GUIDE TO COMMON FILAMENTOUS FRESHWATER MACROALGAE IN SOUTH AFRICA

Margaret Anne Joska
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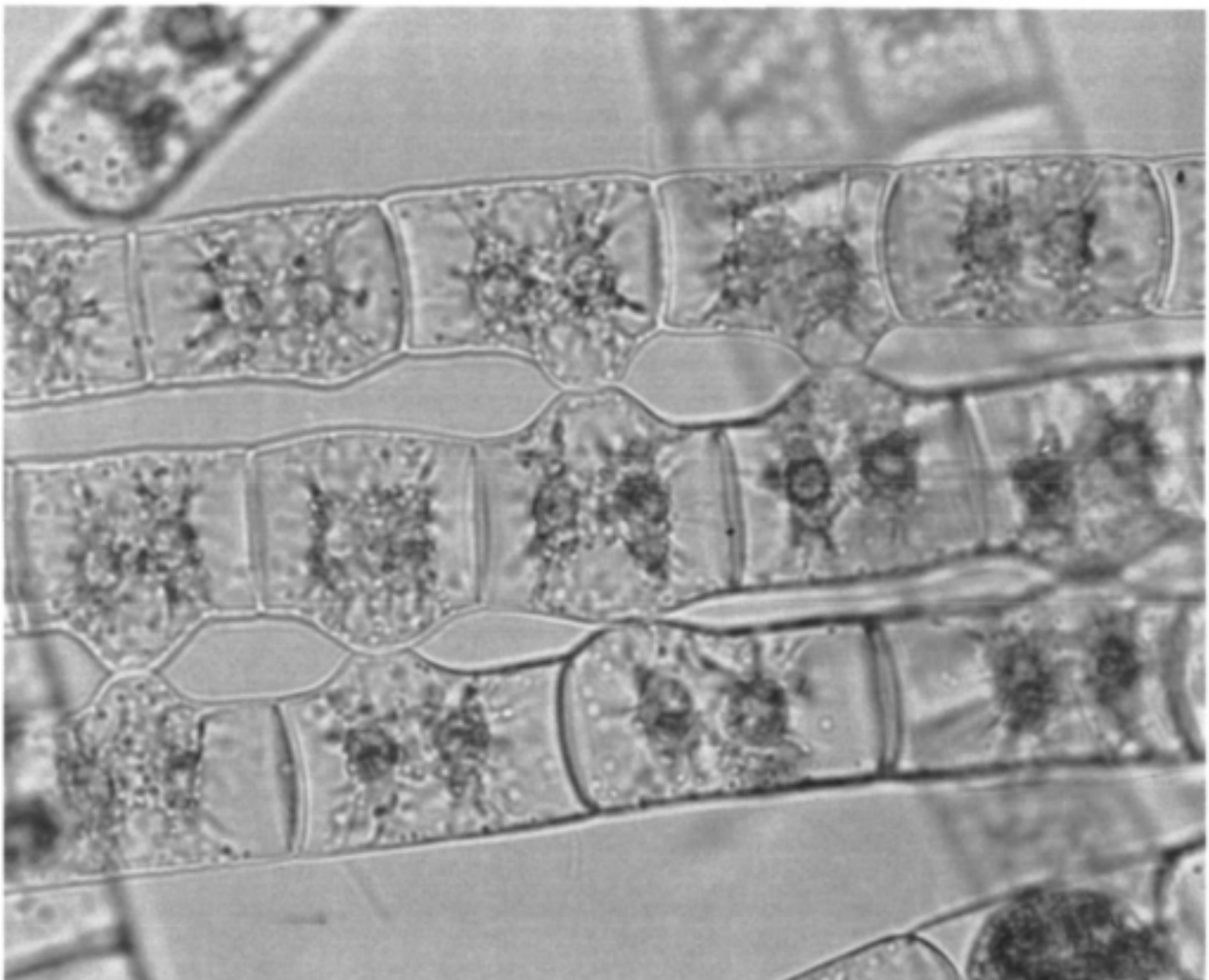

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Picture on cover: *Zygnema* sp.
Line drawings by Heidi Bolton.

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INTRODUCTION

Algae can be defined as simple plants without leaves or flowers. There are many types of freshwater algae. Some of them consist of single cells and are microscopic, although when they occur in large numbers they can cause "blooms" which colour the water green, yellow, red or brown. Single-celled algae may form loosely aggregated colonies and form such dense growths as to cover large areas e.g. *Microcystis aeruginosa* in the Hartbeespoort Dam in the Transvaal. Other algae are known as filamentous' which means thread-like and refers to their being, in at least one stage of their life-cycle, a continuous row or network of cells. They may or may not be branched and can either be so small as to be almost unnoticeable or grow to lengths of greater than a metre. Although mainly green in colour, they can range from yellow-green to brownish-black or even, in the case of the red algae (Rhodophyta) from pinkish to black. Few of these create problems in freshwater systems and similar species tend to be problematic world-wide. This guide is restricted to filamentous algae. The publications by Shillinglaw (1980) and Truter (1987) deal with many single-celled genera however, and Mr W. Harding is producing a key to the phytoplankton of Zeekoevlei which should be published in 1995.

The spores (reproductive cells) of algae are strongly resistant to drought and can easily be carried by wind as well as water currents. Thus, previously unrecorded species may suddenly occur at new sites. A few freshwater algal genera (but usually different species) may also occur in marine and estuarine systems e.g. *Cladophora*, *Enteromorpha* and *Vaucheria*. Certain genera given in this key have not yet been reported as problematic in South Africa, but have been included in that they are known to occur here and have become "problem" genera in other parts of the world with similar climatic conditions e.g. in Australia and North America. Other genera in this key are common algae whose presence tends to indicate "clean water" conditions.

It must be stated that often only one or two species within a genus may be the cause of problem growths whereas the many other species in that genus never become "problem" algae. Only 22 genera are described in this key. There are far more freshwater filamentous genera, but we have only included those which we feel would be of most benefit to general workers in water-related occupations. Two books which we would recommend for those interested in more detailed identification are "How to know the Freshwater Algae" by Prescott (1978) and "Introduction to Freshwater Algae" by Pentecost (1984). For a more detailed survey of the local and international literature on these organisms, refer to Joska and Bolton (1994).

A survey was undertaken by the Florida Department of Natural Resources in 1986 of 1.3 million acres of freshwater. They found that filamentous algae were fifth in level of abundance of aquatic plants, and were found at 50% of sites surveyed (Schardt, 1987). Pollution problems which started in the 1960s in the Great Lakes in the U.S.A. provoked massive filamentous algal growth and consequently also extensive research into this problem (Stoermer, 1988; Lembi, 1991). Certain algal genera, mostly those that occur world-wide can be used as pollution or "problem" indicators in fresh water.

The factors which lead to "problem" growths of algae are very important. In fact, these algal growths can indicate, often in advance, that something is wrong with an ecosystem. The "problem" growth of specific genera is now known to indicate specific water conditions. Since all algae, both filamentous and single-celled, form the base of the food chain, their absence or obvious occurrence may have long-term effects on the environment in which they occur. It is important that people whose work or recreational interest brings them into contact with water systems are aware that large, obtrusive growths of certain algae indicate a problem or a potential problem. We would like to know where these growths occur and we can be contacted at the address on the front page of this guide and/or a sample of the alga may be sent to us by post (preferably by Fast Post). As the algae are best studied live, a small piece of the alga (about one teaspoonful) placed in a plastic bank bag with approximately one tablespoonful of tap water is sufficient. The name of the collector, place of collection and date should be written, in pencil, on a small piece of paper and included with the sample. This sealed bank bag can then be placed within another bank bag. It is advisable to check for leaks! Provided the sample reaches us within a week the alga usually arrives in good condition.

METHODS FOR IDENTIFICATION

This use of this key requires a compound microscope as few algae can be identified without strong magnification. Second-hand microscopes can be obtained for relatively low prices and are perfectly adequate for general use. Universities and commercial laboratories often dispose of "old" microscopes at reasonable prices. The terminology used in this guide is not always strictly botanical but the object is to make the key "user friendly" for those people without botanical training and possibly to encourage interest in these fascinating plants. The glossary explains various botanical terms which we felt had to be used. Algae are most easily identified when still alive and can be taken from the site of collection in a container with a small amount of water. Most can live for quite a long time in a small container if the water is changed occasionally, enough sunlight and air are available and the temperature is not too high (below 20° C if possible). If you need to preserve specimens we suggest a 5% formalin solution - 5 ml of Formaldehyde in 100 ml of tap water (a chemist will make this up at little cost).

The coloured pigments inside the cells of most algae are confined to a structure known as a chloroplast. Preserving methods cause either "clotting" or disintegration of the chloroplast which can lead to problems with identification. The type of chloroplast is a major feature in identification *viz.* ribbon-like in a spiral (e.g. *Spirogyra*), parietal (closely adhering to the inside of the cell wall e.g. *Ulothrix*) or filling the whole cell (e.g. *Cladophora* or *Pithophora* or *Rhizoclonium*), stellate or star shaped (e.g. *Zygnema*). Specifically, *Cladophora*, *Pithophora* and *Rhizoclonium* require some botanical training to differentiate. They have similar filaments, can be branched and may have similar sized cells (Prescott, 1978).

Two further chemical solutions are a useful addition for identification. Firstly, an iodine solution. Iodine, obtainable from any chemist, is diluted 1 in 10 with tap water and placed in a dropper bottle.

This is used as a test for starch and a drop on an algal sample will turn the pyrenoids (starch storage organs of green algae) black. Secondly, a chromic acid solution. **Caution**: Chromic acid is dangerous and should be handled with care. **This solution, as with the 5% formalin solution, is best made up by a chemist/pharmacist.** 20 ml of Chromic acid is mixed with 80 ml of distilled water and kept in a small glass bottle. This solution is used for the identification of *Tribonema* and *Microspora* spp. and will allow the H pieces to be seen. The H-pieces make up the cell walls and the alga disintegrates in the testing process, therefore only a small portion of the sample should be treated. H-pieces are shown in the drawing on page 8.

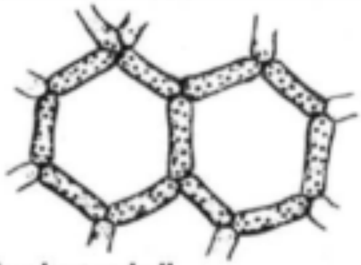
Culturing of specimens (growing them in the laboratory) is commonly required for differentiation of species since this may only be effected once reproductive structures are produced. Reproductive structures are usually not found in specimens when collected, as they occur only for short periods in the life of the plant and the plant commonly disintegrates once it has reproduced. The genera of algae in this guide are discussed in fuller detail in the pages as listed in the key. A brief index and glossary are given on pages 34 - 35 and a reference list of publications cited is given on pages 36 - 39.

KEY TO COMMON GENERA OF FILAMENTOUS ALGAE
(See Glossary on page 33 for botanical terms)

1. a. Algae in the form of a branched or unbranched filament. .... 2.
   b. Alga in the form of a ball/s (like small green marbles), readily visible to the naked eye and with an obvious, firm wall. .... ***Hydrodictyon*** p. **14.**

2. a. Filaments branched. .... 3.
   b. Filaments unbranched. .... 14.

3. a. Filaments joined to form a net-like sheet or ball. .... ***Hydrodictyon*** p. **14.**



   b. Filaments not joined in a net-like sheet or ball. .... 4.

4. a. Plants upright in water, attached in sand/soil substrate. Branches coming off in whorls from main filament. .... 5.
   b. Plants not upright in water and either floating or attached to solid surface or other plants. .... 6.

5. a. Microscopic examination of pineapple-shaped female reproductive body on branches shows 5 "crowning" cells on top. .... ***Chara*** p. **10.**
   b. Microscopic examination of pineapple-shaped female reproductive body on branches shows 10 "crowning" cells on top. .... ***Nitella*** p. **10.**

6. a. Filaments enclosed in mucilage. May have the appearance of frogs eggs to the naked eye. Under the microscope, plants reddish-green with branching coming off the main filament in bunches. Like a trimmed poodle tail. .... ***Batrachospermum*** p. **30.**

   b. Filaments not enclosed in mucilage. .... 7.

7. a. Filament not composed of joined individual cells. Branching occasionally, usually at right angles. It looks rather like a never ending, green flecked sausage. .... ***Vaucheria*** p. **26.**
   b. Filament composed of joined individual cells. .... 8.

8. a. Filaments mostly composed of a row of cells joined end to end. .... 9.
   b. Filaments composed of many joined cells, with a number of cells around the circumference or a sheet of cells. .... 12.

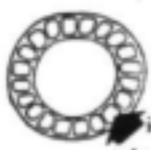
9. a. Branching very rarely. Individual cells filled with dark green "lumpy" bodies.
   No other structures or strands visible.
   Where joined, cell end-walls show layers (laminate)
   Plants commonly found in rivers or running water. .... ***Rhizoclonium*** p. **19.**

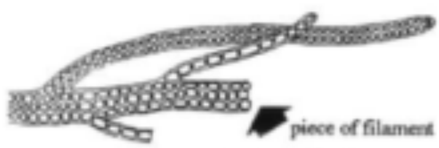
   b. Branching often, bush-like. .... 10.

10.a. Filament soft and gelatinous. Single chloroplasts visible in each cell. Tips of branches sometimes ending in a pointed colourless hair-like cell. .... ***Stigeoclonium*** p. **21.**
   b. Filament usually firm to the feel. Filament and branching usually visible to naked eye. .... 11.

11.a. Cells in filament not swollen. Plants usually in running water. .... ***Cladophora*** p. **12.**
   b. Some cells in filament swollen (barrel-shaped) and darker green in colour. Plants found floating in still water conditions. .... ***Pithophora*** p. **18.**

12.a. Filament usually partially flattened, uniformly green. Some species rarely branched. When cut in narrow sections will be seen to form a hollow tube. .... ***Enteromorpha*** p. **13.**





   b. Filament neither green throughout or hollow. .... 13.

13.a. Filament greenish pink or even blackish in part. Branching obvious to the naked eye and branch not formed of a single row of cells. .... ***Compsopogon*** p. **30.**
   b. Branching and arrangement of cells only visible under microscope. Branches formed from whorls of single cells coming off at regular intervals from main filament. .... ***Batrachospermum*** p. **30.**

14.a. Filament unbranched or rarely branched. Individual cells filled with dark green "lumpy" bodies. No other structures or strands visible. Where joined, cell end-walls show layers (laminate) Plants commonly found in rivers or running water. .... ***Rhizoclonium*** p. **19.**

b. Filament unbranched. Cells not completely filled with green "lumpy" bodies. .... 15.

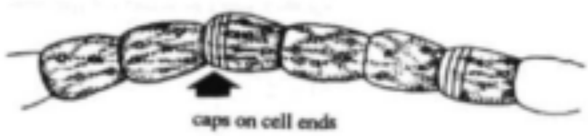
15.a. Filament of capsule-like cells which have a faint band around the centre and are brownish in colour. .... ***Melosira*** p. **25.**

b. Cells in filament without faint central band. Filament green, bluish green or colourless. .... 16.

16.a. Cells in filament with obvious green structure filling the entire cell or part of the cell.. .... 17.

b. Cells in filament without obvious green structure. Cell contents pale and granular. .... 23.

17.a. Chloroplast net-like, filling entire cell. Ends of cells often with ridges or "caps". .... ***Oedogonium*** p. **18.**



b. Chloroplast not filling entire cell. No ridges or "caps" on cell ends. 18

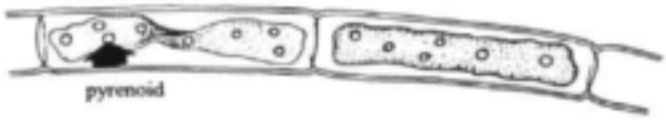
18.a. One or a number of chloroplasts spirally arranged in cell. .... ***Spirogyra*** p. **20.**

b. Cells without spiral chloroplasts. 19

19.a. Two star-shaped chloroplasts in each cell. .... ***Zygnema*** p. **24.**

b. Cells without star-shaped chloroplasts. .... 20.

20.a. Cells with long rectangular chloroplasts, lying along the length of the cell. One or more obvious spherical, colourless pyrenoids lying in the chloroplast. .... ***Mougeotia*** p. **15.**



b. Cells with chloroplasts not as above.. 21.

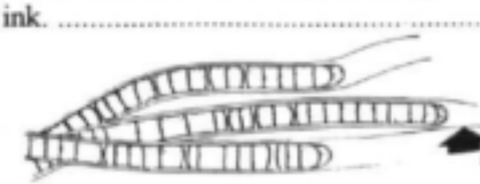
21.a. Cells often not more than twice as long as broad, often squarish but may be rectangular, with a single large chloroplast. This chloroplast looks like a pancake, folded over, but not filling the entire cell .... ***Ulothrix*** p. **21.**

b. Cells rectangular, usually more than 2x as long as broad. H pieces present. .... 22.

22.a. A number small, rounded, disc-like chloroplasts -. .... ***Tribonema*** p. **26.**

b. A single chloroplast, neither rounded or disc-like. .... ***Microspora*** p. **15.**

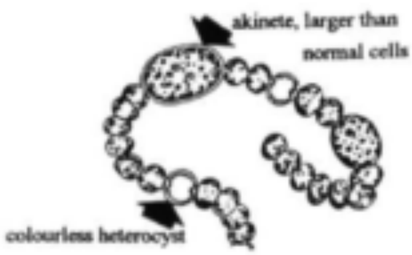
23.a. Filaments with obvious sheaths. Filaments adhering together to form mat-like growths. Sheath best seen by staining with black drawing ink. .... ***Phormidium*** p. **29.**



b. Filaments with no obvious sheath. .... 24.

24.a. Cells broader than long. Whole filament shows slight undulating movement. Commonly found in dense aggregates in water and damp mud. .... *Oscillatoria* p. **29.**

b. Cells bead-like, filaments often single and floating (planktonic). Larger cells may be present in filament, either heterocysts or akinetes. .... *Anabaena* p. **28.**



CHAROPHYTA (Stoneworts)

Charophytes are one of the oldest groups of plants known, and have been found as Devonian (408 million years old) fossils. They are today found in a wide geographical range from northern Norway to Kerguelen Island in the Southern Ocean (Groves & Bullock-Webster,1920; Wood & Imahori, 1965). They differ from the other filamentous algae in this guide in that they have a well developed rhizoidal "root-like" system and require a sandy/soil substrate for anchorage.

Their form is usually readily visible to the naked eye and generally the plants stand upright in quiet to still water conditions. Most species are monoecious (one plant with both sexes) but a few are dioecious (separate male and female plants). The rounded male (antheridia) and pineapple-shaped female (oogonia) reproductive organs are usually visible to the trained eye with the aid of a small pocket lens. These are found either laterally (on the side) on the main "stem" or on the whorls of branches which grow from the nodes on the "stem". These reproductive organs are orange to red or black in colour when fully developed. In some species the main "stems" become stiff with encrusted lime, hence the common name "Stoneworts". A number of species of both *Chara* and *Nitella* are endemic to South Africa.

Chara **and** ***Nitella*** **See Plate 1 a on page 16**

These two genera are discussed together since they occur similar conditions. Some species of *Chara* have been recorded as creating blockages in irrigation canals in India (Gupta, 1987) and Argentina (Sabbatini *et al*., 1986). Maintaining cement irrigation canals free of silt will inhibit the growth of these algae since they cannot adhere to solid substrates. Far more serious problems are encountered in earth-dug irrigation canals or rice paddy fields where the substrate is ideal for them. The two algae look like very fine grass stems emerging from the sediment, but whorls of similar "stems" will be seen growing out from the main "stem" at intervals. They grow from 10 cm to a metre in height and form dense stands under the water. The reproductive oospores are resistant to decay and can live for a number of years in damp sediment (Simons, 1991). The presence of certain species of both *Chara* and *Nitella* can indicate eutrophic conditions whilst conversely, the presence of other species indicate clean uncontaminated water conditions. *C. globularis*, *C. contraria*, *C. aspera* and *N. mucronata* have been reported in water of poor quality (Sabbatini *et al.*, 1986; Simons, 1991). The use of herbicides such as copper sulphate and Paraquat™ has been shown to have only a limited effect on the growth of *C. contraria* and *C. globularis*, respectively (Sabbatini *et al.*,1986; Brooker & Edwards, 1973). Both these species occur in South Africa (Wood & Imahori, 1965). Many species of both *Chara* and *Nitella* have been recorded in Southern Africa, including *C. globularis* (Leistner, 1978). Bally *et al.*(1985) reported that the production of *Chara sp.* in the Bot River estuary on the south-western coast of South Africa was 2 230 g m^{-2} y^{-1}, an order of magnitude greater than previously reported elsewhere. We have observed large growths of *Nitella* in the Olifants River canal system in the south-western Cape. Although both *Chara* and *Nitella* can form large growths in canal systems and water impoundments, they do have some positive merit in that they are considered to act as a nutrient filter in polluted systems (J. Simons pers.comm.).

CHLOROPHYTA (Green Algae)

These are by far the most common filamentous algae in fresh water and are always a definite green colour. They have obvious chloroplasts which are a major feature in their identification. They have a range of thallus (whole plant body of an alga) forms - from slimes coating rocks and mud to very visible growths. It is the ability of this group to spread vegetatively as well as to reproduce sexually that has led to their persistence in often disadvantageous conditions. Entwisle (1989) in Australia and Biggs (1990) in New Zealand found that certain filamentous green algae formed communities indicating eutrophic water conditions. These communities included the genera *Cladophora*, *Oedogonium*, *Stigeoclonium*, *Ulothrix*, *Rhizoclonium* and certain species of *Spirogyra*. Our preliminary investigations in South Africa indicate that these same genera are dominant in similar conditions here. John & Johnson (1991) stressed the importance of macroalgae as water quality indicators in that they are most readily seen and identified.

Cladophora

See Plate 1 b, c on page 16

There are many species in the genus *Cladophora*, and the greater majority are marine. There is no agreement on the number of freshwater species (Dodds & Gudder, 1992) but at least seven have been recognised as occurring in freshwater and estuarine environments. The taxonomy (deciding which species is which) is complicated since the plants often adapt their form to prevailing conditions (Hoek, 1976). Three freshwater species of *Cladophora* have been found to date in South Africa: *C. glomerata*, *C. fracta* and *C. rivularis*.

The species *C. glomerata* is found world-wide and its most prolific growth has been recorded in eutrophic or polluted water. This nuisance growth, especially in irrigation canals in the Transvaal and Orange Free State, has caused blockage of water flow and irrigation jets and has added tremendously to the cost of maintenance of these canals and to water purification works, such as those of Rand Water. Growths some 20 metres long have been observed. The plant generally requires either a solid substrate or another plant for attachment. The basal attaching cell is persistent and even if the top growth is removed this cell can regenerate and form a new plant within a short time. The plant branches profusely and is able to withstand and, in fact, has enhanced growth in moderate to fast water flow conditions. This is because the more water passing over and around the plant allows for more nutrients to be absorbed. It is in waters with high nutrient loads e.g. with sewage, industrial and agricultural effluent, that *Cladophora* becomes most prevalent. The high levels of nitrate, phosphate, conductivity (a measure of the amount of mineral salts) and pH (acidity) produced by these effluents are responsible for this growth (Whitton, 1970). More importantly, certain minimal light levels have been shown as necessary for these nuisance growths, and where water conditions are strongly turbid (cloudy), growth is inhibited (Dodds, 1991; M. Steynberg. pers.comm.).

C. glomerata is often fairly firm to the touch and the branching is visible to the naked eye. No permanent control of this species has been recorded where it has formed nuisance growths due to eutrophic conditions. Permanent reduction in growth requires reduction in the levels of nutrients in the water (nitrogen and, particularly, phosphorus). Temporary control has been effected by manual removal, the application of copper sulphate compounds and some other algicides. World-wide, where eutrophic conditions prevail this is one of the most common nuisance species of alga. In 1987 the annual budget for the control of aquatic macrophytes (mostly *Cladophora*) in the Salt River Canal in Arizona, U.S.A., was US$1.5 million (Lembi, 1991). *Cladophora* is considered to be a good indicator species for nutrient pollution (John & Johnson, 1991) and is able to accumulate copper (Dodds & Gudder, 1992) and DDT (Whitton, 1975). Experiments have also shown that although it is not their preferred food, its dense branching system provides an attachment and refuge for many invertebrates (Power, 1991; 1992).

Enteromorpha **See Plate 1d on page 16**

Three species of *Enteromorpha* have been recorded in South African fresh waters: *E. basiramosa, E. gracillima and E. intestinalis* (Pocock, 1966). *E. intestinalis* is also common in marine and estuarine waters e.g. in brackish lagoons with high nutrient levels such as Sandvlei in the Cape Peninsula, where it occurs as large growths. *Enteromorpha* species are usually bright green and ribbon-like. They are formed as hollow tubes of many cells and may or may not be branched. *E. intestinalis* commonly occurs in large aggregations where the water flow is slow, the conductivity (a measure of the amount of mineral salts) is high, and often where water is more alkaline (pH > 7). This genus is well documented as a pest species in the marine environment - much money and research has gone into its elimination from ship's hulls. It has also been used as an indicator species for instance, Say, *et al*. (1990) used tissue analysis of *Enteromorpha* to indicate heavy metal pollution in British estuaries. We have, to date, found *E. intestinalis* in the Orange, Crocodile, Olifants, Berg, Eerste and Breede river systems in South Africa.

Hydrodictyon **See Plate 2 a on page 17**

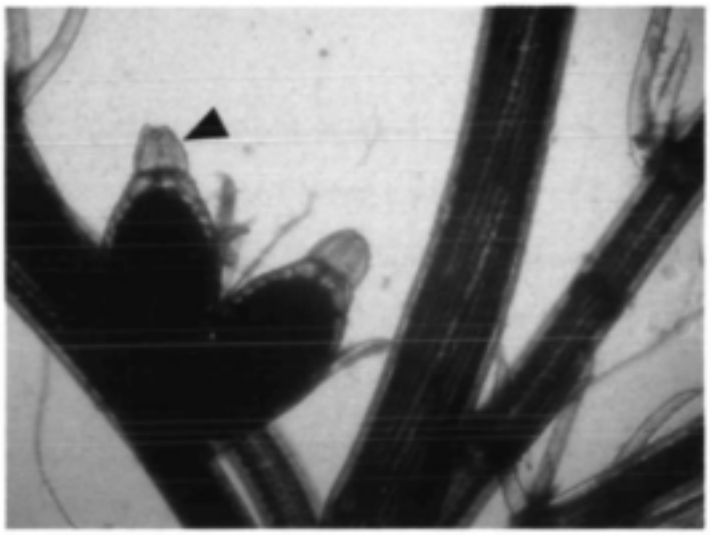
This most interesting alga takes two forms in its life cycle. Commonly it occurs in temporary water bodies and the initial growth is net-like. Many individual cells, which are an elongate rectangle in shape, are joined together to form a flat or spherical net. These net-like balls have been recorded up to 30 cm in diameter. In some species these net cells then alter their shape and become spherical, the net disintegrates and each cell becomes an individual, looking rather like a green marble. These single rounded cells develop a firm outer wall and are able to withstand fairly long periods of drought if the water body they are in is temporary and dries up. *H. africanum*, which is found in vleis in the Cape Peninsula has been called "green frog's eggs" (Pocock, 1960). *H. reticulatum* has not yet been reported as a nuisance in South Africa, but in New Zealand this species has been recorded as invasive. It has formed nuisance growths in lakes and waterways and caused "such damage as to raise economic concerns" (Hawes *et al*., 1991). It has also been reported as a nuisance species in North America in small ponds and irrigation canals (Prescott, 1978). In the Punjab in India it was noted that in irrigated lands where salinisation occurred, *Hydrodictyon* was one of the few algae which could survive this condition. It was thus felt that this alga could be considered as an "indicator" species for increasing salinisation (Iyengar, 1939).

Microspora **See Plate 2 b on page 17**

This member of the green algae is commonly confused with the Chrysophyte algal genus, *Tribonema*. The major means of differentiating between the two is that *Microspora* will indicate the presence of starch if the Iodine Test is used. The starch grains are seen as small black dots in the cytoplasm. The unbranched filament usually has short rectangular to squarish barrel-shaped cells with the cell length seldom greater that the cell width. In most species the cells have similar H pieces to those found in *Tribonema*. The single chloroplast can vary in shape from cell to cell within the same filament, and so a number of cells in the filament should be observed. The chloroplast generally fills the entire cell, but is thickened in some areas and so is uneven in colour. This genus was never found in large amounts in our samples, but its presence was often noted in clean to slightly polluted water.

Mougeotia **See Plate 2 c on page 17**

This alga is composed of long filaments of rectangular cells which do not branch. The single chloroplast is ribbon-like, lying along the central axis of the cell, and usually with one or more very obvious pyrenoids (circular discs which appear pale green or colourless). Its reproductive method is by conjugation with what is commonly called "knee bending". Here the filaments bend towards one another and join with a central section where the zygospore (thick-walled spore) is formed. The shape and decoration of this spore is the method by which the species are defined. The filament cannot be seen in any detail by the naked eye, but large growths of this alga have been described as "clouds" in the water. This alga prefers more acidic (< 7 pH), and less nutrient-rich waters. *Mougeotia* was also found to be the preferred food source for both invertebrate and vertebrate grazers in some Canadian lakes (France *et al.*, 1991). It has never been recorded as a nuisance species, on the contrary, it is often an indicator of "clean" water conditions e.g. in south-western Cape mountain streams.(Bolton & Brown, 1994).



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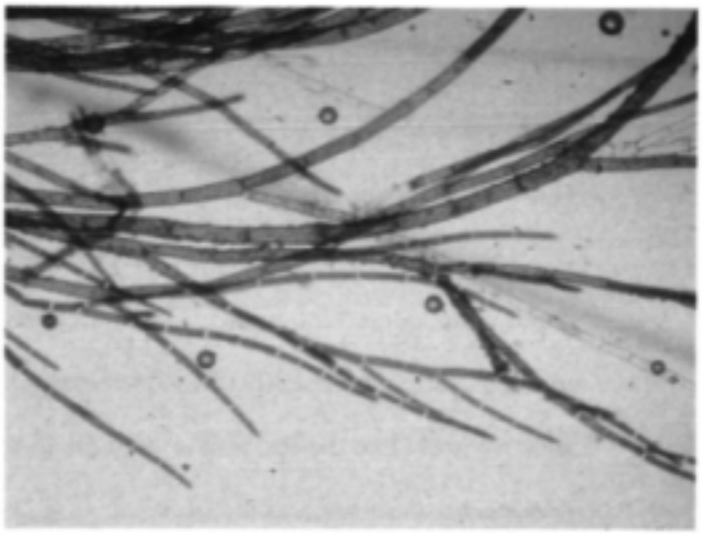

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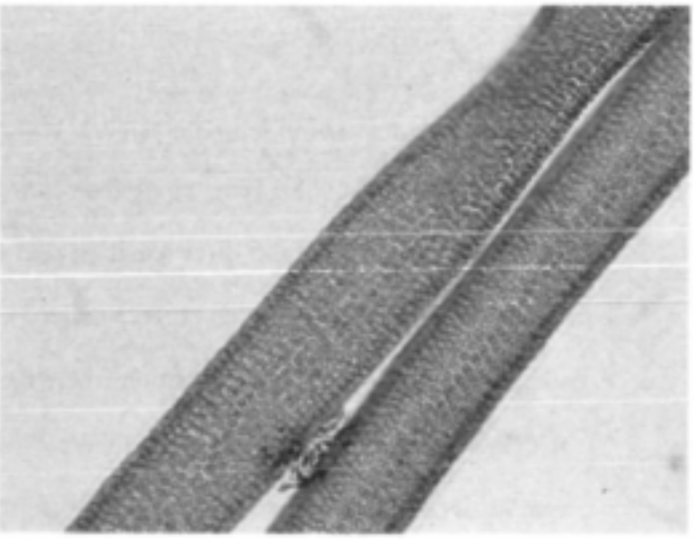


d

Plate 1. a. *Chara* sp. showing oogonium. Arrow indicates "crowning" cells.
b. *Cladophora* sp. showing branching pattern.
c. "Problem" growth of *Cladophora* sp. in irrigation canal.
d. *Enteromorpha* sp. showing many cells in main filament.

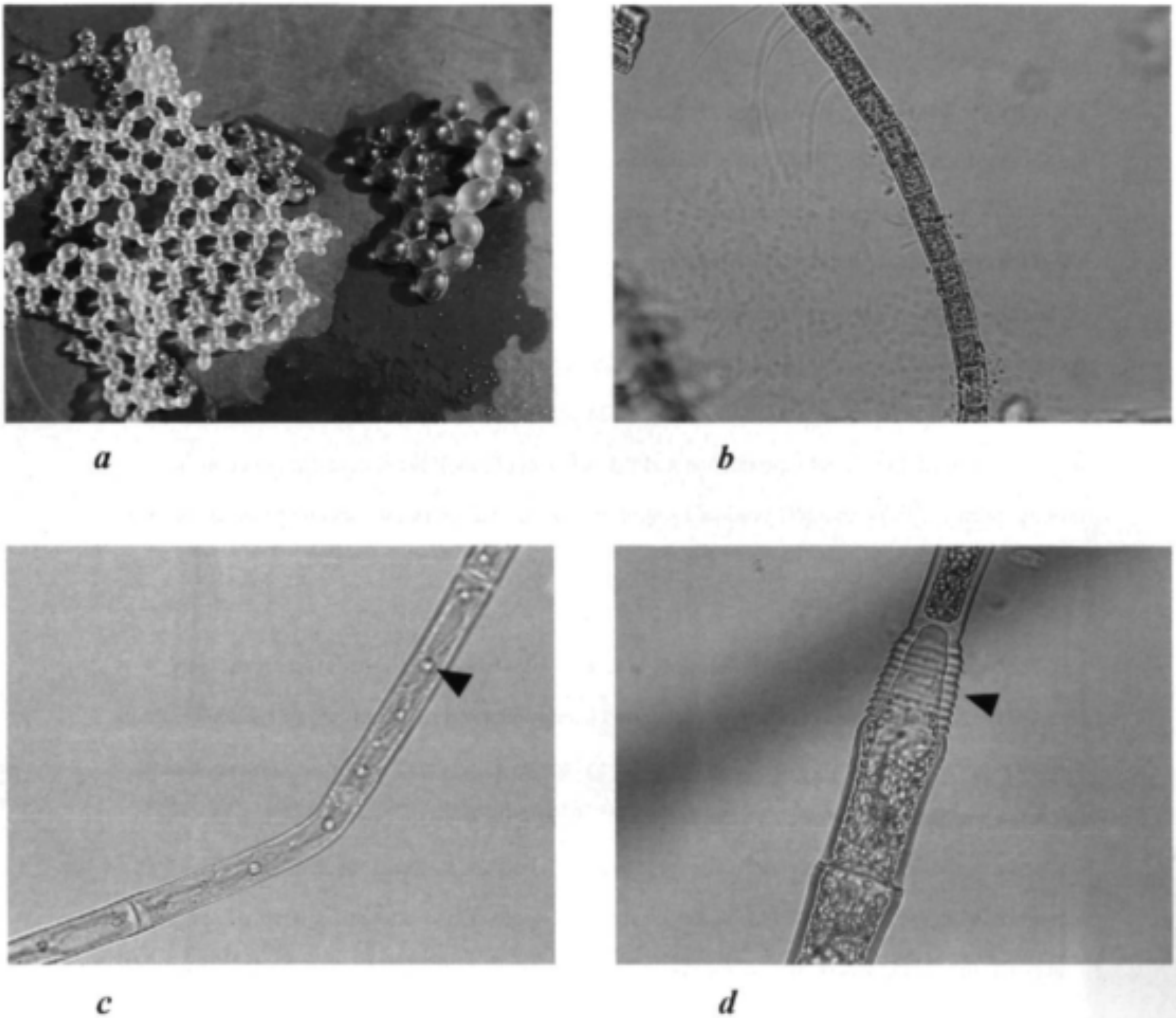


Plate 2. a. *Hydrodictyon* sp. showing net-like filament (l) and "frog's eggs" (r).
b. *Microspora* sp.
c. *Mougeotia* sp. Arrow indicates pyrenoid (1 of 5) in cell.
d. *Oedogonium* sp. Arrow indicates "cap" cells.

Oedogonium **See Plate 2 d on page 17**

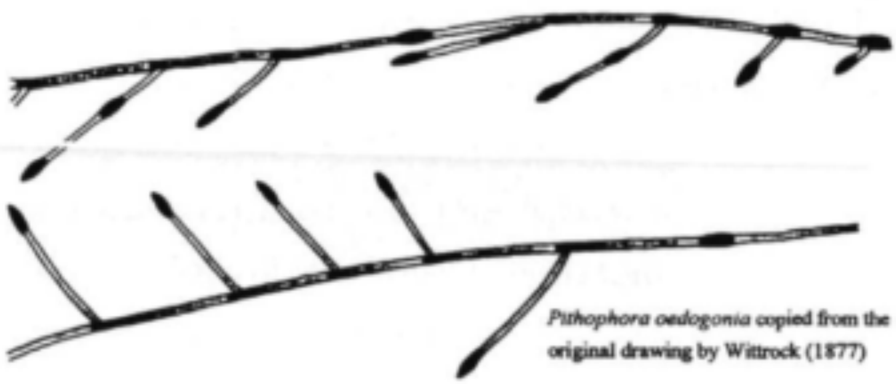
This genus is distributed world-wide and has a large number of species; some 45 have been recorded for South Africa (Tiffany, 1930). It is easily recognised (under the microscope) by distinctive cap cells which occur along the unbranched filaments. The cell walls are quite firm and the distinctive net-like chloroplast fills the entire cell. Small pyrenoids (colourless circular bodies) are held in the mesh of the chloroplast. The "caps" are formed when the cell undergoes division and a ring-like thickening appears at the top of the cell. These pre-formed cells appear like bands or rings - virtually colourless, and to see them often requires careful focusing. The sexual reproductive systems vary between species and the method of this sexual reproduction and the shape and form of the resultant spore define the various species. These sexually produced spores are able to resist drought conditions and can remain viable for long periods.

Very few records have been found of nuisance species. We have noted at least three apparently different *Oedogonium* species which have occurred in eutrophic and semi-eutrophic conditions in South African waters. One species, which we were able to identify as *O. capillare,* formed large nuisance blooms in the Breede River canal system in spring. Algal samples from semi-eutrophic, high conductivity and high pH water in the Orange, Crocodile, Jukskei, Vaal and Bloubankspruit rivers all contained *Oedogonium* spp. Although these samples were dominated in total biomass by *Cladophora glomerata,* the *Oedogonium* spp. were consistently present. In South African waters the presence of some species of *Oedogonium* could therefore indicate polluted water conditions. *Oedogonium* spp. were found in similar situations in New Zealand rivers, often forming large growths with up to 25% cover (Biggs & Price, 1987).

Pithophora

This genus was originally considered to have tropical to subtropical distribution, but has since been recorded in temperate waters (Lembi *et al*, 1980). *Pithophora* was recorded as occurring in Southern Africa by Miss E L Stephens (unpub.) and, given the right conditions could become a nuisance alga in South Africa. It can form large floating mats which block waterways and create aesthetic problems

(Lembi *et al*, 1980). Its microscopic appearance can be similar to that of *Cladophora* (Prescott, 1978) but its tendency to branch frequently and production of reproductive cells (akinetes) are distinguishing features (See illustration below). The problem with this alga is that these akinetes are resistant to herbicides and drop to the sediment and can remain there until more favourable conditions of growth occur. *Pithophora oedogonia* was shown to be resistant to treatment with many algicides (O'Neal *et al*, 1983) and only temporary control was effected with copper sulphate. Although nuisance growths of this genus have not yet been reported in South Africa, its known occurrence could suggest that it may become a problem alga in dams and vleis in the near future.



Pithophora oedogonia copied from the original drawing by Wittrock (1877)

Rhizoclonium **See Plate 3 a on page 22**

This alga is in the same family as *Cladophora* and *Pithophora*, the Cladophorales. The differences between the three genera are not always seen and they are thus often difficult to separate. The individual cells are multinucleate and the filaments are seldomly branched. The cell contents appear as densely green and granular. One species, *R. hieroglyphicum*, has been reported as occurring in South Africa (Pocock, 1966). Reproduction is mainly sexual, by means of swimming spores released from a cell which has become reproductive. This alga can also reproduce vegetatively when parts of the filament fragment, and new rhizoidal (root-like) growths are produced. Although few overseas publications cite *Rhizoclonium* as creating problems, it was noted by Entwisle (1989), in Australia, that this alga and *Cladophora* are easily confused and that *Rhizoclonium* may form more nuisance growths than have so far been attributed to it. Biggs & Price (1987) found that in New Zealand this alga could be the dominant species in some sites, forming up to 100% cover, especially where the water was agriculturally polluted.

Spirogyra **See Plate 3 b on page 22**

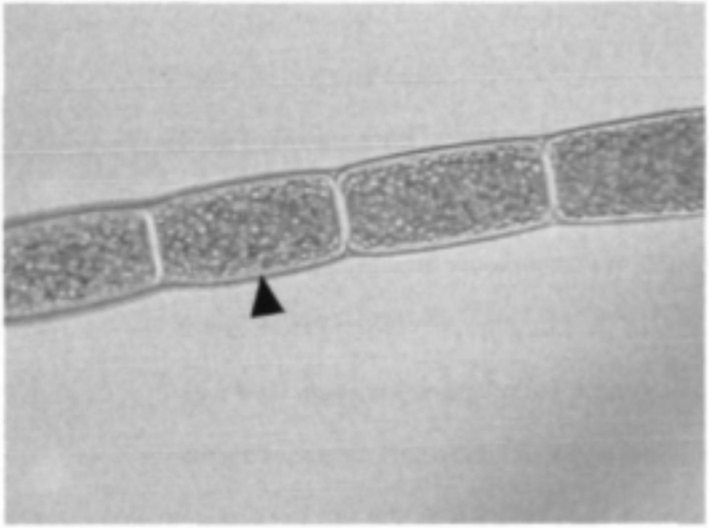
This very easily recognised algal genus has a large number of species, some 275 being recognised by Transeau (1951). The filament, always unbranched, is composed of cells which contain from one to a number of spiral chloroplasts. In this spiral chloroplast, small spherical pyrenoids (usually pale green or colourless) may be seen. These plants reproduce vegetatively, asexually and sexually. In the sexual reproduction the cells in the filament conjugate. A tube-like growth is put out from one cell to a matching growth in another cell - either in the same filament or another filament. The method of conjugation and the type of reproductive spore formed indicate the species. *Spirogyra* tends to occur in moderate to fast flowing water and has a protective mucilage, produced by the cells, which allows water to flow easily over and around the filaments. The common names, "Pond Silk" or "Water Silk", were given probably because of the feel of this alga. *Spirogyra* is in the same group as *Mougeotia* and *Zygnema,* because of their similarities in method of sexual reproduction. Spirogyra was reported as occurring in "little polluted" communities in Australia (Entwisle, 1989) and Holland (Simons & van Beem, 1990). In our algal sampling to date, our findings are similar to those of Biggs (1987, 1988) in New Zealand. Some *Spirogyra* spp. were found to be present in water with a high conductivity and moderate to fast water flow, although not as large nuisance growths. Certain species seem to be more tolerant of some pollution and they could be used as "indicator" algae. However, *Spirogyra* spp. were also commonly found in Cape mountain streams where the pH was low (acidic water) and the water unpolluted. It is now important to establish which species will tolerate polluted water conditions and which are indicative of good quality water.

Stigeoclonium **See Plate 3 c on page 22**

The species *S. tenue* occurs world-wide and can form large "nuisance" growths (Printz, 1962; Pocock, 1966; Simons *et al*, 1986; Entwisle, 1989). To the naked eye *Stigeoclonium* appears as a soft, bright green, almost fluffy alga. Seldom greater than 5 cm in length, it is commonly attached to rocks or other algae and plants. Sometimes, but not always, the tips of the branches are very pointed, almost hair-like. Commonly, the cells at the base of the plant have divided laterally and the single-cell wide filament becomes multi-celled. De Vries (1991) used this species as an "indicator" for assessments of eutrophication where high concentrations of phosphorus and nitrogen were present in farm waste water in the Netherlands. It was also found to occur in Britain and Europe where there was zinc pollution from mining run-off (Harding & Whitton, 1976). *S. tenue* was also found to be twice as resistant to zinc, copper and lead contamination of fresh water than *Cladophora glomerata* (Whitton, 1970). Hancock (1973) reported finding a *Stigeoclonium* species in a mine polluted stream in the Transvaal when pH values rose to 8.6 in the wet summer season. *S. tenue* has also been found as a minor component of "sewage fungus" (Gray, 1985). John & Johnson (1991) consider that *S. tenue* is "an indicator of high levels of organic pollution". Considerably increased growth of this species was recorded on rocks below a trout farm in the Molenaars River, Cape (Guthrie, unpubl.1992).

Ulothrix **See Plate 3 d on page 22**

This is usually a very fine alga, the filaments themselves being only visible under high magnification. The cells in the filament , in some species, are short and rectangular, but may be long and rectangular in others. The single pancake-like chloroplast is folded around the circumference of the cell (parietal), but does not fill it. *Ulothrix* spp. were found to have a high resistance to both copper and lead and moderate resistance to zinc in fresh water contaminated by metals (Whitton, 1970). *U. zonata* caused serious problems in the Great Lakes in North America (Lembi, 1991). Biggs & Price (1987) found that *U. zonata* "frequently formed proliferations" with cover estimates > 40% on cobble substrates in New Zealand. Pocock (1966) recorded ten species from Southern Africa.



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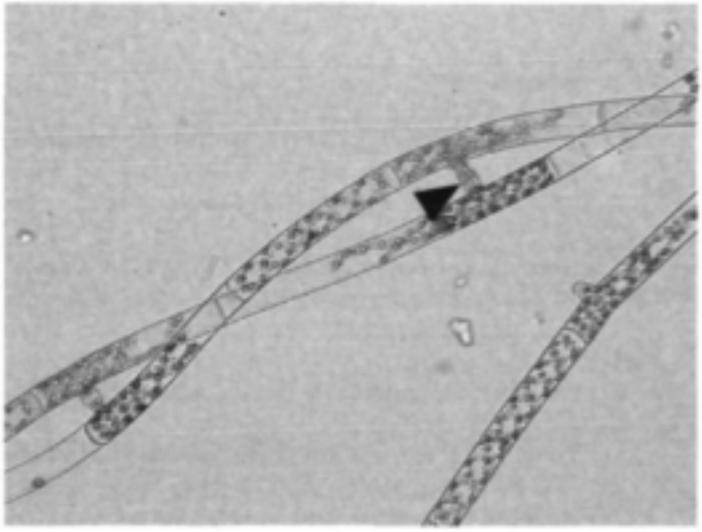

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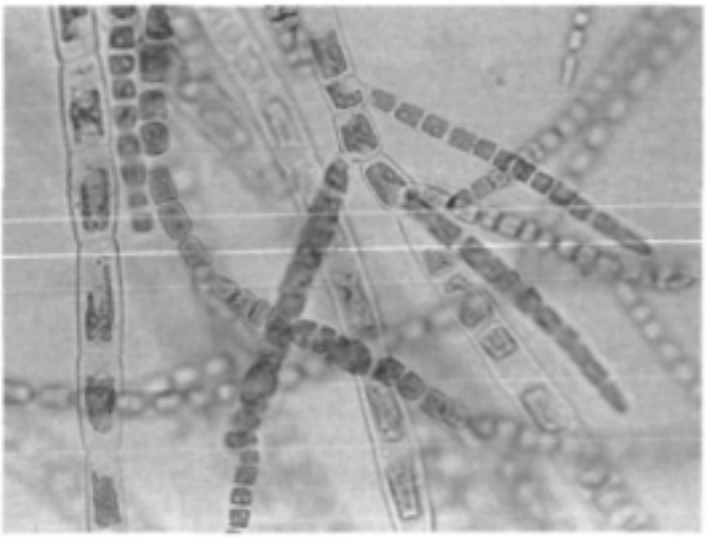

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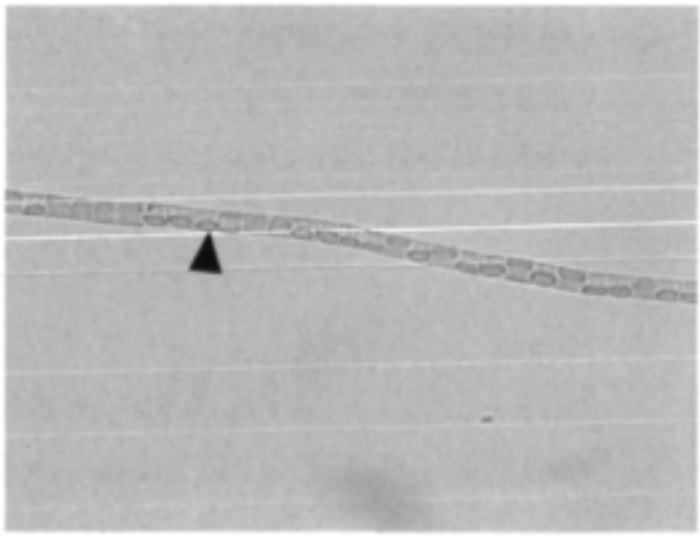

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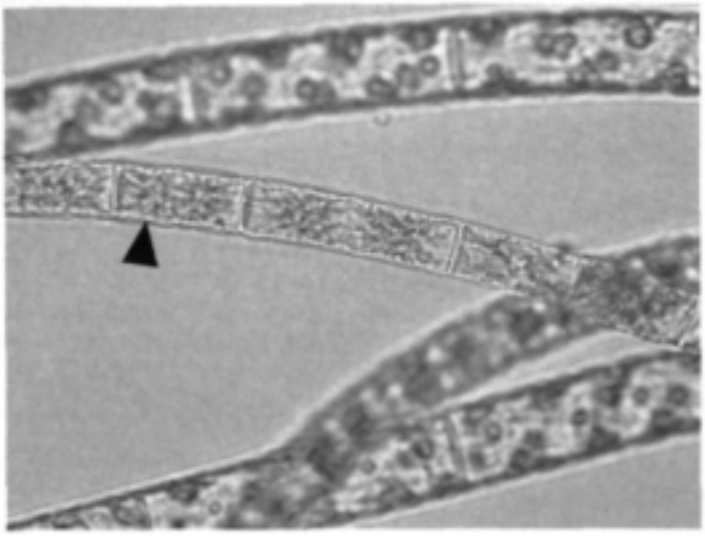
Plate 3. a. *Rhizoclonium* sp. Arrow indicates "lumpy" cell contents.
b. Conjugating *Spirogyra* sp. Arrow indicates conjugation tube.
c. *Stigeoclonium* sp.
d. *Ulothrix* sp. Arrow indicates chloroplast.



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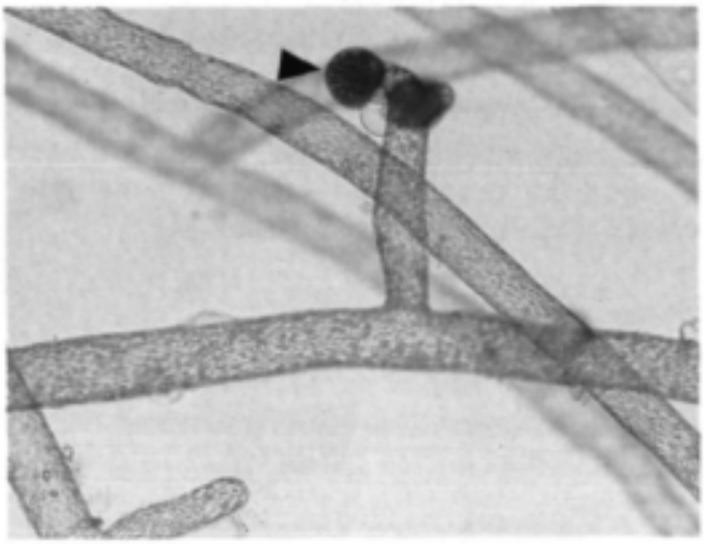

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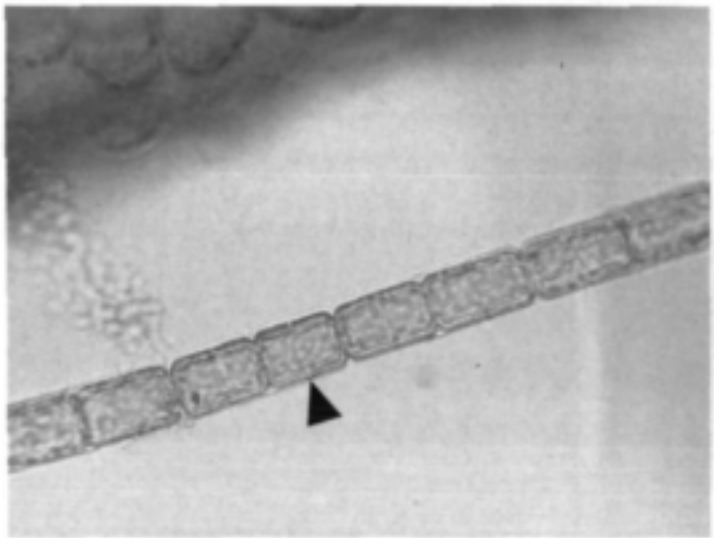

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Plate 4. a. *Zygnema* sp. Arrow indicates one of two star-shaped chloroplasts.
b. *Tribonema* sp. Note slightly barrel-shaped cells.
c. *Vaucheria* sp. Arrow indicates female reproductive organ on "stalk"

d. *Melosira* sp. Arrow indicates central band where two halves of cell join.

Where water is phosphate enriched (as in eutrophic or polluted conditions) *Ulothrix* has been reported as showing increased growth rates and covering a larger amount of available substrate attachment area (Biggs & Price, 1987). Lokhorst & Vroman (1974) reported finding *Ulothrix* spp. in waters with a pH of 7-8 but in South Africa Bolton & Brown (1994) found *Ulothrix* at pH values of 4.8 - 6.4. In Australia (Entwisle,1989) New Zealand (Biggs, 1990) and in the south-western Cape (Guthrie, 1992; Bolton & Brown, 1994), *Ulothrix* tends to be most abundant in winter conditions of high flow and lower temperatures.

Zygnema **See cover illustration and Plate 4 a on page 23**

This alga has filaments which are unbranched and each cell has two distinctive star-shaped chloroplasts. It reproduces sexually by means of conjugation and falls in the same group as *Spirogyra* and *Mougeotia*. Also, as with *Spirogyra* and *Mougeotia*, species definition relies upon the method of conjugation and the size and decoration of the reproductive spore. A few species reproduce by asexual means only. As with *Mougeotia*, *Zygnema* has not been reported as a "problem" genus. It is rather a genus which occurs commonly in "clean" waters, although some species may be tolerant of mild pollution.

CHRYSOPHYTA

This is an extremely diverse group of algae. They can be separated from green algae as they do not have starch as a storage compound. They thus have a negative reaction to the starch test (page 3). The diatoms (Bacillariophyceae) are a huge group within the Chrysophyta and are usually studied by specialists in this group only. The diatoms are distinct in having a rigid cell wall composed of two halves, fitting together like a lidded dish. The cell wall is called a frustule and is mainly composed of silica. Bold & Wynne (1985) describe the diatom wall as "two overlapping halves of a close-fitting container". Each half of the cell wall is called a valve and the area where these two valves join is called a girdle. As the cell walls are rigid, reproduction in the diatoms is mainly vegetative. Many diatoms are single-celled, some are colonial (single cells clumped together) and a few are filamentous. The "yellow green algae" (Xanthophyceae) are another group in the Chrysophyta and may be single-celled, colonial or filamentous.

A. Bacilliarophyceae (Diatoms)

Melosira **See Plate 4 d on page 23**

This alga is a filamentous diatom. Each cell of the filament is, in fact, an individual diatom. In *Melosira* the cells of the filament are shaped like capsules and have inconspicuous disc-like chloroplasts with a brownish/golden colour. They are not attached to a surface but float in the water amongst the filaments of other algae. They are found commonly in polluted or eutrophic water and were noted in New Zealand (Biggs, 1990) as reliable "indicator" species where water had high conductivity (many dissolved salts) and temperatures > 17 °C.

B. Xanthophyceae

Tribonema **See Plate 4 b on page 23**

This is an unbranched alga with distinctive H-pieces, where adjacent cell walls overlap. Usually the H pieces are easily seen under high magnification, but can be readily revealed by adding a drop of a weak solution of chromic acid (as described on p. 3) to a small amount of the algal sample on the microscope slide. This alga is commonly confused with another alga, *Microspora* (Chlorophyta), but the two differ in chloroplast structure. *Tribonema* has one to many distinctive, small round chloroplasts around the circumference of the cell whilst *Microspora* has one chloroplast which fills the entire cell. The cells, as in *Microspora,* may be cylindrical or slightly barrel-shaped. Often the filaments appear golden or brown in colour due to the presence of symbiotic bacteria.

Vaucheria **See Plate 4 c on page 23**

Despite being classed among the Chrysophyta (golden-brown algae) this alga is often bright grass green. However, it has no individual cells in its occasionally-branched filaments. Under medium magnification (100x) it looks rather like a continuous, green-flecked, sausage. It is also found in marine and estuarine environments. Branching, when it occurs, usually goes off at right angles to the main filament. These algae are found not only in water, but on damp soil. They reproduce both vegetatively, with balloon-like extensions of the filament, and sexually. The sexual reproductive organs may be produced on the main filament or on separate, small "stalks", off the main filament. Male and female reproductive organs are borne either on separate "stalks" or the same "stalk", depending on the species. In the past *Vaucheria* was not considered as a nuisance alga, but it has recently been cited as a problem in drainage systems in England (Gibson & Barrett, 1989).

CYANOPHYTA (Blue-green algae)

Many biologists do not consider the Cyanophyta as plants but as bacteria (Cyanobacteria) because they lack a membrane around the nucleus. As the algae comprise a variety of, in many cases, unrelated organisms we have no hesitation in retaining the name "blue-green algae". The terms used to describe the Cyanophyta are different from those used for other algae. As with the diatoms, the blue-green algae are a group studied best by specialists. Individual filaments are usually extremely small and can often only be studied under high magnification (400x). Despite their size they have been recorded as causing huge problems in water systems and, in fact, some species are highly toxic. Blue-green algae may be single-celled, colonial or filamentous, and often form mats of closely packed filaments in fresh flowing waters.

The filaments of blue-green algae are called trichomes. In some genera the trichomes are coiled or twisted and one or more trichomes are often held within a "sheath" (see drawing on p. 8). This sheath is often quite difficult to see. A drop of black drawing ink dropped onto the microscope slide and allowed to flow around the algal specimen will show up the sheath. The cells of the blue-green algae do not contain distinct chloroplasts or nuclei. The contents of the separate bodies (e.g. chloroplasts) found in other plant cells which perform the chemical processes of life, are in fact present but fragmented and scattered throughout the whole cell. The cells usually appear "grainy" or "granular" and have very pale colouring under the microscope. Most filamentous blue-green algae are not branched. Reproduction is most often vegetative i.e. pieces of trichome break off and regrow. Non-sexual spores are commonly produced by akinetes which are enlarged, and darker cells in the trichome. Also common to some genera of blue-green algae are cells called heterocysts which are also enlarged but colourless and opaque. These heterocysts are able to fix nitrogen (trap nitrogen from the air, making it available for plants), which makes this group of algae agriculturally important especially where crops require very wet growth conditions (e.g. rice paddy fields). Many genera of blue-green algae are cosmopolitan (occur world-wide) and contain species which can indicate pollution (VanLandingham, 1982; Lembi, 1991). The three genera of Cyanophyta included in this guide, together with *Hydrodictyon*, *Pithophora* and *Spirogyra* in the Chlorophyta, were found to be the most abundant in a survey made by the Florida (USA) Department of Natural Resources (Lembi, 1991). *Anabaena* and *Oscillatoria* are known to produce toxins, possibly only under certain growth conditions, which are harmful to mammals and may adversely affect water supplies for humans (Toerien, 1975; N.R.A., 1990).

Anabaena **See Plate 5 b on page 32**

This blue-green algal genus has many species, only some of which are indicative of polluted water. The filaments (trichomes) are microscopic in width (4-10 µm) and may be found as single filaments floating or clumped, forming a gelatinous mass on wet soil or in the water. They are characterised by their "bead-like" appearance. Along the trichome the akinetes and heterocysts often form in adjoining cells. Large accumulations of noxious *Anabaena* species can form in nutrient-rich waters. In 1991, 1000 km of the Barwon and Darling rivers in Australia turned a foul-smelling green. This was, in the main, caused by *Anabaena* which had been stimulated by high summer temperatures, high nutrient input and a drop in the rate of river flow. This event caused a national emergency in South Australia (Creogh, 1992).

The use of copper sulphate or organic herbicides to control these blooms has not always proved successful. Unfortunately, using these algae for the prediction of water problems has limited use since very large numbers occur before the "bloom" becomes visible. Regular water sampling with counts made of the number of trichomes per litre of water could be effective. Most often cited in the literature as being a "problem" are *A. flosaquae* and *A. circinalis* - both of these species have been found in South Africa.

Oscillatoria **See Plate 5 a on page 32**

Species within this genus have been described as the most important indicators of water quality (Van Landingham, 1982). Organically polluted and stagnant waters favour growths of many species. The trichomes are solitary and, under the microscope can be observed to move slowly. There is no sheath and very often the trichomes taper at the end and there is a "cap" on the end cell known as a calyptra. As with *Anabaena*, *Oscillatoria* blooms can produce toxins which cause allergic reactions in humans and fish-kills (N.R.A., 1990).

Phormidium

Species within this genus occur within a very wide range of ecological conditions, and certain species such as *P. uncinatum* have been recorded in extremely polluted waters (VanLandingham, 1982). The individual trichomes have sheaths which are thin and difficult to see. The end cells of the trichomes often have "caps", usually slightly pointed. Species in this genus are very similar to those in *Oscillatoria*, but there is no sheath in the latter genus. In *Phormidium* these trichomes are grouped together and form a slimy mat on a rock surface in water or on damp soil. As with *Oscillatoria* there may be some slight movement of the trichomes. Entwisle (1994) and VanLandingham (1982) reported species in this genus from saline water.

Unfortunately, the similarities between species in the two genera, *Oscillatoria* and *Phormidium*, and also similarities with other blue-green algae make exact identification often difficult. Additionally, blue-green algal taxonomists (specialists who name these algae), are not in agreement and reports of problem growths may have incorrect genus names.

RHODOPHYTA (Red Algae)

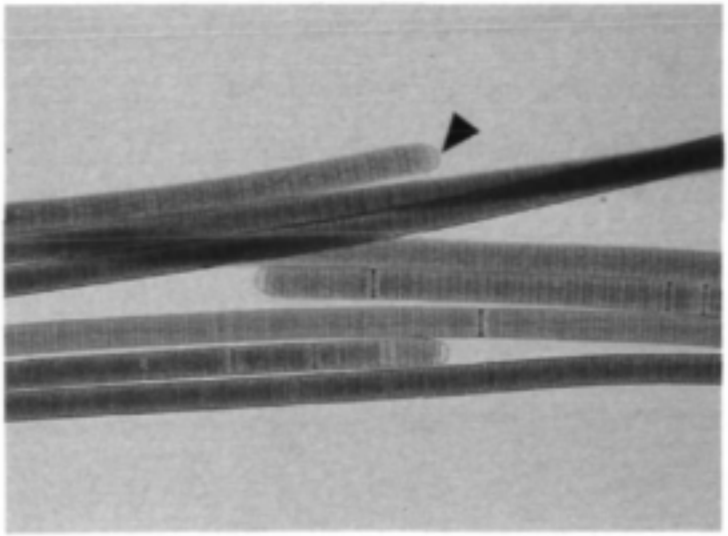
Although a large number of genera of red algae occur in the marine environment, about 3% of genera are found in fresh water (Sheath & Hambrook, 1990). Six fresh water genera have so far been recorded in South Africa. The two genera listed in this guide do not have an obvious red colour. The morphological form of these algae is usually more complex than the green algae. Chloroplasts are present, but not obviously green. This is due to masking pigments called phycoerythrin and phycocyanin. The reproductive structures are often complex and *Batrachospermum* spp. has a heteromorphic life cycle (two different morphological forms). The red algae prefer running water and apart from *Compsopogon* spp. tend to occur in water which has pH values < 7.

Batrachospermum **See Plate 5 c on page 32**

This genus has the largest number of species of all freshwater red algae (Sheath & Hambrook, 1990). The plants may or may not be visible to the naked eye and can vary from dark brown to pale greenish pink in colour. This alga tends to prefer a semi-shaded position in fairly fast-flowing water. The main thallus may be a row of single cells with alternate branching or a main filament composed of many cells around a central core. In this latter type the branches come off in whorls at regular intervals, looking almost fluffy; the reproductive cells form on these branches. The presence of this genus generally indicates good water quality where conductivity, nutrient levels and pH are low e.g. in shaded mountain streams in the south-western Cape. No "problem" growths of this genus have been recorded.

Compsopogon **See Plate 5 d on page 32**

Compsopogon coeruleus, which is found world-wide, usually in warm temperate to tropical waters, commonly occurs in South Africa. It can grow to 1 m in length and varies from pale pink, to greenish to black in colour. Branching occurs frequently and although slightly slippery to the feel it is firm. The whole main thallus and branches are formed of densely packed small cells around a central row of cells. Reproduction is asexual (sexual reproduction has never been observed). In our algal sampling to date we have found it in estuaries and rivers which have moderate to high conductivities and pH levels. Although it does not form "problem" growths its presence often indicates polluted water. Entwisle & Kraft (1984), found that in Australia, this species often formed a community with *Cladophora*, *Stigeoclonium* and *Vaucheria*.



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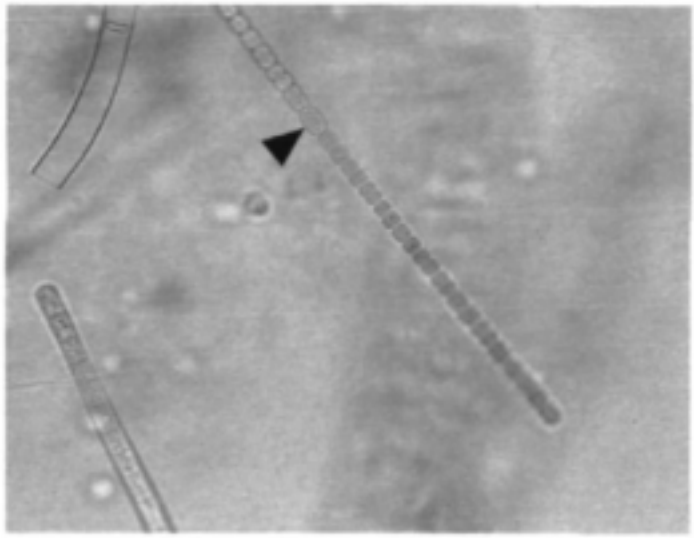

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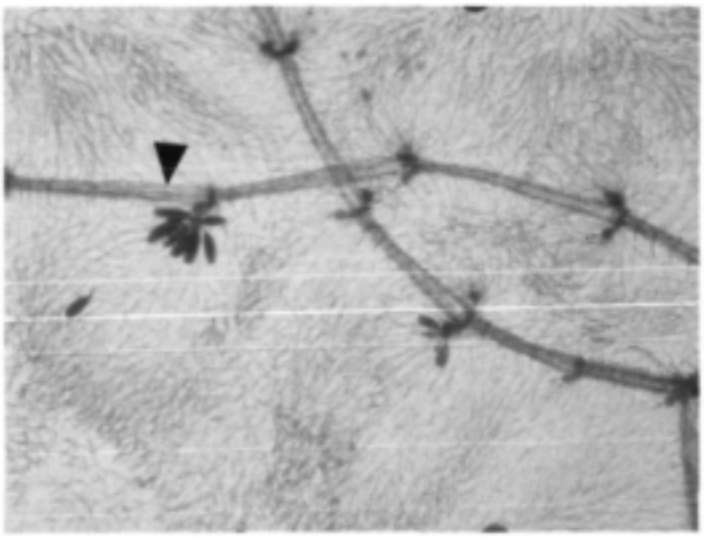

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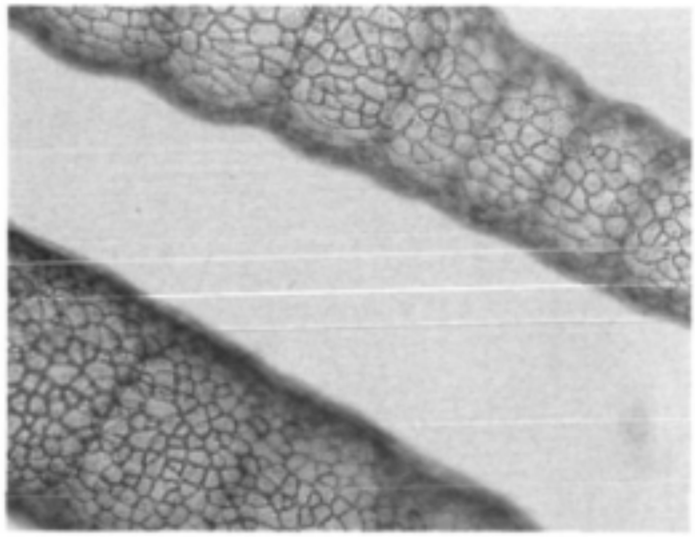

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Plate 5. a. *Oscillatoria* sp. Arrow indicates "cap".
b. *Anabaena* sp. Arrow indicates colourless heterocyst.
c. *Batrachospermum* sp. Arrow indicates cells on main filament. Cone-shaped structures are reproductive organs.
d. Close-up of main filament of *Compsopogon* sp., showing many-celled structure.

INDEX AND GLOSSARY OF ALGAL TERMS

Akinete: a thick-walled resting spore formed from a vegetative cell.
Alkaline : having a high pH.
Anabaena: a blue-green algal genus (Cyanophyta) p. 28
Apical: at the top, upper end of a filament.

Batrachospermum: genus of red algae (Rhodophyta) p. 30
Blue-green algae: used to describe algae in the Cyanophyta or Cyanobacteria.

Chara: a genus of algae (Charophyta). Common name - Stonewort. p. 10
Charophyta: algal division containing the genera, *Chara* and *Nitella*.
Chlorophyta: algal division; the green algae.
Chloroplast: a membrane bounded structure (also called a plastid) in plant cells (except the blue-green algae) which contains chlorophyll and other photosynthetic pigments.
Chrysophyta: algal division containing the golden algae e.g. *Vaucheria*, *Tribonema* and the diatoms e.g. *Melosira*..
Cladophora: genus of green algae (Chlorophyta). p. 12
Compsopogon: genus of red algae (Rhodophyta) p. 30
Conjugation: a form of sexual reproduction where two filaments are joined by a fusion tube and through which the gametes (sexual spores) pass.
Found in genera such as *Spirogyra*, *Zygnema* and *Mougeotia*.
Cortex (Corticating cells): layer of small cells surrounding a main axis as in *Batrachospermum* spp.
Culture; Culture medium: indicating growing algae in a laboratory in a solution which is made containing the basic nutrients required for growth.
Cyanophyta: algal division containing the blue-green algae. Sometimes called Cyanobacteria.

Dioecious: having separate male and female plants.

Enteromorpha: genus of green algae (Chlorophyta).
Epiphyte: living upon another plant.
Eutrophic: having relatively high levels of plant nutrients, particularly phosphorus and nitrogen.
Filament: threadlike; usually composed of a long thread of cells attached end to end.
Frustule: the silica cell wall of a diatom, made up of two overlapping halves.

Genus: group of related species. See p.1 of this guide.
Granular: as if composed of minute grains.

H- pieces: portions of cell wall in the shape of an H, overlapping where they meet.
Habit: mode of growth of a plant.
Habitat: situation in which a plant grows.

Heterocyst: an enlarged cell, usually colourless, in the filament of a blue-green alga, site of nitrogen fixation from the atmosphere.

Iodine test: application of a 10% solution of iodine in order to stain starch in cells.

Lateral conjugation: sexual reproduction where two adjoining filaments are linked by cells which send out protrusions which join and form a passageway for the cell contents. Found in members of the Zygnemataceae e.g. *Spirogyra* and *Mougeotia*.

Macroscopic: large enough to be seen with the naked eye..
Microscopic: visible only under magnification.
Monoecious: with separate male and female reproductive organs on the same plant.
***Mougeotia* spp.**: genus of green algae. p. 15

***Nitella* spp.**: genus of alga, members of the Charophyta. p. 10

***Oedogonium* spp.**: genus of green algae. p. 18
Oogonium: a single-celled female reproductive structure.
***Oscillatoria* spp.**: genus of blue-green algae. p. 29

Parietal: along the wall; following the line of the cell wall..
***Pithophora* spp.**: genus of green algae. p. 18
Planktonic: drifting or floating plants.
Polluted: having input of substances from man's activities (especially of nutrients or toxins such as heavy metals).
Pond silk: common name for *Spirogyra*.

Red algae: Rhodophyta.
Rhizoclonium: genus of green algae. p. 19
Rhizoid: root-like cell extension, often used for anchorage to substrate.
Rhodophyta: red algae.

Sheath: covering of some blue-green algal filaments, often open-ended.
Spirogyra: a genus of green algae. p. 20
Stigeoclonium: a genus of green algae. p. 20
Stoneworts: common name for Charophyta.

Tribonema: genus of Chrysophyta. p. 26
Trichome: filament of blue-green alga.

Ulothrix: a genus of green algae. p. 21

Valve: one of the two parts of diatom wall.
Vaucheria: a genus of Chrysophyta. p. 26
Vegetative: non-sexual. Often refers to normal non-reproductive cells in a filament.

Water net: common name for *Hydrodictyon* spp.
Water silk: common name for *Spirogyra*.
Whorl: branches growing from the main "stem"-like spokes on an umbrella. Many branches from one point on the filament.

Xanthophyceae: group (family) within the Chrysophyta.
Zygnema: a genus of green algae. p. 24

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