Institute of Terrestrial Ecology
NATURAL ENVIRONMENT RESEARCH COUNCIL

An illustrated guide to River Phytoplankton

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The cover shows the River Mole Near Leatherhead
(Photograph by Kenneth Scowen)

Inset are *Diatoma elongatum* (left), *Tetraëdron minimum* (right).
(Photographs by the authors)

The *Institute of Terrestrial Ecology* (*ITE*) was established in 1973, from the former Nature Conservancy's research stations and staff, joined later by the Institute of Tree Biology and the Culture Centre of Algae and Protozoa. ITE contributes to and draws upon the collective knowledge of the fourteen sister institutes which make up the *National Environment Research Council*, spanning all the environmental sciences.

The Institute studies the factors determining the structure, composition and processes of land and freshwater systems, and of individual plant and animal species. It is developing a sounder scientific basis for predicting and modelling environmental trends arising from natural or man-made change. The results of this research are available to those responsible for the protection, management and wise use of our natural resources.

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Foreword

The purpose of this guide is to enable a non-specialist to identify most of the algae occurring in the plankton of rivers. In addition it will be found helpful in identifying algae in canals, broads and lowland pools, the plankton of which contains many of the same organisms.

We hope to produce a future guide including the commoner benthic diatoms of rivers. A few of these, present frequently in the plankton during periods of high rate of flow, have been included in the present publication.

Many readers, in search of a name, will want to look at the pictures first, hence these are placed before the key and descriptions. Numbers following the names opposite the plates refer to page numbers of the descriptions.

Contents

Introduction

During the spring and summer, rivers which flow through lowland areas generally contain microscopic algae in suspension. In these regions, the addition of non-toxic substances from agricultural land and of sewage effluent from towns leads to increased algal growth, and this often causes the water to be noticeably brown or green. In several papers dealing with the ecology of small algae in British rivers, R. W. Butcher concluded that those found in suspension were there only temporarily, and they consisted almost entirely of individuals either accidentally removed from their usual habitat on the bottom or washed out of lakes or backwaters*. He was convinced that to develop a 'true' plankton, a river needed to be far larger than any in Great Britain, for example, the bigger European rivers such as the Rhine or the Volga. It is unfortunate that his views were influential in forming the opinion, widely held among ecologists, that there is no appreciable phytoplankton in British rivers.

The fact that relatively small rivers† can and do contain substantial reproducing populations of suspended algae is of importance both ecologically and from the practical aspect of human use. For the purpose of this guide we include under the word 'plankton' all those algae which can reasonably be expected to be found *fairly commonly* in suspension in rivers. In addition to those which reproduce extensively while in the stream itself, namely, the 'true' plankton, there are others, easily recognized by the experienced observer, which are normally bottom-living or attached cells swept into this situation by chance. These algae will probably sink fairly rapidly out of suspension, but while suspended it seems reasonable to consider them part of the plankton, and here they will contribute to its whole chlorophyll content and animal nutrient potential.

A knowledge of the plankton algae in rivers is becoming of increasing practical importance in view of the need to develop

* See references on page 60

† The terms 'small' and 'large' are open to considerable difference of interpretation.

and maintain adequate supplies of water of suitable quality for domestic and industrial use. Any treatment plant designed for raw river water must be able to deal with dense growths of phytoplankton. According to their size and shape, different algae have different capacities for filter-clogging, and heavy populations can be extremely troublesome. The various water transfer schemes now being carried out are likely to affect algal populations in the rivers concerned. A relatively trouble-free river might produce unexpectedly large populations of phytoplankton if suitable inocula were introduced with 'foreign' water. Problems resulting from enrichment by nitrates and phosphates derived from agricultural run-off and sewage have become commonplace. To tackle these problems it is helpful to be able to recognize the dominant forms in populations.

Plankton algae are part of the food chain or web involving the higher animals. Relatively little appears to be known in detail of the complex relationships existing, but, for the smaller invertebrates, algae are a major source of food, and such animals as *Daphnia* and a variety of rotifers are frequently seen with their guts stuffed with green cells. The young stages of some fish (e.g. perch) feed largely on diatoms and the enormous populations of freshwater mussels living in muddy river beds (as in the Thames at Reading) must take in large numbers of algae during the course of their filter feeding.

COMPOSITION OF THE PHYTOPLANKTON

The algae to be found in suspension in rivers normally reach significant numbers only during the spring and summer. In spring diatoms are predominant, the characteristic plankton species belonging mainly to the centric sub-group, when they often occur in concentrations of five million cells per litre, or more. Centric diatoms are cylindrical or discoid in shape, and typical members of this group in rivers belong to the genera *Cyclotella* and *Stephanodiscus*. The valves of these genera bear a fringe of extremely fine, long spines which can be seen with phase contrast illumination. The spines are shed when the material is 'cleaned' for detailed examination, but their presence probably enhances the high filter clogging capacity of the centric diatoms.

Pennate diatoms (the other major sub-group) seem to be much less well adapted for a planktonic existence, although a few species, especially of the genera *Nitzschia* and *Synedra,* do form appreciable populations while in suspension and are widely distributed in rivers. Members of this group are characteristically elongated and bilaterally symmetrical, and in general they are less troublesome as regards filter clogging than the centrics whose cells can build up into dense masses.

Apart from diatoms, other algae belonging to many taxonomic groups can also be abundant, with a preponderance of green ones in summer. These include motile forms like *Chlamydomonas* and non-motile examples such as *Scenedesmus.* A peculiarity of the river flora is that a usually infrequent species may suddenly have a burst of growth and become temporarily dominant.

FACTORS CONTROLLING THE GROWTH OF PHYTOPLANKTON

The development of a phytoplankton community in a river depends directly upon the physical factors of flow and turbidity, and when either or both of these is too great, no appreciable populations can be formed. Day length and temperature, particularly the former, seem also to be important, and the highest numbers of algae occur during prolonged periods of bright dry weather, when the rate of flow and silt are also at a minimum.

In most lowland rivers nitrates and phosphates, derived from agriculture and from sewage, are present in abundance for algal growth. Deficiency of silica, however, may lead to the end of vigorous populations of diatoms in spring, which are then often succeeded by a mixed plankton, mainly of green algae, throughout the summer.

NOTE ON EUTROPHY AND EUTROPHICATION

In discussions of aquatic biology the words 'eutrophic' and 'eutrophication' frequently occur, and something should be said as to their meaning. 'Eutrophy' and 'eutrophic' have been in use as medical terms since the mid-18th century to mean good (i.e. healthy) nutrition, and the promoting of good nutrition, respectively (Shorter Oxford English Dictionary, 1965). In a limnological sense 'eutrophic' was first used by

E. Naumann in 1919, when he contrasted this condition (i.e. of being rich in plant nutrients) with 'oligotrophic' (poor in nutrients). Naumann later defined the process of 'eutrophication' as an increase in nutrients, especially nitrogen and phosphorus. In recent years more or less any form of enrichment, either natural or as a result of human activity, has been described as eutrophication. This can be somewhat confusing as the meaning may be extended to overlap the non-toxic, or rather, positively beneficial-to-organisms, forms of pollution. A different but related criterion of eutrophication (appearing in the more specialized literature) takes into account the effect of nutrient enrichment upon water chemistry, bodies of water (usually lakes) being categorized as eutrophic in which regular depletion of oxygen takes place in summer.

'Eutrophic' can thus generally be taken to mean simply 'nutrient enriched' and 'eutrophication' as 'nutrient enrichment'. There seems to be no generally accepted borderline between 'eutrophication' and 'pollution'.

METHODS

The following suggestions are kept as uncomplicated as possible; more sophisticated techniques are to be found in the references.

Collection: 1 The simplest method is to use a jug and line. It is best to collect well away from the river bank, as conditions at the edge are likely to be different from those in the main stream. The jug can either be thrown from the bank or from a bridge or jetty. Polythene jugs, unless weighted, are too light, and the most satisfactory kinds are the old fashioned enamelled metal ones. With practice, it is possible to fill a jug with surface water only, and thus have roughly comparable samples from different rivers. *2* A piece of hosepipe may be used to provide a mixed water sample down to a given depth. A line is tied round one end of the pipe and this end is pushed down vertically into the water, while holding the free end of the line. At its full depth, the upper end of the pipe is closed with the hand and the lower end is pulled up. The tube then contains a column of water of its own length and diameter. A disadvantage of this method is that the operator needs to be at water level, though it is possible, but difficult, to manipulate both ends of the pipe at a distance. A hosepipe, moreover, is only practicable where the current is weak.

Examination: Living material is to be preferred, but as some algae die fairly rapidly, especially in hot weather, it is as well to fix part of the sample immediately on collection. As a general preservative, Lugol's iodine is recommended. This is a saturated aqueous solution of potassium iodide, to which is added crystalline iodine to saturate it again. From this stock solution, only a few drops are needed, enough to colour the water sample a pale brown. After a few weeks or months of storage the samples may become decolourized, when more iodine should be added.

The presence of mucilage surrounding individual cells or colonies is of taxonomic significance. It may be difficult to see, but shows up clearly on adding a little Indian ink to a liquid mount, when the particles of pigment do not penetrate the mucilage which appears as a bright halo.

As collected, a drop of water on a microscope slide may contain few organisms, and some form of concentration is indicated. The best and quickest method is to centrifuge, using 10 ml tapering tubes. A method for constructing an efficient miniature centrifuge is given by Belcher (1978).

If no centrifuge is available, the sample can be passed through a fine filter paper, washing down the sides of the funnel and thus concentrating a good proportion of the plankton into a volume of about 0.5 ml. A small drop of the concentrate is put on to a microscope slide and left to settle out for a minute or so before carefully laying on the coverslip. This prevents loss of cells to the sides and it is also helpful to examine the uncovered drop with a low power objective. This gives an immediate impression of the overall density and composition of the sample, and it draws attention especially to the larger forms which are often less conspicuous when dispersed by the pressure of the coverslip. When mounted, examination should not be too prolonged because of drying out and because some delicate flagellates die rapidly on a slide. For keeping temporary mounts for several hours, or even until the next day, an effective method is to seal the edges of the coverslip with a petroleum jelly such as

'Vaseline'. This can be heated in a small flat tin lid with a handle like a miniature frying pan, and applied molten with a paint brush.

Fixed samples may also be centrifuged, but as iodine-impregnated cells are heavy, they are easily concentrated by sedimentation (settling). The sample in its original container may simply be allowed to stand for 24 hours and the water siphoned off to leave a sediment for examination. For quantitative work, known volumes are sedimented (100 ml tubes are convenient) and a factor calculated. The least disturbance to the sediment takes place if the lower end of the glass or polythene siphon tube is bent upwards.

If algal cells have been too darkly pigmented by the iodine, they can be decolourized by a trace of sodium thiosulphate solution (or photographic fixer). In seasons of vigorous growth, there may be too many cells in the original sample to be able to count readily in the residue from 100 ml. In this case, a series of sub-dilutions is set up and a suitable concentration chosen to count.

Counting: There are two main methods. A haemacytometer of the Fuchs-Rosenthal type is suitable for the smaller more compact cells, and is especially useful for the centric diatoms. To count the larger colonial or filamentous forms an inverted microscope is invaluable. Here small sedimentation tubes are placed on the stage and the counts made directly through their glass bottoms. A counting chamber of the Lund type (Lund 1959, 1962) enables all the algae in a small volume of water to be counted. This is more accurate but considerably more time-consuming than the other methods.

In quantitative work, the problem arises of how many cells to count. For statistical respectability, about 100 cells of all sorts are considered reasonable. With exceptionally 'thin' samples one has sometimes to make do with fewer, but the smaller the number of cells counted the less comparable are different samples. The converse does not apply. Increased 'accuracy' flattens off rapidly the greater the number counted above 100, and the extra effort is seldom worth the time expended.

A word on the use of haemacytometers for counting algal cells may be appropriate. The centre of the slide bears an engraved rectangular area of given size, subdivided by intersecting lines. When a drop of liquid is mounted, the special coverslip is supported at a known height above the central area by the slightly raised 'shoulders' of the slide. A simple calculation then gives the volume of liquid contained over the grid and a conversion factor can be worked out to find the concentration of cells per ml of the original unconcentrated water.

Boney (1975) should be referred to for a helpful section on preservation, sedimentation and counting methods.

Recording: A preliminary check-list of British freshwater algae has been produced (Whitton, Holmes & Sinclair, 1978), available from the Department of the Environment Water Data Unit, Reading Bridge House, Reading. 1000 species are listed and the authors explain in the introduction that 'Each species . . . . has a unique 6-digit code for the presentation of records in a standard manner and for use in computing'. Where more than one name is in use for an alga the one chosen in this guide agrees with that in the check-list.

Unicellular green flagellates

1 *Chlamydomonas monadina* (*C. cingulata*) (p. 37) ; 18-35 µm long.

2 *Chlamydomonas pertusa* (p. 37) ; up to 25 µm long.

3 *Chlamydomonas isogama* (p. 37) ; up to 12 µm long.

4 *Haematococcus droebakensis* (p. 38) ; up to 70 µm long.

5 *Haematococcus pluvialis* (p. 38) ; up to 65 µm long, *a, b* show individual variation in shape.

6 *Mesostigma viride* (p. 38) ; up to 18 µm long, *a* anterior view ; *b* side view.

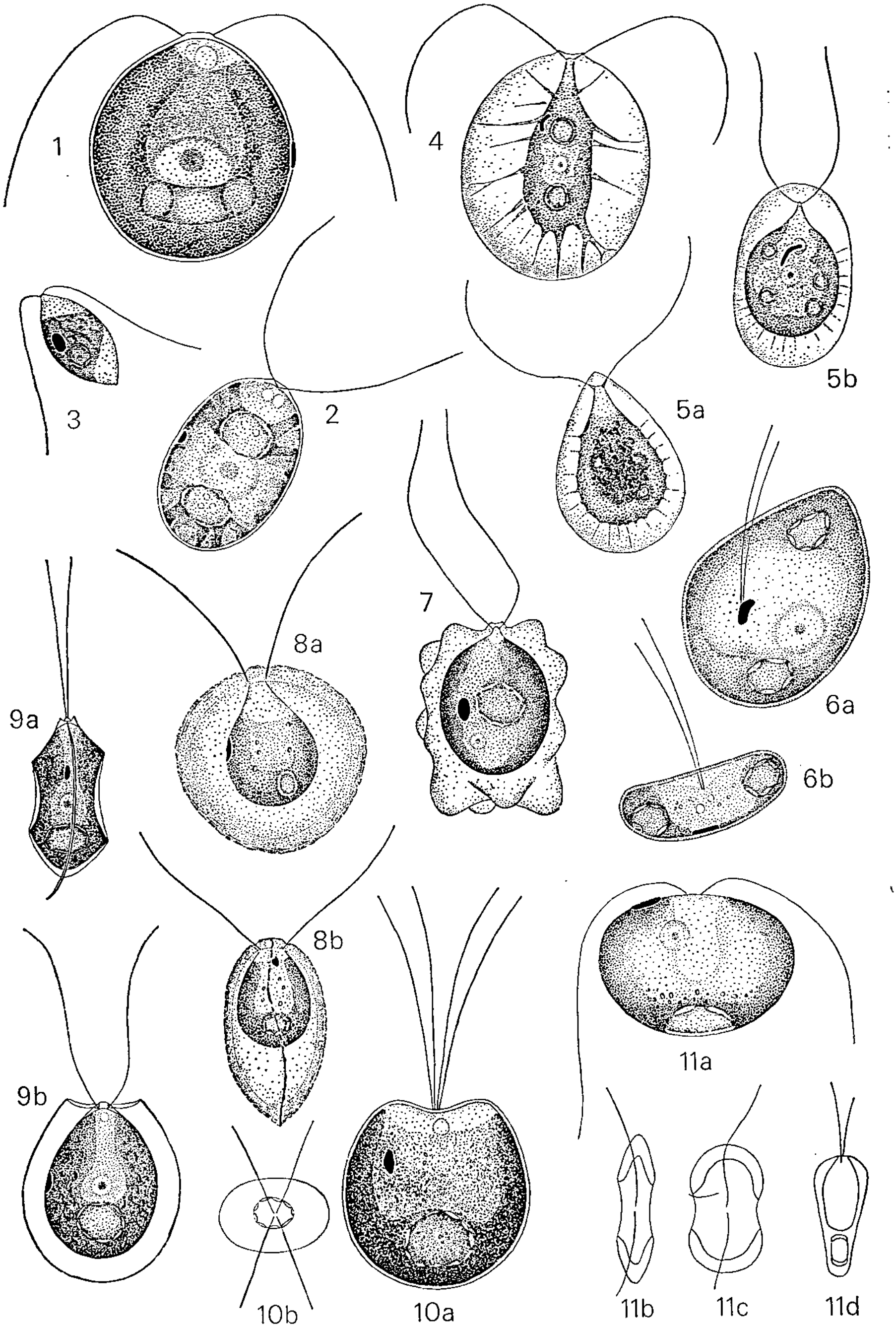
7 *Lobomonas ampla* (p. 38) ; up to 40 µm long.

8 *Phacotus lenticularis* (p. 38) ; up to 20 µm in diameter, *a, b* side views at right angles to each other.

9 *Pteromonas angulosa* (p. 38) ; up to 20 µm long, *a, b* side views at right angles to each other.

10 *Platymonas cordiformis* (*Tetraselmis cordiformis*) (p. 38) ; up to 25 µm long, *a* side view ; *b* diagram of anterior view.

11 *Nephroselmis angulata* (*Heteromastix angulata*) ; (p. 39) up to 15 µm long, *a* side view ; *b, c* cells of two different widths (anterior view) ; *d* side view at right angles to *a*.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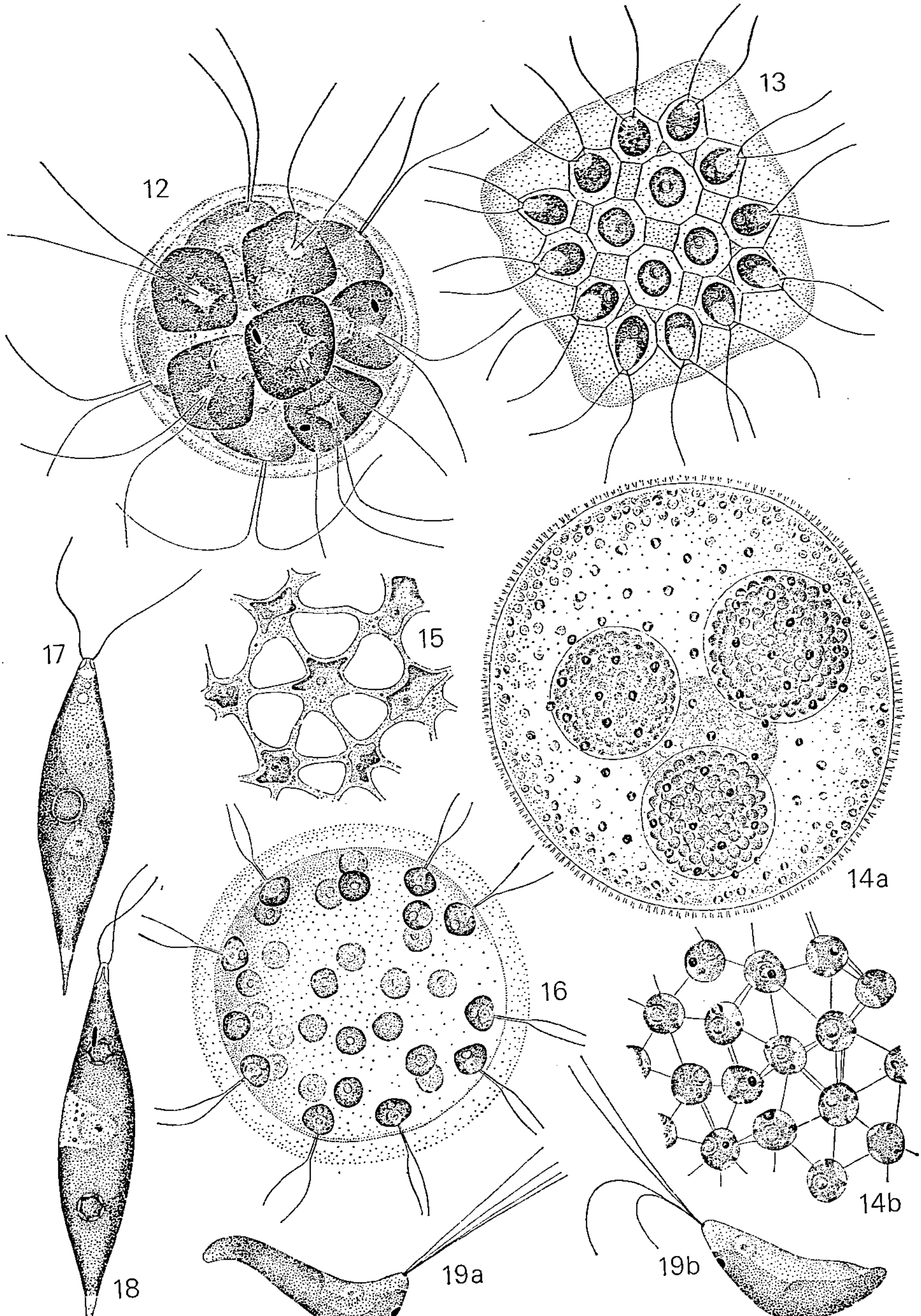
Unicellular green flagellates (cont.) and Colonial green flagellates

12 *Pandorina morum* (p. 39) ; colonies up to 50 µm in diameter.
13 *Gonium pectorale* (p. 39) ; colonies up to 100 µm across.
14 *Volvox aureus* (p. 39) ; colonies up to 500 µm in diameter, *a* colony with daughter colonies ; *b* part of surface of colony to show cells joined by protoplasmic connexions.
15 *Volvox globator* (p. 39) ; colonies up to 600 µm across, details of cells to show differences from those of *V. aureus.*
16 *Eudorina elegans* (p. 39) ; colonies up to 200 µm in diameter.
17 *Chlorogonium tetragamum* (p. 37) ; up to 33 µm long, single pyrenoid.
18 *Chlorogonium elongatum* (p. 37) ; up to 45 µm long, two pyrenoids.
19 *Spermatozopsis exsultans* (p. 39) ; up to 12 µm long, *a, b* two individuals differing slightly in shape.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19b

Colonial green flagellates (cont.)

20 *Gonium sociale* (p. 39) ; colonies up to 50 µm across, lateral view showing remains of mother cell wall attached below, a character of the var. *sacculum* (*Basichlamys sacculifera*) ; *b* anterior view.

21 *Pascherina tetras* (p. 39) ; colonies up to 25 µm long.

Green non-motile unicells

22 *Ankistrodesmus angustus* (*A. contortus; A. falcatus* var. *spirilliformis; Monoraphidium contortum*) (p. 40) ; three cells, length up to 35 µm.

23 *Ankistrodesmus subcapitatus* (p. 41) ; cells up to 18 µm long (up to 9 µm across 'ring'), group of five cells, one showing cross walls prior to division.

24 *Ankistrodesmus gracilis* (*Selenastrum gracile*) (p. 40) ; up to 40 µm long.

25 *Tetraëdron incus* (p. 46) ; up to 30 µm across, *a* older and *b* younger cells to show differences in shape.

26 *Tetraëdron caudatum* (p. 46) ; up to 25 µm across, *a* older and *b* younger cells showing differences in shape.

27 *Tetraëdron minimum* (p. 46) ; up to 20 µm across.

28 Unicellular stages of a species of *Scenedesmus*, resembling *Chodatella subsalsa* (p. 42) ; up to 10 µm long.

29 *Goniochloris mutica* (N.B. Xanthophyceae) (p. 47) ; up to 10 µm across.

30 *Trachychloron circulare* (Xanthophyceae) (p. 47) ; up to 10 µm in diameter, *a* face view ; *b* edge view.

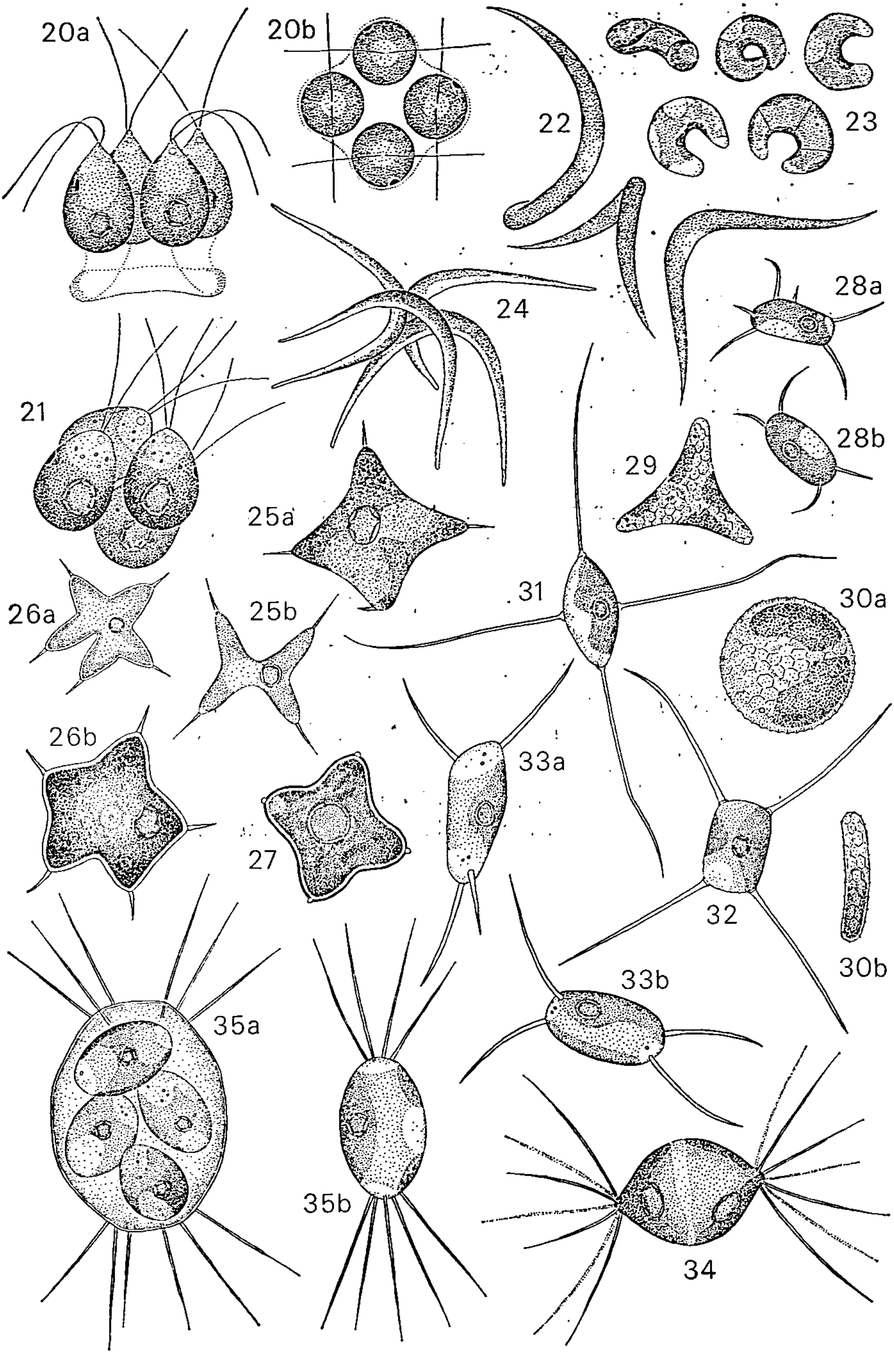
31 *Lagerheimia wratislaviensis* (p. 41) ; up to 14 µm long (excluding spines).

32 *Lagerheimia genevensis* (p. 41) ; up to 10 µm long (excluding spines).

33 *Chodatella quadriseta* (p. 42) ; up to 15 µm long, *a, b* two cells showing variation in shape. (N.B. see comments on unicellular *Scenedesmus* stages, p. 42).

34 *Chodatella citriformis* (p. 41) ; up to 25 µm long (excluding spines).

35 *Chodatella ciliata* (p. 41) ; up to 25 µm long (excluding spines), *a* mother cell with young cells which have not yet grown their spines ; *b* vegetative cell.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35b
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Unicellular (mostly) non-motile green unicells (cont.)

36 *Didymogenes palatina* (p. 42) ; up to 8 µm long, *a*, *b* two pairs of cells.

37 *Scenedesmus grahneisii* (*Didymocystis inconspicua* (p. 45) ; up to 8 µm long.

38 *Polyedriopsis spinulosa* (p. 44) ; up to 20 µm across (excluding spines).

39 *Chlorella vulgaris* (p. 41) ; 2-10 µm, *a* young cells ; *b* four daughter cells within mother cell wall.

40 *Siderocelis ornata* (p. 45) ; up to 15 µm long, *a* young cell ; younger and older cells.

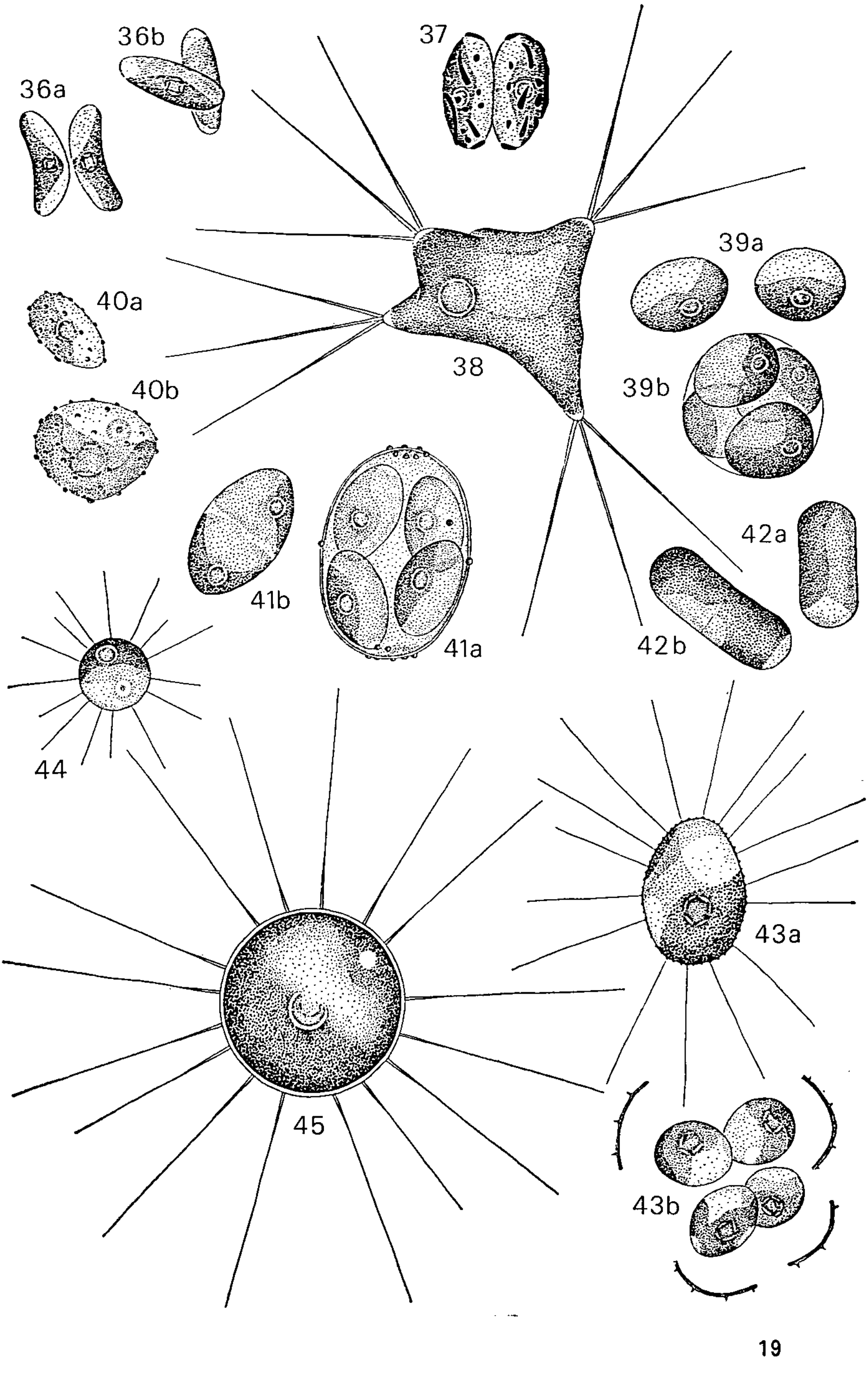
41 *Oocystis pseudocoronata* (p. 44) ; up to 15 µm long, *a* daughter cells inside mother cell wall ; *b* young cell which could belong to a number of unornamented species.

42 *Stichococcus bacillaris* (p. 45) ; up to 4 µm wide, *a* single cell ; *b* dividing cell—the daughter cells often remained joined for some time to form short filaments.

43 *Siderocystopsis fusca* (p. 45) ; up to 20 µm long, *a*, *b* *b* newly released daughter cells lying within remains of mother cell wall.

44 *Golenkiniopsis parvula* (p. 43) ; about 6 µm in diameter.

45 *Golenkinia radiata* (p. 43) ; up to 18 µm in diameter.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43b
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Elongated non-motile green unicells

46 *Ankistrodesmus acicularis* (*Monoraphidium aciculare*) (p. 40); up to 200 µm long, *a* dividing cell; *b* bundle of young cells; *c* vegetative cell.

47 *Koliella longiseta* (*Raphidonema longiseta*) (p. 43); up to 150 µm long, *a, b* vegetative cells; *c* cells about to divide; *d* young cell before elongation.

48 *Ankistrodesmus fusiformis* (p. 40); up to 100 µm long, *a* group of cells in characteristic arrangement; *b* single cell enlarged.

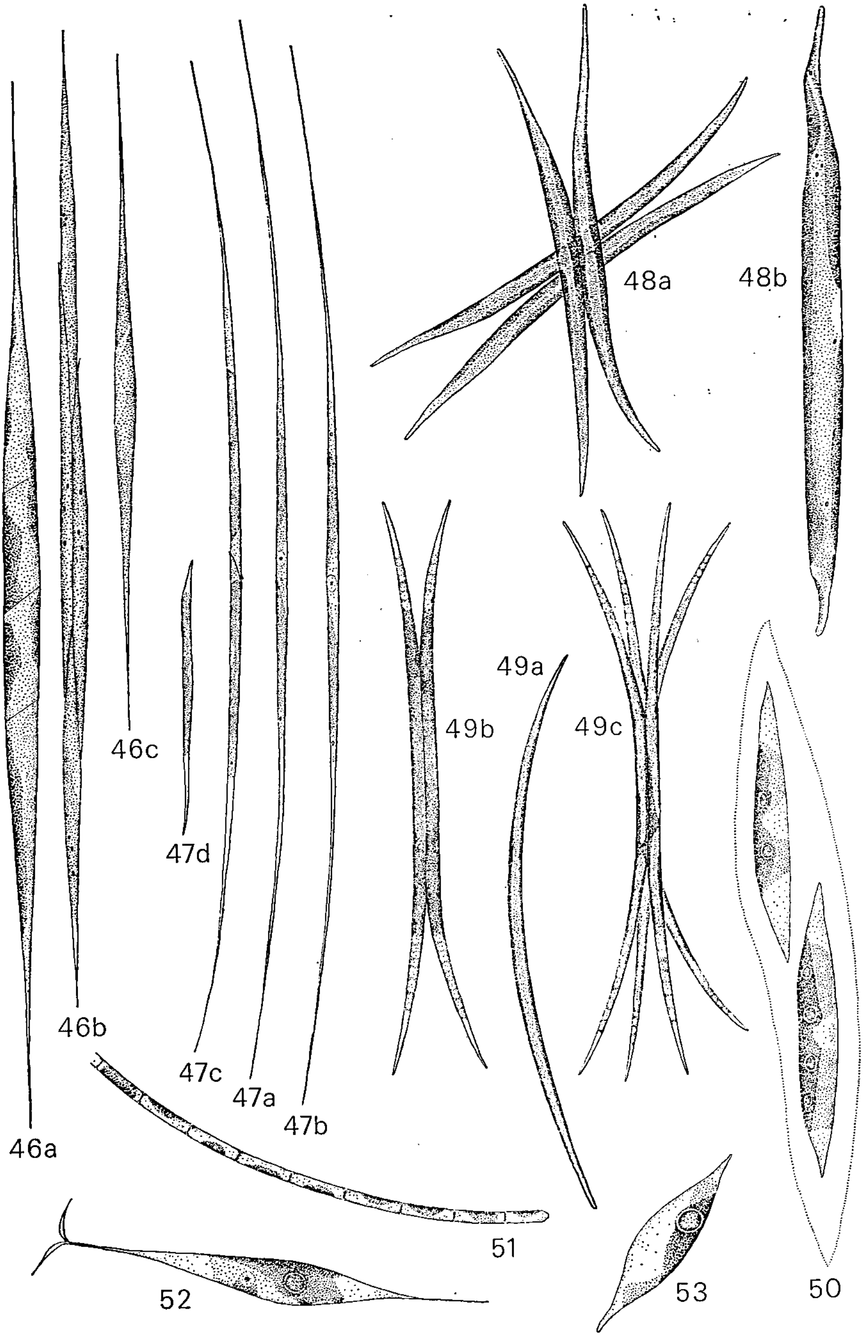
49 *Ankistrodesmus falcatus* (p. 40); up to 80 µm long, *a* single cell; *b, c* two-celled and four-celled bundles.

50 *Elakatothrix gelatinosa* (p. 43); up to 30 µm long, usually two cells in mucilage envelope.

51 *Gloeotila pelagica* (p. 43); filament about 2 µm wide.

52 *Ankyra judayi* (p. 41); up to 100 µm long.

53 *Scenedesmus acuminatus* (p. 44); unicellular stage, up to 30 µm long.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49b
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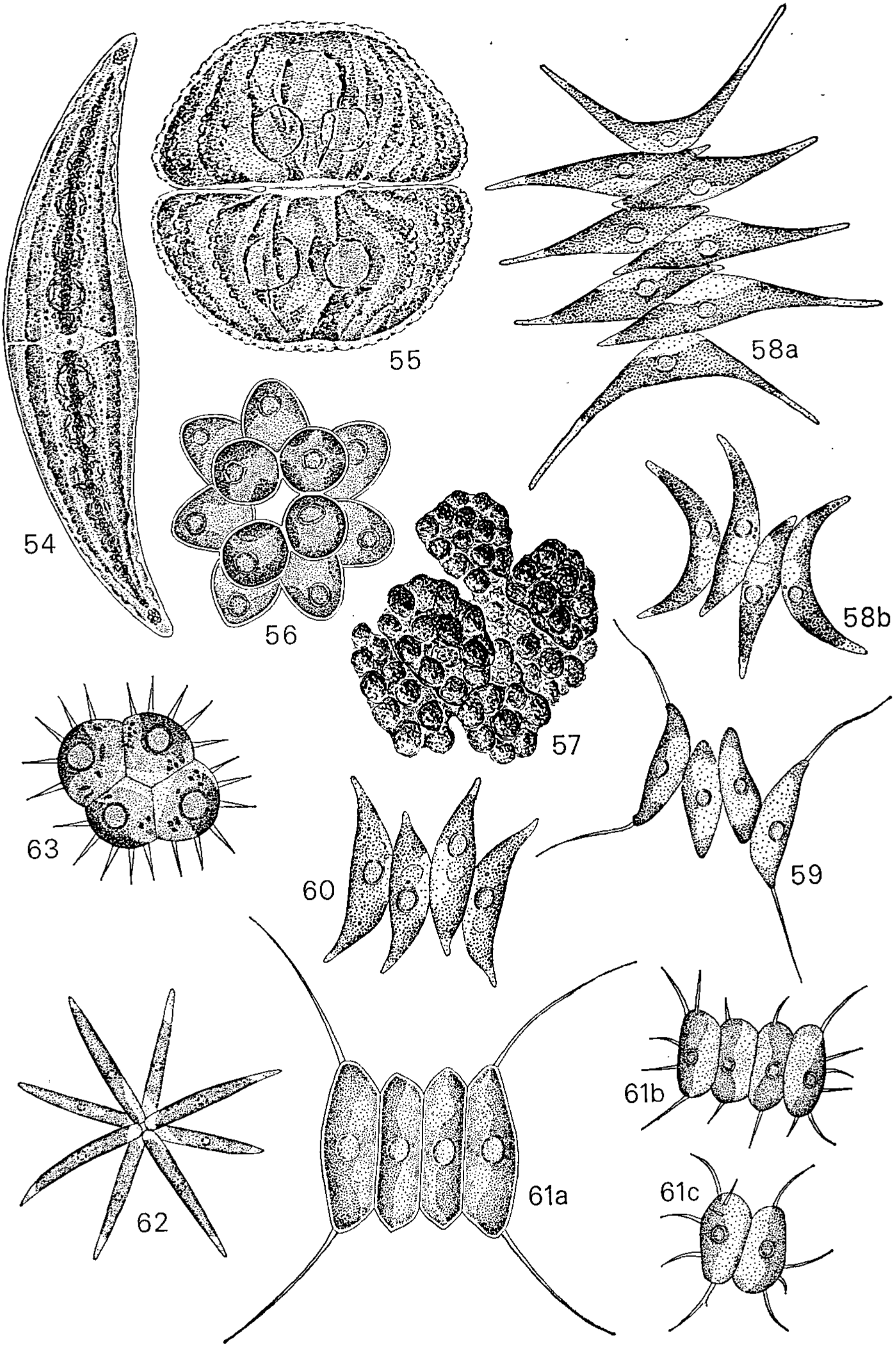
(mostly) Non-motile green colonies

54 *Closterium moniliferum* (p. 46) ; up to 400 μm long.
55 *Cosmarium botrytis* (p. 47) ; up to 90 μm long.
56 *Coelastrum microporum* (p. 42) ; cells up to 10 μm, colonies up to 60 μm across.
57 *Botryococcus braunii* (p. 41) ; cells up to 10 μm long, colonies variable in shape and size, up to 1 mm across. Colour green to reddish brown.
58 *Scenedesmus acuminatus* (p. 44) ; cells up to 30 μm long, *a* eight-celled colony ; *b* four-celled colony. Shape of cells variable.
59 *Scenedesmus protruberans* (p. 45) ; cells up to 30 μm long.
60 *Scenedesmus obliquus* (*S. acutus*) (p. 44) ; cells up to 20 μm long.
61 *Scenedesmus quadricauda* (p. 45) ; cells up to 25 μm long, *a* 'typical' four-celled colony ; *b, c* '*Chodatella*' stages.
62 *Actinastrum hantzschii* (p. 40) ; cells up to 25 μm long.
63 *Tetrastrum staurogeniaeforme* (p. 46) ; cells up to about 6 μm.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61b
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Non-motile green colonies

64 *Dictyosphaerium pulchellum* (p. 42) ; cells up to 10 μm across.

65 *Micractinium pusillum* (p. 43) ; cells up to 10 μm across.

66 *Crucigenia tetrapedia* (p. 42) ; each cell of four-celled packet up to 8 μm across.

67 *Crucigenia fenestrata* (p. 42) ; individual cells up to 8 μm across, *a* older colony dividing ; *b* young colony.

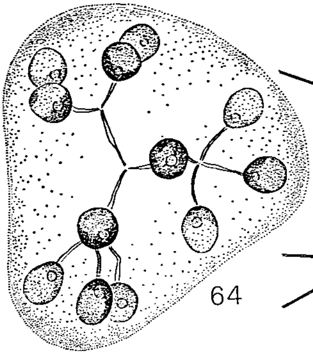
68 *Crucigenia apiculata* (p. 42) ; cells up to 8 μm long.

69 *Crucigenia rectangularis* (p. 42) ; cells up to 8 μm long.

70 *Pediastrum boryanum* (p. 44) ; colonies up to 200 μm in diameter.

71 *Pediastrum duplex* (p. 44) ; colonies up to 200 μm in diameter.

72 *Pediastrum tetras* (p. 44) ; colonies up to 30 μm across, *a* eight-celled colony ; *b* four-celled colony.



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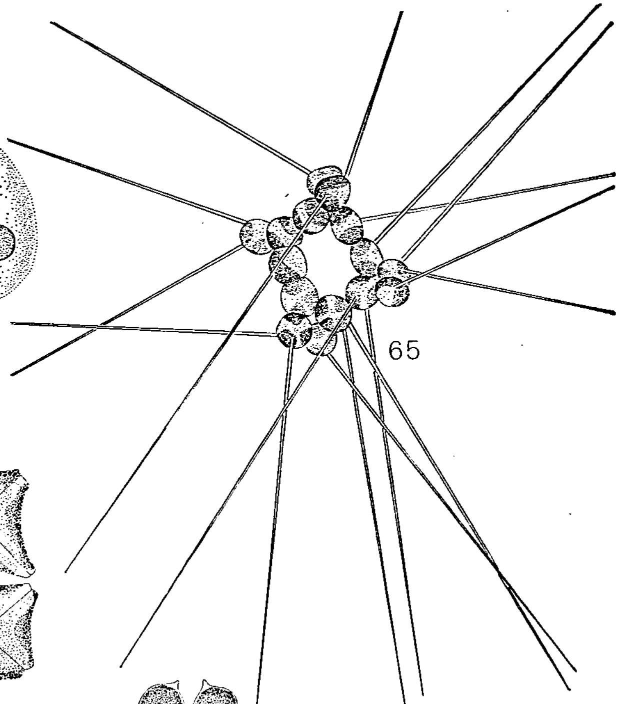

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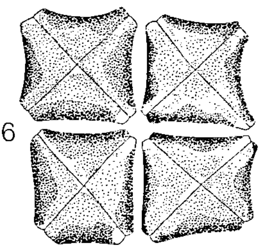

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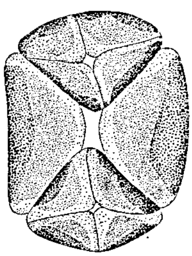

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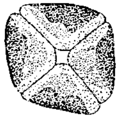

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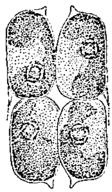

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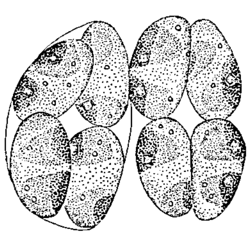

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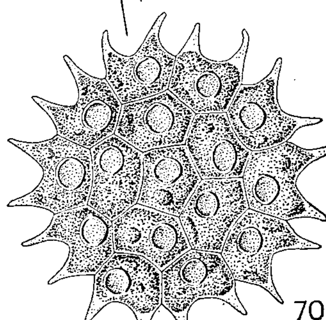

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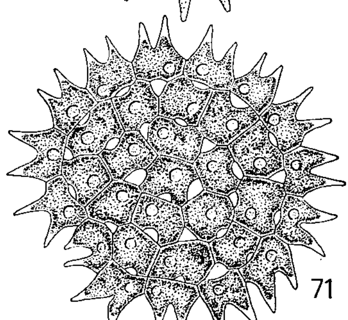

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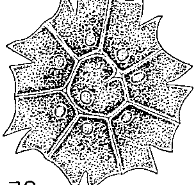

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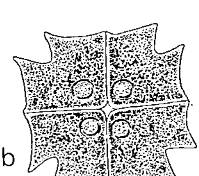
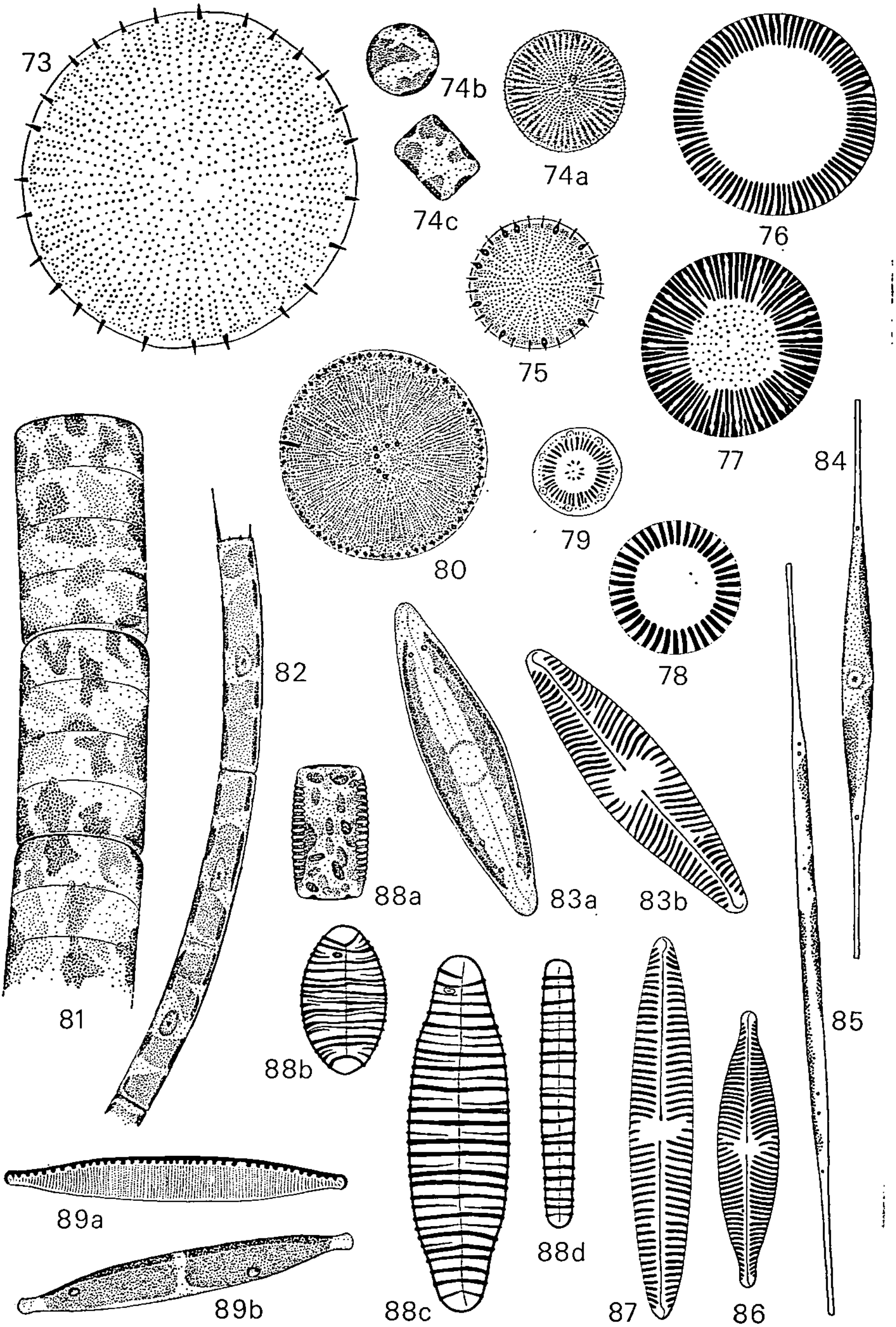


72b

Diatoms

73 *Stephanodiscus astraea* (p. 48) ; valves up to 70 µm in diameter.
74 *Stephanodiscus invisitatus* (p. 48) ; valves up to 20 µm in diameter, *a* cleaned valve ; *b, c* living cells.
75 *Stephanodiscus tenuis* (p. 48) ; valves up to 30 µm in diameter.
76 *Cyclotella kuetzingiana* (p. 49) ; valves up to 45 µm in diameter.
77 *Cyclotella comta* (p. 49) ; valves up to 30 µm in diameter.
78 *Cyclotella meneghiniana* (p. 49) ; valves up to 30 µm in diameter.
79 *Cyclotella pseudostelligera* (p. 49) ; valves up to 10 µm in diameter.
80 *Thalassiosira fluviatilis* (p. 49) ; valves up to 25 µm in diameter.
81 *Melosira varians* (p. 50) ; cells up to 30 µm wide. Part of living filament.
82 *Melosira granulata* (p. 50) ; cells 5-20 µm wide. Part of living filament.
83 *Navicula viridula* (p. 51) ; up to 80 µm long, *a* living cell ; *b* cleaned valve.
84 *Nitzschia acicularis* (p. 51) ; up to 150 µm long. Living cell.
85 *Synedra acus* (p. 51) ; up to 300 µm long. Living cell.
86 *Navicula cryptocephala* (p. 51) ; valves up to 40 µm long.
87 *Navicula gracilis* (p. 51) ; up to 60 µm long.
88 *Diatoma vulgare* (p. 50) ; 10-60 µm long, *a* living cell, girdle view ; *b, c, d* valve views to show differences in shape and size.
89 *Nitzschia palea* (p. 52) ; up to 65 µm long, *a* cleaned valve ; *b* living cell.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Diatoms (cont.); Chrysophyceae

90 *Nitzchia sigmoidea* (p. 52) ; up to 500 μm long. Living cell.

91 *Asterionella formosa* (p. 50) ; individual cells of colony up to 130 μm long. Living colony.

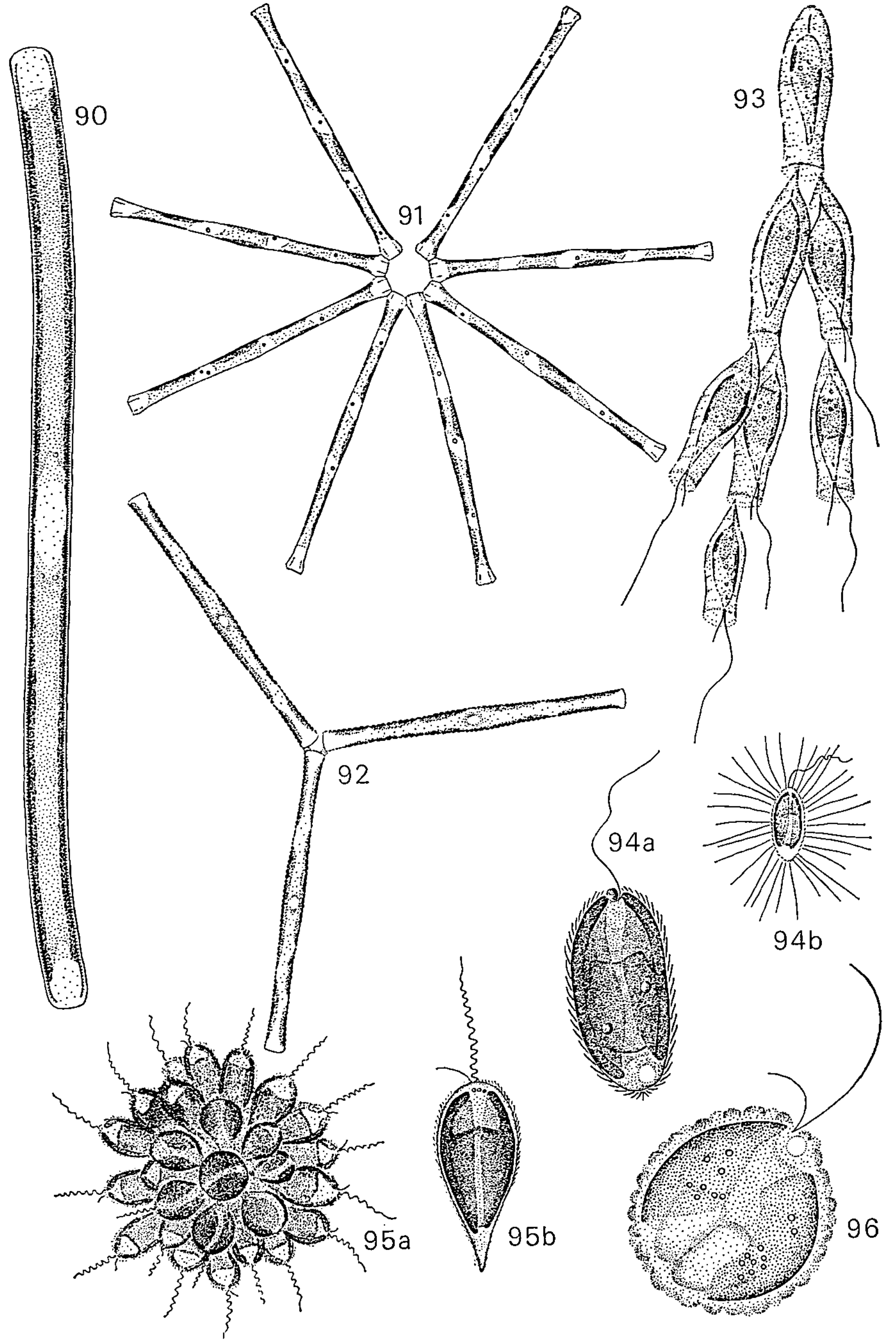
92 *Diatoma elongatum* (p. 50) ; individual cells up to 120 μm long. Living 3-celled colony.

93 *Dinobryon sertularia* (p. 52) ; 'flasks' 30-100 μm long. Living colony.

94 *Mallomonas* spp. (p. 52) ; cells 5-50 μm long, *a* cell of species with scales but no spines ; *b* cell with both scales and spines.

95 *Synura petersenii* (p. 53) ; colonies up to 500 μm in diameter, *a* whole colony ; *b* individual cell, 20-40 μm long.

96 *Ochromonas tuberculatus* (p. 53) ; up to 20 μm long.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Miscellaneous

97 *Cryptomonas* sp. (p. 53) ; in the genus cells range from 10-80 µm in length.

98 *Chroomonas* sp. (p. 54) ; small cells not more than about 10 µm long.

99 *Rhodomonas lacustris* var. *nannoplanktica* (*R. minuta* v. *nannoplanktica*) (p. 54) ; up to 10 µm long.

100 *Trachelomonas volvocinopsis* (p. 55) ; up to 25 µm in diameter, *a* living cell in optical section, *b* diagram of exterior of 'pot' (lorica).

101 *Euglena viridis* (p. 55) ; up to 75 µm long.

102 *Peridinium* sp. (p. 54) ; large species are up to 70 µm long.

103 *Phacus pleuronectes* (p. 55) ; up to 80 µm long.

104 *Microcystis aeruginosa* (p. 55) ; cells 3-9 µm across, colonies variable in shape and up to macroscopic size.

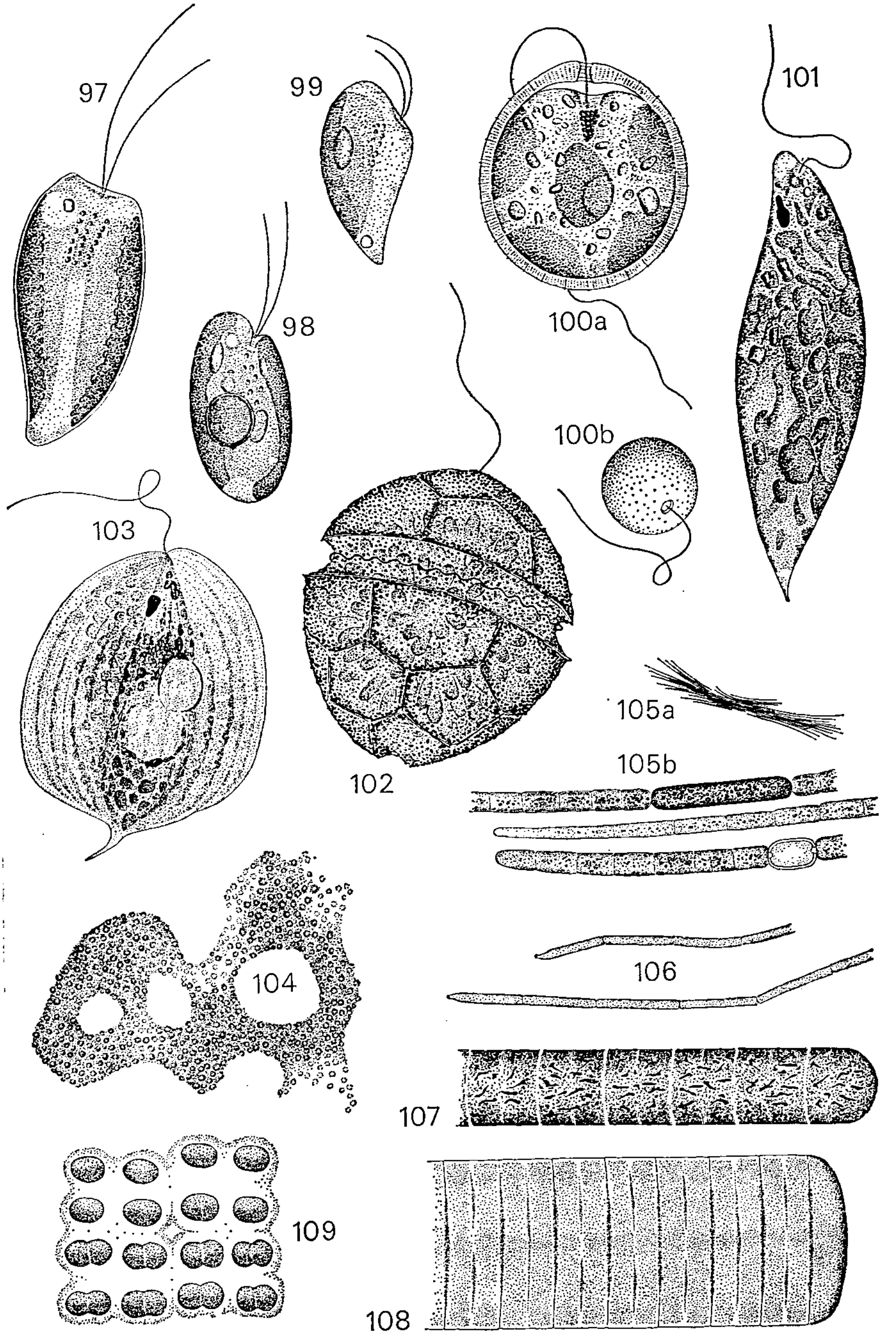
105 *Aphanizomenon flos-aquae* (p. 56) ; *a* bundle of filaments, each up to 6 µm wide, bundles may reach macroscopic size ; *b* cells of filaments showing spore (upper), end of filament (middle) and heterocyst (lower).

106 *Oscillatoria limnetica* (p. 56) ; filaments about 1.5 µm wide.

107 *Oscillatoria agardhii* (p. 56) ; filaments approx. 7 µm wide.

108 *Oscillatoria limosa* (p. 56) ; filaments about 15 µm wide.

109 *Merismopedia glauca* (p. 56) ; each cell of 'packet' about 4 µm across.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Key to genera

CELLS SWIM (WITH FLAGELLA)	Section
Unicellular	A
Colonial	B
CELLS DO NOT SWIM (NO FLAGELLA, BUT MAY CREEP)	
Unicellular	
Green elongated	C
Green 'chunky'	D
Yellow or brown	E
Colonial	
Green	F
Brown or other colour	G
Filamentous	H

Section A : single motile cells

Cell with wide envelope enclosing a smaller protoplast

- Envelope ± thick and strong, pale yellow to brown or black
  - Envelope spherical or flask-shaped, smooth or ornamented, one flagellum . . . . . *Trachelomonas*
  - Envelope lenticular, patterned, two flagella . . . . . . *Phacotus*
- Envelope thin and delicate, two flagella
  - Outline lobed . . . . . *Lobomonas*
  - Outline smoothly oval, not winged . *Haematococcus*
  - With longitudinal wings, side view flattened . . . . . . *Pteromonas*

Cell without wide envelope, wall fits closely

- Chloroplast brownish or yellowish
  - Cells drop- or heart-shaped . . *Cryptomonas*
  - Cells lemon- or egg-shaped, sometimes with long 'tail', often having hairy appearance due to covering of scales or spines . . . . *Mallomonas* single *Synura* cells

- Cells armour-plated, helmet-like, often "large" . . . . . *Peridinium*
- Cells irregularly rounded, fragile, chloroplast often pale . . . *Ochromonas*

Chloroplast bright blue, drop-shaped . *Chroomonas*

Chloroplast green

- Cells spherical to elongated, not flattened
  - Cells spherical or oval, two flagella *Chlamydomonas*
  - Cells broadly spindle-shaped, can change shape, one flagellum . *Euglena*
  - Cells narrowly spindle-shaped, rigid, two flagella . . . . *Chlorogonium*
  - Cells banana-shaped, two or four flagella, swim in spirals . . *Spermatozopsis*
- Cells flattened
  - Cells oval, four flagella from anterior depression . . . *Platymonas*
  - Cells bean-shaped, two flagella, swims sideways . . . . *Nephroselmis*
  - Cells shaped like rubber dinghy, two flagella arise from middle . *Mesostigma*

Purple cells, sausage-, cigar- or screw-shaped (not illustrated) . . Purple sulphur bacteria

Section B : motile colonies

Cells brownish or yellowish

- Cells densely packed into spherical or somewhat elongated colonies . . . *Synura*
- Cells in flask-like envelopes, colony branching . . . . . . *Dinobryon*

Cells green

- Colony flat, four or sixteen cells . *Gonium*
- Colony ± spherical
  - Four cells in a small bunch . . *Pascherina*
  - Sixteen, thirty-two or sixty-four cells
    - Cells closely packed so that centre of colony ± solid . . . *Pandorina*
    - Cells loosely packed round outside of hollow sphere . . . . *Eudorina*
  - Hundreds of cells forming hollow sphere . . . . . . *Volvox*

Section C : non-motile elongated green unicells

Cells straight
  Cells single or in pairs, with wide mucilaginous coating . . . *Elakatothrix*
  Cells without wide mucilage coat
    Spindle-shaped with processes at one end like feet or handlebars . *Ankyra*
    Needle-shaped, extremely long and thin . . . . . *Ankistrodesmus*
    Raphidonema

Cells curved
  Cells very large, with several pyrenoids *Closterium*
  Cells smaller, slender, single or in bunches, usually no pyrenoids . . *Ankistrodesmus*
  Selenastrum

Section D : non-motile 'chunky' green unicells

With spines
  Six spines or less
    Spines short, cells four or five-angled *Tetraëdron*
    Spines long, cells ellipsoidal . . *Lagerheimia*
    Chodatella
    Scenedesmus (single cells)

  More than six spines
    Spines in tufts at angles of irregular cell . . . . . *Polyedriopsis*
    Spines at each end of ellipsoidal cell *Chodatella*
    Spines delicate, over whole surface of ellipsoidal cell . . . *Siderocystopsis*
    Spines scattered over surface of spherical cell . . . . *Golenkinia*
    Golenkiniopsis

Without spines
  Cells flattened
    Cells of two identical halves, with 'waist', often large . . . *Cosmarium*
    Cells triangular . . . . *Goniochloris*
    Cells four or five-angled . . *Tetraëdron*
    Cells round, discoid . . . *Trachychloron*

Cells not flattened

Wall with brown spots or dots . *Siderocelis* *Siderocystopsis* *Oocystis*

Wall without brown spots or dots

Cells cylindrical, sometimes loose filaments of two or three cells . *Stichococcus*

Cells spherical or ovoid . . *Chlorella*

Cells ellipsoidal, lemon- or barrel-shaped . . . . *Oocystis*

Cells crescent-shaped . . *Ankistrodesmus*

Cells short, spindle-shaped . *Scenedesmus* (single cells)

Section E : non-motile yellow or brown unicells

Cells cylindrical or disc-shaped, rectangular in side view . . . . *Cyclotella* *Stephanodiscus* *Thalassiosira*

Cells long and narrow

Two chloroplasts, arranged fore and aft, plant can creep . . . *Nitzschia*

Several chloroplasts, not arranged as above, plant cannot creep . . *Synedra*

Cells like flat-bottomed boats, narrowly rectangular in side view

Two chloroplasts, arranged longitudinally, side by side . . . . *Navicula*

Two chloroplasts, arranged fore and aft *Nitzschia*

A number of chloroplasts, not arranged as above, wall with heavy transverse ridges going right across . . *Diatoma*

Section F : green non-motile colonies

Flat plate of two, four or eight elongated parallel cells . . . . *Scenedesmus* *Didymogenes*

Flat plate of cells in foursquare or radial pattern . . . . . *Crucigenia* *Tetrastrum* *Pediastrum*

Colonies of shapes other than flat

Cells in irregular solid mass . . *Botryococcus*

Cells closely packed into a ball . . *Coelastrum*

Cells more loosely held together

Cells attached distantly by narrow strands of mucilage, like balloons on strings . . . . . . *Dictyosphaerium*

Cells spherical, attached side by side in irregular ring or square, or in smaller groupings, with long thick spines . . . . . . *Micractinium*

Cells elongated, attached to centre of colony by one end and radiating outwards . . . . *Actinastrum*

Section G : non-motile colonies, not green

Cells blue-green or blackish green .

Colony irregular in shape, often large, many small spherical cells . . *Microcystis*

Colony a small flat plate, with spherical pale blue-green cells in rows . . *Merismopedia*

Colony of small filaments in tufted bundles . . . . . . *Aphanizomenon*

Cells or colony brownish

Colony a dense irregular mass of green cells often masked by brown pigment . *Botryococcus*

Colony of long narrow cells arranged in stars or zig-zags . . . *Asterionella*, *Diatoma*

Section H : planktonic filaments

Short filaments of a few cells loosely joined together

Cells green, c. 4 µm wide . . . *Stichococcus*

Cells yellow-brown . . . *Stephanodiscus*, *Cyclotella*, *Thalassiosira*

Filament of cells firmly fastened together

Cells banded with green, about 2 µm across . . . . . . *Gloeotila*

Cells yellow-brown, sometimes with spikes at ends . . . . *Melosira*

Cells blue-green, blackish, purple, greyish or pale, not green or brown . *Oscillatoria*, *Aphanizomenon*

Descriptions of species illustrated

(Numbers in brackets refer to illustrations)

Class Chlorophyceae

These, the green algae, have bright green chloroplasts, but among them is a great variety of form and organization. Planktonic genera range from the apparently simple *Chlorella* to the elaborate colonies of *Volvox.* More freshwater algae belong to the Chlorophyceae than to any other group.

ORDER VOLVOCALES

Flagellated forms, unicellular or colonial. For simplicity we include here four genera, *Platymonas, Nephroselmis, Mesostigma* and *Spermatozopsis,* which since the advent of electron microscopy are now generally held to belong to a separate group of green flagellates, the Prasinophyceae.

Chlamydomonas (1-3) Spherical, ovoid or elongated cells with a smooth close-fitting wall and two equal flagella. Chloroplasts and pyrenoids variable. A vast genus, difficult to identify. The three species illustrated are common in rivers and have well-marked characteristics.

C. monadina Stein (1) (*C. cingulata* Pascher) Spherical, 18-35 µm diameter, with a cup-shaped chloroplast and a pyrenoid which may be a flattened sphere, a doughnut-like ring, or in two or three separate pieces. This species is often dominant or semi-dominant in a plankton population.

C. pertusa Chodat (2) Ovoid cells up to 25 µm long, with two pyrenoids placed fore and aft, each enclosed in a stellate chloroplast.

C. isogama Korshikov (3) Small fusiform cells up to 12 µm long, with a lateral chloroplast and single pyrenoid.

Chlorogonium (17, 18) Green fusiform cells with two equal flagella. Two species are common in rivers.

C. tetragamum Bohlin (17) Up to 33 µm long, with one central conspicuous pyrenoid.

C. elongatum Dangeard (18) Up to 45 µm long, with two pyrenoids, one anterior and one posterior.

Haematococcus (4, 5) The characteristic wide gap between the outer wall and the central chloroplast is crossed by readily visible fine strands of protoplasm. Two equal flagella.

Two species found in rivers (also, more often, in standing water).

H. pluvialis Flotow em. Wille (5a, *b*) Up to 65 µm long and has several pyrenoids, but these and the green pigment often masked by an accumulation of red oil. Frequent in rivers. Also responsible for the red colouration common in bird baths and small water bodies.

H. droebakensis Wollenweber (4) A striking object, up to 70 µm long, with only two pyrenoids and more conspicuous, branching protoplasmic strands than in *H. pluvialis.* Occasional in British rivers, but in Central Europe has given much trouble, dense growths causing problems of smell in water supplies.

Lobomonas (7) *Chlamydomonas*-type cells, but with a wide transparent envelope whose surface is thrown into lobes.

L. ampla Pascher (7) Up to 40 µm long, occasional in rivers.

Mesostigma (6) (Prasinophyceae) Small flagellates, flattened and shaped like a rubber dinghy, the chloroplast forming a green rim, with a red eye spot in the centre and a pyrenoid at each end. The two flagella stand up from the centre. The cells have a characteristic appearance when swimming.

M. viride Lauterborn (6*a, b*) Up to 18 µm long. This is the the only British species.

Phacotus (8) Cells like those of *Chlamydomonas,* but enclosed in a wall resembling two shallow dishes placed together. Wall sometimes thin and transparent, but usually thick and sculptured.

P. lenticularis (Ehrenb.) Stein (8*a, b*) Up to 20 µm in diameter. Sometimes frequent.

Platymonas (10) (Prasinophyceae) Flattened green heart-shaped cells with four flagella and a basal pyrenoid.

P. cordiformis (N. Carter) Korshikov (10*a, b*) Up to 25 µm long and often found in rivers.

Pteromonas (9) Cells like those of *Chlamydomonas* but flattened, with a wing on either side like an elm fruit.

P. angulosa (Carter) Lemmermann (9*a, b*) Up to 20 µm long, common.

Nephroselmis (11) (Prasinophyceae) Bean-or kidney-shaped green flagellates with two flagella. Swim jerkily with one end of the 'bean' going forwards.

N. angulata (Korshikov) Skuja (11*a-d*) (*Heteromastix angulata* Korshikov) Up to 15 µm long, common.

Spermatozopsis (19) (Prasinophyceae) Small flagellates with two or four flagella, shaped like slender fish and swim rapidly in spirals.
S. exsultans Korshikov (19) Up to 12 µm in length and sometimes common. Its swift darting movements make it noticeable in a mixed sample.

Eudorina (16) Colonial, with thirty-two or sixty-four green cells widely separated at the surface of a gelatinous sphere.
E. elegans Ehrenberg (16) with cells 5-15 µm long and colonies up to 200 µm across, is often abundant.

Pandorina (12) Colonial. Differs from *Eudorina* in that the cells fit closely together without a large central space.
P. morum (Müller) Bory (12) Cells 8-20 µm long, colonies up to 50 µm across. Often abundant.

Gonium (13, 20) Colonies form a flat plate composed of 14 or 16 cells. Two species are common.
G. pectorale Müller (13) Sixteen-celled colonies up to 50 µm across.
G. sociale (Dujardin) Warming (20*a, b*) four-celled colonies up to 50 µm across. The colony illustrated in 20*b* shows the remains of the mother cell wall below, which is characteristic of the variety *sacculum* J. Stein. This is sometimes distinguished under the name *Basichlamys sacculifera* (Scherffel) Skuja.

Pascherina (21) Colonies of four cells like those of *Chlamydomonas*, arranged in a tetrad and readily breaking apart into single cells. One species only.
P. tetras (Korsh.) Silva (21) Colonies up to 25 µm across, frequent in rivers.

Volvox (14, 15) Macroscopic spherical colonies containing hundreds of cells. Two species are occasionally found in British rivers, a third one being much rarer.
V. aureus Ehrenberg (14*a, b*) has colonies up to 500 µm in diameter and the individual cells appear round (*b*).
V. globator Linn. em. Ehrenb. (15) Even larger colonies than *V. aureus*, which are superficially like the previous species, but the cells are stellate.

ORDER CHLOROCOCCALES

Green algae in which the vegetative states are non-motile. Unicellular or colonial but not filamentous.

N.B. For convenience, three members of the Ulotrichales are included here (*Gloeotila, Koliella* and *Stichococcus*).

Actinastrum (61) Stellate colonies of four or eight elongated, cigar-shaped cells which radiate outwards from a central point of attachment.

A. hantzschii Lagerheim (61) Cells up to 25 µm long, common in rivers.

Ankistrodesmus (including *Monoraphidium*) (22-24, 46, 48, 49) A large genus of elongated cells, straight or curved, which may live singly or be united loosely into colonies. The following species are frequently seen.

A. acicularis (A. Braun) Korshikov (46) Cells needle-shaped (acicular), straight, up to 200µm in length. Differs from *Koliella* (*Raphidonema*) in tapering gradually from near the centre towards the ends, and in producing several daughter cells within the mother envelope. *Koliella* is almost parallel-sided for much of its length and breaks across the middle to form two daughter cells.

A. fusiformis Corda (48*a, b, c*) Cells thicker in proportion and more 'stumpy' than those of *A. acicularis*, with ends narrowly tapered but not needle-like. Up to 100 µm long. Young cells often in crossed arrangement (48*a*), while older cells are solitary (48*b*).

A. falcatus (Corda) Ralfs (49*a, b, c*) Cells narrowly fusiform, curved into a smooth wide arc, not spiral, up to 80 µm long. Sometimes joined in loose bundles as illustrated.

A. gracilis (Reinsch) Korshikov (*Selenastrum gracile* Reinsch) (24) Cells narrowly fusiform, up to 40 µm long, sharply curved into semicircles, often united into loose colonies as shown.

A. angustus Bernard (*A. contortus* Thuret; *A. falcatus* (Corda) Ralfs var. *spirilliformis* G. S. West (22*a, b, c*) Cells narrowly fusiform, up to 35 µm long with needle points, twisted into a part of a spiral, giving to the cell in many positions the characteristic appearance of having one sharp and one blunt end.

A. subcapitatus Korshikov (23) Small blunt-ended sausage-shaped cells up to 18 μm long, curved through half a circle or more (about 9 μm across), and may be slightly twisted.

Ankyra (52) Fusiform cells extended into a long narrow point at each end, one tip bearing two small processes like horns or handle-bars.
A. judayi (Smith) Fott (52) Cells up to 100 μm long; seen occasionally in rivers.

Botryococcus (56) Forms irregular lumpy colonies up to 1 mm across, with numerous green cells 5-10 μm long embedded in an oily matrix. This may be colourless, when the colony looks green, or brown with carotenoids which mask the green cells so that the colonies appear rust-red. May float on the surface and form a conspicuous scum or bloom.
B. braunii Kützing (56) occurs occasionally in rivers.

Chlorella (39) Small spherical or ovoid cells with a single chloroplast .Two or four daughter cells enclosed for a time within the parent wall.
C. vulgaris Beijerinck (39*a, b*) Cells 2-10 μm in diameter, *b,* four young cells inside mother cell wall. Sometimes abundant in rivers.

Chodatella and *Lagerheimia* (28, 31-35) These genera will be considered together as there is much confusion between them, some species being assigned to either one or the other by different authorities. Both have small single cells which bear regularly arranged spines. The system of Fott (1948) is followed here, in which the main criterion is the presence in *Lagerheimia* of a tubercle or knob at the base of each spine. But this is not easy to see and it is best to recognise the species by their distinctive shapes.
Chodatella ciliata (Lagerh.) Lemmermann (35*a, b*) Smoothly ellipsoidal cells up to 25 μm long with about six long spines at each end. Frequent.
C. citriformis Snow (34) Resembles *C. ciliata* in position and number of spines, but cells lemon-shaped. Occasional.

Lagerheimia wratislaviensis Schröder (31) Ellipsoidal, up to 15 μm long with four strong spines arranged one at either end and two at the equator to form a cross. Frequent.
L. genevensis Chodat (32) Cells regularly oblong, up to 10 μm long with a spine at each corner, all in same plane. The spines have fairly visible basal tubercles. Frequent.

Chodatella quadriseta Lemmermann (33*a, b*) Oblong cells up to 15 µm long, bearing four spines more or less at the corners, but without basal tubercles. The pairs at each end are usually not in the same plane, but when they are the cells are superficially like those of *Lagerheimia genevensis* but usually less regular in shape. A further difficulty is that cells of this kind could be single cell stages of *Scenedesmus quadricauda* which occur in cultures of some strains of that species. Fig. 28*a* and *b* illustrates two such *Scenedesmus* cells, these resembling *Chodatella subsalsa* Lemmermann, (up to 10 µm in length). The above comments may be unhelpful, but it seems better to point out the problems than to give over simplified and misleading information.

Coelastrum (56) Regular spherical colonies composed of up to thirty-two cells, each of which can produce within itself a daughter colony which is released as a whole.
C. microporum Naegeli (56) with cells up to 30 µm across is common.

Crucigenia (66-69) After dividing, cells of this genus stay attached to each other in groups of four, in one plane; often two generations are grouped together. Frequent.
C. tetrapedia (Kirchner) W. & G. S. West (66) Individual cells up to 8 µm across. The primary groups of cells fit together closely, with no central space.
C. fenestrata Schmidle (67) Individual cells more rounded than in *C. tetrapedia* and the groups of four surround a central gap.
C. apiculata Schmidle (68) Cells up to 8 µm long in a closely packed rectangle; characteristic points, like those on orange pips.
C. rectangularis (Nägeli) Gay (69) Smooth ovoid cells up to 8 µm long, lying together in rectangles with what appears to be minimal attachment.

Dictyosphaerium (64) Colonies of small ovoid cells held loosely together in a clear mucilage by fine branching strands which are often barely visible. The latter are probably formed from the mother cell walls.
D. pulchellum Wood (63) Rounded cells up to 10 µm across.
D. ehrenbergianum Näg., with transversley elongated cells of the same size, also occurs, but less frequently.

Didymogenes (36) Colonies of small, elongated, round-

ended cells lying crosswise and joined by mucilage.
D. palatina Schmidle (36) Two curved sausage-shaped cells up to 8 µm long.

Elakatothrix (50) Fusiform cells up to about 40 µm in length, in pairs, or more, enclosed in a mucilage envelope. They are sometimes found in rivers but are difficult to identify to species. The one illustrated is probably *E. acuta* Pascher.

Gloeotila (51) A green filamentous alga belonging to the Ulotrichales.
G. pelagica Skuja (51) forms filaments only about 2 µm wide, but the green chloroplasts distinguish it immediately from planktonic blue-green algal filaments. Has been seen in several rivers.

Golenkinia (45) Spherical cells, usually solitary, covered with numerous long radiating spines. The green chloroplast contains a cup-shaped pyrenoid.
G. radiata Chodat (45) is up to 20 µm in diameter.

Golenkiniopsis (44) Similar to *Golenkinia,* but has a spherical pyrenoid.
G. parvula (Woronich.) Korshikov (44) is found in rivers and can be distinguished from *Golenkinia radiata* by its small size, only about 6 µm in diameter. As the spines are thin and difficult to see, it may also be confused with *Chlorella* (39).

Koliella (*Raphidonema*) (47) Extremely long narrow straight cells with a superficial resemblance to some species of *Ankistrodesmus.* However, they belong to the Ulotrichales (*Ankistrodesmus* is placed in the Chlorococcales) and divide by breaking into halves across the middle and not by the production of daughter cells within a mother cell wall.
K. longiseta (Vischer) Hindák (*Raphidonema longiseta* Vischer) (47*a, b, c, d*) Cells up to 150 µm long and 1.5-3.0 µm wide. *a, b* vegetative cells; *c* dividing cell; *d* young cell. Common in rivers.

Micractinium (65) Round spiny cells usually in open-centred colonies, each cell having 1 or 2 long conspicuous spines.
M. pusillum Fresenius (65) with cells up to 10 µm across is frequent.

Oocystis (41) Ellipsoidal cells without spines, containing 1, 2 or 4 chloroplasts according to the state of division. In

some species the wall is ornamented with raised spots. After division the mother cell wall may enlarge and retain the daughter cells for some time.
O. pseudocoronata Korshikov (41a) is shown with daughter cells inside the mother cell wall. Cells normally up to 15 μm long. (41b) is a young cell which could belong to any one of a number of unornamented species.

Pediastrum (70, 71, 72) A colonial form in the shape of flat green plates containing varying numbers of cells.
P. boryanum (Turp.) Menegh. (70) has no gaps between individual cells, of which there are usually 16 but sometimes 32 or 64. The peripheral cells each have 2 points. Colonies up to 200 μm in diameter. The commonest species.
P. duplex Meyen (71) is similar but there are distinct gaps between the cells. Colonies up to 200 μm across. Occasional.
P. tetras (Ehrenb.) Ralfs (72) is in general much smaller, with only 2, 4 or 8 cells per colony, which are up to 30 μm across and have a more angular appearance than *P. boryanum.* (72a) and (72b), 8-celled and 4-celled colonies respectively.

Polyedriopsis (38) Cells of irregular shape with rounded angles from which arise tufts of long strong spines.
P. spinulosa Schmidle (38) has polyhedral cells up to 20 μm across. Occasional in rivers.

Scenedesmus (58-60) In this genus the elongated cells are joined side by side to make flat rectangular plate-like colonies of two, four or eight cells, often with spines at the corners and elsewhere, Some species show brownish markings due to iron compounds. The usual method of reproduction is by a daughter colony being formed inside each cell of the old one. In some species, however, single celled stages may be produced under certain conditions. These often look like species of *Chodatella* and can cause much nomenclatural confusion.
S. acuminatus (Lagerh.) Chodat (58*a, b;* 53) Fusiform cells, the outermost crescentic with long points. Eight-celled colonies frequent (*b*). Cells up to 30 μm long. Common in plankton. Unicellular stages also occur (53).
S. obliquus (Turp.) Kützing (60) (*S. acutus* Meyen) Fusiform cells without spines, the outer cells of the colony not crescent-shaped as in *S. acuminatus.* Cells up to 20 μm long. Common in plankton.

S. quadricauda (Turp.) Bréb. (61*a, b, c*) In this common and variable species, or aggregate of species, the cells are cylindrical and not drawn out at the ends. The colony has a long spine at each corner, typically as in *a,* but there may be extra shorter spines as in *b* and *c.* The latter are from a clone which regularly produced the *Chodatella*-like stages illustrated in (28). (33) is of *Chodatella*-stages from another form of *S. quadricauda.* In the wild these stages are impossible to distinguish from such species as *Chodatella quadriseta.* The cells of *S. quadricauda* are usually up to 25 µm long, but are occasionally much bigger.

S. protruberans Fritsch (59) Cells fusiform, the outer ones with ends drawn out into rounded or capitate tips, ending in long strong spines, often somewhat bent. Cells up to 30 µm long. A frequent, characteristic form.

S grahneisii (Heynig) Fott (37) Belongs to a group of species with small two-celled colonies. The cells are usually decorated with brown spots or stripes and are without spines. Sometimes included in the genus *Didymocystis.* Cells up to 8 µm long. Common.

Siderocelis (40) Small spherical or ovoid cells rather like *Chlorella,* but the wall is covered with raised brown spots.

S. ornata Fott (40*a, b*) Cells ovoid, up to 15 µm long but often much smaller. Evenly dispersed brown spots. Frequent.

Siderocystopsis (43) Ellipsoidal cells like those of *Oocystis,* but with numerous long fine spines radiating outwards. Walls covered with minute brown spots.

S. fusca (Korsh.) Swale (*Siderocystis fusca* Korsh.) (43*a, b*) Cells up to 20 µm long. *b* shows smooth-walled young cells within remains of mother cell wall. The spines of this organism are often hard to see.

Stichococcus (42) Small cylindrical cells with rounded ends, sometimes forming short chains. Each cell contains a single chloroplast, except before a cross wall is formed at division. The genus is placed among the filamentous members of the Ulotrichales.

S. bacillaris Nägeli (42) Cells up to 4 µm in diameter, frequent.

Tetraëdron (25-27) Comprises a number of species with small angular cells, some with a short spine arising from each angle. (Spines never in bundles).

T. minimum (A. Braun) Hansgirg (27) Cells flat and more or less square, often with rather concave sides like a cushion. Up to 20 μm across. Common.
T. incus (Teilung) G. M. Smith (25*a*, *b*) Four-cornered cells with the corners produced into relatively narrow points ending in a spine. Cells often slightly twisted so that the points are not all in the same plane. Up to 30 μm across. Young cells, *b*, are more deeply indented than older ones. Occasionally found in rivers.
T. caudatum (Corda) Hansgirg (26*a*, *b*) Cells with five spine-tipped angles. As with *T. incus* the young cells are more deeply indented, but here one side is always much deeper than the others. Up to 25 μm across. Occasional.
T. muticum (A. Br.) Hansg. See *Goniochloris mutica* Fig. 29 p. 47.

Tetrastrum (62) Forms four-celled flat colonies like some species of *Crucigenia* (p. 42) above, but differs in having spines (often only small) and in not producing compound colonies of more than one generation.
T. staurogeniaeforme (Schroeder) Lemm. (62) Each cell has a rounded external wall bearing a row of spines, the other sides being faceted due to mutual compression. Cells up to 6 μm across. Occasional.

ORDER DESMIDIALES

The *desmids* are a sharply defined group of non-flagellate green algae distinguished by their characteristic shape and in having peculiar sexual and asexual reproduction. Bipolar symmetry is almost always shown and the transverse 'equator' is often marked by a constriction (the 'isthmus'). Although tiny ones occur, desmids tend to be much bigger than members of the Chlorococcales.

Closterium (54) The cells vary from crescent-shaped to long and thin with slightly curved pointed ends. A row of conspicuous pyrenoids can often be seen up the longitudinal axis. Of the many species, only a few are common in lowland districts. Individuals are occasionally found in rivers.
C. moniliferum (Bory) Ehrenberg (53) is perhaps the most likely in this habitat. Cells crescent-shaped, thicker than most species, with an axial row of pyrenoids, sometimes difficult to see. Up to 400 μm long.

Cosmarium (55) A large and varied genus found mostly in soft water districts. Elliptical or angular cells with a strong constriction across the centre and without spines.
C. botrytis (Bory) Menegh. (54) Elliptical with truncated ends; pyrenoids may be obscured by dense storage products. Up to 90 µm in length. Occasional in river plankton.

Class Xanthophyceae

A group containing green or yellowish algae, distinguished from the Chlorophyceae by the form of their zoospores and by their pigments. As well as the conspicuous filamentous genera *Tribonema* and *Vaucheria* the class includes many small unicellular flagellates, some with sculptured walls. Only two species are frequent in the plankton of rivers.

Goniochloris (29) Small triangular or polyhedral cells, some of them described originally as species of *Tetraëdron.*
G. mutica (A. Braun) Fott (*Tetraëdron muticum* (A. Br.) Hansgirg (29) Triangular cells up to 10 µm across, the walls with a delicate honeycomb pattern. Usually two yellowish green chloroplasts without pyrenoids (the clearest distinction from *Tetraëdron*). Frequent.

Trachychloron (30) Discoid cells with honeycomb pattern on walls like *Goniochloris.*
T. circulare (Bourrelly & Georges) Fott (*Pseudostaurastrum circulare* Bourrelly & Georges) (30*a, b*) Circular cells flattened like a coin, or slightly bent. two yellowish green chromatophores. About 10 µm in diameter. Frequent.

Class Bacillariophyceae (Diatoms)

A group of unicellular, colonial or filamentous algae (freshwater and marine) with brown chloroplasts and glass-like silica walls. This enclosing *frustule* has the form of a box, and is usually sculptured, the pattern being of much importance taxonomically. The view of the lid or base of the box (which is in two halves fitting together) is known as the *valve view,* and that of the side the *girdle view.* Though some species are recognisable at a superficial glance, identification often depends on the preparation of 'cleaned' material (i.e. freed from organic matter by heat or oxidising agents), which is then mounted in a medium of high refractive index.

A detailed treatment of cleaning and mounting is beyond the scope of this guide, but may be found in Lund (1961).
The diatoms fall into two main groups, the *centric* and *pennate,* the former showing radial symmetry like a petri dish, while the latter are bilaterally symmetrical about a longitudinal axis. The centric species will be described first.

CENTRIC DIATOMS (CENTRICAE)

The following eight species are difficult if not impossible to determine unless cleaned. All have the shape of a shallow tin can, and thus appear rectangular or round in girdle and valve views respectively. They have two or several brown or brownish green chloroplasts, often pale, and when multiplying fast may be joined into short loose filaments. The living cells of many centric diatoms have a crown of long delicate spines radiating from the valve edges. These are visible with the light microscope but are always lost in prepared material.

Stephanodiscus (73-75) In this genus a valve pattern of rows of puncta (or spots) radiates from the centre to the edge of the frustule. Towards the periphery the rows become double or multiple, forming a wedge like a narrow slice of pie. Identifying species of *Stephanodiscus,* apart from *S. astraea,* is a specialist's job, but two of the smaller species are given here as examples.
S. astraea (Ehrenb.) Grunow (*S. rotula* (Kutz.) Hendey) (73) A relatively large and coarse species, 25-70 µm in diameter, with numerous chloroplasts, and conspicuous spines around the margin. The puncta can be seen easily with a 1/6 inch or 4 mm objective. Common in reservoirs and often found in rivers.
S. invisitatus Hohn & Hellerman (74) This is usually, but incorrectly, referred to in ecological studies as *S. hantzschii* Grun., which also occurs, although less frequently. The markings are almost invisible with the light microscope, even with an oil immersion objective, and are generally composed of double rows of spots forming faint stripes. As shown in the figure, a single larger spot near the centre may be seen with phase contrast illumination. Cells up to 15 µm across. Abundant in rivers and canals.
S. tenuis Hustedt (75) Markings more distinct than in *S. invisitatus* and are made up of rows of puncta about

three wide at the margin. Up to 30 µm in diameter. Abundant and in our experience the most frequently occurring species.

Cyclotella (76-79) Small diatoms resembling *Stephanodiscus* when alive, but the valve pattern shows distinct outer and inner zones.

C. meneghiniana Kützing (78) Up to 30 µm in diameter. This is by far the commonest species of *Cyclotella* and is often abundant. It is confused with small species of *Stephanodiscus,* from which it cannot be distinguished when alive. The centre of the valve is plain, except for one or two small puncta, while around the edge is a broad band of heavy striae, arranged so that eight or ten occupy 10 µm of the circumference.

C. kuetzingiana Thwaites (76) Much less common than *C. meneghiniana* and has finer and more closely packed marginal striae. (c. fifteen per 10 µm) Up to 45 µm in diameter

C. comta (Ehrenb.) Kütz. (77) The marginal striae form a wider border than in the two previous species and the centre of the valve is heavily punctate. Up to 30 µm across. Occasional in rivers, more frequent in reservoirs and pools.

C. pseudostelligera Hustedt (79) A small species, 10 µm or less in diameter. Valve pattern variable. Outside the marginal zone of striae is a ring of small puncta. A single punctum at the centre is usually surrounded by an inner ring of small striae. Common in rivers.

Thalassiosira (80) Species of this genus are more common in the sea than in freshwater. Valve pattern variable. Cells often joined by a thread of mucilage to form short loose chains.

T. fluviatilis Hustedt (*T. weissflogii* (Grunow) G. Fryxell & Hasle) (80) Radiating lines of extremely fine spots give the valves a characteristic mottled appearance. Three to eight large puncta lie irregularly in the centre and around the periphery is a ring of puncta broken by a single short radial slit, like a hole made by a screwdriver. Up to 25 µm in diameter. Common in rivers.
A rarer species, *T. guillardii* Hasle, lacks the mottled appearance and the central puncta, and the slit is shorter.

Melosira (81-82) Cells always in filaments. Individual cells held together much more firmly than in the loose, temporary chains occurring during rapid growth in the previous eight species.

M. varians C. A. Agardh (81) Filaments up to 30 µm wide, the individual cells being generally a little longer than wide. In each cell are several lobed brown chloroplasts. With the light microscope the valves appear completely without markings, like the bottom of a glass beaker. A common benthic form, often swept into the plankton.
M. granulata (Ehrenb.) Ralfs (82) Cells 5-20 µm wide and up to 20 µm long. Fig. 82 is part of a filament of narrow elongated cells, but the species is extremely variable and it is possible to find both long and narrow and short and broad celled filaments mixed together in the same sample. However, the sculpturing of fine puncta like a nutmeg grater (visible sometimes in living cells) and the terminal spines (one long and several short) is highly characteristic. Frequent.

PENNATE DIATOMS (PENNATAE)

Species in this group have cells bilaterally symmetrical about a long axis. They are abundant in the benthos, from which they are often disturbed and swept up into the plankton. A few, in particular *Nitzschia acicularis,* seem to be more or less 'true' planktonic forms, this species being almost ubiquitous in the surface water of lowland rivers. Pennate diatoms having the longitudinal structure known as a raphe are able to glide over solid surfaces.

Asterionella (91) The long narrow cells are joined by pads of mucilage at one end to form radiating star-shaped colonies.
A. formosa Hassall (91) Cells up to 130 µm long united into star-shaped colonies (rarely in zig-zags) of four, eight or sixteen individuals. The cells are somewhat expanded at each end, the inner ends being larger. A well-known alga abundant in lakes and reservoirs and also frequently seen in the bigger rivers.

Diatoma (88, 92) The species show much variation in shape and size, but all have characteristic heavy transverse ridges in valve view.
D. vulgare Bory (88*a, b, c, d*) Greatly variable in shape and in size ranges from 10-60 µm long. Common in river plankton in winter.
D. elongatum Agardh (92) Narrow elongated cells up to 120 µm in length which tend to remain attached to one another to form either zig-zags or radial colonies which can

be confused with *Asterionella*. There are usually not more than three cells in the radiating colonies, however, and the inner ends are not enlarged as in *Asterionella*. In valve view the strong ribs can be seen, and in girdle view (the position usually visible in living samples when examined) the ends of the ribs give a rough, thickened appearance to each margin.

Synedra (85) In this genus the cells are usually long and narrow.

S. acus Kützing (85) Needle-shaped cells up to 300 µm long. Frequent in rivers as scattered individuals, but seems not to divide rapidly in the plankton as does *Nitzschia acicularis*. Living cells can be distinguished from the latter in having several (instead of only two) chloroplasts, and in not being able to glide over a solid surface.

S. ulna (Nitzsch.) Ehrenb. var. *danica* (Kütz.) Grun. is similar to the above, and common in lake plankton. It is distinguished by the spacing of the transverse striae, about ten in 10 µm rather than twelve to fourteen in *S. acus*.

Navicula (83, 86, 87) A large genus whose members are usually oblong or boat-shaped in girdle view. All species can move and have two chloroplasts, one on each side of the cell seen in valve view. The three species described here represent common benthic forms often seen in suspension. As there are many species of *Navicula* looking much alike to the non-specialist, this must be taken as only a rough guide to nomenclature.

N. viridula Kützing (83) Cells up to 80 µm long, diamond-shaped in valve view, with ends not noticeably pulled out.

N. gracilis (Ehrenb.) Kützing (87) Cells up to 60 µm in length. Differs from *N. viridula* in being boat-shaped in valve view, with the sides curved more gently and regularly.

N. cryptocephala Kützing (86) A smaller species, up to 40 µm long, with knob-like ends in valve view.

Nitzschia (84, 89, 90) A large genus of elongated diatoms having transverse fine striae right across the valve and a characteristic row of coarse spots down one margin. They move actively on a slide and can be distinguished in life from *Navicula* and *Synedra* by having two chloroplasts arranged fore and aft instead of side by side in *Navicula* or several along the cell as in *Synedra*.

N. acicularis W. Smith (84) Narrow elongated cells up to 150 µm long, with ends drawn out like glass rods. One of the commonest diatoms in rivers and appears to be 'truly' planktonic, dividing and building up populations rapidly while suspended.

N. palea (Kütz.) W. Smith (89) One of a large group of species all looking much alike. In waterworks practice several of these tend to be 'lumped' as *N. palea* as it is difficult, even for a specialist, to sort out the differences. Cells in valve view have parallel straight sides and tapered ends often slightly knobbed. 20-65 μm long. Very common.

N. sigmoidea (Ehrenb.) W. Smith (90) An abundant benthic species occasionally found in the plankton. Immediately recognizable by its large size, up to 500 μm long, and sigmoid shape.

Class Chrysophyceae

Mainly motile forms, unicellular or colonial, with yellow-brown chloroplasts. Although common, they are often hard to examine as the cells tend to be fragile and die and break up readily when centrifuged or mounted on a microscope slide. It is therefore quite possible to underestimate or even completely overlook members of this group in a sample. The examples illustrated are relatively robust. For detailed identification see Huber-Pestalozzi 1941.

Dinobryon (93) Cells with brown chloroplasts and two unequal flagella, contained within a transparent flask-shaped lorica. Individuals are joined into apparently branching colonies of highly distinctive shape. At times some or most of the loricas contain spherical smooth walled spores instead of vegetative cells. Found occasionally in rivers and (like *Synura*, below) may be responsible for unpleasant taste and odour in drinking water.

D. sertularia Ehrenb. (93) with individual 'flasks' 30-100 μm long is the commonest species.

Mallomonas (94*a*, *b*) A genus with many species, which are difficult to identify with the light microscope. The cells are 5-50 μm in length, with one flagellum, yellow-brown chloroplasts, and are covered all over with scales of silica (*a*), or with these plus long bristles (*b*), which give a roughness to the cell outline. Using an electron microscope, the structure of the scales provides a means of distinguishing species.

Synura (95*a*, *b*) Swimming colonies, usually spherical but occasionally elongated, of pear-shaped cells joined together by their 'tails'. Individual cells rather like those of *Mallomonas*, scaly and with brownish chloroplasts, but with two unequal flagella. Colonies up to 500 µm across, which often break up into separate cells after collection (and nearly always on centrifuging). Electron microscopy may be necessary to identify some of the species, but *S. petersenii* Korshikov, figured here, is by far the commonest in rivers.
Synura is a well-known cause of taste and odour in water supplies.

Ochromonas (96) Motile unicells with one or two chloroplasts, and with a long and a short flagellum. Up to 25 µm long. Many species have been described, but they are often difficult to identify. Occasional in rivers. Fig. 96 is of *O. tuberculatus* Hibberd, which is fairly representative of the bigger species.

NOTE

Cells of *Chromulina* are similar to those of *Ochromonas* but have only one visible flagellum. They too are to be seen occasionally in rivers. Another similar genus is *Chrysococcus*, with small cells up to 10 µm in diameter but enclosed in a spherical lorica from which a single flagellum protrudes like a miniature *Trachelomonas* (Fig. 99*b*). This is sometimes common in river plankton.

Class Cryptophyceae

The Cryptophyceae is a small group whose members are widespread and often abundant. They are generally heart- or leaf-shaped, swimming with two flagella and mostly brownish or olive green in colour. There is an opening known as the 'gullet' at the anterior end of the cell near the base of the flagella (although they do not take in solid food). This is lined with spots called 'trichocysts'. The genera are easy to recognize, but the species are usually difficult to determine.

Cryptomonas (97) Cells 10-80 µm long, of a brown or olive green colour and highly characteristic shape. Mostly two chloroplasts arranged as in the figure. Species of *Cryptomonas* are extremely hard to determine, but they are widespread and common, the bigger ones being conspicuous.

Chroomonas (98) Unmistakable on account of the bright blue-green colour of the one or two chloroplasts. Species difficult to identify, usually about 10 μm long. Frequent as odd individuals in the plankton.

Rhodomonas (99) The common representative of the genus is *R. lacustris* Pascher et Ruttner var *nannoplanktica* (Skuja) Javornicky (*R. minuta* Skuja var. *nannoplanktica* Skuja), which has cells about 10 μm long and is frequent in most types of water body. The cells are heart-shaped, pale olive brown in colour, and have a single chloroplast and pyrenoid. A conspicuous refractive granule in the 'tail' is a useful aid to recognition.

Class Dinophyceae

The Dinophyceae form a large and complex group, reaching their greatest diversity in the marine plankton. These flagellates are often covered with armour-like plates, whose arrangement is used in classification. Of the two flagella, one is directed backwards and the other lies in a groove around the centre of the cell. In general the species are hard to identify and need specialist keys.

Peridinium (102) A large and difficult genus of more or less spherical or flattened armoured forms without horns, up to 70 μm long and usually brown in colour. Species of *Peridinium* are the only flagellates of this type common in rivers. Similarly shaped but unarmoured cells are likely to belong to the genus *Gymnodinium*. A colourless species of *Gymnodinium* containing an orange oil drop sometimes occurs in noticeable numbers.

Class Euglenophyceae

Another large and complex group of flagellates which includes many colourless forms. In most euglenoids only one thick flagellum is visible. The three members mentioned below all have bright green chloroplasts, one apparent flagellum and a conspicuous red eye spot at the front end.

Euglena (101) Spindle-shaped green flagellates which swim vigorously. Examples of the many species are common in polluted or slightly polluted (or enriched) water.
E. viridis Ehrenberg (101) Up to 70 μm in length, with a central pyrenoid from which arms of the chloroplast radiate to most parts of the cell. Reserve products often obscure details of the cell contents. Found occasionally in rivers.

Phacus (103) Flattened and leaf-like green flagellates, often twisted and with spiked 'tails'. As with *Euglena* a large number of species has been described.
P. pleuronectes (O. F. M.) Dujardin (103) Up to 80 μm long. This and other species sometimes occur in river plankton.

Trachelomonas (100) Cells similar to those of *Euglena*, but enclosed in a 'pot' with a hole through which the flagellum emerges. The pot or lorica varies in colour from yellow to brown and from spherical to vase-shape according to the species, which also differ in the degree of ornamentation of the wall.

T. volvocinopsis Swirenko (100*a, b*) Lorica brown, spherical and smooth, with no collar and up to 25 μm in diameter. The cell contains several green chloroplasts quite clearly to be seen through the wall. *T. volvocina* Ehrenberg is similar but has only two chloroplasts. Both are sometimes found in river plankton.

Class Myxophyceae (Cyanophyceae)

These, the blue-green algae, are considered to be more closely related to bacteria than to the other algal classes. The nuclear material and photosynthetic apparatus are not organized in membrane-bounded organelles and there are no flagellated stages. The gliding movements of the filamentous forms are caused by the extrusion of mucilage. In colour they may be bluish-green, grey, brownish, blackish or even purple, but never bright green.

Microcystis (104) Cells small, rounded and embedded in mucilage to form irregular floating masses of various shapes.
M. aeruginosa Kützing (104) Cells 3-9 μm across. Colonies often perforated with holes, variable in size and may be

macroscopic. Occurs mainly in eutrophic lakes and sometimes in the more enriched rivers.

Merismopedia (109) This genus is easily recognized by its characteristic colonies of small rounded cells which divide in only two planes to produce flat rectangular rafts. Cells in multiples of four.
M. glauca (Ehrenb.) Nägeli (109) Rafts of pale bluish green cells, each about 4 µm across. Found occasionally in rivers.

Aphanizomenon (105) Cells in fine filaments aggregated together into bundles of irregular size.
A. flos-aquae (L.) Ralfs (105*a, b*) Individual colonies reach macroscopic size and consist of filaments up to 6 µm wide which taper towards the ends. In 104*b* a spore and heterocyst (specialized cell) are shown, together with the tip of a filament. This is one of the species which form dense blooms in eutrophic pools and lakes, and may be found occasionally in river plankton.

Oscillatoria (106-108) Unbranched filaments with neither spores nor heterocysts. A large genus, many of the species need specialist knowledge for identification. Often difficult to distinguish from the related genera *Phormidium* and *Lyngbya.* The following are representative of those which may be found in river plankton.
O. limnetica Lemm. (106) Extremely fine pale filaments about 1.5 µm in width, slightly constricted between the cells like a string of sausages. Occasional.
O. limosa Agardh (108) One of the most characteristic species, with thick greyish green filaments about 15 µm wide. The cells are short in proportion to their width, rather like the segments of an earthworm. Filaments creep rapidly over the surface of a microscope slide. *O. limosa* is found living on the bottom mud of slow flowing rivers, but pieces of filament may be swept into suspension.
O. agardhii Gomont (107) One of the many species intermediate in size between *O. limnetica* and *O. limosa*.

The cells are about 7 µm in width, greyish in colour and mottled with elongated black markings which are gas-containing vacuoles. Found as single filaments in the plankton of lakes and is occasionally carried into rivers.

NOTE

Though not part of the plankton, the conspicuous flocculent masses, usually several inches across, seen floating on the surface of many lowland rivers in spring and early summer, are composed largely of matted filaments of *Oscillatoria.* These grow as a felt on the bottom mud and during vigorous photosynthesis bubbles of oxygen are trapped among the filaments, causing whole patches of algae and mud to break away and float upwards.

Glossary

Acicular	needle-shaped
Axile	in the centre of the cell
Benthic	bottom-living (as distinct from planktonic)
Capitate	terminating in a head or knob
Carotenoid	orange-coloured fat soluble pigment
Centric	applied to a sub-division of the diatoms in which the cells are usually shaped like short cylinders
Chloroplast	(or *chromatophore*) the photosynthetic organ in plant cells, usually green or brown, but also red or blue-green in algae
Flagella	(singular *flagellum*) whip-like structures used by cells for swimming, hence 'flagellates'—a general term for cells which move by flagella
Frustule	cell wall of diatom, formed of silica
Fusiform	spindle- or cigar-shaped
Girdle-view	applied to view of diatom cell in which the junction between the two valves can be seen (as distinct from valve-view)
Heterocyst	specialized non-pigmented thick-walled cell occurring in blue-green algal filaments
Lorica	pot- or vase-shaped structure enclosing various algal cells
Macroscopic	term loosely applied to anything visible with the unaided eye
Parietal	lying against the wall of a cell (as distinct from axile)
Pennate	applied to a sub-division of the diatoms in which the cells are mostly bilaterally symmetrical and usually elongated
Plankton	general term for floating organisms which are either non-motile or unable to move strongly enough to be independent of water movements

Puncta	(singular *punctum*) spots on diatom frustules used in identification together with other markings
Pyrenoid	colourless structure associated with the chloroplast and concerned with the formation of starch
Raphe	the linear structure (an elaborate slit) along the valve side of some pennate diatoms; only those with a raphe can glide over surfaces
Sigmoid	of an elongated S-shape, like *Gyrosigma*
Spore	general term applied to asexually produced resting cell
Stellate	star-shaped
Striae	the striped markings on diatom frustules, used in identification
Tetrahedral	applied to cells arranged in a group of four to fit into the shape of a regular triangular pyramid (a tetrahedron)
Valve	applied to the wall of one half of the box-like diatom frustule; 'valve-view' is 'top-view' and contrasts with the lateral 'girdle-view'

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This guide is a companion to 'A beginners guide to freshwater algae' which has proved so popular in schools and universities in Britain and abroad. Its purpose is to help anyone interested in freshwater biology to identify most of the algae in the plankton of rivers. It will also be helpful in identifying algae in canals, broads and lowland pools, whose plankton contains many of the same organisms.

Like its predecessor, this guide has been compiled by the same authors, whose delightful drawings contain the same blend of accuracy, authority and artistry as before. In addition, a Key to genera has been provided, and related to the drawings and descriptions.

We hope the guide will be useful not only to older children and teachers in secondary schools, but also to university students and their teachers as well as professional freshwater biologists in research, government and industry.

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