletic assemblage, including a few strangely incongruous species which occupy places far apart in the evolutionary scheme of the genus *Cosmarium.* It must be remembered that the primitive chloroplast of the Desmids is an axile one and that the parietal condition has been independently acquired in *Cosmarium* by a few scattered members of the genus. I have already stated[1] that if the large genus *Cosmarium* is ultimately split up, the sections will not have to be based upon single characters alone, but upon combinations of characters of which the external form will be the most paramount. Until more is known concerning the distribution of species of *Cosmarium,* the genus is best left in its entirety.

The zygospores may be globose, angular-globose, cubical, or almost of any outward form; they may be smooth, scrobiculate, furnished with simple or furcate spines of variable length, or adorned with conical papillæ. In a few species, such as *C. melanosporum* Arch., the spore-wall becomes perfectly black.

As there are 250 British species of *Cosmarium* it is not easy to point out the chief peculiarities of the genus. The largest species which occurs in Britain, and also one of the rarest, is *C. ovale* Ralfs (length 182—188 μ; breadth 100—107 μ). The smallest is *C. subretusiforme* W. & G. S. West (length 7·8—8 μ; breadth 6·2—6·5 μ). The commonest species found in the ponds and ditches of lowland districts are *C. Botrytis* (Bory) Menegh., *C. præmorsum* Bréb. (fig. 62 H), *C. subcostatum* Nordst., *C. humile* Gay, *C. granatum* Bréb. var. *subgranatum* Nordst. (fig. 62 C and D), *C. abbreviatum* Racib. and several forms of *C. Meneghinii* Bréb. In the bogs of moorland districts *C. Cucurbita* Bréb. is usually abundant, and in upland Sphagnum areas *C. Ralfsii* Bréb., *C. pyramidatum* Bréb., *C. subtumidum* Nordst., and others, are fairly general. Some species, such as *C. Holmiense* Lund., *C. anceps* Lund., *C. subspeciosum* Nordst. and *C. Pokornyanum* (Grun.) W. & G. S. West, are usually found on dripping rocks, and *C. Dovrense* Nordst., *C. microsphinctum* Nordst., and several others, prefer wet calcareous rocks. *C. pygmæum* Arch. sometimes occurs in myriads amongst the leaves of submerged Sphagnum.

Genus **Xanthidium** Ehrenb., 1834. The cells of this genus are somewhat flattened as in most species of *Cosmarium,* and the

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[1] G. S. West, 'Alga-flora of Cambridgeshire,' Journ. Bot. 1899, p. 115.

median constriction is invariably deep. The semicells may be elliptical, trapeziform, hexagonal or octagonal in outline, and the angles are furnished with simple or furcate spines. The presence of these spines constitutes the primary distinction between *Xanthidium* and *Cosmarium*, and they are usually arranged in one plane or in two parallel planes. In the centre of each semicell is a thickened, scrobiculate area, or a protuberance of variable size, and this character is the sole distinguishing feature between *Xanthidium* and *Arthrodesmus*. In a few species the spines are reduced to small apiculations at the angles. The chloroplasts are parietal in most of the species and are arranged in the form of cushions, four or six in each semicell, each with a pyrenoid. In some of the minute species there is a single, central chloroplast in each semicell, furnished with one pyrenoid.

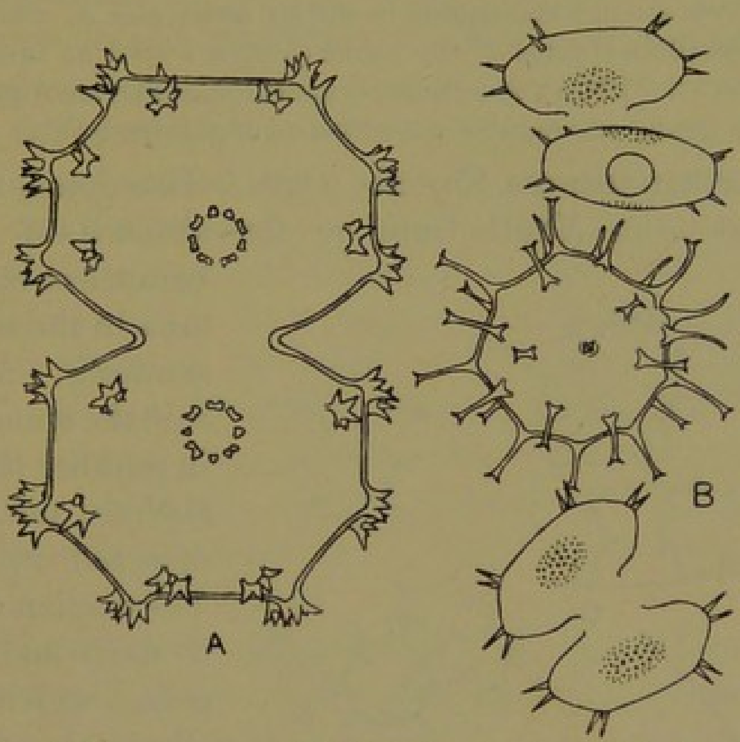

Fig. 63. A, *Xanthidium armatum* (Bréb.) Rabenh., from Sligachan, Skye (× 365). B, zygospore of *X. antilopæum* (Bréb.) Kütz., from Ballynahinch, Galway, Ireland (× 365).

The zygospores are globose and adorned with blunt papillæ or long slender spines, simple or furcate at their extremities.

The genus was divided by Lundell in 1871[1] into two sub-genera; sub-genus *Holocanthum*, in which the spines are entire; sub-genus *Schizacanthum*, in which the spines are forked at the apex. These

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[1] Lundell in Nova Acta Reg. Soc. Scient. Upsala, 1871, ser. 3, vol. viii, p. 74.

were put forward as genera by Wille[1], but upon insufficient grounds. Even in the most typical species which would fall under *Schizacanthum*, namely *X. armatum*, the spines are sometimes simple[2], and in some of the tropical species there are numerous intermediate stages between simple and much-forked spines.

There are 14 British species, of which a few are general but not abundant, and the rest are very scarce. *X. armatum* (Bréb.) Rabenh. is a large and handsome Desmid occurring in moderate quantity in the bogs of the hilly districts of the British Isles; length with spines 137—200 μ; breadth with spines 88—110 μ; fig. 63 A. *X. antilopæum* (Bréb.) Kütz. (fig. 63 B) and *X. cristatum* Bréb. are not uncommon in certain areas, and *X. concinnum* Arch., which is the smallest species of the genus (length 9—9·5 μ; breadth without the apiculations 9·5—10·5 μ), sometimes occurs abundantly amongst Sphagnum. Species of this genus are regular constituents of the freshwater plankton.

Genus **Arthrodesmus** Ehrenb., 1838. This genus is primarily distinguished from *Xanthidium* by the absence of the protuberance or scrobiculated area in the centre of the semicells. As a general rule the spines are fewer in number than in *Xanthidium*, and they are all disposed in one plane. The median constriction is deep and the semicells, which may be elliptical, trapeziform, or subhexagonal in shape, are furnished at the lateral angles with one or two spines of variable size and strength. In the vertical view the cells are always elliptical and the poles are furnished with spines. There is a single central chloroplast in each semicell contain-

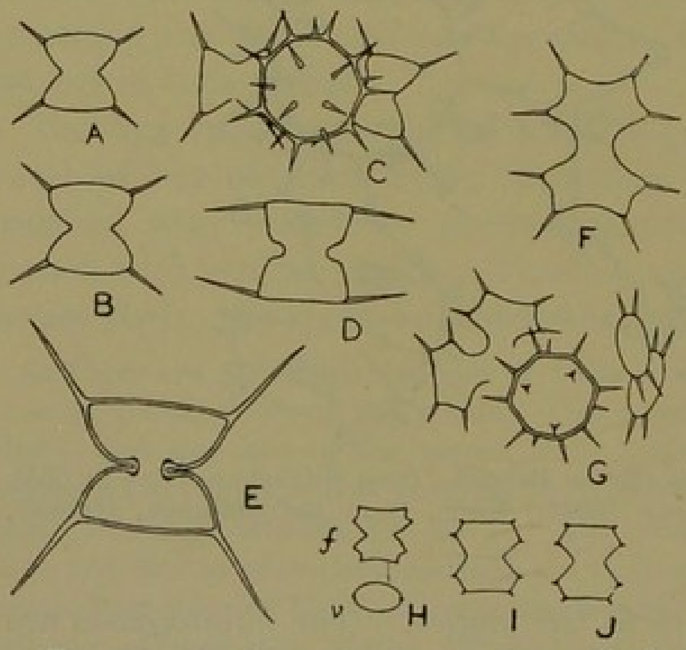

Fig. 64. A—C, *Arthrodesmus Incus* (Bréb.) Hass., from Harrop Tarn, Cumberland; C, zygospore (×365). D, *A. Incus* var. *Ralfsii* W. & G. S. West, from Capel Curig, N. Wales (×365). E, *A. Incus* var. *validus* W. & G. S. West (a form), from near Glenties, Donegal, Ireland (×474). F and G, *A. octocornis* Ehrenb.; F, from Llyn Idwal, N. Wales; G, zygospore from Puttenham Common, Surrey (×474). H—J, *A. bifidus* Bréb. var. *truncatus* West; H, from Strensall Common, N. Yorks.; I and J, from Keston Common, Kent (×474). *f*, front view; *v*, vertical view.

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[1] Wille in Engler & Prantl's Natürl. Pflanzenfam. 1890, p. 11.

[2] West in Journ. Linn. Soc. Bot. xxix, 1892, p. 164, t. xxii, f. 1.

ing one or two pyrenoids. The zygospores are globular, and the outer surface may be smooth or clothed with simple, conical or subulate spines.

Of the eleven British species, *A. Incus* (Bréb.) Hass. is the only one that is general and abundant. It is a small species, frequently met with in the conjugating state, and is one of the most variable of Desmids; length without spines 13—33 μ; breadth without spines 13—28 μ; length of spines 5—32 μ; fig. 64 A—C. *A. convergens* Ehrenb. and *A. octocornis* Ehrenb. (fig. 64 F and G) are not uncommon, but the other species are all rare.

Genus **Staurastrum** Meyen, 1829. This is the second largest genus of Desmids and contains some hundreds of species of very varied character, the majority of which possess a deep median constriction. The semicells are elliptical, semicircular, oblong, or cyathiform in outline, and the vertical view is generally triangular, but may be quadrangular or polygonal. The angles are sometimes rounded, sometimes acute, or they may be produced into processes of considerable length. In many cases the angles of one semicell alternate with those of the other. The cell-wall is occasionally smooth, but it is more frequently adorned with a variety of spines or wart-like excrescences, usually symmetrically disposed. In those species in which the angles are produced into processes the latter are generally furnished with two or three strong diverging spines at their extremities.

There is usually one chloroplast in each semicell, consisting of a central mass with a number of radiating plates, varying from five to eight (usually six; two in each angle). One pyrenoid is present in each chloroplast. In a few species there are several chloroplasts in each semicell disposed in the manner of parietal cushions, but intermediate states between this condition and a central mass are not infrequent. This indefinite character was utilized by Lundell[1] for the formation of a sub-genus, *Pleurenterium*, which has recently been proposed as a genus[2]. The absurdity of such a genus is realized on considering the few incongruous forms it would have to include. It should be borne in mind that the parietal condition of the chloroplasts has been arrived at quite independently by a few widely different species of the genus *Staurastrum*.

The zygospores are globose or angular, rarely winged, but more commonly clothed with long spines, which are simple or furcate at

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[1] Lundell in Nov. Acta Reg. Soc. Scient. Upsala, 1871, ser. 3, vol. viii, p. 72.

[2] Wille in Engler & Prantl's Natürl. Pflanzenfam. 1890, p. 11.

their extremities, and often situated each at the apex of a mamillate or obtusely conical protuberance.

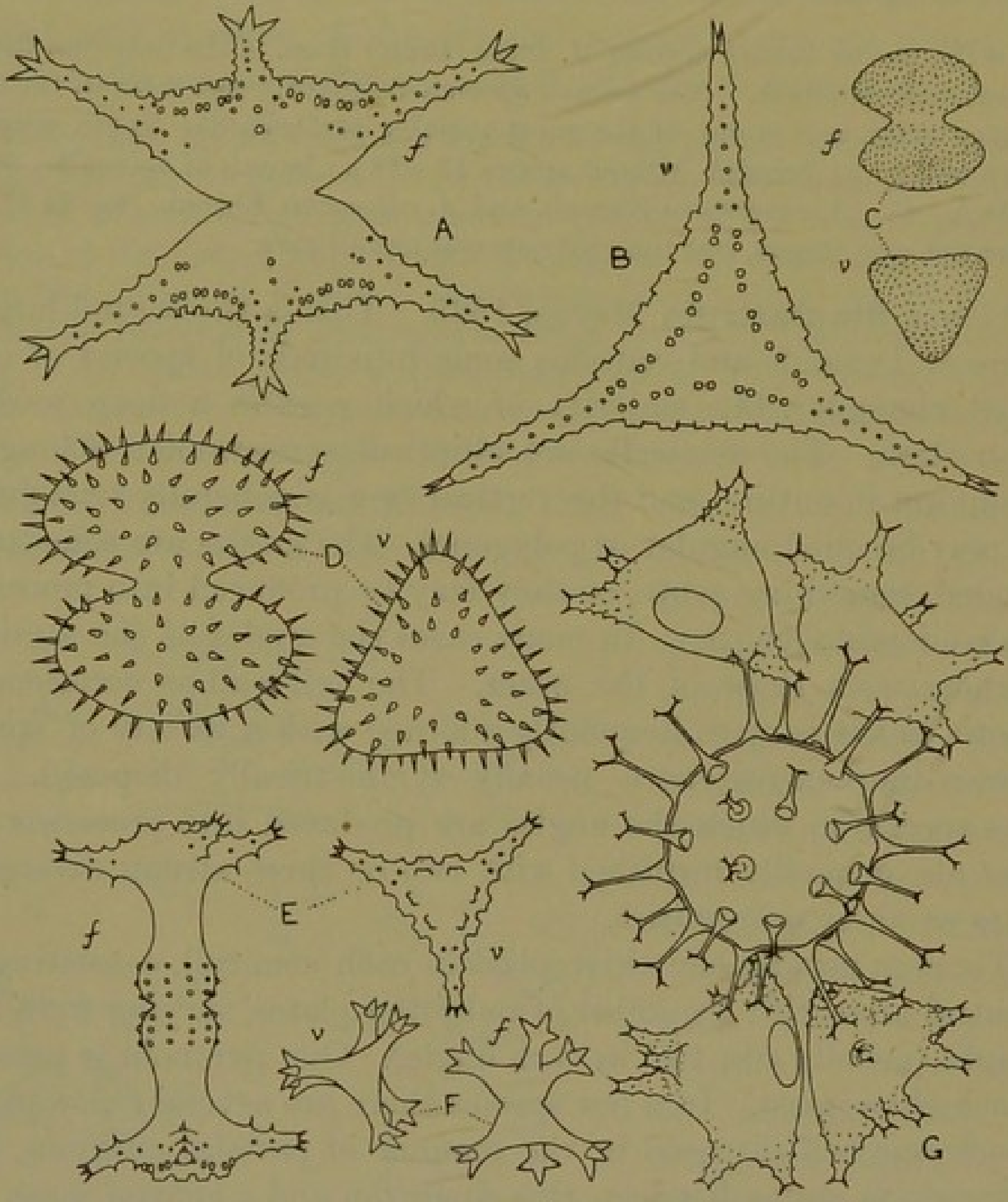

Fig. 65. A and B, *Staurastrum anatinum* Cooke & Wills, from Llyn-y-cwm-ffynon, N. Wales (× 473). C, *St. punctulatum* Bréb., from Esher Common, Surrey (× 473). D, *St. polytrichum* Perty, from Galway, Ireland (× 365). E, *St. elongatum* Barker, from Rhiconich, Sutherland (× 473). F, *St. brachiatum* Ralfs, from Down, Ireland (× 473). G, zygospore of *St. furcigerum* Bréb., from Pilmoor, N. Yorks. (× 473). *f*, front view; *v*, vertical view.

There are more than 160 species of this genus known to occur in the British Islands, but few of them are abundant. The most frequent species in low-lying districts are *St. pygmæum* Bréb., *St. punctulatum* Bréb. (fig. 65 C) and *St. hexacerum* (Ehrenb.) Wittr. In moorland areas *St. margaritaceum* (Ehrenb.) Menegh. is general. The most abundant of the spiny species is *St. teliferum* Ralfs. One of the largest British species of the genus is *St. tumidum* Bréb. (length 112—132 μ; breadth 91—103 μ) and the smallest is *St. iotanum* Wolle. Some species, such as *St. capitulum* Bréb., *St. pileolatum*

Bréb., *St. Kjellmanii* Wille (fig. 51 E), *St. acarides* Nordst. and *St. Arnellii* Boldt, are principally confined to mountainous regions; others, such as *St. pelagicum* W. & G. S. West, *St. pseudopelagicum* W. & G. S. West, *St. jaculiferum* West, *St. paradoxum* Meyen var. *longipes* Nordst., *St. brevispinum* Bréb. and forms of *St. anatinum* Cke. & Wills (fig. 65 A and B), are abundant in the plankton of lakes. A few of the most beautiful species of the genus, amongst which may be mentioned *St. Ophiura* Lund., *St. Cerastes* Lund., *St. Arctiscon* (Ehrenb.) Lund., *St. verticillatum* Arch. and *St. longispinum* (Bail.) Arch., are confined to the extreme western districts of Scotland, Wales and Ireland, and are most abundant in the plankton of those areas.

Genus **Cosmocladium** Bréb., 1856. The cells of this genus are similar to those of some of the smooth species of *Cosmarium*, but the individual cells are united by relatively thin mucilaginous threads into branched colonies. Sometimes the entire colony is enveloped in a mucilaginous mass of much less density than the connecting threads. There is one chloroplast in each semicell containing a single pyrenoid. The zygospores are globose and smooth, or they may be lobed (as in *C. perissum* Roy & Biss.).

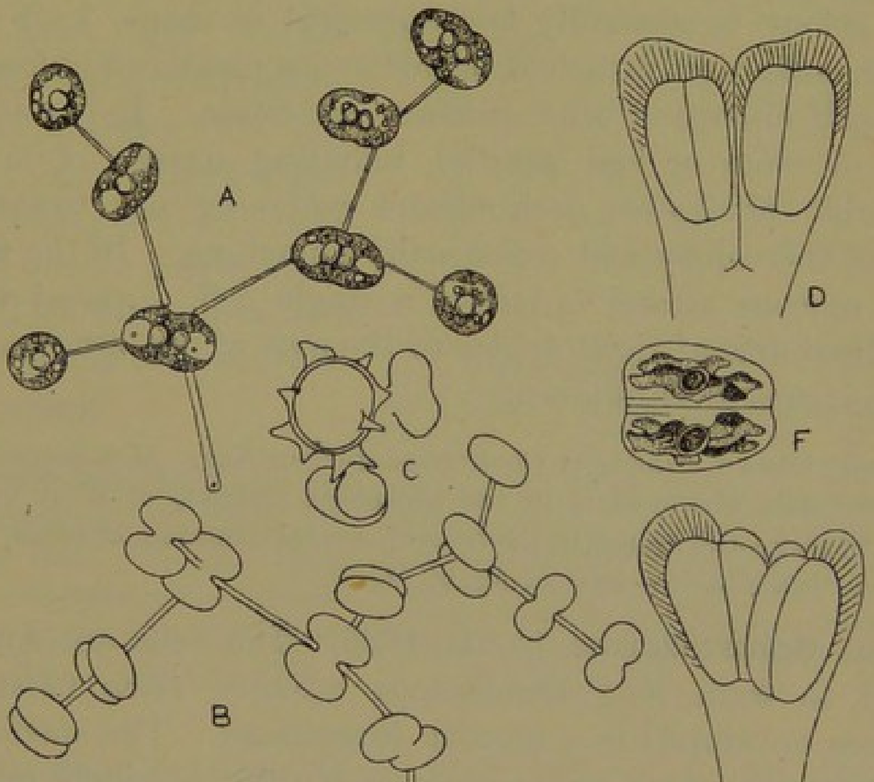

Fig. 66. A, *Cosmocladium constrictum* (Arch.) Josh., from Pilmoor, N. Yorks. (×475). B, *C. pulchellum* Bréb., from near Tarbert, Harris, Outer Hebrides (×475). C, zygospore of *C. perissum* Roy & Biss., from the Clova Mts., Forfar (×475). D—F, *Oocardium stratum* Näg., after Lütkemüller (×730).

There are five British species of this genus all of which are very rare. *C. constrictum* (Arch.) Josh. (fig. 66 A) and *C. pulchellum* Bréb. (fig. 66 B) are perhaps more often observed than the others. All the species are very small, the largest being *C. Saxonicum* De Bary; length 15—17 μ; breadth 13·5—14·5 μ.

Genus **Oocardium** Näg., 1849. This is the most extraordinary of all the genera of Desmids and usually occurs in large colonies. The cells are small, slightly constricted and much depressed, being considerably broader than their length. The semicells are unequally depressed on the two sides, so that the plant is symmetrical in one plane only. The vertical view is broadly elliptical. There is one chloroplast in each semicell, consisting of somewhat irregular plates radiating from a central mass containing one pyrenoid.

The colony is generally hemispherical in shape, 1—2 mm. in diameter, and occurs attached to calcareous rocks, not unfrequently being itself encrusted with calcium carbonate. It consists of a number of more or less parallel, radiating strands of mucus of considerable thickness, each strand widening out towards the surface of the colony and occasionally branching. In the free end of each mucous strand is lodged a single cell, disposed with its longitudinal axis at right angles to the axis of the mucous strand. The zygospores are unknown.

The only known species is *Oocardium stratum* Näg. It is extremely rare and I have only observed it in the limestone districts of West Yorkshire, attached to rocks and stones in the beds of several mountain streams. Length 13—16·5 μ; breadth 18—19·5 μ; fig. 66 D—F.

Genus **Sphærozosma** Corda, 1835. The cells are small and attached to form long filamentous colonies, often twisted and sometimes enveloped in a mucous investment. The median constriction may be deep and narrow or it may be widely open, and the semicells may be elliptical, oblong, or subrectangular in form. The attachment of the cells is apical and is effected by small rounded tubercles or short capitate processes. The vertical view is elliptical. There is one axile chloroplast in each semicell, furnished with a single pyrenoid. The zygospores, which are globose or oblong, are either smooth or furnished with subulate spines.

There are only five British species of the genus and none of them is abundant. *S. vertebratum* Ralfs (length of cells 19 μ; breadth 21—24 μ;

fig. 67 C) is the largest, and *S. excavatum* Ralfs (fig. 67 D—F) and *S. granulatum* Roy & Biss. are the most widely distributed.

Genus **Onychonema** Wallich, 1860. The cells are small and form simple filamentous colonies. The median constriction is deep and narrow, and the semicells are elliptical or reniform, sometimes with strong lateral spines at each side. There are two capitate processes of considerable length attached to each apex and disposed asymmetrically. The cells are united into long flexible filaments by the overlapping of these processes over the adjacent cells. There is one axile chloroplast in each semicell, with a single pyrenoid. The zygospores are globose and furnished with simple spines.

There are three British species of the genus, all of which are distinctly rare. The one most generally observed is *O. filiformis* (Ehrenb.) Roy & Biss. (length of cells 14—15 μ; breadth 14·5—16 μ).

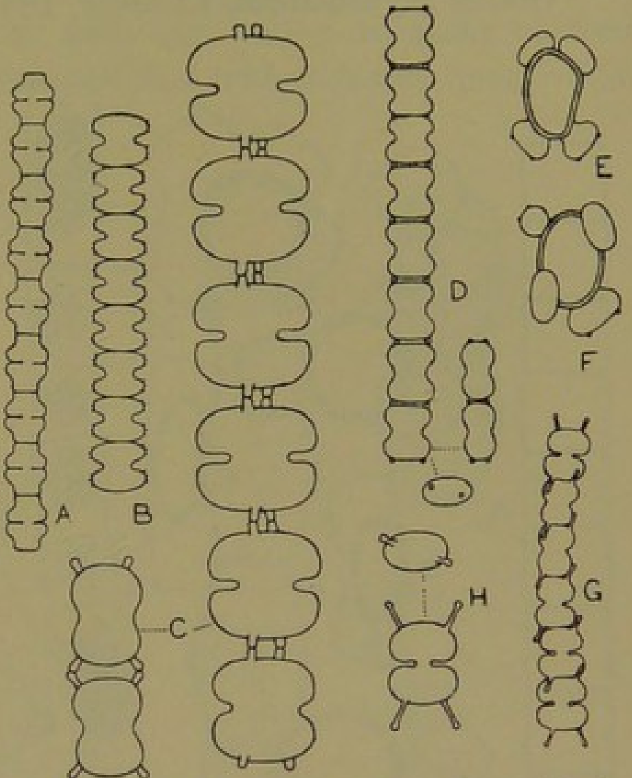

Fig. 67. A, *Spondylosium pulchellum* Arch., from Glen Shee, Perthshire (× 365). B, *S. papillatum* W. & G. S. West, from Skipwith Common, E. Yorks. (× 475). C, *Sphærozosma vertebratum* Ralfs, from near Crowan, Cornwall (× 475). D—F, *Sph. excavatum* Ralfs; D, from Llyn Idwal, N. Wales (× 475); E, zygospore from Puttenham Common, Surrey (× 475); F, zygospore from New Forest, Hants. (× 475). G—H, *Onychonema Nordstedtiana* Turner, from Strensall Common, N. Yorks. (G, × 475; H, × 730).

Genus **Spondylosium** Bréb., 1844. [*Leuronema* Wallich, 1860.] The cells are small or of medium size and are united by their apices to form filamentous colonies, occasionally twisted and often enveloped in a copious mucus. The median constriction is usually deep and linear and the semicells are of very variable form. The apices are flat or concave and the cells are joined merely by the close apposition of their apices, this being the sole distinguishing feature between *Spondylosium* and *Sphærozosma*. The vertical view is elliptical, triangular, or trilobed. The chloroplasts are as in *Sphærozosma*, and the zygospores are globose and smooth.

There are seven species of the genus known to occur in the British Islands, none of which is abundant. *S. papillatum* W. & G. S. West (length of cells 8—9·5 μ; breadth 9·5—10·5 μ; fig. 67 B) and *S. pulchellum* Arch. (length 12·5—15 μ; breadth 11—12·5 μ; fig. 67 A) are the most widely distributed.

Genus **Hyalotheca** Ehrenb., 1841. The cells are more or less cylindrical and are connected by their broadly truncate apices into filamentous colonies. The median constriction is very slight and the semicells are trapezoid, subquadrate or oblong in form, with straight or convex lateral margins. The filaments are usually twisted and always enveloped in a thick coat of mucus. There are frequently several slight swellings at the base of each semicell near the constriction, causing the circular vertical view to possess two or three nipple-like projections at equal intervals round the margin. There is one chloroplast in each semicell, consisting of a central mass with a number of radiating plates, and containing one pyrenoid. The zygospores are globose and smooth, and in *H. dissiliens* the four empty semicells unite to form a cruciform structure which surrounds each spore.

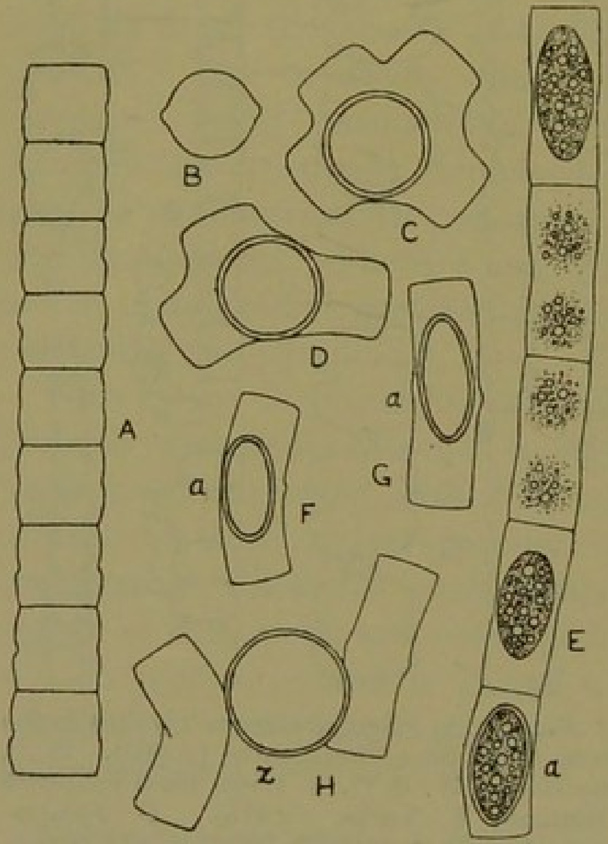

Fig. 68. A—C, *Hyalotheca dissiliens* (Sm.) Bréb.; A and B, from Capel Curig, N. Wales (×365); C and D, zygospores from Galway, Ireland (×365). E—H, *H. neglecta* Racib., from the New Forest, Hants. (×475); E—G, showing aplanospores (*a*); H, zygospore (*z*).

There are four British species of the genus, of which *H. dissiliens* (Sm.) Bréb. is general and often abundant; length 15—25 μ; breadth 21—33 μ; fig. 68 A—C. This Desmid is more frequently found with zygospores than any other. *H. mucosa* (Dillw.) Ehrenb. is a much scarcer plant, although widely distributed. *H. undulata* Nordst. (length 13·5—17·5 μ; breadth 7·5—9 μ) and *H. neglecta* Racib. (length 28—34·5 μ; breadth 11·5—13 μ; fig. 68 E—H) are amongst the rarest of British Desmids.

Series b. The oblique junction of the new and old halves of the cell-wall (at the region of the isthmus) develops an internal girdle-like thickening which projects into the old semicells during the earlier stages of division. The cells are united to form thread-like colonies.

Genus **Desmidium** Ag., 1824. [*Didymoprium* Kütz., 1843; *Aptogonum* Ralfs, 1848.] The cells are united to form twisted filamentous colonies, often enveloped in a wide mucous coat. The median constriction is moderately deep and the semicells are much depressed, so that the cells are generally much broader than their length. The attachment of the cells is either by the close apposition of their flat apices or by the apposition of corresponding truncate apical projections. In the latter case there is a space of variable width visible between the actual apices of two adjacent cells. In vertical view the cells may be triangular, quadrangular, or elliptical with mamillate poles. There is a single central chloroplast in each semicell containing as many pyrenoids as there are angles in the vertical view, and there are two longitudinal plates diverging from each pyrenoid into the angle. The zygo-

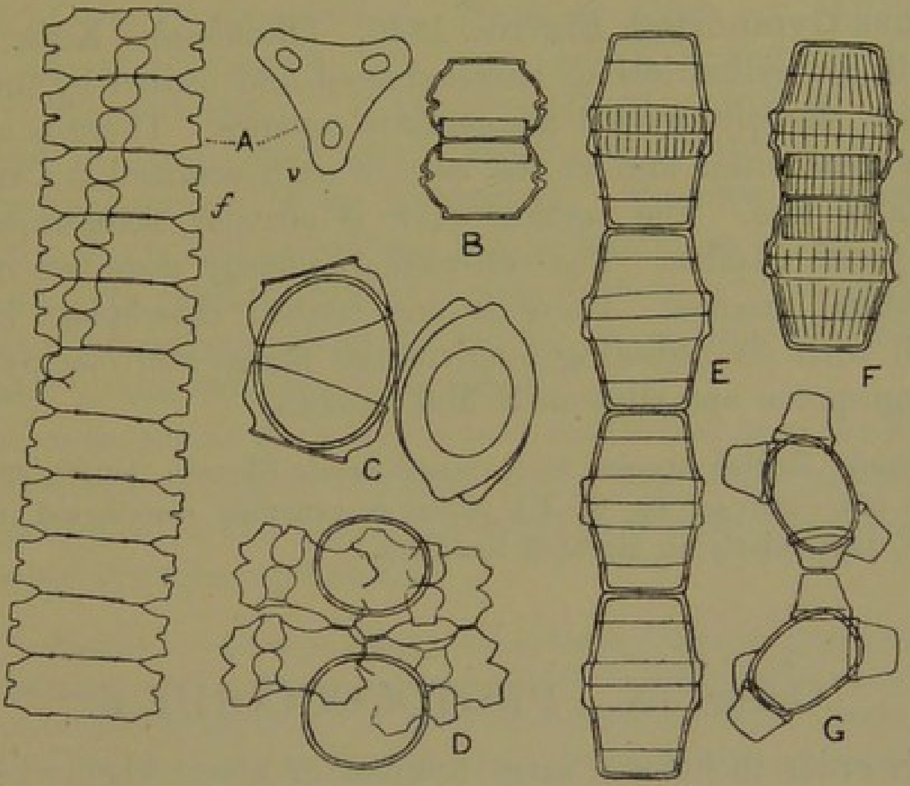

Fig. 69. A, *Desmidium Swartzii* Ag., from near Preston, Lancashire (×365). B, *D. quadratum* Nordst., showing cell-division (×475). C, zygospore of *D. cylindricum* Grev., from Donegal, Ireland (×350). D, zygospores of *D. aptogonum* Bréb. (×475). E and F, *Gymnozyga moniliformis* Ehrenb., from Rhiconich, Sutherland (×475); F, showing cell-division. G, zygospores of *G. moniliformis* var. *gracilescens* Nordst. (×475).

spores are ellipsoidal, smooth or furnished with somewhat flattened or conical papillæ.

There are six British species of the genus, none of which is abundant. *D. Swartzii* Ag. (length 14—19 μ; breadth 37—43 μ; fig. 69 A) and *D. cylindricum* Grev. (fig. 69 C) are the two most general species. *D. quadratum* Nordst. (fig. 69 B) and *D. graciliceps* (Nordst.) Lagerh. are two species very rarely met with in the British Isles.

Genus **Gymnozyga** Ehrenb., 1840. [*Bambusina* Kütz., 1845.] The cells are cylindrical or barrel-shaped and united by their flat ends into slightly twisted filamentous colonies. There is a slight median constriction and at the base of each semicell is a swelling of variable size. The vertical view is circular, sometimes with two opposite papillæ. The cell-wall frequently possesses delicate longitudinal grooves. There is one central chloroplast in each semicell with six radiating longitudinal plates and one pyrenoid. The zygospores are ellipsoidal and smooth.

The only British species is *G. moniliformis* Ehrenb. (length 25—30 μ; breadth 17·5—22·5 μ; fig. 69 E), which is generally distributed in boggy districts, particularly in elevated localities.

Order IX. PROTOCOCCOIDEÆ.

This order includes a large number of green Algæ which are mostly unicellular in character. The cells are commonly aggregated to form loose irregular colonies and are often embedded in a copious mucilage. In a few of the forms a small multicellular expansion is developed, and in others a definite cœnobium which is sometimes cœnocytic in character. In some the cells are normally ciliated and the plants are either motile unicells or more or less complex motile colonies.

The order includes the lowest and most primitive of the green Algæ, forms through which most of the other Chlorophyceæ have been evolved along divergent lines.

They are wonderfully varied in character and are found in almost all possible situations. The cell-walls may be extremely delicate or firm and thick, and there is often a great development of the gelatinous pectose compounds. The number and disposition of the chloroplasts vary greatly in the different genera, and pyrenoids may or may not be present.

Most of the Protococcoideæ multiply by simple cell-division, which takes place in one, two, three, or sometimes in many directions of space.

Asexual reproduction is generally accomplished by the production of one or many biciliated zoogonidia from a mother-cell, and in some families this is the sole method of reproduction. There are many different types of asexual spores found in the genera of the Protococcoideæ. Some of these are akinetes and others are aplanospores. One type, which is worthy of special note, is the autospore. A number of autospores are generally produced in a cell, each spore having on liberation the general form and appearance of the mother-cell. In some of the cœnobic forms the plants are reproduced by the formation of autocolonies.

Most of the methods of sexual reproduction, both isogamous and heterogamous, which are exhibited by the various Chlorophyceæ, are found in the order Protococcoideæ.

The order seems to me to be best subdivided into the following eight families, of which the first one is doubtfully placed in the Protococcoideæ as the plants included in it have certain relationships with the Chætophoraceæ.

Family 1. *Chætopeltideæ.* Unicellular or multicellular, sometimes pseudoparenchymatous. Some or all of the cells furnished with hairs or bristles, either simple or sheathed and often mucous. Multiplication by division of cells in two directions. Reproduction by 2- or 4-ciliated zoogonidia and by 2-ciliated gametes.

Family 2. *Volvocaceæ.* Unicellular or consisting of a definite cœnobium of cells, which are either united by protoplasmic processes or enclosed within the swollen mucous mother-cell-wall. All the cells are ciliated and motile in the vegetative state.

Family 3. *Endosphæraceæ.* Unicellular or slightly branched and cœnocytic; cells solitary, generally rounded, often with button-like excrescences of cellulose; chloroplasts with numerous pyrenoids. No vegetative division. Reproduction by spores, zoogonidia and gametes. All the genera are endophytic.

Family 4. *Characieæ.* Unicellular; cells solitary, differentiated into base and apex, epiphytic on other Algæ; chloroplast parietal with one pyrenoid. No vegetative division. Reproduction solely by zoogonidia formed by successive divisions of the contents of a mother-cell.

Family 5. *Pleurococcaceæ.* Unicellular and globular, or of short, ramified, few-celled filaments, never attenuated into hairs; often pseudoparenchymatous; chloroplasts one or several, parietal, with or without pyrenoids. Multiplication by division in two or three directions, and more rarely by zoogonidia. Cell-walls very firm.

Family 6. *Hydrodictyaceæ.* Thallus consisting of a cœnobium of cœnocytes, non-motile, and formed by the apposition of quiescent zoogonidia, which may or may not have escaped from the mother-cœnocyte. Reproduction sometimes by resting-spores.

Family 7. *Protococcaceæ* (*or Autosporaceæ*). Cells solitary, free-swimming, or colonial and associated in minute, more or less definite colonies, easily dissociated or persistent. Multiplication by successive division of contents forming autospores or autocolonies. Zoogonidia rarely developed.

Family 8. *Palmellaceæ.* Microscopic or macroscopic, gelatinous and indefinite. Cells embedded in a copious gelatinous envelope. Multiplication by division in every direction; cells often grouped in twos or fours, sometimes with pseudocilia. Colonies free-floating or attached. Zoogonidia with two cilia.

Family 1. **CHÆTOPELTIDEÆ.**

The Algæ included in this family consist of several genera of very obscure affinities, all of which can be distinguished from other members of the Protococcoideæ by the presence of setæ or bristles. At present they are but little known and the true nature of the bristles has not yet been thoroughly worked out. They are unicellular, or aggregates of loose cells, sometimes forming short filaments or flat, pseudoparenchymatous expansions, which in some instances appear to have arisen by a concrescence of short dichotomous branch-systems.

The flat thallus of *Chætopeltis* is similar to that found in the Ulvaceæ, except from point of view of size and the fact that it is attached by the whole of one surface. *Chætosphæridium* is a genus which may, perhaps, owing to the short creeping filaments which it sometimes develops and the sheathed bristles, have some relationship to the Herposteiraceæ, but its characters are so widely different from those of *Herposteiron* that it is best kept apart from the Chætophorales until our knowledge of the genus is augmented. It may be that the resemblances between the Chætopeltideæ and certain of the Chætophorales, such as they are, are due to a parallelism of modification rather than to a direct affinity. This has been illustrated in the table I have given of the phylogeny of the green Algæ on page 30.

In genera such as *Chætosphæridium* and *Conochæte* multiplication certainly takes place by the division of the cells in two directions.

Reproduction has been observed to take place in several of the genera by zoogonidia with two or four cilia, and by biciliated isogamous gametes.

Throughout the entire family there is a marked dorsiventrality such as appears elsewhere in the Coleochætaceæ, Trentepohliaceæ, etc.

The following British genera are known:—

A. Plants with a disciform thallus furnished with scattered bristles.................................... *Chætopeltis.*

B. Plants consisting of a loose aggregate of cells in one stratum.

* Each cell with one seta or bristle.

Bristles with a basal sheath; chloroplasts parietal .... *Chætosphæridium.*

** Each cell with several setæ or bristles.

† Bristles few, with basal sheaths .... *Conochæte.*

†† Bristles many, without basal sheaths ...... *Polychætophora.*

Genus **Chætopeltis** Berth., 1878. The thallus is a flat plate, almost circular in outline, and consists of a single layer of compact cells, more or less radiating from the centre. The growth of the thallus is peripheral as in *Coleochæte*, but the cell-walls are much more gelatinous. From the upper surface of the thallus a number of scattered mucous setæ arise, which are unseptate, simple, and of considerable length. Each cell contains one parietal chloroplast, which is often much lobed and perforated, and is furnished with a single pyrenoid. Reproduction takes place by zoogonidia of which 2—8 arise from a mother-cell, each one possessing four cilia. Isogamous gametes are also produced, similar in appearance to the zoogonidia but with two cilia.

Ch. orbicularis Berth. is not an uncommon plant in this country, occurring as an epiphyte on the stems and leaves of various aquatic Phanerogams. The thallus varies greatly in size and sometimes reaches a diameter of 1 mm.

Genus **Chætosphæridium** Klebahn, 1892[1]. The cells are small and spherical, generally occurring in loose aggregates, epiphytic on larger Algæ and other aquatic plants. They are sometimes enveloped in mucus, but more often quite destitute of a gelatinous investment. Klebahn states that the cells are commonly joined in a short filament by means of empty cylindrical utricles, but I have not observed the presence of these structures

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[1] Klebahn in Jahrbüch. wissensch. Bot. xxiv, 1892, pp. 268—282, pl. 4.

in any British specimens. Each cell possesses at its upper pole a small conical projection which forms a basal sheath for a long, delicate seta or bristle. This bristle is extremely fine and fragile, and is commonly broken off at the apex of the basal sheath. In most specimens it is impossible to see any sheath-like structure in the conical projection, the bristle appearing to arise from its apex. The chloroplast is very variable, but in some specimens it is distinctly parietal with one pyrenoid. The division of the cells sometimes takes place by the formation of a horizontal division-plane, the lower daughter-cell migrating to the side. Asexual reproduction occurs by zoogonidia, produced four (or more ?) in a cell.

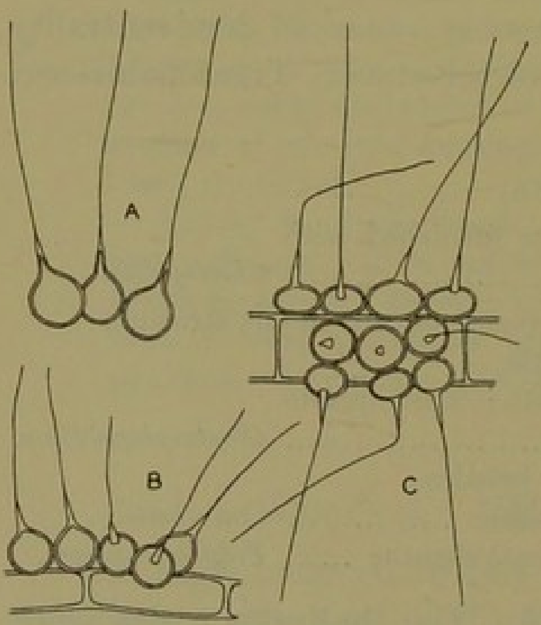

Fig. 70. A and B, *Chætosphæridium globosum* (Nordst.) Klebahn; A, from Esher Common, Surrey; B, from Bowness, Westmoreland. C, *Ch. globosum* var. *depressum* (West & G. S. West), from the New Forest, Hants. (All × 370.)

There is some little confusion between this genus and one described by Borzi in 1892 as *Nordstedtia*[1]. The latter was supposed to be founded on a plant described by Nordstedt as *Herposteiron globosa*[2], and since referred by Wolle to the genus '*Aphanochæte*.' Klebahn, who compared the original specimens of Nordstedt with Borzi's drawings of *Nordstedtia*, affirmed that the latter represented an entirely different plant. This being the case, one is compelled to accept the genus *Chætosphæridium* for the plants described by Nordstedt as "*Herposteiron globosa*."

Ch. globosum (Nordst.) Klebahn is widely distributed in the British Islands, occurring chiefly in the Sphagnum-pools of permanent bogs. The cells are 11—18 μ in diameter, loosely associated, and occasionally surrounded by a gelatinous envelope (fig. 70 A and B). There is a curious var. *depressum* of this species with the cells much depressed (fig. 70 C).

The plant described as *Chætosphæridium Pringsheimii* by Klebahn appears to be identical with *Aphanochæte globosa* var. *minor* Hansgirg, and if it is distinct from *Ch. globosum* it should be known as *Ch. minus* Hansg. Most

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[1] Borzi in Nuova Notarisia, iii, 1892, p. 50.

[2] Nordstedt, Alg. aq. dulc. et Char. Sandvic. 1878, p. 23, t. ii, f. 22, 23.

probably, however, it is but a small variety of *Ch. globosum* with the cells 9—12 μ in diameter[1].

Genus **Conochæte** Klebahn, 1893. The cells are comparatively small, loosely aggregated, and embedded in a small amount of mucus. Each cell is subglobose, often depressed, and possesses a number of delicate bristles which radiate in all directions. Each of the latter arises either from the apex of a mamillate protuberance of the cell-wall or from the base of an elongated sheath. There are one or two chloroplasts in each cell, each furnished with one pyrenoid. The cells are markedly dorsiventral and sometimes a prominent oil-globule is present in the basal half of the cell. The plants multiply by cell-division in two directions and by zoogonidia, of which four or eight are formed in each cell[2].

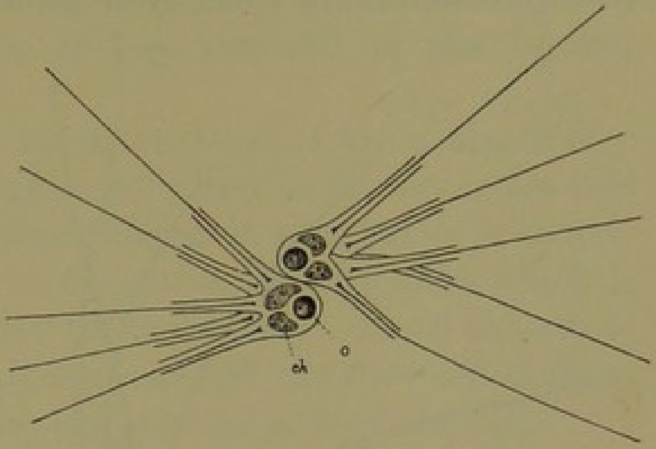

Fig. 71. A form of *Conochæte comosa* Klebahn, from the New Forest, Hants. (× 370). *ch*, chloroplast; *o*, oil-globule.

Two British species are known, both of which are exceedingly rare. *C. comosa* Klebahn possesses cells 13—26 μ in diameter and the bristles, which are 3—5 in number, are sheathed at the base (fig. 71). *C. polytricha* (Nordst.) Kleb. possesses cells 10—16 μ in diameter and the bristles arise from the apices of a number of mamillate protuberances of the cell-wall, the latter exhibiting a well-marked stratification.

Genus **Polychætophora** West & G. S. West, 1903. The plants are unicellular or sometimes composed of short, loosely connected filaments of six or eight cells. The cells are subglobose or ovoid, and the cell-walls are exceedingly thick and lamellose. From the outer layers of this lamellose cell-wall from 8 to 12 long flexuose bristles are given off. The bristles are very delicate and attenuated to fine points; they are quite simple, without any trace of a basal sheath or any basal swelling, and they radiate in every direction. Sometimes the cell-wall is unequally developed, a large stratified outgrowth having been developed on one side. Such a cell has a stalked appearance which presents many points of

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[1] This small form is known from N. Yorkshire; *vide* West & G. S. West in Trans. Yorks. Nat. Union, 1900, vol. v, p. 22.

[2] Schmidle in Hedwigia, 1899, p. 162, t. vi, f. 16—19.

resemblance to the cells in Borzi's genus *Hormotila*. Each cell contains a single chloroplast, sometimes distinctly parietal, but frequently subcentral and filled with highly refractive oil-globules. The presence of pyrenoids has not been definitely determined. Multiplication takes place by division of the cells in two directions.

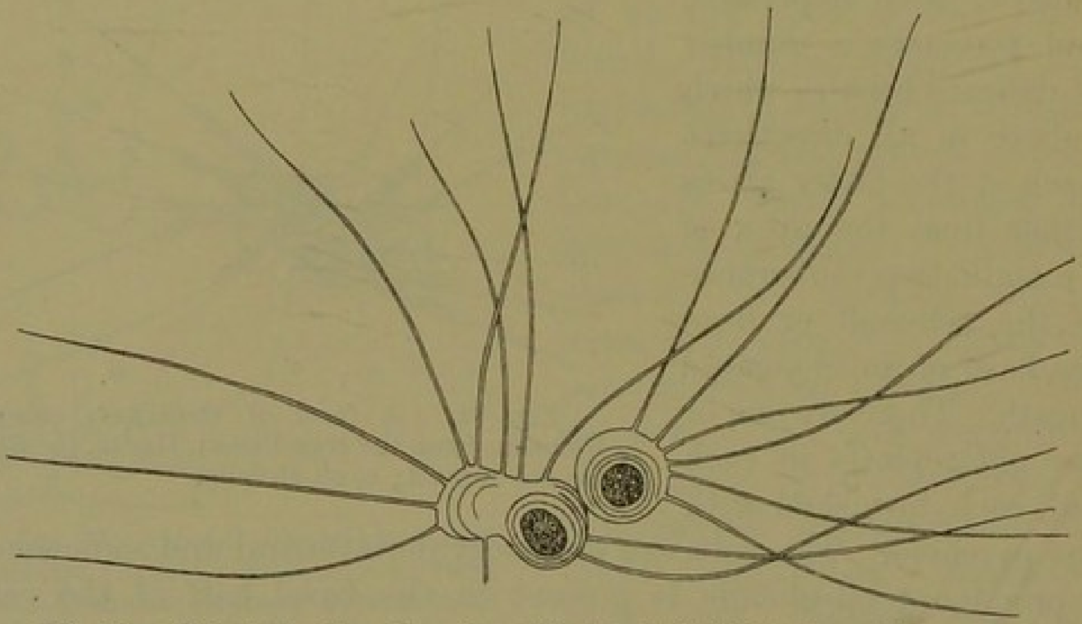

Fig. 72. *Polychætophora lamellosa* West & G. S. West, from Cirencester, Gloucestershire (× 370).

P. lamellosa West & G. S. West is the only species of the genus and has been found in Gloucestershire amongst *Tolypothrix pygmæa*. Diam. of cells 19—35 μ; thickness of cell-wall 2·8—10·5 μ; length of bristles 86—183 μ (fig. 72).

Family 2. **VOLVOCACEÆ.**

The plants contained in this family are either unicellular or they consist of definite cœnobia of cells. They are distinguished from all other Protococcoideæ by being ciliated and motile in their vegetative condition. The cœnobia consist of a definite group of cells either united together by protoplasmic processes or superficially arranged within the swollen wall of a mother-cell. The number of cells in any cœnobium remains constant so long as the individual exists, and they all arose by cell-division while the plant was still an embryo within the wall of the original mother-cell.

The cells are rounded, angular, or ovoidal in form, generally with a narrower anterior end to which are attached two, or rarely four, cilia. The protoplasm of the anterior region of the cells is hyaline in character and often contains a prominent pigment spot and two (sometimes more) contractile vacuoles. The pulsation of these vacuoles is alternate. There is a single nucleus, usually occupying a central position in the cell. One chloroplast is present containing one or more pyrenoids, and although its form is very variable, it is generally more or less confined to the broader posterior end of the cell.

Multiplication takes place by the division of the contents of a mother-cell into 2, 4, or 8 daughter-cells, and, as the latter are new motile individuals, the vegetative division in this family is strictly homologous with the asexual reproduction by zoogonidia which is found in the other groups of the Chlorophyceæ. In all the reproductive processes in this family the plane of the first cell-division is usually at right angles to the longitudinal axis of the cell.

Sexual reproduction occurs in most of the forms by the union of isogamous planogametes formed in a similar manner to the vegetative daughter-cells, but in greater numbers. In some of the higher forms there is a marked heterogamy, sexual reproduction being brought about either by the union of heterogamous planogametes or by the fusion of antherozoids and oospheres. In the zygospores or oospores the pigment spots of the two gametes disappear, but the chloroplasts remain distinct and the cell-wall becomes cuticularized. Germination takes place after a period of repose.

As one passes from the lower to the higher members of the Volvocaceæ there is a more striking progressive evolution of forms than is exhibited in any other family of Algæ. There is a gradual replacement of isogamy by heterogamy, ultimately reaching the highest condition of oogamy, and associated with this is an increase in the number of cells and size of the cœnobium, accompanied by a differentiation of vegetative from reproductive cells.

The plants of this family are of great interest on account of the fact that they are the connecting links between the lower forms of the green Algæ and the Flagellata, a Protozoan group which exhibits a mixture of animal and vegetable characters, and from which it is now generally recognized that the Chlorophyceæ have been evolved. There can be no doubt, however, in the mind of anyone who has carefully studied the Volvocaceæ, that their characters are such as to clearly separate them from the Flagellata and place them as a family of the green Algæ.

Plants of this family sometimes occur in prodigious quantity in stagnant water, giving it a pale-green colour and a somewhat unpleasant odour. They are occasionally the cause of foulness of drinking-water, imparting to it a distinct oily taste[1].

Excluding the Polyblepharideæ, which exhibit a mixture of Flagellate and Volvocine characters, the British Volvocaceæ are divided into the three following sub-families[2]:—

Sub-family I. *Chlamydomonadeæ.* Unicellular; globose or ovoidal, with a distinct but thin cell-wall. Cilia (or flagella) two, rarely four. With one chloroplast of very variable form, usually including a single pyrenoid.

Sub-family II. *Phacoteæ.* Unicellular, with the cells as in the Chlamydomonadeæ, but with a thick solid cell-wall which separates into two halves on the escape of the daughter-cells.

Sub-family III. *Volvoceæ.* Motile cœnobia of Chlamydomonadine cells, usually embedded in a common mucilaginous investment; more rarely united by protoplasmic processes. All the cells are capable of reproducing the plant or there is a differentiation into vegetative and reproductive cells. Vegetative multiplication by division of some or all of the cells to form daughter cœnobia. Isogamous or heterogamous sexual reproduction.

Sub-family I. CHLAMYDOMONADEÆ.

This division of the Volvocaceæ includes a number of unicellular Algæ which are spherical, ovoid, subcylindrical, or rarely fusiform in shape, and are provided with a thin cell-wall and two, or more rarely four, cilia. The chloroplast is of variable form, but is typically cup-shaped and occupies the posterior region of the cell, more or less surrounding a central mass of protoplasm which contains the nucleus. There is usually one pyrenoid, and a lateral pigment spot is also generally present in the anterior region of the cell.

Reproduction takes place by the division of the contents of a cell which has come to rest into 2, 4, or 8 daughter-cells, each of which soon acquires the characters of the mother-cell. The successive division-planes are at right angles to each other and the daughter-cells are ciliated motile individuals. Sometimes the vegetative cells assume a palmelloid condition, in which they

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[1] Whipple in Trans. Amer. Micr. Soc. xxi, 1900.

[2] This classification is after Dill, 'Die Gattung Chlamydomonas und ihre nächsten Verwandten.' Jahrbücher für wissenschaftliche Botanik. Berlin, 1895, Bd xxviii.

become rounded and repose in a copious mass of mucilage. Akinetes are also known to occur.

Sexual reproduction occurs by the conjugation of isogamous or heterogamous planogametes, which are smaller but otherwise similar to the vegetative individuals. They arise as do the latter by the division of the contents of a mother-cell, but as many as 64 may be produced in one cell.

A. Vegetative cells with 4 cilia .... *Carteria.*
B. Vegetative cells with 2 cilia.
    * Cell-wall thin, closely adherent.
        † Cells spherical, ovoid, or ellipsoid, rarely fusiform; chloroplast definite, with one pyrenoid .... *Chlamydomonas.*
        †† Cells fusiform, 3 or more times longer than the diameter; chloroplast indefinite, with two or more pyrenoids .... *Chlorogonium.*
    ** Cell-wall thin, outstanding and connected by protoplasmic threads .. .. *Sphærella.*

Genus **Carteria** Diesing, 1868. [*Pithiscus* Dang., 1888; *Corbiera* Dang., 1888.] The cells are spherical, ellipsoid, or cordiform, with a bell-shaped chloroplast containing a single large pyrenoid. There is a prominent pigment-spot towards the anterior end of the cell, and there are four cilia. The only distinction between this genus and *Chlamydomonas* is the presence of four cilia instead of two.

C. multifilis (Fresen.) Dill is a fairly abundant species in small pools, more particularly of rain-water. Diam. vegetative cells 10—16 μ (fig. 73 A—G).

Genus **Chlamydomonas** Ehrenb., 1833. The vegetative cells are of variable size, spherical, ovoid, oblong-ellipsoid, or pyriform, and the anterior end is often slightly produced to form a small beak or rostrum to which are attached two cilia. The cell-wall is hyaline, often very indistinct, and is closely adherent to the cell-body. The chloroplast is very variable in form, and is usually furnished with a single pyrenoid (rarely entirely without or with several pyrenoids). There are two (rarely more) contractile vacuoles in the anterior region of the cell, and generally a pigment-spot. The reproduction is typically that described for the sub-family, and the wall of the zygospore may be smooth or asperulate.

There are about 29 known species of the genus, but the characters of some of them are not clearly evident. Little work has been done at the British species of this genus, but *Chl. Kleinii* Schmidle (length of cell 28—32 μ; breadth 8—12 μ; fig. 73 J and K), *Chl. De Baryana* Gorosch. (breadth 12—20 μ; fig. 73 H and I) and *Chl. pulvisculus* Ehrenb. (= *Chl. Ehrenbergii* Gorosch.; breadth 14—26 μ) are not uncommon in ponds, ditches and rain-pools.

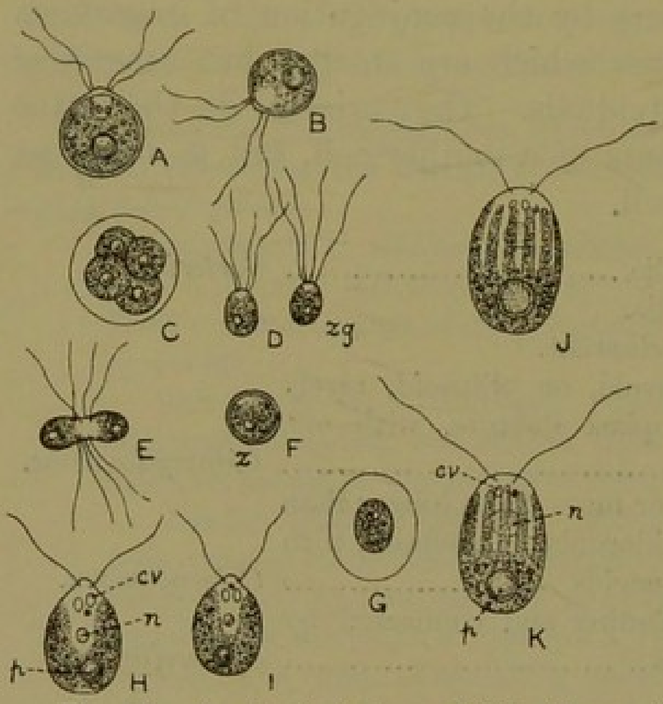

Fig. 73. A—G, *Carteria multifilis* (Fresen.) Dill, from Bradford, W. Yorks. A and B, vegetative cells; D, gametes; E, conjugating gametes; F, zygospore. H and I, *Chlamydomonas De Baryana* Gorosch., from St Just, Cornwall. J and K, *Chl. Kleinii* Schmidle, from Uxbridge, Middlesex (All × 475). *cv*, contractile vacuoles; *n*, nucleus; *p*, pyrenoid; *zg*, gamete; *z*, zygospore.

Concerning *Chlamydomonas* Blackman and Tansley[1] write,—"This genus holds a unique position among the Green Algae, and indeed among the whole of the Green Plants. It may be regarded as the phylogenetic starting point of the various lines of Chlorophyceous descent. The history of these is a history of the intercalation of a vegetative phase between two successive motile (Chlamydomonadine) generations, these motile phases being retained for reproductive purposes as zoospores and gametes; in the oogamous types the male gamete alone remains motile, and constitutes in the Archegoniate series the last remaining representative of the Chlamydomonadine cell.

"The co-existence within the limits of an undoubtedly natural genus of the most primitive form of gamogenesis (the conjugation of equal clothed gametes) with a gamogenesis which has the essential characteristics of true oogamy is also a feature of unique interest."

Genus **Chlorogonium** Ehrenb., 1830. The vegetative cells are fusiform, three or more times longer than the diameter, with a thin cell-wall closely adhering to the body. There are two cilia attached to the anterior extremity and a number of contractile vacuoles scattered through the protoplasm. The chloroplast is ill-defined, spongy and anastomosing in character, and contains four or five, or sometimes many pyrenoids. Francé describes the chloroplast as forming a regular or irregular annular band, which may split into a single or double spiral. Reproduction takes place by

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[1] Blackman & Tansley in The New Phytologist, 1902, vol. 1, pp. 23, 24.

zoogonidia, four of which arise in a mother-cell by the double transverse division of the contents. Sexual reproduction also occurs by the fusion of isogamous or heterogamous gametes.

Chl. euchlorum Ehrenb. (length up to 50 μ; breadth 8—12 μ) is apparently a very scarce British Alga of which I have examined a few specimens from stagnant ditches near the Lizard, Cornwall.

Cercidium elongatum Dang. (1888) would be more correctly placed as another species of this genus.

Genus **Sphærella** Sommerfeldt, 1824. [*Hæmatococcus* Ag., 1828; *Chlamydococcus* A. Br., 1849.] The cells are ovoid and very similar to those of *Chlamydomonas,* but the cell-wall stands out away from the cell-body, being connected to it by delicate strands of protoplasm. The chloroplast is bell-shaped and contains one or several pyrenoids. The genus is scarcely separable from *Chlamydomonas,* only differing in the outstanding cell-wall and the absence of contractile vacuoles, the zoogonidia being exactly of the Chlamydomonadine type.

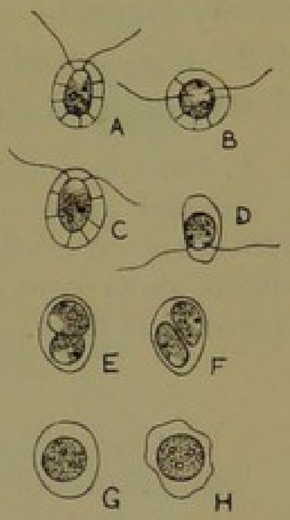

Fig. 74. A—H. *Sphærella lacustris* (Girod.) Wittr., from Bradford, W. Yorks. (×475).

Sph. lacustris (Girod.) Wittr. [*Chlamydococcus pluvialis* (Flot.) A. Br.] is abundant all over the country in ditches, rain-pools and bog-pools. The cells, which frequently become brick-red in colour owing to the presence of hæmatochromin, vary from 8 to 30 μ in diameter; they often become encysted, and the reproduction is by zoogonidia and isogamous gametes (fig. 74). The curious phenomenon known as "Red Rain" owes its colour in a few instances to the presence of this Alga. *Sph. nivalis* Sommerf., which can scarcely be specifically distinguished from *Sph. lacustris,* is the "Red Snow" plant.

Wille[1] has recently attempted to show that *Hæmatococcus* is the correct name of this genus, but I fail to see the reason for such a change. The remarks made by Hazen[2] on the nomenclature of this genus should also be consulted.

Sub-family II. PHACOTEÆ.

This sub-family is only distinguished from the Chlamydomonadeæ by the thick, solid cell-wall, which on the escape of the daughter-cells during reproduction separates into two portions.

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[1] Wille, 'Algologische Notizen X,' Nyt Magazin f. Naturvidenskab, Bd 41, H. 1, Kristiania, 1903.

[2] Hazen, 'The Life-History of *Sphærella lacustris*,' Mem. Torr. Bot. Club, vi, 1899, p. 236.

The two component parts of the cell-wall are sometimes evident in the ordinary vegetative condition. The reproduction is similar to that of the Chlamydomonadeæ.

Genus **Phacotus** Perty, 1852. The cell-body is ovoid in form and considerably flattened, so that when viewed from the side it is relatively narrow and biconvex. The cell-wall is thick, dark in colour, with a rough or rugulose exterior, and consists of two valve-like pieces. The chloroplast is large and parietal, with one or many pyrenoids. There is a clear space of some size at the anterior end of the cell, and two long cilia are attached immediately opposite. The reproduction takes place by the formation of 2—8 zoogonidia in a vesicle which bursts apart the two halves of the mother-cell-wall by a longitudinal split.

P. lenticularis (Ehrenb.) Stein is not uncommon in stagnant water.

Another genus of this sub-family is *Pteromonas* Seligo (1886) of which there are seven or eight species known from continental Europe. No doubt some of these occur in the lakes of the British Islands, but as yet there are no records of them.

Sub-family III. VOLVOCEÆ.

The plants of this sub-family are composed of a motile cœnobium of Chlamydomonadine cells, generally embedded in a considerable mucous envelope, and sometimes connected by protoplasmic processes. Attached to each cell are two cilia which project through the mucous coat and give the cœnobium a rotatory motion by their combined movements. The number of cells present in a single cœnobium varies from four in one species of *Gonium* to 22,000 in some forms of *Volvox*. In the lower forms all the cells are equal and capable of reproducing the plant, but in the higher forms there is a differentiation amongst the cells of the cœnobium, some of which are purely vegetative, whereas others are solely reproductive cells.

Reproduction in the lower forms takes place by the formation of a daughter-cœnobium from every cell of the mother-cœnobium. The daughter-cœnobium is formed within the wall of the mother-cell, which swells up and ultimately sets the young colony free. In the higher forms only certain of the reproductive cells, often termed *parthenogonidia*, give rise to daughter-cœnobia.

Sexual reproduction occurs in the lower forms by the union of isogamous or heterogamous planogametes which arise by the division of all the cells of the cœnobium. In the higher forms there is a further differentiation of the sexual elements into antherozoids and oospheres, each of which arise from special reproductive cells termed respectively *androgonidia* and *gynogonidia*.

Genus **Gonium** Müller, 1773. [Inclus. *Tetragonium* West & G. S. West, 1896.] The cœnobium is flat and plate-like, consisting of four or sixteen ovoid or slightly polygonal cells arranged in one plane and enclosed in a common mucilaginous investment. The cells are connected by protoplasmic processes, and the cilia all arise from one surface of the plate-like colony. The chloroplast is bell-shaped, much hollowed, and contains a single pyrenoid. Two contractile vacuoles are present in each cell. Reproduction takes place by zoogonidia, which are formed four in each cell or by the dissociation of the colony into individual motile cells. Conjugation of isogamous gametes results in a zygospore with a smooth or rough cell-wall. Multiplication also occurs by the development of daughter-cœnobia from each of the cells of the mother-cœnobium.

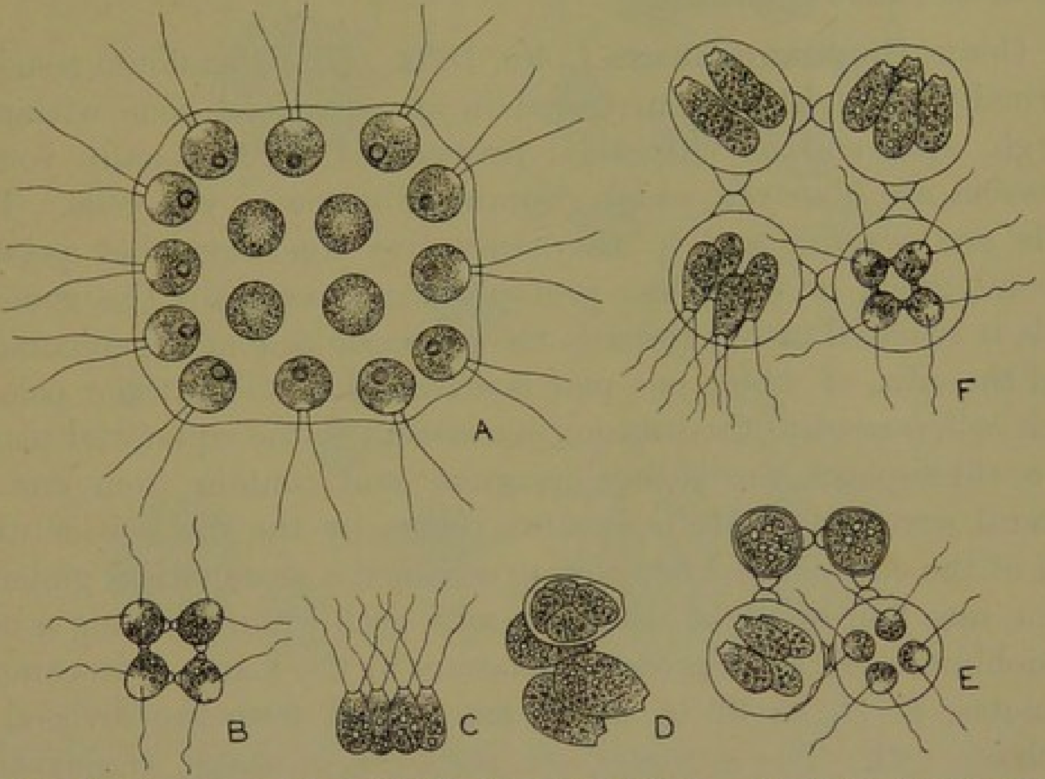

Fig. 75. A, *Gonium pectorale* Müll., from Cambridge. B—F, *G. lacustre* nob., from Esher Common, Surrey. E and F show the formation of new colonies (× 475).

G. pectorale Müll. consists of a flat, somewhat quadrate colony of sixteen cells, each of which is 7—11 μ in diameter and of which twelve are peripheral and four central (fig. 75 A). It is a frequent and striking Alga in many stagnant ditches and ponds. *G. lacustre* nob. [= *Tetragonium lacustre* W.

& G. S. West[1]] possesses a colony of four ovoid cells, each of which is 11·5—19 μ in length and 7·5—15·5 μ in breadth; fig. 75 B—F. The anterior extremity of each cell is somewhat protracted and the cilia are only vibratile towards their extremities, the movements of the cœnobium being correspondingly sluggish. It is a much rarer plant than *G. pectorale* and prefers the open water of large ponds and lakes. It may possibly be identical with *G. sociale* (Duj.) Warming, but it appears to differ in the grouping of the cells and in the nature of the cilia.

Genus **Stephanosphæra** Cohn, 1852. The cœnobium consists normally of eight cells arranged in an equatorial zone within a tough, spherical or ellipsoidal investment. Occasionally young cœnobia are observed which contain only one or two cells. The cells are ovoidal, and in the vegetative condition they possess several green or colourless protoplasmic processes. The zone of cells is situated rather towards the posterior pole of the cœnobium and the cilia, of which one pair is attached to the anterior pole of each cell, penetrate the mucous investment in the equatorial plane. The chloroplasts are rather irregular and contain from one to several pyrenoids. Multiplication occurs by the division of each cell of the cœnobium, after having assumed a more or less globular form, into four or eight daughter-cells, each group forming a new cœnobium. Sexual reproduction occurs by the fusion of isogamous gametes, 8, 16, or 32 of which are formed from the division of a single cell. The gametes are fusiform in shape, conjugating laterally to form spherical 'zygozoospores' which soon become quiescent and of a yellowish-brown colour.

St. pluvialis Cohn, which is the only species of the genus, is known to occur both in England and Ireland. It is one of the scarcest of the Volvocaceæ and is usually found in the rain-water which collects in the hollows of rocks. The cells are 6—12 μ in diameter and the colonies 26—60 μ; fig. 76 K.

Genus **Pandorina** Bory, 1824. The cœnobia are spherical or subspherical and usually contain 16 cells closely packed within the mucous investment. Sometimes cœnobia of 8, or rarely of 32, cells are observed. The cells are pyramidal in shape and reach almost to the centre of the spherical colony, the pressure of contact often causing them to become quite angular. Two widely divergent cilia are attached to the broad end of each cell. Multiplication takes place by the formation of 16-celled cœnobia from each of the cells of the mother-cœnobium. The daughter-cœnobia

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[1] West & G. S. West in Journ. Roy. Micr. Soc. 1896, p. 160, t. iii, f. 1—13.

often remain within the old mucous investment of the mother-cœnobium for some time, and the 16-ciliated colonies present the appearance of a composite cœnobium.

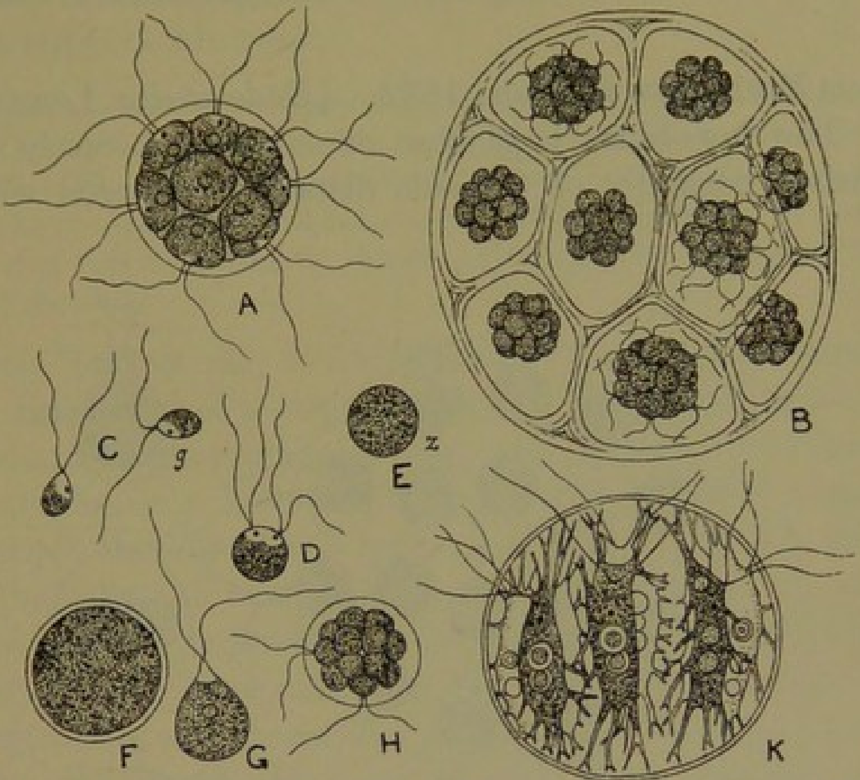

Fig. 76. A—H, *Pandorina morum* (Müll.) Bory; A, adult colony; B, group of daughter-colonies within the swollen mother-cell-wall; from near Bradford, W. Yorks. (×475). C—H, formation of zygospore (*z*) and its development (after Pringsheim). K, *Stephanosphæra pluvialis* Cohn, ordinary vegetative colony (after Hieronymus, ×320). *g*, gamete.

Asexual reproduction is by zoogonidia of a precisely similar nature to the cells of *Chlamydomonas*[1]. The zoogonidia arise by the longitudinal division of the contents of the mother-cell, and each one secretes in addition to its own membrane a gelatinous investment which ultimately forms the common investment of the colony. Schröder[2] has also described an asexual method of reproduction in which the zoogonidia loose their cilia, vacuoles and pigment-spots, and form a new colony. The gametes arise by the division of the cells into 16 or 32 parts, and they exhibit considerable variability in size. Sexual reproduction occurs by the fusion of a pair of gametes, sometimes by the fusion of a smaller active (male) gamete with a larger and more sluggish (female)

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[1] Dangeard in Le Botaniste, vii, 1900.

[2] B. Schröder in J. B. Schles. Gesellsch. Vaterl. Cult. 1898, Zool., bot. sect.

gamete. The zygospores possess smooth cell-walls and the germination is indirect.

P. morum (Müll.) Bory is abundant in ponds and ditches all over the country. The cells are 8—15 μ in diameter and the colonies 20—42 μ (fig. 76 A—H).

Genus **Eudorina** Ehrenb., 1832. [*Eudorinella* Lemmermann, 1900.] The cœnobium is globose or subglobose, rarely ellipsoid, and consists normally of 32 cells distantly arranged within the periphery of a copious mucous investment. The cells are globose, with a single bell-shaped chloroplast containing one or more pyrenoids. Small colonies of only eight or sixteen cells are sometimes met with. The cilia (one pair) attached to each cell are parallel until they reach the outer surface of the investment, when they widely diverge. Multiplication takes place as in *Pandorina* by the division of all the cells of the cœnobium to form daughter-cœnobia. Sexual reproduction occurs by the union of fusiform or pear-shaped antherozoids, produced 64 in a cell, with oospheres which are slightly larger than the vegetative cells. The oospores have smooth cell-walls and germination is direct.

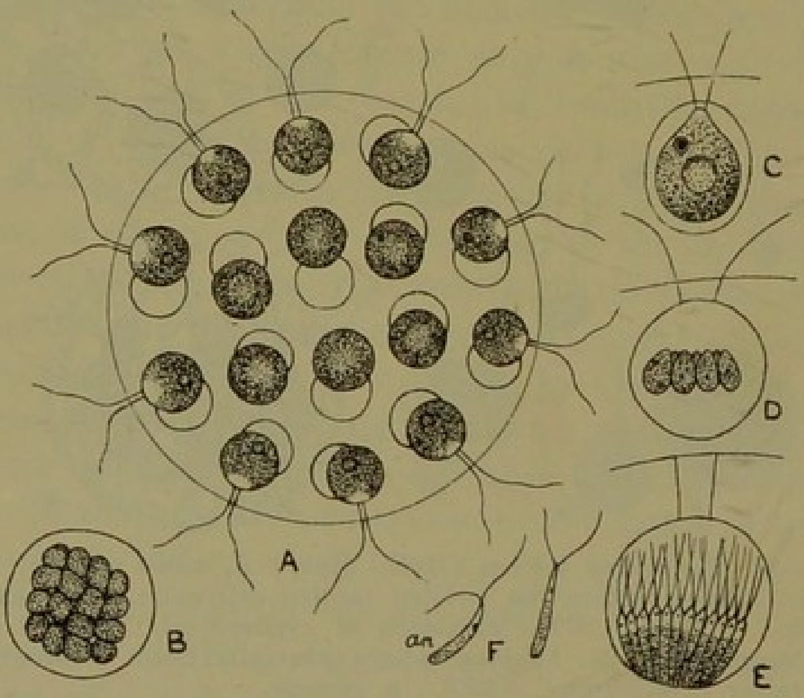

Fig. 77. *Eudorina elegans* Ehrenb. A, adult colony (×475); B, young colony formed by division of contents of mother-cell (×730), from Frizinghall, W. Yorks. C—E, development of antherozoid-clusters from mother-cell; F, antherozoids (after Goebel).

There seems no valid reason for the separation of Lemmermann's genus *Eudorinella*[1]. Chodat[2] also considers that the two described species of *Pleodorina* Shaw[3] should be regarded merely as forms of *Eudorina elegans*, but the marked differentiation which exists between the vegetative and reproductive cells of *Pleodorina* does not support his view.

Eudorina elegans Ehrenb. is widely distributed in ponds, ditches and lakes all over the British Islands. The cells are 10—25 μ in diameter and the colonies 40—150 μ; fig. 77. The ellipsoid colonies of this plant are sometimes described as possessing several mucous mamillate projections at one pole, but I do not find this character in British examples, the colonies of which are invariably globose.

Genus **Volvox** (L., 1758) Ehrenb., 1830. The cœnobium is globose, consisting of a large number of small cells (200—22,000) arranged in a single peripheral layer within the mucous investment. The cœnobium is a hollow sphere and the cells are connected by protoplasmic threads of varying stoutness. There is a differentiation of the cells, the vast majority of them being purely vegetative (somatic), and the remainder either parthenogonidia, androgonidia, or gynogonidia. Each cell possesses a distinct chloroplast, two or more contractile vacuoles, and a pair of cilia. Asexual reproduction occurs by the development of new colonies from the parthenogonidia, of which about 8 (1 to 16) are found in a single cœnobium. These parthenogenetically formed individuals become detached in the hollow cavity of the mother-cœnobium and are ultimately set free on its death. Sexual reproduction takes place by the fusion of an antherozoid with an oosphere. The antherozoids arise by the division of few or many androgonidia, which are similar in appearance to the parthenogonidia. The divisions of the androgonidia produce either a plate-like or a spherical mass of antherozoids, each of which is a small fusiform body, much attenuated at the anterior end and furnished with two cilia. The gynogonidia are few in number, larger than the vegetative cells, and each one becomes an oosphere. The oospores are globular, either smooth or substellate, and their germination is direct, after a period of repose. Both asexual and sexual colonies occur, and the latter, which sometimes possess parthenogonidia, may be either monœcious or

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[1] Lemmermann in Berichte Deutsch. Botan. Gesellsch. xviii, 1900, p. 307.

[2] Chodat in Beiträge zur Kryptogamenflora der Schweiz, Bd i, Heft 3, Berlin, 1902, p. 152.

[3] Shaw in Botan. Gazette, 1894, xix, p. 279; Kofoid in Bull. Illinois State Lab. v, 1898, p. 273; also in Ann. Mag. Nat. Hist. ser. 7, vol. vi, July, 1900.

diœcious. The most thorough investigations of the life-history of the genus have been made by Klein[1].

This genus is the culminating point in the evolution of motile cœnobic forms, and although the individual cells are of the primitive Chlamydomonadine type, the entire organism, by reason of the differentiation of its component cells, has attained along its own line a state of evolution quite comparable with the structural differentiation attained along other lines by the highest known forms of the green Algæ.

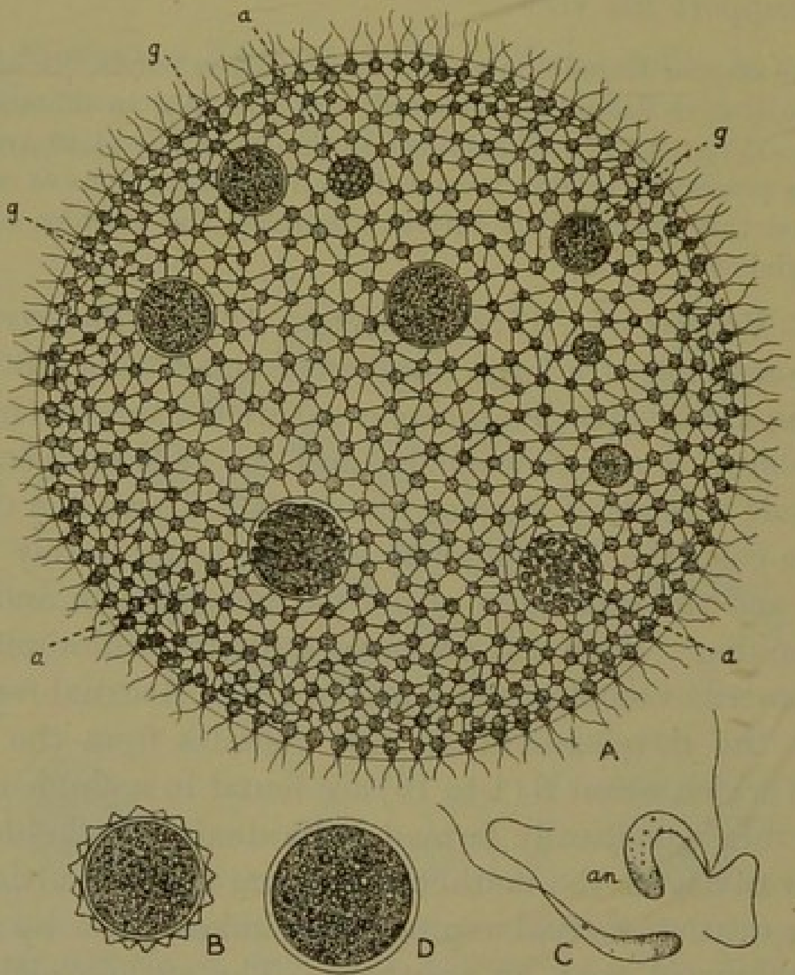

Fig. 78. A, C, and D, *Volvox aureus* Ehrenb. A, monœcious sexual colony (×210), from Rawcliffe Common, W. Yorks.; D, ripe oospore (×475); C, two antherozoids (after Klein). B, ripe oospore of *V. globator* (L.) Ehrenb., from Preston, Lancashire (×475). *a*, androgonidia; *an*, antherozoid; *g*, gynogonidia.

The Rotifer *Notommata parasitica* sometimes occurs as a parasite within the hollow cœnobia of *Volvox*, swimming about within the central cavity and feeding on the green cells either of the adult or of the parthenogenetic daughter-cœnobia.

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[1] Klein 'Morphol. u. biol. Studien über die Gatt. Volvox,' Pringsh. Jahrbüch. f. wissensch. Bot. 1889, Bd xx.

Two well-known species of *Volvox* exist in the deeper ponds and ditches of the low-lying areas of the British Islands. They are often associated with *Lemna*, and prefer ponds which receive a plentiful supply of rain-water. The adult colonies of *V. globator* Ehrenb. are 680—800 μ in diameter, the cells are very numerous, the protoplasmic strands connecting them are of considerable thickness, and the ripe oospores are substellate (fig. 78 B). *V. aureus* Ehrenb. is usually smaller than the preceding species, the adult colonies being 200—500 μ in diameter; fig. 78 A, C, and D; the cells are less numerous, the protoplasmic threads connecting them are extremely delicate, and the walls of the ripe oospores are smooth.

Family 3. **ENDOSPHÆRACEÆ.**

This family includes a number of endophytic Algæ in which the plant-body is either a simple rounded cell or a slightly branched cœnocyte, occurring wedged between the epidermal cells of aquatic or marsh-loving plants. The cells are somewhat variable in form and the cell-wall is sometimes thick and lamellose, often developing on one side a button-like excrescence of cellulose.

Reproduction takes place by the formation of zoogonidia or planogametes, or both. In the best known genus, *Chlorochytrium* Cohn, the contents of the endophytic cell become broken up by successive divisions, in a manner similar to that which occurs in *Characium*, into a large number of small zoogonidia or gametes. These are liberated by the gelatinization of the inner layer of the cell-wall, which becomes protruded as a large vesicle such as is found in the Pediastreæ and many of the Protococcaceæ. The biciliated gametes are isogamous and on their fusion the motile 4-ciliated zygospore comes to rest on the epidermis of the host-plant. Germination takes place without any period of rest, the new endophytic cell forcing a protuberance either between two cells of the epidermis or into a stoma.

Some of these endophytic cells become akinetes and in this condition they pass the winter.

There is a complete absence of ordinary vegetative division.

Seven genera have been described, but some of these are doubtfully distinct.

The researches of Klebs have shown that Cohn and other previous investigators were wrong in regarding certain of these plants as parasites, and that not merely can the endophyte live quite independently of its host-plant, but that the latter receives no injury beyond the little mechanical pressure exerted by the growing endophyte. The anomalous habit of these Algæ is explained by the protection afforded by the intercellular spaces of the host. Freeman[1] has suggested that the condition of affairs met with in *Chlorochytrium* lends itself to the development of parasitism and that the allied genus *Phyllobium* is progressing in that direction.

Genus **Chlorochytrium** Cohn, 1874. The cells are generally solitary, globose, ellipsoid, ovoid, or irregularly curved and lobed, and they contain a large parietal chloroplast furnished with many pyrenoids. Both starch and oil are often found in the cells. Zoogonidia are formed by successive bipartitions of the cell-contents, at first by perpendicular, and afterwards by radially disposed walls. Gametes arise in a similar manner, and conjugation takes place within the vesicle formed by the protrusion of the inner layer of the gametangium. Some of the species of this genus are endophytes in the leaves of *Lemna, Mentha, Rumex, Lychnis, Sphagnum*, etc., and others are marine, occurring in the thalli of various marine Algæ.

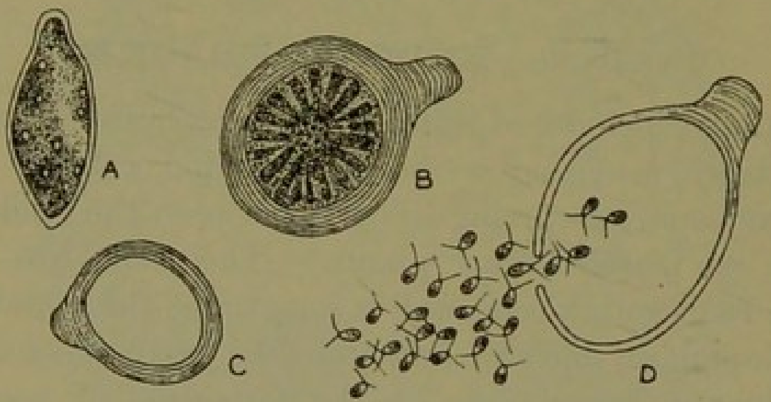

Fig. 79. A, Vegetative cell of *Chlorochytrium Lemnæ* Cohn, from Frizinghall, W. Yorks. (×475). B—D, *Centrosphæra Facciolaæ* Borzi; B and C, from near Senens, Cornwall (×475); D, showing escape of zoogonidia (after Borzi, ×410).

Chl. Lemnæ Cohn occurs frequently in the leaves of *Lemna trisulca*; diam. cell. 40—143 μ; fig. 79 A. *Chl. Knyanum* Szymanski is found on the leaves of *Lemna minor* and *L. gibba*.

The genus *Stomatochytrium* Cunningham (1888) differs from *Chlorochytrium* mainly in the absence of the vesicle which surrounds the gametes in the latter genus. This feature can scarcely be regarded as a generic difference.

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[1] Freeman, 'Obs. on Chlorochytrium,' Minnesota Botan. Studies, vol. II, part III, p. 198.

Genus **Centrosphæra** Borzi, 1883. The cells are globose or shortly ellipsoid and generally occur aggregated in a more or less diffuse stratum beneath colonies of various members of the Oscillatoriaceæ. The cell-walls are thick and lamellose, and possess a projecting lamellose button of cellulose. Reproduction takes place by biciliated zoogonidia, which usually arise in large numbers from the zoogonidangia. Gametes have not been observed.

C. Facciolaæ Borzi[1] is known from the south of England. Diam. of vegetative cells 26—42 μ; zoogonidangia up to 80 μ; zoogonidia 2—3 μ in breadth; fig. 79 B—D.

There is scarcely any distinction between *Centrosphæra* Borzi, *Endosphæra* Klebs and *Scotinosphæra* Klebs[2], the vegetative cells being almost alike in all three. In *Endosphæra* the reproduction is by gametes, zoogonidia not having been observed. In *Scotinosphæra* the only observed reproduction is by zoogonidia, which arise according to Klebs in a most extraordinary manner.

Genus **Phyllobium** Klebs, 1881. The plants of this genus are endophytic cœnocytes which occur in the leaves of certain marsh-loving plants. They send out branching tubes through the intercellular spaces of the host-plant after the manner of *Phyllosiphon* amongst the Siphoneæ. These branched tubes may or may not be septate, and projecting from the surface of the leaf are small, bright-green swellings. The latter contain a number of radiating chloroplasts, each with a pyrenoid. Biciliated macro- and microgametes occur.

P. dimorphum Klebs, which occurs in the leaves of *Ajuga*, *Lysimachia*, etc., has not been observed from this country, but I have recently obtained what may prove to be another species from N. Uist, Outer Hebrides, thickly studding the leaves of damp *Sphagnum*, the whole tissue of the leaf being permeated by the branched tubes of the *Phyllobium*.

Family 4. CHARACIEÆ.

The plants of this family are unicellular and they generally occur as epiphytes, either solitary or in clusters, on other larger Algæ. The vegetative cells are of very variable form, but in most cases they are attenuated and slightly oblique. There is always a distinct differentiation into base and apex. The base is often drawn out into a stalk of variable length with a disc for purpose of attachment, and the apex is generally acuminate. There is a

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[1] Borzi, 'Studi Algologici I,' Messina, 1883.

[2] Klebs in Botan. Centralbl. 1881, xxxix, p. 16—21.

single parietal chloroplast in each cell, generally of considerable extent and containing one pyrenoid.

There is no vegetative division.

Reproduction takes place by the formation of numerous zoogonidia in each cell. There is a repeated division of the cell-contents, several transverse divisions occurring before the first longitudinal division, and in a short time each portion loses its angular character, becomes rounded off, and forms a biciliated zoogonidium. The escape of the zoogonidia takes place either by a lateral or a terminal aperture. The pyrenoid disappears (in some species) during the formation of the zoogonidia, and reappears on their germination. Each zoogonidium on coming to rest develops into a new plant.

Genus **Characium** A. Br., 1849. [*Hydrocytium* A. Br., 1855; *Hydrianum* Rabenh., 1868.] The cells are fixed by a basal stalk, usually rather short, but sometimes much elongated; in form they are spherical, ellipsoid, oblong, or fusiform, and they are generally asymmetrical. The cells as a rule give rise to 16 or 32 zoogonidia.

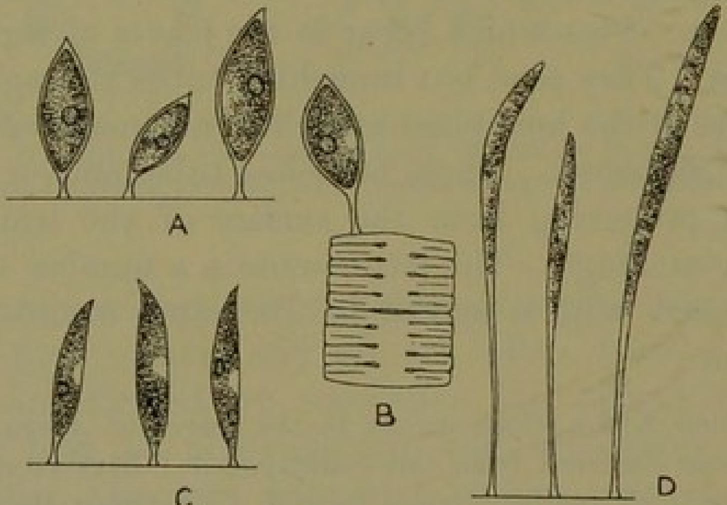

Fig. 80. A and B, *Characium Pringsheimii* A. Br.; A, from Mitcham Common, Surrey; B, attached to a frustule of *Tabellaria flocculosa*, from Gunwen Moor, Cornwall. C, *Ch. subulatum* A. Br., from Wimpole Park, Cambridgeshire. D, *Ch. ensiforme* Herm., from Pilmoor, N. Yorks. (All × 520.)

Some eight or ten species of the genus are known to occur in Britain, of which *Ch. Sieboldii* A. Br. (length 40—70 μ; diam. 20—33 μ), *Ch. ambiguum* A. Br. (length 15—30 μ; diam. 2·5—4 μ), *Ch. Pringsheimii* A. Br. (length 18—35 μ; diam. 5—11·5 μ; fig. 80 A and B) and *Ch. ornithocephalum* A. Br. (length 19—33 μ; diam. 8—12·5 μ) are the most general. *Ch. ensiforme* Herm. (length 65—86 μ; diam. 2·5—3·8 μ; fig. 80 D) is the most elongate species of the genus.

Family 5. PLEUROCOCCACEÆ.

The plants of this family are either unicellular or composed of very short, slightly branched filaments, which consist of few cells and are never attenuated to form hairs. The short filaments are generally creeping and are often compacted into pseudoparenchymatous masses. Considerable polymorphism is exhibited by the different members of this family.

The cells are variable in outward form and contain one or several parietal chloroplasts, with or without pyrenoids.

Multiplication takes place by division in two or three directions, and asexual reproduction occasionally occurs by the formation of biciliated zoogonidia. Gametes are rarely produced.

In the two most frequent genera of the family, namely *Pleurococcus* and *Trochiscia*, the cells are more or less globose and occur aggregated in large masses; the former prefers a subaërial habitat whereas the latter prefers an aquatic existence. In *Hormotila* there is a marked increase in thickness of the cell-wall at one side only, branched colonies of cells being formed by the more or less complete fusion of these remarkable lamellose excrescences. *Protoderma* is usually epiphytic, and its short cell-filaments commonly assume a pseudoparenchymatous character; it is placed here on account of its close resemblance to certain of the more uncommon states of *Pleurococcus*.

The cell-walls are usually very strong and firm, and the cells are associated to form indefinite colonies or irregular aggregations. This fact, and the complete absence of autospores, separate the Pleurococcaceæ from the Protococcaceæ.

Chodat[1] includes in this family the genera *Microthamnion* and *Gongrosira*, Algæ which I have referred to a distinct family—the Microthamniaceæ—of the Chætophorales. There is considerable resemblance between certain states of *Pleurococcus* and the young, germinating plants of *Microthamnion*, but the latter genus has reached a much higher stage of development than is ever attained by forms of *Pleurococcus*. It is very probable that the family Microthamniaceæ has had a direct origin from certain of the Pleurococcaceæ.

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[1] Chodat in Beiträge zur Kryptogamenflora der Schweiz, Bd I, Heft 3, Berlin, 1902.

Wille[1] has placed the genus *Trochiscia* in the Volvocaceæ in close proximity to *Chlamydomonas,* but a careful consideration of the facts of the case shows this change to be unjustifiable. The ordinary vegetative condition of *Trochiscia* is a non-motile resting state, zoogonidia rarely being produced; whereas the normal vegetative condition of *Chlamydomonas* (and indeed, of all the Volvocaceæ) is a motile one.

Genus **Pleurococcus** Menegh., 1842. [*Protococcus* Ag., 1824 (in part); *Cystococcus* Näg., 1849; *Chlorococcum* Fries, 1825 (in part); *Chlorosphæra* Klebs, 1883 (in part); *Pseudopleurococcus* Snow, 1899.] The cells are more or less globose, sometimes angular by compression, and they occur frequently in groups of two or four due to imperfect separation after division. As division occurs in three directions a small cubical colony is occasionally produced, but this easily dissociates into its individual cells. The cell-walls are strong and firm. There is one parietal chloroplast in each cell, extremely variable in size and form, and with or without a pyrenoid.

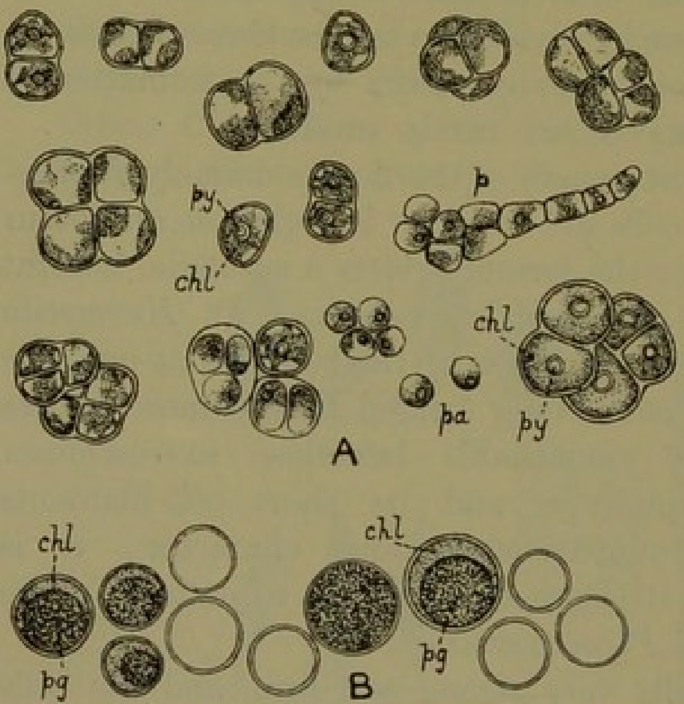

Fig. 81. A, *Pleurococcus vulgaris* Menegh., from Cirencester, Gloucestershire. B, *Pl. rufescens* (Kütz.) Bréb. var. *sanguineus* W. & G. S. West, from near Arncliffe, W. Yorks. (All × 520.) *chl*, chloroplast; *p*, protoderma stage; *pa*, palmelloid state; *pg*, bright red pigment; *py*, pyrenoid.

In moist places short filaments of cells are sometimes produced which exhibit a simple type of branching; they frequently radiate from a few central cells of an angular, more or less parenchymatous form. This condition is readily produced in cultures and can be described as the 'Protoderma-stage.'

Vegetative multiplication takes place by division and subsequent separation of the cells. Reproduction is brought about

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[1] Wille, 'Alg. Not. VII,' Nyt Magazin f. Naturvidenskab. 1901, Kristiania, B. 39, H. 1, p. 9.

by the formation of one or many spores (aplanospores), by the rejuvenescence of the contents of a mother-cell, by biciliated zoogonidia, and by isogamous gametes. The polymorphism exhibited by plants of this genus under various conditions of humidity, temperature, etc., has caused much confusion with regard to the identity of the different forms.

Pl. vulgaris Menegh. is one of the commonest of Algæ, occurring in great profusion in all kinds of damp situations, on stones, walls, palings, tree-trunks, etc., and it usually forms a thin green incrustation on the windward side of the objects on which it grows. The cells are as described for the genus and the chloroplast is a massive lobed plate containing a prominent pyrenoid. Diam. cells 9—20 μ; fig. 81 A. In *Pl. rufescens* (Kütz.) Bréb. the cell-contents are of a brick-red colour due to the presence of hæmatochromin, which usually appears to be dissolved in oily material. This species has a preference for calcareous rocks; a variety of it (var. *sanguineus* West & G. S. West) has been observed in the limestone districts of West Yorkshire, forming large brilliant blood-red patches, covering those stones and rocks in the beds of streams which could not be displaced by the rapidity of the current and which are often left dry. Diam. cells 11—20 μ; fig. 81 B.

Genus **Trochiscia** Kütz., 1845. [*Acanthococcus* Lagerh., 1883; *Glochiococcus* De Toni, 1888.] This genus is very closely related to *Pleurococcus*, differing mainly in the external ornamentation of the cell-wall and in the aquatic habit. The cells are perfectly globose and usually occur in large aggregates in quiet water, or rarely on damp ground. The cell-wall is either areolated or thickly clothed with denticulations, spines, or other prominent

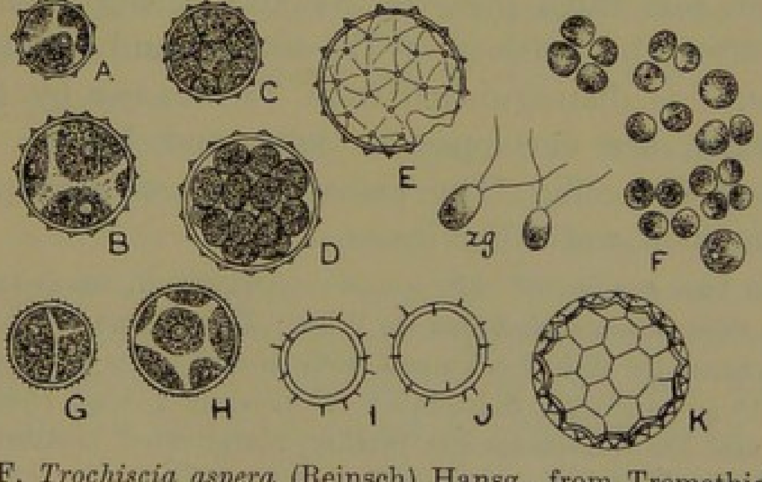

Fig. 82. A—F, *Trochiscia aspera* (Reinsch) Hansg., from Tremethick, Cornwall; A and B, vegetative cells; C and D, formation of zoogonidia; E, empty cell from which zoogonidia (*zg*) have escaped; F, palmelloid state. G and H, *T. hirta* (Reinsch) Hansg., from Cambridge. I and J, *T. paucispinosa* West, from Ben Lawers, Perthshire. K, *T. reticularis* (Reinsch) Hansg., from Keston Common, Kent. (All × 520.)

processes. There are usually several parietal chloroplasts in each cell, some or all of which contain a single pyrenoid. Multiplication rarely occurs by cell-division as in *Pleurococcus*, but reproduction commonly takes place as in that genus by the formation of non-motile gonidia or spores. Zoogonidia are rarely developed and the plants sometimes pass into a palmelloid condition (*vide* fig. 82 F).

There are eight or nine British species of this genus, distinguished by their external ornamentation. *T. aspera* (Reinsch) Hansg. (diam. veg. cells 13·5—29 μ; fig. 82 A—F), *T. aciculifera* (Lagerh.) Hansg. and *T. reticularis* (Reinsch) Hansg. (diam. veg. cells 24—32 μ; fig. 82 K) are amongst the most frequent species met with in quiet waters. *T. hirta* (Reinsch) Hansg. (diam. veg. cells 17—27 μ; fig. 82 G and H) is often found on damp ground near the base of tree-trunks.

Genus **Radiococcus** Schmidle, 1902[1]. [*Westella* De Wild.[2], 1897 (in part).] The plants consist of microscopic families of few cells (generally four) arranged in a tetrahedral manner and enveloped in a mass of jelly. The cells are rounded or occasionally angular by mutual pressure, with firm cell-walls, and they contain a single parietal chloroplast with one pyrenoid. Reproduction takes place by the formation of four daughter-cells (spores) tetrahedrally disposed within the wall of the mother-cell, which ruptures and sets them free, the remains of the mother-cell-wall persisting after the manner of *Tetracoccus* and *Schizochlamys*.

The genus is distinguished from *Tetracoccus* by the smaller families, which are enveloped in jelly, and by the tetrahedral disposition of the cells. The plants often occur attached to the under surfaces of water-lily leaves.

There are two species of this genus[3], of which *R. nimbatus* (De Wild.) Schmidle (= *Pleurococcus nimbatus* De Wild.; *Tetracoccus nimbatus* Schmidle; *Westella nimbatus* De Wild.) is known from several parts of England. Diam. of cells 8—15 μ. In 1894 Schmidle[4] erroneously placed this Alga under *Tetracoccus* and De Wildeman has further complicated matters by creating the useless name *Westella*.

Genus **Protoderma** Kütz., 1843; Borzi, 1895. This genus occupies a position in the Pleurococcaceæ by reason of the resemblance between it and certain states of *Pleurococcus vulgaris*. The plants generally consist of a minute thallus of short cell-filaments radiating from a small central group of pseudoparenchymatous

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[1] Schmidle in Allgem. Botan. Zeitschr. 1902, p. 41.

[2] De Wildeman in Bull. de l'Herb. Boissier, 1897, p. 503.

[3] Schmidle in Hedwigia, 1902, Bd xli, Heft 4, p. 159.

[4] Schmidle in Flora, 1894, Heft 1, p. 45.

cells. The cells are of a variable shape and the branches are sometimes a little attenuated. There is a large parietal chloroplast in each cell containing a single pyrenoid.

P. viride Kütz. (fig. 83 A—C) is usually found epiphytic on larger Algæ, such as *Coleochæte orbicularis*, or on the stems and leaves of aquatic Phanerogams, such as *Callitriche*, *Elodea*, etc. I have previously suggested[1] that certain plants described as *Entocladia gracilis* Hansgirg[2] (=*Endoderma gracile* De Toni) are most probably referable to *Protoderma viride* Kütz.

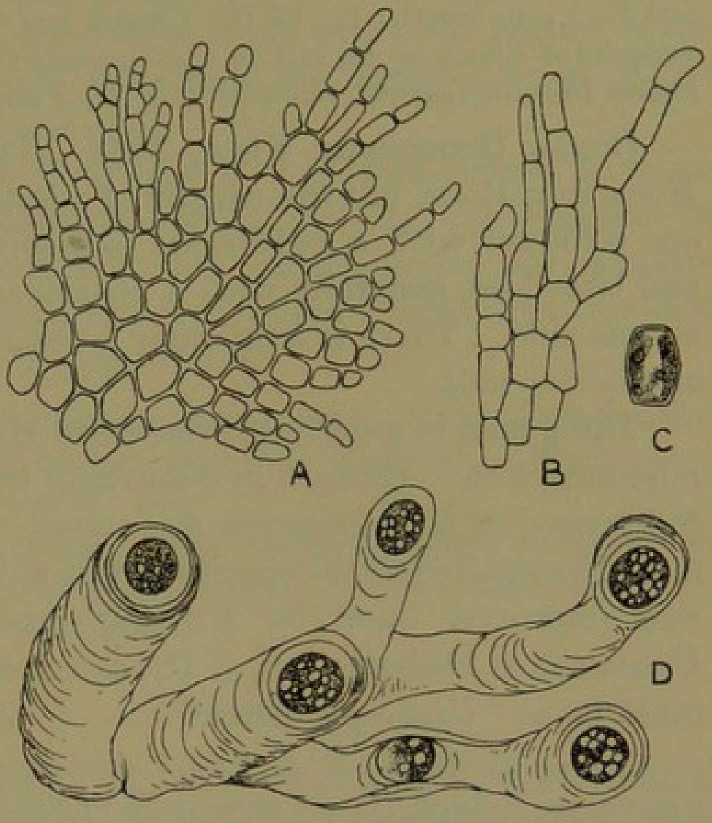

Fig. 83. A—C, *Protoderma viride* Kütz., from Baildon, W. Yorks., epiphytic on *Callitriche stagnalis*; A and B, outlines of colonies, × 520; C, single cell, × 700. D, *Hormotila mucigena* Borzi, from Boston Spa, W. Yorks. (× 520).

Genus **Hormotila** Borzi, 1883. The vegetative cells are spherical, ovoid, or ellipsoid, rarely oblong, and from two to sixteen of them occur within a more or less ample, firm, gelatinous integument, which is often concentrically lamellose. There is a large chloroplast in each cell, frequently very granulose and destitute of a pyrenoid. Multiplication takes place by cell-division, at first in three directions, but subsequently in two, and finally in one direction. In this way more or less moniliform series of cells are produced, all of which are connected by cylindrical lamellose integuments. Zoogonidangia arise from vegetative cells by an increase in size of the cell, and reproduction takes place by numerous minute zoogonidia, each with two cilia. Gametes have not been observed.

The only known species is *H. mucigena* Borzi, an Alga which I have observed from Boston Spa in West Yorkshire. It forms an expanded, dull

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[1] G. S. West in Journ. Bot. Febr. 1899, p. 58.

[2] Hansgirg, 'Ueber Entocladia Reinke und Pilinia Kütz.,' Flora, 1888, no. 33, t. xii, f. 6—15.

green stratum on the damp surfaces of calcareous rocks. Diam. of veg. cells 4—12 μ; zoogonidangia up to 30 μ in diameter; zoogonidia 1—2·5 μ in breadth and 3—5 μ in length; fig. 83 D. Chodat has observed '*Hormotila* stages' of a species of *Pleurococcus*, and he also suggests that they may be in part *Dactylothece Braunii* Lagerh., but with this latter suggestion I cannot agree.

Genus **Urococcus** Kütz., 1849. The cells are much as in *Hormotila* Borzi, but are usually of a larger size and their contents are coloured with a red-brown pigment. The cell-wall is thick and lamellose, generally with a considerable increase in thickness on one side. There is frequently an exuviation of the outer layers of the cell-wall.

The genus is usually attributed to Hassall, but this is due to a misconception. Hassall, in describing the characters of his "First Subgenus" of *Hæmatococcus* Ag., stated[1] that "the term *Ouracoccus* might be applied to the species of this subgenus." This suggestion was improved upon by Kützing, who established the genus *Urococcus* of Hassall; but, if *Urococcus* is to remain as a genus, it must be as "*Urococcus* Kütz.[2]"

U. insignis (Hass.) Kütz. [=*Hæmatococcus insignis* Hass.; *Chroococcus macrococcus* Rabenh.] is not uncommon in the bogs of moorland and upland districts. Diam. of cells without integument 25—51 μ, with integument 41—78 μ. It sometimes occurs in quantity amongst submerged Sphagnum, especially in peaty pools.

Family 6. HYDRODICTYACEÆ.

In this family of the Protococcoideæ the plant-body consists of a non-motile cœnobium of cœnocytes which floats freely in the water. The cœnocytes are arranged either as a flat plate or after the manner of a net, and they are of very variable form. In *Euastropsis* there are only two cells (cœnocytes?) in the cœnobium, in *Pediastrum* there may be more than fifty cœnocytes, and in *Hydrodictyon* there are often many hundreds, the cœnobium reaching a length of several centimetres.

Multiplication sometimes occurs by the formation of autocolonies.

Reproduction takes place by the development of hypnospores (usually aplanospores), by the formation of new cœnobia by the apposition of biciliated zoogonidia which have become quiescent, and in some by the fusion of isogamous gametes to form a zygospore. The germination of the zygospore is indirect.

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[1] Hassall, Brit. Freshw. Alg. 1845, i, p. 322.

[2] Kützing, Spec. Algar. 1849, p. 206. *Vide* West & G. S. West in Journ. Bot. June, 1897, p. 239.

The method of reproduction by the apposition of quiescent zoogonidia to form new cœnobia distinguishes the Hydrodictyaceæ from all the other Protococcoideæ, and the cœnocytic nature of the cœnobium also distinguishes them from the cœnobic forms of the Protococcaceæ (or Autosporaceæ).

It is most likely that *Hydrodictyon* and *Pediastrum* have no direct affinity, the resemblance being due to convergence of modification, but until more is known concerning the phylogenetic relationships of these genera the Hydrodictyaceæ are best divided into the two following sub-families:—

Sub-family I. *Hydrodictyeæ.* New cœnobium formed by apposition of zoogonidia within the mother-cœnocyte. Plants macroscopic, cœnocytes arranged in the form of a net.

Sub-family II. *Pediastreæ.* New cœnobium formed by apposition of zoogonidia outside the mother-cœnocyte. Plants microscopic, cœnocytes arranged to form a flat plate.

Sub-family I. HYDRODICTYEÆ.

This sub-family includes only the one genus *Hydrodictyon.* The plants are macroscopic and consist of very large cœnocytes which are disposed so as to form a more or less cylindrical net. The zoogonidia swarm and become quiescent within the wall of the mother-cœnocyte, and there they become apposed to form the new cœnobium.

Genus **Hydrodictyon** Roth, 1800. The cœnobium is a net-like sac, freely floating in the water, and reaches a length of 8—10 centimetres. The meshes of the net are of variable size and each one is bounded by either five or six cœnocytes, the angles being formed by the junction of three cœnocytes. The protoplasm of each cœnocyte is confined to a lining layer containing many nuclei, the central portion of the segment being occupied by a large vacuole. There are no definite chloroplasts, the chlorophyll being more or less diffuse through the whole protoplasm, but numerous pyrenoids are present.

The normal method of reproduction is by the formation of a very large number of zoogonidia within the mother-cœnocyte, which swarm within the wall of the segment and then become quiescent, immediately forming a reticulated daughter-cœnobium by the apposition of their extremities. The old cell-wall then ruptures and the young cœnobium is set free. The zoogonidia are biciliated; they possess one nucleus and contain a single pyrenoid, but as the young reticulum increases in size the pyrenoids of each segment multiply rapidly. Timberlake[1] states that the swarming condition of the zoogonidia can be induced by the use of a reagent composed of 100 c.c. of 1 per cent. solution of iridium chloride and 3 c.c. of glacial acetic acid. He points out that the cell-contents first break up into large multinucleated masses, which in turn break up into smaller masses, until each mass contains a single nucleus. Reproduction also occurs by the union of isogamous, 4-ciliated gametes, which escape from the mother-cœnocyte by a lateral pore. The gametes are smaller than the zoogonidia and their escape is preceded by a swelling of an inner layer of the cell-wall. This inner layer ruptures the outer layers and protrudes as a vesicle in which the gametes swarm. On becoming free they conjugate in pairs[2]. The zygospore is globose and after a

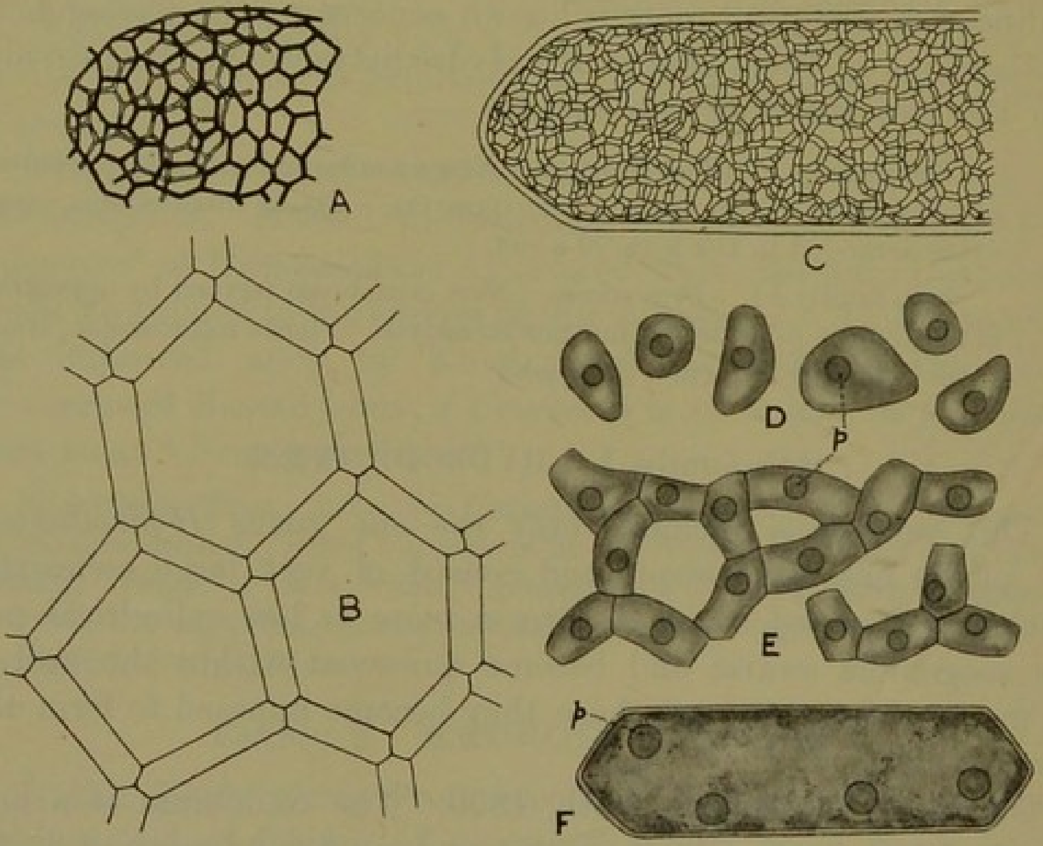

Fig. 84. *Hydrodictyon reticulatum* (L.) Lagerh., from the River Lea. A, nat. size; B, small portion of a young colony (× 110); C, part of a large cœnocyte containing a very young colony (× 110); D, quiescent zoogonidia (× 480); E, zoogonidia which are becoming apposed to form a new colony (× 480), *p*, pyrenoid; F, slightly older cœnocyte with four pyrenoids (*p*), × 480.

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[1] Timberlake in Botan. Gazette, xxxi, 1901, p. 203.

[2] Klebs in Bot. Zeitung, xlix, 1891.

short rest forms two or four large biciliated zoospores, which on coming to rest assume a polyhedral form. The repeated division of the cell-contents of these polyhedral bodies results in the formation of numerous zoogonidia, which by apposition give rise to new net-like cœnobia.

The division of the protoplasm of the adult cells of this genus to form either zoogonidia or gametes is a splendid example of free-cell-formation.

The only known species, *H. reticulatum* (L.) Lagerh., which has received the name of the "Water-net," is a very rare plant in Britain. The average length of the adult cœnocytes just before they become zoogonidangia is 4 or 5 mm., but they are known to attain a length of 1 cm. The length of the quiescent zoogonidia at the time of their apposition is 13·5—25 μ. The swarming zoogonidia are 10 μ in length by 8 μ in breadth and the gametes are a little smaller. Fig. 84.

Sub-family II. PEDIASTREÆ.

The plants of this sub-family are microscopic in size and consist of a number of small cœnocytes united to form a flat, disc-like cœnobium. The zoogonidia swarm in a vesicle which is protruded from the mother-cœnocyte and the new cœnobium is thus formed outside the old cœnocyte.

Genus **Pediastrum** Meyen, 1829. The cœnobium is always a free-floating, flat plate, disc-shaped or star-shaped, and consists of a single layer of small cœnocytes which is rarely duplicated in the centre. The cœnocytes are either parenchymatous and closely united, or there are perforations of variable size between them which give the cœnobium a sieve-like aspect. The marginal cœnocytes are of different form from those in the centre and they are generally furnished with a pair of diverging processes. There is a single chloroplast in each cœnocyte, containing one pyrenoid.

The number of cœnocytes in a cœnobium varies from 2 to 64, or even more. Cœnobia of two cœnocytes are very rarely observed, and possibly belong to the genus *Euastropsis*, but in one species (*P. tetras*) four is the regular number. The cœnocytes are often arranged in distinct rings round a central one, 8, 16, 32, or more being the number in the cœnobium. Nägeli[1] pointed out that the cœnobia were usually constructed as follows:—Colony of

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[1] Nägeli, Gatt. einzell. Alg. Zurich, 1849.

8 = 1 + 7; colony of 16 = 1 + 5 + 10; colony of 32 = 1 + 5 + 10 + 16; but this arrangement is not always observed.

Multiplication occurs in some species by the formation of autocolonies which arise by the division of the contents of a single cœnocyte. Hypnospores are also frequently formed (fig. 85 E *h*).

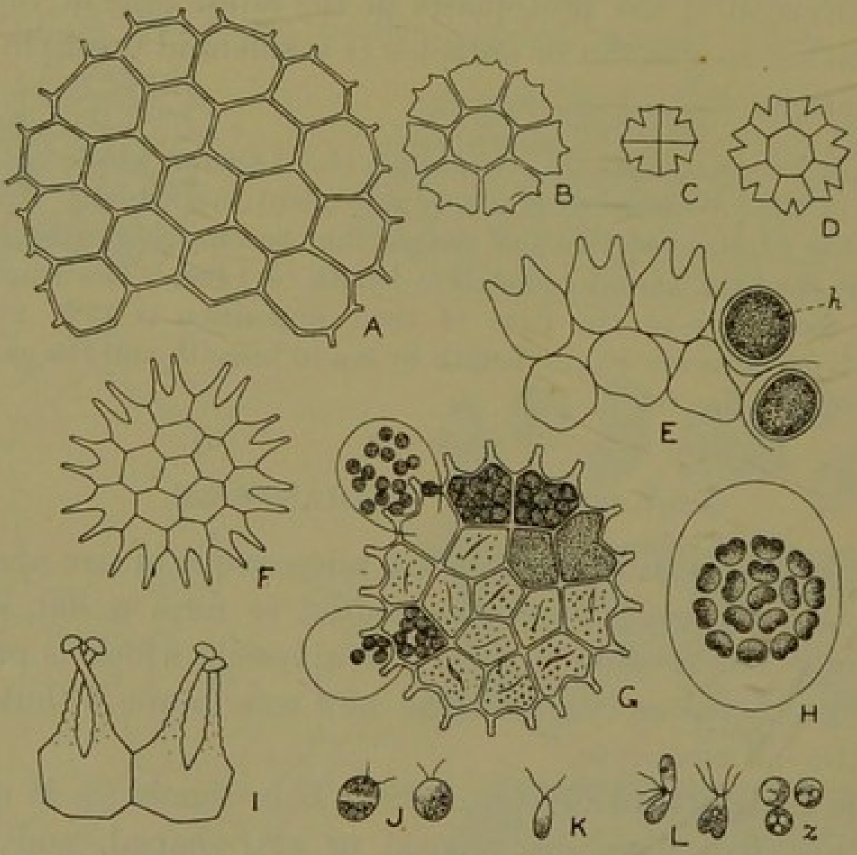

Fig. 85. A, *Pediastrum integrum* Näg., from Ben Lawers, Perthshire (× 475). B, *P. tricornutum* Borge, from Glen Tummel, Perthshire (× 475). C and D, *P. tetras* (Ehrenb.) Ralfs, from Pilmoor, N. Yorks. (× 475). E, *P. duplex* Meyen, from Lough Fea, Londonderry, Ireland; hypnospores (*h*) (× 475). F—H, *P. Boryanum* (Turp.) Menegh.; G, showing escape of zoogonidia; H, young colony formed by apposition of quiescent zoogonidia; F, from Frizinghall, W. Yorks., × 475; G and H, × 220 (after Kerner). I, two marginal cells of *P. glanduliferum* Benn., from Bisley Common, Surrey. J—L, zoogonidia and gametes of *P. Boryanum* (after Askenasy); J, zoogonidia and K, gamete (× 500); L, conjugation of gametes to form zygospores (*z*) (gametes × 730, zygospores × 220).

Reproduction takes place by the successive division of the contents of a cœnocyte to form a number of zoogonidia, which are suddenly liberated into an external vesicle through a slit in the wall of the mother-cœnocyte. The zoogonidia swarm in this vesicle and at length become quiescent, arranging themselves in one plane as a new cœnobium. Biciliated gametes have been observed by Askenasy[1], which are much smaller than the zoogonidia

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[1] Askenasy, 'Entwickl. von Pediastrum,' Ber. Deutsch. Bot. Gesellsch. vi, 1888.

and conjugate in pairs, the zygospore being polyhedral in form. A new cœnobium arises by the segmentation of the contents of this polyhedral body.

The species of this genus exhibit great variation in the characters both of their central and marginal cells, the length of the marginal processes, etc.; especially is this the case in cultures. Their natural habitat is in small ponds and ditches amongst other water-plants, and not uncommonly in quiet bog-pools. Sometimes they are numerous in the freshwater plankton.

The two most abundant species are *P. Boryanum* (Turp.) Menegh. (fig. 85 F—H and J—L) and *P. tetras* (Ehrenb.) Ralfs (fig. 85 C and D), the former sometimes reaching a relatively large size (200 μ in diameter). The marginal processes of *P. Boryanum* are extremely variable and the cell-walls are often granulated. *P. tetras* generally occurs in cœnobia of 4 (diam. 10·5—18 μ) or 8 (diam. 22—29 μ) cells. *P. duplex* Meyen 1829 (fig. 85 E) (= *P. pertusum* Kütz. 1845) is also a widely distributed species. *P. simplex* Meyen (= *P. clathratum* Lemm.) and *P. integrum* Näg. (fig. 85 A) are much rarer species. *P. Boryanum* and *P. duplex* are the most abundant species in the plankton.

Genus **Euastropsis** Lagerh., 1894[1]. In this genus the cœnobium is free-floating and consists of two flattened cells,

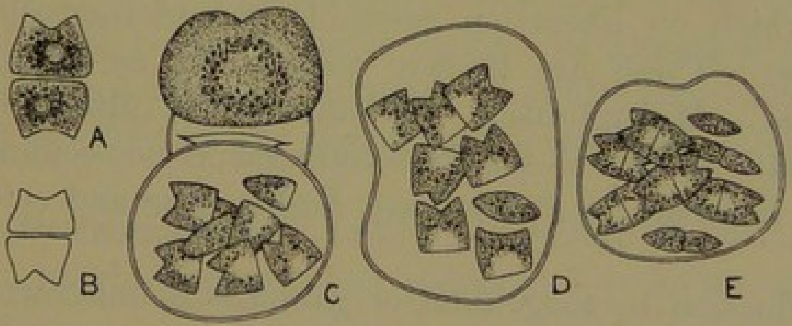

Fig. 86. *Euastropsis Richteri* (Schmidle) Lagerh. A and B, from near Senens, Cornwall (× 760). C—E, showing formation of young cœnobia (after Lagerheim; highly magnified).

which are closely applied along their straight inner margins, the outer margins being widely notched. The entire cœnobium has a certain resemblance to a minute species of the genus *Euastrum*, and was originally described as such[2]. There is a single parietal chloroplast in each cell containing one pyrenoid. Lagerheim describes the presence of one nucleus in each cell, but suggests that there may be more. Reproduction occurs by oval, biciliated

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[1] Lagerh. in Tromsö Museums Aarshefter 17, 1894, pp. 12—21, t. i, f. 8—27.
[2] Schmidle in Flora, 1894, p. 60, t. 7, f. 25.

zoogonidia which swarm in a vesicle as in *Pediastrum*. On becoming quiescent they arrange themselves in pairs and assume the form of the adult cells, each pair forming one cœnobium.

E. Richteri (Schmidle) Lagerh. is only known in the British Islands from Cornwall. Length of cœnobium 10—40 μ, breadth 6—25 μ (fig. 86).

Family 7. **PROTOCOCCACEÆ** (or **AUTOSPORACEÆ**).

The Algæ included in this family are free-floating, solitary or colonial, and are most commonly associated to form minute colonies of a definite construction. The cells are sometimes firmly united to form a definite cœnobium, as in *Cœlastrum* and *Sorastrum*, but as a rule the colonies easily dissociate into single cells or smaller groups (or families) of cells. With few exceptions there is very little mucus surrounding the colony. There is generally one chloroplast (sometimes many) in each cell, parietal or occupying the whole cell, and with or without a pyrenoid. There is one cell-nucleus.

Multiplication takes place by the successive division of the cell-contents either to form spore-like bodies which assume the characters of the mother-cell before being liberated, or to form colonies which on liberation resemble the mother-colony in all except size. These are known respectively as *autospores* and *autocolonies*. Multiplication by autospores, although such a characteristic feature of the Protococcaceæ, is not confined to this family, as it occurs in *Pediastrum*, *Radiococcus* and certain other genera.

Reproduction by zoogonidia or gametes is unknown except in the genus *Dictyosphærium*.

The Algæ of this family are well marked off from the Pleurococcaceæ and Palmellaceæ by their definite colonies and by their method of multiplication. They are little removed from the most primitive forms of green Algæ and a few of them are capable of profound modification by cultivation in different media. In their natural state, however, they exhibit a remarkable constancy of character and many of them are ubiquitous in all climates.

The family is best subdivided into the seven following groups:—

Sub-family I. *Cœlastreæ*. Cells primarily globose or broadly lunate, forming a definite spherical or polyhedral cœnobium.

Sub-family II. *Crucigenieæ*. Cells of variable form, arranged in a regular flat plate.

Sub-family III. *Selenastreæ.* Cells elongated, often greatly attenuated and frequently curved; solitary or associated in definite or loosely coherent colonies. One chloroplast in each cell.

Sub-family IV. *Oocystideæ.* Cells globose, ellipsoid, reniform or sometimes sublunate. Daughter-cells generally retained in the enlarged wall of the mother-cell. Several or many chloroplasts (rarely one) in each cell.

Sub-family V. *Tetraëdrieæ.* Cells solitary; flattened and angular, with a definite number of angles, or tetrahedral, octahedral or polyhedral. Angles generally furnished with simple or furcate spines.

Sub-family VI. *Phythelieæ.* Cells globose or ellipsoid, solitary or colonial, furnished with two or more long attenuated bristles.

Sub-family VII. *Dictyosphærieæ.* Cells globose, ellipsoid or ovoid, associated to form colonies, and joined more or less completely by the persistent old walls of the mother-cells, which sometimes become transformed into special connecting-threads.

Sub-family I. CŒLASTREÆ.

This is the only group of the Protococcaceæ in which there is a definite and regular cœnobium of spherical or polyhedral form. The cells are either globose or polygonal, with or without short projecting processes, by means of which they are united to form a hollow sphere; or they are broadly lunate and united at the centre of the spherical colony by short stalks. Multiplication is by the formation of an autocolony in each cell of the cœnobium, which is ultimately set free by the dissolution or splitting of the mother-cell-wall.

Genus **Cœlastrum** Näg., 1849. [*Hariotina* Dang., 1889.] The cœnobium, which is spherical or polyhedral, is hollow and is com-

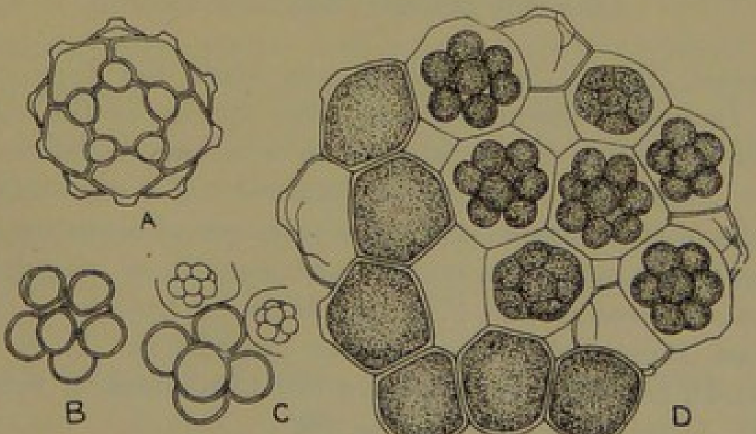

Fig. 87. A, *Cœlastrum cambricum* Archer, from Lough Gartan, Donegal, Ireland. B—D, *C. sphæricum* Näg.; B and C, small cœnobia from near Penzance, Cornwall; D, large cœnobia giving rise to daughter-cœnobia (autocolonies), from Bowness, Westmoreland. (All × 475.)

posed of a variable number of cells united by their lateral margins to form a single peripheral layer. In some species the cells are globose, in others more or less angular, and in others they are furnished with projecting processes by means of which they are joined together. The latter forms exhibit intercellular spaces of variable size and the cells are often furnished with a truncate projection (rarely two) on their free outer surfaces. The maximum number of cells observed in a single colony is 64, but in most species the number is 8, 16, or 32. Each cell contains a single chloroplast with one pyrenoid. The multiplication is by typical autocolonies, which are liberated by a split in the wall of the mother-cells or more rarely by the entire gelatinization of the mother-cell-walls. Single spores are sometimes developed from individual cells.

The two most frequent species are *C. sphæricum* Näg. (diam. cœnob. 18—92 μ; diam. cells 4—23 μ; fig. 87 B—D) and *C. cambricum* Arch. 1868 (=*C. pulchrum* Schmidle 1892); fig. 87 A. In the former species the cells are somewhat conical with a polygonal base, and in the latter species they are more or less distinctly lobed and furnished at the same time with a truncate surface projection. *C. cubicum* Näg., *C. microporum* Näg., *C. verrucosum* Reinsch and *C. proboscideum* Bohlin are species of considerable rarity.

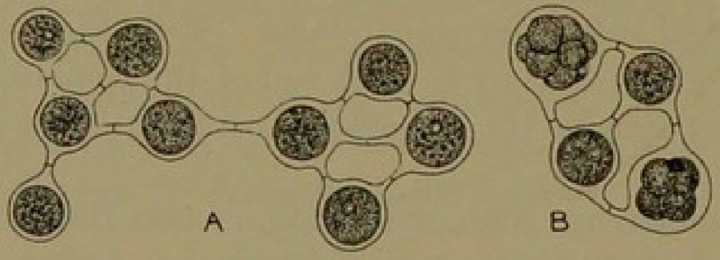

Fig. 88. *Cœlastrum reticulatum* (Dang.) Senn, a small irregular form from Churchill, Donegal, Ireland (× 475).

C. reticulatum (Dang.) Senn, which was made the type of the genus *Hariotina* by Dangeard, differs from all other species in the nature and disposition of the processes of the cells. The cœnobium consists of 4, 8, or 16 cells, and the young autocolonies are retained for a relatively long period within the walls of the mother-cells. The processes of attachment of the cells are narrow prolongations, often curved, and sometimes irregularly disposed. This plant has also been named *C. subpulchrum* by Lagerheim and *C. distans* by Turner, but Dangeard's name[1] takes precedence. It is known from Donegal, Ireland[2], and large colonies are not infrequent in the plankton of Lough Neagh. Diam. cells 6—24 μ; fig. 88.

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[1] Dangeard, 'Mémoire sur les Algues,' Le Botaniste, 1889; Chodat & Huber in Bull. Soc. Bot. France, tom. xli, 1894.

[2] West & G. S. West in Journ. Bot. March, 1903.

Genus **Sorastrum** Kütz., 1845. [*Selenosphærium* Cohn, 1879.] The cœnobium is globose, consisting commonly of 16 to 64 (rarely 4 or 8) stalked cells, the stalks uniting in the centre of the cœnobium to form a small faceted sphere. In small colonies the stalks of the cells are very short and the central sphere is not always apparent. The cells are broadly sublunate, reniform, or subtriangular in shape, and each extremity is furnished with two spines (rarely one) of moderate length. There is one chloroplast, containing a pyrenoid, in each cell. The multiplication is by the formation of autocolonies, but the details have not been worked out.

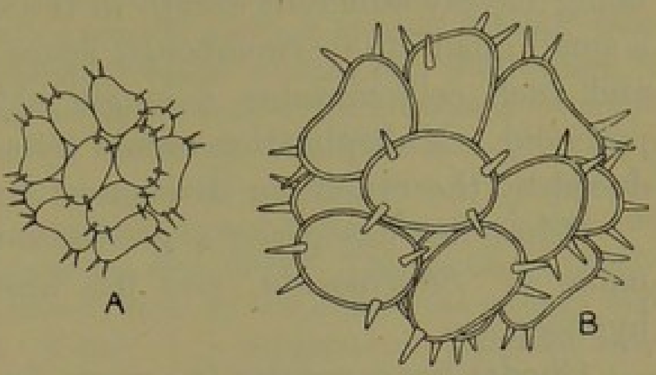

Fig. 89. *Sorastrum spinulosum* Näg., A, small cœnobium from Pilmoor, N. Yorks. (× 475); B, large cœnobium from Clifden, Galway, Ireland (× 450).

The British species usually met with is *S. spinulosum* Näg.; diam. of cœnobia 31—90 μ; length of cells without spines 11—26 μ; fig. 89. It is a scarce plant occurring in bog-pools or amongst aquatic Phanerogams in the quiet margins of lakes. *S. Americanum* (Bohlin) Schmidle occurs in the freshwater plankton of the Outer Hebrides.

Sub-family II. CRUCIGENIEÆ.

The cœnobia consist of few or many cells regularly arranged in the form of a flat plate. The cells are very variable in form, generally somewhat rounded, and occasionally furnished with spines. They are disposed in groups of four, the latter being held in position by a tough mucilage. In some the chloroplasts possess a single pyrenoid, but in others pyrenoids are absent.

The multiplication is by autocolonies, which in some cases are set free almost immediately, but in others remain for some time as part of the mother-colony.

Genus **Crucigenia** Morren, 1830. [*Staurogenia* Kütz., 1849; *Lemmermannia* Chodat, 1899; *Willea* Schmidle, 1900.] The cœnobium consists of 4, 8, 16, or 32 cells arranged as a flat plate and held in position by a mucilaginous envelope, but under favourable conditions of environment as many as 128 cells have been observed in one colony[1]. Even in the large colonies the cells are distinctly arranged in groups of four, the cells of each group being closely adherent except in the centre, where there is usually a small quadrate or rhomboidal space. The cell-walls are smooth, and each cell contains a single chloroplast with or without a pyrenoid. Multiplication occurs by autocolonies of four cells produced by the cruciform division of the contents of a mother-cell.

Schmidle[2] has given a good account of this genus under the name of '*Staurogenia*,' and has also described the formation of hypnospores.

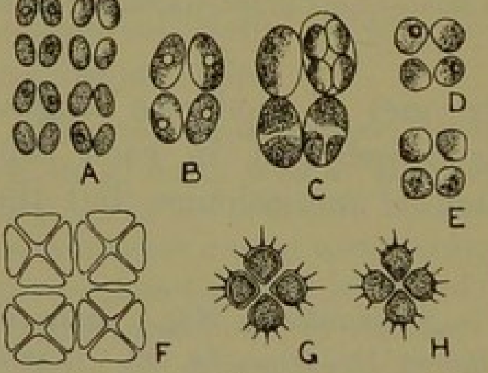

Fig. 90. A—C, *Crucigenia rectangularis* (Näg.) Gay, from Lough Shannacloontippen, Galway, Ireland; C, with formation of autospores. D and E, *C. quadrata* Morren, from Settle, W. Yorks. F, *C. Tetrapedia* (Kirchn.) W. & G. S. West, from plankton of L. Neagh, Ireland. G and H, *Tetrastrum Staurogeniæforme* (Schröd.) Chod., from near Rievaulx Abbey, N. Yorks. (All × 520.)

Chodat has separated the genus *Lemmermannia* from *Crucigenia* mainly owing to the absence of a pyrenoid from the chloroplast. For the present I prefer to regard the two as identical. There is no difference in the structure of the colonies and the mode of multiplication is precisely the same in each, the daughter-cells persistently remaining as parts of the mother-colony in several species of *Crucigenia* as well as in *Lemmermannia*. In all the specimens I have observed of *Crucigenia Tetrapedia*, which was the plant upon which Chodat founded the genus *Lemmermannia*[3], there was the same small gap in the centre of each group of four cells that is present in all other species of *Crucigenia*.

C. rectangularis (Näg.) Gay is the most frequent species of the genus; length of cells 5—9 μ; breadth 4—6 μ; fig. 90 A—C. *C. quadrata* Morren 1830 (=?*C. triangularis* Chod. 1900) is a much rarer species; diam. cells 5—5·5 μ; fig. 90 D and E. *C. Tetrapedia* (Kirchn.) W. & G. S. West[4] (=*Lemmermannia emarginata* Chod.) is known from the plankton of Lough

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[1] West & G. S. West in Ann. Bot. xii, 1898, p. 36.

[2] Schmidle in Berichte Deutsch. Bot. Gesellsch. 1900, Bd xviii, pp. 149—157.

[3] Under the heading of *Lemmermannia emarginata*, Chodat (in Beiträge zur Krypt.-fl. Schweiz, Bd I, Heft 3, 1902, p. 222) makes some irrelevant remarks concerning *Tetraëdron pentaëdrica* W. & G. S. West (which, for some reason, he seems to think was described as a *Tetrapedia*!) and *Tetrapedia morsa* W. & G. S. West, which clearly show that he is quite unacquainted with either the published descriptions or figures of the plants in question.

[4] West & G. S. West in Trans. Roy. Irish Acad. vol. xxxii, sect. B, part i, 1902, p. 62.

Neagh, Ireland; diam. cells 4·8—9·5 μ; diam. cœnob. of 4 cells 10·5—15·5 μ; fig. 90 F. All the species are regular constituents of the freshwater plankton.

C. irregularis Wille[1] is known from the plankton of several lochs in the Shetlands, and from Norway. It is a most interesting species, differing from *C. rectangularis* only in the somewhat irregular colonies and the absence of pyrenoids from all the cells of the colony. Some of the cells in a colony of *C. rectangularis* are often destitute of pyrenoids, and Wille was quite right in placing his Norwegian plant (*C. irregularis*) as a species of *Crucigenia*. Unfortunately, however, the useless generic name '*Willea*' has been put forward by Schmidle[2] to include *Crucigenia irregularis*. This genus is simply founded upon the absence of pyrenoids from all the cells of the colony; and Lemmermann[3] has since placed '*Willea*' as a subgenus of *Cohniella*, also owing to the absence of pyrenoids! Surely, in *Willea*, *Lemmermannia*, and Lemmermann's suggestion that *Willea* should be a subgenus of *Cohniella*, the climax of absurdity has been reached with regard to the presence or absence of pyrenoids as a generic distinction. No one who has been fortunate enough to observe colonies of *Crucigenia irregularis* could dispute their close affinity with forms of *C. rectangularis*. The former species has most likely had a direct origin from the latter.

Genus **Tetrastrum** Chodat, 1895. [*Cohniella* Schröder, 1897.] The cœnobium consists of four cells arranged in one plane and surrounded by a thin mucous envelope. The cells are rounded or somewhat angular, and they possess from two to five spines of variable length on their external margins. The multiplication is by the formation of autocolonies of four cells in each mother-cell. Pyrenoids may be present or absent. The genus only differs from *Crucigenia* in the presence of the marginal spines and in the regular 4-celled condition of the cœnobium.

The only two known species of the genus are *T. heteracanthum* (Nordst.) Chod. and *T. Staurogeniæforme* (Schröd.) Chod. The former is known from West Ireland and the latter (fig. 90 G and H; diam. of cells without spines 3—6 μ) occurs in North Yorkshire.

Sub-family III. SELENASTREÆ.

This group of the Protococcaceæ is characterized by the elongation of the cells, which are often very narrow with the extremities attenuated to fine points. They are frequently lunate or arcuate, and may be solitary or associated to form colonies of a more or less

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[1] Wille, 'Algologische Notizen IV,' Nyt Magazin for Naturvidenskb. Bd 38, Heft 1, 1900, p. 10, t. 1, f. 15.

[2] Schmidle, l. c. p. 157.

[3] Lemmermann in Berichte Deutsch. Bot. Gesellsch. 1904, Bd xxii, p. 22.

fragile character, the cells in some instances being held in position only by the enveloping mucus. There is a single chloroplast in each cell, which may contain one or several pyrenoids or may be destitute of them. In rare instances the chloroplast is fragmented. The cell-wall is firm but delicate.

Multiplication is principally by autospores and autocolonies, and this often takes place by the oblique division of the contents of the mother-cell.

The following genera of the Selenastreæ are British:—

A. Cells or colonies almost destitute of mucus.
  * Cells attenuated to acute apices; multiplication by oblique division of contents of mother-cell, the daughter-cells often remaining loosely attached by their apices .... *Dactylococcus.*
  ** Cells ellipsoid or much attenuated, forming more or less definite colonies consisting of a row of cells in one plane .... *Scenedesmus.*
  *** Cells sublunate or ellipsoid, arranged in groups of four in one plane, the groups being attached to form an irregular colony.......... *Dimorphococcus.*
  **** Cells elongate and acutely attenuated, often lunate, solitary or loosely grouped in irregular bundles.
    † Cells of moderate length, usually with not more than one pyrenoid .... *Ankistrodesmus.*
    †† Cells greatly elongated, pyrenoids numerous... *Closteriopsis.*
  ***** Cells ovoid, oblong, or club-shaped, often attached by their apices to form radiating colonies *Actinastrum.*
  ****** Cells attenuated, lunate, arranged back to back to form definite colonies .... *Selenastrum.*
B. Colonies enveloped in a copious mucus.
  Cells lunate or much curved, disposed more or less irregularly in the enveloping jelly .... *Kirchneriella.*

Genus **Dactylococcus** Näg., 1849. [Inclus. *Coccomyxa* Schmidle, 1901.] The cells are ellipsoidal, fusiform or pyriform, often sublunate and generally with acute apices, which are sometimes unequally prolonged into spine-like processes. They occur solitary or loosely connected by their acute extremities to form fragile colonies of few cells. The chloroplast is single and parietal, and sometimes contains a single pyrenoid; occasionally it becomes fragmented into two, three, or four parietal pieces. Some species are truly aquatic, but most of them occur on wet rocks and moist surfaces, forming a dark green mucous stratum. Multiplication is by the oblique longitudinal division of the contents of the mother-cell.

D. bicaudatus A. Br. is a lunate species with the apices greatly prolonged and its chloroplast is destitute of a pyrenoid; length of cells 13—39 μ; diam. of cells 2·5—5·8 μ; fig. 91 A. *D. dispar* W. & G. S. West is unequally developed at the extremities and the cells frequently become irregular; fig. 91 D. The Alga described as *D. Debaryanus* Reinsch, which often occurs in large numbers as an epiphyte on *Cyclops* and other small Crustacea, is a species of *Characium*.

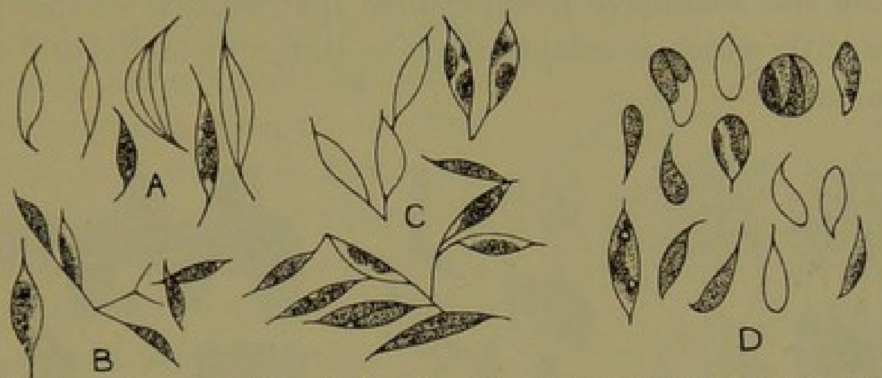

Fig. 91. A, *Dactylococcus bicaudatus* A. Br., from near Bradford, W. Yorks. B and C, *D. bicaudatus* var. *subramosus* W. & G. S. West, from Widdale Fell, N. Yorks. D, *D. dispar* W. & G. S. West, from Dorking, Surrey. (All × 520.)

There is little doubt that *D. infusionum* Näg. is merely a state in the life-history of *Scenedesmus obliquus* (Turp.) Kütz. It is usually aquatic and often occurs in immense quantity in the water of flower-pots and in aquaria. It exhibits great variability of form and its chloroplast commonly contains a pyrenoid; length of cells 7·5—19 μ, breadth 2·8—5·8 μ.

Genus **Scenedesmus** Meyen, 1829. In this genus there is a cœnobium of more or less definite form, consisting of a variable number of cells arranged either in a single row or in two alternating rows. The cells are generally disposed in one plane and in some species the terminal cells of the row differ considerably from the central cells. There is a wide range of variation in the form of the cells, which may be ellipsoid, oblong, or fusiform, and the extremities of all the cells of the cœnobium, or of the terminal cells only, may be furnished with one or more spines. In some the cells are longitudinally ridged and in others spines may be attached to the middle region of the cells. There is a large parietal chloroplast, often completely filling the cell, and generally containing a single pyrenoid. Multiplication takes place by the formation of autospores and autocolonies, and rarely by globular resting-spores. In cultures these plants have been said to pass into a palmelloid or glœocystiform condition.

Grintzesco[1] has shown that remarkable malformations of *Scenedesmus obliquus* can be produced by cultures in a nutritive medium of agar and glucose, and that this Alga possesses the physiological property of liquefying gelatine. He finds a *Dactylococcus*-stage equivalent to Nägeli's *D. infusionum*, and he attributes the extensive geographical distribution of this plant to the ease with which it adapts itself to different media and different temperatures.

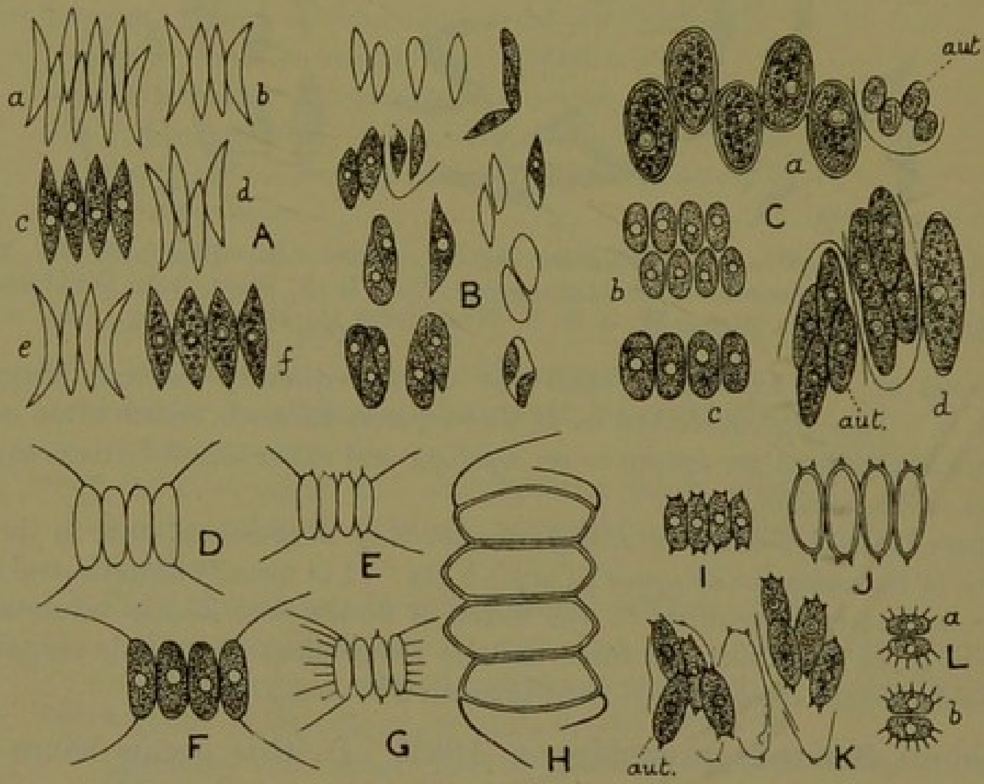

Fig. 92. A, *Scenedesmus obliquus* (Turp.) Kütz., from Bradford, W. Yorks. B, the state of *S. obliquus* known as *Dactylococcus infusionum* Näg., from Bowness, Westmoreland. C, *S. bijugatus* (Turp.) Kütz., from various localities. D—F, *S. quadricauda* (Turp.) Bréb., from Bradford, W. Yorks. G, *S. quadricauda* var. *horridus* Kirchn., from S.E. Surrey. H, *S. quadricauda* var. *maximus* W. & G. S. West, from Pilmoor, N. Yorks. I—K, *S. denticulatus* Lagerh. var. *linearis* Hansg.; I and J, from Westmoreland; K, from Mayo, Ireland. L, *S. spicatus* W. & G. S. West, from Saltburn, N. Yorks. (All × 520.) *aut*, autocolonies.

There are about 10 British species, of which *S. quadricauda* (Turp.) Bréb. (fig. 92 D—F), *S. bijugatus* (Turp.) Kütz. (=*S. obtusus* Meyen; fig. 92 C) and *S. obliquus* (Turp.) Kütz. (=*S. acutus* Meyen; fig. 92 A and B) are general and abundant. All three species vary much in size and also in general characters; they are regular constituents of the freshwater plankton, but occur most abundantly in stagnant water, especially in association with *Pediastrum Boryanum*, *Cœlastrum sphæricum*, etc. The cells of the largest forms of *S. quadricauda* reach a length of 30 μ and a breadth of 14 μ. *S. denticulatus*

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[1] Grintzesco, 'Recherch. Expériment. sur la Morph. et la Phys. de *Scenedesmus acutus*,' Bull. de l'Herb. Boissier, 2me. sér. 1902.

Lagerh. var. *linearis* Hansg. (fig. 92 I—K) is widely distributed, but rarely occurs in such abundance as the three preceding species. The cells of *S. costatus* Schmidle and *S. acutiformis* Schröder possess prominent longitudinal ridges. *S. Hystrix* Lagerh. and *S. granulatus* W. & G. S. West are very uncommon species remarkable for their external ornamentation.

Genus **Dimorphococcus** A. Br., 1849. The cells are arranged in composite colonies, each colony consisting of an irregular agglomeration of definite groups of four cells. The cells of each group are disposed obliquely in one plane and are of two kinds; the two central cells are ellipsoid or oblong and the two outer cells are sublunate. The groups of four are held in position by irregular portions of the old walls of the mother-cells. There is a large parietal chloroplast with one pyrenoid. Autocolonies of four cells are produced in each mother-cell; these remain attached to the parent-colony until the latter becomes too large, when it breaks up into several smaller colonies.

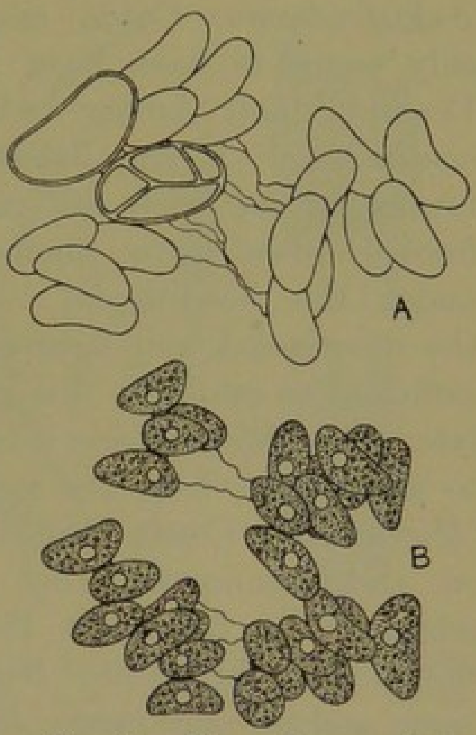

Fig. 93. *Dimorphococcus lunatus* A. Br.; A, from the plankton of Loch Mor Bharabhais, Lewis, Outer Hebrides; B, from Bowness, Westmoreland (× 520).

D. lunatus A. Br. is a rare plant in Britain[1]. It sometimes occurs in the plankton, but is met with more often in the small tarns of mountainous districts. The colonies are 57—86 μ in diameter and the cells 11—25 μ in length; fig. 93.

Genus **Ankistrodesmus** Corda, 1838; Ralfs, 1848; Archer, 1862. [*Rhaphidium* Kütz., 1845; *Schröderia* Lemmermann, 1898.] The cells are fusiform with acute apices, rarely obtuse, and they are generally many times longer than their diameter. They are straight, lunate, arcuate, or sigmoid, and although frequently solitary, are more often variously grouped in loose aggregates. In some forms the apices are greatly produced and almost bristle-like. The cell-wall is very thin and there is a single parietal chloroplast, usually occupying the greater part of the cell-cavity.

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[1] *Vide* West in Journ. Roy. Micr. Soc. 1892, p. 735, t. ix, f. 39; West & G. S. West in Trans. Roy. Irish Acad. xxxii, sect. B, part i, 1902, p. 66.

Pyrenoids are commonly absent, but one or two may occur in some forms. Multiplication takes place by means of autospores formed by the division of the contents of the mother-cell; they generally arise by oblique divisions, but may be produced by repeated transverse or longitudinal divisions.

There has never been any doubt concerning the identity of *Ankistrodesmus* Corda and *Rhaphidium* Kütz., but this fact only seems to have been acted upon by Ralfs in his 'British Desmids' and Archer[1] when he described his *Ankistrodesmus acutissimus.* I am indebted to Dr Nordstedt of Lund for furnishing me with full information concerning *Ankistrodesmus* from Corda's scarce memoir[2]. The remarks made by Corda under the heading of "*Ankistrodesmus* novum genus," and the description and figures he gives of *A. fusiformis*, are quite sufficient to establish this genus, and also to show that Kützing's later genus *Rhaphidium* is identical with it. Kuntze[3] endeavoured to prove that these two genera should be placed as synonyms of '*Micrasterias* Corda (1835)[4],' a genus which he tried to establish on the assumption that *Micrasterias* Ag. (1827) should be relegated to *Helierella* Bory (1826). Nordstedt[5] has clearly shown that the name '*Helierella*' cannot be used as a generic name, and in consequence *Micrasterias* Ag. (1827) is a valid genus. It follows from this that *Ankistrodesmus* Corda is the earliest generic name given to the common plants which Kützing named *Rhaphidium*, and as Corda's description and figures are also sufficiently characteristic, his name must be accepted for the genus.

The genus *Schröderia* was established by Lemmermann[6] in order to include an Alga which had previously been found by Schröder[7] and described by him as "*Reinschiella? setigera*." This Alga I have observed from North Yorkshire along with other plankton forms. The only distinction that can be drawn between *Schröderia* and *Ankistrodesmus* is the greater attenuation of the

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[1] Archer in Quart. Journ. Micr. Sci., n. s. vol. 2, 1862, pp. 255—261, t. xii (in part).

[2] Corda in Almanach de Carlsbad par J. de Carro, Prague, 1838, pp. 196—198.

[3] Kuntze Revis. Gen. Plant. II, 1891, pp. 904, 905.

[4] Corda in Almanach de Carlsbad, 1835, p. 206. Corda's only mention of *Micrasterias falcata* is in the description of the plates on p. 206; there is no text reference and the figures are on t. ii, f. 29.

[5] Nordstedt in Hedwigia, 1893, Heft 3, pp. 149—151.

[6] Lemmermann in Hedwigia, 1898, Bd xxxvii, p. 311.

[7] Schröder, 'Ueber das Plankton der Oder,' Berichte Deutsch. Bot. Gesellsch. 1897, Bd xv.

apices of the former, and I do not regard this as a sufficient generic difference. "*Reinschiella? setigera*" must be considered as an *Ankistrodesmus* having the same relationship to other species of the genus as *Dactylococcus bicaudatus* has to other species of *Dactylococcus*.

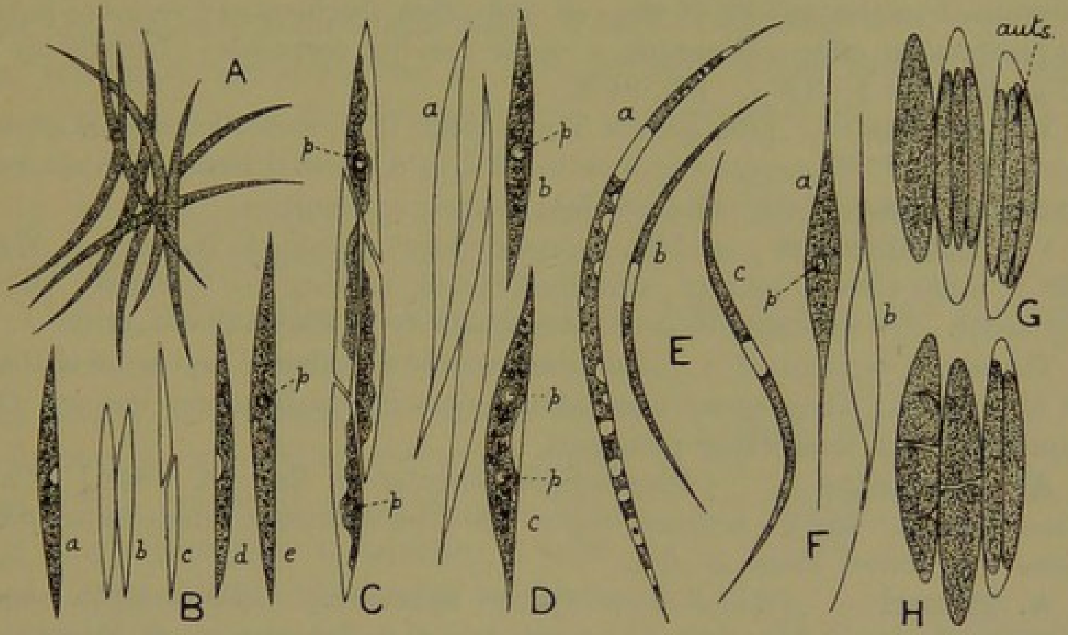

Fig. 94. A, *Ankistrodesmus falcatus* (Corda) Ralfs, from Bowness, Westmoreland. B and C, *A. falcatus* var. *acicularis* (A. Br.); B, from Pilmoor, N. Yorks.; C, from the plankton of Loch M. Bharabhais, Lewis, Outer Hebrides. D, *A. falcatus* var. *tumidus* nob., from Puttenham Common, Surrey. E, *A. falcatus* var. *mirabilis* nob., from Wimbledon Common, Surrey. F, *A. setigerus* (Schröd.) nob., from near Rievaulx Abbey, N. Yorks. G and H, *A. Pfitzeri* (Schröd.) nob., from the plankton of Loch M. Bharabhais, Lewis. (All × 520.) *auts*, autospores.

As plants of this genus are often very abundant and the synonymy is much confused, the following synopsis will be found useful:—

A. falcatus (Corda) Ralfs. [*Micrasterias falcata* Corda 1835; *Ankistrodesmus fusiformis* Corda 1838 (in part); *Rhaphidium fasciculatum* Kütz. 1845; *Rh. polymorphum* Fresen. var. *falcatum* Rabenh.] Cells lunate or arcuate, 16—24 times longer than the diameter (1·5—3 μ), with the apices acute; associated in loose aggregates or close bundles, rarely solitary. Chloroplast usually devoid of a pyrenoid. Fig. 94 A.

Var. **acicularis** —. [*Rhaphidium aciculare* A. Br. 1849; *Rh. polymorphum* var. *aciculare* Rabenh.; *Closterium subtile* Bréb.; *Ankistrodesmus acutissimus* Arch. 1862.] Cells usually solitary, commonly straight or slightly curved, with acutely attenuated apices. Length 36—65 μ; breadth 2·5—3·5 μ. Chloroplast sometimes furnished with one pyrenoid (or more). Fig. 94 B and C. It is most probable that *Rh. pyrogenum* Chod. belongs here.

Var. **duplex** —. [*Rhaphidium duplex* Kütz. 1845.] Cells elongate, sigmoid, associated end to end in pairs. *Rh. nivale* Chod. may possibly be a form of this variety.

Var. **tumidus** —. [*Rh. polymorphum* var. *tumidum* W. & G. S. West 1897.] Cells solitary or in small aggregates, curved, in the middle inflated; apices most acute; length 61—73 μ; breadth 4·5—6·5 μ. Chloroplast with one or two pyrenoids, or destitute of them. Fig. 94 D.

Var. **mirabilis** —. [*Rh. polymorphum* var. *mirabile* W. & G. S. West 1897.] Cells solitary and considerably longer than in typical *A. falcatus*, variously curved, often sigmoid; apices very acute. Chloroplast completely interrupted in the middle of the cell and often fragmented; vacuoles in the cell-protoplasm often containing a single moving corpuscle. Length up to 117 μ; breadth 2—3·5 μ. Fig. 94 E.

Var. **spiralis** —. [*Rh. spirale* Turn. 1893; *Rh. fasciculatum* var. *spirale* Chod. 1902.] Cells grouped in bundles of 4 or 8, twisted round each other in the central region of the cells, but free at their extremities.

Var. **spirilliformis** —. [*Rh. polymorphum* var. *spirale* W. & G. S. West 1898.] Cells always solitary, spirally twisted, making 1—1½ turns; apices very acute. Often occurs in prodigious quantity in stagnant water.

The above varieties of *A. falcatus* are widely distributed and some of them are abundant. They occur most abundantly in small ponds, but are also frequent in the freshwater plankton.

A. convolutus —. [*Rhaphidium convolutum* Rabenh. 1868.] Cells solitary, short, only 3—6 times longer than the diameter, lunate or arcuate; apices very acute; diam. 3—6 μ.

A. Pfitzeri —. [*Rhaphidium Pfitzeri* Schröder.] Cells straight, somewhat asymmetrical, 5½—6 times longer than the diameter, much attenuated with rounded apices; forming small colonies embedded in mucilage. Length 38—49 μ; breadth 7—8 μ. In the Scottish plankton; not uncommon. Fig. 94 G and H. Perhaps this species would be better placed as a form of *A. biplex* (Reinsch) nob. [=*Rh. biplex* Reinsch 1867.]

A. setigerus —. [*Reinschiella? setigera* Schröder 1897; *Schröderia setigera* Lemm. 1898; *Rhaphidium setigerum* W. & G. S. West 1901.] Cells fusiform, with the apices much attenuated into fine hair-like prolongations. Chloroplast with one pyrenoid. Diam. 5·7—6·5 μ; length 75—88 μ. Mostly found in the plankton. Fig. 94 F.

Genus **Closteriopsis** Lemm., 1898[1]. This genus only differs from *Ankistrodesmus* in the great length of the cells and in the consequent increase in the number of pyrenoids. The cells are narrow, greatly elongated, and the extremities are much attenuated into bristle-like points. The chloroplast contains a dozen or more pyrenoids in an axial series.

Cl. longissima Lemm. is only known from the plankton. In the British Islands it has been found in Lough Neagh, Ireland, from Finstown, Orkneys, and in Loch Asta, Shetlands. Length 330 μ; breadth 3·8—4·2 μ.

Genus **Actinastrum** Lagerh., 1882. The cells are ovoid, oblong or club-shaped, from three to six times longer than their

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[1] Lemmermann in Forschungsberichten Biol. Stat. Plön. vii, 1898, p. 29.

diameter, and are generally attached by their apices to form radiating colonies of small size. Each cell possesses a parietal chloroplast furnished with a pyrenoid. Multiplication takes place by the longitudinal division of the cell-contents, with the occasional formation of another transverse wall. The products of division diverge outwards, but remain attached by their proximal ends, and the colonies sometimes reach a relatively large size owing to the repeated new divisions of the contents of the radiating cells. As a general rule four young cells (autospores) are produced in each mother-cell.

A. Hantzschii Lagerh. is a very rare Alga in Britain and is confined principally to the plankton. Length of cells 10—24 μ; breadth 3—6 μ.

Genus **Selenastrum** Reinsch, 1867. In this genus the cells are arcuate or lunate, attenuated to fine points, and arranged back to back to form a 4- or 8-celled colony of small size. The cell-wall is thin and firm, and the chloroplast is without a pyrenoid. The multiplication is by autospores which arise as in *Ankistrodesmus* and *Kirchneriella*.

The species of this genus are very uncommon, usually occurring amongst other water-plants at the margins of ponds and lakes. *S. Bibraianum* Reinsch, *S. gracile* Reinsch (fig. 95 A—D) and *S. acuminatum* Lagerh. (fig. 95 E—G) all occur in Britain. Chodat considers the latter species to be a *Scenedesmus*, but that I cannot agree with.

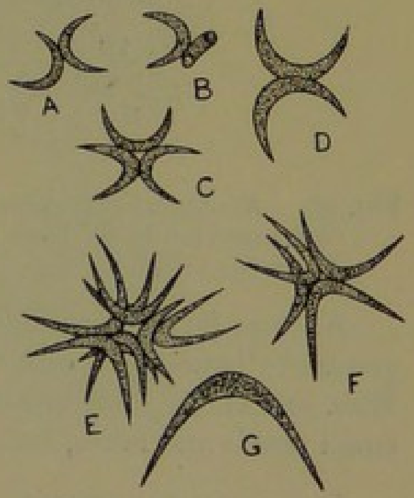

Fig. 95. A—D, *Selenastrum gracile* Reinsch; A—C, from near Settle, W. Yorks.; D, from Puttenham Common, Surrey. E—G, *S. acuminatum* Lagerh., from Bowness, Westmoreland. (All × 520.)

Genus **Kirchneriella** Schmidle, 1893. [Inclus. *Selenoderma* Bohlin, 1897.] The cells are arcuate or crescent-shaped, attenuated or subcylindrical, often bent until the apices almost touch each other; they are loosely aggregated, without any definite disposition, within a large enveloping mass of jelly. The cell-wall is very thin and the chloroplast is parietal, being situated on the convex wall of the cell. There is one pyrenoid, but it is frequently absent. The multiplication is by autospores, four or eight of which are produced in a mother-cell by oblique or more or less transverse divisions. The genus differs from *Selenastrum* in the loosely aggregated colonies of cells, which are irregularly disposed, and in the large enveloping mass of jelly.

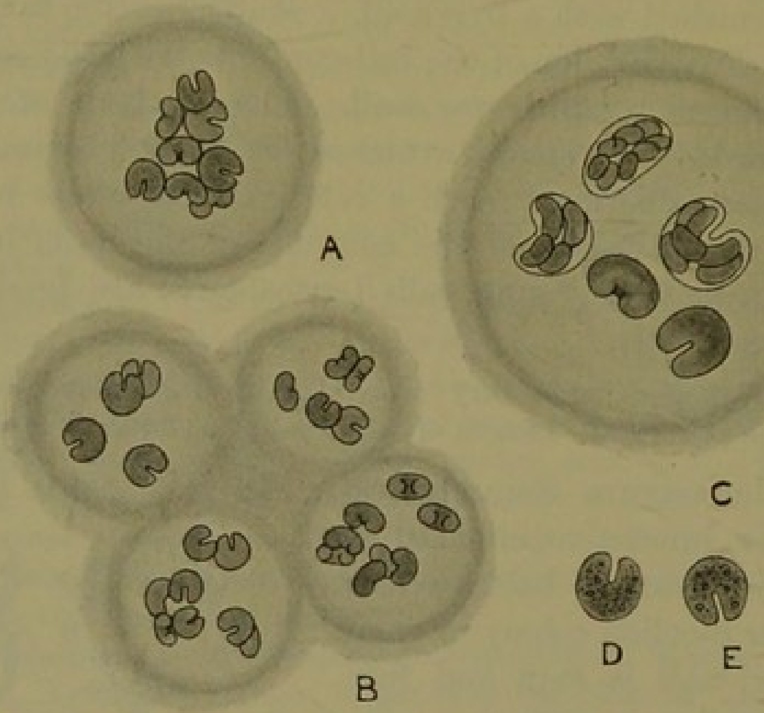

Fig. 96. *Kirchneriella obesa* (West) Schmidle. A, B, D and E, from Bowness, Westmoreland; C, from the plankton of Loch Mor Bharabhais, Lewis, Outer Hebrides (× 485).

K. obesa (West) Schmidle (breadth of cells 2—9·5 μ; apices 1·5—4 μ apart; greatest diameter of cell 6—16 μ; fig. 96 A—E) and *K. lunaris* (Kirchn.) Möb. are widely distributed in the British Islands, occurring sparingly in the small ponds and lakes, but in quantity in the plankton of the larger lakes.

Sub-family IV. OOCYSTIDEÆ.

This sub-family is characterized by the globose or ellipsoid cells (curved or even sublunate in *Nephrocytium*), which are frequently retained within the swollen wall of the old mother-cell. There may be one or many chloroplasts in each cell, which are parietal and usually contain one pyrenoid. In all except *Palmellococcus* the cell-walls are firm and somewhat thick. The multiplication is by autospores, which generally grow and attain their full size whilst still forming part of the mother-colony.

The following are the British genera:—

* Cells ellipsoid	*Oocystis.*
** Cells curved, subcylindrical or sublunate	*Nephrocytium.*
*** Cells spherical.	
† Cells large, solitary and free-floating	*Eremosphæra.*
†† Cells minute, forming a thin stratum	*Palmellococcus.*
††† Cells minute, sparsely scattered and symbiotic	*Chlorella.*

Genus **Oocystis** Näg., 1845. The cells are ellipsoid, subcylindrical or panduriform, with a firm cell-wall which commonly possesses a nodular thickening at each pole. There are usually several parietal chloroplasts in each cell, destitute of pyrenoids. In some cases, however, there may be one pyrenoid in each chloroplast. Multiplication is by autospores, which are generally retained for some time within the greatly swollen wall of the mother-cell. Sometimes several generations are contained within one large mother-cell-wall.

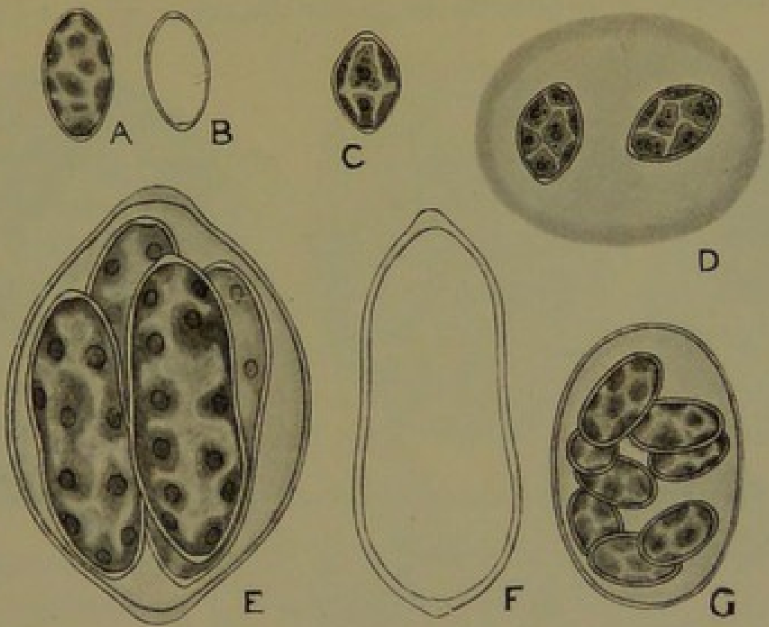

Fig. 97. A and B, *Oocystis solitaria* Wittr., from Ben Lawers, Perthshire. C and D, *O. crassa* Wittr.; C, from Lanlivery Moor, Cornwall; D, plankton form from Lough Beg, Ireland. E and F, *O. panduriformis* W. & G. S. West; E, from Pilmoor, N. Yorks.; F, from near Clifden, Ireland. G, *O. elliptica* West, from Derryclare Lough, Galway, Ireland. (All × 485.)

There are about ten British species of the genus, some of which are widely distributed in the quiet waters of ponds and lakes. *O. solitaria* Wittr. (length of cells 15—48 μ; breadth 9·5—25 μ; fig. 97 A and B) is undoubtedly the commonest species, although *O. elliptica* West (fig. 97 G) is abundant. *O. parva* West & G. S. West (length 6—12 μ; breadth 4—7 μ) is the smallest species and *O. gigas* Arch. (length 41—50·5 μ; breadth 32·5—40 μ) is the largest. *O. crassa* Wittr. is not common except in the plankton; fig. 97 C and D. *O. asymmetrica* W. & G. S. West is another solitary species.

Chodat states that *O. gigas* Arch. and *O. panduriformis* W. & G. S. West (fig. 97 E and F) are merely stages in the life-history of *Eremosphæra*, but this statement I do not accept. These plants often occur in localities from which *Eremosphæra* is absent and they reproduce themselves in the manner of true species of *Oocystis*. Moreover, I invariably find the life-history of *Eremosphæra* to be remarkably free from polymorphic forms (*vide* page 229).

Genus **Nephrocytium** Näg., 1849. The cells are oblong, ellipsoid or subcylindrical, slightly curved or sublunate, sometimes almost reniform. There is at first a large expanded chloroplast in each cell, furnished with a single pyrenoid, but later the chloroplast fragments. The multiplication is by autospores similar to those of *Oocystis,* and formed within the mother-cell soon after the segmentation of the chloroplast. The young autospores are often spirally disposed round the inside of the mother-cell-wall. The genus is distinguished from *Oocystis* primarily by its curved cells without any trace of apical thickenings.

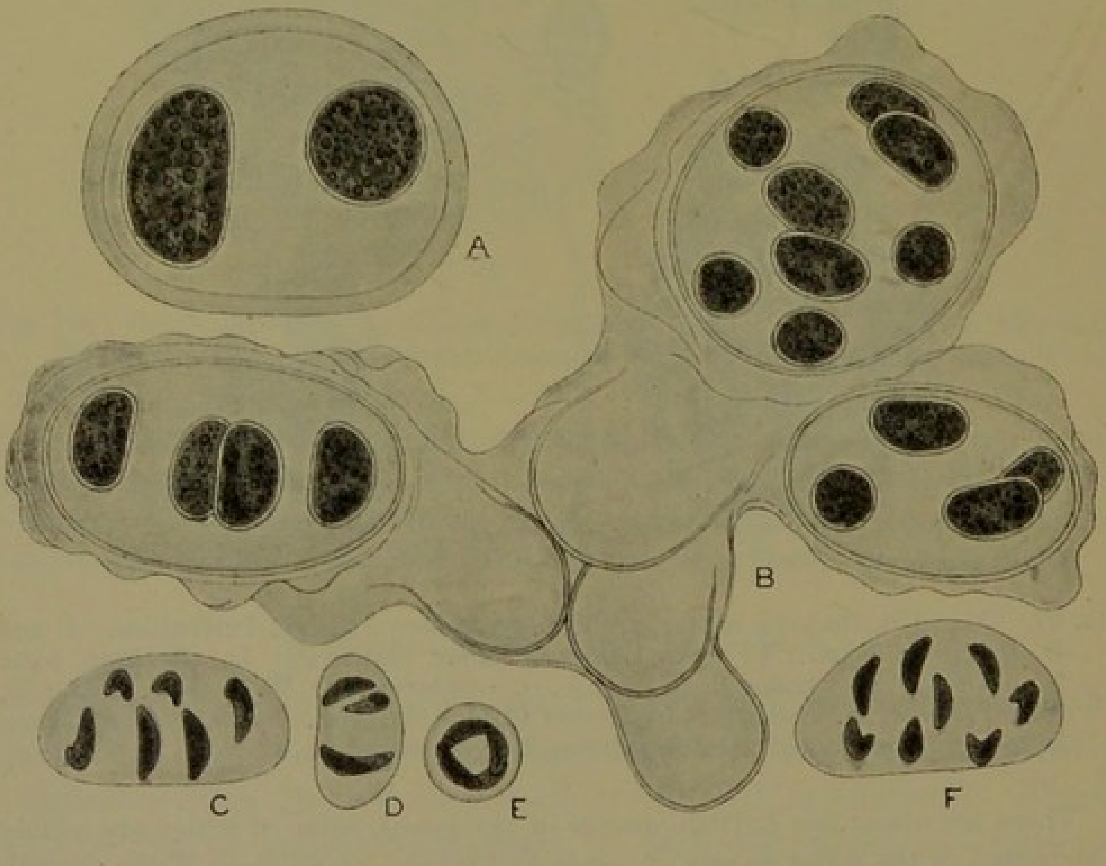

Fig. 98. A, *Nephrocytium obesum* West, from Angle Tarn, Cumberland. B, *N. ecdysiscepanum* West & G. S. West, from near Goring, Oxfordshire. C—F, *N. lunatum* West; C—E, from near Bowness, Westmoreland; F, from near Roundstone, Galway, Ireland. (All × 367.)

N. Agardhianum Näg. (inclus. *N. Nägelii* Grun.) is a widely distributed species in the stagnant waters of small pools and lakes; length of cells 12—22 μ; breadth 7—12 μ. *N. obesum* West is the largest species, characterized by the short, stout cells and by the great thickness of the mother-cell-walls; length of cells 34—42 μ; breadth 24—28 μ; fig. 98 A. *N. lunatum* West is a characteristic species (supposed by Chodat to be a stage of *N. Agardhianum*) which is very local, but sometimes abundant among submerged Sphagnum; length of cells 14—18 μ; breadth 4—6·5 μ; fig. 98 C—F. *N. ecdysiscepanum*

W. & G. S. West is a curious species in which the mother-cell-walls throw off a number of integuments, several generations being disposed in a fan-shaped manner and held in position by the partly exuviated layers of the mother-cell-walls; length of cells 24—26·5 μ; breadth 13—17 μ; fig. 98 B.

Genus **Eremosphæra** De Bary, 1858. [*Chlorosphæra* Henfrey, 1859.] The cells are solitary, large, and spherical, with a thick, firm cell-wall distinctly differentiated into two layers. Each cell contains a large number of small parietal chloroplasts furnished with a conical projection directed towards the centre of the cell. There is one pyrenoid in each chloroplast. The nucleus is generally contained in a small mass of protoplasm suspended in the central region of the cell by a network of protoplasmic threads. Multiplication takes place by the division of the contents of a mother-cell into two or four smaller but similar daughter-cells (autospores), which are set free by the rupture of the mother-cell-wall. Chodat[1] has described the occurrence of certain polymorphic forms of this Alga, but although I have examined large quantities of it from every part of the British Islands, and from elsewhere, I have never yet seen any trace of such forms. Specimens kept under cultivation for two years developed no forms other than globular daughter-cells. Moore[2] also disputes the alleged polymorphism of this Alga.

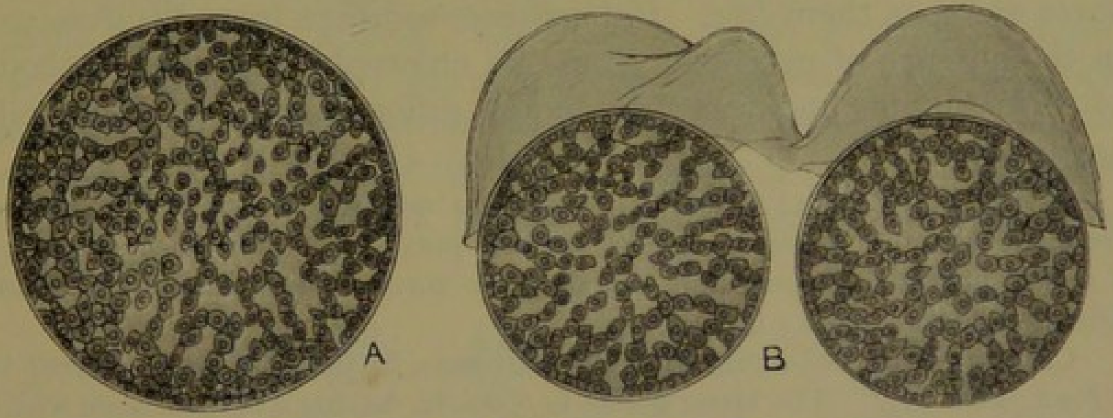

Fig. 99. *Eremosphæra viridis* De Bary, from near Clapham, W. Yorks. (× 175).

E. viridis De Bary is widely distributed all over the British Islands, more especially in Sphagnum-bogs. It is a constant associate of certain Desmids. The cells vary from 55—200 μ in diameter; fig. 99.

Genus **Palmellococcus** Chodat, 1894. [?*Protococcus* Ag. 1824 (in part).] The cells are more or less globular, with a firm cell-wall, and aggregated to form a thin mucous stratum. There is in

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[1] Chodat in Botan. Zeitung, liii, 1895, t. v.

[2] Moore in Proc. Amer. Assoc. Adv. Sci. 1900, pp. 278, 279.

each cell a parietal plate-like chloroplast devoid of a pyrenoid, which is often hidden by an orange-red oil. There are three methods of multiplication; 1st, by division of the original mother-cell into two or four daughter-cells; 2nd, by a rejuvenescence of the cell-contents and an exuviation of the wall of the mother-cell; 3rd, by the formation of 8, 16, 32, or 64 spores within the wall of the mother-cell, which then ruptures and sets them free. *Palmellococcus* differs from *Pleurococcus* in the absence of pyrenoids from the chloroplasts, in the methods of reproduction, and therefore in the different aspect of the cell-aggregates.

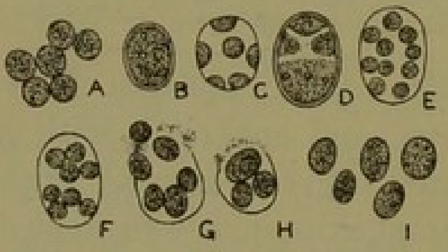

Fig. 100. *Palmellococcus miniatus* (Kütz.) Chodat, from near Bradford, W. Yorks. (× 720).

P. miniatus (Kütz.) Chod.[1] (*Pleurococcus miniatus* Näg.) is not an infrequent Alga on the outer surfaces of plant-pots and similar objects, forming a moist, brownish-green scum, which often turns to an orange-red colour. Diam. cells 2—12·5 μ; fig. 100.

Certain plants belonging to this genus have in the past been referred to "*Protococcus* Ag." The latter genus is obsolete, having included Algæ which are now referred to a number of other genera.

Genus **Chlorella** Beyerinck, 1890[2]. The cells are small, globular or ellipsoid, with firm cell-walls, and with a single parietal chloroplast containing a pyrenoid. They occur in abundance in symbiotic relationship with *Hydra viridis*, species of *Amœba*, *Paramœcium*, *Ophrydium*, etc. Multiplication takes place by the quadripartition of the cell contents. Radais[3] has confirmed Beyerinck's observations that this Alga has the faculty of cell-increase and the formation of chlorophyll in the dark as in the light. Grintzesco[4] also affirms that development takes place more rapidly in total darkness than in full daylight. The latter author has cultivated *Chlorella* in various media and finds that glucose stimulates its development and that peptone is a better source of nitrogen than nitrates. Cultures of this Alga do not liquefy gelatine.

Chl. vulgaris Beyr. is widely distributed and often abundant in cultures or in stagnant aquaria. The cells are 5—10 μ in diameter.

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[1] Chodat in Bull. Herb. Boissier, tom. ii, 1894, pp. 429 and 599.

[2] Beyerinck in Botan. Zeitung, xlviii, 1890.

[3] Radais in Comptes Rendus, cxxx, 1900, p. 793.

[4] J. Grintzesco in Rev. Gén. Bot. xv, 1903.

Sub-family V. TETRAËDRIEÆ.

The plants of this sub-family are always solitary unicells. Each cell is flattened and angular, usually with a definite number of angles, or it is tetrahedral, octahedral, or polyhedral. The angles may be rounded, emarginate, or furnished with spines.

Genus **Tetraëdron** Kütz., 1845. [*Polyedrium* Näg., 1849.] The cells of this genus, which occur as solitary individuals or rarely collected into temporary aggregates, are flattened and angular (triangular, quadrangular, or polygonal) or polyhedric. The angles are obtuse, acuminate, or furnished with one or more simple or furcate spines. There is a single large chloroplast, parietally disposed and containing one pyrenoid. Multiplication takes place by the formation of four or eight autospores, which are set free by the rupture of the wall of the mother-cell. Sometimes they are expelled into a delicate vesicle, which, however, soon disappears.

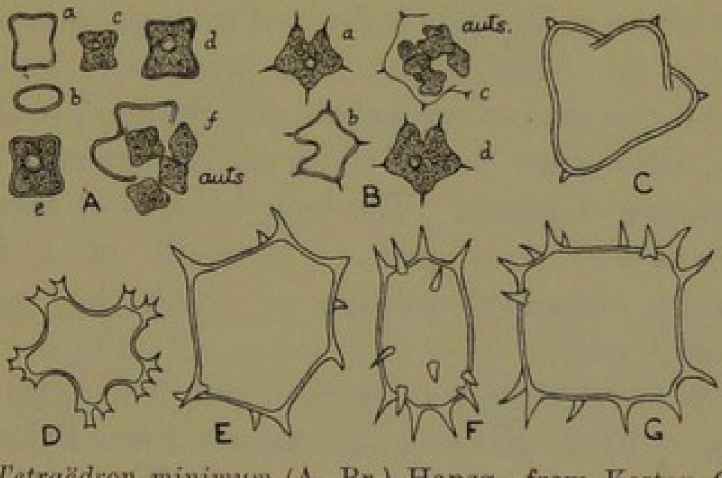

Fig. 101. A, *Tetraëdron minimum* (A. Br.) Hansg., from Keston Common, Kent. B, *T. caudatum* (Corda) Hansg., from Pilmoor, N. Yorks. C, *T. regulare* Kütz., from near Bowness, Westmoreland. D, *T. enorme* (Ralfs) Hansg., from Mickle Fell, N. Yorks. E—G, *T. horridum* W. & G. S. West, from Putney Heath, Surrey. (All × 450.) *auts*, autospores.

There are about 14 species of the genus known to occur in the British Islands. *T. minimum* (A. Br.) Hansg. is the most abundant of the flattened species; diam. of cells 6·5—16 μ; thickness of cells 5—7 μ; fig. 101 A. *T. regulare* Kütz. (= *Polyedrium tetraëdricum* Näg.) is the commonest of the polyhedric species; diam. of cells 13·5—40 μ; fig. 101 C. *T. enorme* (Ralfs) Hansg. was originally described as a Desmid; fig. 101 D.

The genus **Cerasterias** Reinsch (1867) is sometimes separated from *Tetraëdron* owing to the depth of the lobulation. The cells are solitary, tetrahedric in character, and the divisions into lobes are so deep that there is no central body. *C. rhaphidioides* Reinsch and *C. longispina* (Perty) W. & G. S. West are both plants of rare occurrence.

Sub-family VI. PHYTHELIEÆ.

This is one of the most interesting sub-families of the Protococcaceæ, and the Algæ contained in it have only recently been brought to light, largely by the plankton investigations of Lemmermann and Chodat. The plants are unicellular or sometimes grouped so as to form a more or less definite cœnobium, and in all cases they float freely in the water. As a rule the cells are almost devoid of a mucous envelope, and they are furnished with several stiff bristles considerably longer than their own diameter. Multiplication occurs typically by the formation of autospores, which usually attain all the characters of the adult before their liberation from the swollen wall of the mother-cell. Zoogonidia have been observed in *Golenkinia*.

The name of the sub-family is derived from the genus *Phythelios* Frenzel (1891), an Alga which was originally described as a Heliozoan. All the genera are practically confined to the plankton of large lakes, although a few of them are occasionally observed in the surface waters of ponds. The long bristles of these Algæ are protective characters developed as a result of a free-floating existence amidst numerous animals to which they would otherwise be an easy prey.

The genera have been well worked out and monographed by Lemmermann[1]. Four of them are known from Britain.

A. Cells globular.	
* Cells solitary with evenly distributed bristles	*Golenkinia.*
** Cells in colonies of 8, 16, or more, bristles attached to the outer faces only	*Richteriella.*
B. Cells ellipsoid or subcylindrical.	
* Bristles with a basal swelling	*Lagerheimia.*
** Bristles without a basal swelling	*Chodatella.*

Genus **Golenkinia** Chodat, 1894. The cells are globular, usually solitary, with a firm cellulose wall, which is enveloped in a thin layer of mucilage. Each cell is furnished with a number of radiating bristles of considerable length, evenly disposed over the

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[1] Lemmermann in Hedwigia, Bd xxxvii, 1898.

outer surface of the cell. There is a parietal chloroplast containing one pyrenoid. Multiplication normally takes place by autospores, but also by simple vegetative division, and reproduction by quadriciliate zoogonidia has been observed by Chodat.

G. radiata Chodat[1] is known from Surrey; diam. of cells 10—15 μ; length of bristles 25—45 μ; fig. 102 D and E. *G. paucispinosa* West & G. S. West[2] is known from the plankton of Lough Neagh, Ireland; diam. of cells 15—16 μ; length of bristles 16 μ; fig. 102 F.

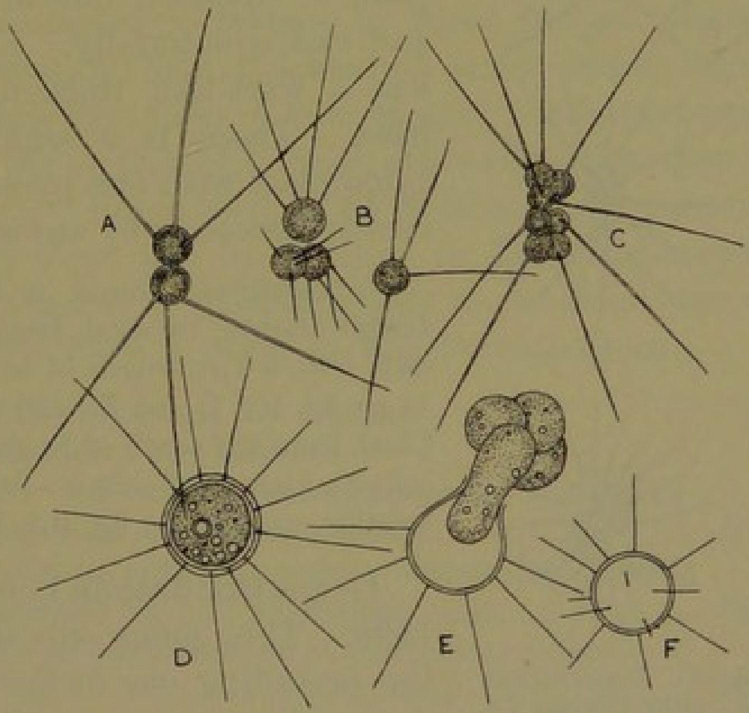

Fig. 102. A, *Richteriella botryoides* (Schm.) Lemm., after Lemmermann, × 520. B and C, *R. botryoides* forma *quadriseta* (Lemm.) Chod.; B, from the plankton of Lough Beg, Ireland (× 450); C, after Lemmermann (× 520). D and E, *Golenkinia radiata* Chod., after Chodat (× about 800). F, *Golenkinia paucispinosa* W. & G. S. West, from the plankton of Lough Neagh, Ireland (× 450).

Genus **Richteriella** Lemmermann, 1896. The cells are spherical and generally aggregated to form loose cœnobia of 8, 16, 32, or 64 cells. The cell-wall is thin and firm, and is furnished with long, radiating bristles attached only to those surfaces of the cells which face outwards. There is a single parietal chloroplast with one pyrenoid. Multiplication has only been observed to take place by vegetative division. This genus only differs from *Golenkinia* in the aggregation of the cells and the fact that the bristles are more or less confined to the exposed surface of each cell.

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[1] Chodat in Morot, Journ. de Bot., Paris, 1894, p. 305, t. iii.

[2] West & G. S. West in Trans. Roy. Irish Acad. xxxii, sect. B, part i, 1902, p. 68, t. i, f. 18.

R. botryoides (Schmidle) Lemm., forma *quadriseta* (Lemm.) Chod. is known from the plankton of Lough Beg, Londonderry, Ireland; diam. of cells 3—9·6 μ; length of bristles 23—60 μ; fig. 102 B and C.

Genus **Lagerheimia** Chodat, 1895. The cells are solitary, ellipsoid, or subcylindrical with rounded extremities, and with a firm cell-wall. There are four bristles arranged in diverging pairs at each pole, or disposed one at each pole and two equatorially. Each bristle has a wart-like thickening at its base. There is a single parietal chloroplast with one pyrenoid. The multiplication is by autospores.

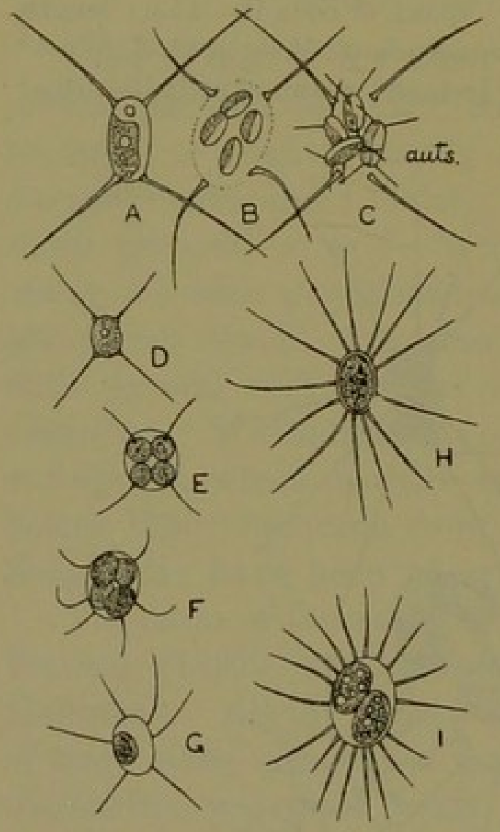

Fig. 103. A—C, *Lagerheimia genevensis* Chod., after Chodat (× about 850). D and E, *L. subglobosa* Lemm.; D, after Lemmermann (×520); E, from Lough Gartan, Donegal, Ireland (×450). F and G, *Chodatella breviseta* W. & G. S. West, from Lough Gartan, Ireland (×450). H and I, *Ch. ciliata* (Lagerh.) Lemm. var. *amphitricha* (Lagerh.) Chod. (×450); H, from Skipwith Common, E. Yorks.; I, from near Bowness, Westmoreland. *auts*, autospores.

L. subglobosa Lemm. is known from Lough Gartan, Donegal, Ireland (diam. of cells 5·5—9·4 μ; length of bristles 10·5—13 μ; fig. 103 D and E), and *L. genevensis* Chod. from the south of England (diam. of cells 3 μ; length of cells 9—10 μ; length of bristles up to 16 μ; fig. 103 A—C).

Genus **Chodatella** Lemmermann, 1898. This genus only differs from the preceding one in the absence of the swellings or wart-like thickenings at the base of the bristles. The cells are solitary, ellipsoid, and furnished with four or many elongated bristles, which are sometimes radiating and sometimes curved. There may be one or several parietal chloroplasts, with or without pyrenoids. The genus differs from *Oocystis* in the absence of the polar thickenings and the presence of the long spine-like bristles.

Ch. ciliata (Lagerh.) Lemm. var. *amphitricha* (Lagerh.) Chod. [=*Ch. radians* (West) Lemm.] occurs in several localities in the British Islands; length of cells 8—18 μ; breadth 4—13·5 μ; length of bristles 12—20 μ; fig. 103 H and I. *Ch. breviseta* West & G. S. West is known from Lough Gartan, Donegal, Ireland; length of cells 12—12·5 μ; breadth 8—9·5 μ; length of bristles 11·5—17·5 μ; fig. 103 F and G.

Sub-family VII. DICTYOSPHÆRIEÆ.

This sub-family contains a few genera the affinities of which are somewhat doubtful. The cells are globose, ovoid, or ellipsoid, and are associated to form more or less indefinite colonies. The colony is often of a fragile nature, the cells being held in position by the persistent old walls of the mother-cells, which sometimes become transformed into definite connecting-threads. A copious mucous investment is present in some, but in others it may be entirely absent. The multiplication is by simple vegetative division or by the formation of four daughter-cells (autospores) within the wall of the mother-cell, which gradually splits open and permits their escape. Reproduction by biciliated zoogonidia has been observed by Zopf and by Massee[1] in *Dictyosphærium.*

The sub-family is most probably an artificial one and perhaps it should not have a place in the Protococcaceæ.

The five following genera are British :—

A. Cells indefinitely disposed.
- * With well-marked, subdichotomous connecting-threads; chloroplast parietal........................ *Dictyosphærium.*
- ** Cells in radiating series; connecting threads scarcely visible; chloroplast axile.................. *Dictyocystis.*

B. Cells grouped in fours in one plane; colonies irregular .... *Tetracoccus.*

C. Cells in botryoidal clusters.
- * Freely exposed in a thin gelatinous envelope ...... *Botryococcus.*
- ** Clusters covered by a firm, irregular, tough membrane .... *Ineffigiata.*

Genus **Dictyosphærium** Näg., 1849. The cells are globose, ovoid, or subreniform in shape, with a firm cell-wall, and they are connected by dichotomously branched threads to form a roughly spherical or ellipsoidal colony. The entire colony is enveloped in mucus, and the cells are situated somewhat far apart towards its periphery, large colonies often becoming very irregular. Each cell contains a more or less bell-shaped, parietal chloroplast,

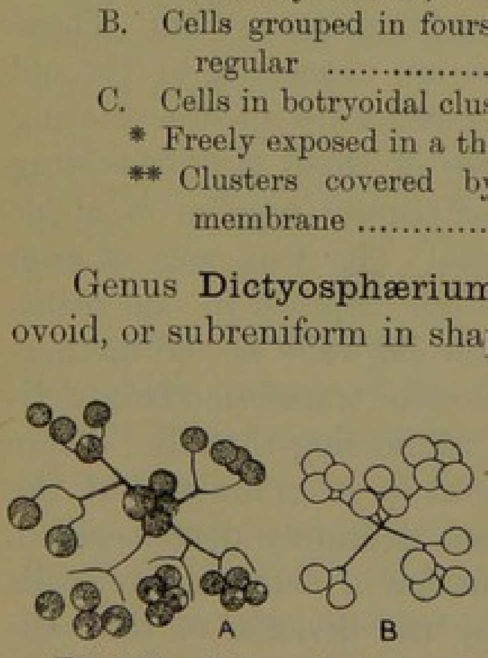

Fig. 104. *Dictyosphærium pulchellum* Wood. A, from the plankton of Loch Shin, Sutherland; B, from Cam Fell, W. Yorks. × 450.

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[1] G. Massee in Journ. Linn. Soc. Bot. xxvii, 1891.

furnished with a single pyrenoid. The connecting-threads are often derived from the old mother-cell-walls, but in some cases it is doubtful if they do arise in this manner. Multiplication takes place normally by the formation of four daughter-cells within the mother-cell. Reproduction by biciliated zoogonidia occurs, but has been very rarely observed.

D. Ehrenbergianum Näg. is a widely distributed British Alga, often occurring in quantity in the surface waters of ponds and in the plankton of lakes; diam. of cells 4—10 μ. *D. pulchellum* Wood (fig. 104), *D. reniforme* Buln. and *D. oviforme* Lagerh. are more rarely found, but it is probable that the five so-called species of this genus are merely forms of *D. Ehrenbergianum*.

Genus **Dictyocystis** Lagerh., 1890[1]. The cells are ellipsoid or oblong, and are arranged in radiating series to form a small free-floating colony. The radiating series of cells frequently branch and the cells are held in place by delicate mucous threads. Each cell possesses a central chloroplast with one pyrenoid.

D. Hitchcockii (Wolle) Lagerh. is a rare British Alga, occurring in the bogs of N. Ireland and N. W. Scotland, and also in the Scottish plankton. Diam. of cells 9—11 μ; the American specimens are larger.

Genus **Tetracoccus** West, 1892[2]. [*Westella* De Wild., 1897 (in part).] The cells are small, globose or subglobose, sometimes a little angular, and are closely arranged in groups of four. These groups are connected by the old mother-cell-walls into free-floating colonies of small size, consisting of a maximum number of about 80 cells. The four cells of each group are disposed in one plane, and the old walls of the mother-cells become transformed into delicate connecting-threads. There is one chloroplast which contains several large granules, but the presence of pyrenoids has not yet been definitely demonstrated. Multiplication takes place by the formation of four daughter-cells within the mother-cell, which arise by the division of the cell-contents in two directions in one plane. The colonies are almost entirely free from enveloping mucus.

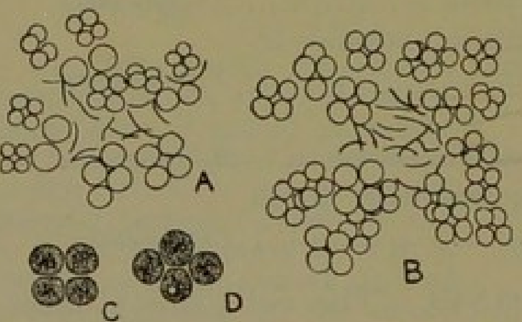

Fig. 105. *Tetracoccus botryoides* West, from Bowness, Westmoreland. A and B, ×450; B and C, two "tetrads," ×715.

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[1] Lagerheim in Nuovo Notarisia, 1890, p. 226.

[2] West in Journ. Roy. Micr. Soc. 1892, p. 735, t. x, f. 43—48.

Schmidle[1] gave what he termed an 'amended description' of this genus in 1894, but as the plant he included in it is not a species of *Tetracoccus*, his amended description is not a correct one[2].

T. botryoides West is widely distributed in the British Islands, generally occurring in the surface waters of ponds and in the plankton of large lakes. Diam. of cells 3·8—5·7 μ; diam. of colonies 30—57 μ; fig. 105.

Genus **Botryococcus** Kütz., 1849. The colony is free-floating and consists of an aggregate of botryoidal groups of cells. The cells are globose or ovoid in form and are closely aggregated to form clusters of 16 or 32 cells, the clusters being held together partly by old mother-cell-walls and partly by a gelatinous investment. There is a single cup-shaped chloroplast in each cell, but pyrenoids have not been observed. Chodat and Cretier[3] have observed in the chloroplast a small body which can be regarded as a pyrenoid without an amylosphere. As a rule this Alga is of a bright green colour, but when occurring in large quantity, as it frequently does in the freshwater plankton, the cells become filled with a brick-red oil.

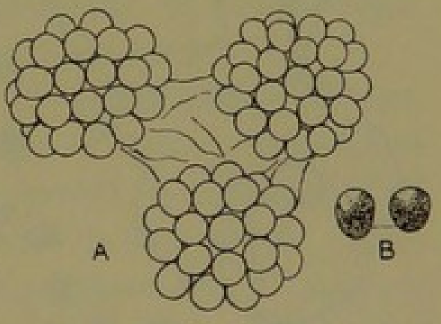

Fig. 106. *Botryococcus Braunii* Kütz., from the New Forest, Hants. A, small colony; B, two isolated cells (× 450).

B. Braunii Kütz. is the best known representative of the genus, and is a frequent plant in bog-pools, large ponds, lakes, etc. Diam. of cells 5·5—9 μ; fig. 106. *B. sudeticus* Lemm. (which may only be a form of *B. Braunii* with globose cells) and *B. calcareus* West are rarer British species.

Genus **Ineffigiata** West & G. S. West, 1897; em. 1903. This Alga consists of free-floating colonies of very irregular form and destitute of a gelatinous investment. The colony is composed of several families of cells agglutinated together, each family being small, more or less spherical, and consisting of a peripheral layer of cells surrounding a central cavity. The cells are ellipsoid or ovoid in form, and each one is furnished with a parietal chloroplast, often containing what has been described as a single small

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[1] Schmidle in Flora, 1894, Heft 1, p. 45.

[2] *Vide* West & G. S. West in Journ. Roy. Micr. Soc. 1896, p. 162.

[3] Chodat & Cretier in Arch. Sci. Phys. et Nat. x, 1900.

pyrenoid, but which I am inclined to believe is a small granule of starch. In some cells starch appears to be quite absent. The outer surface of each family of cells is enveloped in a tough elastic membrane of irregular form, which contains a trace of cellulose, and is folded and produced into all manner of irregular wrinkles, lobes, processes and spines. Sometimes these irregular projections are wanting, but at other times they are exceedingly numerous. The membrane is a secretion of the underlying cells, and its presence renders observations on this Alga more difficult than on any other of the Protococcaceæ. Sometimes the smaller colonies are united by more or less rigid prolongations of the enveloping membranes into much larger colonies.

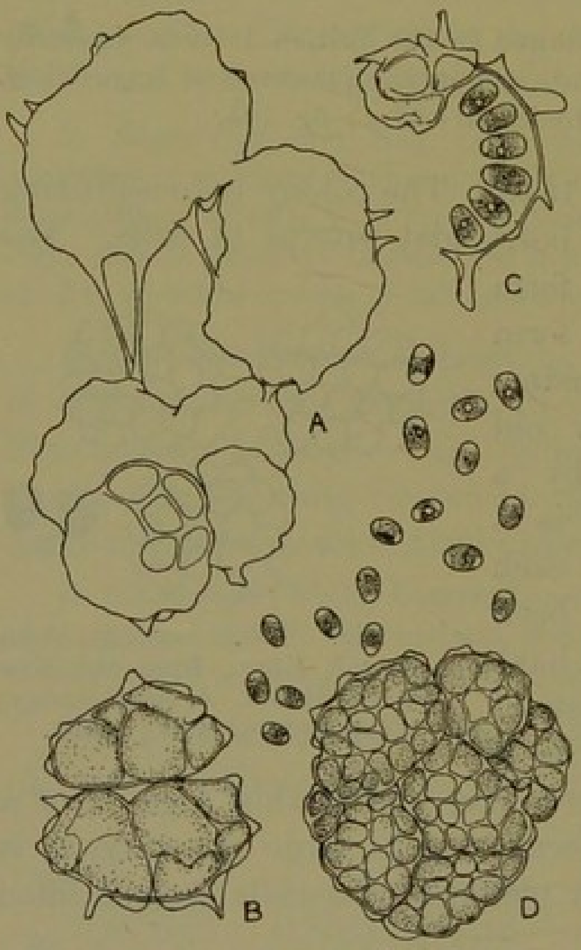

Fig. 107. *Ineffigiata neglecta* W. & G. S. West, from Harris, Outer Hebrides. A, outline of colony; B, smaller colony; C, part of single family in section; D, showing escape of cells from a small colony.

The families multiply by division, forming larger and larger colonies, which ultimately become separated into smaller groups by the development of elongated processes of the enveloping membranes. The reproduction is unknown[1].

In situations in which *Ineffigiata* occurs in quantity, such as in the freshwater plankton, the cells develop the brick-red oily material which is found in the preceding genus.

I. neglecta W. & G. S. West is one of the most widely distributed of British Algæ, occurring in all kinds of situations—in ditches, bogs, tanks, water-butts, etc.—and forming a regular and considerable constituent of the freshwater plankton. Diam. of single families 21—56 μ, of colonies 46—350 μ; length of cells 5·7—10·5 μ, breadth 3·4—5·3 μ; fig. 107.

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[1] *Vide* Journ. Bot. March, 1903, t. 447, f. 1—6.

Family 8. PALMELLACEÆ.

The Palmellaceæ is one of the most primitive families of green Algæ, primarily distinguished from the other groups of the Protococcoideæ by the indefinite colonies of cells enveloped in a conspicuous mass of mucilage. In the ordinary vegetative condition these plants present the appearance of a group of more or less irregularly disposed cells embedded in a copious mass of jelly, which is either structureless or differentiated into concentric envelopes. The colonies are either microscopic or macroscopic, and sometimes reach a length of several centimetres.

The cells are globose or ellipsoid, of small size, and are frequently arranged in pairs or in groups of four. Sometimes these groups of four or 'tetrads' are disposed in a tetrahedral manner, but at other times they are situated in one plane. Each cell contains a somewhat bell-shaped chloroplast which may or may not be furnished with a pyrenoid. The nucleus is situated in the hollow of the chloroplast. In some genera (e.g. *Tetraspora* and *Apiocystis*) each cell is furnished with a pair of 'pseudocilia,' which consist of long motionless protoplasmic threads penetrating through the enveloping mucus to the exterior. These were first discovered by Thuret.

Multiplication takes place by cell-division in two or three directions, followed sooner or later by a diffluence of a large part of the enveloping mucus and the consequent dismemberment of the colony into smaller portions, each of which increases as before either by simple cell-fission or by the formation of two or four daughter-cells within each mother-cell.

Asexual reproduction takes place by biciliated zoogonidia. The latter are formed either by the transformation of a vegetative cell into a zoogonidangium in which several zoogonidia arise, or by the assumption by the ordinary vegetative cell of the motile Chlamydomonadine condition. The motile state greatly resembles the Chlamydomonad-type, and these plants have no doubt arisen by the intercalation of a simple though well-marked vegetative condition between two successive motile phases.

Sexual reproduction has been observed in some of the Palmellaceæ. It consists of a fusion of isogamous planogametes, either similar in all respects to the zoogonidia and produced singly in a gametangium, or much smaller than the zoogonidia and produced in numbers from a gametangium.

In some of these plants the colony has no definite form, but in others the cells, although irregularly grouped, are contained in a mucous mass which invariably assumes a definite shape.

The family can be divided into three sub-families, in each of which the mucus may be indefinite or developed in accordance with some definite plan.

Sub-family I. *Palmelleæ.* Cells irregularly grouped within a structureless mass of mucus.

Sub-family II. *Tetrasporeæ.* Cells grouped in fours or sometimes irregularly disposed at the periphery of a structureless mass of mucus. Each cell with two pseudocilia.

Sub-family III. *Glœocystideæ.* Cells grouped in twos or fours within a lamellose mucous investment.

Sub-family I. PALMELLEÆ.

This sub-family is characterised by the large number of globose cells which are irregularly grouped within a structureless mass of mucus. The latter is usually of indefinite extent, but in *Palmodactylon* it is more or less cylindrical and often much branched. The cell-walls are generally firm and thin, and in *Schizochlamys* the outer layers are periodically thrown off in one or several pieces.

Genus **Palmella** Lyngb., 1819. The cells are spherical, with thin cell-walls, and they are surrounded by mucous coats which have fused to form an indefinite mass of jelly. The parietal chloroplast contains a pyrenoid. Multiplication takes place by repeated bipartitions of the cells in all directions of space, accompanied by an extreme gelatinization of the mother-cell-walls. Reproduction occurs by macrozoogonidia, by microzoogonidia, and by small isogamous planogametes.

One of the few true species of this genus is *P. miniata* Leibl., which occurs as a mucous expansion of a brick-red colour on damp ground, wet rocks, etc.; diam. of cells 3—5 μ. *P. mucosa* Kütz. and *P. hyalina* Bréb. are aquatic species of a green colour; the former may possibly be a state of *Tetraspora.*

Genus **Palmodactylon** Näg., 1849. This is a well-marked genus of the Palmelleæ, differing from *Palmella* mainly in the definite form of the enveloping jelly. The chloroplast is parietal and irregularly lobed, but is destitute of a pyrenoid. Multiplication of the cells takes place in all directions, but preponderates in one direction, so that the cells are grouped irregularly within a cylindrical mass of mucus. This cylindrical mucous envelope frequently branches, each branch being similar to the primary mucous cylinder.

P. varium Näg. (inclus. *P. subramosum* Näg.) is a common British Alga in peaty ditches and in bog-pools. Diam. of cells 6·5—9·5 μ; diam. of cylindr. mucous investment 11·5—33 μ; fig. 108.

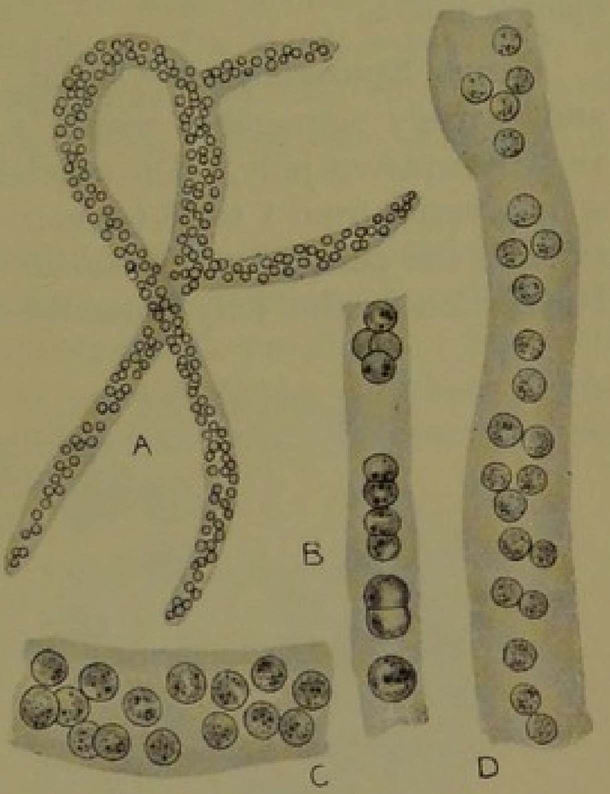

Fig. 108. *Palmodactylon varium* Näg., A—C, from Esher Common, Surrey; D, from Strensall Common, N. Yorks. A, × 100; B—D, × 450.

Genus **Schizochlamys** A. Br., 1849. The cells are globular or slightly ellipsoid, with a firm cell-wall of some thickness, and they are irregularly disposed within an indefinite jelly. The chloroplast contains no pyrenoid. The outer portion of the cell-wall commonly becomes ruptured, being cast off either in one piece or in four distinct pieces, which are held in a position somewhat remote from the cell by the intervening jelly. It is the formation of this large quantity of gelatinous material that causes the rupture of the firmer part of the cell-wall. Multiplication occurs by division into two or four daughter-cells, usually subsequent to the rupture of the outer layer of the cell-wall.

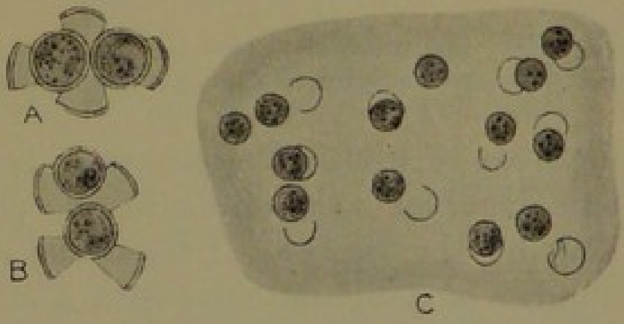

Fig. 109. A—B, *Schizochlamys gelatinosa* A. Br., from Loughrigg, Westmoreland. C, *Sch. delicatula* West, from near Bowness, Westmoreland (× 450).

S. gelatinosa A. Br., in which the outer layer splits in four pieces, occurs in ditches, ponds, etc.; diam. of cells 9·5—15 μ; fig. 109 A and B. *S. delicatula* West is also a frequent species, in which the outer layer is thrown off in one piece; diam. of cells 5·8—6·7 μ; fig. 109 C. *S. gelatinosa* usually occurs in very extensive gelatinous masses, often several cms. in diameter, whereas the colonies of *S. delicatula* are very much smaller, rarely exceeding a diameter of 300 μ. The latter species has also a distinct preference for Sphagnum-pools.

Genus **Sphærocystis** Chodat, 1897[1]. The cells are globose and sparsely aggregated within a free-floating globular mass of very transparent jelly. The number of cells within each gelatinous sphere varies from 1 to 16 (or more), and they are usually disposed towards the periphery. Sometimes there is a slight indication of lamellation in the jelly immediately surrounding the cells. The methods of multiplication are:—1st, by division of the cells into four daughter-cells, either in one plane or tetrahedrally disposed; 2nd, by the rupture of the walls of a sporangium containing a number of daughter-cells, with a slight retention of the old walls of the mother-cells as in *Schizochlamys*; 3rd, by the formation of biciliated macro- and microzoogonidia. This genus very closely resembles *Glœocystis* Näg.

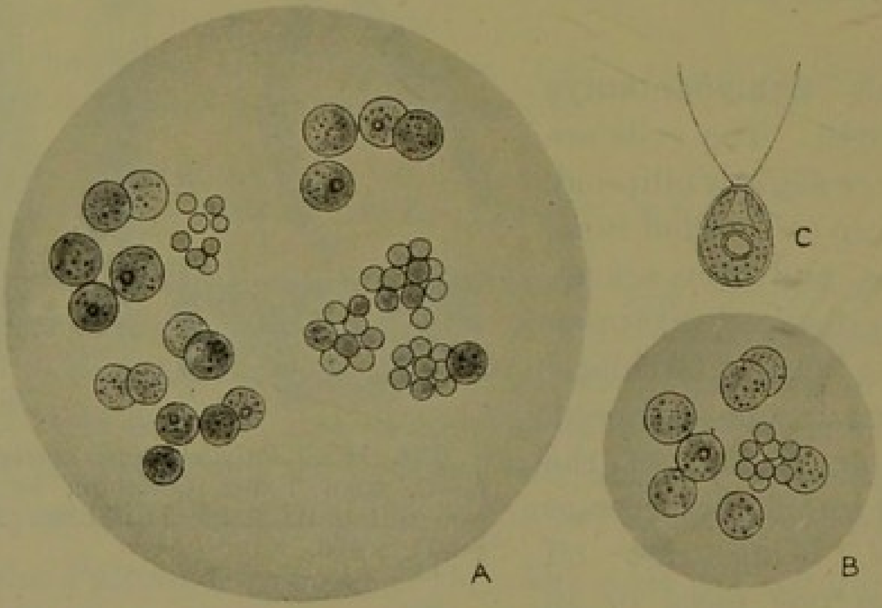

Fig. 110. *Sphærocystis Schroeteri* Chod.; A and B, from the plankton of Loch Shin, Sutherland, ×450; C, zoogonidium, after Chodat (×about 700).

Sph. Schroeteri Chod. is an abundant Alga in the freshwater plankton, occurring in all the larger lakes of the British Islands; diam. of colonies 50—1200 μ; diam. of cells 6—10 μ; fig. 110. Chodat regards both *Tetraspora lacustris* Lemm. and *Botryococcus sudeticus* Lemm. as stages of this plant. With regard to the former he is possibly correct, but the latter is a close relative of *Botryococcus Braunii* and certainly has no affinity with *Sphærocystis*.

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[1] Chodat in Bull. Herb. Boissier, 1897, p. 292, t. ix.

Sub-family II. TETRASPOREÆ.

The cells are usually grouped in fours, or more rarely irregularly disposed, towards the periphery of a structureless mass of jelly. The sub-family is distinguished from the Palmelleæ and the Glœocystideæ by the 'pseudocilia' which are attached in pairs to each cell.

Genus **Tetraspora** Link, 1809. [Inclus. *Stapfia* Chodat, 1897.] The colonies are gelatinous, macroscopic or microscopic, indefinitely expanded or more or less intestiniform and convoluted. The cells are spherical, distributed without order near the periphery of the enveloping jelly or grouped in twos and fours. In structure the cells are similar to those of *Palmella*, with the addition of two (or more rarely four) 'pseudocilia.' Multiplication takes place by repeated division of the cells, chiefly in two directions in one plane, with the gelatinization of the mother-cell-walls. Reproduction occurs by biciliated zoogonidia and isogamous planogametes. Hypnospores, with thick cell-walls of a brown colour, are also produced.

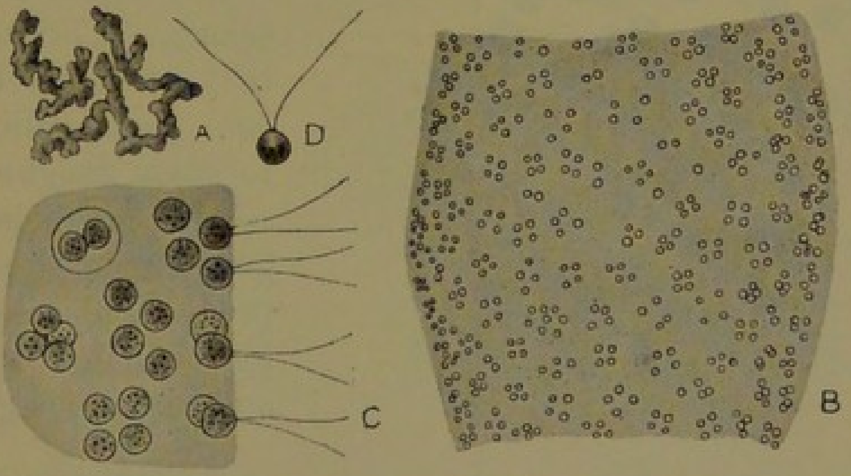

Fig. 111. *Tetraspora lubrica* (Roth) Ag., from near St Just, Cornwall. A, nat. size; B, portion of colony, ×100; C, ×450; D, zoogonidium, ×450.

Several 'species' of this genus occur in the stagnant waters of the British Islands, but it is very doubtful if they are specifically distinct. *T. gelatinosa* (Vauch.) Desv. is the commonest form, with a vesicular gelatinous colony and cells 6—12 μ in diameter. *T. lubrica* Ag. (fig. 111) and *T. explanata* Ag. are most probably other forms of this species. *T. lacustris* Lemm., which is a form confined to the plankton, is possibly a stage in the life-history of *Sphærocystis Schroeteri* Chod.

Genus **Apiocystis** Näg., 1849. The gelatinous colonies are relatively small and attenuated towards the base, which is usually fixed to other larger Algæ. The cells are similar in structure to those of *Palmella*, and they are disposed without order near the periphery of the gelatinous vesicle. Each cell is furnished with two 'pseudocilia,' which penetrate through the jelly into the surrounding water. Multiplication occurs by the division of the cells in two or three directions accompanied by a corresponding increase in the size of the colony. Correns[1] states that when a cell divides one pseudocilium goes to each daughter-cell, a second one being subsequently developed. Reproduction takes place by biciliated zoogonidia and isogamous gametes[2].

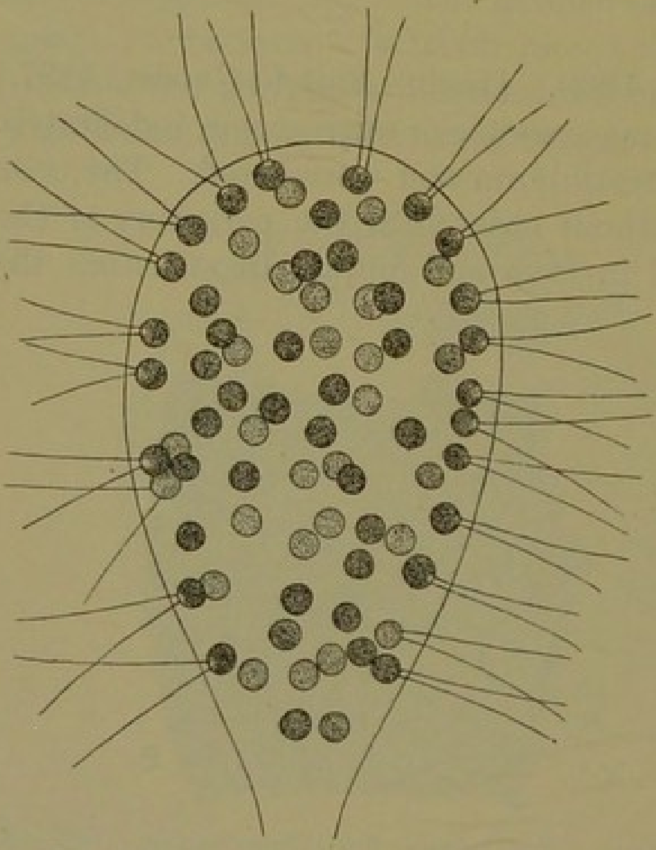

Fig. 112. *Apiocystis Brauniana* Näg., from near Bowness, Westmoreland (×400).

A. Brauniana Näg. is not uncommon in ponds, ditches, bog-pools, etc., and its pyriform colony is commonly attached by the base to larger filamentous Algæ. The colonies are 12—1000 μ (or upwards) in length and the cells 6—8 μ in diameter; fig. 112.

Sub-family III. GLŒOCYSTIDEÆ.

The colonies of this sub-family consist of an aggregate of cells within a common mucilaginous envelope, which exhibits a lamellose structure. As a rule concentric coats of mucus can be distinguished round each individual cell or round a small group of daughter-cells. The lamellation of the mucous integument reaches a

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[1] *Vide* Bot. Centralbl. liv, 1893, p. 146.

[2] Moore in Journ. Linn. Soc. Bot. xxv, 1890.

maximum in some species of *Glœocystis*. Multiplication occurs principally by a tetrahedric division of the mother-cells, accompanied by a gelatinization of the mother-cell-walls. Reproduction also takes place by biciliated zoogonidia.

Genus **Glœocystis** Näg., 1849. [*Chlorococcum* Fries, 1825 (in part).] The plants occur as small irregular colonies consisting of an indefinite group of cells formed by the successive division of the mother-cells. The enveloping mucus generally shows a

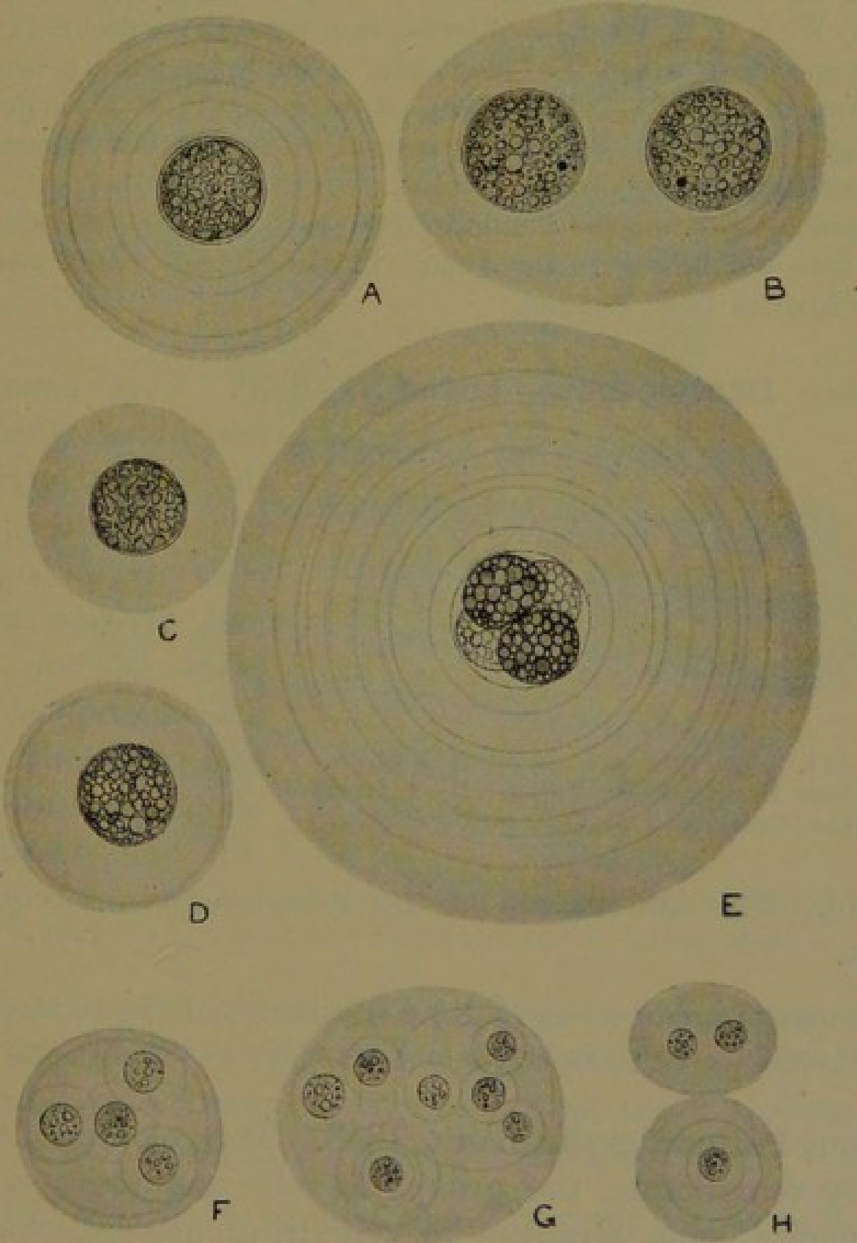

Fig. 113. A—E, *Glœocystis infusionum* (Schrank) W. & G. S. West, from Barnes Common, Surrey. F—H, *Gl. gigas* (Kütz.) Lagerh., from Wimbledon Common, Surrey. (All × 420.)

marked lamellation, similar to that exhibited by *Glœocapsa* among the Myxophyceæ. The cells are globose or ellipsoid, with a parietal bell-shaped chloroplast furnished with one pyrenoid.

The most abundant species is *Gl. gigas* (Kütz.) Lagerh. [=*Chlorococcum gigas* Grun.; *Glœocystis ampla* (Kütz.) Rabenh.], which is found in stagnant waters among other Algæ; the cells are globose and 10—17 μ in diameter; fig. 113 F—H. *G. vesiculosa* Näg. is also a very common species of the genus in which the cells are ellipsoid and 4—12 μ in diameter. *Gl. infusionum* (Schrank) W. & G. S. West [=*Chlorococcum infusionum* (Schrank) Menegh.] is a large species in which the lamellation of the integument is most remarkable; diam. of cells 25—30 μ; diam. of integuments of a single cell often 180 μ; fig. 113 A—E. There are several other so-called 'species' of this genus, but they are of doubtful value.

The genus *Capsulococcus* Bennett (1888) is of very doubtful character and possibly does not belong to the Algæ. *C. crateriformis* Benn. was described from the English Lake District.

Genus **Dactylothece** Lagerh., 1883[1]. This genus closely resembles *Glœocystis* in the general arrangement of the colony, but the cells are oblong-ellipsoid and division only takes place in one direction. The chloroplast is a parietal plate only occupying about two-thirds of the cell and destitute of a pyrenoid. The lamellation of the integuments is frequently indistinct.

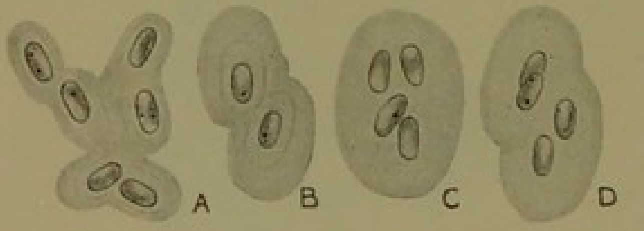

Fig. 114. *Dactylothece Braunii* Lagerh., A, from near Bradford, W. Yorks.; B—D, from near Senens, Cornwall (× 420).

D. Braunii Lagerh. occurs in damp situations and also in stagnant pools. The cells are 7·5—10·5 μ in length and 3·5—4·8 μ in breadth; fig. 114.

Genus **Palmodictyon** Kütz., 1845. The colonies of this genus are very remarkable, the groups of cells and their surrounding integuments being arranged in cylindrical masses, which branch and anastomose with each other. The external mucous coats of these elongated colonies often become very tough and assume a reddish-brown colour. Reproduction occurs by the formation of resting-spores or hypnospores with brown cell-walls. The germi-

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[1] Lagerheim in Öfvers. af K. Sv. Vet.-Akad. Förh. 1883, no. 2, t. 1, f. 22—24.

nation of these resting-spores results almost immediately in the formation of an elongated colony.

Palmodictyon viride Kütz. is a very rare British Alga which I have only observed from the extreme south-west of England. The cells are globose and 5·5—9 μ in diameter; the cylindrical colonies vary from 28—52 μ in diameter; fig. 115.

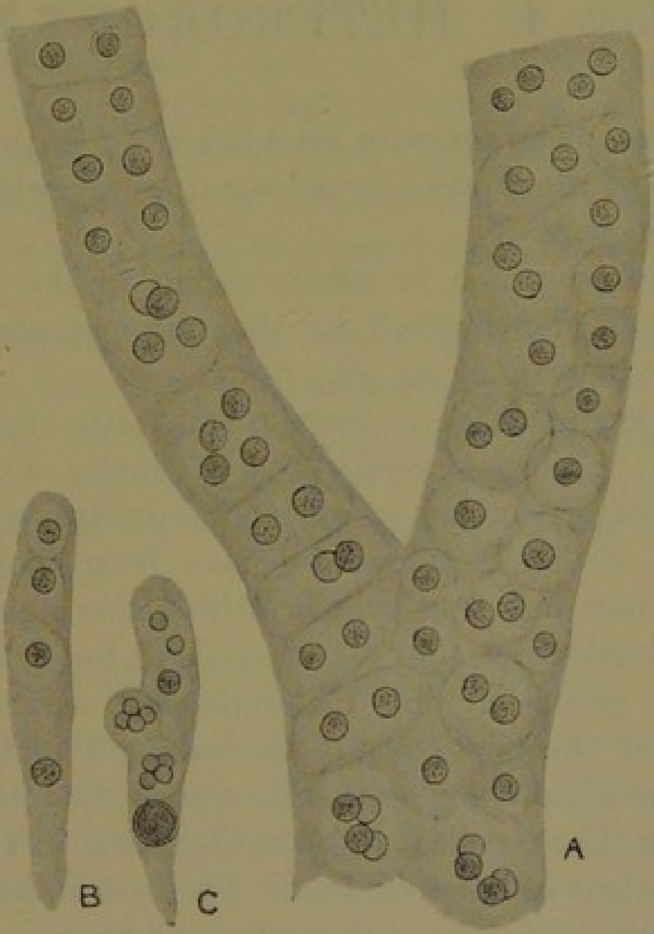

Fig. 115. *Palmodictyon viride* Kütz., from near St Just, Cornwall (× 420). A, part of adult, branched colony; B and C, young colonies.

Genus **Botrydina** Bréb., 1839. The colonies consist of subspherical aggregates of cells of the *Glœocystis*-type, enveloped in a thick gelatinous integument which may reach a diameter of 500 μ. The genus requires further investigation.

B. vulgaris Bréb. occurs amongst mosses on damp ground, on the trunks of trees, etc. The cells are globose or ellipsoid and 2—7 μ in diameter. It sometimes occurs in large quantity amongst *Leucobryum glaucum.*

Class 4. HETEROKONTÆ.

THIS class has been recently established by Luther to embrace a number of Algæ which were for a long time regarded as members of the Chlorophyceæ.

They are yellow-green in colour owing to the presence of a large quantity of xanthophyll in the chromatophores, and the product of metabolism is an oil.

The class was instituted to include two series of organisms, one of which, the 'Chloromonadales,' is distinctly a group of the Flagellata, including certain primitive Flagellate organisms from which the rest of the Heterokontæ have been evolved. Bohlin, and also Blackman and Tansley, place the genus *Vaucheria* in this class under a third series, the 'Vaucheriales'; but I have preferred to retain this genus in the Chlorophyceæ in the old family Vaucheriaceæ of the Siphoneæ. Excluding *Vaucheria* and the Flagellate group Chloromonadales, the rest of the Heterokontæ fall under the order 'Confervales' proposed by Borzi in 1889, and they are all strictly algal in organization. They are unicellular, multicellular, or cœnocytic in character, exhibiting a considerable variety of form, and occurring as simple rounded unicells, long multicellular filaments, or large gregarious cœnocytes. The cells usually contain many chromatophores (rarely only one), which are discoidal in form, of a yellow-green colour, and devoid of pyrenoids and starch. In other respects the cell-structure is similar to that described for the Chlorophyceæ.

Multiplication by cell-division does not take place in some genera.

The usual method of asexual reproduction is by zoogonidia of a somewhat peculiar character. They are generally ovoid or pear-shaped and are furnished with two cilia. The latter have only been accurately examined in a few genera and have been found to be of unequal length. They are attached to one side of the anterior extremity of the zoogonidium and are generally carried in opposite directions. Each zoogonidium usually possesses several parietal chromatophores (*vide* fig. 121 C).

Aplanospores are also frequently formed, usually one in each cell and possessed of thick cell-walls.

Sexual reproduction occurs by the fusion of isogamous planogametes which most probably resemble the zoogonidia in the possession of two unequal cilia[1]. It is only very recently (1898) that the second short cilium was demonstrated, up to that time the zoogonidia and gametes of these Algæ having been described as possessing only one cilium. The second short cilium is usually carried in a backward direction, pressed closely against the body of the cell.

The Heterokontæ contains only a limited number of genera. None of the Flagellate series 'Chloromonadales' have been observed from the British Islands, and all the remaining genera belong to the Confervales. *Chlorobotrys* Bohlin, which that author referred to the Chloromonadales, is strictly algal in character and belongs to the Tribonemaceæ.

Order I. CONFERVALES.

In this order the cells are entirely algal in character, thus differing from those of the Flagellate order Chloromonadales.

The plants are unicellular, multicellular, or cœnocytic, and the cell-walls are sometimes very thick. Each cell contains several or many discoidal chromatophores, with a parietal disposition, and from which pyrenoids are absent.

The reproduction is by zoogonidia and isogamous planogametes, the former possessing a pair of unequal cilia.

The order is divided into three families:—

Family 1. *Chlorotheciaceæ.* Unicellular or colonial; cells small, often attached by basal stalks, uninucleate, with one or many chromatophores.

Family 2. *Tribonemaceæ.* Unicellular or filamentous; cells often elongate, uninucleate or subcœnocytic, with several or many chromatophores; cell-walls firm and thick.

Family 3. *Botrydiaceæ.* Plant-body large and cœnocytic, fixed, with well-developed organs of attachment; chromatophores numerous.

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[1] Gametes have been described in certain genera with two equal cilia, but such statements are not established facts and require re-investigation.

Family 1. CHLOROTHECIACEÆ.

In this family the plants are very small, unicellular, gregarious, or colonial. The solitary and gregarious cells are attached each by a basal stalk, generally to some larger filamentous Alga, but in the colonial forms the cells are united by mucilaginous bands or stalks. Each cell contains a single nucleus and one or many parietal chromatophores. Multiplication takes place in some genera by vegetative division, but not in others. Reproduction occurs by zoogonidia and isogamous gametes, with one long cilium and most probably a shorter one, the presence of which has not yet been ascertained.

The three following genera are known as British:—

A. Cells stalked; no vegetative division.
  * Cells gregarious, living in the mucilaginous investments of other Algæ and attached by a stalk of extreme tenuity; with one chromatophore .... *Stipitococcus.*
  ** Cells ovoid, rounded, or ellipsoid, attached by a thick stalk; chromatophores several or many............... *Characiopsis.*
B. Cells united to form branched colonies by tubular stalks of mucilage; vegetative division abundant... *Mischococcus.*

Genus **Stipitococcus** West & G. S. West, 1898[1]. The cells are very minute, gregarious, and epiphytic on other filamentous Algæ, being embedded in the mucilage surrounding the filament, to which they are attached by long stalks of extreme fineness. In shape the cells are ovoid and apiculate, or somewhat campanulate, with a rounded base and an attenuated or irregularly expanded apex. There is a single parietal chloroplast of a pale green colour, somewhat irregular in form and curled round the inner surface of the cell-wall. A single small nucleus is present in the centre of the cell. Reproduction is by zoogonidia,

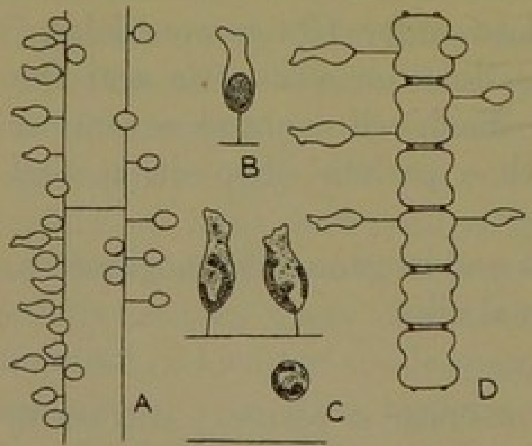

Fig. 116. *Stipitococcus urceolatus* W. & G. S. West; A—C, epiphytic on a filament of *Mougeotia*, from Oughtershaw Tarn, W. Yorks.; A, ×500; B and C, ×780; D, epiphytic on *Sphærozosma excavatum*, from Harris, Outer Hebrides (×500).

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[1] West & G. S. West in Journ. Bot. Sept. 1898.

two of which are produced from each mother-cell. Only one long cilium has been observed on the zoogonidia, but it is very probable that another shorter one has been overlooked. The zoogonidia become attached by the end of the long cilium, the latter then forming the stalk of the new unicellular plant.

The genus closely resembles *Peroniella* Gobi[1], which is also an epiphyte, occurring in the mucous investments of *Hyalotheca*. The cells are, however, smaller than in that genus and their apices are acute or expanded. The general form of the cells is thus different from the rounded cells of *Peroniella*.

S. urceolatus West & G. S. West is known from W. Yorkshire and from N. W. Scotland, occurring as an epiphyte on *Mougeotia* and *Sphærozosma*; diam. of cells 3—4·2 μ; length 6·5—10·5 μ; length of hyaline stalk 4—6 μ; fig. 116. Schmidle[2] has described another species from Germany.

Genus **Characiopsis** Borzi, 1895. Most of the plants of this genus were at one time described as species of *Characium* A. Br. The cells are rounded, ellipsoid, or ovoid, sometimes acuminate at the apex, with a firm cell-wall and a short basal stalk of some thickness. They occur as epiphytes, solitary or gregarious, and there is no vegetative division. Each cell contains several or many small, parietal chromatophores of a pale-green colour. Reproduction occurs by the division of the cell-contents either to form eight (or more?) zoogonidia, which are set free by the dissolution of the upper portion of the mother-cell-wall, or to form a number of globose aplanospores which become gametangia immediately on liberation, each producing two or four gametes.

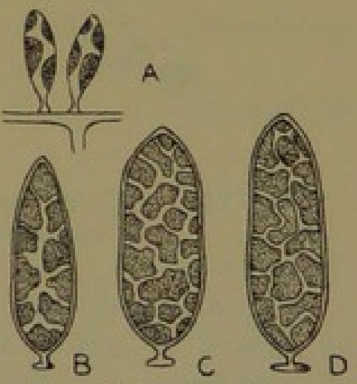

Fig. 117. A, *Characiopsis minuta* (A. Br.) Borzi, from near Penzance, Cornwall. B—D, *Ch. turgida* W. & G. S. West, from Keighley Moor, W. Yorks. (× 500).

There are a number of species, several of which are known from Britain. *Ch. minuta* (A. Br.) Borzi is the most frequent; length of cells 17—18 μ; breadth 5·5 μ; fig. 117 A. *Ch. turgida* W. & G. S. West is the largest species of the genus; length of cells 36—46 μ; breadth 11·5—16 μ; fig. 117 B—D.

Genus **Mischococcus** Näg., 1849. The cells are globular and are united by thick tubular stalks of mucilage to form small

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[1] Gobi in Scripta Botan. Horti Univers. Imp. Petropolitanæ, tom. i, 1866-7, pp. 244—250, t. 1.

[2] Schmidle in Hedwigia, Bd xli, 1902, Heft 4, p. 153, fig. A 1.

branched colonies; they are situated only at the extremities of the mucous tubes and each possesses from one to four chromatophores. Reproduction takes place by zoogonidia and isogamous planogametes. The zoogonidia usually germinate directly to form a small typical colony, but the zygospore divides in two directions in one plane forming an epiphytic cushion, all the cells of which are situated on short, broad, mucilaginous stalks.

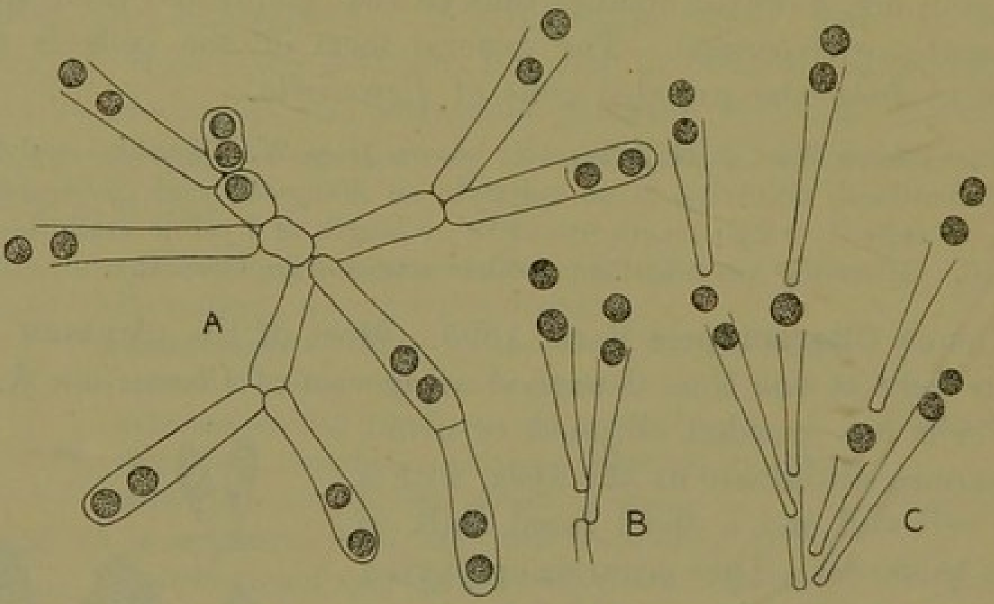

Fig. 118. *Mischococcus confervicola* Näg. A, from Cam Fell, W. Yorks.; B and C, from Ruislip Reservoir, Middlesex (× 500).

M. confervicola Näg. is a rather uncommon Alga, occurring as an epiphyte on various filamentous species of Cladophoraceæ, Tribonemaceæ, Ulotrichaceæ, Œdogoniaceæ, etc. It is generally found in small ponds and ditches, or more rarely in peaty pools; diam. of cells 3·5—5·5 μ; fig. 118.

Another genus belonging to the Chlorotheciaceæ has been recently described by Schmidle[1] under the name of **Oodesmus.** Lemmermann reports having found this genus in some plankton material forwarded to him from Loch Doon, Ayrshire. The cells are ovoid and united by short bands of mucus to form free-swimming colonies. Each colony consists of four cells, which are disposed in one plane. The cell-wall is relatively thick and there are one or two chromatophores in each cell. *O. Doederleinii* Schmidle is the only known species; cells 8 μ in length and 6 μ in breadth.

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[1] Schmidle in Hedwigia, Bd xli, Heft 4, 1902, p. 162, fig. B 4.

Family 2. TRIBONEMACEÆ.

The plants of this family are unicellular or filamentous. The cells are globose, cylindrical, elongate, often spirally coiled or united to form long flexuose filaments. There is generally a single nucleus in each cell, but sometimes two or more are present, giving the cell a more or less cœnocytic character. The cell-walls are always firm and usually of some thickness, except in the genus *Bumilleria*, in which the walls sometimes become swollen and hyaline. Asexual reproduction takes place by zoogonidia with one long and one short cilium, and two or several parietal chromatophores. Aplanospores are also of frequent occurrence in the genus *Tribonema*. Sexual reproduction occurs by isogamous planogametes which have been described, but perhaps erroneously so, as having two equal cilia.

There are four British genera, three of which are abundant.

A. Plants unicellular.
  * Cells globose, aggregated in mucilaginous colonies ... *Chlorobotrys.*
  ** Cells elongate, usually shortly stipitate and often spirally coiled .... *Ophiocytium.*
B. Plants filamentous.
  * Cell-walls firm, splitting into H-pieces .... *Tribonema.*
  ** Cell-walls hyaline, H-pieces not very evident; filaments small.................... *Bumilleria.*

Genus **Chlorobotrys** Bohlin, 1902[1]. The cells are globose or subglobose, solitary, or more commonly aggregated in families of 2, 4, 8, or 16. Each family is surrounded by an ample mucous integument, very hyaline and quite homogeneous. The cell-walls are firm, smooth, of some considerable thickness, and they contain a certain proportion of silica. The chromatophores are parietal, yellow-green discs, from 6 to 30 of which are disposed on the walls of each cell. Sometimes the pigment becomes more or less diffuse. There is frequently a prominent red pigment-spot in each cell of the family, but sometimes this is entirely absent. Multiplication takes place by the division of the cells primarily in two directions, but afterwards in three directions[2]. Families of 4, 8, or 16 cells are therefore frequently very symmetrical, but beyond this number they become irregular. During cell-division the contiguous walls

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[1] Bohlin in Bihang till K. Sv. Vet.-Akad. Handl. Bd 27, no. 4, 1902, p. 34, t. i, f. 9.

[2] West & G. S. West in Journ. Bot. April, 1903.

of the daughter-cells are at first much flattened, but afterwards become more convex. Zoogonidia have not been observed.

Bohlin was distinctly in error in referring this Alga to the Chloromonadales, as the plants are strictly algal in character. The ordinary vegetative condition of the organisms belonging to the Chloromonadales is a ciliated or flagellated one, whereas a motile condition of *Chlorobotrys* has never been observed. Moreover, *Chlorobotrys* is a very abundant Alga and one which I have had under observation for many years; and the motile condition, far from being the ordinary state of the plant, must be exceptionally rare.

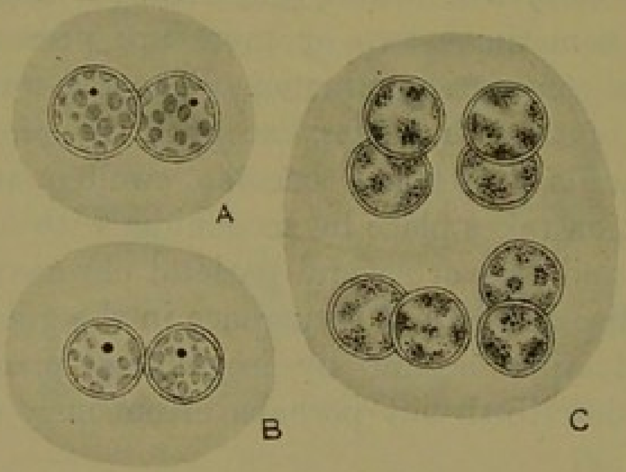

Fig. 119. *Chlorobotrys regularis* (West) Bohlin, from Tremethick Moor, Cornwall (× 450).

The genus is undoubtedly nearest to *Botrydiopsis* Borzi, but differs in the smaller size of the cells, which are associated to form colonies, and the prominent mucous investment. Moreover, it is only found in still water, whereas *Botrydiopsis* inhabits running water.

Chl. regularis (West) Bohlin [*Chlorococcum regulare* West[1]] is widely distributed and often abundant in the Sphagnum-bogs of the British Islands. I have also examined numerous specimens of it from Norway, Switzerland and the United States. The cells are 12—19 μ in diameter and the families (with the mucous investments) are 34—90 μ in diameter; fig. 119.

Genus **Ophiocytium** Näg., 1849. [Inclus. *Sciadium* A. Br., 1855.] The cells are free or attached and generally many times longer than the diameter. They are commonly solitary, but sometimes colonial, and they are usually curved or spirally contorted. The apex of the cell may be capitate or apiculate and is sometimes attenuated into a long spine. Each cell contains several nuclei and a number of large parietal chromatophores of a somewhat cylindrical form. The presence of oil drops is a feature of some species. The cell-wall consists of a homogeneous lid fitted to the apex of a long tube composed of apposed layers of pectose

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[1] West in Journ. Roy. Micr. Soc. 1892, p. 737, t. x, f. 55.

compounds. Vegetative division does not occur. Asexual reproduction takes place by the division of the cell-contents to form ellipsoidal aplanospores, or to form eight ovoidal zoogonidia with two cilia. In those species which are attached the zoogonidia generally come to rest on the rim of the empty tube-like cell and there grow into adult cells. A repetition of this process produces a curious branch-system. Sometimes the zoogonidia develop on the apices of other cells which contain the cell-contents. No gametes have been observed. The genus was monographed by Lemmermann[1], but the validity of the thirteen species he puts forward is questionable.

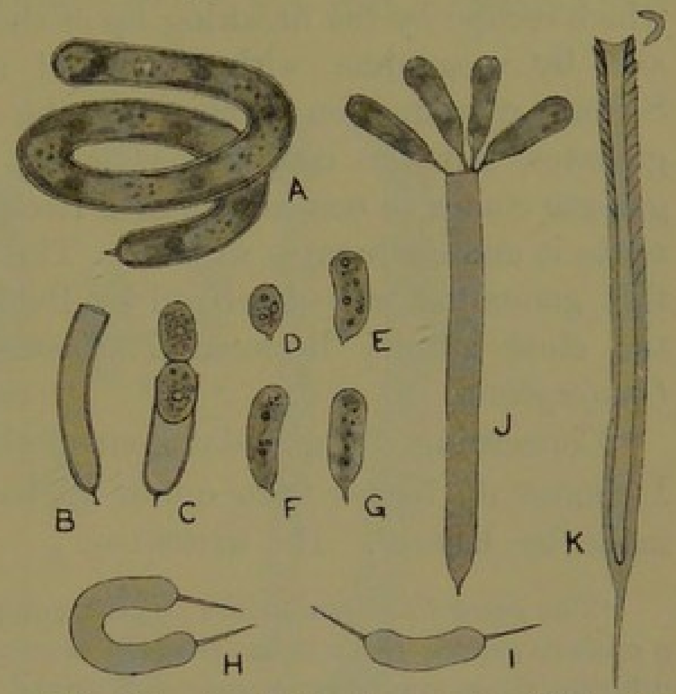

Fig. 120. A, *Ophiocytium majus* Näg., from Bowness, Westmoreland. B—G, *O. cochleare* (Eichw.) A. Br., from same locality. H and I, *O. bicuspidatum* (Borge) Lemm. forma *longispina* Lemm., from Pilmoor, N. Yorks. J, *O. Arbuscula* (A. Br.) Rabenh., from Mitcham Common, Surrey. (All ×450.) K, *O. graciliceps* (A. Br.) Rabenh., after treatment with potassium hydrate (after Bohlin, ×570).

Several species are widely distributed in the British Islands. *O. Arbuscula* (A. Br.) Rabenh. is an attached species, often with very pretty branch-systems; diam. of cells 3—8 μ; fig. 120 J. *O. majus* Näg. is the largest species, the cells reaching a diameter of 17 μ; fig. 120 A. *O. cochleare* (Eichw.) A. Br., *O. capitatum* Wolle, *O. bicuspidatum* (Borge) Lemm. and *O. parvulum* (Perty) A. Br. are also frequent species.

Genus **Tribonema** Derbes & Solier, 1856. [*Conferva* in the sense used by Lagerheim, 1888.] The plants of this genus are simple filaments of cylindrical or slightly barrel-shaped cells with strong cell-walls. The latter are often of considerable thickness and the filaments frequently break up into **H**-pieces. Each **H**-piece consists of a transverse cell-wall with a cylindrical piece on either side, and the whole is composed of a number of layers of pectose compounds. Each cell is thus bounded by the halves of two **H**-pieces. The cells contain one (or sometimes two) nuclei and a variable number of parietal chromatophores. In some

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[1] Lemmermann in Hedwigia, Bd xxxviii, 1899, pp. 20—38, t. iii & iv.

species the chromatophores are few and irregular, but more often they are numerous and discoidal. Asexual reproduction takes place by the formation of globular or ellipsoidal aplanospores, which escape by the breaking up of the filament (fig. 121 B and I); also by zoogonidia with a pair of unequal cilia (fig. 121 C). Sexual reproduction occurs by the conjugation of isogamous gametes, but the conjugation is not strictly isogamous, as one gamete comes to rest and rounds itself off before another swarms up to it and conjugates with it. The structure of the cell-wall of this genus was well described by Bohlin[1], who also demonstrated the close affinity between *Tribonema* (*Conferva* Lagerh.) and *Ophiocytium*.

Concerning the abandonment of the generic name '*Conferva*,' I cannot do better than quote at length the remarks recently made by Hazen[2]. He writes:—

"The name *Conferva* is very ancient, going back to the time of Pliny. As a modern generic name it has received most varied treatment, and covered at different times very diverse groups of plants.

"Under this name Linnæus included a very large part of the branching, as well as the simple, filamentous algæ. He adopted the genus from Dillenius. The first species mentioned by Linnæus, *Conferva rivularis*, is undoubtedly the oldest of his group, so far as the history of these ill-defined forms can be determined. This species, according to the synonymy of Linnæus (Sp. Pl. 1164. 1753), is *Conferva fluviatilis, sericea vulgaris et fluitans* of Dillenius (Hist. Musc. 12, pl. 2, f. 1. 1741); this in turn is *Conferva Plinii* Dillen. (Cat. Plant. sponte Gissam nascentium, 199. 1719); the earliest description of *C. Plinii* that we have seen is in L'Obel's Plantarum Observationes, 664. 1576, but undoubtedly the name is of more ancient origin.

"Now no one would imagine that the ancient herbalists or even Linnæus could distinguish the numerous filamentous forms known to us only by the use of good microscopes. Indeed, the fact that Linnæus described only two unbranched species is sufficient proof of this. *Conferva rivularis* as collected by him, was very likely at one time a *Spirogyra* and at another time an *Œdogonium*. This type species, however, as interpreted by the earlier algologists, *e.g.*, Dillwyn, Lyngbye and Mueller, is evidently a form belonging to what is now known as *Rhizoclonium*, and has come down to us as *R. rivularis* (L.) Kütz. This identification is also confirmed by Linnæus himself, who (Sp. Pl. Ed. 14. 1784) quotes the figure of *C. rivularis* from Flora Danica.

"At any rate, there is no warrant whatever for employing the name *Conferva* to designate the genus recognized under that name in Lagerheim's revision, for there is no evidence that these species were ever collected by

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[1] Bohlin in Bihang till K. Sv. Vet.-Akad. Handl. 1897, Bd 23, no. 3.

[2] Hazen in Memoirs Torr. Bot. Club, xi, 1902, no. 2, pp. 181—183.

Linnæus, and certainly none of them were distinguished by him from other simple filamentous forms.

"For Lagerheim's group of species, as for all genera, the adoption of a generic name based on a recognizable species, as a type, is essential. The earliest such name in the present case is *Tribonema* Derbes & Solier (1856)[1]. This genus was based on a single species, *Conferva bombycina*, and in the diagnosis, for the first time in the history of the species, explicit mention was made of the most essential character, namely, the form of the chromatophores, although it had been previously suggested in the plates of Kützing. The method of zoospore dispersal was also first described and illustrated by Derbes & Solier. There is, then, every reason for employing the name *Tribonema* as a memorial of the discernment of these authors."

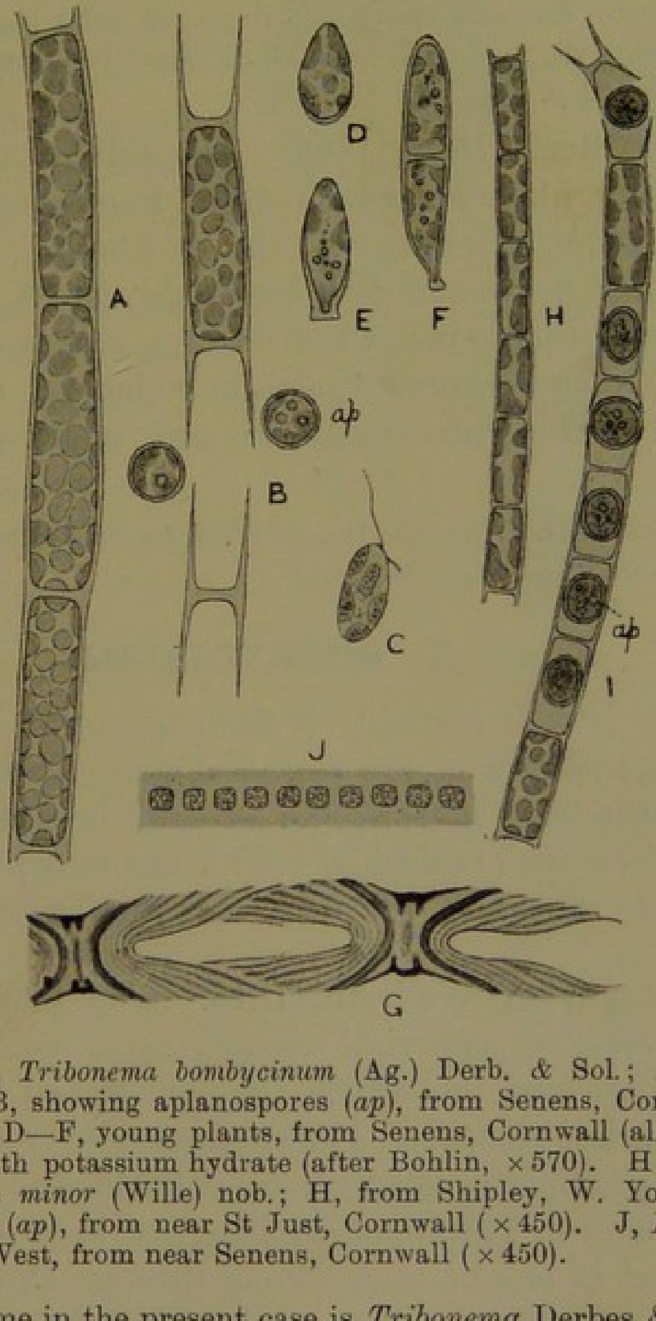

Fig. 121. A—G, *Tribonema bombycinum* (Ag.) Derb. & Sol.; A, from Shipley, W. Yorks.; B, showing aplanospores (*ap*), from Senens, Cornwall; C, zoogonidium, and D—F, young plants, from Senens, Cornwall (all × 450); G, after treatment with potassium hydrate (after Bohlin, × 570). H and I, *T. bombycinum* forma *minor* (Wille) nob.; H, from Shipley, W. Yorks.; I, showing aplanospores (*ap*), from near St Just, Cornwall (× 450). J, *Bumilleria pumila* W. & G. S. West, from near Senens, Cornwall (× 450).

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[1] Derbes & Solier, Mém. sur quelques points de la physiologie des Algues, 1856.

T. bombycinum (Ag.) Derb. & Sol. (=*Conferva bombycina* Ag.) is general throughout the British Islands; diam. of cells 8—15 μ; fig. 121 A—G. A small form of this species [forma *minor* (Wille) nob.] is also very common; diam. of cells 5—6·5 μ: fig. 121 H and I. *T. affine* (Kütz.) nob. (=*Conferva affinis* Kütz.) is the thinnest species with the most elongate cells, and the chromatophores are few and irregular; diam. of cells 5—5·4 μ. *T. obsoletum* nob. (=*Conferva obsoleta* West & G. S. West) is a much rarer species; diam. of cells 19—21 μ.

Genus **Bumilleria** Borzi, 1895. The cells of this genus are arranged in long filaments which differ from those of *Conferva* principally in the structure of the cell-wall. The latter is practically homogeneous and does not readily break into **H**-pieces. The pectose constituents instead of forming closely apposed layers may form a distinct mucous cylinder in which the cells appear to be embedded. The chromatophores are small, pulvinate and parietal.

B. pumila West & G. S. West is the only known British species; length of cells 5—6 μ; diam. 4·8—5·7 μ; fig. 121 J.

Family 3. **BOTRYDIACEÆ**.

This family is well marked off from the other groups of the Confervales by the form of the plants alone. Each individual is a rounded cœnocyte of macroscopic size and is attached to damp mud by well-developed 'rhizoids.' The chromatophores are very numerous and the methods of reproduction are somewhat diversified.

Genus **Botrydium** Wallroth, 1815. The plants consist of green, pear-shaped or spherical cœnocytes of considerable size, growing on damp mud into which they are rooted by a branched system of colourless rhizoids. The cœnocytes are vesicular, with a lining layer of protoplasm in which are embedded numerous nuclei and chromatophores. The latter are irregular in form, more or less evenly scattered in one or more layers through the lining protoplasm, and are generally in close contact with the nuclei. Bodies of the nature of pyrenoids have been observed in the younger stages of the plant, but starch is not formed. The rhizoids possess protoplasmic contents and many nuclei. Wager has observed mitotic division of the nuclei and states that the chromatic substance appears to reside wholly in the nucleolus.

This plant reproduces itself asexually in a great variety of ways, depending largely on the conditions of environment, any change of conditions usually resulting in a corresponding variation in the reproductive process. These different processes have been worked out by Rostafinski and Woronin[1] and the final result is in each case either the production of zoogonidia or aplanospores. The zoogonidia are small and ovoid in shape, with one or two chromatophores and one long cilium. (Very probably there is a second shorter cilium, but its presence has not yet been ascertained.) The whole plant frequently becomes a huge zoogonidangium, especially if it becomes submerged, and the zoogonidia escape through an apical opening. The aplanospores, which are globose or ellipsoid, often become hypnospores, and they are frequently produced in numbers in the rhizoids. On the green portion of the plant above ground becoming too dry, the contents migrate into the rhizoids and a large number of aplanospores are formed. The development of the young plants varies much, depending upon the external conditions.

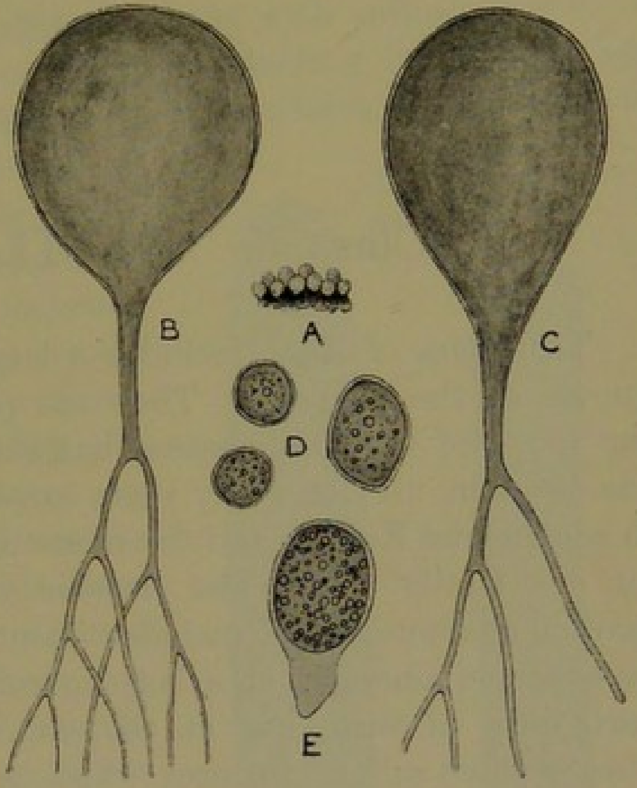

Fig. 122. *Botrydium granulatum* (L.) Grev., from Calverley, W. Yorks. A, nat. size; B and C, × 45; D and E, × 450; D, aplanospores; E, germinating aplanospore.

Rostafinski and Woronin described a sexual reproduction by the conjugation of isogamous gametes, but Klebs has given good reasons for doubting this.

B. granulatum (L.) Grev. is a very local plant. It occurs widely distributed over the British Islands, but the conditions are not often suitable for its appearance above ground. It is found almost exclusively on drying-up mud, and sometimes occurs in countless numbers on mud turned out from a canal or on the drying bottom of a muddy pond. I have observed these plants so thick as to stand out in mulberry-like masses from the surface of the damp mud. The nature of the mud is immaterial and the Alga is not uncommonly found on chalk mud. The plants reach a diameter of 2·25 mm. Fig. 122.

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[1] Rostafinski & Woronin in Botan. Zeitung, xxxv, 1877.

Class 5. BACILLARIEÆ.

THIS class of Algæ includes a large number of minute plants known as the Diatoms. They are perhaps better known under the name of the Diatomaceæ, but the earlier name 'Bacillarieæ' has been in use for many years among systematists, particularly in continental Europe, and the name 'Diatomaceæ' is here retained for one family only. The class is a very large one, with well-marked characters, and includes about 10,000 species. As would be expected among such a large number of species there is great variability of form, but at the same time the Diatoms always possess those salient features which mark them off from all other Algæ.

They are universally distributed in both fresh and salt water, and as the wonderful sculpture of their cell-walls renders them objects of great beauty, they have long been made the subject of special study by numerous students of natural history.

Diatoms are unicellular plants, mostly of minute size, the cell-walls of which are composed of an organic matrix impregnated with silica. The silica can be removed by the action of hydrofluoric acid, leaving the organic matrix behind; or the organic matrix, which is allied in composition to cellulose, can be removed by calcination leaving behind the siliceous constituent.

Each individual Diatom is termed a *frustule*, and the cell-wall consists of two more or less equal *valves*, joined together by two *connecting-bands* which overlap. Each half of the Diatom is thus composed of two pieces, a valve and a connecting-band, and the connecting-band of the older half fits over that of the younger half like the lid of a cardboard-box. The connecting-bands, although closely fitted to their respective valves, are distinct from them, and the two bands together form what is termed the *girdle*. The latter does not usually consist of two closed hoops, but as

Palmer and Keeley[1] have pointed out, each band of the girdle is a two-ended band of silica with the ends overlapping without being joined. Each frustule possesses a thin coat of mucus which can be readily demonstrated by slight staining with aniline dyes.

Diatoms often occur as solitary, free-floating individuals, but they may adhere to one another to form chains, either by their valve-faces to form ribbon-like or thread-like colonies (*Eunotia, Melosira*), or by mucous cushions at their angles to form zig-zag colonies (*Tabellaria*). Some adhere closely to larger plants by the whole of one valve-face (*Cocconeis*), or they are affixed to some larger object by simple or branched gelatinous stalks (*Gomphonema*); others occur in large colonies embedded in a common mucilaginous envelope, either as a compact mass or a simple or branched tube. This condition is commoner in marine species than in freshwater ones, and is variable even in individual species. Marine Diatoms also reach a much larger size than freshwater ones.

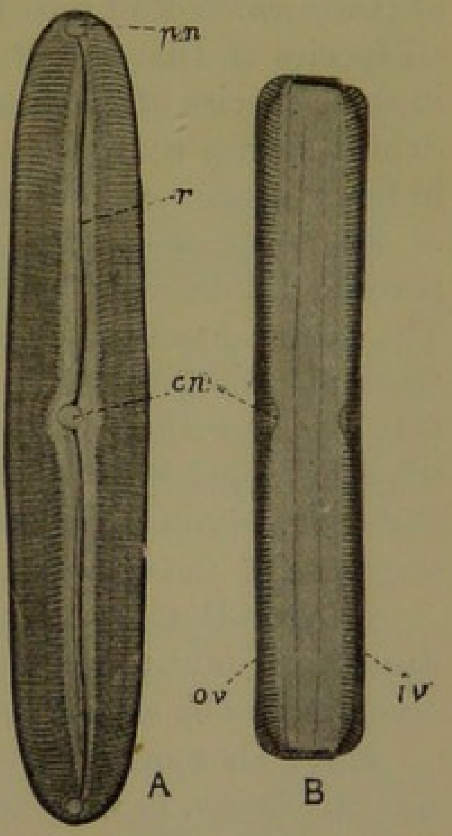

Fig. 123. A, valve view of *Navicula nobilis* Ehrenb. var. *Dactylus* (Ehrenb.) V. H., from Dolgelly, Wales (×250). B, girdle view of *N. major* Kütz., from Shipley, W. Yorks. (×300). *cn*, central nodule; *iv*, inner valve; *ov*, outer valve; *pn*, polar nodule; *r*, raphe.

In referring to any individual Diatom, the aspect in which the girdle side is exposed to view is best termed the *girdle-view* (or *zonal-view*), and that in which the surface of the valve is exposed to view the *valve-view*.

The valves are as a rule thin and transparent, slightly convex on the outside, and in almost all species they are ornamented with variously disposed striæ. The best lenses, however, have shown that these striæ consist of series of small cavities within the siliceous wall of the Diatom, and it is their close and regular arrangement that causes them to appear as striæ. The striæ are

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[1] Palmer and Keeley in Proc. Acad. Nat. Sci. Philadelphia, 1900.

so extremely fine and constant in some species as to furnish splendid test-objects for the definition and angular aperture of the lenses of microscopes. The valves of some genera, particularly the marine ones, exhibit a beautiful areolated structure, due to the presence of chambers in the siliceous cell-wall. These chambers may be open to the exterior or covered by a thin membrane, and their inner walls are perforated by exceedingly minute apertures or pores which lead into the cell. These pores are not present in all species of Diatoms, Müller and Lauterborn having shown that in some species of *Navicula* (*Pinnularia*) they are probably absent. Schütt affirms that there is no question of the existence of pores in many species of Diatoms, and their existence in a large number of others is extremely probable. He draws a distinction between pores and dots, and this has been further emphasized by Müller. The latter[1] has termed small circular dots which resemble pores 'poroids'; he gives $0·1\mu$ as the minimum diameter of pores, and $0·4—0·5\mu$ as their maximum diameter, and all structures over $0·6\mu$ he regards as 'poroids[2].' Müller[3] recommends treatment with hot sodium carbonate and potassium hydrate in studying the structure of the cell-wall.

Héribaud[4] states that increased altitude and enfeebled light cause a diminution of the number of striæ and of their strength, accompanied by an increase in the length and breadth of the valves.

Many Diatoms exhibit a thickening of the cell-wall, visible in the valve-view, in the centre of the valve and very often at both extremities. These thickenings are known as *nodules*. The nodules are very frequently connected by a long median line known as the *raphe*. If the central nodule spreads out in a lateral direction it is known as a *stauros*. A portion of the valve on each side of the raphe and round the central nodule is often quite devoid of striæ; this plain or smooth portion of the valve is sometimes spoken of as a *hyaline area*.

The raphe, for at least some part of its length, is a true cleft in the valve through which the protoplasmic contents of the cell are placed in communication with the surrounding medium. (*Consult* Fig. 124*r*.)

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[1] O. Müller in Berichte Deutsch. Bot. Gesellsch. xvii, 1899.
[2] O. Müller, tom. cit. xviii, 1900.
[3] O. Müller, tom. cit. xix, 1901.
[4] Héribaud in Comptes Rendus, cxviii, 1894.

Some Diatoms possess a *pseudo-raphe*, which is a simple line, central or sub-central, and without a central nodule. Often the raphe is conspicuous in both valves, but sometimes it is only present in one valve (*Achnanthes, Cocconeis, Rhoicosphenia*). In many Diatoms the raphe is obscure and marginal or submarginal. In some species, such as *Navicula nobilis* Ehrenb., there is a smaller accessory raphe which lies alongside the primary one, and is united to it close to the central and terminal nodules. In *Vanheurckia* there is a siliceous rib on each side of the raphe and nodules, and in *Amphipleura* the central nodule is greatly elongated.

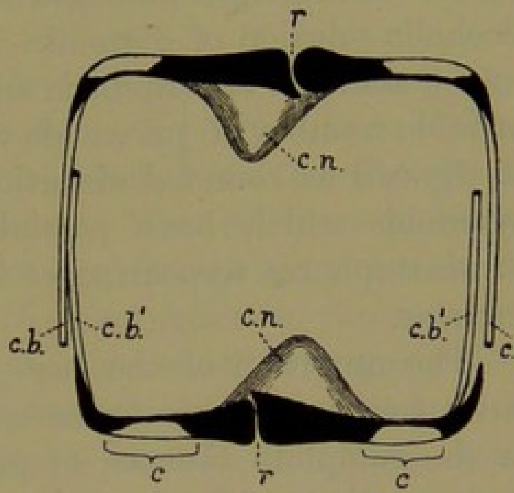

Fig. 124. Transverse section of the frustule of a *Navicula*. (From Van Heurck, after W. Prinz.) *cb* and *cb'*, the two connecting-bands forming the girdle; *r*, raphe; *cn*, central nodule; *c*, costa of valve. (Very highly magnified.)

Some Diatoms (Fragilarioideæ, *Mastogloia*) possess longitudinal septa which are always more or less considerably perforated. These septa are parallel to the valve-faces and are usually situated between the girdle and the valves.

Each individual Diatom contains a more or less centrally disposed *nucleus*, generally with a nucleolus. A very weak solution of methylene blue will bring out the nucleus in living Diatoms, staining it clearly before the rest of the protoplasm. The protoplasmic mass surrounding the nucleus is connected with the primordial utricle either by two broad bands of protoplasm or by a number of radiating or anastomosing threads. One or several large *vacuoles* occupy the central portions of the cell.

The *chromatophores* of Diatoms are somewhat variable. One or many may be present in each cell; they may be small and discoidal, large and plate-like, or extensive anastomosing masses occupying a large part of the lining protoplasm. In many species they are extremely irregular in form, being band-like, lobed, or even presenting the appearance of perforated plates. They are of a golden-yellow or brown colour, or very rarely green, as in some forms of *Navicula viridis* Kütz. and *N. cuspidata* Kütz. They contain chlorophyll, but this is masked by the presence of a brown pigment known as *diatomin*, which resembles the phycophæin of the Phæophyceæ. The diatomin, which can be extracted by alcohol forming a yellow-brown solution, is itself a complex substance containing, amongst other pigments, xanthophyll. An alcoholic solution of diatomin turns a beautiful blue-green colour on the addition of sulphuric acid. The chromatophores contain a variable number of pyrenoids which often project into the interior of the cell as rounded elevations. Mereschkowsky[1] has observed pyrenoids which have partially or entirely emerged from the chromatophores, appearing as free colourless bodies on their inner surfaces.

The nutrition of the vast majority of Diatoms is holophytic, but a few saprophytic forms are known[2]. The latter are peculiar in the complete absence of pigment, and they apparently occur in water in which there is an abundance of decaying organic matter[3]. Karsten[4] has found that *Nitzschia palea* (Kütz.) W.Sm. when cultivated in favourable nutritive media will become saprophytic.

Diatoms are incapable of growth in size owing to the siliceous nature of their cell-walls, but slight alterations of volume can take place by a sliding movement of the connecting-band of the older half of the cell over that of the younger half.

In addition to the symmetrically arranged markings on the valves, the frustules of Diatoms possess an external symmetry in one or more planes. Some of them are zygomorphic in one plane only, some in three planes at right angles, and others exhibit a radial symmetry.

The *movements of Diatoms*:—Most of the solitary, unattached species of Diatoms exhibit movements which have long been a puzzle to students of biology. This power of locomotion is especially marked in species of a naviculoid form, and various explanations have at different times been put forward to account for it. The movements of some forms are very slow, but others are capable of propelling themselves with considerable rapidity backwards and forwards in the direction of their longer axis. This spontaneous movement is sometimes creeping and steady, but at

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[1] Mereschkowsky in Flora, xcii, 1903, pp. 77—83.

[2] The following are colourless saprophytic Diatoms:—*Nitzschia putrida* Benecke, *N. leucosigma* Benecke, and *Synedra hyalina* Provasck.

[3] Benecke in Pringsheim's Jahrb. f. wissensch. Bot. xxxv, 1900.

[4] Karsten in Flora, lxxxix, 1901.

other times jerky, and is generally along a fixed substance with which the Diatom is in contact. It is not at all comparable to the free-swimming movements of many other Algæ, and, as a rule, only takes place when one valve-face of the Diatom is in contact with the fixed object.

Ehrenberg (1838) imagined the movement to be due to the protrusion of cilia or of a pseudopodium through the raphe of the valve, whereas Nägeli (1849) attributed it to the passage of osmotic currents through the cell-wall. Max Schultze (1865)[1], who observed the movements of minute foreign particles down the length of the raphe, attributed the locomotion to the contractility of a small portion of the protoplasm which was protruded through the raphe. Hallier (1880) considered it to be due to a contractile layer of protoplasm, and Onderdonk (1885) also regarded it as due to an external movement of protoplasm, but Mereschkowsky (1880)[2] concluded that the evidence was in favour of Nägeli's theory of osmotic currents through the cell-wall. O. Müller (1889)[3] demonstrated the presence of a large number of minute pores and anastomosing fissures in the valves of certain of the large species of *Navicula* (*Pinnularia*), and showed that the central and terminal nodules are traversed by straight and curved canaliculi which run towards the raphe and are eventually merged with it. Owing to intracellular pressure the protoplasm emerges from the pores of the central or terminal nodules and passes down the whole length of the raphe, returning into the cell-cavity through the pores of the terminal or central nodules as the case may be. There are thus two sets of currents on each valve of the Diatom. The cause of the movement of the frustules was ascribed by Müller to the reaction of the motive forces of this living stream of protoplasm upon the surrounding water. Schiberszky (1891)[4], from observations on *Synedra*, agreed with Pfitzer that the movement was due to a coating of protoplasm which escapes from the raphe, and which is in a condition of vibratile motion. He believed that the currents along the raphe were usually interrupted jerking or pulsating movements.

Cox (1890)[5] revived the idea of a line of cilia along the raphe,

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[1] Max Schultze in Archiv für Mikr. Anat. Bd i, 1865, p. 376.

[2] Mereschkowsky in Bot. Zeitung, 1880, p. 529.

[3] O. Müller in Berichte Deutsch. Bot. Gesellsch. Bd vii, 1889.

[4] Schilberszky in Hedwigia, xxx, 1891.

[5] J. D. Cox in The Microscope, July, 1890.

and suggested that the absence of silica along this line could be accounted for by the obstruction of the moving cilia. Bütschli (1892) also imagined that the presence of a cilium or a fine flagellum would explain the phenomenon, but no methods of staining have ever demonstrated the existence of such structures.

The movements of some of the larger species of *Navicula* (*Pinnularia*) have been explained by Bütschli (1892)[1] and by Lauterborn (1894)[2] to be due to the production of a delicate filament which is protruded from the raphe at a point opposite the central nodule. The frustules of *Navicula major* Kütz., *N. nobilis* Ehrenb., and *N. viridis* Kütz. are surrounded by a distinct mucilaginous envelope, and the protruded filament is quite colourless and transparent, resisting all attempts to stain it with aniline dyes. It lies alongside the raphe, but not in contact with it, and it elongates by a series of jerks. Bütschli puts this forward as the explanation of the jerky movement of Diatoms, the frustule being pushed backward by the elongation of the filament, the distal end of which is fixed to the substratum.

In 1893 O. Müller[3] again emphasized his previous explanation of the movements of Diatoms, affirming that they were dependent on the forces connected with the protoplasmic currents on the surface of the valve, and he denied that the movements could be the result of the filaments described by Bütschli and Lauterborn. He likewise stated that these filaments were composed of protoplasm, and not of mucilage. Lauterborn (1894)[4] contested that the production of motility by the streaming of protoplasmic currents, as suggested by Müller, would be an isolated phenomenon in either the vegetable or animal kingdom, whereas movements are known to occur in the Desmidiaceæ and Oscillatoriaceæ as a result of the excretion of mucilage, and, according to Schewiakoff, in the creeping Gregarinidæ also. Müller (1894)[5] replied again to the criticism of his hypothesis, and stated that the analogy which had been drawn between the movements of Diatoms and of Desmids was a false one.

There is no doubt that in many of the smaller motile species there is a complete absence of gelatinous filaments such as those

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[1] Bütschli in Abhandl. naturh.-med. Ver. Heidelberg, 1892, Bd iv, Heft 5.

[2] Lauterborn in Berichte Deutsch. Bot. Gesellsch. Bd xii, 1894, p. 73.

[3] O. Müller in Berichte Deutsch. Bot. Gesellsch. Bd xi, 1893.

[4] Lauterborn, tom. cit. xii, 1894.

[5] O. Müller, tom. cit. xii, 1894.

occurring in the larger species of *Navicula* (*Pinnularia*), even though the movements of the frustules, the structure of the valves, the system of fissures and pores, and the arrangements of the protoplasmic currents are the same. In some of the small species of *Navicula* the movements are extremely active, comparing not unfavourably with the slow movements of certain of the Infusoria. If the movements of such Diatoms be due to the secretion of gelatinous material, then the amount secreted in a short space of time must be relatively enormous.

After a careful consideration of the facts which have been brought forward with a view to the elucidation of this most interesting problem, there appears to be no doubt that the movements are connected with the raphe, and the balance of evidence indicates that in some Diatoms at least they are due to an exudation of mucilage.

The *multiplication of Diatoms* takes place by successive bipartitions, each division resulting in a gradual reduction in the size of the individuals. A slight increase in the volume of the frustule is the first appreciable change, after which the nucleus divides karyokinetically. A division of the cell-protoplasm now takes place, and a new siliceous valve is formed over each divided surface. These new valves are situated within the girdle of the original frustule, and the connecting-bands of the new valves are soon developed, sometimes making their appearance before and sometimes after the separation of the individuals. Thus, each individual consists of a new valve and an old one, the connecting-band of the old valve overlapping that of the new valve. Sometimes the cells do not separate, but remain in contact after division, successive bipartitions resulting in a chain of individuals. Owing to the formation of a pair of new valves within the girdle of the old ones, and since the cells when once formed are incapable of growth, every succeeding generation becomes reduced in size by the double thickness of a connecting-band. This statement is not strictly true, however, in the case of some of the filamentous species, and possibly in many others. It has been shown that daughter-cells are often produced of larger size than the parent-cells, such daughter-cells being recognizable by the thickened rim of the valves. This fact has a retarding influence on the diminution of the size of the cells, the reduction in size not being in strict proportion to the number of bipartitions; and, concerning the multiplication in the filamentous genus *Melosira*, Müller[1] has drawn up a definite law of division. He has shown that the multiplication of the cells takes place in such a manner as to prevent as much as possible the division of the smallest daughter-cells. This law, although indicating the prevailing conditions of multiplication in *Melosira*, is not true of all Diatoms.

On the greatest diminution of size having been reached for any one species, the maximum size of the species is regained by the formation of an *auxospore*, and there are five methods of *reproduction by auxospores*.

(1) The protoplasm of a cell of the smallest size (sometimes termed a 'microfrustule') swells up and forces apart the halves of the frustule, escaping to the exterior enveloped in a cellulose membrane. This is the auxospore, the wall of which rapidly becomes silicified and assumes the markings characteristic of the species, but the form of the cell is usually very different from that of the original frustule, and often most irregular. This large, newly-formed cell of irregular appearance almost immediately undergoes division, the individuals of each succeeding generation rapidly regaining their characteristic form and elegance. Miquel[2], who has made a special study of the manner in which the maximum form of a Diatom is re-established, based upon experimental cultures of a number of species, states that such re-establishment of the maximum size is habitually brought about by the formation of this simple type of auxospore. It is merely the rejuvenescence of a single cell accompanied by an increase in size. (Fig. 125 C and D.)

(2) Two auxospores may be produced by the division of the contents of a single frustule. Each of the two portions of the cell-contents emerges from the cell and develops as in the first method. This method has only been observed in *Rhabdonema arcuatum* (Ag.) Kütz. and *Achnanthes longipes* C. Ag.

(3) An auxospore may be formed by the conjugation of the contents of two frustules. The two Diatoms become enveloped in a common mucous covering, and the cell-contents emerge and fuse to form a single body, which then develops into an auxospore.

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[1] Müller, 'Die Zellhaut und die Gesetze der Zelltheilungsfolge von Melosira arenaria Moore.' Berlin, 1883.

[2] Miquel in Annal. de Micrographie, iv, 1892.

This is a true conjugation of aplanogametes with the formation of a zygospore. (Fig. 125 B.)

(4) Sometimes two frustules approximate and the cell-contents throw off the old valves, but there is no conjugation. The two rounded masses of cell-contents lie close together or separated by some of the enveloping jelly, and each develops independently into an auxospore.

(5) A pair of Diatoms approximate, but before conjugation the protoplasm of each cell divides into two daughter-cells. Two auxospores are then formed by the fusion of a daughter-cell from each mother-cell with a daughter-cell from the opposite mother-cell. This is known to occur in *Amphora ovalis* Kütz., *Epithemia Argus* (Ehrenb.) Kütz.[1], and *Navicula limosa* Kütz. (Fig. 125 A.)

A normal auxospore can be regarded as one produced by the conjugation of two cells (or gametes), those produced without conjugation being parthenogenetic. The first and the fourth methods are the ones most frequently observed. The most important feature in the formation of an auxospore is the increase in size of the cell. Karsten[2] considers that the majority of Diatoms exhibit undoubted sexuality.

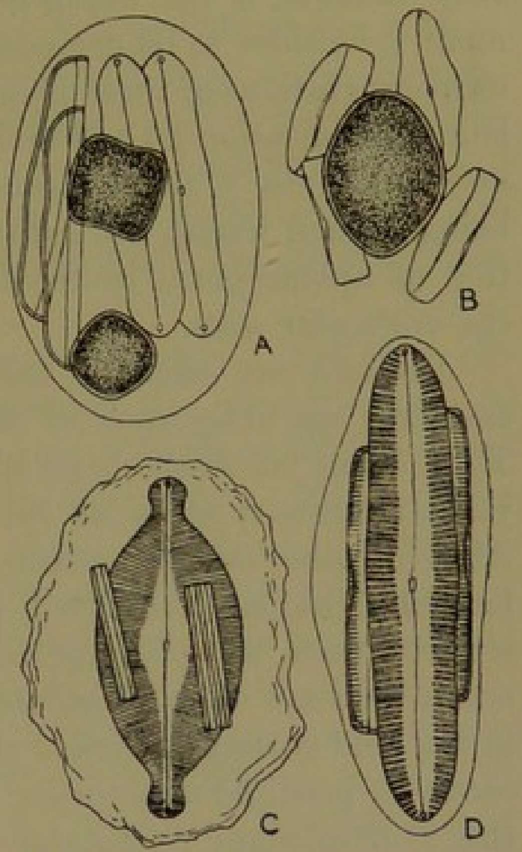

Fig. 125. A, *Navicula limosa* Kütz., from the New Forest, Hants. (×450). B, *Achnanthes flexella* (Kütz.) Bréb., from Craig-an-Lochan, Scotland (×450). C, *Navicula Amphisbæna* Bory, from Barnes Common, Surrey (×450). *N. viridis* Kütz., from Clough, Antrim, Ireland (×350). C and D illustrate the first method of auxospore formation, B, the third method, and A the fifth method.

Castracane and other observers have recorded another method of reproduction by the formation of small *spores* within the frustules. Kitton[3] and Lockwood[4] have each stated that Diatoms may possess spores ("*microspores*") so small as to pass through

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[1] Klebahn in Jahrb. für wissensch. Bot. xxix, 1896.

[2] Karsten in Biol. Centralbl. xx, 1900; Flora, lxxvii, 1900.

[3] Kitton in Journ. Quekett Micr. Club, ser. 2, ii, 1885, p. 178.

[4] Lockwood in Journ. New York Micr. Soc. 1886, ii, p. 153.

filter-papers, but these observations require confirmation, as they do not seem to agree with the researches of Miquel. Castracane[1] has stated that the normal method of reproduction of Diatoms is by spores or germs, and that multiplication by division, although very common, is the exception rather than the rule. This statement I consider to be erroneous, as I am fully convinced from my own observations of these plants that the normal method of increase is a multiplication by cell-division.

Sometimes a resting condition occurs, a pair of new valves being formed within the old ones. This corresponds to the formation of aplanospores in the Chlorophyceæ, and has been termed the *craticular state*.

Diatoms are amongst the commonest of microscopic objects, and they are ubiquitous in all kinds of damp and wet situations. They occur in fresh, brackish, and salt water, often forming a yellowish-brown scum at the surface, or thickly clothing larger Algæ or other aquatic plants. They are most abundant in cold latitudes, having a decided preference for cold water, although some of them have become adapted to life in hot-springs. In the ocean they are more abundant than any other pelagic plants, and in the cold surface-waters of the Arctic and Antarctic Oceans they occur in prodigious quantity. They form a considerable part of the food of many freshwater and marine animals, and are often found in quantity in the alimentary tracts of Molluscs, Crustacea, Tunicates and Fishes. They are found in abundance in Guano, having passed through the alimentary canals of birds which feed on marine animals. Since they occur in quantity in the surface-waters of the ocean and of lakes, they constitute a very large proportion of both the marine and freshwater plankton. Many of these plankton Diatoms are furnished with long spines or spinous processes, and they are frequently associated to form free-floating colonies. Some genera and species are exclusively pelagic in habit. According to Voigt[2] such forms are sometimes furnished with gelatinous threads and membranes, by means of which their floating capacity is materially assisted.

Some of the freshwater species are occasionally the cause of foulness of drinking water[3]. This is due to the formation of an oil

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[1] Castracane in Annal. de Micrographie, ix, 1897.

[2] Voigt in Biol. Centralbl. xxi, 1901.

[3] Whipple & Jackson in Journ. New Engl. Waterworks Assoc. xiv, 1889.

analogous to the essential oils, and the foulness could be prevented by storing water in the dark. It has been suggested that the immense beds of petroleum which exist in certain regions have had their origin from the oil secreted in the protoplasm of Diatoms[1].

Miquel has made many interesting experiments on the cultivation of Diatoms, and he finds that, although they thrive in water at freezing point, they cannot withstand being frozen. Their vitality is destroyed at − 15° C., and a temperature above 45° C. is rapidly fatal. Desiccation is also fatal. The yellow rays of light are the most favourable for cultivation, so that cultures should be placed under yellow glass.

Large numbers of fossil Diatoms are known. Not only are these minute plants actively engaged at the present time in forming oceanic and lake deposits, but the numerous *Diatomaceous Earths* are a proof of their activity in former ages. These earths are of a white or grey colour, often so soft and friable as to crumble readily between the fingers, and they are composed almost entirely of the siliceous valves of Diatoms. They may have had a marine or a freshwater origin, and most of the forms contained in the deposits belong to genera, and many of them to species, now living. The deposits have been formed in past times at various periods of the earth's history, but they appear to be principally associated with rocks belonging to the Tertiary formations. Some of them are of economic importance, being used as polishing powders ("Tripoli"), as non-conducting materials, as absorbents for nitroglycerin in the manufacture of dynamite ("Kieselguhr"), as a dentifrice, and for other purposes. Although many species usually occur in deposits of this nature, one is usually predominant, forming the great mass of the material. In some parts of the world, such as in China, Japan, Siberia, Lapland, and other countries, certain earthy deposits of a diatomaceous origin are mixed with meal to make a kind of flour. The best known deposits in the British Islands are those at Dolgelly in Wales, and at Toome Bridge in Antrim, Ireland. The deposit at Biln, in Bohemia, which is about 14 ft. in thickness, was estimated by Ehrenberg to contain some 40,000,000 of the frustules of Diatoms in every cubic

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[1] Krämer & Spiller in Berichte Deutsch. Chem. Gesellsch. xxxii, 1899.

inch[1]. The well-known deposit at Richmond, Virginia, U.S.A., is very extensive and reaches a thickness of 30 ft., while on some of the recent geological surveys beds have been discovered in the western states of America no less than 300 ft. in thickness. These earths contain on an average 80 °/ₒ of Silica.

It is generally assumed that the earliest appearance of fossil Diatoms is in the Upper Cretaceous (chalk), although Castracane has recorded the occurrence of certain species in coal from the English Carboniferous beds, and Edwards[2] has stated that he has found valves of Diatoms belonging to the genera *Synedra* and *Melosira* in still older rocks in New Jersey. These observations, however, require confirmation.

The Bacillarieæ has been placed by some authors in close proximity to the Conjugatæ and by others as an order of the Phæophyceæ, but the characters of Diatoms are sufficiently distinctive and their structure so uniform as to warrant their position as a distinct class, the affinities of which are doubtful.

I have adopted, with slight alterations, the classification of Diatoms put forward by Schütt[3], and since followed by Lemmermann and others. It is to my mind the most natural one, as it separates all those Diatoms with a radial symmetry from those in which the frustules are zygomorphic or otherwise irregular.

Classifications based upon the disposition and mode of division of the chromatophores, such as those suggested by Pfitzer[4], Petit[5], Pelletan[6] and Ott[7], are impracticable owing to the fact that so many genera and species are unknown in the living state. That published by Prof. H. L. Smith[8] and subsequently adopted by Van Heurck in his 'Treatise on the Diatomaceæ,' is based upon certain features in the structure of the valves, such as the form of the raphe, but these characters are not so clear and distinctive

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[1] In a report on the chemical composition of the plankton of the Baltic Sea, Brandt states that 675,000,000 of the dried frustules of Diatoms (mostly *Chætoceros*) weigh one gramme. Cfr Brandt, 'Beitr. zur Kenntn. der chem. Zusammens. des Planktons,' Wissensch. Meeresuntersuch., Neue Folge, Bd iii, Heft 2, 1898.

[2] Edwards in Amer. Monthly Micr. Journ. xx, 1899, p. 292.

[3] Schütt in Engler & Prantl's Die Natürl. Pflanzenfam. I Teil, i, Abteilung b, 1896.

[4] Pfitzer, 'Untersuchungen über Bau und Entwicklung der Bacillariaceen,' Bonn, 1871.

[5] Petit in Bull. de la Soc. Bot. de France, Paris, 1877.

[6] Pelletan in Journ. de Micrographie, xvi, 1892.

[7] Ott in S. B. k. Akad. Wissensch. Wien, cix, 1900.

[8] H. L. Smith in The Lens, Chicago, 1872.

as the primary divisions adopted by Schütt. The Bacillarieæ are divided into the two following orders:—

Order I. *Centricæ.* Valves with a concentric or radiating symmetry around a central point; without a raphe or pseudo-raphe; valve-view circular, polygonal, or broadly elliptical, rarely boat-shaped or irregular.

Order II. *Pennatæ.* Valves truly zygomorphic or irregular, never centric; valve-view mostly boat-shaped or needle-shaped, with markings arranged in a sagittal manner in relation to the raphe or pseudo-raphe (sagittal axis).

Order I. CENTRICÆ.

This order includes a relatively small proportion of the known species of Diatoms, and few even of these are inhabitants of fresh water.

The cells are commonly cylindrical and when seen in cross-section (or from the valve-view) they are circular, polygonal, elliptical, or rarely more elongate. Some forms are disc-shaped, their diameter being much greater than their length; others are of equal length and breadth or longer than their diameter. Many occur as solitary, free-floating individuals, but others are joined more or less firmly by their valve-faces to form cylindrical filaments of variable length.

The structure of the valves is typically centric, even in those species in which the valve-view is zygomorphic in outline. The markings on the valve-face are either concentrically disposed or arranged in the form of radiating striæ, the latter often terminating in marginal punctulations or dots. In all cases the arrangement of the markings is in relation to a morphological centre and never in relation to a middle line. There is no raphe or pseudo-raphe.

There are usually many small parietal chromatophores of a plate-like form in each cell, but occasionally only two large plates are present.

Auxospores are known only in a few species.

The order is divided into four sub-orders, only two of which include British freshwater species. One of the sub-orders—the *Biddulphioideæ*—includes a large number of conspicuous marine Diatoms.

Sub-order 1. *Discoideæ.* Cells shortly cylindrical or disc-shaped, in valve-view circular; hyaline or with radiating or areolated markings.

Sub-order 2. *Solenoideæ.* Cells elongate, cylindrical or subcylindrical, circular or broadly elliptical in cross-section (or in the valve-view); valves exhibiting a scaly structure; apices often obliquely conical and furnished with a spine or a hair.

Sub-order 1. DISCOIDEÆ.

In this division of the Centricæ the cells are more or less shortly cylindrical and often disc-shaped. In the valve-view or in cross-section they are circular, and the valve-faces are frequently very convex. The cells may be solitary and free-floating, or they may be joined into long chains or filaments by gelatinous cushions. The valves are generally without any kind of protuberances, and they may be hyaline or exhibit areolations or radial striations of any degree of coarseness. Very often the markings on the valves are divided into distinct sectors, and sometimes there is a ring of small spines (rarely of long bristles) at the outer margin of each valve.

The chromatophores consist of numerous small plates, either circular in outline or with lobed margins. The nucleus is generally central, but it may lie near the girdle in a slight thickening of the primordial utricle.

Only two British families of this sub-order possess freshwater representatives.

Family 1. *Melosiraceæ.* Cells subspherical or shortly cylindrical, circular in cross-section, and united to form long filaments or chains; girdle usually with a well-marked structure.

Family 2. *Coscinodiscaceæ.* Cells mostly disc-shaped and solitary; valve-view circular; girdle usually without structure.

Family 1. **MELOSIRACEÆ.**

The cells are mostly shortly cylindrical, rarely subspherical, and they are usually united by gelatinous cushions to form filaments of considerable length. The valve-view (and the cross-section of the cell) is circular or very rarely somewhat compressed. There is a great uniformity in the type of the cell, and the valves may be flat, convex, or greatly arched. The valve-face is often divided into concentric areas, a broad central region and a peripheral ring of variable width. In some forms there is a circular keel, occasionally provided with small wart-like protuberances, and in others the valves possess a peripheral ring of small spines or teeth. The girdle usually exhibits a well-marked structure. The chromatophores are small, numerous, parietal and plate-like.

Genus **Melosira** Ag., 1824. [*Gaillionella* Bory; *Lysigonium* Link; *Liparogyra* Ehrenb.; *Orthosira* Thwaites; *Sphærophora* Hass.] The frustules are cylindrical, ellipsoidal, or globular, and are united to form filaments of variable length. The valve-view is circular and plainly punctate. Auxospores are formed without conjugation, by the rejuvenescence of the contents of a mother-cell to form a much larger daughter-cell, the long axis of which is either parallel or at right angles to that of the mother-cell. These large daughter-cells continue to divide while still remaining parts of the original filament.

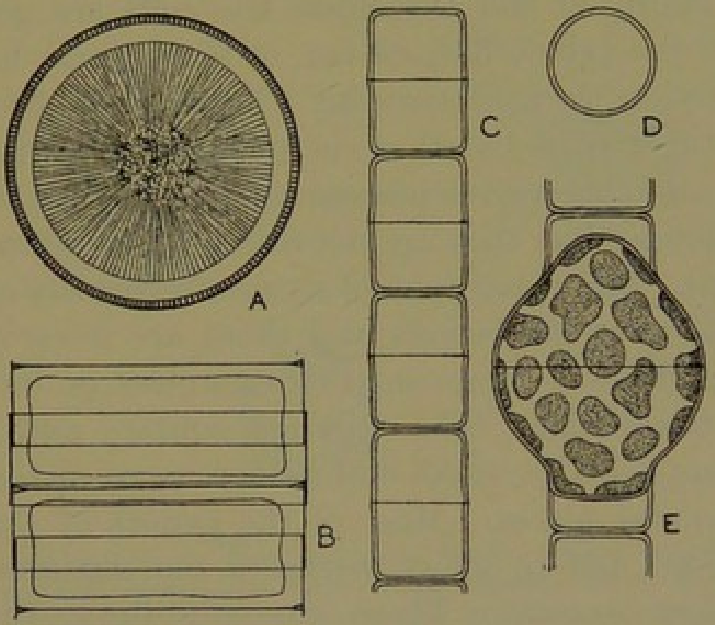

Fig. 126. A and B, *Melosira arenaria* Moore, from Shipley Glen, W. Yorks. C—E, *M. varians* Ag., from the river Cam at Cambridge; E, showing formation of auxospore. (All × 450.)

The genus is divided into four sections:—Sect. 1. *Eumelosira* Schütt, including *M. arenaria* Moore, *M. granulata* (Ehrenb.) Ralfs and *M. Roeseana* Rabenh.; Sect. 2. *Lysigonium* Link, including *M. varians* Ag.; Sect. 3. *Podosira* Ehrenb., marine; Sect. 4. *Gaillionella* Bory, including *M. nummuloides* (Bory) Ag.

There are some six or eight freshwater species occurring in the British Islands. *M. varians* Ag. is one of the most abundant of the centric Diatoms, occurring in large quantities in ponds, ditches and slow rivers (fig. 126 C—E). *M. arenaria* Moore occurs on wet rocks, sometimes forming crisp mat-like masses on dripping sandstone rocks. It is common on the Carboniferous Sandstone of England. *M. granulata* (Ehrenb.) Ralfs occurs in boggy pools and also in the plankton. *M. Roeseana* Rabenh. occurs on damp rocks among various Myxophyceæ and also among damp mosses. The filaments of *M. granulata* are sometimes not more than 5μ in diameter, but those of *M. arenaria* reach 100μ in diameter (fig. 126 A and B).

Family 2. **COSCINODISCACEÆ.**

In this family of the Discoideæ the cells are generally disc-shaped, with the valves flat, convex, or more rarely highly arched. In the valve-view they are circular. There is an absence of warts or other protuberances, but there is sometimes a peripheral ring of spines. In some the valves possess concentric areas with different types of structure. but they are not divided into sectors by special radial strands. The usual type of structure consists of radial rows of punctulations or areolations, and there are never any excentric spots. The girdle is commonly structureless or its structure is almost indeterminable. The cells are solitary and free-floating. The chromatophores are small and numerous, consisting of rounded or lobed, parietal plates. Most of the genera of this family are marine or fossil, and in many instances the distinctions between them are very obscure. There are only three British genera inhabiting fresh water.

Genus **Cyclotella** Kütz., 1833. The frustules are disc-shaped and the valves are circular, exhibiting two concentric areas. The inner area is smooth or granulate, but the outer annular area possesses radiating striæ, which are smooth or punctate. Occasionally minute spines are present near the margin of the disc. The valves are excentrically bullate in most species, so that the frustule seen from the girdle-view possesses undulate margins.

There are five species known to occur in the freshwaters of the British Islands. *C. operculata* Kütz. (fig. 127 B and C), *C. Meneghiniana* Kütz., and *C. Kützingiana* Chauvin are more or less widely distributed, and *C. comta* (Ehrenb.) Kütz. is often abundant in the plankton. They vary in diameter from 10—30μ.

Genus **Stephanodiscus** Ehrenb., 1845. The valves are circular, with radiating series of punctulations alternating with radiating smooth spaces which present the appearance of lines. In the centre of the valve there are scattered punctulations and round the margin is a ring of simple acute spines. The centre of the valve is generally bullate.

St. Hantzschianus Grun. occurs in the plankton of Lough Neagh and in the river Thames; diam. of frustules 12—20μ; fig. 127 A.

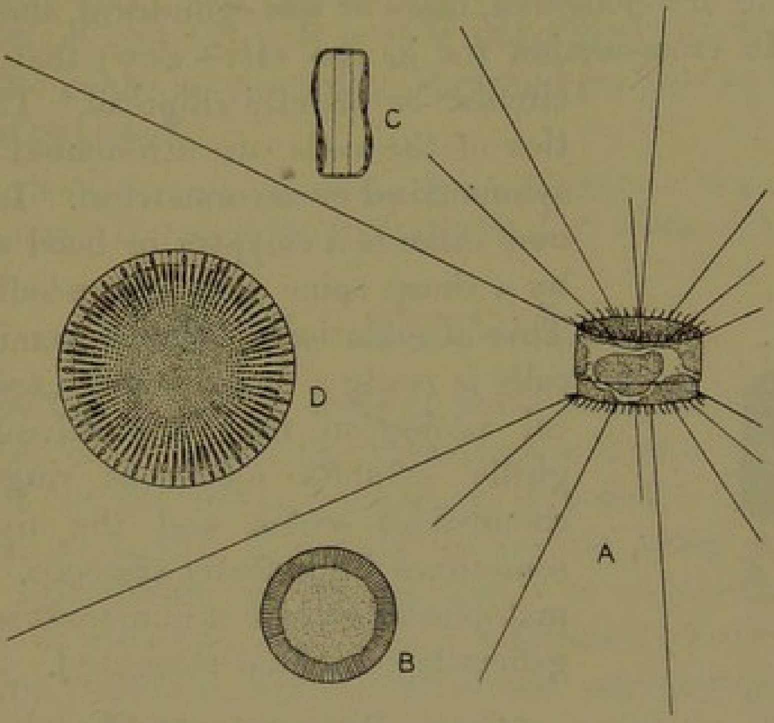

Fig. 127. A, *Stephanodiscus Hantzschianus* Grun. (After Schröder, × 544.) B and C, *Cyclotella operculata* Kütz., from Shipley Glen, W. Yorks. (× 450). D, *Coscinodiscus lacustris* Grun., from the plankton of Lough Neagh, Ireland (× 450).

Genus **Coscinodiscus** Ehrenb., 1838. The valves are circular, elliptical, or rarely subrhomboidal, without any striæ or costæ, but with radiating punctulations or areolations. There is a distinct edge to the disc, usually furnished with a ring of submarginal spines.

The limits of this genus are exceedingly difficult to define and the synonymy is most confusing. There are over 300 known species, mostly marine, and only one occurs in the freshwaters of the British Islands. *C. lacustris* Grun. occurs in the still waters of rivers and lakes, and reaches a diameter of 60μ (fig. 127 D). It sometimes occurs in the plankton of lakes.

Sub-order 2. SOLENOIDEÆ.

In this second sub-order of the Centricæ the cells are rod-shaped, many times longer than the diameter, and mostly circular in cross-section. After division the cells sometimes remain attached in more or less fragile chains.

Family 1. RHIZOSOLENIACEÆ.

The cells are elongated, more or less cylindrical, and often form chains. In cross-section (or in the valve-view) they are either circular or broadly elliptical. The extremities of the cells are attenuated and either symmetrical or asymmetrical. In the latter case there is a calyptra or hood surmounted by a sharp spine or a long needle-like seta. This attenuation of the extremities of the cells is really a more or less excentric, conical projection from the valve-faces. The girdle exhibits numerous rings of large rhomboidal scales, and the frustules are sometimes imperfectly siliceous. The chromatophores consist of numerous small plates, generally somewhat elongated.

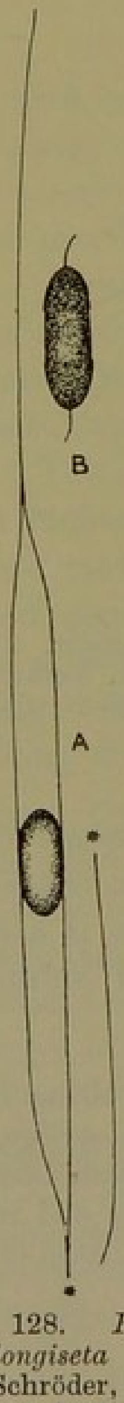

Fig. 128. *Rhizosolenia longiseta* Zach. (After Schröder, × 544.) A, frustule showing resting spore; B, germination of resting spore.

Genus **Rhizosolenia** Ehrenb., 1858; em. Peragallo, 1892. The frustules are very elongated and subcylindrical. The valves are asymmetrical, terminating in a hood which is furnished with a spine or a long seta. The spines or bristles are excentric, but are disposed parallel to the long axis of the cell. The girdle region of the cell consists of rings of scales, which are more or less imbricate. The chromatophores are small, rounded or elongated plates. The auxospores are formed without conjugation. Hypnospores are sometimes produced, one or two in each mother-cell.

Most of the species of this genus are marine, but two are known to occur in the freshwater plankton of the British Islands. *R. longiseta* Zach. (fig. 128) occurs in the plankton of Loch Shin and Loch a Gharbh Bhaid Mhoir, Sutherland, and *R. eriensis* H. Smith also occurs in Loch Shin.

Genus **Cylindrotheca** Rabenh., 1859. The frustules are symmetrical and spindle-shaped, with the apices much attenuated.

They are ornamented with several spiral lines, running along the walls of the valves from end to end of the frustule and crossing one another at intervals. The chromatophores are small and granular. The structure of the cell-wall is only imperfectly known and the position of the genus is uncertain. It should perhaps be associated with the Nitzschiaceæ.

C. gracilis (Bréb.) Grun. [=*Nitzschia Tænia* W. Sm.] is the only known species and is a rare Diatom in the fresh and brackish waters of England.

Order II. PENNATÆ.

This is by far the largest order of the Bacillarieæ and includes all those Diatoms in which the valves are not of a centric type. The structure of the valves is arranged in relation to a line and not to a central point. The cells are acyclic, being rod-shaped, elliptic, or boat-shaped in cross-section (or valve-view). The marks (striæ or costæ) on the valves are disposed on either side of a sagittal line (which is either a raphe or a pseudo-raphe), sometimes arranged at right angles to it and sometimes forming an acute angle with it.

The cells exhibit great variability of form and in most cases are truly zygomorphic. The commonest type of cell is the naviculoid or boat-shaped type, but the frustule may be a flattened plate or an elongated rod, which may be straight, arcuate, or sigmoid.

The different forms exhibit all degrees of development of the raphe. In the lowest forms of the Fragilarioideæ it is entirely wanting, but in other forms of the same group there are the first beginnings of a pseudo-raphe. In the Naviculoideæ the raphe is present on both valves of the frustule, and it is sometimes situated on a median or obliquely disposed keel. It reaches its highest development in the Naviculaceæ.

There is a striking absence of spines and long processes from the frustules of Diatoms of this order, although in a few instances they are furnished with small prickle-like excrescences.

Great variation is exhibited in the size and form of the chromatophores, which are in all cases parietal. In the lower families of the Pennatæ each cell contains a large number of small plates (the coccochromatic arrangement), but in the higher families one or few large lobed plates occupy the greater part of the inner surface of the cell-wall (the placochromatic arrangement).

The methods of formation of auxospores are as yet only imperfectly known. In some of the higher forms the method is a sexual one, and the highest known type is found in the Surirellaceæ.

The order is divided into the following sub-orders:—

Sub-order 1. *Fragilarioideæ.* Cells mostly straight, rod-shaped or lanceolate, without a raphe, but sometimes with a pseudo-raphe or showing indications of the commencement of a raphe.

Sub-order 2. *Achnanthoideæ.* Cells crooked or suddenly bent, with a raphe on one valve and a pseudo-raphe on the other.

Sub-order 3. *Naviculoideæ.* Each valve of the cell with a raphe; valves without a keel (or rarely with a keel) in the sagittal line (line of raphe).

Sub-order 4. *Nitzschioideæ.* Each valve of the cell with a raphe, which is situated in a sagittal keel with carinal dots. The keels of the two valves are situated on opposite sides of the frustule or displaced to the same side. Cells in transverse section rhombic.

Sub-order 5. *Surirelloideæ.* Each valve of the cell with a pseudo-raphe and generally with spreading submarginal wings; valves strongly costate.

Sub-order 1. FRAGILARIOIDEÆ.

In this sub-order the cells are mostly rectangular in the girdle-view, and rod-shaped, lanceolate, or arcuate in the valve-view. In the Meridionaceæ they are elongate and cuneate in both views. Sometimes they occur as solitary individuals, but they are more commonly joined by gelatinous cushions into either straight or zig-zag, ribbon-like filaments. In some there are false septa traversing the frustules, but in others these are absent. There is no raphe, but in most of them there is a pseudo-raphe forming a sagittal line in relation to which the markings of the valves are arranged. In the Meridionaceæ the presence of this pseudo-raphe is scarcely evident. The chromatophores are mostly numerous, small and granular, but in the Eunotiaceæ they are few in number, large and plate-like.

The sub-order includes the following five families:—

Family 1. *Tabellariaceæ.* Cells forming tabular plates in the girdle-view, united to form band-like or zig-zag filaments; with well-developed false internal septa. Valves with a straight median pseudo-raphe.

Family 2. *Meridionaceæ.* Cells elongate and cuneate, united to form a flat spiral filament or situated on branched gelatinous stalks; with false septa. Valves with a very indistinct median pseudo-raphe.

Family 3. *Diatomaceæ.* Cells mostly rod-shaped or subrectangular, united into band-like or zig-zag filaments; valves with feebly developed transverse septa and a median pseudo-raphe.

Family 4. *Fragilariaceæ.* Cells in girdle-view rectangular, generally united to form ribbon-like filaments. Valves without any false septa and with a median pseudo-raphe.

Family 5. *Eunotiaceæ.* Cells slightly curved or arcuate in the valve-view, solitary or united into band-like filaments. Pseudo-raphe nearer to one edge of the valve.

Family 1. **TABELLARIACEÆ.**

The cells are stout and expanded in the girdle-view to form flat, rectangular plates. In the valve-view they are bilaterally symmetrical, linear or linear-elliptic, often with a swollen median portion and sometimes with subcapitate extremities. They are mostly united to form band-like or zig-zag filaments by mucous cushions on the valve-faces or at the angles. In the interior of the frustules are two or more false longitudinal septa. Both valves are precisely similar with a straight median pseudo-raphe (sagittal line). The chromatophores are numerous and granular.

Genus **Tetracyclus** Ralfs, 1843; em. Grun., 1862. The frustules are tabular and are united to form short or long, ribbon-like filaments. There are a number of perforated longitudinal septa, which appear in the girdle-view as ribs with thickened apices. There are also false transverse septa at right angles to these, which appear as few or many costæ (or ribs) in the valve-view. The median portion of the valve may or may not be swollen.

There are two British species, *T. lacustris* Ralfs (length of valves up to 30μ; fig. 129 A—C), which prefers hilly districts and is often found in the plankton of mountain lakes, and *T. rupestris* (A. Br.) Grun., a species which occurs on dripping rocks in mountainous areas.

Genus **Tabellaria** Ehrenb., 1839. The frustules are tabular and united to form zig-zag filaments, the basal cell often being fixed to the substratum by a mucous cushion at one corner of the valve. There are a number of perforated longitudinal septa, which appear in the girdle-view as prominent lines which fail to reach the middle of the cell. Sometimes instead of a large perforation in a septum, the septa are alternate, and only extend about two-thirds the distance from one end of the valve to the centre. The valve-view is sublinear, more or less strongly swollen in the middle and subcapitate at the extremities; its surface is transversely striated, the striations being slightly broken in the middle, thus indicating the presence of a rudimentary pseudoraphe. The auxospores are formed two in each mother-cell.

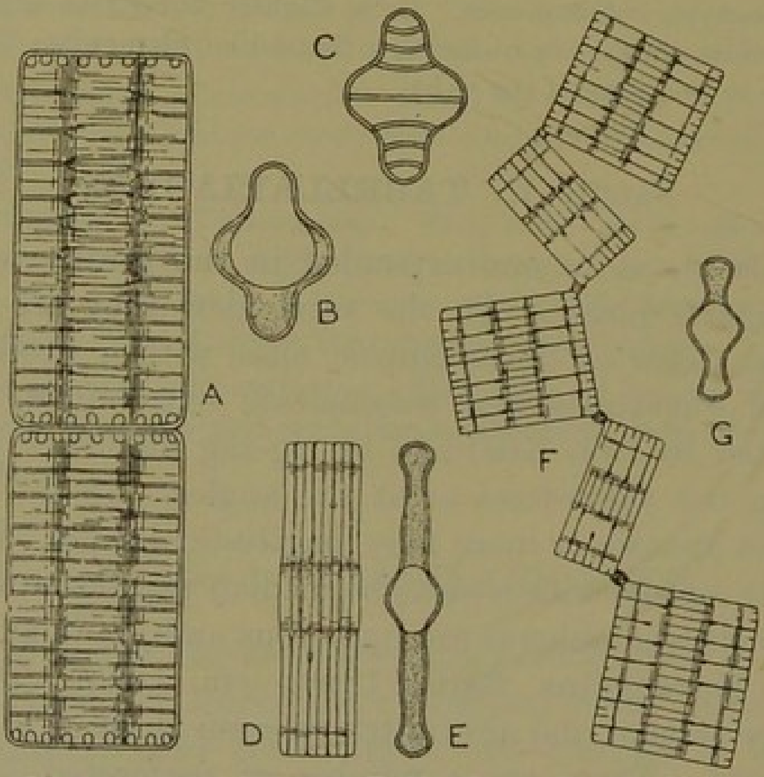

Fig. 129. A—C, *Tetracyclus lacustris* Ralfs, from the plankton of Loch Shin, Sutherland. D and E, *Tabellaria fenestrata* (Lyngb.) Kütz., from Mickle Fell, N. Yorks. F and G, *T. flocculosa* (Roth) Kütz., from Mickle Fell, N. Yorks. (All × 500.)

There are two common British species, of which *T. flocculosa* (Roth) Kütz. (fig. 129 F and G) is the most abundant. *T. fenestrata* (Lyngb.) Kütz. (fig. 129 D and E) has more slender and elongate valves, the largest specimens noticed having reached a length of 137 μ[1]. A pretty variety of the latter species—var. *asterionelloides* Grun.—in which the frustules are arranged in circles, is known from the plankton of Loughs Neagh and Beg in Ireland, and from that of many lochs in Scotland and in the English Lake District. It is probably general in the British freshwater plankton and there are two very distinct forms of it.

Genus **Diatomella** Grev., 1855. The frustules are tabular, solitary, or joined to form ribbon-like filaments. There are only

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[1] West & G. S. West in Trans. Roy. Irish Acad. 1902, vol. xxxii, sect. B, part 1, p. 90, t. iii, f. 8.

two false longitudinal septa, well seen in the rectangular girdle-view, and which are perforated by three openings, one central and two polar. The valve-view is oblong-lanceolate, with a slight median swelling; its surface is transversely striated with indications of a pseudo-raphe and slight traces of nodules.

D. Balfouriana Grev. is a rare British Diatom the frustules of which reach a length of 30 μ.

Genus **Denticula** Kütz., 1844. The frustules are more or less tabular, solitary or attached to form short filaments. There are a row of imperfect transverse septa in each valve, which appear as capitate marginal ribs in the subrectangular girdle-view. The valve-view is lanceolate and the septa appear as strong transverse ribs, between which are delicate punctate striæ. The face of each valve is carinate and for this reason *Denticula* has been associated with *Nitzschia*. In the region of the girdle, and between it and the valve on either side, is a longitudinal septum with a row of perforations, the edges of these perforations being fused to the transverse septa. There is no raphe or pseudo-raphe.

D. elegans Kütz. and *D. tenuis* Kütz. (fig. 130 C and D) are both frequent amongst mosses on wet or dripping rocks. Valves up to 45 μ in length.

Family 2. MERIDIONACEÆ.

The frustules are more or less rod-shaped and cuneiform, and are either united by their valve-faces to form a flat spiral filament, which often makes two complete turns, or they are disposed at the extremities of a branched system of gelatinous stalks. In both the valve- and girdle-views the frustules are symmetrical in relation to a longitudinal axis, but asymmetrical about a transverse axis. In some there are two (sometimes more) false longitudinal septa, but no transverse septa; sometimes these are confined to the broad end of the frustule (*Licmophora*) and at other times they extend the whole length of the valves (*Climacosphenia*). In others there are no false longitudinal septa, but numerous short transverse septa pass across the keeled face of each valve (*Meridion*). There is no raphe, but there is a structureless sagittal line which indicates the first commencement of a pseudo-raphe. Reaching almost up to this clear line are numerous transverse striations of a very delicate character. The chromatophores are scattered in the form of numerous small plates. Two auxospores arise from two mother-cells.

Genus **Meridion** Ag., 1824. The frustules are very similar to those of the genus *Diatoma*. The valve-view is clavate, sometimes with a subcapitate apex, and the girdle-view is cuneate with a truncate base and apex. There are no false longitudinal septa, but a number of imperfect transverse septa, which appear as very short marginal costæ in the girdle-view and as transverse costæ in the valve-view. Between these costæ are fine punctate striæ interrupted in the middle by a smooth line or pseudo-raphe. The frustules remain attached after division, forming beautiful, flat, spiral filaments, which are free-floating.

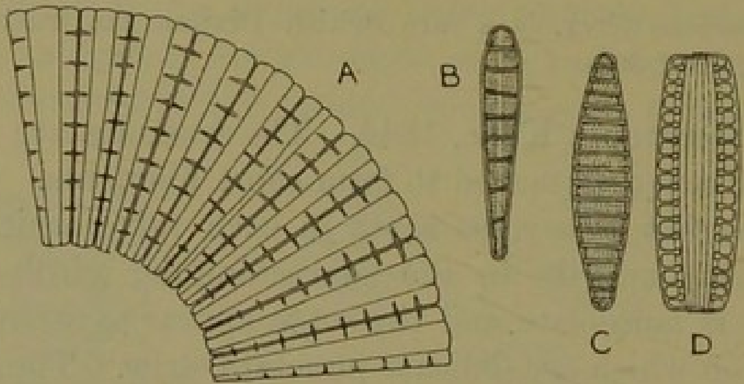

Fig. 130. A and B, *Meridion circulare* (Grev.) Ag., from Shipley Glen, W. Yorks. (×500). C and D, *Denticula tenuis* Kütz., from Wicken Fen, Cambridge (×600).

M. circulare Ag. (fig. 130 A and B) is often abundant in stagnant ditches and ponds, and may frequently be obtained in pure masses. The var. *constrictum* (Ralfs) V. H. is also frequent. It is a Diatom which appears to be most abundant in the early spring, often forming brown flocculent masses around submerged grass-leaves, etc. It is one of the prettiest of British freshwater Diatoms; length of valves up to 25 μ.

Family 3. DIATOMACEÆ.

The frustules are elongate, rod-shaped or lanceolate in the valve-view, and are united to form ribbon-like or zig-zag filaments. There is no keel, but the valves possess strongly marked transverse ribs which project inwards as more or less deep transverse septa. There are no false longitudinal septa. The pseudo-raphe is conspicuous or it may be wanting. The girdle-view is rectangular.

Genus **Diatoma** D.C., 1805. The valve-view is lanceolate or linear, sometimes with capitate extremities, and is furnished with transverse ribs or costæ, between which are fine punctate striæ. The pseudo-raphe is indistinct. Sometimes there are slight traces of longitudinal septa. This genus is distinguished from *Denticula* by the absence of a keel on the valve-faces and the absence of perforated longitudinal septa.

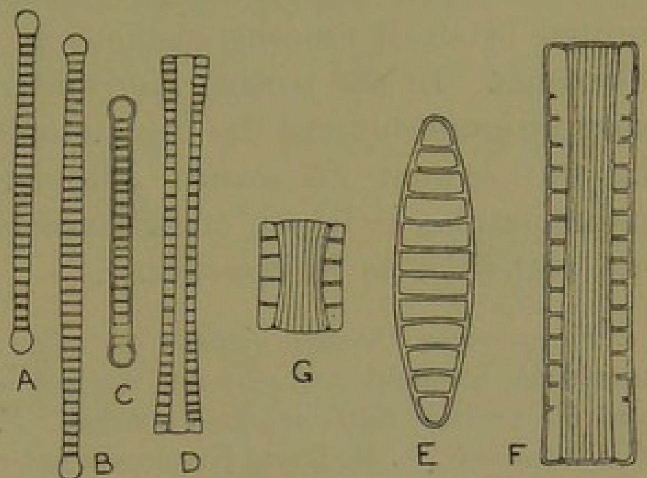

Fig. 131. A—D, *Diatoma elongatum* Ag., from Wicken Fen, Cambridge. E and F, *D. hiemale* (Lyngb.) Heib., from Howgill Fells, W. Yorks. G, *D. hiemale* var. *mesodon* (Kütz.) V. Heurck, associated with the typical form. (All × 500.)

There are four British species, three of which, *D. vulgare* Bory (length of valves 40—50 μ), *D. elongatum* Ag. (length of valves up to 70 μ; fig. 131 A—D) and *D. hiemale* (Lyngb.) Heib. (fig. 131 E—G) are common. The two former are generally distributed in quiet waters, but the last-named is more abundant in hilly districts, often occurring in pure masses or mixed with a smaller variety (var. *mesodon*).

Family 4. FRAGILARIACEÆ.

In this family the cells are mostly elongate and rod-shaped. They may be solitary, joined to form ribbon-like or zig-zag filaments, or arranged in a circle like the radiating spokes of a wheel. There is no keel, the valve-faces being plane or almost plane. The pseudo-raphe is evident or entirely wanting, and there are sometimes slight traces of central and polar nodules. The girdle-view is generally rectangular, but the valve-view is lanceolate or elongate, sometimes with produced apices or with one or two lateral swellings. There are transverse costæ or ribs and no false septa, but the valve-faces are marked with transverse punctate striæ of variable intensity. The chromatophores are sometimes small and granular, or they may be in the form of large plates.

Genus **Fragilaria** Lyngb., 1819. [*Odontidium* Kütz.; *Grammatonema* Kütz.; *Ralfsia* O'Meara.] The valve-view is fusiform, lanceolate or linear, generally with produced apices, and sometimes with one or two lateral inflations. The pseudo-raphe is sometimes scarcely evident, sometimes broad, and there are no nodules. The valve-faces possess transverse striations, which may be exceedingly fine or rather coarse and composed of bead-like punctulations. The girdle-view is rectangular. The frustules are joined together by their valve-faces to form ribbon-like filaments, or they are united by small mucous cushions at their corners to form zig-zag filaments. In the section *Eufragilaria* Ralfs the pseudo-raphe is very insignificant and the chromatophores are small and granular; in the section *Staurosira* Ehrenb. (= *Odontidium* Kütz.) the pseudo-raphe is broad, often lanceolate, and the chromatophores are plate-like as in *Synedra*.

F. capucina Desmaz. (length of valves 30—60 μ; fig. 132 C and D) is much the commonest freshwater species, but *F. mutabilis* (W. Sm.) Grun. and *F. virescens* Ralfs are also general. *F. construens* (Ehrenb.) Grun. and *F. Crotonensis* (A. M. Edw.) Kitton are rarer freshwater species.

Genus **Synedra** Ehrenb., 1831. The frustules are much elongated and occasionally bent or somewhat undulated. The valve-view is commonly linear or linear-lanceolate, with obtuse or subcapitate extremities, and there is generally a pseudo-raphe or a hyaline sagittal line. In the centre of the valve-face there is generally a small rounded hyaline space, and sometimes central and polar nodules are present. The valves are finely striated, the striæ being transverse and reaching up to the pseudo-raphe on each side. The girdle-view is elongated with truncate apices. Each frustule contains two plate-like chromatophores with undulated or indented edges. Most of the species are solitary, but some occur clustered in radiating or fan-shaped colonies.

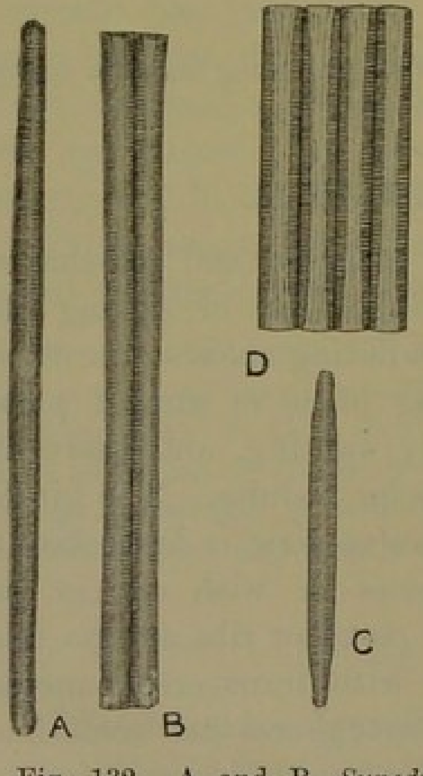

Fig. 132. A and B, *Synedra pulchella* Kütz., from Cambridge (×500). C and D, *Fragilaria capucina* Desmaz., from Shipley, W. Yorks. (×520).

There are about eight British freshwater species, several of which are common, being found in almost every kind of suitable locality and often occurring in immense abundance in the waters of lakes and springs. *S. Ulna* (Nitzsch) Ehrenb. (length of valves 150—250 μ), *S. pulchella* Kütz. (length 60—130 μ; fig. 132 A and B) and

S. Acus (Kütz.) Grun. are the most abundant. A variety of *S. Ulna*—var. *splendens* (Kütz.) V. H.—is a very striking object, the valves being arranged in radiating groups and reaching a length of 340 μ. *S. capitata* Ehrenb. is general, but not so common as the previous species.

Genus **Asterionella** Hassall, 1850. The frustules are narrow and linear, with swollen apices both in the valve- and girdle-views; they are grouped in radiating colonies in one plane, like the spokes of a wheel, their basal extremities being attached by delicate mucous cushions. In the valve-view the cells are narrowly linear-fusiform with capitate apices, one apex being larger than the other. In the girdle-view the cells are linear with swollen, truncate extremities. The valves possess delicate transverse striations, and there is a median pseudo-raphe and a hyaline area in each capitate apex.

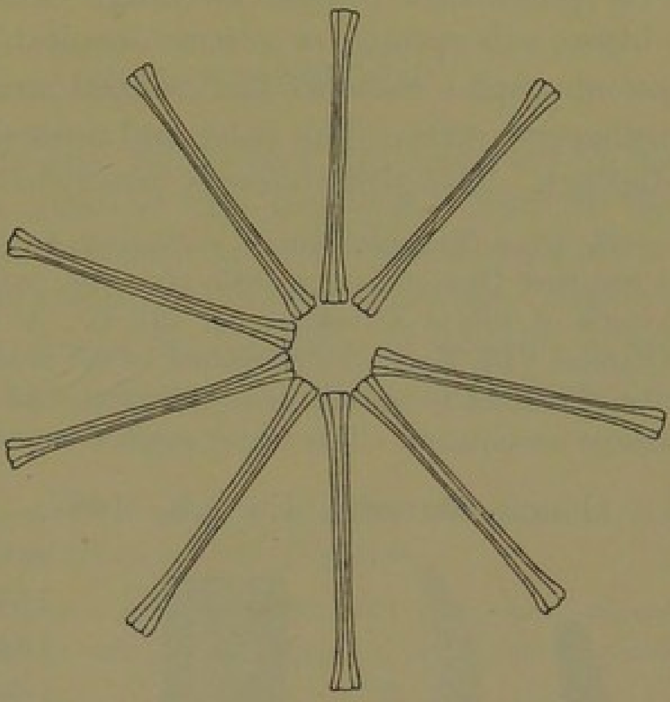

Fig. 133. *Asterionella formosa* Hass., from the plankton of Lough Neagh, Ireland (× 450).

A. formosa Hass. (fig. 133) is a common species in the quiet waters of ditches, ponds and lakes; length of valves 65—90 μ. *A. gracillima* Heib. is narrower and more elongate (length of valves up to 130 μ), and with the preceding species, of which it is perhaps only a variety, is a regular and abundant constituent of the British freshwater plankton. The colonies of this genus are somewhat fragile and they easily become dismembered.

Family 5. EUNOTIACEÆ.

The cells are free-floating and either solitary or united by their valve-faces to form ribbon-like filaments. The frustules are more or less curved or arcuate in the valve-view, the dorsal border of which is often undulate, the ventral margin being concave and with or without a central swelling. There is either a reduced raphe or a pseudo-raphe close to the ventral or concave margin, and the valve is transversely striated. The central nodule is mostly absent, but the polar nodules are disposed near the ventral margin. The girdle-view is generally rectangular. Each frustule possesses two, parietal, plate-like chromatophores.

Genus **Ceratoneis** Ehrenb., 1840. The cells are solitary and in the valve-view the ventral or concave side exhibits a more or less prominent central swelling. The apices of the valves are obtuse, subcapitate, or rostrate-capitate. There is a well-marked pseudo-raphe close to the ventral margin and interrupting the transverse striæ. The polar and central nodules are comparatively distinct. The girdle-view is linear-rectangular.

C. Arcus (Ehrenb.) Kütz. [= *Eunotia Arcus* W. Sm.], with obtuse apices, is a frequent Diatom in mountainous areas, particularly in mountain streams; length of valves 35—60 μ; fig. 134 D. A variety of it—var. *Amphioxys* (Rabenh.) De Toni—distinguished by its produced and subcapitate apices, is also abundant in mountainous districts, and pure gatherings of it are by no means uncommon. The valves reach a length of about 85 μ.

Genus **Eunotia** Ehrenb., 1837. [*Himantidium* of various authors; *Desmagonium* Ehrenb., 1848; *Amphicampa* Ehrenb., 1849; *Pseudeunotia* Grun., 1865; *Climacidium* Ehrenb., 1867.] The valve-view is arcuate or bow-shaped and the dorsal margin is often undulate or nodulose. The apices are obtuse or more often subcapitate. There is no central nodule and the pseudo-raphe is not very evident owing to its position along the ventral margin. The transverse striæ are interrupted across the valve-face. The girdle-view is rectangular. In one section of the genus (*Himantidium*) the cells are united by their valve-faces to form long, flexuose, ribbon-like filaments. In the other section (*Eunotia*) the cells are generally solitary, but they may be epiphytic in clusters on other larger Algæ.

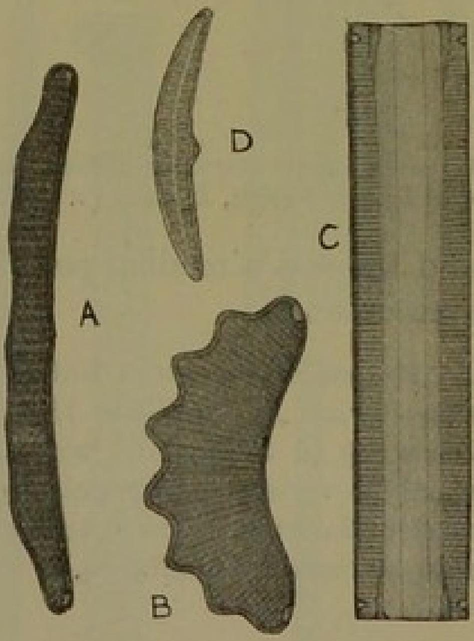

Fig. 134. A, *Eunotia pectinalis* (Kütz.) Rabenh. var. *undulata* Ralfs, from Baildon, W. Yorks. (×600). B, *E. robusta* Ralfs, from Dolgelly, Wales (×600). C, *E. gracilis* (Ehrenb.) Rabenh., from Lerwick, Shetlands (×500). D, *Ceratoneis Arcus* Kütz., from Cautley Spout, W. Yorks. (×520).

In the first section, *E. gracilis* (Ehrenb.) Rabenh. (fig. 134 C) and *E. pectinalis* (Kütz.) Rabenh. are the two commonest species. In the second section, *E. lunaris* (Ehrenb.) Grun. is much the commonest species (length of valves 50—90 μ), but *E. tetraodon* Ehrenb., *E. Veneris* Kütz. and *E. biceps* nob. [=*Synedra biceps* W. Sm.; *E. flexuosa* var. *bicapitata* Grun.] are general in mountainous areas.

Sub-order 2. ACHNANTHOIDEÆ.

The Diatoms of this sub-order are at once distinguished by the crooked or geniculate character of the frustules. Seen in the girdle-view each frustule is *suddenly* bent in its median portion, a character not exhibited by any other group of Diatoms. Another important feature of the group is the presence of a raphe on one valve of the frustule and a pseudo-raphe on the other. Only two families are included in the sub-order.

Family 1. *Achnanthaceæ.* Frustules elongate and more or less rod-shaped, generally occurring as stalked epiphytes.

Family 2. *Cocconeidaceæ.* Frustules flat and plate-like, subcircular or broadly elliptical in outline, occurring as epiphytes attached by their flat valve-faces.

Family 1. **ACHNANTHACEÆ.**

The frustules are straight and symmetrical in outline in the valve-view, but geniculate and asymmetrical in the girdle-view. In the valve-view they are in all cases linear or fusiform, often with capitate apices. One valve possesses a pseudo-raphe without any trace of nodules, whereas the other valve possesses a true raphe with both central and terminal nodules. The valves are transversely striated, the striæ consisting of fine rows of punctæ, and in some species costæ are present between the rows of punctæ. The chromatophore is usually a thick parietal plate, mostly covering the convex valve, but in some species there are a number of small granular chromatophores.

Genus **Achnanthes** Bory, 1822. [*Achnanthidium* Kütz., 1844; Grun., 1880.] The Diatoms of this genus possess the essential features of the family, and are either free-floating and solitary or stalked and epiphytic. There are two sub-genera, *Euachnanthes*

Schütt, in which the raphe and pseudo-raphe are straight and median or a little excentric; and *Achnanthidium* Kütz., in which the raphe and pseudo-raphe are sigmoid. In some species there is a distinct stauros on the lower valve. Auxospores may be formed in two ways: two from a mother-cell without conjugation, or one formed by the conjugation of two cells.

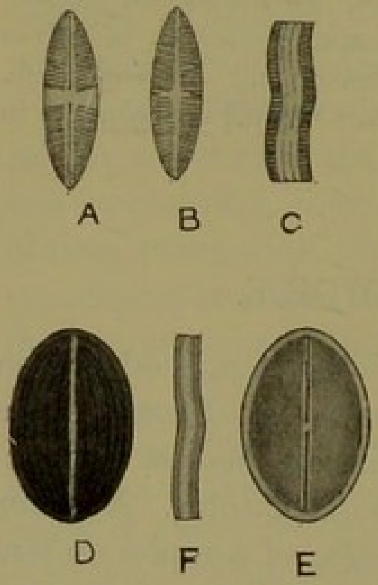

Fig. 135. A—C, *Achnanthes Hungarica* Grun., from near Sutton, Cambridge (× 520). D—F, *Cocconeis Placentula* Ehrenb., from Sheep's Green, Cambridge (× 520).

The largest freshwater species with a straight raphe, and also rather a rare one, is *A. coarctata* Bréb.; length of valves 18—43 μ. *A. exilis* Kütz., *A. linearis* W. Sm. and *A. microcephala* Kütz. are very small species which are often abundant, frequently occurring as stalked epiphytes in thick masses round other filamentous Algæ. *A. flexella* (Kütz.) Bréb. possesses a sigmoid raphe and often occurs in abundance in hilly districts; length of valves 35—50 μ.

Family 2. **COCCONEIDACEÆ.**

The frustules are symmetrical in both the valve-view and in transverse section, as in the family Achnanthaceæ. They are, however, flat and plate-like, exhibiting a broadly elliptical or subcircular outline in the valve-view. The valves are dissimilar, one possessing a pseudo-raphe and the other a raphe with a central nodule, but polar nodules are generally absent. The frustules frequently possess perforated transverse septa which appear in the valve-view as ribs. The girdle-view is generally more or less bent or arched. The cells possess one chromatophore, which is mostly parietal on the convex valve.

Genus **Cocconeis** Ehrenb., 1835. [*Orthoneis* Grun., 1868; *Anorthoneis* Grun., 1868.] This is the only genus of the family containing any freshwater species. The frustules are flat, plate-like or leaf-like, and somewhat the shape of a concavo-convex lens; they possess punctate striæ, transverse in the middle of the valve and radiating towards the poles. The costæ seen in the valve-view of some species and which represent the false septa, are confined to the outer border of the valve. One auxospore is formed from a single mother-cell.

There are many marine species of this genus, but only two—*C. Pediculus* Ehrenb. and *C. Placentula* Ehrenb. (fig. 135 D—F)—inhabit fresh water, both of them being abundant and widely distributed all over the British Islands. *C. Pediculus* is distinguished from *C. Placentula* by the form of the valves, which are more attenuated towards the poles, and by the different markings. They are both of approximately the same size (12—35 μ in length) and occur as epiphytes on filamentous Algæ and other water-plants. Filaments of *Cladophora* and *Vaucheria* are often completely covered with these epiphytes, which are attached by their flat valve-faces.

Sub-order 3. NAVICULOIDEÆ.

This is much the largest sub-order of the Pennatæ and is characterized by the presence of a true raphe on each valve of the frustule, which is furnished with a central and two polar nodules. The valves are usually without a keel, but if present it is situated in the line of the raphe (sagittal line). The frustules may be free-floating, occurring in large numbers in mucous tubes, or attached to some fixed object by hyaline stalks. There are three well-marked families.

Family 1. *Naviculaceæ*. Valves straight, rarely oblique or sigmoid, generally with a perfectly straight raphe, more rarely with an oblique one; mostly symmetrical about a longitudinal axis (line of raphe) and a transverse axis; girdle-view generally symmetrical and rectangular.

Family 2. *Gomphonemaceæ*. Valves mostly straight (rarely curved) and symmetrical about a longitudinal axis (line of raphe); in both valve- and girdle-view wedge-shaped.

Family 3. *Cocconemaceæ*. Valves always curved, symmetrical about one longitudinal plane and a median transverse plane; valve-view generally curved, often sublunate; girdle-view straight and sub-rectangular.

Family 1. **NAVICULACEÆ.**

The Diatoms of this family are exceedingly numerous and well-defined. The frustules are generally straight and symmetrical in three planes at right angles to each other (*Navicula*, *Vanheurckia*, etc.), or they may be sigmoid (*Gyrosigma*), or twisted (*Rhoicosigma*). The valves are almost always elongated, although in a few genera (*Amphiprora*) they may be relatively short. The raphe is somewhat variable; it is generally median with central and polar nodules, but it may take up a curved position according to the form of the valve. In some the central nodule forms a wide stauros (*Stauroneis*) and in others it is enclosed between two siliceous ridges (*Vanheurckia*). In a few genera the valves are carinate, or they are unequal, with a straight margin and an inflated one. The valves are striated, the striæ being commonly transverse, punctate, and interrupted by the raphe. In *Mastogloia* the valves are compound, being composed of an ordinary striated valve superposed on a perforated plate. The frustules are mostly solitary and free-floating, but in some forms they are enclosed within a tough mucous envelope which is often much branched; others are attached to a substratum by hyaline stalks. The chromatophores generally consist of two large parietal plates which are principally disposed over the walls of the girdle-faces. Two auxospores are commonly produced by the conjugation of two mother-cells, which surround themselves with a wide mucous investment.

There are seven British freshwater genera of the family, distinguished as follows:—

A. Valves simple.
  * Frustules straight and symmetrical in three planes at right angles; raphe straight.
    † Raphe straight and simple, with polar and central nodules.
      ‡ Central nodule small .... *Navicula.*
      ‡‡ Central nodule forming a stauros ...... *Stauroneis.*
    †† Raphe straight, enclosed between two longitudinal ribs.
      ‡ Central nodule small........................ *Vanheurckia.*
      ‡‡ Central nodule linear and greatly elongated .... *Amphipleura.*
  ** Frustules sigmoid; raphe sigmoid .... *Gyrosigma.*
  *** Frustules twisted; with sigmoid keel in the sagittal line; raphe sigmoid .... *Amphiprora.*
B. Valves composed of two superposed plates............ *Mastogloia.*

Genus **Navicula** Bory, 1822. [*Pinnularia* Ehrenb., 1843; *Schizonema* Ag., 1824; *Colletonema* Bréb., 1849; *Diadesmis* Kütz., 1844.] The frustules are solitary and free-floating or enclosed in mucous tubes, rarely united by their flat valve-faces to form ribbon-like filaments. The valves are quite straight and symmetrical with regard to the line of the raphe (sagittal line). The raphe is straight with central and polar nodules. In the girdle-view the frustules are straight and subrectangular. In the valve-view the form of the cell is very variable, although the predominant shape is lanceolate or fusiform. The markings on the valves are more or less transverse, sometimes somewhat radiating, and are arranged in relation to the line of the raphe. They consist of striæ or costæ of variable strength and are frequently composed of rows of punctæ. The striæ never quite reach up to the raphe, and sometimes there is a hyaline area of considerable size on each side of the central nodule. In rare cases the striæ are interrupted by a smooth longitudinal area on each side of the raphe and parallel to it. The chromatophores consist of two large parietal plates and in the formation of auxospores two spores are formed by the conjugation of two mother-cells.

Navicula is much the largest genus of Diatoms, or indeed, of any group of Algæ, embracing upwards of 1,000 species, which occur widely distributed in fresh, brackish and salt water. Many are also known in a fossil condition. It has been subdivided by Cleve into the three subgenera *Navicula*, *Stauroneis* and *Dictyoneis*. The first of these subgenera is divided into the two groups *Eunavicula* and *Schizonema*, and there are twenty-two sections of the first group, twelve of which contain British freshwater species; in the second group there are two sections, one of which contains

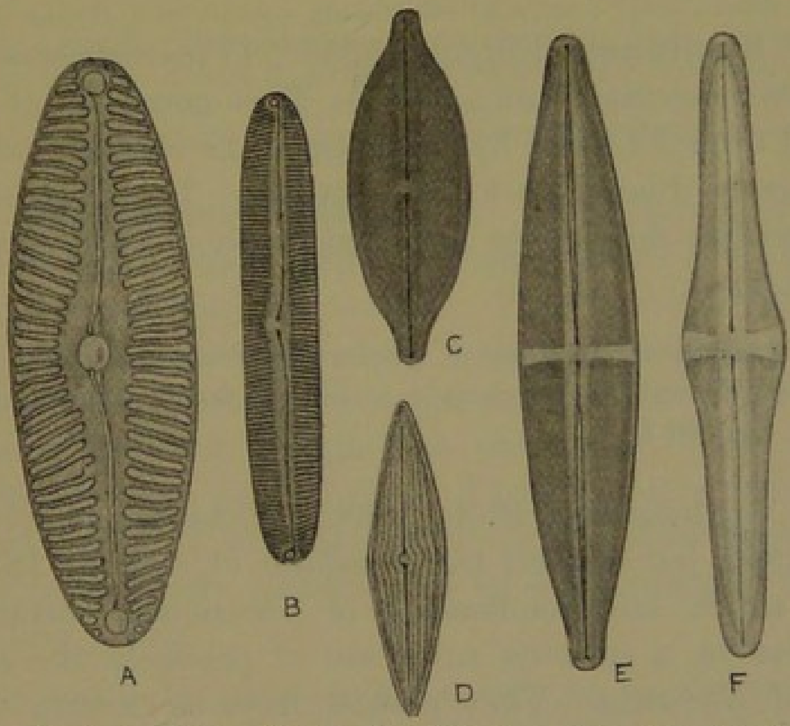

Fig. 136. A, *Navicula alpina* (W. Sm.) Ralfs, from Lerwick, Shetlands (×400). B, *N. viridis* Kütz., from Baildon, W. Yorks. (×400). C, *N. sphærophora* Kütz., from Wimpole Park, Cambridge (×500). D, *N. serians* (Bréb.) Kütz., from Mickle Fell, N. Yorks. (×400). E, *Stauroneis Phœnicenteron* (Nitzsch) Ehrenb., from Adel Bog, W. Yorks. (×400). F, *St. acuta* W. Sm., from Shipley Glen, W. Yorks. (×450).

freshwater species; the second subgenus—*Stauroneis*—I prefer to regard as a genus; and in the third subgenus there are three sections which are exclusively marine.

There are about 70 freshwater species occurring in the British Islands, principally in stagnant waters. The most striking are *N. cuspidata* Kütz., *N. nobilis* Ehrenb., *N. major* Kütz., *N. alpina* Ralfs (fig. 136 A) and *N. lata* Bréb., the two last-mentioned species preferring boggy tracts in elevated regions, in which localities they are sometimes frequent. *N. perpusilla* Grun. (length 12·5 μ) and *N. gallica* (W. Sm.) V. H. (length 8—15 μ) are amongst the smallest British species; *N. nobilis* Ehrenb. is the largest species (length 200—400 μ) and *N. viridis* Kütz. (fig. 136 B) is perhaps the commonest. Some of the small and abundant species, such as *N. exilis* Grun. and others, are remarkable for the rapidity of their movements. Some of the species of this genus are utilized as test-objects for the objectives of microscopes.

Genus **Stauroneis** Ehrenb., 1843. [*Pleurostauron* Rabenh., 1859; *Schizostauron* Grun., 1867.] This genus is at once distinguished from *Navicula* by the form of the central nodule, which is transversely dilated to form a stauros. The frustules may be solitary and free-floating or attached by their valve-faces to form short filaments.

There are about six freshwater species occurring in Britain, of which *St. Phœnicenteron* Ehrenb. is the largest and most frequent; length of valves 100—170 μ; fig. 136 E.

Genus **Vanheurckia** Bréb., 1868. [*Frustulia* as amended by Rabenh., 1851, but scarcely the *Frustulia* of Agardh, 1824.] The frustules, which are free-floating or occasionally arranged in a linear series in a mucous tube, are of precisely the same type as those of *Navicula*. They possess, however, a very distinctive feature in the sagittal line of the valves. There are distinct polar and central nodules, which are elongated and enclosed along with the raphe between two parallel siliceous ribs. The valves are transversely striated, the striæ being very fine and parallel, rarely slightly radiating in the median portion of the valve.

There are only two British species, *V. rhomboides* (Ehrenb.) Bréb. [=*Navicula rhomboides* Ehrenb.; fig. 137 A and B] and *V. vulgaris* (Thw.) V. H. *V. rhomboides* var. *Saxonica* (Rabenh.) G. S. West [=*Navicula crassinervia* Bréb.] is very abundant and widely distributed in the British Islands, being one of the most frequent Algæ in boggy districts; length of valves 50—80 μ. Pure gatherings of it can often be collected from Sphagnum-pools.

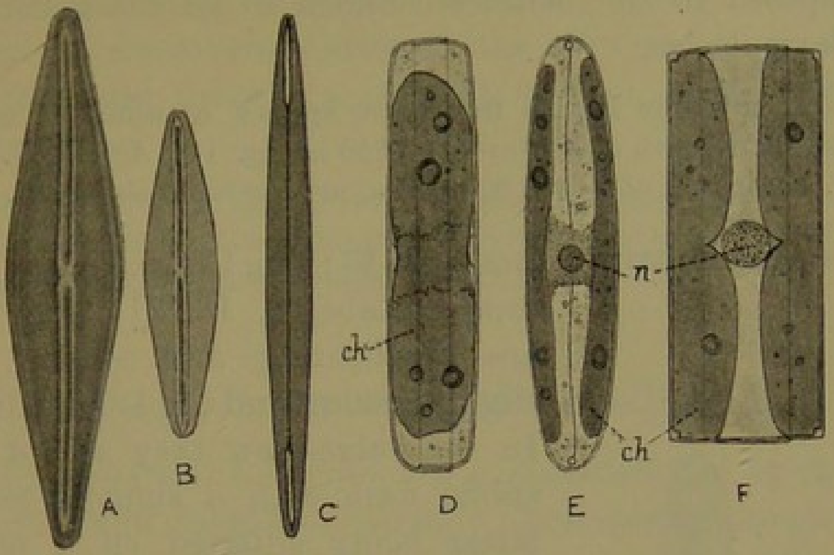

Fig. 137. A and B, *Vanheurckia rhomboides* (Ehrenb.) Bréb., from Mickle Fell, N. Yorks. (× 520). C, *Amphipleura pellucida* Kütz., from Chippenham Fen, Cambridge (× 520). D and E, girdle- and valve-views of *Navicula viridis* Kütz., to show chromatophores (*ch*) and nucleus (*n*), × 400. F, *Eunotia gracilis* (Ehrenb.) Rabenh., girdle view to show chromatophores and nucleus (× 400).

Genus **Amphipleura** Kütz., 1844. The frustules are solitary and free-floating, elongate-fusiform in shape, with a small marginal keel near each edge of the valves. The valve-view is narrowly lanceolate and the central nodule is greatly elongated, forming a narrow rib which separates the raphe into two short portions, each portion being situated towards one extremity of the valve and enclosed between two parallel ribs. These two ribs unite together at each extremity of the valve to form the polar nodules. The valves are transversely striated and in some species these striæ are exceedingly fine.

Only one species, *A. pellucida* Kütz., inhabits the freshwaters of the British Isles. It is generally distributed and often abundant; length of valves 80—140 μ; fig. 137 C. The striæ of this species are extremely fine (about 37 in 10 μ) and the valves are used as microscopic test-objects. Some very large forms of it sometimes occur in the freshwater plankton.

Genus **Gyrosigma** Hassall, 1845. [*Pleurosigma* W. Sm., 1853; ? *Scalprum* Corda, 1835.] The frustules are elongated, of the naviculoid type, and the valves are convex. In the valve-view they are sigmoid with obtuse or attenuated extremities. The raphe is also sigmoid. There are two sets of striations on the valves, which cross one another either at right angles or obliquely. The girdle-view is generally straight and linear-oblong in shape. The chromatophores consist of a pair of large jagged or perforated plates disposed in the manner common to all the genera of the family Naviculaceæ.

There are only four British freshwater species, of which *G. attenuatum* (Kütz.) Rabenh. (length of valves 190—250 μ; fig. 138 A) and *G. Spencerii* (Queck.) O. K. (length of valves 80—130 μ) are the most abundant.

Genus **Amphiprora** Ehrenb., 1843; em. Cleve, 1891. [*Amphicampa* Rabenh., 1864.] The frustules are free-floating and solitary, with a slight twist around the longitudinal axis. In the valve-view they are of a naviculoid form with a sigmoid raphe, the latter being situated on a prominent sigmoid keel in the sagittal axis. In the girdle-view the frustules are broadly inflated, with a median constriction and truncate ends. The girdle itself exhibits a slight twist, and seen obliquely the sigmoid keels of the valves cause the frustules to appear much more twisted than is truly the case. The terminal nodules are not very conspicuous and there is a small central nodule. The valves are finely and transversely striated.

A. paludosa W. Sm. is often found in fresh water, sometimes in great abundance in small ponds and ditches; length of valves 40—80 μ; fig. 138 B and C. *A. ornata* Bailey is also known from the freshwaters of England.

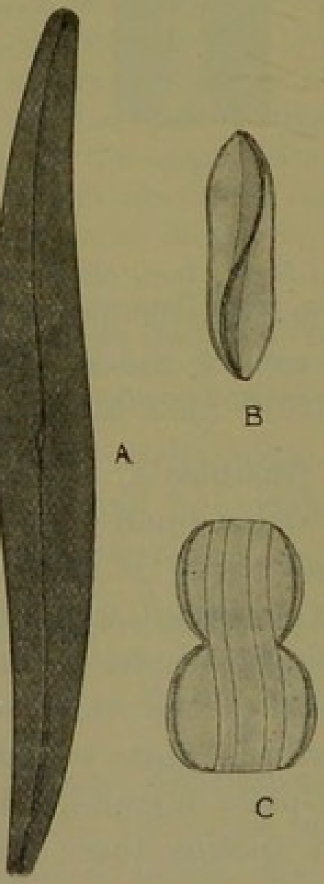

Fig. 138. A, *Gyrosigma attenuatum* (Kütz.) Rabenh., from Chippenham Fen, Cambridge (×400). B and C, *Amphiprora paludosa* W. Sm., from Wimbledon Common, Surrey (×400).

Genus **Mastogloia** Thwaites, 1848. The frustules are of a naviculoid form and are enclosed in a gelatinous envelope of considerable size. The valve-view is usually elliptic-lanceolate, generally with produced extremities, and the girdle-view is sub-rectangular. Each frustule possesses two longitudinal septa with a large central perforation and a row of marginal ones on each side. These two longitudinal septa are per-

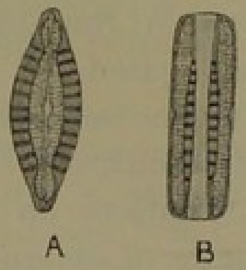

Fig. 139. *Mastogloia Smithii* Thw., from Baildon, W. Yorks. (×500).

forated siliceous plates situated between the girdle and each valve. The valves are transversely striated, the striæ radiating somewhat in the centre, and there is a straight median raphe with central and polar nodules.

About four species are known from the freshwaters of the British Islands, of which *M. Smithii* Thwaites (length of valves 30—45 μ; fig. 139) and *M. Dansei* Thwaites are the most generally distributed.

Family 2. **GOMPHONEMACEÆ.**

This family of the Naviculoideæ is characterized by the wedge-shaped form of the frustules, especially when seen in the girdle-view. In the valve-view they are naviculoid in form, with one pole generally much larger than the other and with sinuate margins. The valves are symmetrical about the sagittal axis (line of raphe) and the raphe is straight and median. Longitudinal septa are present between the valves and the girdle, but they do not extend far into the cavity of the cell. Each frustule possesses a large parietal chromatophore, which is somewhat sinuate and fits closely along one girdle-face, covering the valve-faces and most of the other girdle-face. The frustules are generally attached by their inferior (or smaller) extremities to a branched system of hyaline stalks, which is attached to a substratum. There are only two genera, *Gomphonema*, in which the frustules are straight, and *Rhoicosphenia*, in which they are curved. Two auxospores are formed from two mother-cells without conjugation and grow parallel to each other.

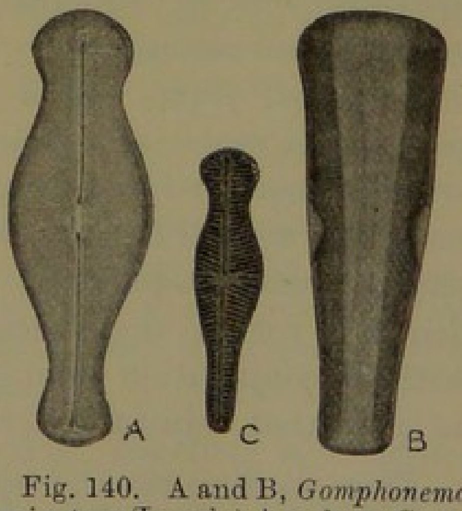

Fig. 140. A and B, *Gomphonema geminatum* (Lyngb.) Ag., from Cautley Spout, W. Yorks. (× 400). C, *G. constrictum* Ehrenb., from Chippenham Fen, Cambridge (× 400).

Genus **Gomphonema** Ag., 1824. [*Gomphonella* Rabenh.; *Gomphoneis* Cleve.] The frustules are of variable form in the valve-view, generally with one extremity conspicuously larger than the other, often fusiform in outline or sinuate at the margins. Each valve possesses a straight median raphe, and the central and polar nodules are well-marked. The valves are generally strongly striated, the striæ more or less radiating from the sagittal axis and in some forms consisting of distinct beads. In the girdle-view the frustules are cuneate in outward form.

There are about 14 British species of the genus, some of which, such as *G. constrictum* Ehrenb. (fig. 140 C), *G. acuminatum* Ehrenb., *G. parvulum* Kütz. and others, are common in every part of the British Islands, frequently occurring as epiphytes on other Algæ. *G. geminatum* (Lyngb.) Ag. is the largest species (length of valves 90—120 μ; greatest breadth 35—40 μ; fig. 140 A and B) and is principally confined to hilly districts, often forming thick felt-like masses of a greyish-white colour on dripping rocks.

Genus **Rhoicosphenia** Grun., 1860. In the valve-view the frustules are similar in form to those of *Gomphonema,* being fusiform with dissimilar poles; in the girdle-view they are cuneate and considerably curved. The valves are dissimilar, the upper valve only possessing a pseudo-raphe and no nodules, whereas the lower valve possesses a raphe and central and polar nodules.

R. curvata (Kütz.) Grun. is common all over Britain, often clothing in dense masses the thicker branches of species of *Cladophora*; length of valves 13—45 μ.

Family 3. **COCCONEMACEÆ.**

The family is principally characterized by the curvature of the frustules in the plane of the girdle, so that the valve-view always appears bent or sublunate. The girdle-view is straight and generally subrectangular. The frustules are symmetrical about a longitudinal plane and a median transverse plane. Each valve possesses a raphe, sometimes straight, but more often curved, and situated more or less near the concave margin. There are distinct polar and central nodules except in *Epithemia.* There is one large parietal chromatophore in each cell, the median part of which is disposed within the concave girdle-face. Two auxospores arise without conjugation from two mother-cells, growing side by side as elongated rejuvenized cells.

There are three British freshwater genera:—

A. Valves without transverse ribs.
  * Cells not very asymmetrical; raphe removed from the edge of the girdle; girdle small, without striæ *Cocconema.*
  ** Cells strongly asymmetrical; central nodule very near the girdle on the concave side; girdle broad, with longitudinal striations .... *Amphora.*
B. Valves with transverse ribs; raphe often strong and conspicuous. *Epithemia.*

Genus **Cocconema** Ehrenb., 1829. [*Cymbella* Ag., 1830; *Encyonema* Kütz., 1833.] The frustules are asymmetrical, straight, or more often sublunate, being strongly attenuated from the middle towards the extremities, which are obtuse. In the valve-view one margin is strongly convex, whereas the other may be slightly convex or concave. In the latter case it is generally tumid in the middle. The raphe is well-marked and is nearer the concave or the less convex side of the valve. The valves are striated, the striæ slightly radiating from the raphe and consisting in many species of distinct series of dots. The girdle-view is straight, often subrectangular, and the actual girdle is generally very narrow. In some species the frustules are free, in others they are stipitate, and in others they are enclosed in gelatinous tubes, these differences in habit having been formerly utilized as generic characters.

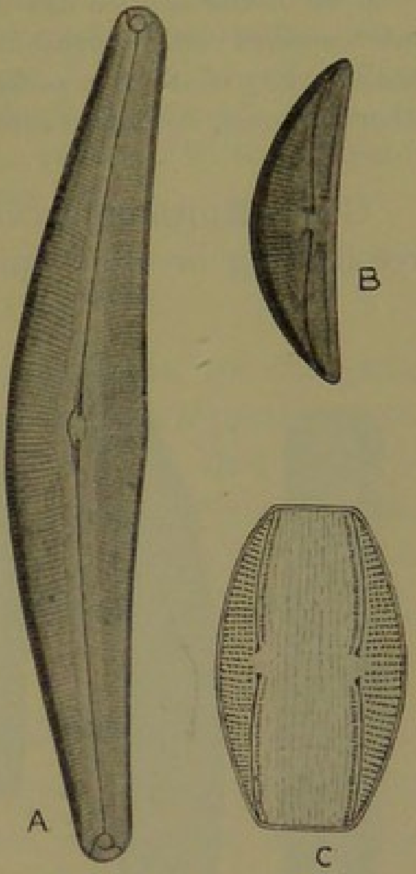

Fig. 141. A, *Cocconema lanceolatum* Ehrenb., from Shipley Glen, W. Yorks. (× 500). B and C, *Amphora ovalis* Kütz., from Moidart, Inverness (× 500).

C. lanceolatum Ehrenb. is the largest and one of the most abundant species of the genus; length of valves 80—150 μ; fig. 141 A. *C. Cistula* Ehrenb. and *C. cymbiforme* Ehrenb. are smaller species almost equally abundant. *C. Ehrenbergii* (Kütz.) nob. is a large species of rare occurrence. *C. cuspidatum* (Kütz.) nob. is widely distributed and often abundant on wet rocks in mountainous regions, frequently forming gelatinous masses of a greyish-brown colour. The frustules of *C. prostratum* (Berk.) nob., *C. cæspitosum* (Kütz.) nob. and *C. gracile* (Rabenh.) nob. occur in more or less linear series enclosed in gelatinous tubes.

Genus **Amphora** Ehrenb., 1831. The frustules are asymmetrical, curved or sublunate in the valve-view, with a well-marked raphe near the concave side. The central nodule is adjacent to the concave margin and is sometimes widened into a stauros. The striation of the valves is similar to that of *Cocconema*. The girdle-view is elliptical with truncate apices and the girdle is broad with irregular longitudinal striations. The chromatophore is similar to that of *Cocconema*, from which genus *Amphora* principally differs in the position of the raphe, in the form of the girdle-view, and in the broad striated girdle.

Most of the species are marine, but *A. ovalis* Kütz. is a common fresh-water species with valves 50—70 μ in length; fig. 141 B and C. A very small variety of it—var. *pediculus* Kütz.—occurs as an epiphyte, generally on other Diatoms, such as *Nitzschia sigmoidea*.

Genus **Epithemia** Bréb., 1838. The frustules are solitary and free-floating or often epiphytic on other Algæ and more highly organised plants. In the valve-view they are slightly curved or lunate, with an inner concave margin and an outer convex margin. The valves are apparently without a true raphe, which is replaced by an excentric pseudo-raphe situated close to the concave margin. O. Müller has shown, however, that one species possesses a true raphe, and it is highly probable that the so-called 'pseudo-raphe' of all the other species is morphologically a true raphe. There are strong transverse ribs in the valve-view which represent transverse septa, and the valves are also sculptured with transverse rows of beads or finely punctate striæ. The girdle-view is subrectangular, lanceolate, or broadly elliptical with truncate apices. The transverse septa also show as costæ in the girdle-view owing to the convex nature of the valves, and they sometimes terminate in small globular expansions at their point of contact with a partial longitudinal septum, which is situated on each side of the girdle between it and the valves. There is either one large chromatophore in

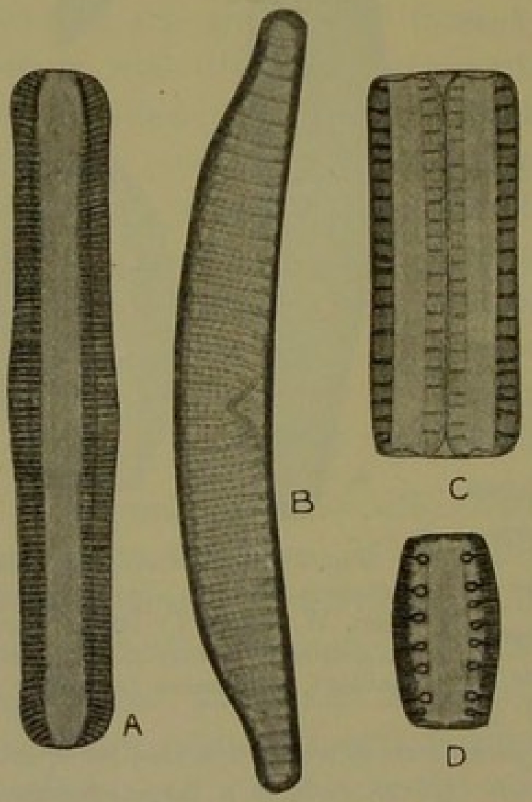

Fig. 142. A, girdle-view of *Epithemia gibba* Kütz., from Wicken Fen, Cambridge. B, valve-view of *E. turgida* (Ehrenb.) Kütz., from Keighley, W. Yorks. C, girdle-view of dividing specimen of *E. turgida*, from Lerwick, Shetlands. D, girdle-view of *E. Argus* (Ehrenb.) Kütz., from Wicken Fen, Cambridge. (All × 450.)

each cell or two smaller ones. Auxospores are formed in pairs from two mother-cells after conjugation.

The genus is almost entirely freshwater in habit, *E. turgida* (Ehrenb.) Kütz. being the most abundant British species; length of valves 70—150 μ; fig. 142 B and C. *E. gibba* Kütz. (fig. 142 A) and *E. zebra* (Ehrenb.) Kütz. are also common species in all kinds of localities. *E. gibberula* Kütz. var. *producta* Grun. and *E. Argus* (Ehrenb.) Kütz. var. *alpestris* (W. Sm.) Rabenh. often occur in large quantity in mountainous areas.

Sub-order 4. NITZSCHIOIDEÆ.

In this sub-order of the Pennatæ the frustules are elongated and asymmetrical, generally with more or less of a sigmoid curvature. Each valve possesses a keel in the sagittal line, and the two keels may be diagonally opposite or both displaced to the same side of the frustule. The edge of the keel is usually furnished with strong carinal dots. In transverse section the frustules are rhombic.

Family 1. **NITZSCHIACEÆ.**

This is the only family of the sub-order. The valve-view is generally straight, with attenuated apices, and a row of carinal dots, either median or at one edge. The girdle-view is linear or sigmoid, with truncate apices. The keel is along the sagittal line of the valve and contains a true raphe. The chromatophores are variable; the cells may contain one diagonal plate-like chromatophore, or two smaller diagonal plates, or a large parietal plate the median portion of which is opposite one girdle-face.

There are three genera, distinguished as follows:—

A. Keel median; valves a little convex; cells joined to form loose bands .... *Bacillaria.*
B. Keel displaced to one side; valves convex; cells free.
  * Keels of two valves diagonally opposite .... *Nitzschia.*
  ** Keels of two valves displaced to same side of frustule .... *Hantzschia.*

Genus **Bacillaria** Gmelin, 1788. The frustules are straight and united to form plate-like or ribbon-like colonies, which exhibit a gliding movement of one frustule over another. The girdle-view is linear, with truncate apices and with a row of carinal dots along each lateral margin. The valve-view is narrowly linear, with attenuated apices and a median row of carinal dots. The valves are slightly convex, transversely striated, and furnished with a median keel.

B. paradoxa Gmel. occurs in the freshwater dykes and drains of the north-east and east of England; length of valves 60—70 μ.

Genus **Nitzschia** Hassall, 1845; em. Grun., 1880. [*Tryblionella* W. Sm., 1853; *Grunowia* Rabenh., 1864; *Nitzschiella* Rabenh., 1864.] The frustules are generally curved, rarely straight, usually free-floating or more rarely forming a thin stratum. Each valve possesses a keel which is displaced to one side, the two keels being displaced to opposite sides of the frustule and therefore diagonally opposite each other. The valve-view is elongated or elliptic-lanceolate, with attenuated and capitate or even rostrate apices, and possesses a row of conspicuous carinal dots at one edge. The girdle-view is often elongated with parallel margins and truncate apices, but sometimes the sides are inflated and there is a median constriction. It is occasionally straight, but more often sigmoid. The edge of each keel is furnished with a row of strong carinal dots, which are sometimes prolonged into short ribs, and the valves are transversely striated.

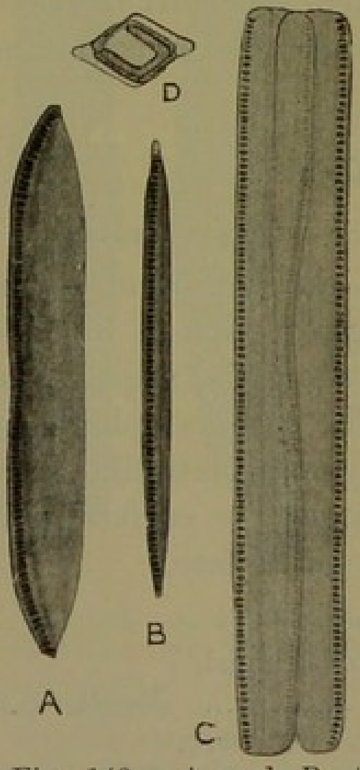

Fig. 143. A and B, two single valves of *Nitzschia constricta* (Kütz.) Pritch., from Hawksworth, W. Yorks. (× 500). C and D, *N. sigmoidea* (Ehrenb.) W. Sm.; C, short, straight, abnormal form in process of division (girdle-view, ×400); D, transverse section (after Schütt, from Pfitzer).

This large genus of Diatoms has been divided by Grunow into 22 sections (including *Bacillaria*). There are about 24 British freshwater species, of which *N. palea* (Kütz.) W. Sm. (length of valves 20—65 μ) and *N. sigmoidea* (Ehrenb.) W. Sm. (length of valves up to 480 μ) are the most abundant and at the same time exhibit the greatest extremes of size. *N. linearis* (Ag.) W. Sm. and *N. communis* Rabenh. are common species, and *N. sinuata* (W. Sm.) Grun. is general on dripping rocks. *N. acicularis* W. Sm. is a small species with greatly produced extremities; it is often exceedingly abundant in ponds and ditches, and is remarkable for the rapidity of its movements.

Genus **Hantzschia** Grun., 1877. This genus differs principally from *Nitzschia* in the position of the keels of the two valves, which are displaced to the same side of the frustule. The valve-view is somewhat curved with rostrate apices, and the girdle-view is straight and linear-rectangular. The carinal dots are very conspicuous.

H. Amphioxys (Ehrenb.) Grun. is the only freshwater species and is a frequent British Diatom. It often occurs in prodigious quantity on damp earth; length of valves 45—75 μ.

Sub-order 5. SURIRELLOIDEÆ.

The frustules are generally symmetrical with regard to the sagittal axis and each valve frequently possesses two rows of wing-like projections (or alæ). There is a median pseudo-raphe without any trace of nodules, which is sometimes situated on a sagittal keel. The valves are generally strongly costate.

Family 1. **SURIRELLACEÆ.**

The Diatoms of this family exhibit considerable variety of form, although they are almost always symmetrical with regard to the sagittal axis. In the valve-view they may be elliptical, linear, ovate, cuneate, or subcircular, with a median pseudo-raphe from which radiate strong costæ (or ribs). In some forms the valves are winged, each being furnished with wing-like outgrowths which project outwards at the junction of the valve and the girdle. The pseudo-raphe is sometimes situated on a pronounced sagittal keel. The valve-faces are occasionally undulate, the undulations showing plainly on each side of the girdle-view, and the frustules are rarely twisted. There are two large chromatophores in each cell, one within each valve-face, and sometimes with projecting internal lobes. In all cases the frustules are solitary and free-floating. One auxospore is produced by the conjugation of two mother-cells.

The family includes the three following genera:—

A. Valve-faces undulate .... *Cymatopleura.*

B. Valve-faces not undulate.

  * Valves elliptical or keel-shaped, straight, with strong transverse ribs; pseudo-raphe of one valve parallel to that of other ...... *Surirella.*

  ** Valves circular and saddle-shaped; pseudo-raphe of one valve at right angles to that of other.. *Campylodiscus.*

Genus **Cymatopleura** Turpin, 1827. The frustules are broadly elliptical or sublinear in the valve-view, often broadly concave at each side and with subacuminate apices. The valves are furnished with a distinct but inconspicuous pseudo-raphe and with very fine transverse striations. Along the margins are short costæ which simulate coarse beads, and the valve-faces are undulate. In the girdle-view the frustules are linear with a number of large undulations along the lateral margins. The genus is entirely freshwater in habit.

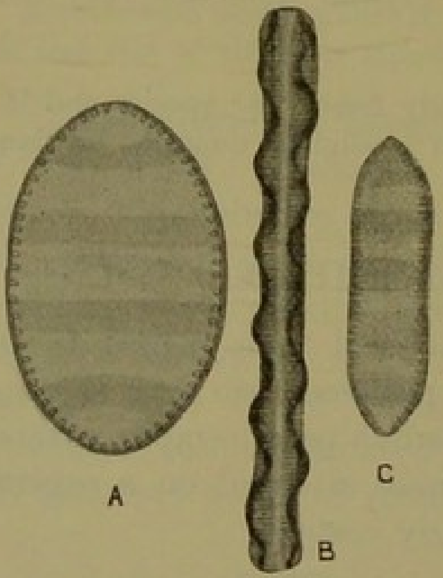

Fig. 144. A, *Cymatopleura elliptica* (Bréb.) W. Sm., from Comberton, Cambridge (× 350). B and C, *C. Solea* (Bréb.) W. Sm.; B, girdle-view of large specimen from Esholt, W. Yorks.; C, valve-view of small specimen from Cornwall (× 350).

C. Solea (Bréb.) W. Sm. is the commonest British species; the valves are elongated and slightly narrowed in the median portion; length 50—130 μ; fig. 144 B and C. *C. elliptica* (Bréb.) W. Sm. is almost equally abundant and possesses broadly elliptical or elliptic-lanceolate valves; length 80—140 μ; fig. 144 A.

Genus **Surirella** Turpin, 1827. [Original spelling—'*Suriraya.*'] In the valve-view the frustules are elliptical, linear, ovate, or sometimes twisted. There is a median pseudo-raphe and strong transverse costæ. The pseudo-raphe of one valve is parallel to that of the other. The valves possess a sagittal keel and short wing-like projections (alæ) along their margins. The four sets of alæ are best seen in a transverse section. The girdle-view is subrectangular, oblong, or cuneate, and the girdle exhibits irregular longitudinal striations.

S. biseriata Bréb. (length of valves 100—170 μ; fig. 145 A) and *S. robusta* Ehrenb. (length of valves 160—230 μ) are two of the largest and most frequent freshwater species. A variety of the latter, *S. robusta* var. *splendida* (Ehrenb.) V. H., is general in the British freshwater plankton (fig. 145 C). A much smaller species, *S. ovalis* Bréb., with numerous varieties, is very abundant; length of valves 16—80 μ. *S. spiralis* Kütz. is remarkable for the twisting of the valves round the longitudinal axis.

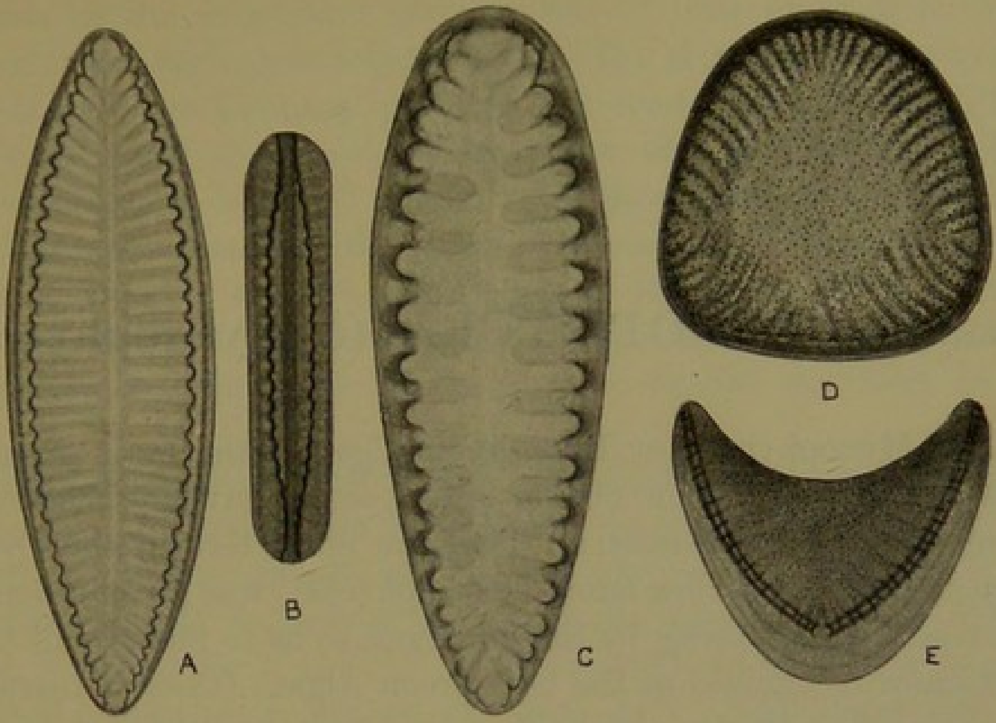

Fig. 145. A, *Surirella biseriata* Bréb., from Adel Bog, W. Yorks. (valve view, × 400). B, *S. linearis* W. Sm., from Mickle Fell, N. Yorks. (girdle view, × 400). C, *S. robusta* Ehrenb. var. *splendida* (Ehrenb.) V. H., from near Penzance, Cornwall (valve view, × 400). D and E, *Campylodiscus Hibernicus* Ehrenb., from Baildon, W. Yorks.; D, valve view; E, view showing the saddle-shaped frustule; × 400.

Genus **Campylodiscus** Ehrenb., 1841. The valves are apparently irregularly circular, although in reality they are perfectly circular. The apparent irregularity is due to their curvature, the frustule being saddle-shaped. Each valve possesses a median pseudo-raphe, and the pseudo-raphe of one valve is at right angles to that of the other. The valves are furnished with costæ, generally short and often beaded. The genus is mostly marine.

C. Echineis Ehrenb. and *C. Hibernicus* Ehrenb. (fig. 145 D and E) are general but scarce in the freshwaters of the British Islands. Diam. of valves about 100 μ.

Class 6. MYXOPHYCEÆ (or Cyanophyceæ).

The Myxophyceæ (or Blue-green Algæ) is the most primitive class of the Algæ, some of the lowest forms having considerable resemblance to the Bacteria. They are often termed the Cyanophyceæ[1], but the earlier name 'Myxophyceæ' was given a definite and restricted meaning by Stizenberger, so as to include all those plants now recognized as the blue-green Algæ. (*Consult* Introduction, page 3.) It also emphasizes the most conspicuous habit of these plants, namely, the manner in which the great majority of them exist in gelatinous masses or strata. A few of them are unicellular, some are colonial, and others filamentous. They are found everywhere in damp and wet situations, and many of them are almost entirely subaërial in habit. In moist climates many of the richest tints of the landscape are due to the presence of Algæ of this class, which occur in every conceivable situation on rocks, stones, and the trunks of trees, and in some regions they give a decided character to the country[2]. The filamentous species frequently form compact, felt-like, mucous or leathery patches of various colours and of considerable extent, occurring on the vertical faces of rocks which are kept permanently moist or wet. Numerous Myxophyceæ occur in the sea, although they are more abundant in fresh water. Many of them exist in quantity in both the marine and freshwater plankton.

Some of the Myxophyceæ have become adapted to a life in hot water, and they constitute the principal vegetation of hot-springs. The part played by certain of these Algæ in the formation of rock-

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[1] There was little necessity for the re-naming of this class by either Rabenhorst (who termed it the Phycochromophyceæ) or Sachs (who termed it the Cyanophyceæ). The class already possessed much the best name that has yet been given it (the Myxophyceæ), and the exactitude of its limitations could not be improved upon by either of those authors.

[2] The *Pedras negras* of Angola are due to the prolific growth of *Scytonema Myochrous* var. *chorographicum*; *vide* West & G. S. West in Journ. Bot. 1897, p. 303.

masses by the extraction of carbonate of lime or silica from the water of hot-springs is considerable. The deposits formed around the hot-springs in many parts of the world consist of brightly-coloured basins or terraces of travertine and sinter. The colours are very varied, being all shades of yellow, orange-red, pink, blue, and blue-green, and are due to the presence of brilliantly-coloured Algæ within the deposit. In the case of the travertine deposits the deposition of the carbonate of lime is due very largely to the extraction by the Algæ of the carbon dioxide dissolved in the water.

That Algæ do actually cause the elimination of carbonate of lime from the water was first shown by Cohn[1], and Weed[2] has given a very able account of the assistance of the Myxophyceæ in the formation of the travertine and sinter deposits of the Yellowstone National Park, U.S.A. He states that from $\frac{1}{20}$ to a $\frac{1}{16}$ of an inch of travertine is formed in three days. He found that the character and colour of the deposit depended upon the temperature of the water and the situation of the spring or geyser. The highest temperature at which filamentous Myxophyceæ are known to exist is 85° C.[3], but unicellular Algæ have been observed by Brewer in California in water at a temperature of 94·5° C.[4]

The *cell-wall*, which is never absent, is composed partly of cellulose, partly of pectose compounds, and very largely of chitin. It presents a similarity to the cuticle of higher plants[5], offering considerable resistance to chemical reagents, and it sometimes contains silica[6].

Many of the colonial forms are embedded in a somewhat extensive mass of mucilage, the external surface of which is covered with a thin cuticle, and in most of the filamentous forms there is secreted either a thin mucous sheath or a tough chitinized sheath, often lamellose in character. This sheath is undoubtedly secreted by the enclosed cells, and in some genera (e.g. *Lyngbya*) all stages are met with between a thin hyaline investment and a hard, lamellose, sheathing tube.

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[1] Cohn in Abhandl. der Schles. Gesellsch. Nat. 1862, p. 35.

[2] Weed, 'Formation of Travertine and Siliceous Sinter by the Vegetation of Hot Springs.' Rep. U.S. Geol. Survey, 1887–8.

[3] G. S. West, 'Some Algæ from Hot Springs,' Journ. Bot. July 1902, p. 241.

[4] W. H. Brewer in Amer. Journ. Science, ser. 2, xli.

[5] R. Hegler in Pringsh. Jahrb. für wissensch. Bot. 1901, xxxvi.

[6] Hyams & Richards in Technol. Quarterly, Boston, 1902, xv, pp. 308—315.

The pigment of the cells is principally *phycocyanin*, which partially hides the chlorophyll and gives many of these plants their characteristic blue-green colour. In some species, however, pigments of other colours are present, such as *carotin*, *myxophycin*[1] and *polycystin*[2]. In the great majority of the blue-green Algæ the pigment is lodged in the cytoplasm in the form of small granules, each of which usually contains a mixture of chlorophyll and phycocyanin. These granules may occupy a somewhat indefinite extent of the cytoplasm or they may be restricted to certain regions, and it is a vexed question whether or not this pigmented part of the cytoplasm should be regarded as a true chromatophore.

Stockmeyer[3] and Zacharias[4] have each stated that the pigmented protoplasm cannot be considered as a true chromatophore. Massart[5] also considers that although the coloured layer functions as a plastid, it cannot be regarded as a true chromatophore on account of its indefinite limits towards the interior of the cell, and the fact that it may contain both gas and liquid vacuoles. On the other hand, Deiniga[6] finds in certain blue-green Algæ (such as *Aphanizomenon* and *Nostoc*) structures which he regards as true chromatophores, having the form of a more or less reticulated or perforated plate in contact with the cell-wall. Zukal[7] also considers that *Tolypothrix* possesses a true chromatophore, and Fischer[8] and Hegler[9] each regard the pigmented peripheral layer of protoplasm as a parietal chromatophore. The latter carefully described the granular disposition of the pigment and termed the pigmented layer a *cyanoplast*. Hieronymus[10] concludes that the pigmented peripheral layer is of the same nature as the chromatophore of higher plants, but not identical with it; and Wager[11] also states that its structure recalls the chromatophore of other organisms. In the family Glaucocystaceæ there is a true chromatophore.

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[1] Chodat in Journ. Bot. de Morot, 1896, x. *Myxophycin* is identical with Sorby's "*pink phycocyanin*."

[2] Zopf in Berichte Deutsch. Bot. Ges. 1901, xviii.

[3] Stockmeyer in Berichte Deutsch. Bot. Ges. 1894, xii.

[4] Zacharias in Bot. Zeitung, 1891, xlix; in Abhandl. a.d. Geb. Naturw. Ver. Hamburg, 1900, xvi.

[5] Massart in Recueil de l'Inst. Bot. Univ. de Bruxelles, 1902, v.

[6] Deiniga in Bull. Soc. Imp. Nat. Moscou, 1891, no. 2.

[7] Zukal in Berichte Deutsch. Bot. Ges. 1892, x.

[8] Fischer, Unters. über d. Bau d. Cyanophyceen u. Bakterien, Jena, 1897.

[9] Hegler in Pringsheim's Jahrb. für wissensch. Bot. 1901, xxxvi.

[10] Hieronymus in Beiträge zur Biol. d. Pflanzen (Cohn), 1892, v.

[11] Wager, Report Brit. Assoc. 1901 (1902), p. 830.

The pigment in the cells of the Myxophyceæ is unquestionably variable in its disposition, and although in certain of these plants it occupies a somewhat indefinite extent of the cytoplasm, in others it is undoubtedly collected into definite areas. It must be remembered, however, that indefiniteness of the pigmented areas is not confined to the blue-green Algæ alone, but is often observed in some of the lowly Protococcoideæ, and even in such a highly specialized group as the Desmidiaceæ.

Kohl has regarded each of these minute granules of pigment as a chromatophore, but I prefer to adopt Hegler's idea of a *cyanoplast* for that part of the protoplasm in which the granules of pigment are collected. This cyanoplast, which can be regarded as an archaic type of chromatophore, exhibits much variation in the degree of its differentiation, and attains in one family—the Glaucocystaceæ—the highly differentiated condition met with in the higher groups of Algæ. This is one of the reasons which has induced me to primarily subdivide the Myxophyceæ into the Glaucocystideæ and the Archiplastideæ.

The pigment is generally confined, as mentioned above, to the more peripheral areas of the protoplasm, the clear central portion of which often stands out prominently as a rounded mass. This has received the name of the '*central body*' and of late much attention has been given it, more particularly with the view of determining whether it should be regarded as a nucleus or not. Most of the recent investigations show that the 'central body' differs considerably in its structure from the cell-nucleus of higher plants.

Stockmeyer and Zukal have each denied that the 'central body' has any relation to the nucleus of higher plants, and Marx[1] stated that he had obtained negative results in his search for a nucleus. Zacharias[2] states that the term 'nucleus' should not be used for the 'central body' as nothing is known of the part it plays in the economy of the cell, and Massart affirmed that there was no reason to consider it as a nucleus as it was sometimes vacuolated and had no definite outline. Fischer, and also Palla[3], found no chromatin in the 'central body' of the blue-green Algæ they examined, but other observers have described the presence of both granules and

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[1] Marx 'Untersuch. über d. Zellen d. Oscillarien,' Erlangen, 1892 (*vide* Bot. Centralbl. liii, 1893).

[2] Zacharias in Bot. Zeitung, 1892, l.

[3] Palla in Pringsheim's Jahrb. für wissensch. Bot. 1893, xxv.

filaments of chromatin. The investigations of Wille[1], Zacharias[2], and Scott[3] clearly show that the cells of the blue-green Algæ contain a body of a nuclear character. Hegler has shown that at least in some cases, the 'central body' consists of a faintly stainable ground substance in which is embedded a small quantity of chromatin, but that it differs from a nucleus in the absence of a nuclear membrane and nucleolus; and the still more recent investigations of Wager[4] and Kohl[5] have amply confirmed these observations. Dangeard[6] describes a nucleus in *Merismopedia,* but states there is no trace of a nucleolus.

Kohl states that the nucleus of the blue-green Algæ not only differs from that of higher plants in the absence of a nuclear membrane and nucleolus, but also in its remarkable form. It possesses numerous radiating outgrowths of a pseudopodium-like character, which sometimes extend as far as the cell-wall. It may be that these nuclear outgrowths are in some instances partly responsible for the indefinite nature of the chromatophore. In addition to a certain amount of chromatic substance the nucleus contains a number of granules of albuminous material, which have been termed 'central granules.' These have not been observed outside the nucleus.

It would appear from these and other observations, that the 'central body' of the Myxophyceæ differs from a true nucleus in certain essential points, such as the absence of the nuclear membrane and nucleolus, and in its extraordinary form; but at the same time chromatin is undoubtedly present, and Hegler and Kohl have each observed a polar separation of the chromatic substance during division, accompanied by the formation of a chromatic figure. From a consideration of these facts the term '*open nucleus*' suggested by Hieronymus in contradistinction to the 'closed nucleus' of higher plants, appears to be a very suitable one. Hieronymus was the first to point out the presence of chromatin and the absence of a nuclear membrane in the so-called 'central body,' but he was of the opinion that cell-division was very largely, if not quite, independent of this structure.

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[1] Wille in Berichte Deutsch. Botan. Ges. 1883, p. 243.

[2] Zacharias, tom. cit. 1885.

[3] Scott in Journ. Linn. Soc. Bot. xxiv, 1887, pp. 188—192.

[4] Wager in Report Brit. Assoc. 1901 (1902), p. 830.

[5] Kohl, 'Ueber die Organisation und Physiologie der Cyanophy. und die mitot. Teilung ihres Kernes,' Jena (1903).

[6] Dangeard in Le Botaniste, 1892, iii.

The observations of both Hegler and Kohl seem to show that *glycogen* (or a substance much resembling it) is the first product of carbon-assimilation. Chodat has pointed out that mucilage, soluble starches and cyanophycin may make their appearance in all parts of the cytoplasm. *Cyanophycin* is a reserve albuminous substance containing both nitrogen and phosphorus, and it occurs in small granules which swell up rapidly on the addition of hydrochloric acid. These granules occur abundantly in the spores of the Myxophyceæ and are used up during their germination.

Minute oil-drops may also occur in the cytoplasm.

Étard and Bouilhac[1] state that *Nostoc punctiforme* can maintain itself by a saprophytic existence in absolute darkness, as it has the power of assimilating organic substances such as glucose.

Certain of the free-floating Myxophyceæ of the genera *Glœotrichia, Anabæna, Cœlosphærium,* etc., which sometimes occur abundantly in the plankton, contain dark red granules scattered through the cytoplasm. Klebahn[2] and others have asserted that these red granules are gas vacuoles directly concerned with the floating capacity of the Algæ which possess them. This assertion, however, is by no means proven, Brandt[3] having found them in species which do not float; and there is evidence to show that in some cases they are most probably of an oily nature. Should they ultimately prove to be gas vacuoles, then the cytoplasm of certain of the blue-green Algæ contains both gas and liquid (cell-sap) vacuoles.

In some of the Myxophyceæ, and possibly in many others, there is a protoplasmic continuity between the cells of the filaments. Wille[4] was the first to point this out in *Stigonema compactum* var. *brasiliense.* Borzi[5] described these protoplasmic connections in species of *Nostoc* and *Anabæna,* and Nadson has figured them in *Aphanizomenon* and *Tolypothrix.* It is in certain species of *Stigonema* that these protoplasmic connections are most conspicuous, these plants presenting a condition precisely analogous to the protoplasmic continuity of the cells of the Rhodophyceæ. In all cases the continuity appears to be effected by a median pore

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[1] Étard & Bouilhac in Comptes Rendus, cxxvii, 1898, p. 119.

[2] Klebahn in Flora, 1895, lxxx; in Bot. Zeitung, 1897, lv.

[3] Brandt in Berichte Deutsch. Bot. Ges. 1901, xix.

[4] Wille, 'Bidrag til Sydamerik. Algfl.,' Bih. till K. Sv. Vet.-Akad. Handl. 1884, no. 18, p. 6, t. 1, f. 20.

[5] Borzi, 'Le comun. intracell. della Nostoch.,' Malpighia, i, 1887.

through the polar extremities of the cell or through the transverse cell-walls. This pore is best seen in the young branches of *Stigonema ocellatum*, and I have previously pointed out[1] that it is particularly conspicuous if the plants have first been dried and subsequently soaked in water. Fritsch[2] has also described this protoplasmic continuity between the cells of *Anabæna*.

In the families Nostocaceæ, Scytonemaceæ, Stigonemaceæ and Rivulariaceæ certain special cells, known as *heterocysts*, occur at intervals along the filaments. They are sparsely scattered between the ordinary vegetative cells, and owing to the absence of pigmented material they present a very pellucid appearance. Their walls, which are composed of cellulose, are generally thickened and of a pale yellow-brown or yellow-green colour. The heterocysts are frequently larger than the vegetative cells and their walls commonly possess slight polar thickenings. Each polar thickening surrounds the apical pore through the cell-wall, this pore being closed by a minute plate in old heterocysts.

Heterocysts are developed from ordinary vegetative cells, generally singly from any cell of the filament, or they may be formed from the two cells contiguous to an existing intercalary heterocyst. Under natural conditions heterocysts are almost invariably solitary in all genera except *Tolypothrix* and *Calothrix*, but under unfavourable conditions and in cultures they may become seriate. Both Brandt and Fritsch have described the occurrence of an intercellular substance excreted during the formation of heterocysts. This substance, however, can be frequently observed remote from the heterocysts in *Scytonema*, and it is also excreted by the cells of certain species of the Oscillatoriaceæ, a family of blue-green Algæ in which heterocysts do not exist.

The function of heterocysts is not thoroughly understood. They have been thought to serve as limitations to the length of the filaments, and they are at times undoubtedly connected with the breaking of the filaments. In normal plants of the genus *Anabæna* the filaments break readily at all points, and this fracture cannot therefore be controlled by the heterocysts. Neither does the structure of a filament of *Stigonema* support this view, although in this genus heterocysts limit the hormogones. Hieronymus,

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[1] West & G. S. West, 'Welw. Afric. Freshw. Alg.,' Journ. Bot. June 1897, p. 242.

[2] Fritsch in New Phytologist, iii, April 1904, p. 93.

Hegler, and later, Fritsch, regard the heterocysts as storehouses for reserve substances, the latter passing into the heterocyst along the protoplasmic threads which communicate with the adjoining cells. It must be remarked, however, that only under very unfavourable conditions would this function be taken up by the heterocysts, as under normal circumstances the cell-contents of a heterocyst are absolutely homogeneous.

Brandt[1] has observed (in *Nostoc commune* and *N. microscopicum*) the contents of heterocysts set free as gonidia, which have subsequently developed into new filaments. This germination of the contents of a heterocyst must have taken place under very exceptional and abnormal conditions, and it has not been confirmed. It suggests the possibility that heterocysts are the lingering and abortive relics of a type of spore once possessed by certain of the Myxophyceæ, but which long ago ceased to be functional.

The multiplication of the unicellular and colonial blue-green Algæ is brought about principally by simple cell-fission, division occurring in every direction of space or in certain directions only. Definite or indefinite colonies may thus be produced, which dissociate into smaller groups on attaining their maximum size.

Asexual reproduction takes place in a variety of ways. In some families, such as the Nostocaceæ, Stigonemaceæ and Rivulariaceæ, spherical or cylindrical spores are formed by the rejuvenescence and growth in size of certain of the vegetative cells. In the Chamæsiphoniaceæ the elongated unicell divides into a number of small spores which are then liberated from the free apex of the cell. Among the plants of the entire order Hormogonieæ reproduction occurs by the formation of *hormogones*. These are short filaments of cells which are set free from the extremities of the vegetative filaments, and they ultimately develop into new plants. They can be considered as a primitive type of multicellular gemmæ. Reproduction may occur in certain species of *Nostoc* by means of *cocci*, which are small cells about the same size as the vegetative cells[2]. They form a scum on the surface of the water, and each one is capable of producing a colony by simple cell-division. Reproduction by zoogonidia does not take place in the Myxophyceæ, although a few motile, blue-green unicells are known to exist.

Sexual reproduction is unknown amongst the blue-green Algæ,

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[1] Brandt in Berichte Deutsch. Bot. Gesellsch. 1902, xix.

[2] Sauvageau in Ann. Sci. Nat. Bot. iii, 1897, p. 367.

but Borzi[1] has observed the formation of some rather remarkable spores in the genus *Anabæna*. A single vegetative cell divides into two distinct portions which subsequently coalesce, the product having the characters of a nascent spore.

Many of the Myxophyceæ exhibit considerable polymorphism, passing through a number of diverse states at different periods of their life-history. Much confusion has arisen with regard to this polymorphism and many extraordinary statements have in consequence been made concerning the unicellular forms of the blue-green Algæ. Itzigsohn, Hansgirg and Wolle have all regarded the plants of the Chroococcaceæ as stages in the development of the more highly organised blue-green Algæ, and the last-mentioned author has gone so far as to state that "it is now clearly evident that all these so-called unicellular plants constitute nothing more or less than conditions in the plant-life of higher forms[2]." I have previously pointed out the absurdity of this statement[3], which is erroneously based upon one of the best known facts concerning the Myxophyceæ, namely, the ability of many of the lower forms of blue-green Algæ to live only under the same conditions of environment as the higher forms with which they are so frequently intermingled. There is no direct evidence in proof of the generic or specific identity of many of these forms which live intermingled in a common gelatinous matrix, and there is rarely much difficulty in discriminating between the more or less unicellular stages of the higher types and the unicellular or colonial plants of a lower type.

Some of the Myxophyceæ, principally of the genera *Scytonema*, *Stigonema* and *Nostoc*, are regularly found in symbiotic relationship with Fungi to form the dual organisms known as Lichens. The Algæ which have thus lost their individuality become considerably modified and generally lose almost all traces of their original specific characters.

A few blue-green Algæ belonging to the Oscillatoriaceæ exhibit spontaneous movements, generally of a slow, oscillating, gliding, or rotatory character, and concerning which no convincing explanation has yet been offered. It is in the genus *Oscillatoria* that

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[1] Borzi in Bull. Soc. Bot. Ital. 1895, p. 208.

[2] Wolle, Freshw. Alg. U.S. p. 330. Plates clxxxiv and cxci in Wolle's text-book are typical examples of the crude drawings of the Myxophyceæ given by that author.

[3] G. S. West in Journ. Bot. Febr. 1899, pp. 52, 53.

these movements are most conspicuous, and they become more active under those conditions which cause an increase in the activity of protoplasm, such as an augmentation of the temperature or of the intensity of the light. It has been stated by Cohn[1] and by Correns[2] that the movements only take place when the filaments are in contact with a solid body, and it seems probable that, at all events in certain species, contact with a solid body or with the surface film of water is actually necessary for the performance of these movements. The motion consists of a slow creeping or gliding of the entire filament which at the same time slowly rotates around its axis, and this is often accompanied by a slow oscillation of the extremity of the filament. It must be distinctly understood, however, that the movements are not of precisely the same character in all the species of the genus. The filaments of some species secrete a small quantity of a colourless jelly, and it was to this secretion of mucilaginous matter that Siebold, Engelmann, and others attributed the movements. There is, however, quite as much probability in the explanation put forward by Hansgirg that the movements are due to osmotic changes.

In *Arthrospira* the movements consist of a general bending of the spiral filaments or a slow oscillation of their extremities. These movements are more vigorous than those of *Oscillatoria*, spasmodic and jerky, and I have not observed any rotation of the spiral filaments.

In the genus *Spirulina*, in which the filament is also twisted into a close spiral, the movement consists of a rotation around the axis of the spiral, with a slight propulsion through the water. In *Sp. turfosa* Buln., this rotatory motion is relatively rapid.

Many of the Oscillatoriaceæ emit a very disagreeable odour, and ponds and ditches which contain quantities of *Oscillatoria* often give off bad smells. This is attributed by Jackson and Ellms[3] to the decay of highly nitrogenous organic matter, in which partially decomposed sulphur and phosphorus compounds play a large part.

The phenomena of 'water-bloom' and the 'breaking of the meres' are due to the sudden and often periodical appearance of large quantities of a few species of the Myxophyceæ, and the

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[1] Cohn in Archiv für mikr. Anat. 1167, p. 48.

[2] Correns in Berichte Deutsch. Bot. Ges. 1896, xiv.

[3] Jackson & Ellms in Technol. Quarterly, 1897, x.

Algæ concerned in these phenomena are generally species which normally occur in the plankton of lakes and rivers. The extraordinary rapidity of their increase and the consequent discolouration of the water, together with their equally rapid disappearance, constitute one of the most remarkable facts in the whole domain of algological inquiry. Nelson[1] finds that the presence of this 'water-bloom' often has a fatal effect on cattle which have been drinking the water[2].

The Myxophyceæ, regarded as a whole, are unquestionably of a lower type of organisation than any other class of Algæ, and they must be looked upon as an archaic group which is very little in advance of the Schizomycetes (or Bacteria).

The group of the Glaucocystideæ is much in advance of the rest of the blue-green Algæ, the cells possessing a highly specialised chromatophore and a more highly organised nucleus. This necessitates a primary subdivision of the class into two sub-classes, the Glaucocystideæ and the Archiplastideæ.

Sub-class 1.	*Glaucocystideæ.* Cells with a distinct and highly differentiated chromatophore, and with a true cell-nucleus.
Sub-class 2.	*Archiplastideæ.* Cells with a lower type of chromatophore, often scarcely differentiated, and with a primitive type of nucleus.

Sub-class 1. GLAUCOCYSTIDEÆ.

This sub-class has been instituted in order to include a few blue-green Algæ which are sharply demarcated from the rest of the Myxophyceæ by their cytological structure. There is a true cell-nucleus and also a highly differentiated chromatophore, both of these characters being a distinct advance on all other Myxophyceæ.

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[1] N. P. B. Nelson in Minnesota Bot. Studies, 1903, iii, pp. 47—50.

[2] Other blue-green Algæ also appear to be poisonous. Mr Herbert Wright has forwarded me specimens of *Lyngbya majuscula* Harvey from coral beaches in the Gulf of Mannar, where it occurs in abundance; and he states that numbers of horses have frequently been killed by feeding on it.

Family 1. GLAUCOCYSTACEÆ.

This family includes four genera, only two of which are known from the British Islands. The plants are unicellular or colonial, and propagation takes place by the division of the cells in one direction only, or by division into two, four, or eight cells after a corresponding division of the nucleus.

Genus **Glaucocystis** Itzigsohn, 1854. The cells are ellipsoidal, rarely solitary, but more often occurring in twos, fours, or eights within the enlarged wall of the mother-cell. In external features the plants greatly resemble those of the genus *Oocystis*, but the chromatophores are central (or axile), and of a bright blue-green colour. Each chromatophore consists of a central mass with from 10—20 prolongations, which are more or less radiating and considerably curved.

G. Nostochinearum Itzigsh. is widely distributed throughout the British Islands, but it is somewhat scarce. It is found chiefly among submerged Sphagnum. Length of cells 13—19 μ.

Genus **Chroothece** Hansgirg, 1884. The cells are ellipsoidal with a stout enveloping wall, which increases greatly in thickness at one pole, and is conspicuously lamellose. The chromatophore is central with radial outgrowths.

Ch. Richterianum Hansg. is known from salt marshes in Bohemia, and a small form of it (possibly another species) has been observed on wet limestone rocks in W. Yorkshire. Length of cells (of British form) 20—24 μ.

Sub-class 2. ARCHIPLASTIDEÆ.

The great majority of the blue-green Algæ are included in this sub-class. The plants are unicellular, colonial, or filamentous, and in some of the latter (e.g. *Stigonema*, *Anabœna*, etc.), there is a direct protoplasmic continuity between the cells. The protoplasmic unit in each cell is of a lower type than in any other of the Algæ, and has been termed by Nadson[1] an 'archiplast.' The nucleus is of a primitive type, of peculiar form, and without nucleolus or nuclear membrane; in consequence of the latter character it has been termed by Hieronymus an 'open nucleus.' The chromatophores are likewise of an archaic type, the pigmented protoplasm being scarcely differentiated and never of any characteristic form.

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[1] Nadson in Scripta Botanica Horti Univers. Imp. Petropolit. 1895, iv, fasc. 2.

There are two orders of this sub-class, both of which are abundantly represented in every part of the world.

Order I. *Hormogoneæ.* Plants filamentous; filaments simple or branched, generally consisting of one or more rows of cells within a sheath, attached to a substratum or free-floating.

Order II. *Coccogoneæ.* Plants unicellular or colonial, commonly embedded in a gelatinous matrix, more rarely free-floating.

Order I. HORMOGONEÆ.

This order includes all the filamentous Myxophyceæ. As a rule the filaments consist of a simple row of cells, naked or enclosed within a sheath of varied character. In some of the Oscillatoriaceæ and Stigonemaceæ there are two or more rows of cells contained within the same sheath. A simple row of cells is known as a *trichome,* and the trichome with its enveloping sheath is termed a *filament.* In the Scytonemaceæ, Stigonemaceæ, Nostocaceæ, and Rivulariaceæ heterocysts are more or less abundantly scattered at intervals among the vegetative cells, and in some genera one extremity of the filament is always terminated by a heterocyst. The heterocysts are commonly solitary, but they may occur in groups, as in some species of *Tolypothrix.* The filaments are frequently branched, and there is often a false branch-system due to the close apposition of the basal extremities of a number of filaments. New filaments often arise as lateral outgrowths from the vegetative cells of an older filament. The trichomes of the newer filaments separate from that of the old filament, but their sheaths still remain partially fused, and thus a false branch-system is produced.

Most of the Algæ of this order occur attached to a substratum, and they frequently form dense, felt-like patches or tough gelatinous masses of various colours. Some of them form more fragile gelatinous masses of varied form, either aquatic or on damp earth, and others are free-floating.

Asexual reproduction takes place by means of hormogones, and more rarely by spores.

As a rule the trichomes are cylindrical with obtuse or narrowed extremities, but in some of these Algæ there is a gradual and conspicuous attenuation of the trichome, either from base to apex or from the central part towards each extremity. This character is utilized to subdivide the order.

Sub-order 1. *Psilonemateæ.* Trichomes cylindrical, sometimes narrowed at the extremities.

Sub-order 2. *Trichophoreæ.* Trichomes conspicuously attenuated towards one or both extremities, which are generally piliferous.

Sub-order 1. PSILONEMATEÆ.

The majority of the filamentous blue-green Algæ belong to this sub-order. The trichomes are cylindrical or torulose in character, of a uniform thickness, and with or without a sheath. The sheath may be hyaline and gelatinous, very thin, or of considerable diameter; in many it is tough and lamellose. In some the sheaths contain no small proportion of cellulose, colouring blue with chlor-zinc-iodine, but in others they consist entirely of mucus. The apical cell of the trichome may be obtuse or more or less conical and attenuated, and occasionally the apical and sub-apical cells are suddenly attenuated.

The sub-order includes the four following families:—

Family 1. *Stigonemaceæ.* Filaments usually stout and branched; sheaths thick, firm, and often irregular; trichomes with heterocysts, and frequently consisting of more than one row of cells.

Family 2. *Scytonemaceæ.* Filaments with a false branch-system; sheaths firm and tubular, of more or less equal thickness; trichomes consisting of a single row of cells, with heterocysts, but not of uniform thickness.

Family 3. *Nostocaceæ.* Trichomes commonly tortuose and intricate, enveloped within a large gelatinous mass, consisting of a single row of uniform cells (generally torulose), with heterocysts; sheaths very delicate, mostly confluent.

Family 4. *Oscillatoriaceæ.* Trichomes consisting of a simple row of cells, uniform along their entire length except for the apical cells, which are sometimes attenuated; heterocysts absent; sheaths variable, more or less gelatinous, and sometimes enclosing more than one trichome.

Family 1. **STIGONEMACEÆ.**

In this family the cells are arranged either in a single series or in several more or less irregular series within a strong sheath. This sheath is rarely thin and regular, being more often thick, dark brown in colour, of considerable toughness, and with a very uneven exterior. The filaments are branched, and the branches arise by a growth from one of the cells of the main filament. The filaments increase in length by the division of the cells towards the apices. The heterocysts are intercalary, being scattered at intervals between the vegetative cells. When more than one row of cells exists in a filament the heterocysts are situated in a lateral position.

The robust filaments of most of the members of this family, with their true branches and somewhat irregular outlines, are easily distinguished from the more uniform and thinner filaments of the Scytonemaceæ. The presence of more than one row of cells within the sheath, and the frequent irregular disposition of these cells, are also distinctive features.

There are only two British genera, *Stigonema* and *Hapalosiphon*. In the former the reproduction normally takes place by the development of hormogones from the extremities of the branches, whereas in the latter the normal method of reproduction is by spores.

Genus **Stigonema** Ag., 1824. [*Sirosiphon* Kütz., 1843.] The filaments are free-floating or aggregated to form soft, felt-like masses. The cells are always rounded, and are disposed either in two or more rows, or more rarely in a single row. The heterocysts are commonly lateral, or less frequently intercalary. The sheaths are thick, lamellose, with an uneven exterior, and they are usually

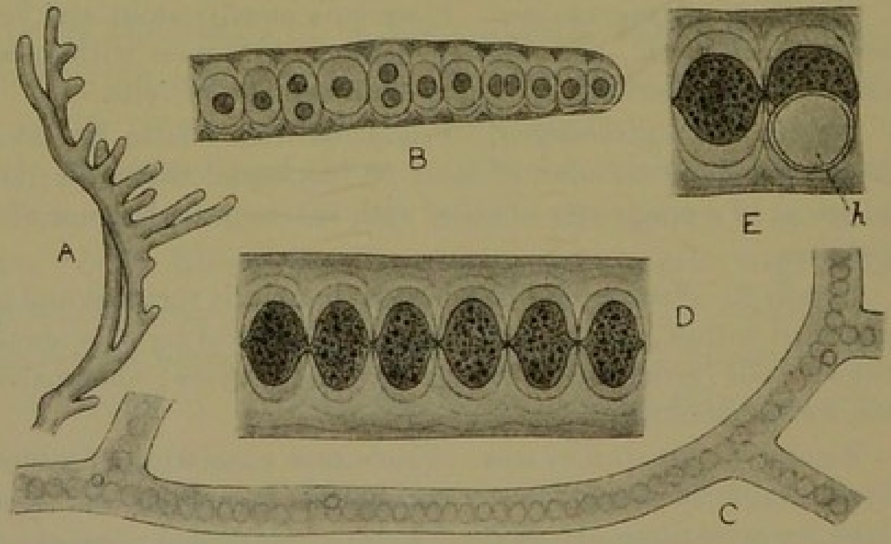

Fig. 146. A and B, *Stigonema minutum* Hass., from Slieve Donard, Down, Ireland; A, ×100; B, ×440. C—E, *St. ocellatum* (Dillw.) Thur., from Llyn Teyrn, Snowdon, N. Wales; C, ×100; D and E, ×440. *h*, heterocyst.

of a golden-yellow or brown colour. The branches are generally short, thick, and irregularly disposed.

Species of this genus occur principally on damp or wet rocks, but are sometimes observed free-floating in ponds and lakes. The largest British species are *St. informe* Kütz. and *St. mammillosum* Ag., the filaments of which reach a thickness of 90 μ. *St. hormoides* (Kütz.) Born. & Flah. is the smallest known species; thickness of filaments 7—15 μ.

Genus **Hapalosiphon** Näg., 1849. [? *Fischerella* (Born. & Flah.) Gomont, 1895.] The filaments are free-floating amongst other Algæ, or they are rarely subaërial in moist situations. The primary filaments are never very thick, and consist of a single row (rarely of two rows) of cells enclosed within a strong sheath of uniform thickness. The branches are sometimes of the same thickness as the primary filaments, but more often slightly narrower, and they are commonly unilateral. They are mostly long and flexuose, and are very slightly attenuated. As a rule they are few and distant, but occasionally they arise in unilateral clusters. The sheaths of the branches are always thinner than those of the primary filaments, and generally quite colourless. The cell of the primary filament opposite the base of a branch usually projects into it, and the cells of the branches are proportionately much longer than those of the primary filament. The spores are formed from the ordinary vegetative cells, and possess thick yellowish-brown cell-walls. Often the majority (or even all) the cells of both primary filaments and branches of some portions of the plant become converted into spores[1].

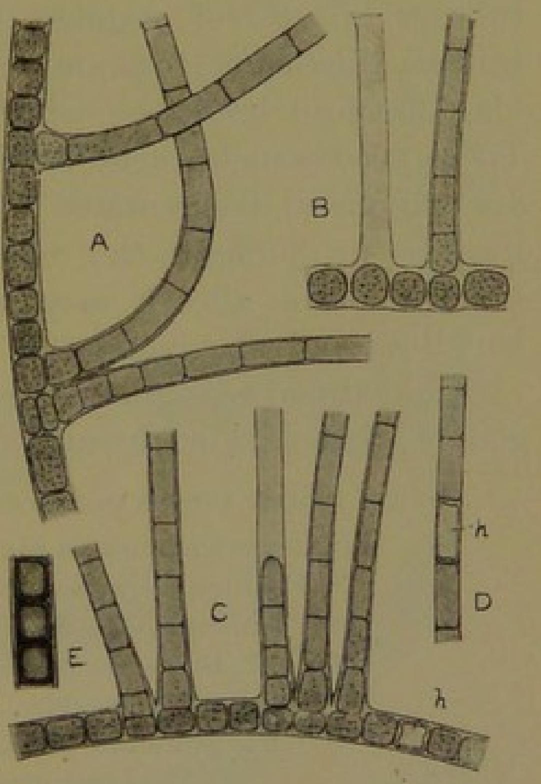

Fig. 147. *Hapalosiphon Hibernicus* West & G. S. West, from Glen Caragh, Kerry, Ireland (×440). E, portion of a row of spores within the sheath.

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[1] West & G. S. West in Journ. Bot. June 1897, p. 241.

The plants of this genus are most frequently met with in the British Islands amongst *Utricularia minor* and submerged Sphagnum. The two most widely distributed species are *H. intricatus* West (diam. of filaments 4—7 μ) and *H. Hibernicus* West & G. S. West (diam. of filaments 6—10 μ; fig. 147).

Family 2. **SCYTONEMACEÆ.**

The plants of this family are at once distinguished from all others of the Hormogoneæ by their type of branching. Except in the three rare genera, *Desmonema, Hydrocoryne* and *Diplocolon*, the cells are always disposed in a single series within a strong tubular sheath of regular thickness. The trichomes of the primary filament perforate the sheath at intervals and issue as long flexuose branches, which develop a sheath of their own. These false branches arise either singly or in pairs. The trichomes are cylindrical, but towards the growing end of the filament they increase in diameter, the cells becoming much shorter and more rounded. The sheath may be homogeneous and colourless, or lamellose and of a yellow or brown colour.

The normal reproduction is by hormogones, but in most of the genera ellipsoidal or globular spores are sometimes produced.

The five British genera can be distinguished as follows:—

A. With one trichome in each sheath.
  * Filaments simple, unbranched .... *Microchæte.*
  * Filaments with false branches ("pseudo-rami").
    † Branches geminate, arising between the heterocysts .... *Scytonema.*
    †† Branches arising singly in the region of the heterocysts .... *Tolypothrix.*
B. With 2—6 trichomes within each sheath.
  * Filaments straight, with basal heterocysts ... *Desmonema.*
  ** Filaments contorted within a common sheath *Diplocolon.*

Genus **Microchæte** Thuret, 1875. [*Coleospermum* Kirchner, 1878.] The filaments are fixed at the base, erect, or tortuose-flexuose, and without branches. The plants greatly resemble unbranched species of *Scytonema*, and they occur in radiating tufts or soft felt-like masses. Kirchner[1] has placed this genus in the Nostocaceæ, but the presence of a prominent tough sheath round each individual trichome, and the thick growing apices with

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[1] Kirchner in Engler and Prantl's Natürl. Pflanzenfam. i, 1 a, p. 76.

shorter cells, are characters which indicate a clear affinity with the Scytonemaceæ.

M. diplosiphon Gom. var. *Cumbrica* West is known from the English Lake District; thickness of internal sheath 6·5—9 μ. Species of this genus are very rarely met with.

Genus **Scytonema** Ag., 1824. [*Petalonema* Berkeley, 1833; *Schizosiphon* Kütz., 1843 (in part); *Symphyosiphon* Kütz., 1843 (in part); *Arthrosiphon* Kütz., 1845.] The filaments generally occur in a dense intricate mass, and are at once characterized by their false branches. These pseudo-branches arise in pairs between the heterocysts, each pseudo-branch being a continuation of the original trichome which has perforated its old sheath. The sheath is tough, lamellose, and of a golden-yellow or brown colour; it is generally of even thickness, but in a few species (e.g. *S. alatum*) in which it is of great width, the margins are irregular.

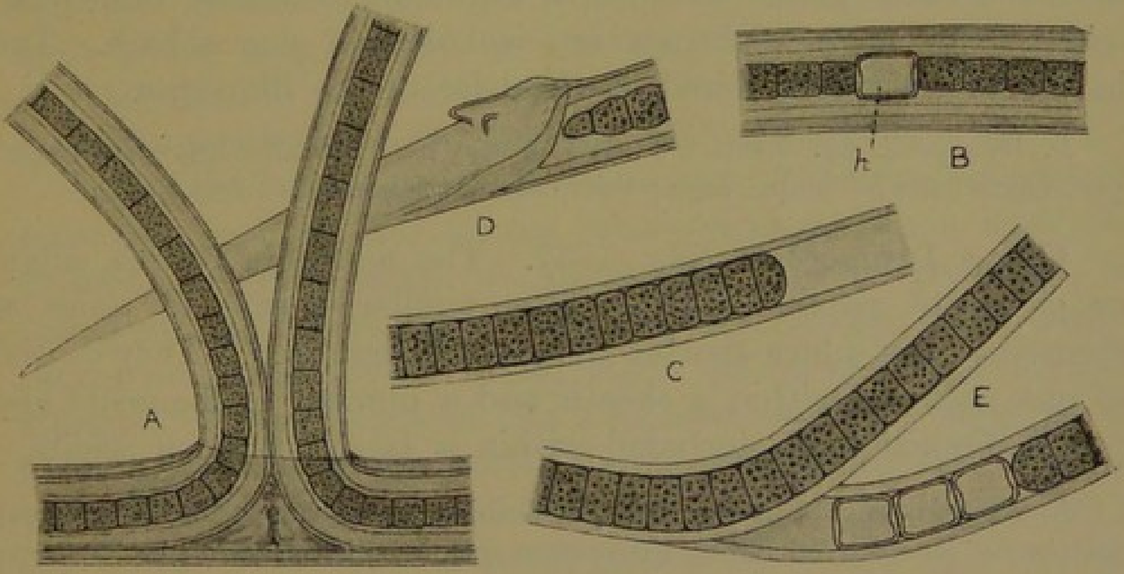

Fig. 148. A—D, *Scytonema mirabile* (Dillw.) Thur., from Cronkley Fell, N. Yorks. (× 440); C, apex of a 'branch'; D, organ of attachment at base of filament. E, *Tolypothrix lanata* (Desv.) Wartm., from Riccall Common, E. Yorks. (× 440).

S. Myochrous Ag. and *S. mirabile* (Dillw.) Thur. [= *S. figuratum* Ag.] are the two most abundant British species, the former often occurring on wet rocks in large felt-like masses an inch in thickness; thickness of fil. 18—36 μ; thickness of trichomes 6—12 μ. *S. alatum* (Berk.) Borzi is frequent on wet rocks of carboniferous limestone, occurring as a brownish-green stratum which is thickly encrusted with lime; thickness of fil. 24—66 μ; thickness of trichomes 9—15 μ.

Genus **Tolypothrix** Kütz., 1843. [Inclus. *Hassallia* Berkeley, 1845.] The filaments of this genus are very like those of *Scytonema*, and the plants are primarily distinguished by the single pseudo-branches. The latter are never geminate as in *Scytonema* and they always issue in the region of the heterocysts. Both terrestrial and aquatic species occur, and the sheaths, which are usually thinner than those of *Scytonema*, may be either flexible or more or less fragile. *Hassallia* could only be separated from *Tolypothrix* by the fragility of its sheaths, and that character is totally inadequate as a generic distinction[1]. The heterocysts are sometimes 3-, 4-, or 5-seriate.

T. lanata (Desv.) Wartm. (thickness of fil. 9—12·5 μ; thickness of trichomes 7·5—10 μ; fig. 148 E) and *T. tenuis* Kütz. (thickness of fil. 8—10 μ; thickness of trichomes 6—8 μ) are the most frequent British species, occurring amongst various aquatic plants in ponds and lakes.

Genus **Desmonema** Berkeley & Thwaites, 1849. The filaments of this genus exhibit a slight dichotomous branching, and two or more trichomes are included in one sheath. The heterocysts are only found at the base of the filaments.

D. Wrangelii (Ag.) Born. & Flah. is a very rare British Alga, occurring in penicillate tufts 5—6 mm. high; thickness of trichomes 9—10 μ.

Genus **Diplocolon** Näg., 1857. The filaments possess single or geminate pseudo-branches of a similar nature to those of *Scytonema* but much shorter and greatly contorted. They consist of one trichome within a sheath, and a number of filaments and pseudo-branches are included within a larger common sheath.

D. Heppii Näg. is known from Yorkshire. It forms a brownish-green gelatinous stratum on damp calcareous rocks; thickness of fil. 20—28 μ; thickness of trichomes 6—10 μ.

Family 3. **NOSTOCACEÆ.**

The plants of the Nostocaceæ are of a simpler type than any others of the Psilonemateæ which possess heterocysts. The filaments are never fixed by one extremity and they are never branched. The trichomes consist of a single series of cells of uniform character. The cells are frequently torulose and the

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[1] West & G. S. West in Journ. Bot. July 1897, p. 266.

heterocysts may be terminal or intercalary. The sheaths are very delicate and invariably gelatinous in character. In some they are more or less distinct, of variable diameter and closely adhering to the trichomes; but in others they become confluent, forming a watery mass of jelly which encloses a large number of trichomes. It is in the genus *Nostoc* that this gelatinous mass becomes most conspicuous. Whenever there is a fracture of a filament the trichome and the sheath both break at the same point, and empty sheaths, such as are commonly found in the Stigonemaceæ and Scytonemaceæ, are never met with. The trichomes are sometimes straight and rigid, but they may be contorted to form densely interwoven masses.

Reproduction occurs by the formation of hormogones and spores. The former are produced by the fragmentation of fully grown trichomes, and in some genera they are set free by the dissolution of the enveloping mucilage. Spores of a spherical, ellipsoidal, or cylindrical form are developed from the vegetative cells, and invariably arise in relation to the position of the heterocysts. They may be developed singly or in series, and by reason of their definite form and position they furnish a character of primary importance in the discrimination of genera and species.

About half the species of *Nostoc* and *Cylindrospermum* are terrestrial in habit, but all the other members of the family are aquatic. Some species of *Nostoc*, and also of *Anabæna*, are endophytic in various parts of such plants as *Azolla, Cycas, Lemna, Sphagnum, Anthoceros,* etc., and other species of *Nostoc* are constituents of the thallus of many Lichens, especially those of the Collemaceæ. Many species of *Anabæna* are a marked feature of the freshwater plankton, and certain species of *Nostoc* are used as food by the inhabitants of divers parts of the world.

A. Trichomes flexuose and contorted within a definite gelatinous investment .... *Nostoc.*

B. Trichomes more or less straight, free, or forming a thin mucous stratum.

 * Heterocysts and spores intercalary.

  † Trichomes nude, or with a thin mucous sheath, free, or aggregated without order to form a flocculent mass; cells equal or longer than their diameter; spores solitary, geminate, or in short series .... *Anabæna.*

†† Trichomes short, aggregated in parallel bundles to form thin, feathery, plate-like masses .... *Aphanizomenon.*

††† Trichomes free; spores seriate, remote from the heterocysts; cells shorter than their diameter .... *Nodularia.*

** Heterocysts terminal and the spores always contiguous to them .... *Cylindrospermum.*

Genus **Nostoc** Vaucher, 1803. The plants of this genus are found as gelatinous masses of a rounded or expanded character, sometimes attached to a substratum, at other times floating freely in the water. When young the plants are almost always globose or ellipsoid, but with advancing age many species become exfoliated to form flattened expansions, often with lacerated margins. The trichomes are much contorted, forming an intricate mass within the gelatinous envelope, and they are generally much denser towards the exterior. The sheaths are never very distinct, and more often they have become completely merged with the enveloping jelly. The cells may be spherical, barrel-shaped, or cylindrical, and the heterocysts are either intercalary, or in the young forms, terminal. The spores are spherical or oblong, and are developed centrifugally in series between the heterocysts[1].

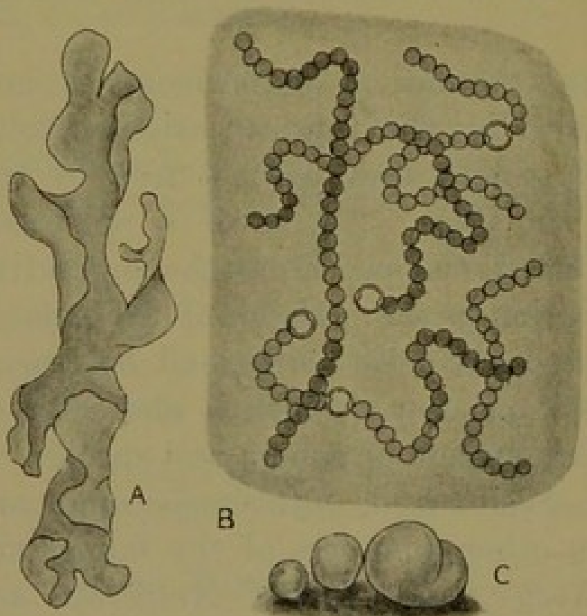

Fig. 149. A and B, *Nostoc Linckia* Bornet, from Ben Lawers, Perthshire; A, nat. size; B, small portion of thallus, × 340. C, *N. cœruleum* Lyngbye, from R. Wharfe at Ilkley, W. Yorks., nat. size.

Young *Nostocs* of different species greatly resemble each other. They consist of a variously contorted trichome within a relatively small, elongated, mucous investment, terminated at each end by a heterocyst.

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[1] Borzi in Giornale Botan. Ital. 1878, x, p. 241.

There are about 15 British species of *Nostoc*, some of which are much more abundant than others. *N. piscinale* Kütz., *N. cæruleum* Lyngbye (fig. 149 C) and *N. pruniforme* Ag. are widely distributed in ponds and ditches, generally occurring as free-floating masses. *N. commune* Vauch. prefers damp ground which is frequently inundated. *N. muscorum* Ag., *N. humifusum* Carm. and *N. macrosporum* Menegh. are found principally among mosses on wet rocks. *N. sphæricum* Vauch. and *N. verrucosum* Vauch. commonly occur attached to the rocks and stones in the beds of rapid streams and rivers. The cells of *N. humifusum* are only 2—2·5 μ in diameter, whereas those of *N. macrosporum* reach a diameter of 8—9 μ.

Genus **Anabæna** Bory, 1822. [*Sphærozyga* Ag., 1827; *Trichormus* Allman, 1842; *Dolichospermum* Thwaites, 1850.] The trichomes are straight or circinate, often destitute of all traces of a sheath, and are either free-floating or aggregated to form a thin mucous stratum. The cells are generally of equal size, but sometimes there is a slight attenuation of the trichome, and the apical cell may be conical. The cell-contents may be either homogeneous or granular. The heterocysts are numerous and intercalary. The spores are variously disposed; in some they are solitary, in others there are two spores one on each side of a heterocyst, and rarely they are in short concatenate series. In most species they arise centrifugally with regard to the heterocysts, but in some they are developed centripetally. The latter were formerly placed in another genus—*Sphærozyga*.

As a rule, *Anabænas* cannot be kept alive very long after collection, unless placed in a large volume of water. One or two days in a small glass vessel is usually sufficient to cause a disarticulation of the filaments of most of the species, and under these conditions they often lose their specific characters, developing forms which are quite unknown in their natural state.

Hansgirg at one time suggested the union of this genus with the genus *Nostoc*, but there are many good reasons for keeping the genera separate. Species of *Anabæna* even when found in a mucous stratum, which is but rarely, never approach in consistency the tough thallus of a *Nostoc*; with one or two exceptions the trichomes are rigid and fragile, and they are never at any time so contorted as those of a *Nostoc*; the spores are generally much more elongate than those produced in the latter genus, and the habits of the two genera are mostly quite different. I doubt if the merest novice at the study of freshwater Algæ would confound an *Anabæna* with a *Nostoc*. He certainly would not had he collected them himself. Why, under these circumstances, should the genus *Nostoc* be made more confusing than it is already?

There are about 10 British species of the genus, some of which are relatively abundant in the waters of ponds and lakes. *A. Flos-aquæ* Bréb. and *A. circinalis* Rabenh. are constituents of the freshwater plankton. *A. oscillarioides* Bory and *A. inæqualis* (Kütz.) Born. & Flah. (fig. 150 A—D) are found among other Algæ in still water. Several species occur among Sphagnum in bogs, but spores seem to be rarely developed in these situations. The trichomes vary in thickness in the different species from 4 to 10 μ, and the cylindrical type of spore may reach a length of 60 μ.

Genus **Aphanizomenon** Morren, 1838. The trichomes are straight and without a definite sheath, being agglutinated to form spindle-shaped or small plate-like bundles, which float freely in the water. Each trichome is slightly attenuated towards the extremities. The spores are solitary, cylindrical, much elongated, and only developed sparingly between the heterocysts.

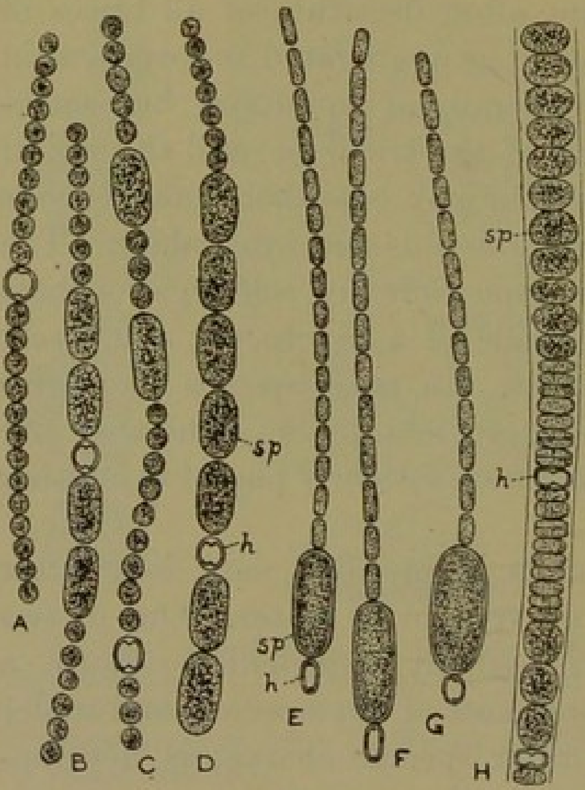

Fig. 150. A—D, *Anabæna inæqualis* (Kütz.) Born. & Flah., from Epping Forest, Essex. E—G, *Cylindrospermum stagnale* (Kütz.) Born. & Flah., from Ribblehead, W. Yorks. H, *Nodularia sphærocarpa* Born. & Flah., from near Ely, Cambridgeshire. (All × 480.)

A. Flos-aquæ (L.) Ralfs is found floating in the still waters of ponds and lakes, sometimes in abundance. The trichomes are rigid and 5—6 μ in diameter. The cells are subquadrate and the heterocysts are cylindrical. The spores are 60—80 μ in length and only 7—8 μ in breadth.

Genus **Nodularia** Mertens, 1822. The filaments are free-floating and are generally furnished with a distinct sheath. The latter is hyaline and mucous, closely enveloping the trichome, and sometimes becomes diffluent. The trichomes are more or less straight, with short, depressed, often discoidal cells. The heterocysts are also depressed. The spores are spherical or discoidal, and are developed in series between the heterocysts.

There are three British species of the genus occurring in fresh water (or sometimes in slightly brackish water). None of them are abundant, although *N. spumigena* Mertens is not uncommon (diameter of trichomes 10—15 μ). *N. sphærocarpa* Born. & Flah. is known from Cambridgeshire (diameter of trichomes 6—7 μ; fig. 150 H).

Genus **Cylindrospermum** Kütz., 1843. The trichomes in this genus are relatively short, destitute of a sheath, and are mostly aggregated to form an expanded mucous stratum. The cells are cylindrical, longer than their diameter, and one end of the trichome is terminated by a solitary heterocyst. The spores are always developed from the cell (or cells) next the heterocyst; they are generally solitary, but in one species they are seriate. The terminal position of the heterocysts and spores at once distinguishes this genus from all the others of the Nostocaceæ.

There are three British species. *C. majus* Kütz. (= *C. macrospermum* Rabenh.) is common on damp stones and earth, often forming a thin stratum on garden paths or at the edge of a pond; thickness of trichomes 5—6 μ. *C. stagnale* (Kütz.) Born. & Flah. is not uncommon in boggy ditches, particularly in peaty ditches; thickness of trichomes 3·8—4·5 μ; fig. 150 E—G. *C. catenatum* Ralfs is a much rarer species occurring on the damp mud of stagnant rivers and ditches.

Family 4. **OSCILLATORIACEÆ.**

This is the largest family of the Psilonemateæ and is distinguished at once from all the others by the entire absence of heterocysts. The trichomes consist of a simple and uniform row of cells, which sometimes exhibits a slight attenuation at the apex. The apical cell may be rounded, conical, or subcapitate, and it occasionally carries a slightly thickened hood or calyptra. The trichomes are straight or flexuose, occurring either free-floating or forming a thin mucous stratum. The slimy stratum formed by filaments of this family may occur on damp surfaces, on submerged stones, or on the muddy bottom of ponds and ditches. Some species of *Oscillatoria* rise to the surfaces of ponds as brown or brownish-green flocculent masses, which are often very conspicuous. This generally occurs in bright sunshine, and the mass floats owing to the retention of numerous bubbles of oxygen amongst the intricate network of trichomes. The cells of some species of this family are joined so closely that the trichome appears perfectly cylindrical with straight margins. In other species there is a faint constriction between the cells, or the latter may even be separated by a mucous layer. In rare instances the trichomes are spirally twisted.

Sheaths are not always present in this family, and when present, they are of very varied character. In some genera, such as *Microcoleus* and *Phormidium*, the sheath is always colourless, transparent, and more or less evanescent, whereas in others, such as *Schizothrix* and *Plectonema*, it is of greater firmness, generally branched, and often lamellose.

Slow, gliding or rotatory movements are exhibited by some species of *Oscillatoria*, *Phormidium*, *Arthrospira* and *Spirulina*.

The family is subdivided into two groups:—

Sub-family I. *Vaginarieæ.* Several trichomes included within a single sheath, which is frequently branched.

Sub-family II. *Lyngbyeæ.* Never more than one trichome within a sheath.

Sub-family I. VAGINARIEÆ.

This sub-family contains the most highly organised of those filamentous blue-green Algæ which do not possess heterocysts. The most important feature of the group is the inclusion of two or many trichomes within the same sheath. The sheaths often exhibit more or less branching, and are of two distinct types. In one type they are firm and lamellose, often brown, brownish-red, or even blue in colour; in the other type they are mucous and hyaline. Those of the first type always become of a blue colour on the addition of chlor-zinc-iodine, whereas those of the second type very rarely become coloured by this treatment.

A. Sheaths generally coloured; trichomes loosely aggregated within the sheath, not very numerous.

* Sheaths firm, lamellose, hyaline or coloured; containing few or many trichomes .... *Schizothrix.*

** Sheaths wide, hyaline or yellow-brown, diffluent; containing very few trichomes .... *Dasyglœa.*

B. Sheaths always hyaline, not lamellose, containing a large number of trichomes.. *Microcoleus.*

Genus **Schizothrix** Kütz., 1843. [Inclus. *Inactis* Kütz., 1843; *Hyphæothrix* Kütz., 1843 (in part).] The filaments of this genus are variously agglomerated to form small cushion-like masses, erect tufts, or a flat stratum, and occasionally they occur floating freely in water. In some instances there is a deposition of lime in the stratum. The filaments are either simple or variously branched, and are sometimes of great length. The sheaths are firm and lamellose, generally attenuated towards the apex, and rarely colourless. The inner layers of the sheath may be any shade of yellow, yellow-brown, purple, or blue, and they are usually of a deeper colour than the outer layers. There are relatively few trichomes (sometimes not more than two) within each sheath, laxly disposed, and sometimes spirally twisted.

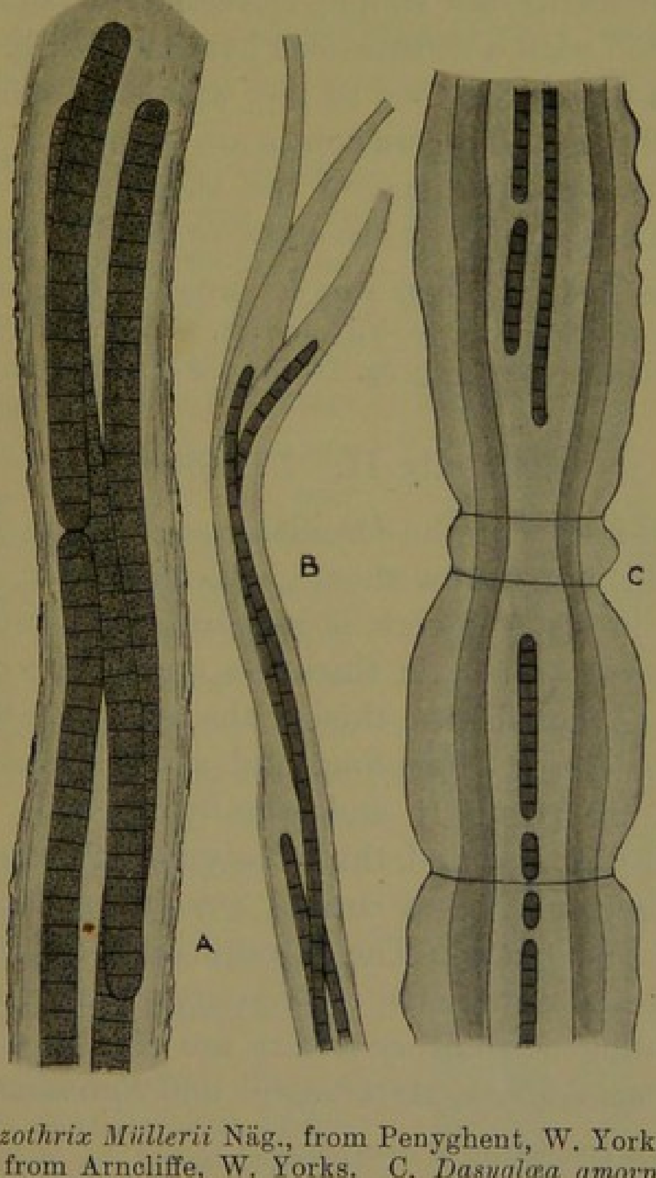

Fig. 151. A, *Schizothrix Müllerii* Näg., from Penyghent, W. Yorks. B, *S. lardacea* (Ces.) Gom., from Arncliffe, W. Yorks. C, *Dasyglœa amorpha* Berk. (a small form) from Thursley Common, Surrey. (All × 460.)

The largest British species is *S. Müllerii* Näg. (thickness of trichomes 7—13 μ; fig. 151 A) and the smallest is *S. delicatissima* W. & G. S. West (thickness of trichomes 0·6—0·8 μ). *S. calcicola* (Ag.) Gom. and *S. lardacea* (Ces.) Gom. (fig. 151 B) are not infrequent on wet rocks. In *S. funalis* W. &

G. S. West, which is another very small species (thickness of trichomes 0·5—0·7 μ), the branches of the filaments are twisted round each other like the strands of a rope.

Genus **Dasyglœa** Thwaites, 1848. This genus differs principally from *Schizothrix* in the possession of relatively wider sheaths, which enclose fewer and more remote trichomes.

D. amorpha Berk. occurs in permanent bogs; thickness of trichomes 4—6 μ. A figure is given of a small form of the species (fig. 151 C).

Genus **Microcoleus** Desmazières, 1823. [*Cthonoblastus* Kütz., 1843.] The filaments are simple, terrestrial or aquatic in habit, and are furnished with a conspicuous hyaline sheath. This sheath is more or less cylindrical, not in any way lamellose, and its apex is generally diffluent. The trichomes are numerous, closely aggregated within the central part of the sheath, and often spirally interwoven. The apical cells are acute or acutely conical.

Plants of this genus are very rare in Britain. *M. subtorulosus* (Bréb.) Gom. (thickness of trichomes 4—5 μ) and *M. delicatulus* W. & G. S. West (thickness of trichomes 1·5—2 μ; fig. 152 A) are known from Scotland.

Sub-family II. LYNGBYEÆ.

In this sub-family of the Oscillatoriaceæ there is never more than one trichome within a sheath, and the latter, although firm and lamellose in some genera, is indefinite or wanting in others. The trichomes vary much in thickness and in the relative length of their cells. As a rule, the thicker the trichome, the shorter the cells. In *Arthrospira*, *Spirulina*, and some species of *Lyngbya*, the trichomes are regularly and spirally twisted. In *Spirulina* the trichome is unsegmented, thus consisting of a single cell. This genus, therefore, approaches certain genera of Bacteria, such as *Spirillum* and *Spirochæte*. The extremities of the trichomes may be obtuse, capitate, acuminate, or even greatly attenuated. Movements of a gliding or rotatory nature are exhibited in the genera *Oscillatoria*, *Phormidium*, *Arthrospira* and *Spirulina*.

A. Trichomes consisting of many cells.
    * Filaments simple, or falsely branched; sheaths firm; apices of trichomes straight.
        † Filaments free or forming felt-like masses, branched; pseudo-branches often geminate *Plectonema*.
        †† Filaments forming erect tufts, often branched; pseudo-branches solitary .... *Symploca*.

††† Filaments free and simple, free-floating or forming a matted stratum .... *Lyngbya.*

** Filaments simple; sheaths thin, always hyaline, mucous, and more or less diffluent, in some species absent; apices of trichomes commonly curved.

† Trichomes more or less agglutinated by their mucous sheaths; cells of trichome often slightly separated by a thin mucous layer... *Phormidium.*

†† Trichomes destitute of sheaths, free, straight, or with curved extremities .... *Oscillatoria.*

††† Trichomes destitute of sheaths, twisted into a regular spiral .... *Arthrospira.*

B. Trichomes consisting of one cell, twisted into a regular spiral .... *Spirulina.*

Genus **Plectonema** Thuret, 1875. The filaments are free-floating, forming cæspitose masses, or they are intricately matted amongst damp mosses and on wet rocks, forming felt-like or mat-like expansions. The sheaths are firm, hyaline or lamellose, and rarely of a yellow-brown colour. The trichomes fit closely within their sheaths, and there is often a slight constriction between the cells. The filaments give origin to false branches exactly similar to those of *Scytonema*; in fact, *Plectonema* only differs from *Scytonema* in the absence of heterocysts and in the more irregular manner of its false branching.

P. Tomasinianum (Kütz.) Born. is the largest and most frequent British species, occurring as greenish-brown felt-like masses on wet rocks. Thickness of filaments 16—27 μ; thickness of trichomes 12·5—22 μ; length of cells 3—9 μ. Thick-walled resting cells, probably of the nature of spores, have been observed in this species.

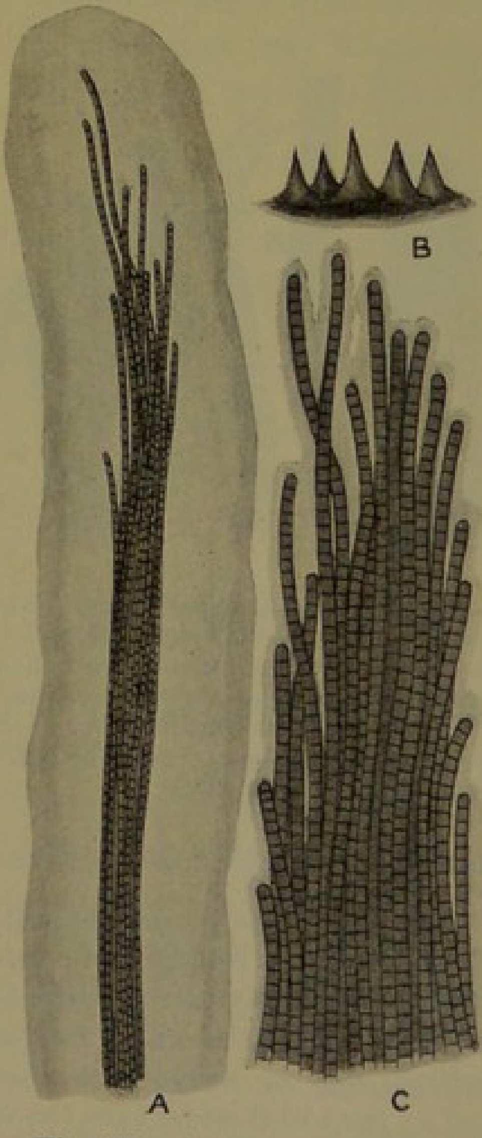

Fig. 152. A, *Microcoleus delicatulus* W. & G. S. West, from Glen Tummel, Perthshire (× 350). B and C, *Symploca muralis* Kütz., from Frizinghall, W. Yorks. (B, nat. size; C, × 350).

Genus **Symploca** Kütz., 1843. In this genus the filaments are densely interwoven to form a creeping stratum from which arise numerous erect tufts of variable height. A false branching is exhibited by the filaments of some species, the branches arising singly. The sheaths are thin, hyaline, and generally firm; they partially coalesce in the erect tufts. Only one trichome is present within a sheath and its apex is straight.

S. muralis Kütz. is known from W. Yorkshire. It occurs on damp earth, walls, or trunks of trees; thickness of trichomes 3·4—4 μ; fig. 152 B and C. Other species occur among mosses and dead leaves, and others in hot springs, the genus having a world-wide distribution.

Genus **Lyngbya** C.Ag., 1824. [*Leibleinia* Endlicher, 1836; *Leptothrix* Kütz., 1843 (in part); *Spirocoleus* Möbius, 1889 (in part).] The filaments are unbranched, free-floating or densely intricate, forming a floccose mass or an expanded stratum. The sheaths are firm, of variable thickness, and sometimes lamellose. They are generally hyaline, but in a few species they become of a yellow-brown colour. The trichomes are either obtuse or slightly attenuated at the apices, and sometimes there are evident constrictions between the cells.

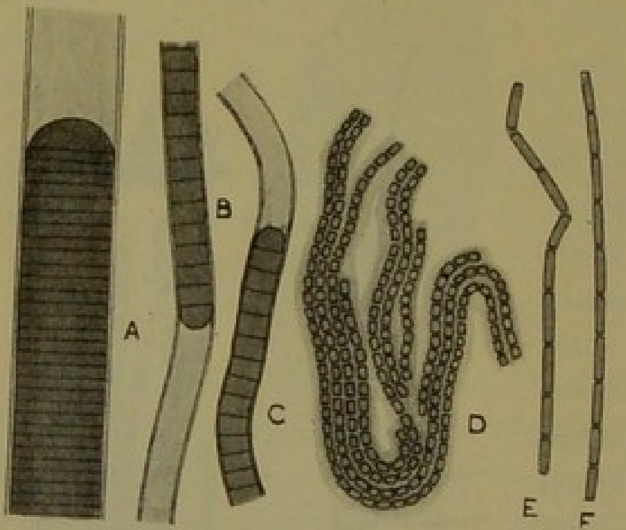

Fig. 153. A, *Lyngbya major* Menegh., from Wimpole Park, Cambridge. B and C, *L. æruginеo-cœrulea* (Kütz.) Gom., from Bradford, W. Yorks. D, *Phormidium molle* (Kütz.) Gom. (a narrow form), from Bradford, W. Yorks. E and F, *Ph. tenue* (Menegh.) Gom., from Wicken Fen, Cambridge. (All × 460.)

Species of this genus are widely distributed and occur in very varied habitats. Those belonging to the subgenus *Leibleinia* are entirely marine and live as epiphytes on other larger Algæ. There are about 10 British freshwater species, of which *L. Martensiana* Menegh. (thickness of trichomes 6—10 μ) and *L. æruginеo-cœrulea* (Kütz.) Gom. (thickness of trichomes 4—6 μ; fig. 153 B and C) are the most abundant. *L. ochracea* (Kütz.) Thur. occurs in water containing much iron, the oxide of iron ultimately forming a thick deposit round the sheaths of the filaments. *L. æstuarii* (Mert.) Liebman is the largest British species which occurs in fresh water (thickness of trichomes up to 24 μ), although it is principally brackish or marine in habit.

Genus **Phormidium** Kütz., 1843. [*Hyphæothrix* Kütz., 1843 (in part); *Leptothrix* Kütz., 1843 (in part).] This genus is intermediate in character between *Lyngbya* and *Oscillatoria*, and undoubtedly serves a useful purpose for the reception of species which cannot be strictly referred to either of those genera. The filaments are simple and invested by delicate hyaline sheaths, which frequently become confluent or altogether diffluent. The filaments are often agglutinated to form an expanded stratum, either on damp earth, wet rocks, or entirely submerged. Sometimes this stratum becomes hard and leathery, but it is more often soft and slimy. The trichomes are cylindrical, and there is frequently a constriction between the cells, a feature which is so prominent in some species as to give the trichome a moniliform or torulose appearance. The apices of the trichomes may be straight or curved, and the apical cells are attenuated, capitate, or even thickened at the extremity.

Plants of this genus are amongst the commonest of the blue-green Algæ, occurring in all kinds of damp and wet situations, and often giving a decided tint to large areas of damp ground, vertical limestone rocks, or those rocks and stones subject to the spray of waterfalls. There are some 13 British species occurring in damp situations or in fresh water. *Ph. autumnale* (Ag.) Gom. (diam. trich. 4—7 μ) is abundant on damp earth, and *Ph. tenue* (Menegh.) Gom. (diam. trich. 1—2 μ; fig. 153 E and F) is frequent among other Algæ in ponds, ditches, and rivers. *Ph. purpurascens* (Kütz.) Gom. forms reddish-purple patches on the vertical faces of wet limestone rocks (diam. trich. 1·5—2 μ).

[Note:—*Clonothrix gracillima* W. & G. S. West is one of the Schizomycetes of the genus *Cladothrix*.]

Genus **Oscillatoria** Vaucher, 1803. [*Oscillaria* Bosc, 1800[1].] The trichomes are free and cylindrical, without a sheath, or with one so thin as to be almost imperceptible. Faint constrictions are sometimes evident between the cells, but more often the edges of the filaments present a continuous and unbroken line. The cells vary much in relative length, but in the larger species they are always much shorter than their diameter. The extremity of the trichome may be straight or curved, and it is often attenuated. The apical cell is sometimes much attenuated, and may be capitate, being frequently furnished with a terminal thickening of the cell-wall known as a calyptra. The genus is found in great profusion

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[1] For reasons for adopting the generic name "*Oscillatoria*" consult Gomont in Journ. Botan. Morot, v, 1891, p. 273.

in all kinds of wet situations, and sometimes on damp ground, or in hot springs. Flocculent masses of *Oscillatoria* are often found floating on the surfaces of ponds and ditches after sunshine, and they commonly give off a more or less distinctive odour. The movements exhibited by the trichomes of this genus are discussed on page 315.

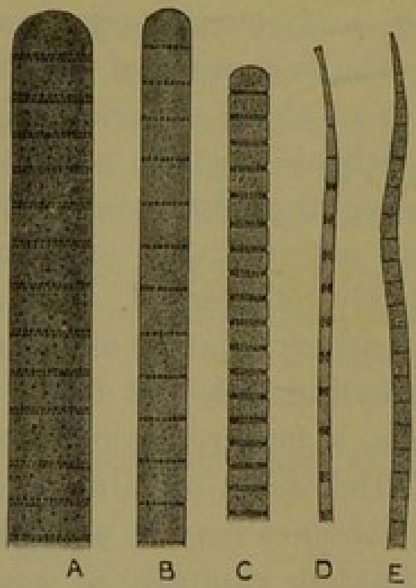

Fig. 154. A, *Oscillatoria limosa* Ag., from Wimbledon Common, Surrey. B, *O. irrigua* Kütz., from Shipley Glen, W. Yorks. C, *O. tenuis* Ag., from Sheep's Green, Cambridge. D, *O. splendida* Grev. var. *attenuata* W. & G. S. West, from Baildon Moor, W. Yorks. E, *O. acuminata* Gom., from Sheep's Green, Cambridge. (All × 460.)

There are about 20 British species of the genus, one of which (*O. decolorata* G. S. West) is destitute of pigment and lives a saprophytic existence in stagnant ditches. *O. princeps* Vauch. is the largest species (thickness of trichomes 25—50 μ) and *O. angustissima* W. & G. S. West is the narrowest (thickness of trichomes 0·6 μ). *O. limosa* Vauch. (thickness of trichomes 12—17 μ; fig. 154 A) and *O. tenuis* Ag. (thickness of trichomes 4—10 μ; fig. 154 C) are the most abundant species. *O. irrigua* Kütz. (fig. 154 B) is common in quickly running water.

Genus **Arthrospira** Stizenberger, 1852. The trichomes are cylindrical, commonly devoid of a sheath, and twisted into a regular spiral. The latter character is the only distinction from *Oscillatoria*. The cells are generally shorter than their diameter.

A. Jenneri (Hass.) Stizenb. is a rare Alga, which occurs in stagnant water, or forms a dark-green mucous stratum in trickling water; diam. of trichomes 5—8 μ; diam. of spiral whorls 9—15 μ.

Genus **Spirulina** Turpin, 1827. The trichomes are very narrow and are twisted into a regular spiral. They consist of a single elongated cell, sometimes of great length, and without transverse septa. This feature at once distinguishes the genus from *Arthrospira*.

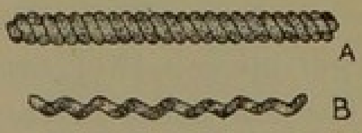

Fig. 155. A, *Spirulina turfosa* Cram., from Lough Neagh, Ireland. B, *Sp. major* Kütz., from Wicken Fen, Cambridge (× 480).

S. major Kütz. is frequent in stagnant water (diam. trich. 1·5—2·5 μ; fig. 155 B), and *S. tenuissima* Kütz. (=*S. subsalsa* Œrsted) is often abundant in salt and brackish water, rarely occurring in fresh water (diam. trich. 1—2 μ).

Sub-order 2. TRICHOPHOREÆ.

This is a small group containing some of the most characteristic of the blue-green Algæ. The trichomes are strongly attenuated either towards one end, or from the middle towards both ends, and in all cases they are sheathed. The sheaths are generally strong, rarely hyaline and delicate, often lamellose, and fimbriate or ocreate along their margins. In certain genera, such as in *Dichothrix* and *Ammatoidea*, a false branching is present. Heterocysts are present in some genera, but absent from others. Asexual reproduction takes place by the formation of hormogones, but in *Glœotrichia* spores are developed from the basal cells next the heterocysts.

There are two sharply differentiated families:—

Family 1. *Rivulariaceæ.* Trichomes attenuated from the base to the apex, which is piliferous; heterocysts basal (rarely absent).

Family 2. *Camptotrichaceæ.* Trichomes attenuated from the middle towards each extremity; heterocysts absent.

Family 1. **RIVULARIACEÆ.**

Algæ of this family are fairly abundant in mountainous districts, and they also occur sparingly in the less elevated parts of the country. They are found principally on the dripping rocks of waterfalls, cataracts and streams, or at the margins of rocky lakes. They form soft felt-like expanses, or hard hemispherical masses, generally of a brown colour, but a few of them occur as blue-green nodules attached to the stems and leaves of submerged plants.

The trichomes are all attenuated to a hair-like point, and at the broad base, in all except a few species, one or two heterocysts are located. Occasionally intercalary heterocysts are present in addition to the basal ones. The sheath is tubular, gelatinous or membranous, and is frequently strongly lamellose. In some species the lamellæ of the sheath become dilated upwards, thus giving the exterior of the filament a fimbriate appearance. It frequently happens that the sheaths of adjacent filaments become fused to such an extent that their individuality is lost. The usual colour of the sheaths is yellow or yellowish-brown, and in some cases they are indurated with carbonate of lime.

The filaments exhibit a false branching due to the growth of new trichomes from some of the inferior cells of the original trichome, the new growth often occurring immediately above an intercalary heterocyst. It is in *Dichothrix* that the false branching and fusion of the sheaths are most marked.

Asexual reproduction takes place by the formation of hormogones, the hair-like apical portion of the trichome being lost. Asexual spores commonly arise in *Glœotrichia* (and also in *Calothrix*) in close apposition to the basal heterocysts.

There are five British freshwater genera, which can be distinguished as follows:—

A. Without heterocysts. Filaments free, very narrow, forming a thin stratum.................................... *Amphithrix.*
B. With heterocysts.
  * Filaments free, simple or forming a dichotomous thallus.
    † Filaments simple or falsely branched; branches distinct and free.................................... *Calothrix.*
    †† Filaments branched; branches several (2—6) within a common sheath .... *Dichothrix.*
  ** Filaments forming a hemispherical or globular thallus, closely united by mucus.
    † Filaments radiately disposed in a tough, globose or hemispherical, attached thallus. Spores unknown .... *Rivularia.*
    †† Filaments radiately disposed in a soft, globose, free-floating thallus. Spores regularly produced .... *Glœotrichia.*

Genus **Amphithrix** Kütz., 1843; em. Born. & Flah., 1886. The filaments form a thin expanded stratum of a purple or violet colour, which consists of two layers. The inferior layer is composed of densely intricate filaments, or of minute radiately disposed series of cells; the superior layer consists of simple, erect filaments, closely packed together and attenuated to fine points. The sheaths are thin, close and continuous, and there are no heterocysts.

A. janthina (Mont.) Born. & Flah. occurs on wet rocks and is known from W. Yorkshire; thickness of filaments 1·5—2·25 μ.

Genus **Calothrix** Ag., 1824. [*Mastigonema* Schwabe, 1837; *Mastigothrix* Kütz., 1843; *Schizosiphon* Kütz., 1843 (in part); *Symphyosiphon* Kütz., 1843 (in part).] The filaments are simple or slightly branched, forming penicillate tufts or soft velvety expansions, which are generally attached to submerged rocks and stones. The heterocysts are basal or intercalary, and in a few species they are absent. The plants often exhibit a slight branching, caused by the close application of the base of one filament to the side of another, the sheaths being continuous. The upper and more attenuated parts of the filaments are, however, always free. Borzi[1] has observed the formation of basal, seriate spores in one species.

There are about six British freshwater species, *C. parietina* (Näg.) Thur. being the most frequent (thickness of trichomes 6—12 μ; fig. 156 A and B). *C. fusca* (Kütz.) Born. & Flah. and *C. epiphytica* W. & G. S. West are epiphytes on other larger Algæ, such as *Vaucheria* or *Batrachospermum*.

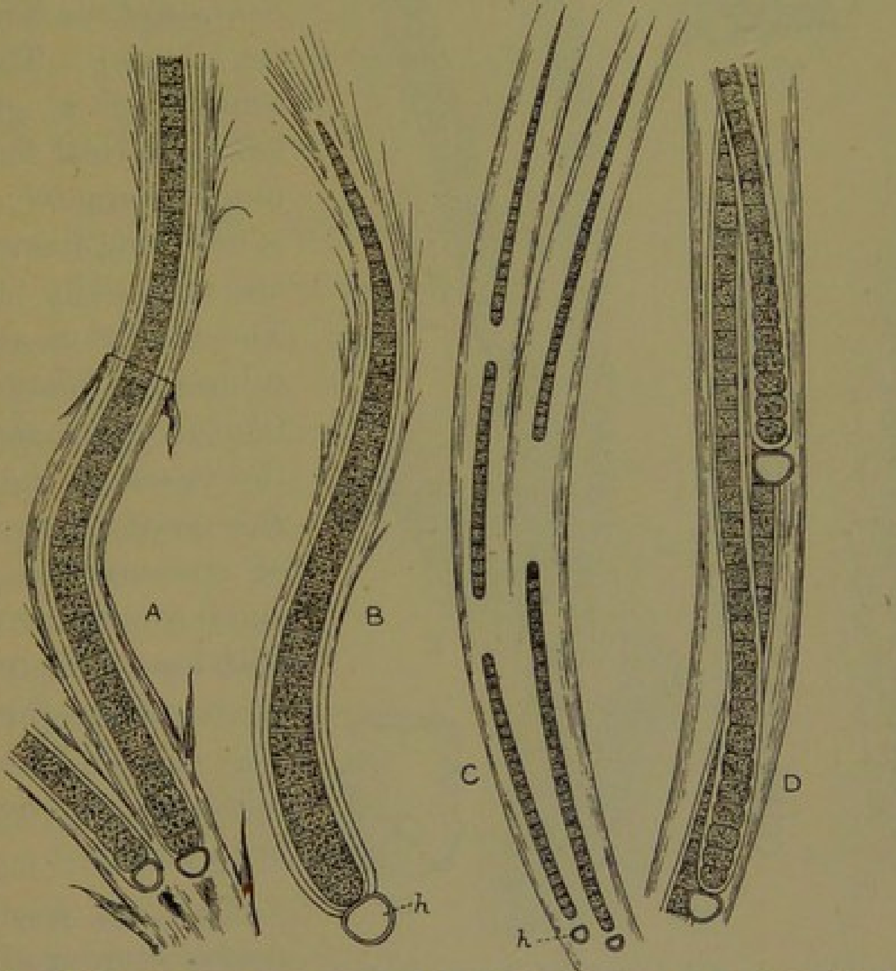

Fig. 156. A and B, *Calothrix parietina* (Näg.) Thur., from Arncliffe, W. Yorks. C, *Dichothrix interrupta* W. & G. S. West, from Slieve Donard, Ireland. D, *D. Orsiniana* (Kütz.) Born. & Flah., from Langdale, Westmoreland. (All × 420.)

Genus **Dichothrix** Zanardini, 1858. In this genus the filaments are more or less dichotomously branched, several trichomes with their sheaths being enclosed within an outer common sheath. The heterocysts are basal or intercalary, and in one species they are absent. The plants generally occur in penicillate tufts on dripping rocks.

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[1] Borzi in Nuovo Giornale Botan. Ital. 1882, xiv, p. 374.

There are five British species, all of which are rare. They occur principally on dripping rocks in mountainous regions. *D. Nordstedtii* Born. & Flah. and *D. Orsiniana* (Kütz.) Born. & Flah. (thickness of filaments 10—12 μ, of trichomes 6—7·5 μ; fig. 156 D) are widely distributed, and *D. interrupta* W. & G. S. West is known from the Mourne Mts, Down, Ireland (fig. 156 C).

Genus **Rivularia** (Roth) Ag., 1824 (in part); em. Thuret, 1885. [*Zonatrichia* J. Ag., 1842; *Limnactis* Kütz., 1843; *Schizosiphon* Kütz., 1843 (in part).] The plants consist of a globose or hemispherical thallus, of a tough character, composed of radiating filaments which are repeatedly 'branched.' The thallus is attached to submerged plants (such as *Chara, Myriophyllum,* or the bases of the stems of *Phragmites*) or to the stones of streams and cataracts, and is sometimes indurated with lime. The heterocysts are basal and the extremities of the filaments are piliferous. Spores have not been observed.

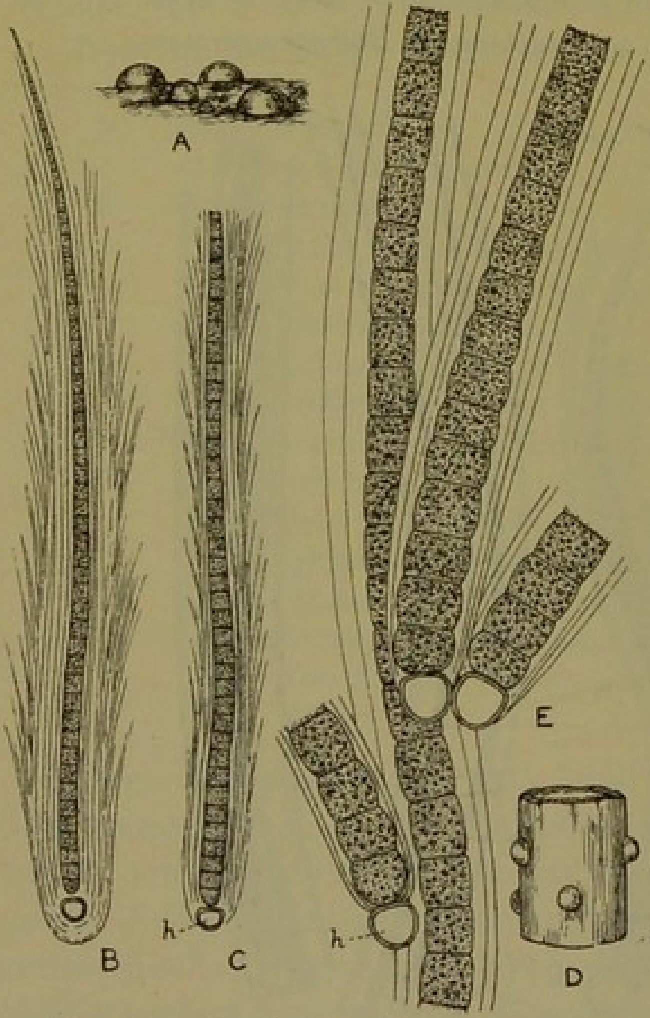

Fig. 157. A—C, *Rivularia Biasolettiana* Menegh., from Arncliffe, W. Yorks.; A, nat. size, on surface of stone; B and C, ×480. D and E, *R. minutula* (Kütz.) Born. & Flah., from Chippenham Fen, Cambridge; D, nat. size, on stem of *Phragmites*; E, ×480.

There are four freshwater species occurring in Britain, of which *R. hæmatites* (D. C.) Ag. [=*Zonatrichia calcarea* (Eng. Bot.) Endlicher] is the most frequent, sometimes occurring in quantity attached to the stones of mountain streams in limestone districts. *R. dura* Roth and *R. minutula* (Kütz.) Born. & Flah. (thickness of trichomes 2—12·5 μ; fig. 157 D and E) are occasionally met with attached to submerged plants, forming small globose masses of a blue-green or greenish-black colour.

Genus **Glœotrichia** J. Ag., 1842. The thallus is globose and free-floating, solid when young, but inflated and hollow when old. The filaments radiate from the centre outwards, and, as in *Rivularia*, exhibit a false 'branching.' The sheaths are only conspicuous near the base of the trichomes, being gelatinous and confluent near the periphery of the thallus. The trichomes are strongly attenuated from the base, and are more or less torulose. From the cell immediately above the basal heterocyst elongated cylindrical spores are developed, which remain for some time within the basal part of the sheath.

There are two British freshwater species, *G. Pisum* (Ag.) Thur. and *G. natans* (Hedw.) Rabenh. The former possesses a thallus which does not reach a greater diameter than 2 mm., but the latter is a larger species with a thallus up to 10 cms. diameter. *G. Pisum* is one of the Algæ frequently concerned in the phenomenon of the "breaking of the meres."

Family 2. **CAMPTOTRICHACEÆ**.

This is a small family sharply marked off from the rest of the Trichophoreæ by the attenuation of the filaments *from the middle towards each extremity*. The plants are epiphytic and there are no heterocysts. The sheath may be very thin and delicate, or thick and lamellose. Only two genera are known, one of which (*Camptothrix*) is a genus of small tropical epiphytes.

Genus **Ammatoidea** West & G. S. West, 1897. The filaments are epiphytic and exhibit a false ramification comparable with that met with in *Rivularia*. They are suddenly bent in their median or widest portion, the two more or less parallel extremities being gradually attenuated to piliferous apices. The sheaths are firm and lamellose, in young filaments colourless, but in older ones of a yellow-brown colour. The trichomes exhibit a slight constric-

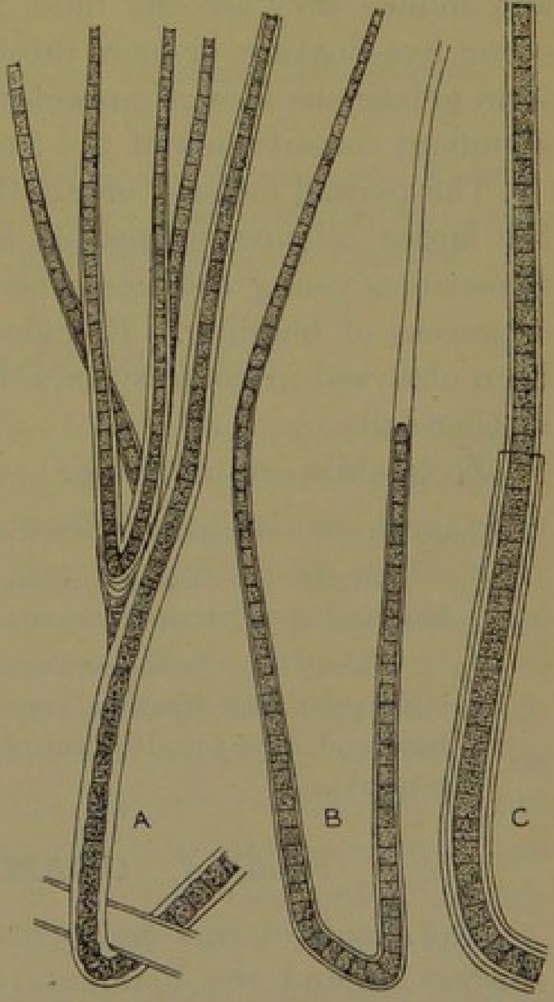

Fig. 158. *Ammatoidea Normanii* W. & G. S. West, from Dartmoor, Devonshire (× 420).

tion between their median cells, and the apical cells are about six times longer than their diameter.

A. Normanii W. & G. S. West is known from Devonshire as an epiphyte on *Batrachospermum moniliforme.* Thickness of filaments 5·5—12·5 μ, of trichomes 3·5—5·5 μ; fig. 158.

Order II. COCCOGONEÆ.

In this order the plants are unicellular or colonial, commonly occurring as colonies of unicells enveloped in a copious gelatinous investment. The colonies vary much in size and shape, being spherical, ellipsoidal, or expanded gelatinous masses. The cells are of varied form and are disposed in a variety of ways within the mucous envelope. The latter is sometimes conspicuously lamellose, but more often it is hyaline and structureless.

The Coccogoneæ constitute the lowest group of the Myxophyceæ, and indeed they are the most primitive of all the Algæ. They occur free-floating, or more rarely as epiphytes, and some of them form gelatinous masses on wet rocks. Not a few are regular and abundant constituents of the freshwater plankton.

The normal method of multiplication is by simple cell-fission, the larger colonies ultimately breaking up to form smaller ones. Sometimes young colonies arise at the sides of the older ones by a process of budding. Rounded asexual spores or gonidia have been observed in some species, being formed within the wall of a mother-cell.

Zoogonidia are unknown.

There are two well-marked families.

Family 1. *Chamæsiphoniaceæ.* Cells epiphytic, with a distinct base and apex; reproduction only by the formation of gonidia.

Family 2. *Chroococcaceæ.* Cells or colonies free-floating or forming a gelatinous stratum, very rarely epiphytic, not differentiated into base and apex; multiplication by simple cell-division (very rarely by gonidia).

Family 1. **CHAMÆSIPHONIACEÆ.**

The plants of this family are epiphytes, generally occurring in clusters around the filaments of larger Algæ. They are in all cases differentiated so as to present a distinction between base and apex, and reproduction occurs by the formation of a number of non-motile spores or gonidia from the contents of a mother-cell. Most Algæ of this family are marine, the only British freshwater genus being *Chamæsiphon.*

Genus **Chamæsiphon** A. Br. & Grun., 1864. [Inclus. *Sphærogonium* Rostaf., 1883.] The cells are small, ovoidal, pyriform, or cylindrical, with very thin cell-walls. The cell-contents are homogeneous and of a blue-green, violet, or yellow colour. The cells are attached by their base and generally widen upwards to their free apex. The gonidia are successively cut off from the upper part of the cell which has become a gonidangium, gradually escaping from the open apex.

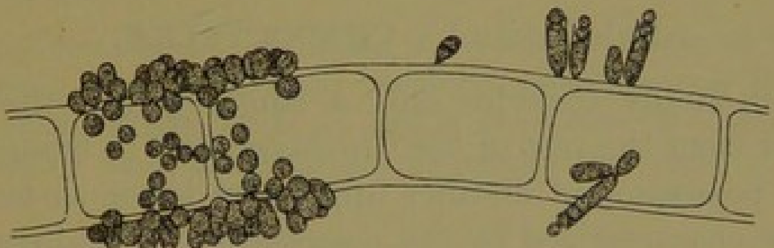

Fig. 159. *Chamæsiphon incrustans* Grun., on a filament of *Rhizoclonium*, from Heaton, W. Yorks. (× 416).

Ch. confervicola A. Br. is found as an epiphyte on *Chætomorpha*, *Rhizoclonium*, *Vaucheria*, etc., and *Ch. incrustans* Grun. (diam. of cells 3·5—4·8 μ; fig. 159) often thickly covers filaments of *Rhizoclonium* and *Œdogonium.*

Family 2. CHROOCOCCACEÆ.

This is the largest family of the Coccogoneæ, and includes a great variety of unicellular and colonial blue-green Algæ. They are abundant in all kinds of damp and wet situations, frequently forming a gelatinous stratum on the damp surfaces of dripping rocks. The cells vary much in shape in the different genera, and the colonies assume different forms according to the direction of division of the cells. In some the cells divide in every direction of space within a gelatinous envelope, producing an irregular colony, often of large size. In others the cells divide only in two directions in the same plane, giving rise to a tabular colony; and in others cell-division takes place in one direction only. In one genus (*Tetrapedia*) the cells are flattened and they possess a striking symmetry of form. *Synechococcus* and *Tetrapedia* are the only genera which are commonly destitute of a mucous envelope. In all others the cells are invariably embedded in a mass of mucus, which varies much in its consistency. It may be firm and lamellose, or very hyaline and diffluent. The cells often contain red, orange, or violet pigments.

Reproduction has been observed in a few species to take place by the formation of non-motile spores or gonidia within a gonidangium.

There are two sub-families:—

Sub-family I. *Chroocysteæ.* Epiphytes on larger Algæ, with a well-defined dorsiventrality.

Sub-family II. *Chroococceæ.* Free-floating or forming a gelatinous stratum, with no dorsiventrality.

Sub-family I. CHROOCYSTEÆ.

This sub-family includes only a single genus, the plants of which differ from the rest of the Chroococcaceæ in being epiphytic, and in the possession of distinct upper and lower surfaces. They are likewise characterized by the possession of prominent bristles.

Genus **Glœochæte** Lagerh., 1883. [*Schrammia* Dangeard, 1889.] The cells are globose or sub-globose, enveloped in a wide mucous coat, and they occur singly, or in twos or fours, attached to larger filamentous Algæ. More rarely they are attached to the

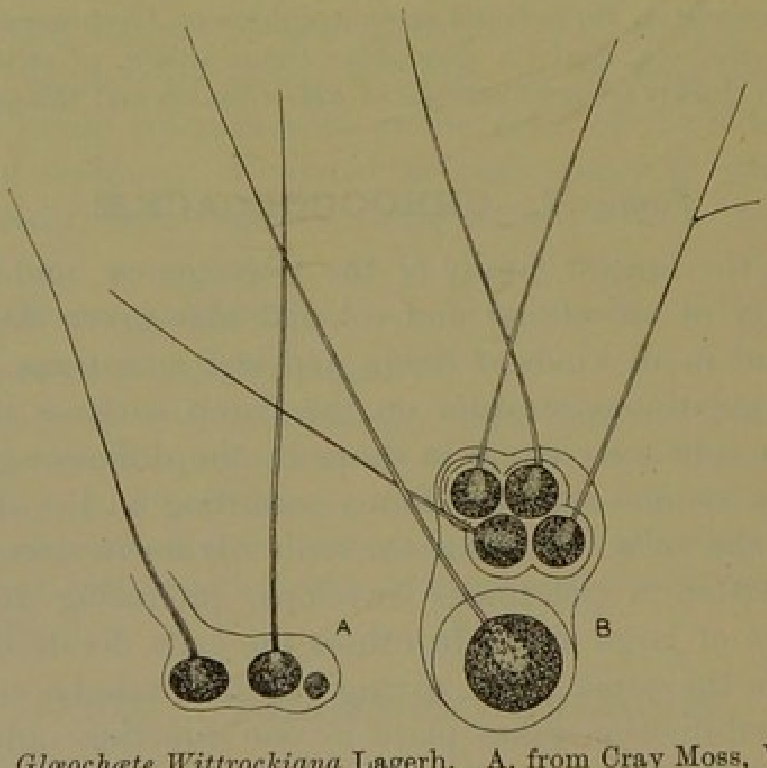

Fig. 160. *Glœochæte Wittrockiana* Lagerh. A, from Cray Moss, W. Yorks.; B, from Pilmoor, N. Yorks. (× 416).

leaves and stems of submerged Mosses or Phanerogams. Each cell is furnished at its upper pole with one or two long, thin bristles, which sometimes give off small branches or spurs near their apices. The primitive chromatophore is bell-shaped, of a brilliant blue-green colour, and there is a clear space in the centre of the cell. Lagerheim in his original description of the genus[1] says "nucleus singulus." The mother-cells give rise to two or four daughter-cells on division.

Many authors have placed this Alga in the Chlorophyceæ, or have recorded a chlorophyceous Alga under the name of '*Glœochæte*.' The genus as I have often found it, and as here figured, most certainly belongs to the Chroococcaceæ.

Gl. Wittrockiana Lagerh. is known from several parts of the British Islands, occurring as an epiphyte on *Vaucheria*, *Cladophora*, or the leaves of Sphagnum. Diam. of cells 6—21 μ; length of bristles 96—260 μ; fig. 160. *Gl. bicornis* Kirchn. has a pair of bristles attached to each cell.

Sub-family II. CHROOCOCCEÆ.

The sub-family Chroococceæ embraces almost all the unicellular and colonial Myxophyceæ. They are unquestionably of a lower type than any other of the Algæ, and some of them bear resemblance to certain of the Bacteria. The cells display considerable variety of form, and with the exception of the genera *Synechococcus, Tetrapedia,* and to a certain extent *Merismopedia,* they are enveloped in a copious covering of mucus. The mucous coat is sometimes firm and lamellose, as in some species of *Chroococcus* and *Glœocapsa,* but more often it is an ample, homogeneous covering, very hyaline in character. It often happens that the coverings of numerous cells have fused together, thus forming gelatinous colonies of various sizes. Some of these colonies are large macroscopic masses, containing many thousands of cells, and possessing a tough exterior. In some genera, such as *Merismopedia* and *Cœlosphærium,* the colonies are of limited size and of definite shape.

Multiplication takes place by the repeated division of the cells and the final fragmentation of the original colony, each fragment growing in size and repeating the processes. In the spherical colonies of *Cœlosphærium* a kind of budding takes place by means

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[1] Lagerheim in Nuova Notarisia, 1890, p. 231.

of which a new colony is developed from the side of the old one, ultimately becoming separated from it. Cell-division may be in one direction only, in two directions in one plane, or in every direction of space.

Reproduction occurs in *Gomphosphæria* by non-motile spores or gonidia[1].

There are thirteen British freshwater genera, which can be arranged as follows:—

A. Cell-division in one direction only.
* Cell-division transverse.
† Cells enveloped in a wide mucous coat.
‡ Cells elongated, each with a mucous coat *Glœothece.*
‡‡ Cells little longer than broad, enveloped in a common mucous investment ... *Aphanothece.*
†† Cells destitute of mucus .... *Synechococcus.*
** Cell-division oblique; cells enveloped in mucus *Dactylococcopsis.*

B. Cell-division in two directions in one plane.
* Cells globular or rounded-quadrate; colonies often large... *Merismopedia.*
** Cells of a definite symmetrical form, solitary, or forming small colonies .... *Tetrapedia.*

C. Cell-division in all directions of space; cells enveloped in mucus.
* Cells forming large colonies.
† Cells arranged at or towards the periphery of spherical colonies.
‡ Cells closely and regularly arranged ... *Cœlosphærium.*
‡‡ Cells geminate and sparsely scattered, markedly pyriform in shape........... *Gomphosphæria.*
†† Cells densely aggregated in globose, elongated, or clathrate colonies .... *Microcystis.*
††† Cells aggregated to form irregular gelatinous colonies.
‡ Individual mucous coats clearly evident round each cell .... *Glœocapsa.*
‡‡ Cells enveloped in a common mucous covering .... *Aphanocapsa.*
‡‡‡ Cells arranged in a compact gelatinous stratum .... *Porphyridium.*
** Cells more or less solitary, or forming very small colonies .... *Chroococcus.*

Genus **Glœothece** Näg., 1849. The cells are cylindrical and elongated, each one being surrounded by a thick mucous coat, which sometimes shows indications of lamellation. Cell-division

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[1] Schmidle in Berichte Deutsch. Botan. Gesellsch. 1901, xix.

is only in one direction, and a number of cells are usually associated to form a small colony.

Species of this genus occur on wet rocks, among wet mosses, and in bog-pools. *Gl. linearis* Näg. (length of cells 10·5—18 μ; breadth 1·3—2·3 μ; fig. 161 A) and *Gl. confluens* Näg. (length of cells 5·7—7·5 μ; breadth 2·6—3 μ; fig. 161 B) are the most frequent British species.

Rhabdoderma lineare Schmidle[1] seems very closely allied to *Glœothece linearis* Näg., if not actually identical with it.

Genus **Aphanothece** Näg., 1849. This genus only differs from *Glœothece* in the aggregation of large numbers of cells within a common mass of mucus. The cells are cylindrical and longer than their diameter.

A. microscopica Näg. (length of cells 5—8 μ, breadth 3·5—4 μ; fig. 161 C) and *A. saxicola* Näg. are the most frequent species. They are found in bog-pools, at the margins of lakes, and on wet rocks.

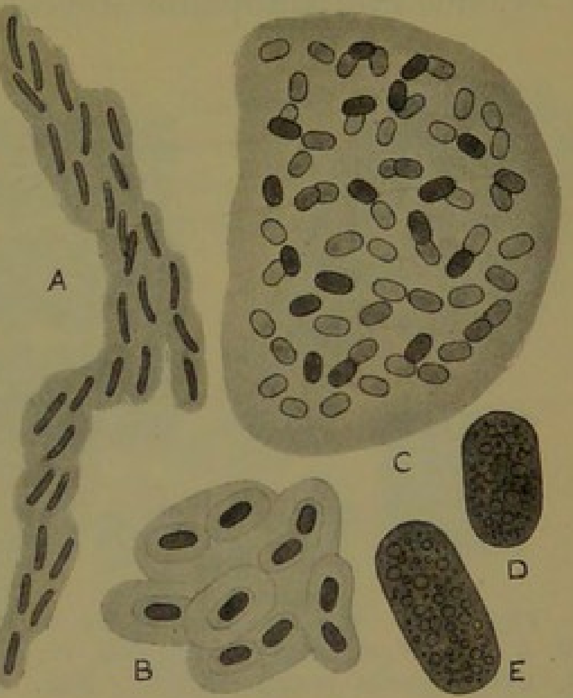

Fig. 161. A, *Glœothece linearis* Näg., from Old Cote Moor, W. Yorks. B, *Gl. confluens* Näg., from near Settle, W. Yorks. C, *Aphanothece microscopica* Näg., from Withiel, Cornwall. D and E, *Synechococcus major* Schroet., from Adel Bog, W. Yorks. (All × 450.)

Genus **Synechococcus** Näg., 1849. The cells, which are cylindrical with hemispherical apices, are larger than in the preceding genera, and are destitute of the outer mucous coat. They occur free-floating in ponds, ditches, and bog-pools, often in considerable quantity. The cell-contents are usually of a brilliant blue-green, rarely of a rose-purple colour, and contain numerous large granules.

S. æruginosus Näg. and *S. major* Schroeter (length of cells 26—29 μ; breadth 15·5—17·5 μ; fig. 161 D and E) are the most abundant British species, the latter often occurring in quantity in bogs.

Genus **Dactylococcopsis** Hansg., 1888. The cells are generally associated to form small colonies, rarely solitary, and in many

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[1] Schmidle in Berichte Deutsch. Botan. Gesellsch. 1900, xviii, p. 149, t. vi, f. 8—11.

cases the colonies are embedded in a copious mucus. The cells are elongated, fusiform or lanceolate, with attenuated extremities, or sometimes sigmoidal in form. The chromatophore is almost homogeneous, of a pale blue-green colour, and somewhat lateral in position. Division of the cells occurs much as in *Dactylococcus*, by oblique septation.

D. montana W. & G. S. West (length of cells 8·6—11·5 μ, breadth 3·5—4 μ; fig. 162 A) occurs in bog-pools amongst Sphagnum. *D. rhaphidioides* Hansg. is known from the plankton of Lough Neagh.

Genus **Merismopedia** Meyen, 1839. This is one of the most striking genera of the Chroococcaceæ, consisting of a flat rectangular colony, the cells of which are arranged in rectilinear series. Cell-division takes place in two directions and the cells appear to be usually arranged in groups of four. The cells are globose, ellipsoidal, or oblong, sometimes slightly angular by compression, and the cell-contents are homogeneous.

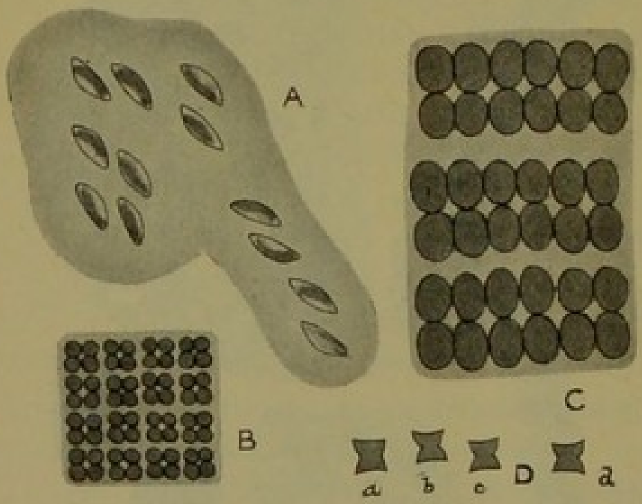

Fig. 162. A, *Dactylococcopsis montana* W. & G. S. West, from Widdale Fell, W. Yorks. B, *Merismopedia glauca* (Ehrenb.) Näg., from Thursley Common, Surrey. C, *M. elegans* A. Br., part of a large colony from Wicken Fen, Cambridge. D, *Tetrapedia Reinschiana* Arch., from near Goring, Oxford. (All × 450.)

M. glauca (Ehrenb.) Näg. is the commonest British species, occurring in ponds, ditches, bogs and lakes; diam. of cells 3·3—3·8 μ; fig. 162 B. *M. punctata* Meyen and *M. æruginea* Bréb. are not infrequent in stagnant water. *M. elegans* A. Br. is the largest species of the genus and is known from few localities in the British Islands; diam. of cells 6·5—9·5 μ; fig. 162 C. The colonies of *M. glauca* and *M. elegans* often reach a large size (diam. up to 220 μ) and may contain as many as 1856 cells.

Genus **Tetrapedia** Reinsch, 1867. In this genus the cells are of some definite and symmetrical shape, often constricted into two equal half-cells. The cell-wall is firm and the cell-contents are homogeneous. In some species the cells are almost invariably solitary, but in others they are grouped in flat colonies similar to those of *Merismopedia*.

All the species are rare, but *T. Reinschiana* Arch. (diam. of cells 5·5—6 μ; fig. 162 D) and *T. glaucescens* (Wittr.) Boldt occur in lakes and bog-pools. *T. setigera* Arch. is a beautiful little species known from N. W. Scotland and W. Ireland, and which has been erroneously referred by some authors to the chlorophyceous genus *Tetraëdron.* The cell-contents of *Tetrapedia setigera* are homogeneous and of a pale blue-green colour.

Genus **Cœlosphærium** Näg., 1849. The cells are more or less closely grouped to form a hollow, spherical colony. They are embedded in a mass of mucus and are arranged just within the periphery of the spherical mass. In form they are globose, ellipsoidal, or ovoidal, and the cell-contents are granular, with so-called gas-vacuoles.

The genus is a common constituent of the freshwater plankton, and is also found frequently in large ponds. *C. Kützingianum* Näg. (diam. of colony 48—90 μ; diam. of cells 3—3·8 μ; fig. 163 A) is the most abundant species, although *C. Nägelianum* Unger and *C. minutissimum* Lemm. both occur in quantity in the British freshwater plankton.

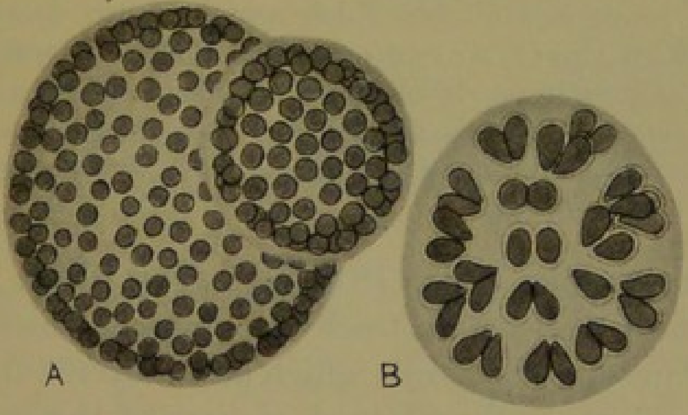

Fig. 163. A, *Cœlosphærium Kützingianum* Näg., from the plankton of Lough Neagh, Ireland. B, *Gomphosphæria aponina* Kütz., from Keston Common, Kent (× 350).

Genus **Gomphosphæria** Kütz., 1836. In this genus the colonies contain fewer and more scattered cells, which are disposed chiefly towards the periphery of a globular or ellipsoid mass of mucus. The cells are grouped in pairs and are distinctly pyriform in shape. Schmidle has observed the formation of 'microgonidia.' The entire colony is solid and the cells divide alternately in three directions.

G. aponina Kütz. (diam. of colonies 64—78 μ; length of cells 8·5—11·5 μ; fig. 163 B) is not uncommon in ponds, lakes, and stagnant ditches.

Genus **Microcystis** Kütz., 1833. [*Polycystis* Kütz., 1845; *Clathrocystis* Henfrey, 1856.] The cells are small, mostly globose, and are densely aggregated to form solid colonies of variable shape. In some species the colonies are globose, ellipsoidal, or oblong; in others they are much elongated; and in others they become clathrate and almost anastomosing. The cell-contents are blue-green, olive-green, or rose-purple in colour, and often contain gas-vacuoles.

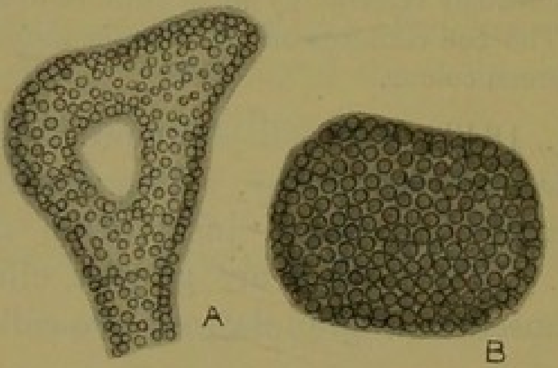

Fig. 164. A, *Microcystis stagnalis* Lemm., from the plankton of Lough Neagh, Ireland. B, *M. marginata* Menegh., from Old Cote Moor, W. Yorks. (×450).

M. marginata Menegh. (diam. of cells 2·6—2·8 μ; fig. 164 B), *M. Flos-aquæ* (Wittr.) Kirchn., *M. elabens* (Bréb.) Kütz., and *M. stagnalis* Lemm. (diam. of cells 1—1·5 μ; fig. 164 A) are all more or less common in bogs and lakes. *M. roseo-persicinus* (Kütz.) often occurs in quantity in ponds and ditches which contain much decaying vegetation. *M. æruginosa* (Kütz.) [=*Clathrocystis æruginosa* (Kütz.) Henfrey] often occurs in prodigious quantity in ponds and in the plankton of lakes.

The three genera *Microcystis*, *Polycystis* and *Clathrocystis* are not sufficiently distinct to warrant their separation. The differences between them are only differences of degree.

Genus **Glœocapsa** Kütz., 1843; em. Näg. 1849. The cells are globose and furnished with a thick integument, which is frequently lamellose. The daughter-cells which arise by the division of the mother-cells are generally retained as part of the colony, a larger integument surrounding the individual envelopes of the cells. In this manner the colonies become of large size and frequently form a gelatinous stratum. The integuments of the cells are sometimes colourless, but they may be yellow, brown, blue, violet, or red. Cell-division takes place in all directions and the colonies are most irregular. Thick-walled resting-spores have been observed in some species.

Kuntze and, following him, certain other authors, have identified *Glœocapsa* Kütz. with *Bichatia* Turp. (1827), but to my mind this identification is uncertain.

There are about 20 British species, some of which are of doubtful specific distinctness. *Gl. punctata* Näg. (diam. of cells 1·5—2 μ) is the smallest species. *Gl. polydermatica* Kütz. is remarkable for the lamellation of the integuments (fig. 165 C—E). *Gl. Magma* (Bréb.) Kütz. with golden-yellow or brown integuments (fig. 165 B), and *Gl. Ralfsiana* (Hass.) Kütz. with bright red or purple integuments, are two of the best-defined species. Most of the species occur on wet or dripping rocks, generally in association with other Myxophyceæ.

Genus **Aphanocapsa** Näg., 1849. The cells are globose and aggregated to form small colonies within a common homogeneous integument. The genus only differs from *Aphanothece* in its globose cells. The integument may be colourless or tinted brown or blue-green, and the cells are of a blue-green or olive-green colour.

There are four British species occurring both in stagnant water and on wet rocks. *A. Grevillei* (Hass.) Rabenh. is the most frequent; diam. of cells 3·4—4·5 μ; fig. 165 A.

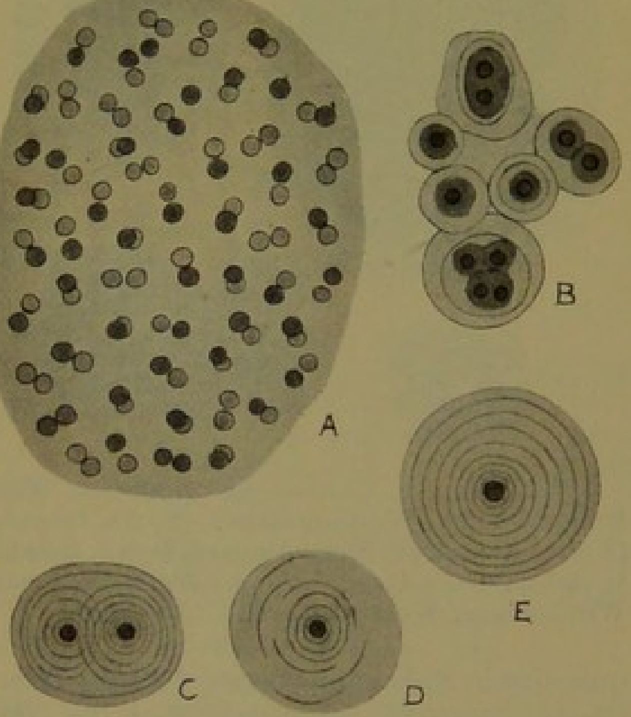

Fig. 165. A, *Aphanocapsa Grevillei* (Hass.) Rabenh., from Helln Pot, W. Yorks. B, *Glœocapsa Magma* (Bréb.) Kütz., from Boston Spa, W. Yorks. C—E, *Gl. polydermatica* Kütz., from Boston Spa, W. Yorks. (All ×450.)

Genus **Porphyridium** Näg., 1849. The cells, which are closely arranged to form a thin gelatinous stratum, are globose or angular by compression. The stratum consists of many layers of cells, and the cell-contents are of a reddish-purple colour. Cell-division takes place in all directions.

P. cruentum (Ag.) Näg. is a common Alga, forming a thin slimy stratum of a dark red colour on damp ground and near the base of damp walls. The cells are 7—9 μ in diameter.

This Alga was at one time placed in the Chlorophyceæ and has since been relegated to the Rhodophyceæ. I agree with Hansgirg, however, in thinking it much better placed in the Myxophyceæ. There are many of the Myxophyceæ which possess as much red or purple pigment as *Porphyridium*, and moreover, the latter genus is generally found in association with blue-green Algæ. It is more nearly allied to *Aphanocapsa* than any other genus of Algæ.

Genus **Chroococcus** Näg., 1849. In this genus the cells are globose or more or less angular, solitary or associated in simple families. They are free-floating or mixed with other blue-green Algæ to form a stratum on wet rocks. The integuments are firm and often wide, homogeneous or lamellose, generally colourless, but sometimes of a yellowish-brown tint. The cell-contents are granulose, of a brilliant blue-green colour, or more rarely violet, olive-green, or yellow-green.

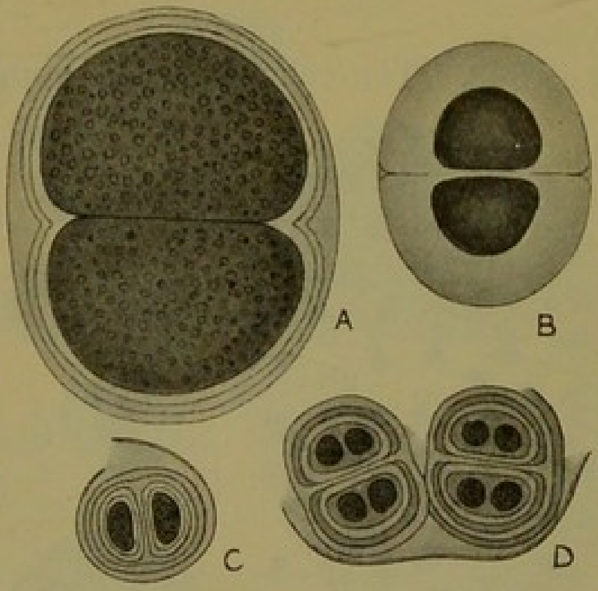

Fig. 166. A, *Chroococcus giganteus* West, from Bowness, Westmoreland. B, *Ch. turgidus* (Kütz.) Näg., from Slieve Donard, Down, Ireland. C and D, *Ch. schizodermaticus* West, from near Windermere, Westmoreland. (All × 450.)

Ch. turgidus (Kütz.) Näg. is the most widely distributed species, often occurring in quantity in Sphagnum-bogs; diam. of cells 13—25 μ; fig. 166 B. *Ch. cohærens* (Bréb.) Näg., *Ch. giganteus* West (fig. 166 A), *Ch. minor* (Kütz.) Näg. and *Ch. pallidus* Näg. are not infrequent in ponds, lakes, and bog-pools. *Ch. schizodermaticus* West (fig. 166 C and D) is remarkable for its tough lamellose integuments, the layers of which are gradually split off and shed. *Ch. limneticus* Lemm. is confined to the freshwater plankton.

INDEX.

[Synonyms are printed in *italics*, and the numbers in strong type refer to the descriptions of the genera, families, orders, etc.]

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