Identification of Blue Green Algae of the British Isles

Guide to the Genera and Use of the Interactive CD-ROM for Identification of Species

R&D Technical Report E84

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Research Contractor:

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This report provides a guide to the genera of blue-green algae of the British Isles and the interactive CD-ROM for the identification of species and, when used together with the CD-ROM, will assist Agency staff engaged in environmental management, monitoring and related purposes in their identification.

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EXECUTIVE SUMMARY

The lack of suitable reference books for accurate naming of blue-green algae has been a major hindrance to algological work within the Agency. Whilst there are both beginner's guides and specialised taxonomic works (usually in foreign languages), a practical blue-green algal flora has not been available. This collaborative project with the University of Durham has produced a key for identification of blue-green algae from the British Isles to assist Agency staff engaged in monitoring work. The principal output is a computer-based interactive system built from LucID Professional, a specialised computer package for developing biological identification systems.

The system was produced initially in CD-ROM format and has subsequently been made available nationally to Agency ecologists through the computer network on the Windows desktop. Images are available for many species including colour micrographs and line diagrams. These can be accessed simply by using the information button (**i**: Images) for each taxon. The approach used for naming follows the conventions of the Botanical Code of Nomenclature, keeping the term 'blue-green alga' rather than 'cyanobacterium'. Recent taxonomic developments have been incorporated for the unicellular species. Copies of the CD-ROM will be available for purchase externally in late Spring 2000 through the University of Durham.

KEY WORDS

Blue-green algae (cyanobacteria), identification, multi-access key, computer package, Lucid, CD-ROM

1 GUIDE TO THE GENERA

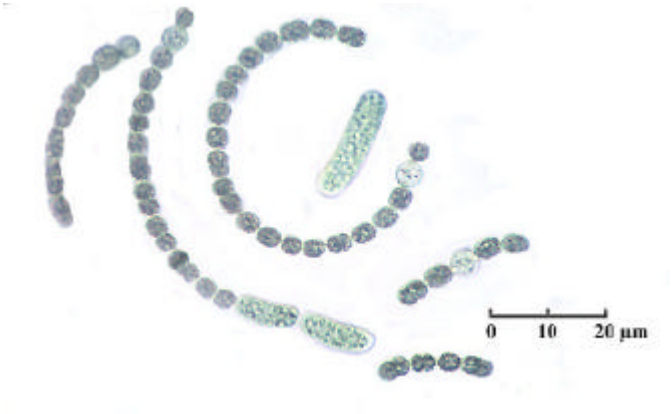
The genera described include all 64 genera for which there are records of named species included in the LucID identification system and six others (*Anabaenopsis*, *Cyanonephron*, *Isactis*, *Kyrtuthrix*, *Pannus*, *Synechocystis)* which are probably present, but for which there is no published or similar reliable record of a particular species.

Amphithrix Kütz. 1843
01010000

Crust-forming colonies, with upright, more or less straight, narrowly sheathed trichomes from a basal mass of cells. The latter is the key feature which separates this genus morphologically from *Homoeothrix*, but can easily be overlooked in a sample scraped from a rock. Trichomes typically tapered, sometimes markedly so and approaching the appearance of a hair. Heterocyst absent. Hormogonia single or many.

Although this genus appears superficially like *Homoeothrix*, it would useful to conduct molecular studies to confirm that it is not in fact a highly modified form of Stigonematales.

Anabaena Bory 1822
01020000 *Anabaena flos-aquae*



A large genus, which is usually easy to recognize: characterized by unbranched trichomes which almost always possess intercalary heterocysts. Trichomes are often aggregated into colonies which may form tufts associated with aquatic plants or films on sediment. However, the aggregations do not form firm colonies with a distinct outer layer (characteristic of many species of *Nostoc*).

Several gas-vacuolate species form water-blooms, usually with characteristic colonies. Field populations probably always form akinetes, though this feature is often lost in laboratory culture. Many species can only be identified morphologically with certainty if the akinete is present.

Features to look for include akinete shape and size, and whether or not the akinete forms next to a heterocyst and, if so, on both or only one side. Different forms of environmental stress lead to akinete formation and in some species there may be one specific factor (such as phosphorus limitation) bringing this about, but the subject requires further study. The heterocyst only forms under conditions of moderate nitrogen limitation, though trichomes are seldom seen in nature looking like *Anabaena*, but lacking heterocysts.

Anabaenopsis V. Miller 1923
01030000

Trichomes spiral or forming loops, typically with a terminal heterocyst at each end, though occasionally only one end or even absent. Akinetes single or in pairs, usually near the middle of the trichome and therefore distant from the heterocyst.

This genus is best known from the tropics and subtropics and there appear to be no reliable records for the British Isles.

Aphanizomenon Morren 1838
01040000

Aphanizomenon flos-aquae

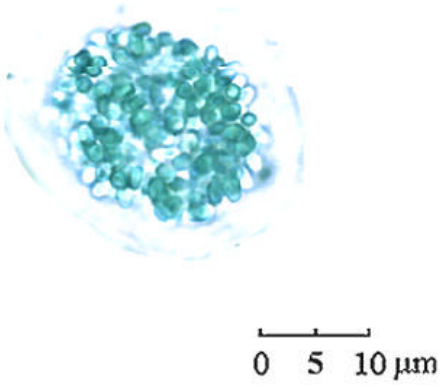
Trichomes straight or nearly so, single or in free-floating bundles; end-cells tapered. Heterocyst intercalary. Akinete single.

The best known species in the British Isles is *Aph. flos-aquae*, which forms characteristic bundles. In this and other species the heterocyst differs a lot in how much its appearance makes it easy to recognize from adjacent vegetative cells. Although they have seldom been reported in

the literature, single trichome forms appear to be widespread in lakes and ponds and are probably often overlooked. They show considerable differences in morphology between sites and do not always correspond closely to a described species; akinete morphology is a key feature to be noted. However, at least some populations recorded correspond quite well to the three single trichome species listed (*Aph. aphanizomenoides*, *Aph. gracil*e, *Aph. issatschenkoi*). It seems likely that some may at times occur without heterocysts and be confused with *Oscillatoria* (see entry for *Aph. issatschenkoi*).

The morphologically quite similar, *Cylindrospermopsis raciborskii* (Wolosz.) Seenayya et Subba Raju, which is best known from the tropics, appears to have become more widespread in temperate countries in recent years. If there is a succession of warm summers, it is likely that records will eventually be made for the British Isles. *Cylindrospermopsis* differs by having a terminal heterocyst at one or both ends of the trichome and none in an intercalary position; trichomes occasionally lack any heterocysts and so might be confused with a form of *Oscillatoria* with tapered ends of the trichome.

Aphanocapsa Nägeli 1849
01050000 *Aphanocapsa litoralis*



Colonies usually microscopic, but sometimes macroscopically visible in a few species, among which *A. grevillei* is the most likely in the British Isles; subspherical in some plankton forms, but terrestrial species are usually irregular in shape. Colonies with many irregularly arranged cells embedded in mucilage, the outer margin of which is usually rather indistinct. Cells spherical or subspherical, with binary division, but successive divisions perpendicular to each. The cells tend to be packed quite closely in forms associated with terrestrial or submerged plants, but are more spaced apart in planktonic forms.

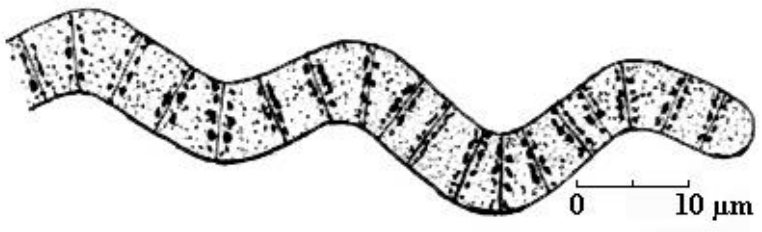
Many species have been recognized, with cell dimensions and habitat being key distinguishing characters. Komárek and Anagnostidis (1999) list 27 species, but it would be hard to distinguish all these in field samples based on the limited number of characters available using microscopy.

The five species listed here for the British Isles are ones which have recorded on a number of times and cover a range of cell dimensions.

Aphanothece Nägeli 1849
01060000

Colony microscopic to macroscopic, reaching several centimetres in *A. stagnina*, with cells loosely or densely arranged in a common mucilage; colony increase occurs by fragmentation of large colonies. Margins of colony may be diffluent or well delimited. Cells spherical or subspherical, with binary division and with successive divisions in the same plane, though sometimes one daughter cell shifts to another plane, giving the superficial appearance of cell division being more like *Aphanocapsa.* Individual cells of some species have their own distinct envelopes. According to Komárek and Anagnostidis (1999) gas-vacuoles occur in a few planktonic species, though the cells of most species are too small to be sure without electron microscopy. Komárek and Anagnostidis (1999) give particular emphasis to the habitat, which means that the limits for some species are more restricted than in some other floras. Other species listed for the British Isles by West and Fritsch (1927) include *A. nidulans* P. Richter and *A. saxicola* Nägeli; they list the small cells often present in colonies of *Coelosphaerium* and some other planktonic blue-green algae as *A. nidulans* var. *endophytica* W. et G.S. West = *A. endophytica* (W. et G.S. West) Komárkova-Legnerová et Cronberg 1994. Their status in the British Isles needs further study.

Arthrospira Stizenb.
01070000 *Arthrospira jenneri*



Trichome cylindrical, without heterocysts, mostly loosely and regularly coiled, usually of a relatively large diameter (> 7 µm) and large spirals, with comparatively short cells; almost always gas-vacuolate. Apex of trichome sometimes (but not always) attenuated, terminal cell rounded, without calyptra; cross-walls distinct. Firm sheath absent, but sometimes a diffluent sheath or mucilage layer. Trichomes often show motility if in contact with a surface.

Spirals of most (but not all) species are anti-clockwise, but mutants occasionally occur in cultures of some strains. Straight mutants of coiled forms also occur occasionally in culture; it is unknown whether these occur in nature, but, if they do, they would be difficult to distinguish from *Oscillatoria*.

Brachytrichia Zanardini
01080000

Colonies usually hemispherical initially, becoming flatter and irregular when old, epilithic on calcareous substrata in intertidal region (and rarely also epiphytic on highly calcareous algae). Trichomes embedded in mucilage, curved-flexuous, but otherwise more or less parallel to each other; false branching present, with a reverse V-shaped structure. Trichomes with intercalary heterocysts and terminal hairs.

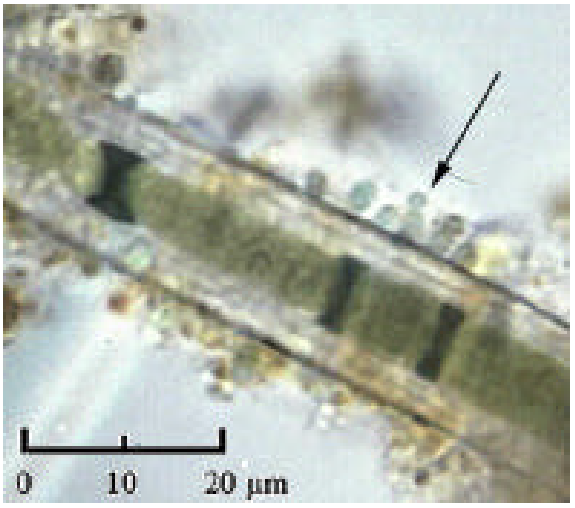
Calothrix C.Agardh
01090000

Calothrix parietina

Filaments single or in small bundles, often united to form distinct colonies; such colonies may be cushions, mats or crusts. Trichomes tapered, running more or less parallel to each other and vertical to the surface in the more cushion-shaped colonies, but intermingled in flatter colonies. Trichomes single or with occasional false branches, surrounded by a firm sheath in the lower part of the trichome (though not the heterocyst). Trichome often ending in a multicellular hair, though apparently not in all species; the hair develops in response to phosphorus limitation and sometimes also iron limitation. The sheath is firm and in many species yellow-brown; sheaths are occasionally embedded in mucilage towards the base, but this appears to be atypical. Basal heterocyst and in some species also a few intercalary heterocysts; collapsed former heterocysts sometimes persist under the active heterocyst. Akinete present in a few species, next to the heterocyst. Hormogonia form at the apical ends of trichomes under phosphorus-rich conditions; when a succession of hormogonia have been released, the sheath may extend beyond the remainder of the vegetative cells. Gas vacuoles occasionally present in hormogonia and such hormogonia can easily be mistaken for *Oscillatoria* when floating in the plankton. .

Freshwater, brackish and marine environments, attached to rocks, other firm substrata or water plants.

Chamaesiphon A.Braun et Grunow
1100000 *Chamaesiphon incrustans*



Mature cells single or arranged into a colony, the colonies of some species forming macroscopically visible structures which are sometimes sufficiently characteristic for recognition with the naked eye. The individual cell is differentiated into a basal end attached to a surface and the distal end either forms exospores or, in some colonies, acts as the surface for another mature cell, which may itself give rise to exospores. The mature cell, which develops from a small spherical exospore, is club-shaped, pear-shaped, ellipsoidal or almost cylindrical. A developing mature cell has a very thin sheath, which becomes more obvious and opens out (pseudovagina) when exospore formation commences. The sheath may be colourless, yellow-brown or rich brown, with the tendency for colour formation to be most obvious in species which form colonies. Some colonial forms have produce obvious mucilage in addition to the sheaths. Colonies arise in one of two different ways or a combination of both. Exospores in various arrangements at the end of outer mother cells. Exospores may move to a position next to the base of a mother cell, eventually giving rise to a flat structure consisting of numerous cells adjacent to each other. In other cases some of the exospores persist in an empty pseudovagina, giving rise to layered or shrub-like colonies.

Most of the species are variable and may sometimes show forms slightly outside the limits given here. However, unlike some other groups of Chroococcales, many of the species do appear to be well characterized and some of the high colonial forms are highly characteristic of particular types of environment.

Geitler (1932) separated the genus *Stichosiphon* and this is characterized by Komárek and Anagnostidis (1999) by the repeated division of exocytes (exospores) forming more or less long pseudofilamentous formations.

Chlorogloea
01110000

Colony mucilaginous, subspherical or irregular and with a granular surface when older due to the presence of many subcolonies; often developing into macroscopic structures. Cells in each subcolony arranged irregularly in common mucilage, though with a tendency for the outer cells to form radially orientated rows when the subcolony is large. Cells spherical or oval, sometimes with their own relatively indistinct sheaths.

Chroococcus Nägeli
01130000

Chroococcus turgidus

Small colonies of cells, each cell usually with its own distinct sheath, rarely single cells. Aggregations of usually 2-16 cells, occasionally many more; colonies sometimes with odd numbers of cells, but one cell of a pair of daughter cells divides before another. Cells subspherical, with divisions in three planes in successive generations, although this pattern of division may be less obvious in larger groups. Cells often form a new sheath layer each time they divide, so that a 4-celled group has cells with three distinct sheath layers; further less distinct layers may also be present, especially in terrestrial forms; sheaths colourless or yellow; some planktonic species have gas vacuoles.

A wide range of freshwater and brackish habitats, including lakes and shallow weedy ponds, on terrestrial rocks and among plants in moist situations.

Clastidium Kirchner
01140000

Cells solitary or in groups, attached to a substratum by the basal end of the cell, elongate, ovoid or pear-shaped, narrowed towards the apex, from which a gelatinous strand extends. There is a distinct mucilaginous sheath, but it is thin and may be overlooked. Cell division by successive transverse division at the apical end and the resulting spore is released and attaches itself to a

substrate; the spore shows a form of slow gliding motility and hence may itself lie close to the parent cell, giving rise to groups of cells in one area.

Coelosphaerium Nägeli
01150000

Colony free-floating in plankton, spherical or subspherical, usually with numerous quite closely packed cells embedded in the outer part of the mucilage. Cells spherical, ellipsoidal or egg-shaped, with outer cells of the colony often heart-shaped, with or without their own individual sheaths, but not attached to distinct mucilage-stalks. Komárek and Anagnostidis (1999) recognize a group of seven closely related genera, but the differences seem so minor that further evidence in their support is needed before it is worth adopting them for those for British records. In addition to *Coelosphaerium*, only *Gomphosphaeria* has been retained here. However, there is certainly in the British Isles a greater variety of colonial organisms quite like *Coelosphaerium* than suggesed by the adoption of only four species here. Many of the forms are probably characteristic of waters of intermediate hardness and enriched by humic materials.

Crinalium Crow
01160000

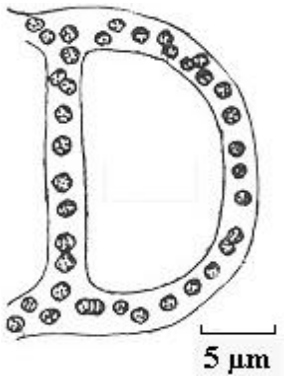
Trichomes flattened in cross-section, heterocysts absent; thin sheath. In view of the fact that the flattened trichome is the only clear diagnostic feature, it seems possible that species may not necessarily be related closely.

Cyanodermatium Geitler

Colony gelatinous or crust, microscopic or macroscopic; composed of more of less parallel rows of cells perpendicular to the surface. Cells irregularly polygonal-rounded, sometimes slightly elongate and surrounded by a thin sheath or layer of mucilage. Reproduction by release of terminal cells (a form of exospore), which are sometimes enlarged in comparison with the underlying cell. The structure is close to *Hydrococcus.*

Cyanodictyon Pascher
01170000

Cyanodictyon reticulatum



Colony free-floating, initially spherical but soon becoming irregular, reticulate and usually slightly elongate. Mucilage diffluent at the margin, colourless. Cell division in one plane in successive generations. Cells subspherical or (after division) hemispherical.

Cyanonephron Hickel 1985
01180000

Colony subspherical or ellipsoidal, sometimes composed of subcolonies, with a system of mucilaginous, pseudodichotomously branched stalks radiating from the centre of a colony. Cells more or less elongate, solitary and crosswise at the ends of the divaricate stalks, more or less on the periphery of the mucilage of the colony; with gas vacuoles.

The one species described, *C. styloides* Hickel, has cells 0.8-1.2 x 2-5.5 µm. Although it has not been reported from the British Isles, it should be looked for in the habitat where it occurs elsewhere: shallow, hypertrophic lakes near the sea.

Cylindrospermum Kütz.
01200000

Colony mucilaginous, consisting of many uniformly broad trichomes; trichomes usually relatively narrow (often about 4 µm wide) and short; heterocyst terminal, at one or both ends. A large akinete develops immediately above the heterocyst; usually single, but occasionally in pairs. Akinete shape highly characteristic in most species and it is usually possible to distinguish outer and inner wall layers. Akinetes frequently form at more or less the same time throughout a colony.

Many species are typical of moist soil and often appear as shining green mats with a very distinct margin. There are often large rod-shaped bacteria attached to the wall of the heterocysts.

Dermocarpa Crouan
01220000

Cells solitary or in irregular groups forming a small colony, almost always attached to a substratum, usually with a narrow firm sheath. During reproduction the whole cell divides by multiple fission into numerous endospores (baeocytes).
Komárek and Anagnostidis (1999) place the forms widely reported as *Dermocarpa* into three genera (not adopted here):
Stanieria Komárek et Anagnostidis 1986 Cells not polarized, usually in irregular groups, attached to the substratum by any side
Cyanocystis Borzi 1882 Cells various shapes, but most often subspherical or hemispherical, attached to the substratum by one end, with first division perpendicular to the substratum
Dermocarpella Lemmerm. 1907 Cells various shapes, but most often hemispherical, attached to the substratum by one end, with first division horizontal to the substratum; sheath sometimes thick and lamellated.

Desmonema Berkeley et Thwaites
01230000

Colony a dichotomously branching group of filaments forming a bushy-cushion shape. Trichomes straight, several within one sheath, each with a basal heterocyst. The overall structure is like a form of *Tolypothrix* with multiple trichomes per sheath.

Desmosiphon Borzi
01240000

Colony crustose, forming flecks on rocks and (rarely) submerged plants. Upright filaments, sparingly branched, with branching sometimes appearing almost dichotomous. Cells inside the filaments usually in a single row, occasionally two rows in old parts of a colony, each cell appearing somewhat separated from the adjacent one. No heterocysts or akinetes.

The genus *Stauromatonema* (not recorded for the British Isles) possesses heterocysts, but is otherwise quite similar, so the possibility should be considered as to whether the non-heterocystous forms are not merely an environmentally induced form.

Dichothrix Zanardini
01250000

Colony forming a mat, cushion or bushy, consisting of many filaments with tapered trichomes. False branching conspicuous and at the base of false branches there are often many trichomes in a common sheath. Trichomes with a basal heterocyst and sometimes also a few intercalary ones; usually ending in a long multicellular hair. Sheaths often yellow-brown. Hormogonia are released from the apical parts of trichomes as a result of phosphate enrichment.

This genus merges with *Calothrix* and is distinguished only by the greater tendency for false branching and the fact that there may be many trichomes in a common sheath. The bushy (penicillate) habit in some species develops because the false branching is subdichotomous.

Entophysalis Kütz.
01260000

Colony irregular, gelatinous, granular, microscopic or macroscopic (consisting of many subcolonies). Cells or groups of cells with a marked tendency to be arranged in rows. Each cell with a distinct sheath, often lamellate. Cells spherical or rounded-polygonal in outline. Cells in three different planes in successive generations (according to Komárek and Anagnostidis, 1999).

Eucapsis Clements et Schantz
01270000

Colony usually free-floating among submerged plants, forming a cube of mucilage, with cells arranged three-dimensionally in perpendicular rows. Large colonies are sometimes composed of sub-colonies.

Fischerella
01280000

Colony usually forming mat on a moist terrestrial surface, but sometimes in shallow water or stream. Branched structure, with most branches derived from cell division in a plane perpendicular to the main axis i.e. true branching. Filament with one or several rows of cells, the main axis usually much broader than the branches; trichomes with intercalary heterocysts.

Hapalosiphon and *Fischerella* merge into each other and the genera are sometimes combined. However, it is suggested that both are retained both for the time being. The only real difference is that the main axes of *Fischerella* tend to differ much more from the side branches than they do in *Hapalosiphon*.

Gloeocapsa Kütz.
01290000

Colony usually epilithic, sometimes epiphytic; initially microscopic, but often developing into an amorphous macroscopic structure; mucilaginous, multicellular. Cells and their immediate groups surrounded by sheaths, which are usually obviously lamellate, although scarcely or not at all so in several species (separated as *Gloeocapsopsis* by Komárek and Anagnostidis, 1999). Cells spherical, subspherical or (after division) hemispherical.

The binomials used in Geitler (1932) have been retained here, because it is sometimes difficult to equate the revisions made by Komárek and Anagnostidis (1999) with ones made by other authors. Komárek and Anagnostidis (1999) separate forms where division occurs in three

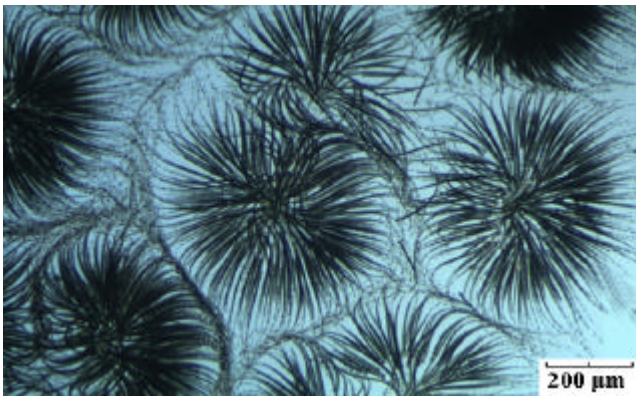
perpendicular planes in successive generations (= *Gloeocapsa* Kütz. 1843 sensu Komárek and Anagnostidis, 1999) and forms where cell division is irregular in successive generations (= *Gloeocapsopsi*s Geitler ex Komárek 1993). As several other characters tend to occur among the latter group, further study may justify separation on this or similar lines. However, it is unlikely that most users will be able to separate the two, so all are retained under the genus *Gloeocapsa* here.

Gloeothece Nägeli
01300000

Colony usually small, composed of sheathed cells or groups of cells; each cell has its own sheath which is formed during or immediately after division; these sheathed cells are usually embedded in communal mucilage. Sheaths often lamellate; colourless, bluish or yellow-brown. According to Komárek and Anagnostidis (1999), cell division is transverse to the longitudinal axis, in one plane in successive generations.

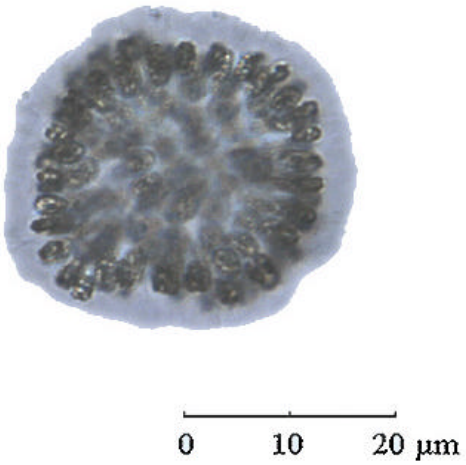
Gloeotrichia J.Agardh
01310000

Gloeotrichia echinulata



Colony spherical or, if attached to a surface, hemispherical or part of a sphere; mucilage throughout the colony or in some species partially hollow when old. Trichome inside colony, tapered, with basal heterocyst, partially enclosed in a sheath. Trichome usually ends in a hair, which is sometimes very long. Sheath firm at the base, becoming soft or even diffluent further from the base. Filaments radial, more or less parallel, often with false branches. Akinete, large, often cylindrical or subcylindrical, forming immediately above the heterocyst. Hormogonia are released from the apical parts of trichomes as a result of phosphate enrichment. Colony formation occurs by aggregation of motile trichomes, either ones released by akinetes or the hormogonia released at the ends of trichomes under nutrient-rich conditions.
Freshwaters.

Gomphosphaeria Kütz.
01320000 *Gomphosphaeria lacustris*



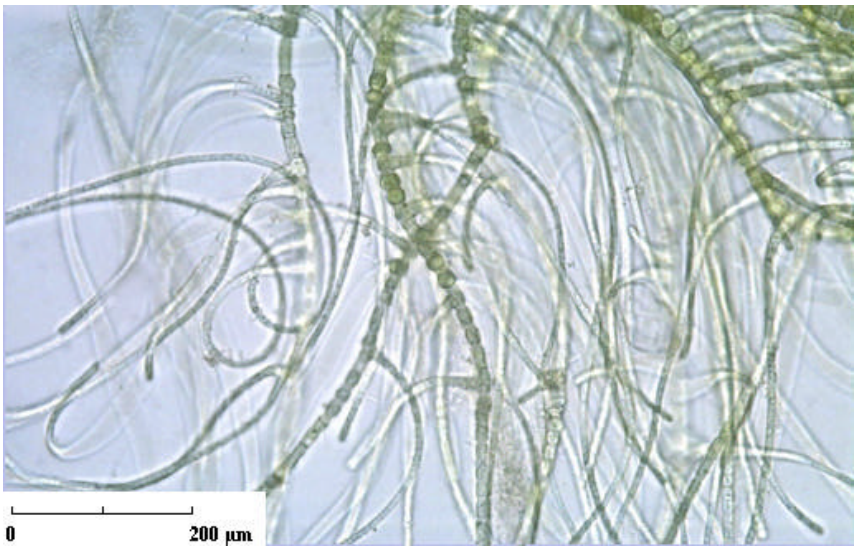
Colonies spherical, subspherical or somewhat irregular in outline due to the presence of the subcolonies which form a stage in the progress towards formation of daughter colonies. Cells elongated in the radial axis and occurring at the ends of branching stalks which are much narrower than the width of the cell. Cells obovate, but remaining partially joined for part of the cell cycle, giving rise a characteristic heart shape. There is always a distinct space beween adjacent single or paired cells.

Hammatoidea W. et G.S.West
01330000

Filaments with trichomes which taper markedly at either end, usually ending in long hairs; heterocysts and akinetes absent. Filaments are usually bent in the middle, sometimes with a false branch.

This is somewhat like a form of *Calothrix* without heterocysts. However, populations appear to exist in this form for long periods, so it is probably not just a growth form of *Calothrix.*

Hapalosiphon Nägeli
01340000 *Hapalosiphon fontinalis*



Colony forming mat on a terrestrial surface or a floating floc; branched structure, with most branches derived from cell division in a plane perpendicular to the main axis i.e. true branching, but sometimes also false branches. Filament with one or two rows of trichomes; trichomes with heterocysts; heterocyst almost always intercalary, sometimes small and easy to overlook, but in other cases distinctly longer the vegetative cells. Branches are usually narrower than the axis from which they arose, but this may be less obvious in floating forms, where the branches tends to occur repeatedly.

Hapalosiphon and *Fischerella* merge into each other and the genera are sometimes combined. However, it is suggested that both are retained both for the time being. For comments on the differences, see *Fischerella*.

Homoeothrix (Thur.) Kirchner sensu Komárek et Kann
01360000

Colony a slightly flattened hemisphere, crust or tuft. Trichome slightly tapered, unbranched or showing false branching, usually with obvious sheath. Heterocysts and akinetes absent.

The genus consists of a range of colony-forming structures with tapered trichomes, which sometimes look quite like a member of the Oscillatoriaceae and other times like a *Calothrix* lacking a heterocyst. Almost certainly the species included here are phylogenetically diverse.

Hydrococcus Kütz.
01380000

Colony small, rarely exceeding 500 µm, more or less circular in outline, epiphytic or epilithic, consisting of densely packed cells which appear almost like a parenchyma. Colony typically

flat initially, but becoming more or less hemispherical when old. Old margins of colony with short radially arranged rows of cells; cells in middle of colony are arranged in vertical rows, though this arrangement sometimes becomes less obvious in old colonies. Cell spherical, oval or slightly elongate and curved at the outer end of a radial row.

Hydrocoleum Kütz.
01390000

Filament consists of a sheathed group of *Oscillatoria*-like trichomes, with several trichomes inside one sheath; sheath usually colourless. End of trichome straight, more or less attenuate, end cell often with calyptra. Filaments tending to branch, forming a tuft or membranous thallus.

Hydrocoryne Schwabe
01400000

Irregularly branched filaments, usually containing several heterocystous trichomes running parallel to each other. Heterocysts intercalary. Akinetes formed.

There are apparently no reliable records from the British Isles for the single species within this genus, but it is widespread in many other countries. The genus is somewhat like a heterocystous parallel to the non-heterocystous genus *Schizothrix*.

Hyella Bornet et Flahault
01410000

Thallus ("colony") on calcareous rocks, mollusc shells or other calcareous substrata, usually clearly differentiated into a surface growth of irregular short branching pseudofilaments and endolithic growth reaching to various distances in the substrate. Pseudofilaments with one or more rows of cells, though the structure less obvious in older parts of the thallus. The endolithic pseudofilaments, which bore into the substrate, are usually morphologically quite different from the initial pseudofilaments. Mucilage sheaths are firm, usually layered and usually evident between adjacent cells.

Isactis Thur.

Colony of sparingly branched upright filaments embedded in communal mucilage. Trichomes tapering markedly, usually ending in long multicellular hair; basal heterocyst.

This is much like a form of *Rivularia* forming a stratum of upright, more or less parallel filaments and the genus should perhaps be recombined with *Rivularia*.

The genus (represented by the single species I. plana (Harv.) Thur.) was originally described from the Britain, but there do not appear to be modern records. It is widespread elsewhere, so should be looked for again. Epiphytic and epilithic in the interlittoral.

Johannesbaptistia De Toni
01420000

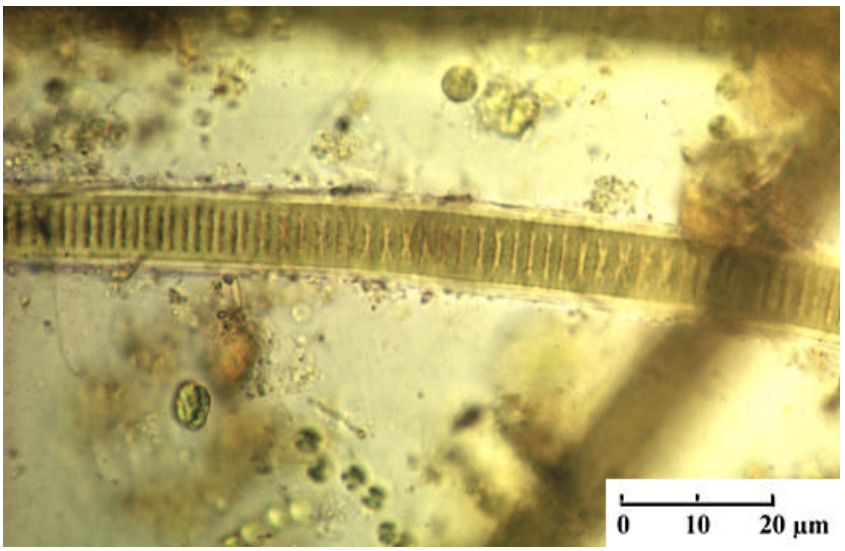
Rows of cells embedded in mucilage and with mucilage separating adjacent cells (= pseudofilament); pseudofilaments occasionally branched. Cells oval, with long axis perpendicular to the axis of the pseudofilament. Mucilage envelopes colourless, structureless, usually with the margin more or less distinct.

Kyrtuthrix Erceg.

Colonies endolithic in calcareous rocks, but forming a rich brown colouration at the surface due to the rich yellow-brown colouration of sheaths near the surface. Trichomes embedded in mucilage flexuous, curved-flexuous, but otherwise more or less parallel to each other; false branching present, with a reverse V-shaped structure. Trichomes with intercalary heterocysts and terminal hairs.

This monospecific genus (*K. dalmatica* Erceg.) is listed here; although there are no British records, it should be looked for in the supralittoral and upper intertidal of limestone cliffs on unpolluted parts of the coast. The species is quite similar in overall morphology to *Brachytrichia quoyi* and should perhaps be incorporated within *Brachytrichia*, as done by Frémy (1929-1933)

Lyngbya C.Agardh
01430000 *Lyngbya aestuarii*



Trichome typically inside a firm sheath, which ranges from thin to very thick according to species. Sheath usually colourless, athough occasionally pale yellow-brown or other colour.

Filaments free-swimming or loosely or firmly attached to a substratum; if attached, this may be at the base, in the middle or the entire filament; sometimes spirally coiled. Hormogonia formed as the result of release of lengths of trichome under conditions particularly favourable for growth. In some of the larger aquatic species (e.g. *L. aestuarii*) the trichome often moves out of the sheath; as this frequently occurs in response to the changed environment in a sample bottle, no doubt many records for large planktonic *Oscillatoria* are in fact *Lyngbya*.

Mastigocoleus Lagerh.
01450000

Thallus growing predominantly endolithically on marine calcareous substrata. Filaments with true branching; branching irregular. Trichomes single with sheath, with heterocysts terminal on short branches or lateral on a much reduced cell which looks like a stalk. In addition to the frequent short branches with heterocysts, there are actively growing branches and branches which are markedly tapered or forming multicellular hairs.

Merismopedia Meyen
01460000

Merismopedia glauca

Colony microscopic or, rarely, macroscopic, forming a square or rectangular plate of cells, often with several subcolonies remaining adjacent. There is a great range of forms and a large number of species have been recognized: 22 in Komárek and Anagnostidis (1999). However, few, if any, species are really well delimited and most appear to be merge into another one another. The names in the LucID package are all ones which have been recorded a number of times in the British Isles and many, but not all, records should fit quite well into one of these.

Pink forms (due to dominance of phycoerythrin) are frequent in strongly shaded microhabitats, but these are almost impossible to distinguish from the photosynthetic bacterium *Thiopedia* with use of fluorescence microscopy (presence of chlorophyll in the blue-green alga). If the latter is unavailable, it may be possible to confirm *Merismopedia*, if a mixed sample including the suspect colonies is transfered to a slightly higher light intensity for several days; *Merismopedia* (but not

Thiopedia) colonies may change to pink-olive. Fluorescence microscopy may also be needed to establish whether plates of very pale cells are in fact *Merismopedia*.

The four species listed here are widespread, differ mainly in cell width and more or less cover the cell size range found within the genus. Notes on gas-vacuolate forms in lake plankton are included under *M. trolleri* in Komárek and Anagnostidis (1999).

Microchaete Thur.
01470000

Filaments attached by one end to a substratum, single, or with colonies of many filaments, which are arranged irregularly or forming a turf. Filament consists of one trichome surrounded by a narrow, but usually very distinct sheath. Trichome not tapered at end; heterocyst basal, occasionally also intercalary. Akinetes occur in some species, usually in short rows next to the heterocyst. Hormgonia formed under nutrient-rich conditions.

Microcoleus Desm.
01480000

Filaments unbranched or sparsely branched, each sheath with a number of trichomes. Sheath colourless (or almost so), more or less cylindrical, not lamellated, but sometimes gelatinizing when old. Trichomes usually many in one sheath, densely aggregated and sometimes coiled and appearing like a rope; the trichomes are sometimes highly motile and may be seen moving backwards and forwards within the sheath. Trichome without heterocyst; end cell usually conical, but seldom capitate.

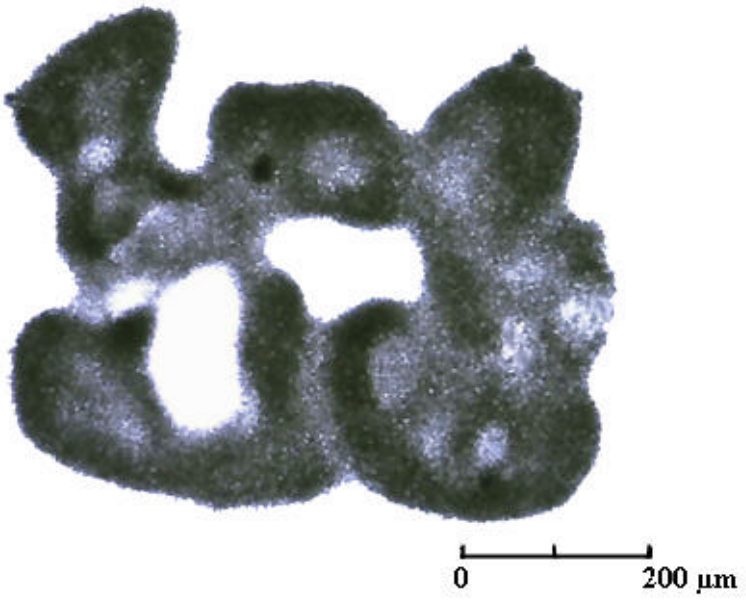
The genus is especially characteristic of saline environments, such as salt marshes and the soil surface in arid regions.

Microcrocis Richter 1892
01350000

Colony microscopic or macroscopic, with cells forming a plate embedded in mucilage; cells elongate, oriented by their longer axis perpendicular to the plane of the colony. Cells often arranged in perpendicular rows in young colonies, but later becoming irregular. Cells ellipsoidal, oval or rod-shaped, with rounded ends. Cells divide lengthwise in two perpendicular planes in successive generations.

The genus was formerly treated as subgenus *Holopedium* Richter of *Merismopedia*, but differs in the elongated cells and their irregular arrangement in older colonies.

Microcystis Kütz. 1833 ex. Lemmerm. 1907 nom. cons.
01490000 *Microcystis aeruginosa*

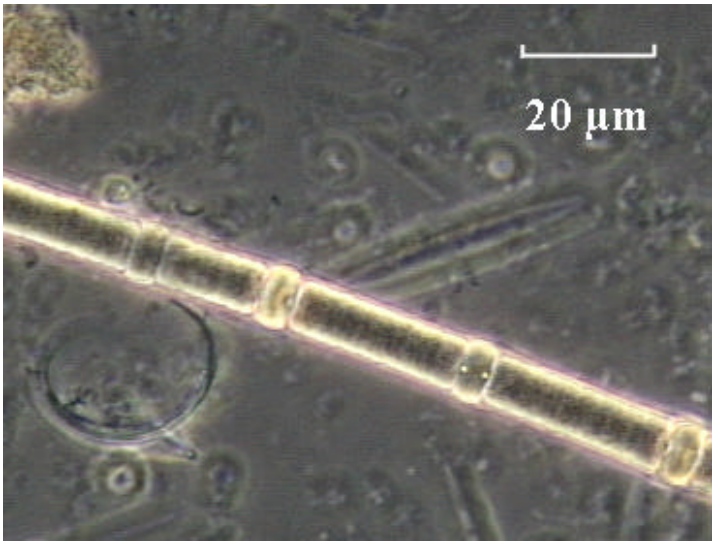


Colony irregular or (less often) subspherical consisting of large numbers of cells embedded in mucilage; colony increase by fragmentation. Cells spherical or hemi-spherical after division; gas vacuoles present when the colonies are planktonic, though gas vacuoles apparently absent or few when colonies rest on bottom sediment. Cell division probably always in three planes perpendicular to each other, though this is hard to distinguish in field samples.

The descriptions adopted for the three species here reflect the accounts of Komárek and Anagnostidis (1999). The species differ in the extent to which the outer margin of the colony is firm, whether or not it contains an outer zone free of cells, how densely the cells are packed in the rest of the colony and, to a lesser extent, on the size of the cells. Forms are likely to be found whch do not correspond particularly well to any of the three descriptions. Photos and notes should be made of populations whose taxonomic status is unsure.

Komárek and Anagnostidis (1999) recognize ten species, but most are highly variable. Further, molecular studies have given little indication that the classical species correspond well with observed molecular differences. It seems likely that different species limits will eventually be adopted than those used here, if in fact it is ever possible to recognize species adequately from field material.

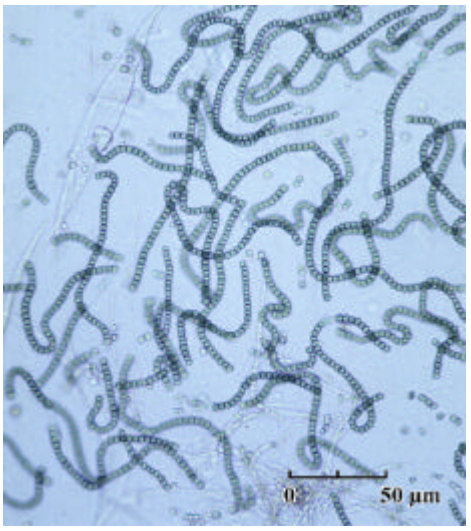
Nodularia Mertens
01510000 *Nodularia spumigena*



Filaments unbranched, with single trichome and either a thin layer of diffluent mucilage or a narrow, but distinct sheath. Trichomes with intercalary heterocysts, occasionally two together. Vegetative cells and heterocysts wider than long, sometimes markedly so (discoid). Akinetes in short rows, usually distant from, but sometimes adjacent to, the heterocyst.

This is characteristically a genus of marine and brackish habitats, though there are occasional records for freshwaters.

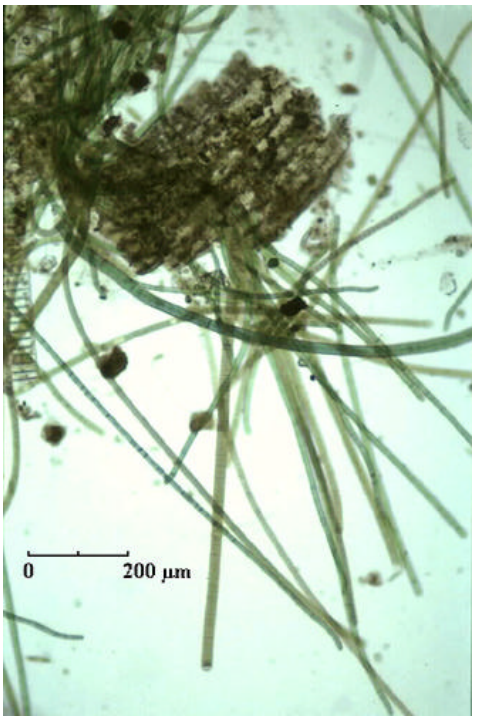
Nostoc Vaucher
01520000 *Nostoc planctonicum*



Colony small and amorphous or, more usually, a macroscopic gelatinous or leathery structure; very small colonies subspherical or elongate, but usually becoming spherical during the early period of rapid growth; subsequently they may develop a variety of shapes which are often characteristic of the species. Colony consists of many trichomes embedded in communal mucilage; in older colonies the trichomes are mostly located towards the exterior. Individual colonies develop from single trichomes, though older colonies may include developing subcolonies. Many species form akinetes, each of which develops from one vegetative cell, which increases in size and develops an obvious wall; akinete morphology is a useful feature to aid identification.

Nostoc is sometimes closely associated with various other organisms.

Oscillatoria Vaucher
01530000 *Oscillatoria* (mixed population)



Trichome single or forming a flat or amorphous free-floating colony. Sheath absent, rarely with a more or less delicate sheath. Trichomes motile when attached to a substratum and sometimes also when adjacent to each other, often with rotation on the longitudinal axis. End of the trichome often with disinctive features which may be important in identification of species. Increase by division of trichome, this involving the formation of a necridium in some species.

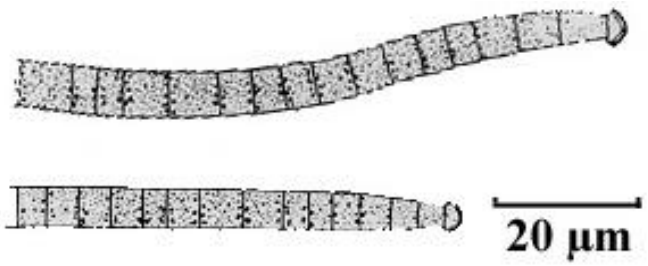
The separation of this genus from *Lyngbya* and *Phormidium* has long worried taxonomists, because the features used to distinguish the genera are often ones markedly influenced by environmental conditions. In addition *Oscillatoria* includes forms which are clearly very different from one another and Komárek and Anagnostidis (1999) has split the genus. The case for the separation of one group as *Planktothrix* is especially convincing, but the generic limits used here are largely those of Geitler (1932), because it seems sensible to adopt a conservative approach until there is a full revision including molecular studies.

Pannus Hickel 1991
01540000

Colony microscopic, free-floating, hollow, in young stages irregularly spherical with holes, later more irregular, in old stages usually elongate and lobate. Cells in one to three layers of often more or less radially, densely distributed cells, embedded in colourless mucilage; often a highly diffluent layer of mucilage external to the main part of the colony. Cells spherical, sometimes with gas vacuoles. Cell division in two planes in successive generations.

Phormidium Kütz.
01550000

Phormidium favosum



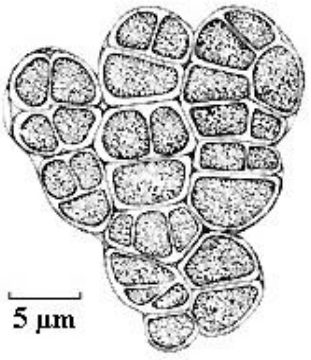
Many trichomes aggregated to form a gelatinous or leathery layer, with the thallus attached to a substratum or floating in water. Sheath present, thin but more or less distinct, but with tendency to agglutinate and sometimes diffluent; sheath colourless. Trichome often modified towards the ends and these features are important in identification.

Plectonema Thur.
01560000

Trichome enclosed in a thin firm sheath, with branches single or geminate (appearing like a pair); heterocysts and akinetes absent. This genus is essentially like *Lyngbya*, but with false branching; in narrow forms it may be difficult to resolve from *Lyngbya*, but the pattern of branching in some wide species is easy to recognize and characteristic. The genus also merges with *Schizothrix*, where there are a number of trichomes within a single sheath.

Pleurocapsa Thur. 1885
01570000

Pleurocapsa minor



Colony attached to a surface, as an irregular individual, crust or a larger irregular group of more or less distinct individual colonies. Growth occurs in three different ways, two or all of which are usually present in the same colony:

i) irregular groups of cells (chroococcalean stages);

ii) radial rows of cells which form 'pseudofilaments' when well developed; pseudofilaments may be 1- or multiseriate;

iii) endospore (baeocyte) formation.

The generic limit recognized by Geitler (1932) has been retained for all three species here, although more recent authors place *P. fluviatilis* in other genera or even family. This may well be justified, but a conservative approach is adopted here until molecular studies have been made.

Pseudanabaena Lauterb.
01580000

Short trichomes of narrow cells distinctly indented at cross-walls.

Pseudoncobyrsa Geitler
01590000

Geitler (1932) included two species within this genus, but Komárek and Anagnostidis (1995) separate the one recorded for the British Isles (Fritsch, 1929) to *Cyanodermatium* Geitler 1933.

Raphidiopsis F.E.Fritsch
01600000

Trichomes short, usually single, typically strongly curved, with one or both end cells tapered to a point. Heterocyst absent; akinetes (where developed) in the middle of the trichome; gas vacuoles usually visible.

Rhabdoderma Schmidel et Lauterb.
01610000

Colony microscopic, more or less ovoid or elongate-irregular, mucilaginous. Cells usually well spaced in colony and often more or less oriented in the direction of the longer axis of the colony. Cells rod-shaped, straight, slightly curved or sigmoid, longer than broad, often several times so. The cells, which divide transversely to the long axis, sometimes remain in loose contact after division, forming a filament-like structure.

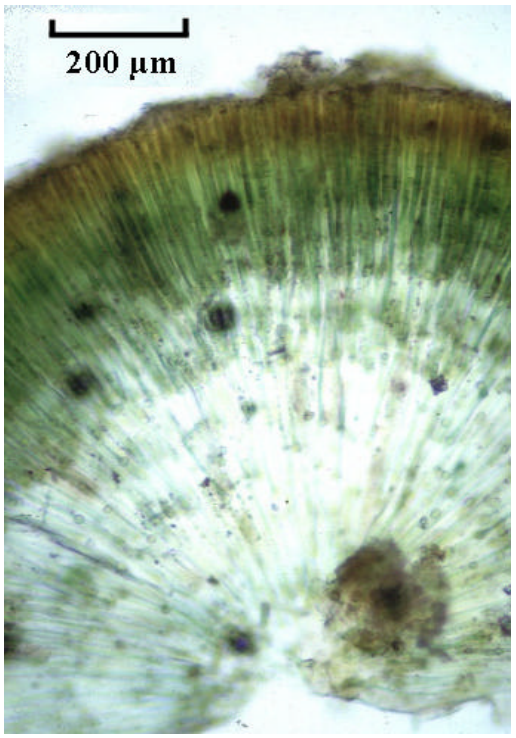
Rhabdogloea Schröder
01210000

Colony mucilaginous, microscopic, irregular in shape, though often slightly elongated; usually free-floating; up to (about) 16 cells spaced irregularly in the mucilage. Cells elongate, narrow, spindle-shaped, ellipsoidal or more or less cylindrical with acute or acute-round poles, straight, slightly bow-shaped or sigmoidally coiled; gas vacuoles absent. Cells with tendency to be oriented in the same direction, especially in smaller colonies.

Cell division binary, transverse to the long axis, giving rise to two more or less equal daughter cells.

The only character separating the genus from *Rhabdoderma* is the shape of the cells, but the name is retained for the time being.

Rivularia Roth
01620000 *Rivularia atra*



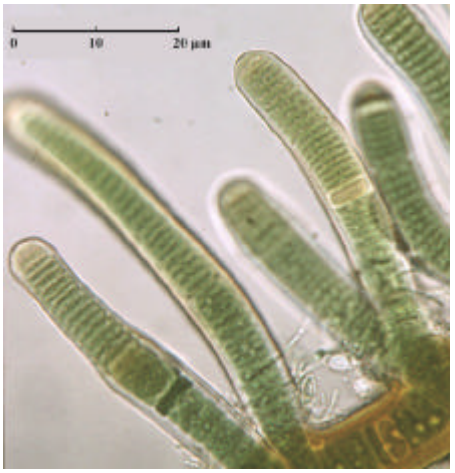
Hemispherical or subspherical colonies containing a large number of filaments which are arranged radially or sometimes parallel to each other in part of the colony. Each filament contains a tapered trichome, which has a basal heterocyst and often ends in a long multicellular hair; occasional intercalary heterocysts sometimes also present. False branching sometimes evident. Sheath extends for much of the length of the trichome and is often frayed at the apical end; outer surface tends to merge with the communal mucilage of the colony. Colonies of some larger species can persist for several years and are often calcified. No akinetes. Hormogonia are released from the apical parts of trichomes as a result of phosphate enrichment. Colony formation occurs by aggregation of the released hormogonia, so a particular colony is not necessarily genetically homogeneous.

Schizothrix Kütz.
01630000 *Schizothrix lardacea*

Trichomes usually many within one sheath, with may be thin or thick. The sheaths are often closely aggregated to form a gelatinous or leathery sheet; individual trichomes of wider species may also have their own sheath and the various sheath layers are often highly lamellated. Sheaths with their component trichomes branched rarely or frequently. Sheath colourless or with a range of colours, especially yellow-brown or red; the red colour may not always be obvious under the microscope in species with narrow trichomes, yet the colony as a whole may appear strongly coloured.

Scytonema C.Agardh
01640000

Scytonema myochrous



Filaments false branched, false branches single or geminate (appearing like a pair); occurrence of geminate branches is the characteristic feature of the genus, but in many species it occurs with only some (perhaps even a minority of) branches. Branches formed laterally generally in between heterocysts. Trichome single in each sheath, straight. Hormogonia formed at the apex under certain favourable growth conditions. Akinetes known in a few species, spherical or oval, surface thin and smooth; it is unclear whether in such cases this ability is characteristic of the species as a whole.

Growth in *Scytonema* tends to occur towards the apex, though in aquatic turf-forming species, the growth region is slightly below the apex, permitting the organism to respond to grazing like grass in a meadow. The older parts of the trichome tend to break down, but the sheaths are often highly persistent, leading in some species to a the development of a miniature algal peat.

The separation of *Scytonema* from *Tolypothrix* is artificial, but it is convenient to retain this, at least until critical studies of a wide range of species have been made.

Siphononema Geitler
01650000

Colonies attached to substratum, microscopic to macroscopic. Initial cell cylindrical, subspherical or club-shaped, with colourless, yellow or orange pseudovagina, subsequently dividing in the upper part to form pseudofilaments or irregular masses of cells embedded in mucilage.

Spirulina Turpin
01660000

Trichome cylindrical, without heterocysts, loosely or tightly coiled into a regular spiral; sheath absent; apex of trichome usually not attenuated, terminal cell rounded, without calyptra; cross-

walls difficult to resolve with light microscopy without staining. Trichomes often show motility if in contact with a surface.

Stigonema C.Agardh
01670000 *Stigonema mamillosum*

Colony a branched structure, with the branches derived from cell division in a plane perpendicular to the main axis i.e. true branching. Branches develop into a structure similar to that of the main axis, so that even in forms with a clear differentiation in prostrate and 'upright' filaments, they all have a broadly similar structure. Filaments with one or several rows of cells, the arrangement into distinct rows sometimes difficult to recognize in the old filaments of several species. Trichomes with heterocysts, which sometimes develop into shapes quite different from that of the original vegetative cell; heterocysts mostly intercalary, but sometimes lateral. Sheath often yellow-brown and sometimes lamellated. Hormogonia formed at the end of young branches, usually consisting of only a few cells (sometimes only 2).

Symploca Kütz.
01680000

Filaments initially prostrate on a surface, but soon developing into a colony of upright bundles of filaments. Filaments occasionally showing false branching, but otherwise a single trichome within the narrow sheath; sheath firm or somewhat gelatinous. Trichomes more or less straight, though sometimes slightly narrowed towards the apex; heterocyst absent.

Some species in this genus are quite similar to some species of *Schizothrix.* The key differences are the tendency to form upright bundles in *Symploca* and fact that the trichome is always single inside the sheath.

Synechococcus Nägeli
01690000

Cells single or grouped into microscopic or macroscopic colony, which is largely free of obvious mucilage. Cells long oval or cylindrical. Cells divide transversely, always in one plane

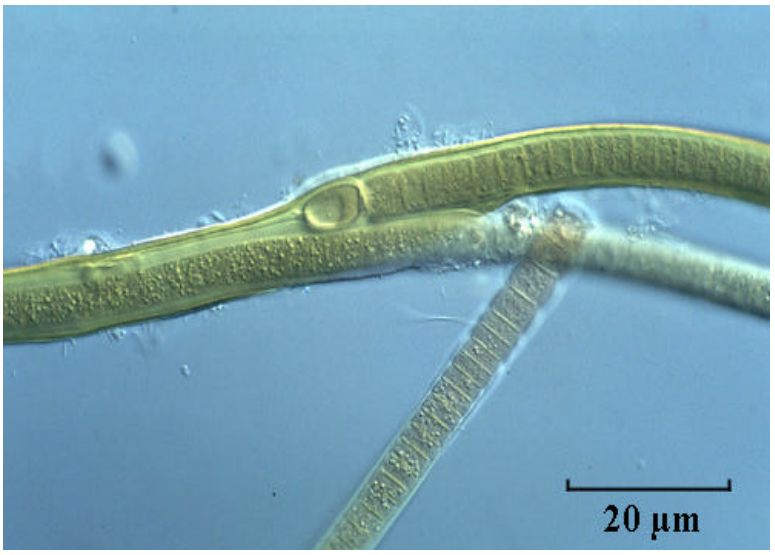
in successive generations, usually giving rise to two similar daughter cells, but occasionally asymmetrical.

Komárek et Anagnostidis (1999) separate three large-cell species into *Cyanothece* Komárek 1976; these often show a characteristic structure for the cytoplasm, which probably reflects the presence of intrathylakoidal vacuoles seen with the electron-microscope. The widespread *S. aeruginosus* is one of these.

Synechocystis Sauv.
01700000

Cells solitary spherical, broadly ovoid, or (after division) hemispherical, either lacking mucilage or with narrow indistinct mucilaginous layer associated with each cell. Cell division by binary division, with successive divisions in two different perpendicular planes. (Description based on Komárek and Anagnostidis, 1999.)

Tolypothrix Kütz.
01710000 *Tolypothrix penicillata*



Filaments with a thin or thick firm sheath, colourless or frequently yellow- to deep brown. False branched, branches single, mostly subtended by a heterocyst. Hormogonia formed at the tips under especially favourable growth conditions. Growth mostly occurs apically; apices often broader, with shorter cells. Akinetes occur in a few species, but it is unclear whether this is a characteristic feature of the species as a whole.

Trichodesmium Ehrenb.
01720000

Trichomes united in free-floating bundles. Trichome may or may not be gradually tapered towards the end; if not so, the end-cell is often narrowed; gas-vacuoles usually obvious.

Mostly marine or highly brackish waters.

Xenococcus Thur.
01730000

Cells solitary or, more usually, forming one-layered groups which can extend over a considerable area, sometimes making a distinct crust; almost always epiphytic. Cells more or less polarized, sometimes slightly elongate along the vertical axis; sheath usually evident around each cell. Mature cells all more or less the same size. Cells divide irregularly in several planes, but usually perpendicular to the substratum; multiple divisions (endospores = baeocytes) occasionally occur.

2 GUIDE TO THE CHARACTERS USED FOR IDENTIFICATION

This Section provides a guide to interpreting the characters needed to identify a blue-green alga and which have been incorporated into the interactive system for identification (LucID). Many blue-green algae are highly variable, therefore, it is often difficult to decide how to score the characters for a particular population. Some of the problems encountered with individual characters are treated in this Section, but the reader needs to refer to Section 3 to understand the comments about LucID.

A few terms are used here or in descriptions of genera and species, but not the interactive key.

thallus is sometimes used instead of colony. In the case of highly amorphous structures, where colony is unsuitable, thallus is the only term to apply to the overall structure.

cordiform heart-shaped.

necridium a specific cell which collapses during trichome division in some species, permitting the two trichomes to separate; this occurs in some *Oscillatoria* species and many forms where hormogonia are released terminally e.g *Calothrix*

obovate egg-shaped, with the narrower end towards the base or substratum

pseudofilament a series of cells formed by repeated transverse division and arranged in a row (or approximately so), but not constituting a trichome.

*** Distinct Colony?**
Present
Absent

This applies whether the colony (a group of individuals, enclosed by a common sheath or joined together) is visible macroscopically or requires a microscope. If in doubt whether the structure should be regarded as a colony, it is best to assume that it is so.

LucID Different combinations of coding for the two states are used to try to overcome the limited number of character states permitted by LucID. Character states are not scored (as 0), if another category makes it inapplicable. For instance, where colonies are always absent, there is no information about colony shape.

*** If Colony, > 2 mm?**
Present
Absent

This is presented as a single state, as it is assumed that such colonies may be absent, normally present or rarely present. Most colonies easily visible macroscopically are larger than 2 mm,

but it is sometimes easy to see shining green colonies which are smaller than this e.g some *Nostoc*. The latter are treated here as 'absent'.

*** Colony Shape:**

Spherical/Subspherical
Hemispherical
Cube
Plate
Clathrate
Floc/Amorphous
Tuft/Bushy
Film/Mat
Crust/Fleck

Some of these terms are largely self-explanatory. Many *Nostoc* start as **spherical** (symmetrically rounded in three dimensions) or **subspherical** (not quite spherical; flattened at the poles) structures, but eventually become irregular and are described as **floc/amorphous**.
Hemispherical describes colonies of this shape such as *Rivularia* and some *Homoeothrix* which grow firmly attached to rocks.
Eucapsis is the only example for a **cube** and *Merismopedia* the typical example for a **plate**.
Clathrate refers to mucilaginous colonies which include extensive internal spaces, which are usually in contact with the external environment.
Floc/Amorphous refers to macroscopically visible groups of filaments, often mucilaginous, without a very distinct bounding layer. These may be floating or associated with submerged plants or other underwater surfaces; aggregated masses of many bloom-forming species are regarded as flocs. Flocs range in dimensions from a couple of millimetres to many centimetres.
Tuft applies to a group of filaments which are close together but without them all being enclosed in a communal sheath. **Bushy** is quite similar, but is where the tuft tends to separate into smaller groups of filaments towards the end. The terms are often, but by no means always, applied to filaments which are orientated perpendicular to the surface.
Film refers to thin layers of filaments on a surface such as a rock or sediment. It often consists of numerous highly motile filaments, frequently mixed with other motile organisms.
Mats are thicker and firmer than films and usually include distinctly sheathed organisms. There a wide range of mat structures and complex laminated structures with layers of different species sometimes occur in freshwaters and quite often do so in marine environments.
Crust/Fleck refers to samples which are very firmly attached to rocks; the form is typical of a number of species in fast-flowing rivers, but sometimes occurs elsewhere. Crusts may or may not be calcified.

*** Cells in Sub-colony/Colony (not filament):**

1
2-4
5-8
9-16
17-32
33 and +

This category is only relevant to the non-filamentous forms:
Aphanocapsa, Aphanothece, Chroococcus, Coelosphaerium, Cyanodermatium, Cyanodictyon, Dermocarpa, Entophysalis, Eucapsis, Gloeocapsa, Gloeothece, Gomphosphaeria, Hydrococcus, Johannesbaptistia, Merismopedia, Microcrocis, Microcystis, Pleurocapsa, Rhabdoderma, Rhabdogloea, Siphonema, Synechococcus, Xenococcus and filamentous non-Hormogonales forms e.g. *Hyella*.

*** Filament?**

Present
Absent

Filament is often used interchangeably with 'trichome' in forms which do not have a sheath (e.g. *Oscillatoria*), but in those forms with a sheath (e.g. *Lyngbya*) it refers to the trichome and its investing sheath. Thus, filament and trichome width are the same in *Oscillatoria*, but the filament width is more than the trichome width in *Lyngbya*.

LucID Pseudofilaments are included as filaments.

*** If Filament present:**

Hormogonales
Non-Hormogonales

Hormogonales is one of the major orders in classicial botanical descriptions of the blue-green algae to describe genera whose species produce a hormogonium. The hormogonium (plural, hormogonia) is a short length of filament broken away from a mature trichome and is considered to be a multicellular reproductive structure. Typically it is much more distinctive in those species of blue-green algae which form heterocysts. Hormogonia usually show gliding motility when attached to a surface, though some are highly gas-vacuolate and may initially not attach to a surface. In *Oscillatoria* and *Cylindrospermum*, the hormogonia are formed by disintegration of whole filaments, while in branching forms such as *Scytonema* and *Stigonema* they are formed by separation at the tip. In hair-forming species (e.g. many *Calothrix* and *Dichothrix*) they form immediately below the hair, which then disintegrates. The genera listed are:
Amphithrix, Anabaena, Aphanizomenon, Arthrospira, Brachytrichia, Calothrix, Crinalium, Cylindrospermum, Desmonema, Desmosiphon, Dichothrix, Fischerella, Gloeotrichia, Hammatoidea, Hapalosiphon, Homoeothrix, Hydrocoleum, Hydrocoryne, Lyngbya,

Mastigocoleus, *Microchaete*, *Microcoleus*, *Nodularia*, *Nostoc*, *Oscillatoria*, *Phormidium*, *Plectonema*, *Pseudanabaena*, *Raphidiopsis*, *Rivularia*, *Schizothrix*, *Scytonema*, *Spirulina*, *Stigonema*, *Symploca*, *Tolypothrix*, *Trichodesmium*

Non-Hormogonales filaments refers to forms which sometimes look filamentous, but never form hormogonia e.g. species of *Hyella*.

*** If Non-Hormogonales, Growth by:**

Binary division (approx.)
Apical spores
Endospores

This group includes all the forms which never form filaments, together with a few others (see above).
Binary division occurs in many non-Hormogonales.
Apical spores (exospores) are products of cell fission and are characteristic of species of *Chamaesiphon* and *Siphonema*.
Endospores are also products of cell fission and are characteristic of species of *Clastidium*, *Dermocarpa*, *Pleurocapsa* and *Xenococcus*. Division may be binary (*Clastidium*, some stages of *Pleurocapsa*) or multiple (other stages of *Pleurocapsa*, *Dermocarpa*, *Xenococcus*). The term 'endospore' is replaced by baeocyte in Castenholz and Waterbury (1989), because the multiple fission found in this group is unique among prokaryotes.

*** Filament Branching (Hormogonales only):**

Unbranched
False branch
True branch

True branching is a branch formed by lateral cell division, whereas **false-branching** is a branch not formed by lateral cell division, but by a lateral outgrowth initiated by cross-breakage of a filament.

*** Firm Sheath/Colony Boundary?**
Present
Absent

This refers to a covering or envelope (usually composed of mucilage) associated with filaments, microscopic colonies such as some species of *Chroococcus* or macroscopic ones such as most *Nostoc*. Note that the *Oscillatoria*-like trichomes of several species of *Lyngbya* often glide out of their sheaths when live material is returned to the laboratory. This tends to occur especially in those species with broader trichomes.

LucID Different combinations of coding for the two states are used to try to overcome the limited number of character states permitted by LucID.

*** Mucilage (not sheath)?**
Present
Absent

This category is used for organisms with an obvious mucilage (gelatinous or jelly-like substance) layer, but no firm outer boundary. Species forming flocs usually belong here.

*** Sheath/Mucilage Layered?**
Present
Absent

The presence of distinct layers in the sheath is a characteristic feature of some genera e.g. *Chroococcus*. Many of the larger filamentous forms also have distinct layers in the sheath, including non-heterocystous genera such as *Lyngbya* and heterocystous ones such as *Scytonema*. They are especially characteristic of most semi-terrestrial surfaces, but by no means confined to them. The presence of very distinct layers in filamentous forms is usually regarded as a feature which distinguishes species where they are present from ones where they are absent.

*** Sheath/Mucilage colour:**
Colourless
Yellow to brown
Red
Blue/Violet

Yellow-brown or brown shades are usually due to the presence of scytonemin and its synthesis apparently normally requires ultra-violet light. Yellow-brownish shades will therefore be more obvious under high light intensity or in the outer parts of individual colonies. If the material in question has not been exposed to high light, the absence of colour may not be a reliable character; if only a small part of the material has a slight colouration, it should be treated as positive. The various colours are often regarded as characteristic of a particular

species and there is some doubt about species which include forms lacking any colour and others with intensive brown colour. Brown colouration can sometimes result from iron and manganese oxide deposits. **Red**, **violet** and **blue** colours are largely restricted to *Gloeocapsa*. *Schizothrix coriacea* and S. *lardacea* can form striking red colourations in moist films on rocks when viewed macroscopically, even though the colour may hardly be visible when a narrow sheath is viewed with the microscope.

*** Calcareous Depositions?**
Present
Absent

Calcareous depositions are sometimes useful as a diagnostic character for species in calcareous environments. The presence of calcite can be checked with dilute HCl.
It seems likely that several of the species characterized mainly by their associated calcification are little, if any, different from other species without obvious calcification. However, a few such pairs of species have been maintained in the list until critical studies have been made e.g. *Schizothriz coriacea* and *S. lardacea*.

*** Cell:**
Width (µm)
Length (µm)

LucID If no numerical value was available an estimate was made from a line drawing. If only a single value was quoted in the reference a range was estimated using the following criteria:
0.3 µm either side of a dimension < = 3 µm
0.5 µm either side of a dimension in the range >3 to < = 10 µm
1 µm either side of a value for a dimension greater than 10 µm
e.g. a cell width of 6.5 µm would become the range 6 to 7 µm.
However, species descriptions which provide only a single dimension (rather than range) must be considered incomplete. If an unknown fits well with all other characters of an organism in the database, but lies slightly outside a narrow width range, this is probably a suitable name for the organism.

*** If Trichome, Cell Length to Width Ratio:**

< 0.5
> 0.5 to 1.0
> 1.0 to 2.0
> 2.0

Trichome refers to a linear arrangement or a thread of cells without the investing sheath.
The symbols for greater than and equal to and less than or equal to are not available in Excel, so:

< 0.5 refers to Ω0.5
> 0.5 to 1.0 refers to > 0.5 to Ω1.0
> 1.0 to 2.0 refers to > 1.0 to Ω2.0
> 2.0 refers to >2.0

LucID Length to width ratios were estimated from floral descriptions and line drawings.

*** Cell Shape (side view):**

Spherical
Subspherical/Ellipsoidal
Barrel-Shaped
Cylindrical/Disk
Spindle

Ellipsoidal Elongate, with slightly convex lateral margins and rounded, slightly narrowed ends.
Barrel-shaped Elongate, with slightly convex lateral margins, but ends which are not rounded.
Cylindrical/Disk Elongate with parallel lateral margins; often some or all of the akinetes in a population are slightly curved, but the extent to which this occurs varies between species.
Spindle 3-dimensional structure, starting cylindrical and slightly narrowing at either end.

*** Width of sheathed Cell/Filament (µm):**

The width of a sheath in relation to cell or trichome dimensions is relatively constant in some species, whereas in others it varies markedly according to environmental conditions or growth stage. This is especially true of false branched filamentous genera where much of the growth is restricted to apical or near-apical parts of the thallus such as most *Scytonema* species. The sheaths of some filamentous species persist long after the associated cells have died and width measurements can still be used for diagnostic purposes. If these is no live trichome inside, take care not to over-estimate the width by squashing the sheath under a coverslip.

*** If Firm Sheathed Hormogonales, Trichomes per Sheath:**
One
Two and +

This applies especially to *Microcoleus*, where individual trichomes may sometimes be seen to move backwards and forwards without leaving the enclosing sheath, and to branched sheathed forms such as species of *Hydrocoleus* and *Schizothrix.* In the latter genera only parts of the thallus may have two or more trichomes within the single sheath, so it is important to check the contents of a slide thoroughly.

*** Trichome or Elongated Sporangium Shape:**
Straight
Slightly Bent/Curved
Coiled
Spiral

Straight versus **Slightly Bent/Curved.** Many long unsheathed trichomes can flex when metabolically active, but the term is applied for taxonomic purposes to forms with a sheath (usually narrow) where there is a distinct bend or curve which persists when viewed over some minutes.
Coiled and **spiral** are terms which are not always used consistently in floras, but coiled typically refers to a more irregular arrangement or to the growth form of some filamentous epiphytes. Spiral refers to the condition where all or almost the whole trichome has a repeated spiral pattern, such as occurs in *Spirulina*.

*** If Spiral, Width of Spiral (µm):**

Spiral refers to the condition where all or almost the whole trichome has a repeated spiral pattern, such as occurs in *Spirulina*.

*** Trichome Tapering:**
Ends in Distinct Hair
Only at End of Otherwise Straight Trichome
Tapered for at Least One-third Length
None

Forms with **tapering** are often extremely variable, even within a population. In general, the most tapered trichomes should be selected for diagnostic purposes. Elongate hairs only form under conditions of nutrient limitation (phosphorus or, sometimes, iron), so may not be apparent in a particular population. Many species able to form **hairs** typically grow under conditions which favour the formation of these hairs, but they are not quite such a consistent feature as the presence of heterocysts in heterocystous genera. Hair morphology differs markedly in *Calothrix* and related genera, usually consisting of colourless cells which become

progressively more elongated the further from the base of the trichome; however the hairs of some species have most apical cells only slightly longer than the more basal cells of the hair. It is worth noting this feature, even though it has not been incorporated into the database.

*** Trichome in Section:**
Round (normal)
Flattened

Obviously **flattened** trichomes occur only in *Crinalium*.

*** Trichome Indented at Cross-wall?**
Present
Absent

The trichomes of some filamentous forms have visually very obvious **indentations** between adjacent cells, such that only parts of the end-wall are in contact with each other. In other cases the longitudinal wall of the trichome is continuous. However, many species are intermediate with respect to this feature and in addition it is sometimes markedly influenced by environmental conditions/growth stage; the decision as to how to code the material is then rather subjective.

LucID If in doubt, ignore this character or test the use of either choice.

*** Trichome with Granule(s) at Cross-walls (not gas vacuoles)?**
Present
Absent

The presence of several **granules** parallel to, and either side of, the **cross-wall** is considered in the floras to be a characteristic feature of some filamentous species, especially in *Oscillatoria* and related genera. In at least the majority of cases these are polyphosphate granules, but staining is needed to confirm that this is always the situation and thus exclude the possibility that they may sometimes be cyanophycin granules. The presence of such granules is likely to be influenced by nutrient conditions, so they are probably not always present and so should not be regarded as essential for diagnostic purposes. However, some species of Oscillatoriaceae never form granules in this position, even when in high nutrient conditions. (The granules often seen at the ends of heterocysts are cyanophycin.)

*** Trichome Apical Cell:**
Rounded
Conical
Capitate/Knob
Calyptra

Apical (end or terminal cell of a trichome; sometimes tapered to a fine point), **conical** (shortly tapered to a fine point), **calyptra** (membranous hood) and **capitate** (heart-shaped)

*** Heterocyst?**
Present
Absent

The **heterocyst** is a specialized cell carrying out nitrogen fixation. It is usually easy to distinguish by the obvious wall and sometimes (but not always) by the paler contents than adjacent vegetative cells. Heterocysts often have glistening granules of cyanophycin next to the end of ends of the cell adjacent to a vegetative cell.
Two character states are included to deal with the fact that some species never form heterocysts, whereas others form heterocysts only under certain conditions. Where heterocysts do occur in a species, this is usually the typical condition in which the material is found, apart from young hormogonia.

*** Heterocyst:**
Width (µm)
Length (µm)

Heterocysts may be larger or smaller than the vegetative cells and this appears often to be a species-specific character, especially where the heterocysts are intercalary.

*** Heterocyst Position:**
Basal
Intercalary
Lateral

Basal (at the base, terminal) **intercalary** (inserted between cells of a trichome rather than terminal or lateral), **lateral** (at the sides). In a few genera, such as *Nostoc*, the intercalary heterocyst may become detached from the vegetative cell on one, but not both sides. This then gives the superficial impression of being basal, whereas it should be scored as intercalary. Such heterocysts appear similar at each end, whereas basal heterocysts do not. Some species of *Calothrix*, *Dichothrix*, *Microchaete* and occasionally in a few other genera have both basal and intercalary heterocysts. This has been included in the scores for these species.

Some (perhaps all) species of *Calothrix* and *Dichothrix* sometimes form a succession of basal heterocysts. This apparently occurs in response to lack of a micronutrient (probably often iron). Only the heterocyst next to the vegetative cell is still active, the other cells collapsing into a range of shapes. The heterocyst next to the vegetative is still termed basal.

* **Akinete?**
Present
Absent

Akinetes are storage structures with an obvious wall and usually considerably larger than the vegetative cell. They are almost entirely restricted to heterocystous filamentous forms, but occur in a few others e.g. *Gloeocapsa magma*. The largest akinetes occur in those genera where many (e.g. some *Anabaena*) or all (e.g. *Cylindrospermum*) vegetative cells in a filament disintegrate during the formation of one akinete. Where almost all cells may differentiate into an akinete (e.g. *Gloeocapsa magma*, some *Nostoc*) the difference in size between akinete and ordinary vegetative cell is much less pronounced.

Akinetes are important in the identification of many species, especially *Anabaena* and *Cylindrospermum*, so it may be necessary to make repeat visits to get akinetes. This is especially important for *Cylindrospermum*, where typically all the akinetes in one colony develop at the same time. It is sometimes possible to obtain akinetes by keeping a field sample in the laboratory under suitable conditions; if possible, try several different light and temperature combinations.

*** Akinete:**
Width (µm)
Length (µm)

Try to get dimensions for mature **akinetes**. Particularly with cylindrical akinetes, there may be a considerable range of lengths, but it is recommended to select the longest for measurement. If the akinetes have started to develop, it is usually possible to obtain mature akinetes by incubation in the laboratory.

*** Akinete shape:**
Spherical
Subspherical
Cylindrical
Bent/Curved
Ellipsoidal/Oval
Other

Cylindrical Elongate with parallel lateral margins; often some of the akinetes in a population are very slightly curved.

Bent/Curved These are forms quite similar to those treated as cylindrical, but with a pronounced bend or curve.
Ellipsoidal Elongate, with slightly convex lateral margins and rounded, slightly narrowed ends.
The various forms merge into each other, but where there is likely to be doubt, they have been coded under more than one category.

*** Akinete surface:**
Smooth
Rough/warted
Colourless
Coloured

There are four possible combinations of these characters. However, it requires mature akinetes to be sure of their condition.

*** Akinete Position (if trichome):**
Contiguous with Heterocyst
Not contiguous with Heterocyst
Terminal

Where an **akinete** is formed in a trichome with a basal heterocyst, the akinete is usually next to this heterocyst and is termed **terminal** here; the heterocyst may or may not still be visible. Where heterocysts of the mature trichome are intercalary, the akinete forms next to a heterocyst in some species and away from it in others. In a few species (e.g. *Anabaena flos-aquae*) both conditions occur. It is uncertain how much this is determined genetically and how much environmentally, but the difference in position is usually so clear-cut that it is recommended that this character should be noted for populations of species where both conditions occur within the species.

*** Gas Vacuoles in Cell/Mature Trichome?**
Present
Absent

Gas vacuoles typically appear as glistening reddish areas within the cell. It is often possible to confirm their presence by comparing the appearance of cells before and after applying pressure. If this is done simply by applying pressure to the surface of a cover-slip, take care to ensure that this is not broken. The abundance of gas vacuoles may vary markedly between cells or trichomes within a population and sometimes within different regions of an individual trichome. Material is likely to be more gas-vacuolate when harvested from near the surface of a calm waterbody.

*** Gas Vacuole Distribution in Mature Trichome:**
Anywhere in Cell
Localized by Cross-wall

Gas vacuoles are typically distributed throughout a cell, but in a few species they are localized towards the ends of the cell. *Oscillatoria redekei* is the commonest species in the British Isles where this occurs.

*** Gas Vacuoles in Hormogonium?**
Present
Absent

This is probably a useful feature for diagnostic purposes, but reliable information is seldom available.

*** Environment:**
Terrestrial
Freshwater - All
Fast-flowing Freshwater
Brackish
Marine
Planktonic/Floating
Benthic/Epilithic
Epiphytic/Periphytic
Endolithic (or partially)

Terrestrial species includes ones on rocks and buildings, on or below the surface of the soil and on tree trunks and occasionally under very moist conditions also on leaves. In the British Isles, they are especially common in calcareous regions, but are by no means confined to them. Many at times form visually obvious colonies, such as those of *Nostoc commune*.
Freshwater species live in various types of inland waters, without a high salt content.
Species of **fast-flowing freshwater** often form crusts or flecks on rocks in parts of streams and upland rivers which are permanently submerged (e.g. some species of *Chamaesiphon*); the colony shape is sometimes highly characteristic for a particular species. Many of these species also occur on submerged rocks in nutrient-poor lakes.
Brackish species live in marine coastal localities, with increased and usually variable salt content.
Marine species occur in coastal or pelagic sea or ocean biotopes.
Planktonic species include picoplanktonic blue-green algae (Ω 2 µm in all dimensions) which lack gas-vacuoles and sometimes constitute the main primary producers in large nutrient-poor freshwater waterbodies and the gas-vacuolate species forming water-blooms in more nutrient-rich ones. In the British Isles, water-blooms typically consist of species of *Anabaena, Aphanizomenon*, *Gloeotrichia*, *Microcystis* and *Oscillatoria.* *Trichodesmium* is the only gas-vacuolate form in the seas off the British Isles and is most likely to be found in summer in the south-west. **Floating** mats of species lacking or with few gas-vacuoles also occur in

freshwaters. In this case bubbles of gas (presumably rich in oxygen by day-time) trapped between sheaths or mucilaginous trichomes help to maintain buoyancy. This occurs with forms of *Oscillatoria* and *Phormidium* in rivers and shallow ponds where the bottom has areas of exposed silt; the amount of floating mat often varies a lot during the daily cycle, being most conspicuous in late morning and the afternoon. Floating mats and flocs of *Lyngbya aestuarii* and *Tolypothrix distorta* may persist for long periods on the surface of weedy ponds in summer. *Lyngbya aestuarii* in particular is especially common in slightly brackish ponds, while *L. majuscula* sometimes forms flocs in pools on the south-west and west coasts.

Benthic means attached or living on the bottom of an aquatic habitat; it is used here for freshwaters, intertidal pools and the sublittoral.

Epilithic means growing on the surface of rock or other hard substratrum; it can apply to terrestrial or aquatic habitats.

Epiphytic means growing on or very closely associated on a plant, including another alga.

The term **periphytic** was first introduced in North America as a replacement for the German term 'Aufwuchs' to mean the whole community of algae and other microorganisms associated with larger aquatic plants, especially fine-leaved freshwater genera such as *Myriophyllum.* It is used like this in the present database (i.e. = aufwuchs). However, the term 'periphytic' is increasingly being used in the literature to describe all communities of algae, other small phototrophs and associated microorganisms growing on any submerged surface. Unfortunately, the muddled terminology now in the literature makes it hard to describe communities.

Endolithic means growing below the surface of a rock or other firm substratum.

3 COMMENTS ON USE OF LUCID

3.1 What the Key Can Do

The aim of the key (on the CD-ROM) is to aid the identification of any blue-green algal sample collected in the British Isles. The list includes the 318 species (in 64 genera) of freshwater, terrestrial and marine blue-green algae recorded. Apart from a few nomenclatural changes, the freshwater and terrestrial species follow the CODED LIST OF FRESHWATER ALGAE OF THE BRITISH ISLES (Whitton et al., 1998).

The LucID key makes use of a spreadsheet of information for each species and has the advantage of being a multi-access key. The CD-ROM holding this LucID key also contains the information for each genus extracted from the spreadsheets and presented in the form of EXCEL spreadsheets. A list of character states for individual species can be found using TAXA in the LucID player main menu, followed by TAXA DESCRIBE.

A few characters useful in identification, but relevant to only a very few species, have not been incorporated into the spreadsheet. In many cases, these can be found in the floristic description for species, which can be found by clicking once on the taxon's information button **i**, which produces a small pop-up menu that shows what media are available to view: use Notes.

Floristic accounts of genera can be found in this booklet and under GENERAL INFORMATION button: Taxonomic Description of Genera. Genera without representative species are not included in LucID but are described in the taxonomic descriptions.

Further details of how the list was put together and all references quoted can be found in INFORMATION USED FOR THE SPREADSHEET (section 3.4); further information is given in the printed version of the CODED LIST.

Views and diagrams in LucID are included for many species, especially the commoner ones. Where there are different types of picture, the following sequence is used: view of a representative site, close-up, colour micrographs, typical line diagram, other line diagrams, other general views. Unfortunately it is necessary to run through the whole sequence until you reach the image required. You can access details of each image, including the source and/or owner of the information . This can be found by using the taxon's information button **i**: Images.

The approach used for naming follows the conventions of floras using the Botanical rather than the Bacteriological Codes of Nomenclature. At present both are essential for understanding and critical study of these organisms, but the former is still needed for rapid identification of mixed populations of field material. This is why we have kept the term 'blue-green alga', rather than 'cyanobacterium'. However, the introduction to cyanobacteria in Bergey's Manual of Systematic Bacteriology (Castenholz & Waterbury, 1989) provides the best general account of their morphological features. Reviews on many aspects of their ecology are given in the book edited by Whitton and Potts (1999).

3.2 Character states

For each species, there are potentially thirty-nine different types of morphological information, though not all are applicable to every species. The more information the user can supply for each organism, the more likely it is that the species can be recognized. Most blue-green algae are highly variable, so your particular specimen may differ in some ways. It is therefore recommended to allow for the possibility of at least one character falling outside the limits given in the spreadsheet and used by LucID at its maximum stringency. There are also some ecological categories and this can sometimes be helpful in recognizing organisms, although a number of forms occur in both freshwater and marine environments. If you are uncertain which type of environment best fits your specimen, select more than one.

3.3 Coded Value for Character

LucID permits each matrix position to be coded as 0, 1, 2, 3, 4 or 5. These are explained more fully in the LucID manual and have the following preset significance for the taxon:

0 does not occur
1 normally present
2 unknown
3 rarely present
4 normally present, but only by misinterpretation
5 rarely present and then only by misinterpretation

(The rather illogical sequence follows the LucID Professional package. Unfortunately the printed LucID Professional Instruction Manuals up to early 1999 and the present version of the HELP file have the 2 and 3 inverted i.e. 2 = rarely present, 3 = unknown)

Coding information for blue-green algae is made difficult by their variability in response to the environment. For instance, akinetes (spores) are needed to identify most species of *Anabaena* for certain, yet they only occur under particular conditions, usually an indication that the environment is becoming less favourable for growth of the population. The part of the LucID scale which deals with relative amounts (0, 1, 3) is insufficient to deal with this situation, so the stored information on blue-greens sometimes requires explanation.

3.4 Information used for spreadsheets and genera descriptions

The data stored in LucID have mostly been obtained from general texts and floras: West and Fritsch (1927), Frémy (1929-1933), Geitler (1932), Skuja (1956), Desikachary (1959), Prescott (1962), Starmach (1966), Whitford and Schumacher (1969), Benson-Evans and Antoine (1996), Komárek and Anagnostidis (1999). Papers were used to provide information on: *Lyngbya vandenberghenii* (Symoens and van der Werff, 1951); *Crinalium epipsammum* (de Winder et al., 1990); *Aphanizomemon aphanizomenoides* (Horecká and Komárek, 1979). Only a few species were described originally from the British Isles, so information and diagrams often depend on material from other countries.

Nomenclatural and other Changes since Publication of CODED LIST OF FRESHWATER ALGAE OF THE BRITISH ISLES

Only a few of the names introduced by the revisions in the various papers of Komárek and Anagnostidis were adopted in the CODED LIST, because it is likely that there will be many further shifts in nomenclature in response to molecular studies. However, publication of the volume on the Chroococcales by Komárek and Anagnostidis (1999) has indicated the need for the following nomenclatural changes since publication of the CODED LIST OF FRESHWATER ALGAE OF THE BRITISH ISLES:

Cyanothece deleted (genus described by Komárek, 1976, to include a few species previously recognized as *Synechococcus.* One of these, *S. aeruginosus*, is included in the CODED LIST and we have retained it within this genus rather adopting *Cyanothece*. There are no records of the other species recorded by Komárek and Anagnostidis, 1999, for the British Isles

Dactylococcopsis changed to *Rhabdogloea* Schröd. (for relevant literature, see Komárek & Anagnostidis, 1999):

D. *planctonica* changed to *Rhabdogloea planctonica* (Teiling) Komárek

D. rhaphidioides changed to *Rhabdogloea smithii* (R. et F. Chodat) Komárek

Holopedium changed to *Microcrocis*

H. geminatum changed to *Microcrocis geminata* (Lagerh.) Komárek et Anagnost. (for relevant literature, see Komárek & Anagnostidis, 1999):

Pseudoncobyrsa changed to *Cyanodermatium* Geitler (for relevant literature, see Komárek & Anagnostidis, 1999):

Pseudoncobyrsa fluminensis changed to *Cyanodermatium fluminense* (Fritsch) Komárek et Anagnostidis 1995

Kyrtuthrix Erceg. added to taxonomic account of genera but not to LucID. This species is quite similar in overall morphology to *Brachytrichia quoyi* and should perhaps be incorporated within *Brachytrichia*, as done by Frémy (1929-1933)

Marssoniella and *M. elegans* have been deleted

Chroococcidiopsis and *Myxosarcina* have also been removed, because of the lack of reliable records.

Freshwater and terrestrial species not in the CODED LIST OF FRESHWATER ALGAE OF THE BRITISH ISLES

Aphanizomenon issatschenkoi (Usacev) Proshk.-Lavr. 1968
Chroococcus pallidus Nägeli
Chroococcus schizodermaticus W.West
Chroococcus varius A.Braun
Gloeocapsa crepidinum Thur.
Gloeocapsa polydermatica Kütz.
Gloeothece rupestris (Lyngb.) Bornet
Gloeotrichia punctulata Thur. brackish

Lyngbya gracilis Rabenh.
Lyngbya lutea Gomont also marine
Phormidium fragile Gomont also marine
Schizothrix coriacea (Kütz.) Gomont
Schizothrix friesii (C.Agardh) Gomont

Marine Species
Species which are entirely marine are not included in the CODED LIST (in spite of a contrary statement in the Introduction to the List). The following is a list of marine taxa included in the LucID database. *Isactis* Thur. is added only as a genus, since there are no firm records for the British Isles; however, based on Frémy, 1929-1933, *I. plana* (Harvey) Thur. is probably widespread in the upper intertidal zone. Note that three species below are also listed above as brackish or occurring in both freshwater and marine environments.

Amphithrix violacea (Kütz.) Bornet et Flahault
Aphanocapsa litoralis W. et G.S.West
Brachytrichia Zanardini
Brachytrichia quoyi (C.Agardh) Bornet et Flahault
Calothrix confervicola (Roth) C.Agardh
Calothrix crustacea Thur.
Calothrix pulvinata C.Agardh
Calothrix scopulorum Bornet et Flahault
Dermocarpa leibleiniae (Reinsch) Bornet and Thur.
Dermocarpa olivacea (Reinsch) Tilden
Dermocarpa prasinia (Reinsch) Bornet and Thur.
Entophysalis (Kütz.)
Entophysalis granulosa (Kütz.)
Gloeotrichia punctulata Thur.
Homoeothrix rubra (Cr.) Frémy
Hydrocoleum glutinosum Gomont
Hydrocoleum lyngbyaceum Kütz.
Hyella balani Lehmann
Hyella caespitosa Bornet et Flahault
Isactis Thur.
Johannesbaptistia De Toni
Johannesbaptistia pellucida (Dickie) Taylor et Drouet
Lyngbya gracilis Rabenh.
Lyngbya lutea Gomont
Lyngbya majuscula Harv.
Lyngbya semiplena J.Agardh
Lyngbya sordida Gomont
Mastigocoleus Lagerh.
Mastigocoleus testarum Lagerh.
Microcoleus chthonoplastes Thur.
Microcoleus tenerrimus Gomont

Oscillatoria margaritifera Kütz.
Phormidium fragile Gomont
Plectonema calothrichoides Gomont
Plectonema norvegicum Gomont
Plectonema terebrans Bornet et Flahault
Pleurocapsa crepidinum Collins
Rivularia atra Roth
Rivularia australis Harv.
Rivularia bullata Berk.
Rivularia nitida J.Agardh
Rivularia polyotis (C.Agardh) Bornet et Flahault
Spirulina labyrinthiformis (Menegh.) Gomont
Spirulina meneghiniana Zanardini
Trichodesmium erythraeum Ehrenb.
Trichodesmium thiebautii Gomont

4 REFERENCES

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