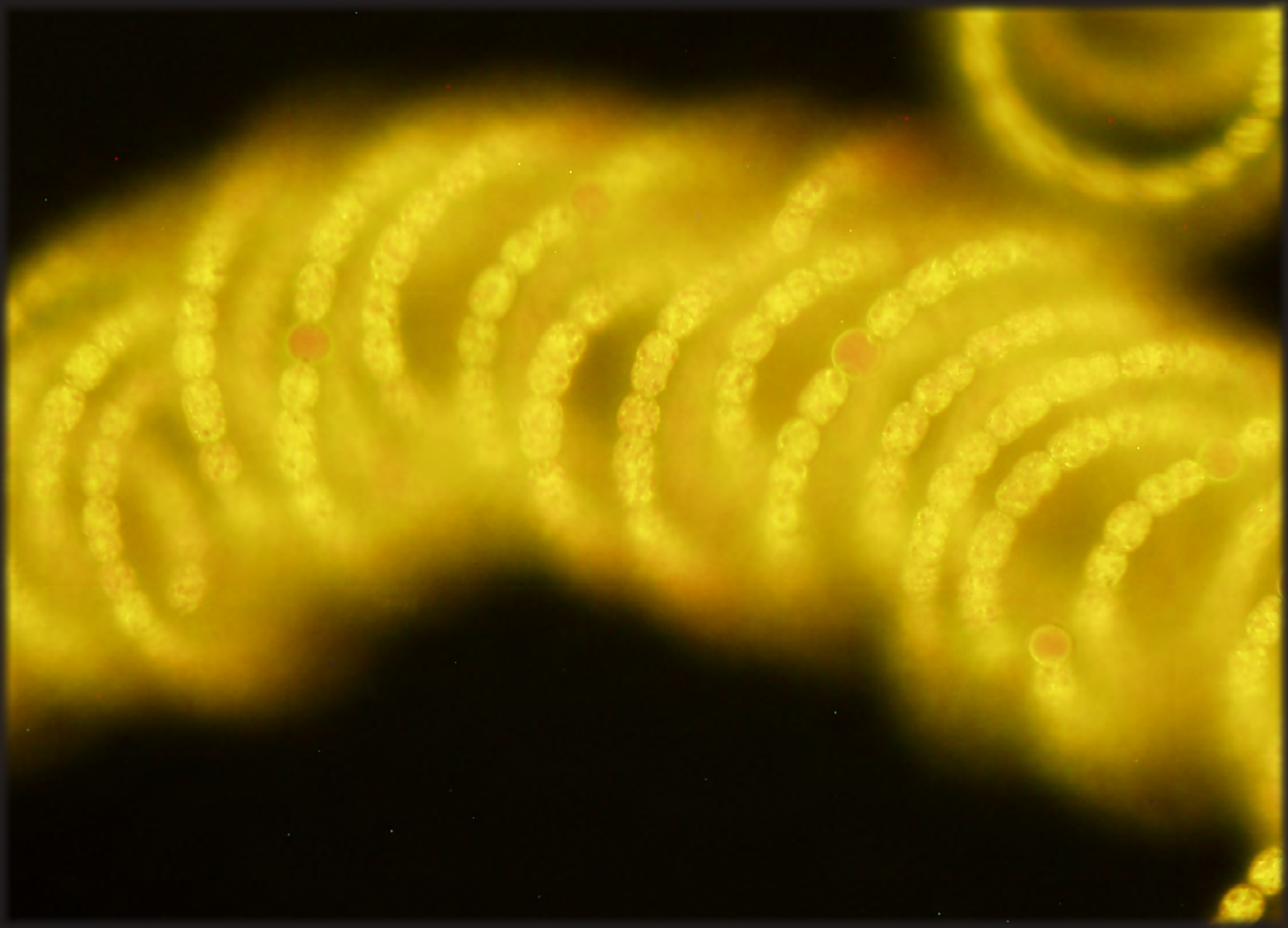
Cyanobacteria of the 2016 Lake Okeechobee and Okeechobee Waterway Harmful Algal Bloom



Open-File Report 2017–1054

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photomicrograph of *Dolichospermum circinale* collected July 9, 2016, from Lake Okeechobee, Florida. These living cells in a coiled filament are illuminated with wide-blue epifluorescence microscopy. Pigments in the cells glow yellow in vegetative cells, which have small orange spots—the aerotopes, and round red cells—the heterocytes.

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U.S. Department of the Interior
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U.S. Department of the Interior
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U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

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Acknowledgments

The U.S. Geological Survey (USGS) has undertaken the task of documenting the cyanobacteria of the 2016 Lake Okeechobee and Okeechobee Waterway bloom in a readily available digital format. These images and associated names are needed for current and future research on algal blooms. This project was funded by the USGS Priority Ecosystem Study program.

The authors are grateful for the taxonomic advice and thorough review of Sue Watson with Environment and Climate Change, Canada (ret.), Ann St. Amand with PhycoTech, and Jennifer L. Graham with the U.S. Geological Survey (USGS).

Samples were provided by Bruce Sharfstein of the South Florida Water Management District and Travis Knight and Robert Clendening of the USGS Caribbean-Florida Water Science Center.

This project was funded by the USGS Priority Ecosystem Study program and USGS Environmental Health Toxic Substances Hydrology Program.

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

$$°F = (1.8 \times °C) + 32.$$

Abbreviations

cf.	compare to
oC	degrees centigrade
HABs	Harmful Algal Blooms
mm	micrometer
mL	milliliter
NOAA	National Oceanographic and Atmospheric Administration
sp.	species
SFWMD	South Florida Water Management District
USGS	U.S. Geological Survey
UV	ultraviolet

Cyanobacteria of the 2016 Lake Okeechobee and Okeechobee Waterway Harmful Algal Bloom

By Barry H. Rosen[1], Timothy W. Davis[2], Christopher J. Gobler[3], Benjamin J. Kramer[3] and Keith A. Loftin[4]

Abstract

The Lake Okeechobee and the Okeechobee Waterway (Lake Okeechobee, the St. Lucie Canal and River, and the Caloosahatchee River) experienced an extensive harmful algal bloom within Lake Okeechobee, the St. Lucie Canal and River and the Caloosahatchee River in 2016. In addition to the very visible bloom of the cyanobacterium *Microcystis aeruginosa*, several other cyanobacteria were present. These other species were less conspicuous; however, they have the potential to produce a variety of cyanotoxins, including anatoxins, cylindrospermopsins, and saxitoxins, in addition to the microcystins commonly associated with *Microcystis*. Some of these species were found before, during, and 2 weeks after the large *Microcystis* bloom and could provide a better understanding of bloom dynamics and succession. This report provides photographic documentation and taxonomic assessment of the cyanobacteria present from Lake Okeechobee and the Caloosahatchee River and St. Lucie Canal, with samples collected June 1st from the Caloosahatchee River and Lake Okeechobee and in July from the St. Lucie Canal. The majority of the images were of live organisms, allowing their natural complement of pigmentation to be captured. The report provides a digital image-based taxonomic record of the Lake Okeechobee and the Okeechobee Waterway microscopic flora. It is anticipated that these images will facilitate current and future studies on this system, such as understanding the timing of cyanobacteria blooms and their potential toxin production.

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[2]National Ocean and Atmospheric Administration, Great Lakes Environmental Research Laboratory

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[4]U.S. Geological Survey, Kansas Water Science Center, Organic Geochemistry Research Laboratory

Introduction

Lake Okeechobee has long been classified as a eutrophic water body (Canfield and Hoyer, 1988). One consequence of nutrient pollution and degraded water quality is the formation of harmful algal blooms (HABs), which occur when the optimal balance of nutrients, light, water column stability and temperature allow any algae or cyanobacteria in the water column to be stimulated and grow more rapidly than neighboring species (Reynolds, 1984). In freshwater systems, HABs are generally dominated by cyanobacteria (also called blue-green algae), often referred to as “CyanoHABs.” Cyanobacteria are true bacteria; however, they contain chlorophyll *a*, and thus were initially classified as algae. They are primary producers like the eukaryotic algae, and performing photosynthesis is common to both types of organisms. Many species of bloom-forming cyanobacteria can regulate their buoyancy, moving down in the water column at night to scavenge phosphorus released from sediments and up in the water column during the day to maximize photosynthesis. As bacteria, they also thrive when temperatures are warm (Visser and others, 2016). One order of cyanobacteria (Nostocales) can also fix atmospheric nitrogen through a specialized cell, the heterocyte, which provides this key element for growth when it is in limited supply, allowing this group to have an advantage over other cyanobacteria and eukaryotic algae. It should be noted that a few species of cyanobacteria without a heterocyte can also fix nitrogen. The ability to regulate their buoyancy, temperature tolerance, and nitrogen fixation are three ecological strategies that give cyanobacteria advantages that allow them to out-compete eukaryotic algae.

CyanoHABs have been documented in Lake Okeechobee and Okeechobee Waterway (Lake Okeechobee, the St. Lucie Canal and River, and the Caloosahatchee River) since the early 1980s (Havens and others, 1995a, b), which are frequently dominated by *Microcystis aeruginosa* (Havens and others, 2016, Philips and others, 2012). Many species of cyanobacteria are present in the Lake Okeechobee

Waterway although no recent study has documented the richness of the cyanobacterial community. It is important to understand taxonomic diversity, as many cyanobacteria can produce a variety of cyanotoxins, including neurotoxins and hepatotoxins such as anatoxins, cylindrospermopsins, and saxitoxins, in addition to microcystins and other potentially harmful metabolites (see reviews by O'Neil and others, 2012; Pearson and others, 2016). The functions of these toxins to the cyanobacteria are the subject of much speculation and no single hypothesis has proven correct (Pearson and others, 2016). The stimulation of toxin production by an organism with the genes for its production also is under intense investigation (Davis and others 2009, 2010, 2015; Harke and Gobler, 2015; Gobler and others, 2016; Pearson and others, 2016).

The photographic documentation and taxonomic assessment of the species (Rosen and Mareš, 2016) present in various locations during the 2016 bloom in the Lake Okeechobee and the Okeechobee waterway can be used to guide future studies and toxin monitoring programs (Rosen and St. Amand, 2015).

Methods

Field Samples

Grab samples of live phytoplankton were collected by either submersing a 1-liter polypropylene bottle at the water surface to capture the uppermost portion of the water column or by using a vertical Van Dorn water sampler to collect the bloom water just below the surface. Three sets of samples were collected on the following dates: June 1, 2016, from the Caloosahatchee River; July 5, 2016, from 5 locations in Lake Okeechobee, and July 9-10, 2016, from Lake Okeechobee locations (Canal Point and Port Mayaca) and down the length of the St. Lucie Canal from S-308 to the estuary (table 1, figure 1). Samples were kept cold and dark after collection, then transported to the laboratory at the Caribbean-Florida Water Science Center, Orlando, Florida, within 48 hours.

Table 1. Sample date, site identification, latitude and longitude, and source for sample collections. Site designations for the Lake Okeechobee sites are from the South Florida Water Management District. Samples from the St. Lucie River and Canal were collected by the National Oceanic and Atmospheric Administration.

[USGS, U.S. Geological Survey; SFWMD, South Florida Water Management District; NOAA, National Oceanic and Atmospheric Administration; SLR, St. Lucie River (Numeral following "SLR" indicates distance from Lake Okeechobee in miles)]

Date	Site Identification	Latitude decimal degrees	Longitude decimal degrees	Source
6/1/2016	Caloosahatchee River	26.7217	-81.6939	USGS
7/5/2016	LZ30	26.817404	-80.889917	SFWMD
7/5/2016	L002	27.0827	-80.7942	SFWMD
7/5/2016	L005	26.9567	-80.9724	SFWMD
7/5/2016	S-308	26.986637	-80.6102	SFWMD
7/5/2016	Pahokee Marina	26.824972	-80.667711	SFWMD
7/9/2016	Canal Point	26.864296	-80.63255	NOAA
7/9/2016	Port Mayaca	26.984979	-80.620918	NOAA
7/9/2016	SLR 1	27.115429	-80.2819	NOAA
7/9/2016	SLR 3	27.13966	-80.261706	NOAA
7/9/2016	SLR 4	27.15646	-80.25502	NOAA
7/9/2016	SLR 5	27.17057	-80.25821	NOAA
7/9/2016	SLR 6	27.1885	-80.26478	NOAA
7/9/2016	SLR 6.5	27.19989	-80.264114	NOAA
7/9/2016	SLR 7	27.20684	-80.26859	NOAA
7/9/2016	SLR 8	27.2608	-80.33047	NOAA
7/9/2016	SLR 9	27.22998	-80.29655	NOAA
7/9/2016	SLR 10	27.20792	-80.25105	NOAA
7/9/2016	SLR 11	27.20509	-80.21291	NOAA
7/9/2016	SLR 12	27.16769	-80.19385	NOAA
7/9/2016	SLR 13	27.16516	-80.16748	NOAA
7/10/2016	SLR 14	27.012359	-80.455056	NOAA
7/10/2016	SLR 15	27.09528	-80.296074	NOAA

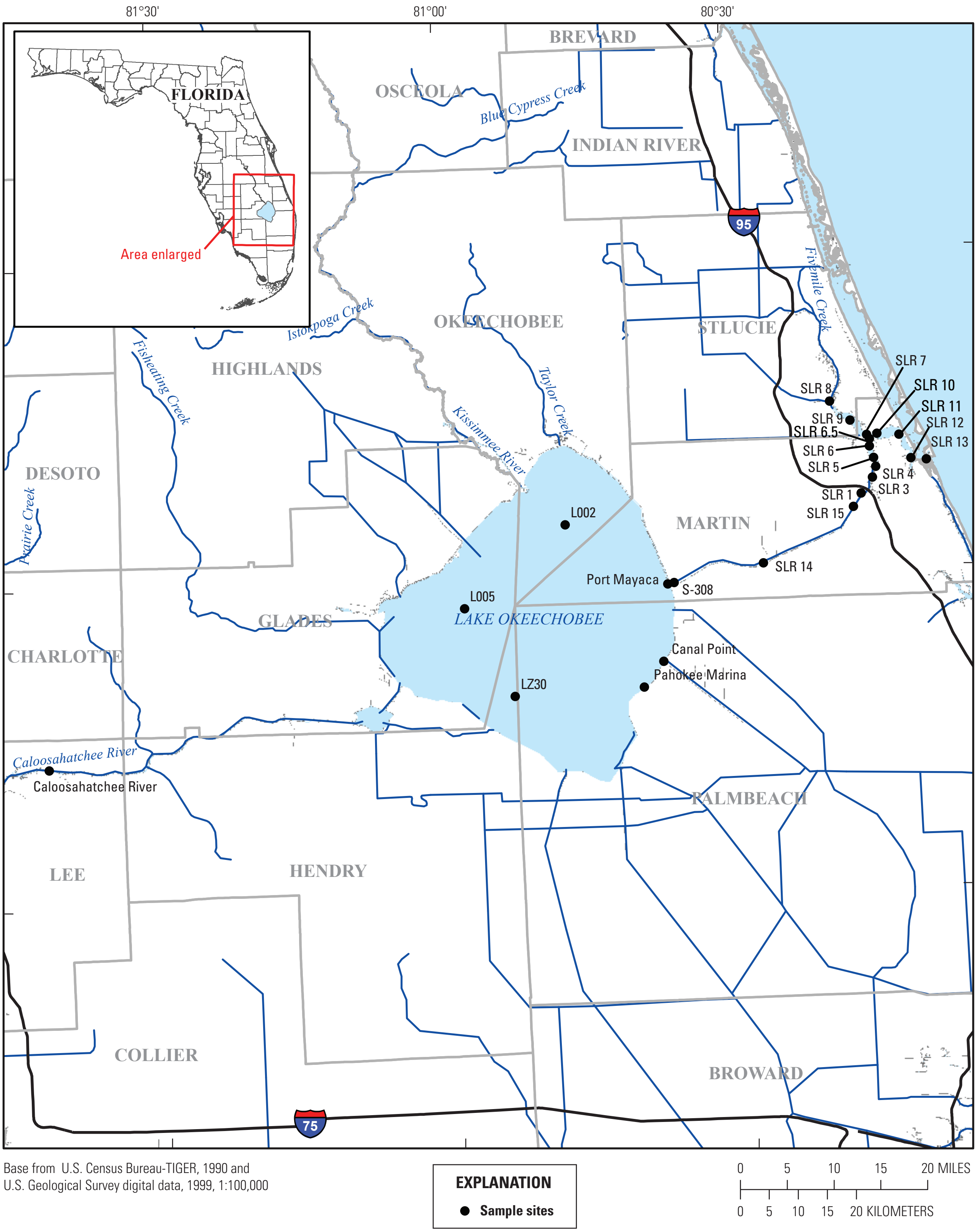

Figure 1. Locations of the water samples taken from Lake Okeechobee and the Lake Okeechobee Waterway for the photomicrographs in this publication.

Morphologically Based Taxonomy

Cyanobacteria were identified by morphological traits such as the dimensions (length and width) of cells, the arrangement of cells in colonies or filaments, the terminal cell shape in a filament, and the presence of specialized structures such as aerotopes (also known as gas vesicles used for regulating buoyancy), heterocytes (specialized cells for nitrogen fixation), and akinetes (specialized resting cells that allow organisms to survive harsh conditions and germinate when environmental conditions allow). The dimensions and shape of these specialized cells are critical to the identification of a species. Several sources were used to identify organisms on the basis of morphology (Komárek and Anagnostidis, 1998, 2005; Komárek, 1984, 2008, 2013; Komárek and others, 2014). The classification and groupings of the images are aligned alphabetically by order, family within the order, and genus within the family. The abbreviation “cf.” in some of the figure captions is commonly read as “compare with.” Collectively, the images are in 4 orders, 10 families, and 17 genera:

Order Chroococcales

- **Family** Microcystaceae
    - **Genus** *Gloeocapsa*
    - **Genus** *Microcystis*

Order Nostocales

- **Family** Aphanizomenonaceae
    - **Genus** *Cuspidothrix*
    - **Genus** *Cylindrospermopsis*
    - **Genus** *Dolichospermum*
- **Family** Fortiaceae
    - **Genus** *Fortiea*
- **Family** Hapalosiphonaceae
    - **Genus** *Hapalosiphon*
- **Family** Nostocaceae
    - **Genus** *Anabaena*
    - **Genus** *Macrospermum*
    - **Genus** *Nostoc*

Order Oscillatoriales

- **Family** Microcoleaceae
    - **Genus** *Planktothrix*

Order Synechococcales

- **Family** Coelosphaeriaceae
    - **Genus** *Coelomoron*
- **Family** Leptolyngbyaceae
    - **Genus** *Planktolyngbya*
- **Family** Merismopediaceae
    - **Genus** *Aphanocapsa*
    - **Genus** *Merismopedia*
- **Family** Pseudanabaenaceae
    - **Genus** *Limnothrix*
    - **Genus** *Pseudanabaena*

With the live samples, some of the morphological traits needed to identify an organism to the species level were lacking, especially in the filamentous Order Nostocales. To induce the formation of these traits, short-term incubations were performed as follows: (1) Raw samples (approximately 30 milliliters (mL) were poured into their own 90 millimeter (mm) diameter sterile plastic petri dish and incubated in indirect sunlight at 24 degrees Celsius (°C); (2) incubated samples were monitored for the formation of key morphological features needed for taxonomic identification to species; and (3) a subset of key organisms of interest was isolated from relevant environmental samples by using aseptic methods following Stein (1973). Briefly, native water from the matching environmental samples was sterile filtered and used as media for each isolate. Water was sterile filtered by using a 250 mL Nalgene® Rapid-Flow sterile disposable filter 0.2 micrometer (µm) nylon membrane (50 mm diameter filter) and stored at 4°C until isolates were added.

Microscopy

Samples initially were observed and photographed by differential interference contrast (DIC) microscopy by using an Olympus BX51 research microscope (Olympus America, Waltham, Massachusetts, USA), at 200x, 400x, 600x (oil), or 1,000x (oil) magnifications (Rosen and others, 2010). Images were all illuminated with DIC, unless otherwise noted. A micrometer scale bar was embedded in the images. The accuracy of the embedded scale was verified with a stage micrometer.

Some cells were further examined and photographed under epifluorescence microscopy with a U-MWU2: Ultraviolet (UV) cube, with excitation wavelengths 330–385 nanometers and emission above 515 nanometer. The illumination source was a xenon lamp (X-Cite Series 120Q).

Organisms

Order Chroococcales
Family Microcystaceae
Genus *Gloeocapsa*

Figure 2. *Gloeocapsa punctata* Nägeli; bar is 10 μm in length (Komárek and Anagnostidis, 1999, fig. 309).

Figure 2 illustrates *Gloeocapsa punctata,* a colonial form, with individual or small groups of cells in their own mucilaginous envelope.

Order Chroococcales
Family Microcystaceae
Genus *Microcystis*

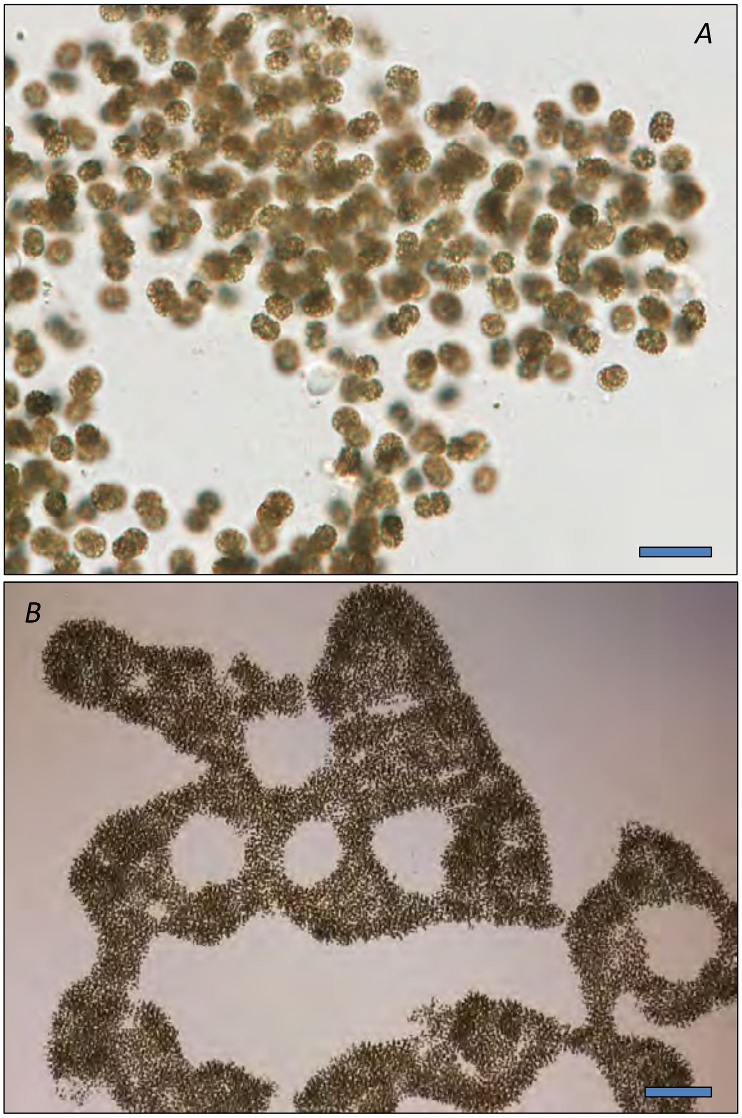

Figure 3. *Microcystis aeruginosa* (Kützing) Kützing; bar is 20 µm in fig. 3*A*, 100 µm in fig. 3*B* (Komárek and Anagnostidis, 1998, fig. 304).

Figures 3*A* and 3*B* illustrate *Microcystis aeruginosa,* a colonial form, with small cells arranged into colonies. Colonies have large open spaces and are commonly visible without a microscope.

Order Chroococcales
Family Microcystaceae
Genus *Microcystis*

Figure 4. *Microcystis wesenbergii* (Komárek) Komárek ex Komárek; bar is 10 μm (Komárek and Anagnostidis, 1998, fig. 305).

Figure 4 illustrates *Microcystis wesenbergii,* a colonial form, with small cells arranged into colonies with thick mucilage and often lobed.

Order Nostocales
Family Aphanizomenonaceae
Genus *Cuspidothrix*

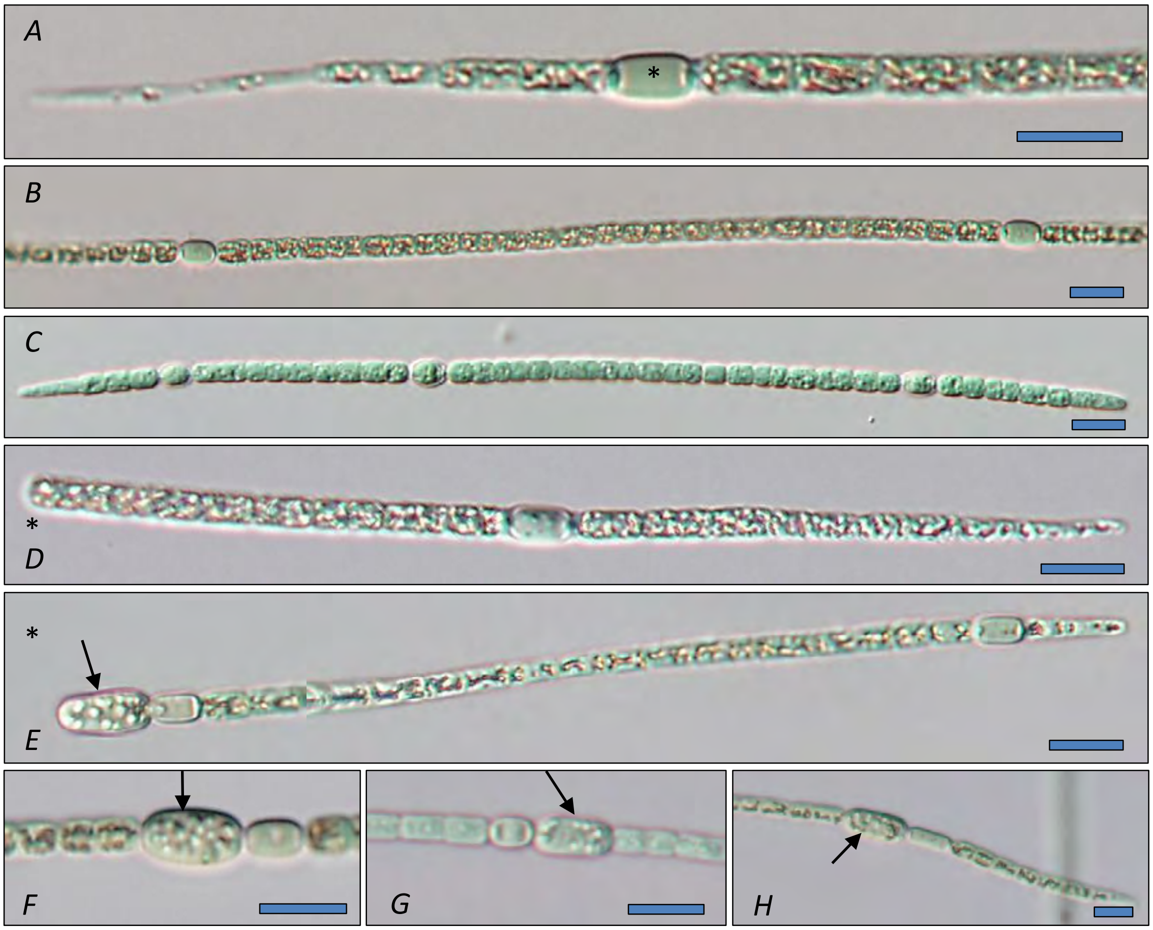

Figure 5. *Cuspidothrix tropicalis* (Horecká & Komárek) P. Rajaniemi, J. Komárek, R. Willame, P. Hrouzek, K. Kastovská, L. Hoffmann & K. Sivonen; bars are 10 µm (Komárek, 2013, fig. 828).

Figure *5A* has the characteristics of *Cuspidothrix issatschenkoi* and may be this species. 5*B*–4*H* illustrate *Cuspidothrix tropicalis,* a filamentous form that has a tapered terminal cell (5*C*–5*E* and 5*H*). Heterocytes are elongated (*) and akinetes (figs. 5*E*–5*H*), at arrows, are wider than the vegetative cells of the filament and are adjacent to the heterocytes. The genus *Cuspidothrix* was separated from *Aphanizomenon* in Rajaniemi and others, 2005. To the authors' knowledge, this is the first time this organism has been reported in the United States.

Order Nostocales
Family Aphanizomenonaceae
Genus *Cylindrospermopsis*

Figure 6. *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya & Subba Raju; bar is 20 μm (Komárek, 2013, fig. 835).

Figure 6 illustrates *Cylindrospermopsis raciborskii,* with straight morphology, is a filamentous form that has a characteristic terminal heterocyte (at arrow).

Order Nostocales
Family Aphanizomenonaceae
Genus *Dolichospermum*

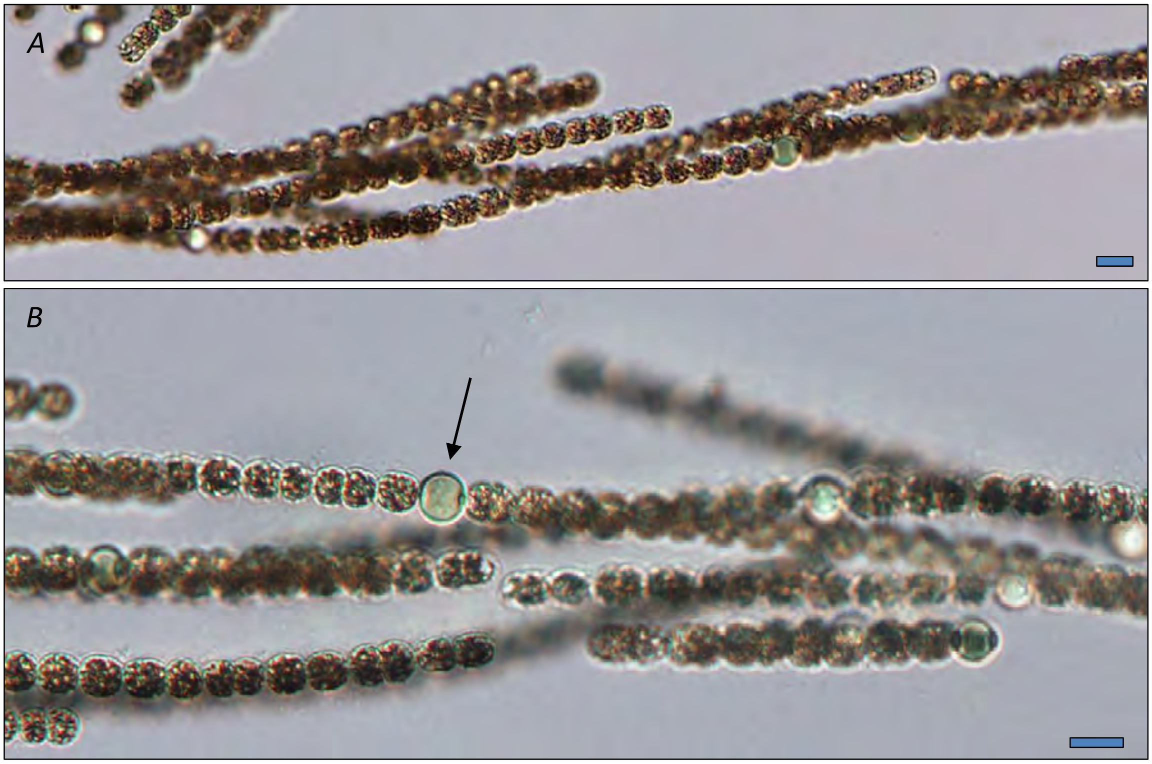

Figure 7. *Dolichospermum affine* (Lemmermann) Wacklin, L. Hoffmann & Komárek; bars are 10 μm in length (Komárek, 2013, fig. 893, Wacklin and others, 2009).

Figures 7*A* and 7*B* illustrate *Dolichospermum affine,* a filamentous form that has a spherical cells and heterocytes (at arrow). Filaments loosely associated in parallel to form fascicles. The genus that encompassed planktonic *Anabaena* was changed to *Dolichospermum* by Wacklin and others, 2009.

Order Nostocales
Family Aphanizomenonaceae
Genus *Dolichospermum*

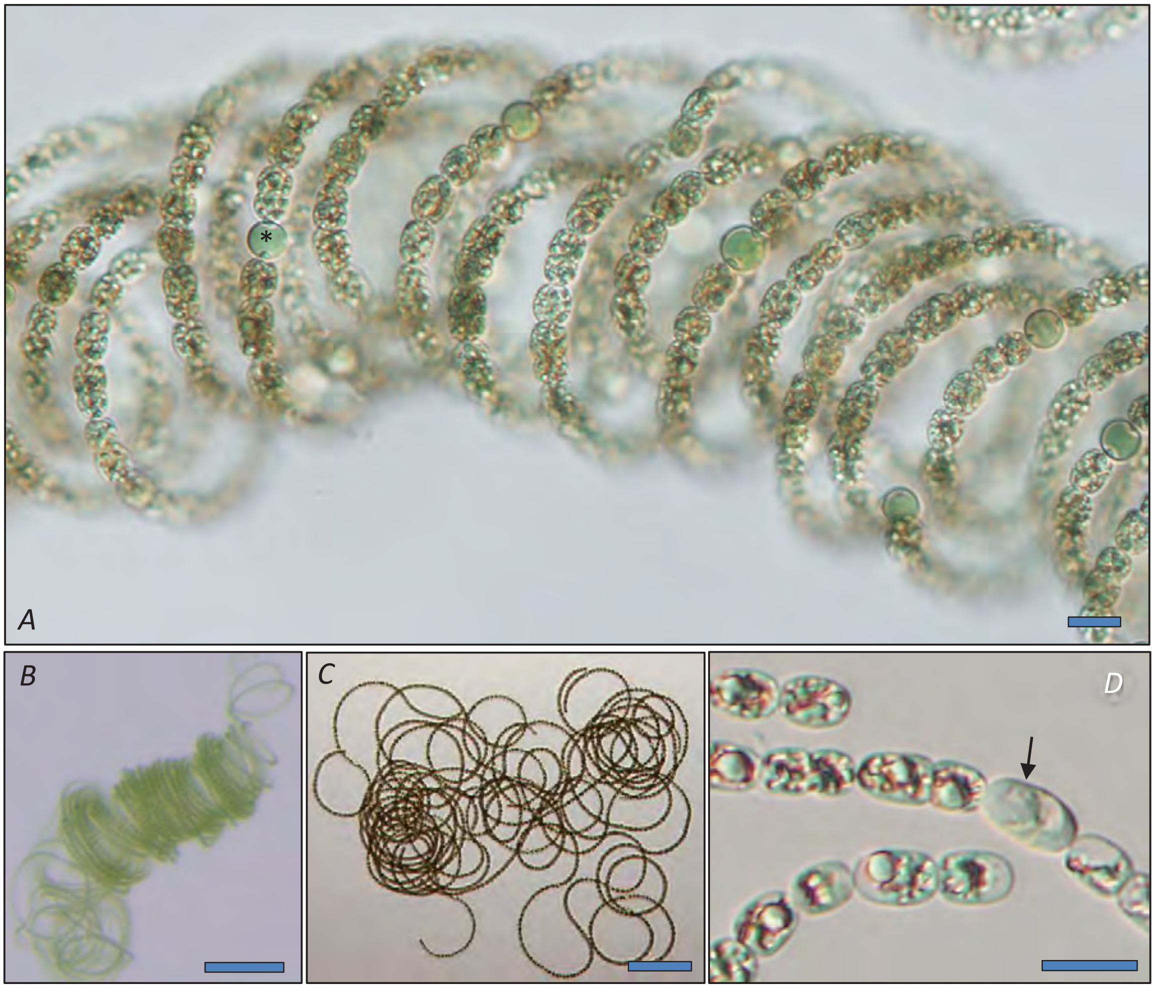

Figure 8. *Dolichospermum circinale* (Rabenhorst ex Bornet & Flahault) P. Wacklin, L. Hoffmann & J. Komárek; bars are 10 µm in length in figs. 8*A* and 8*D*, and 100 µm figs. 8*B* and 8*C*, (Komárek, 2013, fig. 867, Wacklin and others, 2009).

Figures 8*A*–8*D* illustrate *Dolichospermum circinale,* a filamentous form that coils (figs. 8*A*–8*C*). Heterocytes are spherical (*) and akinetes (fig. 8*D*) at arrow, is wider than the filament and larger than the vegetative cells. Filaments loosely associated in parallel to form fascicles. The genus that encompassed planktonic *Anabaena* was changed to *Dolichospermum* by Wacklin and others, 2009.

Order Nostocales
Family Aphanizomenonaceae
Genus *Dolichospermum*

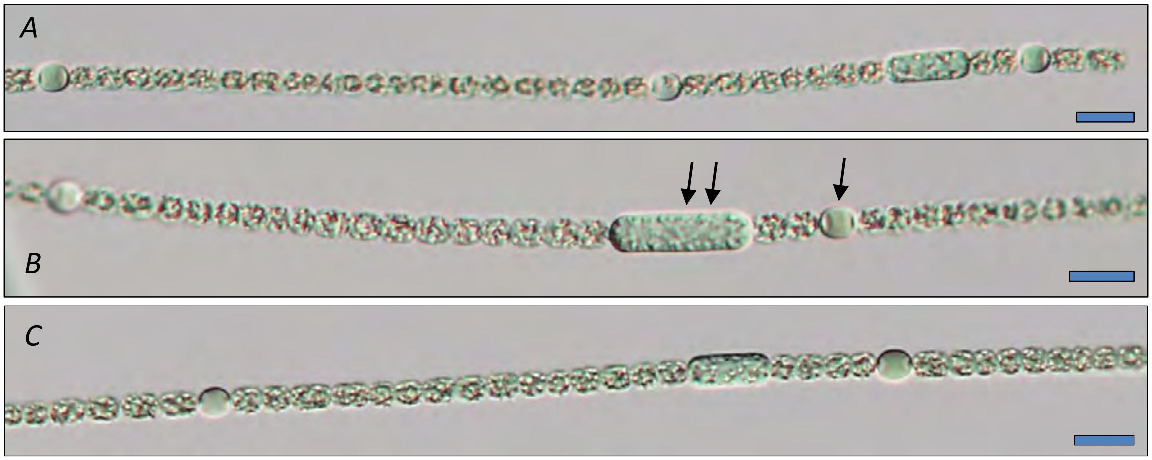

Figure 9. *Dolichospermum heterosporum* (Nygaard) P. Wacklin, L. Hoffmann & J. Komárek; bars are 10 μm (Komárek, 2013, fig. 882).

Figures 9*A*–9*C* illustrate *Dolichospermum heterosporum,* a filamentous form that is mostly straight to slightly curved (figs. 9*A*–9*B*) and is not tapered (fig. 9*A*). Heterocytes are spherical (single arrow) and akinetes are elongated (at double arrow), wider than the filament and within 2–4 cells of the heterocyte. Filaments loosely associated in parallel to form fascicles. The genus that encompassed planktonic *Anabaena* was changed to *Dolichospermum* by Wacklin and others, 2009.

Order Nostocales
Family Aphanizomenonaceae
Genus *Dolichospermum*

Figure 10**.** *Dolichospermum* sp. (Ralfs ex Bornet & Flahault) P. Wacklin, L. Hoffmann & J. Komárek; bars are 10 µm (Wacklin and others, 2009).

Figures 10*A* and 10*B* illustrate *Dolichospermum* sp. that can not be identified to the species level because morphological characteristics are lacking. The genus that encompassed planktonic *Anabaena* was changed to *Dolichospermum* by Wacklin and others, 2009.

Order Nostocales
Family Fortiaceae
Genus *Fortiea*

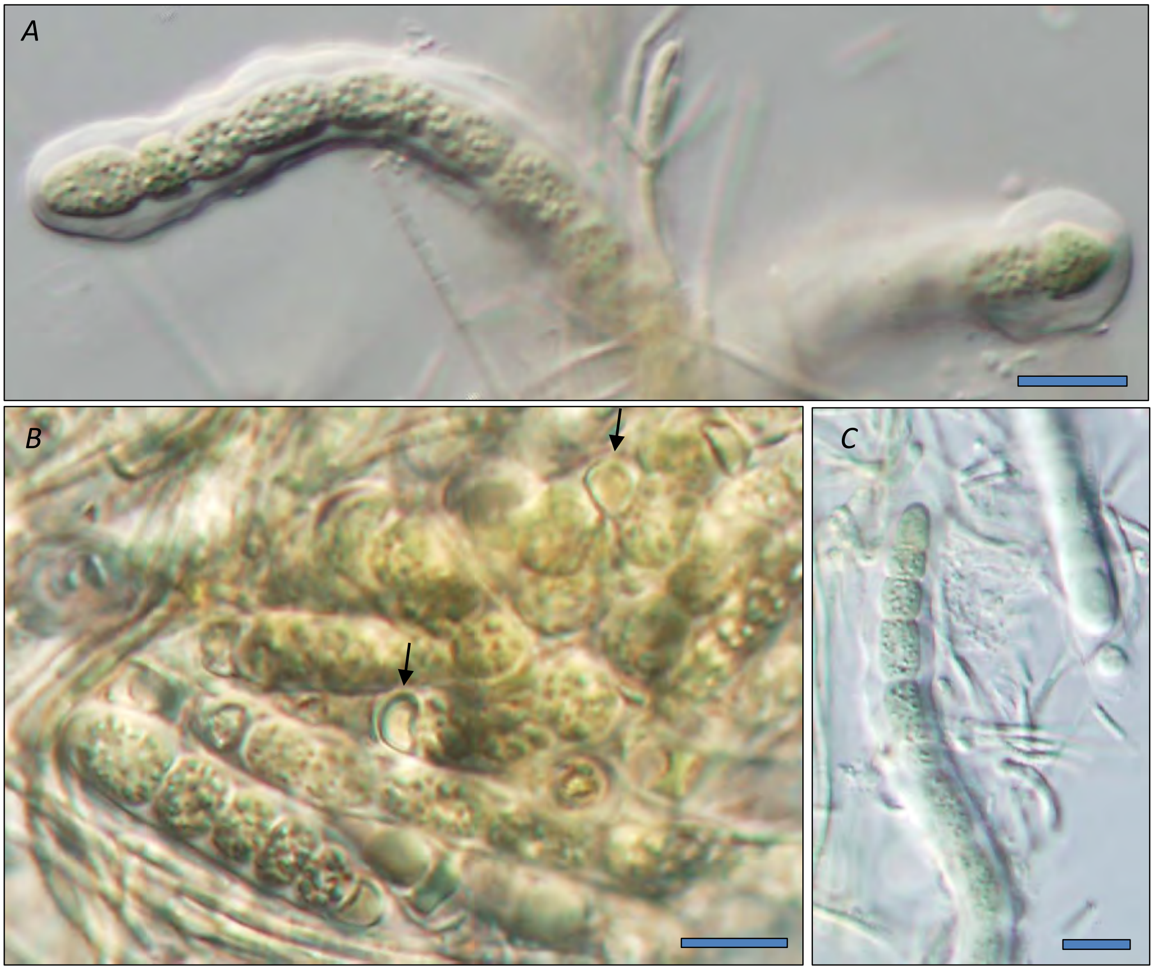

Figure 11. *Fortiea monilispora* Komárek; bars are 10 µm in length (Komárek, 2013, fig. 475).

Figures 11*A*–11*C* illustrate *Fortiea monilispora,* a filamentous form that has terminal cells that are conical and curved filaments (figs. 11*A*–11*C*). Mucilage envelopes each filament. Heterocytes are hemispherical and may be flattened (fig. 11*B* at arrows).

Order Nostocales
Family Hapalosiphonaceae
Genus *Hapalosiphon*

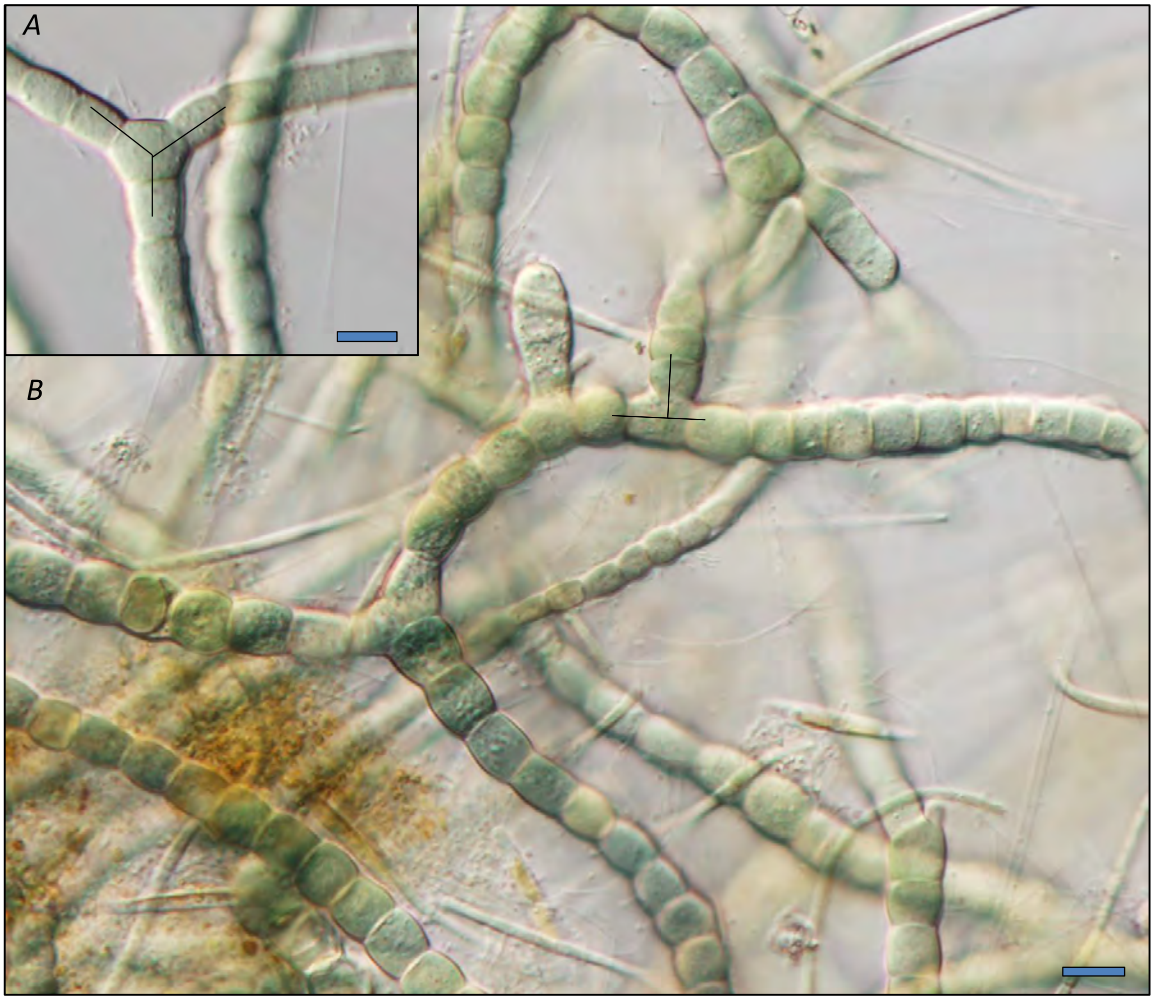

Figure 12. *Hapalosiphon* sp. Nägeli ex É. Bornet & C. Flahault; bars are 10 μm in length (Komárek, 2013). See figure 13 for full description of what is depicted in these images.

Order Nostocales
Family Hapalosiphonaceae
Genus *Hapalosiphon*

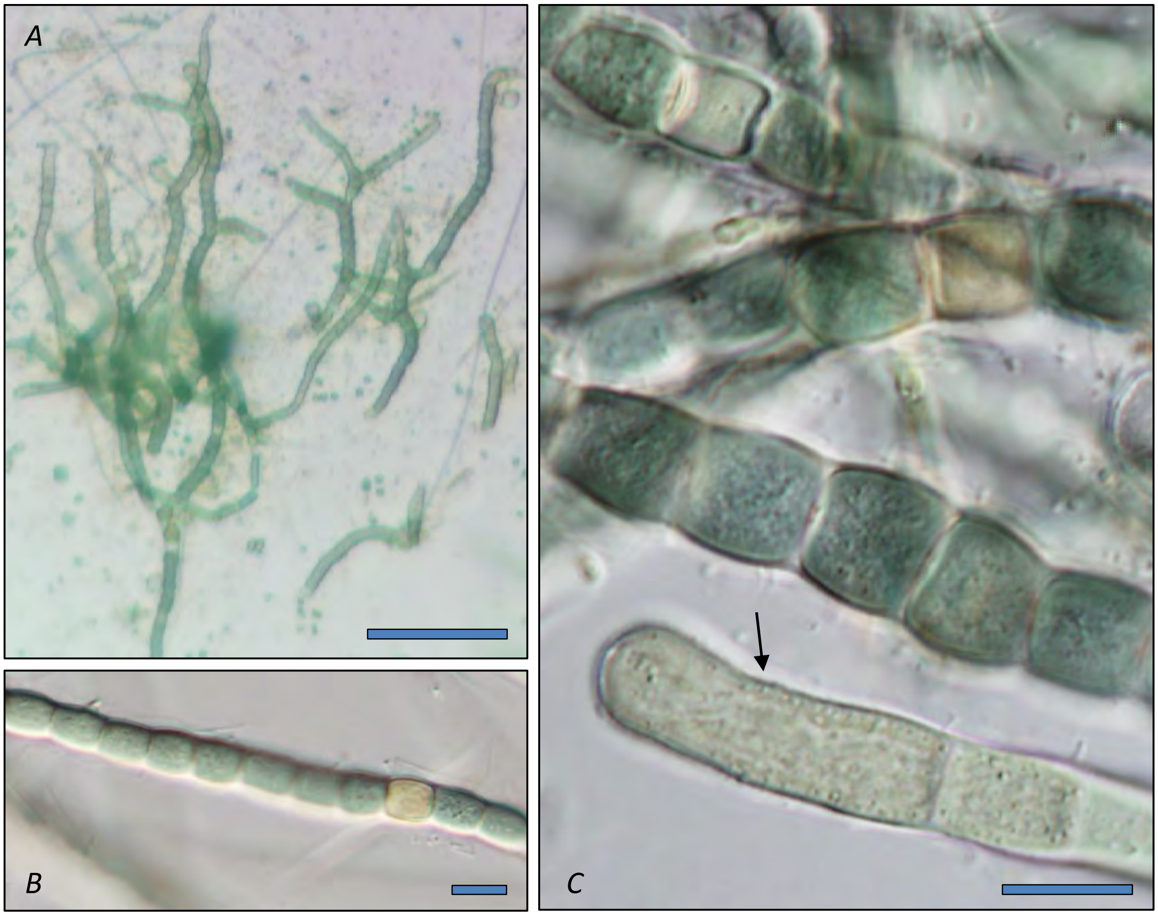

Figure 13. *Hapalosiphon* sp. Nägeli ex É. Bornet & C. Flahault; bar length in fig. 13*A* is 100 μm; bar length in figs. 13*B* and 13*C* is 10 μm (Komárek, 2013).

Figures 12–13 illustrate *Hapalosiphon* sp., a true branching filamentous form that has an elongated terminal cell (fig. 13*C*). The true branching illustrated in fig. 12*A* has the typical "Y" pattern characteristic in this genus. Fig. 12*B* shows that the branches can also form perpendicular to the main filament. Overall, the filaments can form visible tuffs that branch (fig. 13*A*) and heterocytes are intercalary (fig. 13*B*). The elongated terminal cell (fig. 13*C*, at arrow) is not characteristic of this genus, which may indicate that this is a new species.

Order Nostocales
Family Nostocaceae
Genus *Anabaena*

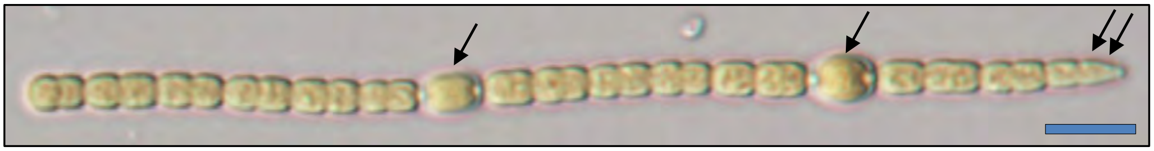

Figure 14. *Anabaena mediocris* N. L. Gardner; bar is 10 μm in length (Komárek, 2013, fig. 1044).

Figure 14 illustrates *Anabaena mediocris,* a filamentous form that is mostly straight to slightly curved and is tapered with a conical terminal cell (double arrow). Heterocytes, which differentiate from vegetative cells, are elongated (at arrows), and are wider than the filament. Note that the different sizes of the two heterocytes in this image, with the smaller one (left single arrow) being formed more recently that the larger heterocyte (right single arrow). Aerotopes are absent.

Order Nostocales
Family Nostocaceae
Genus *Macrospermum*

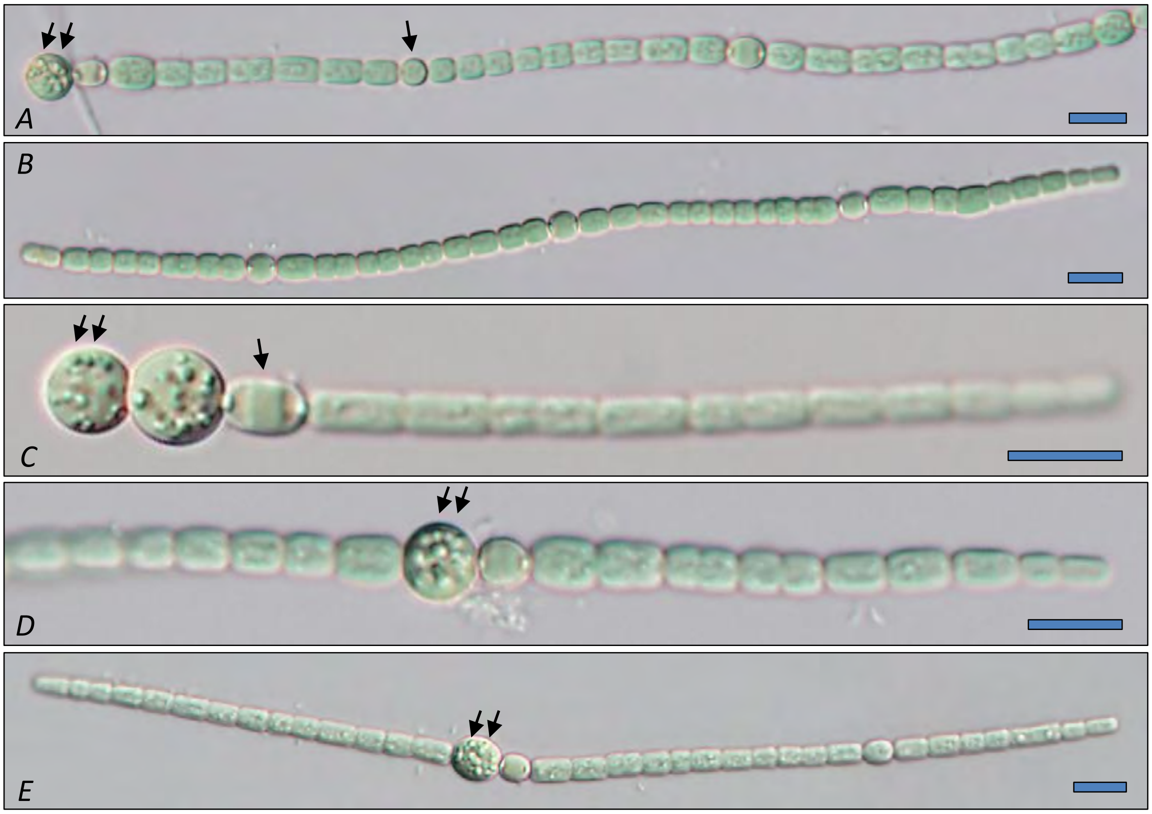

Figure 15. *Macrospermum volzii* (Lemmermann) Komárek; bars are 10 μm in length (Komárek, 2013, fig. 1112).

Figures 15*A*—15*E* illustrate *Macrospermum volzii,* a filamentous form that is mostly straight to slightly curved (figs. 15*B*, 15*C*, 15*D*). Filaments are tapered (figs. 15*C*, fig.15*D* and fig.15*F*). Heterocytes are spherical when young (fig. 15*A* at arrow) and elongate as they mature (fig. 15*C* at arrow). Akinetes are spherical, enlarged and adjacent to the heterocytes, either intercalary (figs. 15*D* and 15*E*, double arrow) or in the terminal position (figs. 15*A* and 15*C*, double arrow).

Order Nostocales
Family Nostocaceae
Genus *Nostoc*

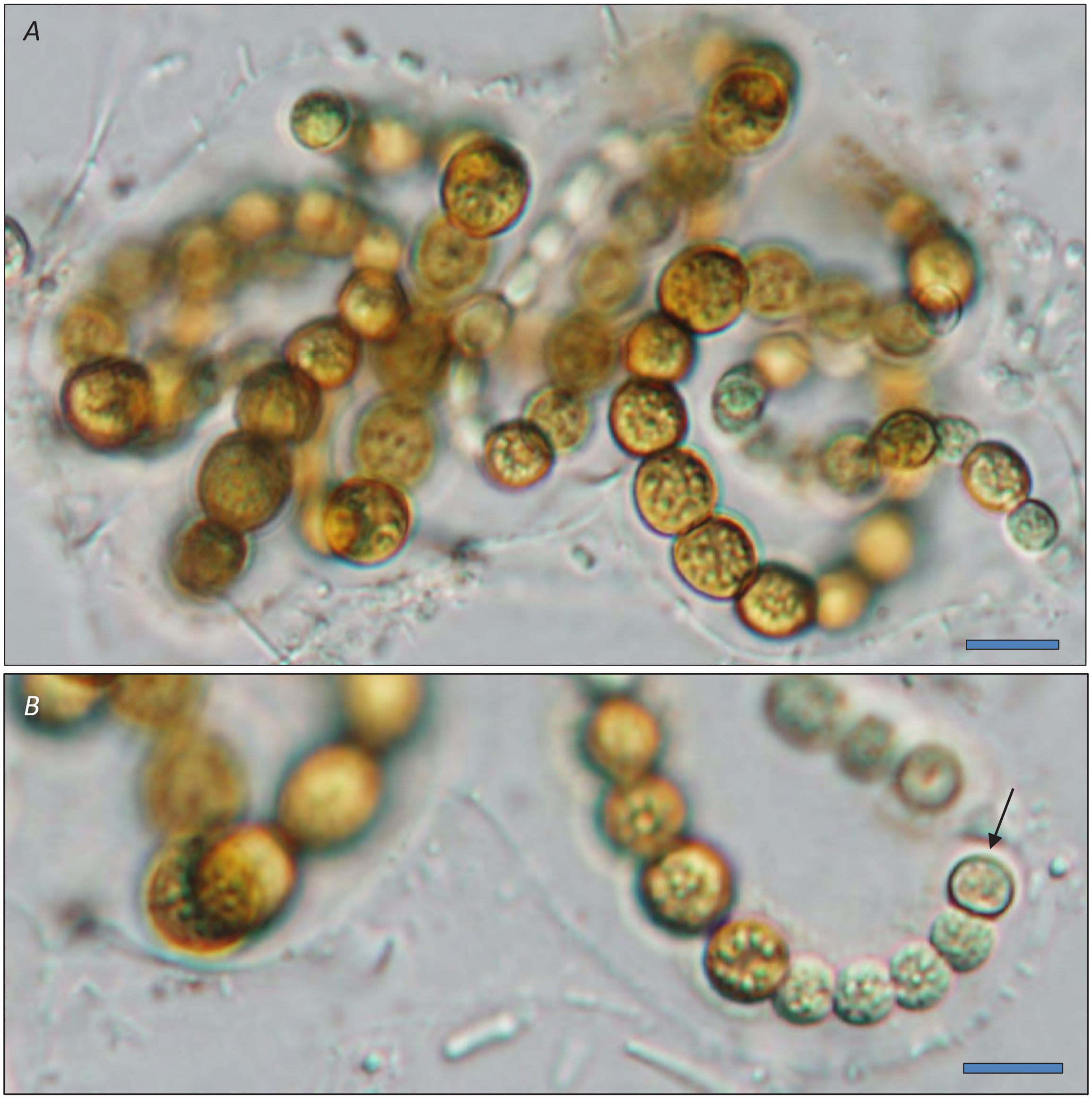

Figure 16. *Nostoc* sp. Vaucher ex Bornet & Flahault; bars are 10 μm in length (Komárek, 2013).

Figures 16*A* and 16*B* illustrates *Nostoc* sp., a filamentous form that is mostly coiled and an abundance of mucilage. Cells are spherical and deeply constricted between cells. Heterocytes spherical and the same size as other cells in the filament (at arrow). Aerotopes are absent.

Order Oscillatoriales
Family Microcoleaceae
Genus *Planktothrix*

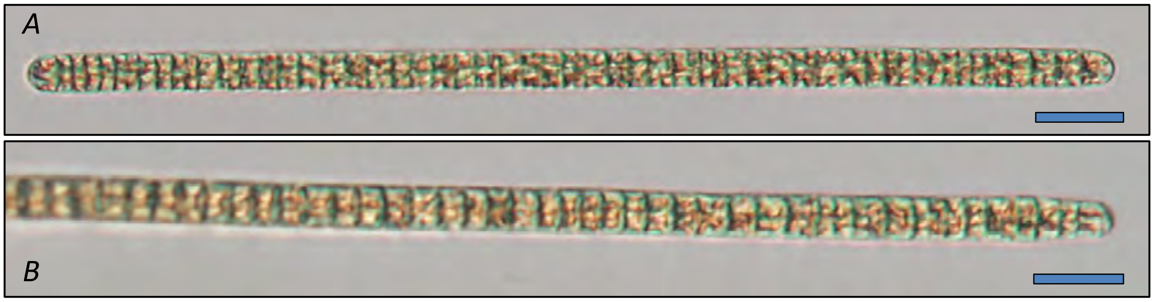

Figure 17. *Planktothrix suspensa* (Pringsheim) Anagnostidis & Komárek; bars are 20 μm in length (Komárek and Anagnostidis, 2005, fig. 498).

Figures 17*A* and 17*B* illustrate *Planktothrix suspensa* , a filamentous form that is mostly straight. Cells are shorter than they are wide, and there is no constriction between cells. Terminal cell is broadly rounded and in some filaments, slightly tapered. Aerotopes are abundant.

Order Synechococcales
Family Coelosphaeriaceae
Genus *Coelomoron*

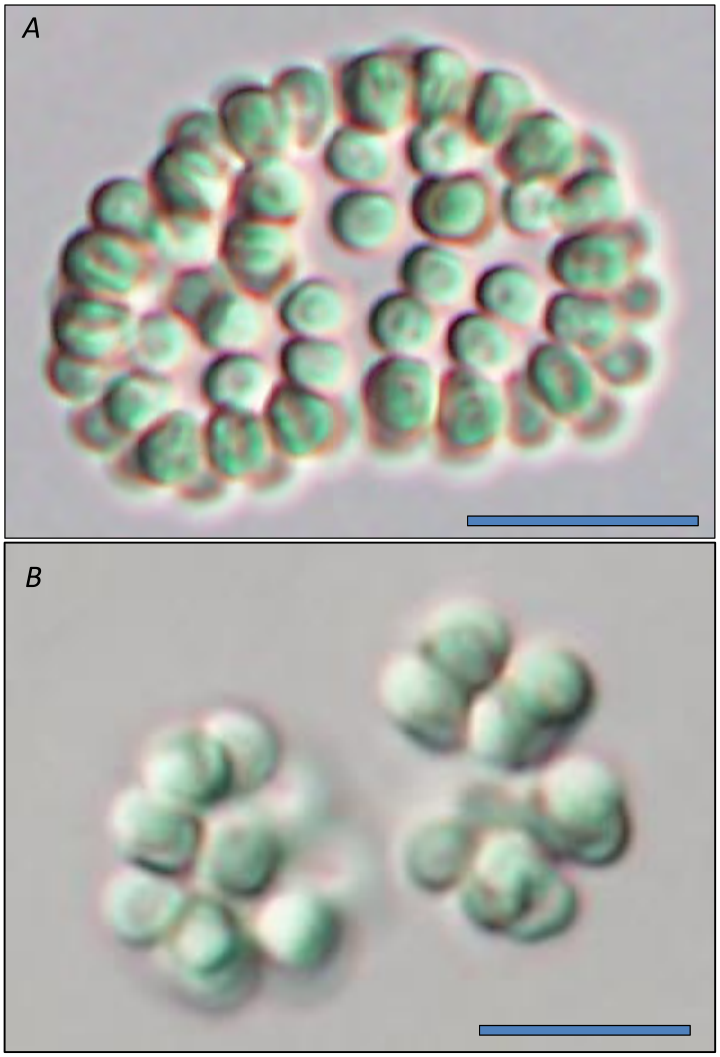

Figure 18. *Coelomoron pusillum* (Van Goor) Komárek; bars are 10 µm in length (Komárek and Anagnostidis, 1998, fig. 262).

Figures 18*A* and 18*B* illustrate *Coelomoron pusillum,* a colonial form, with small cells arranged into colonies. Young colony cells are cells more tightly packed (fig. 18*B*) compared to older colonies (fig. 18*A*).

Order Synechococcales
Family Leptolyngbyaceae
Genus *Planktolyngbya*

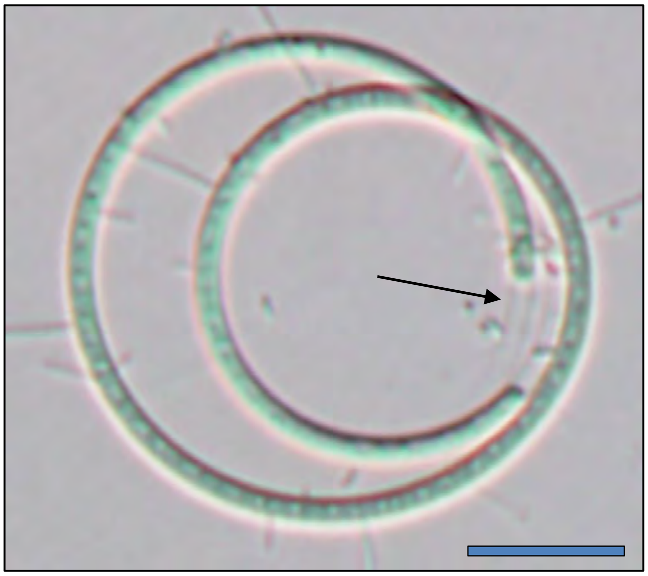

Figure 19. *Planktolyngbya contorta* (Lemmermann) Anagnostidis and Komárek; bar is 10 μm (Komárek and Anagnostidis, 2005, fig. 196).

Figure 19 illustrates *Planktolyngbya contorta,* a thin filamentous form that is coiled. Sheath can be observed (at arrow).

Order Synechococcales
Family Leptolyngbyaceae
Genus *Planktolyngbya*

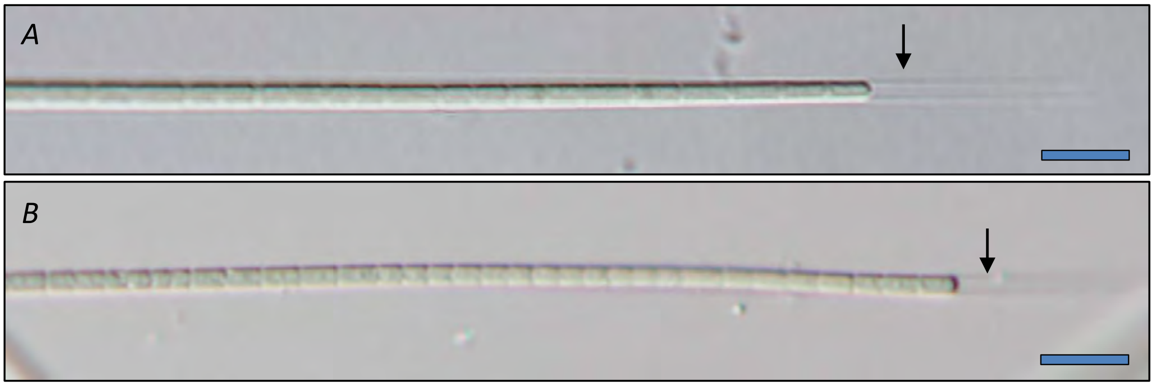

Figure 20. *Planktolyngbya limnetica* (Lemmermann) Komárková-Legnerová and Cronberg Komárková-Legnerová, J. & Cronberg, G.; bars are 10 μm in length (Komárek and Anagnostidis, 2005, fig. 193).

Figures 20*A* and 20*B* illustrate *Planktolyngbya limnetica,* a filamentous form that is straight. Sheath can be observed (at arrows).

Order Synechococcales
Family Merismopediaceae
Genus *Aphanocapsa*

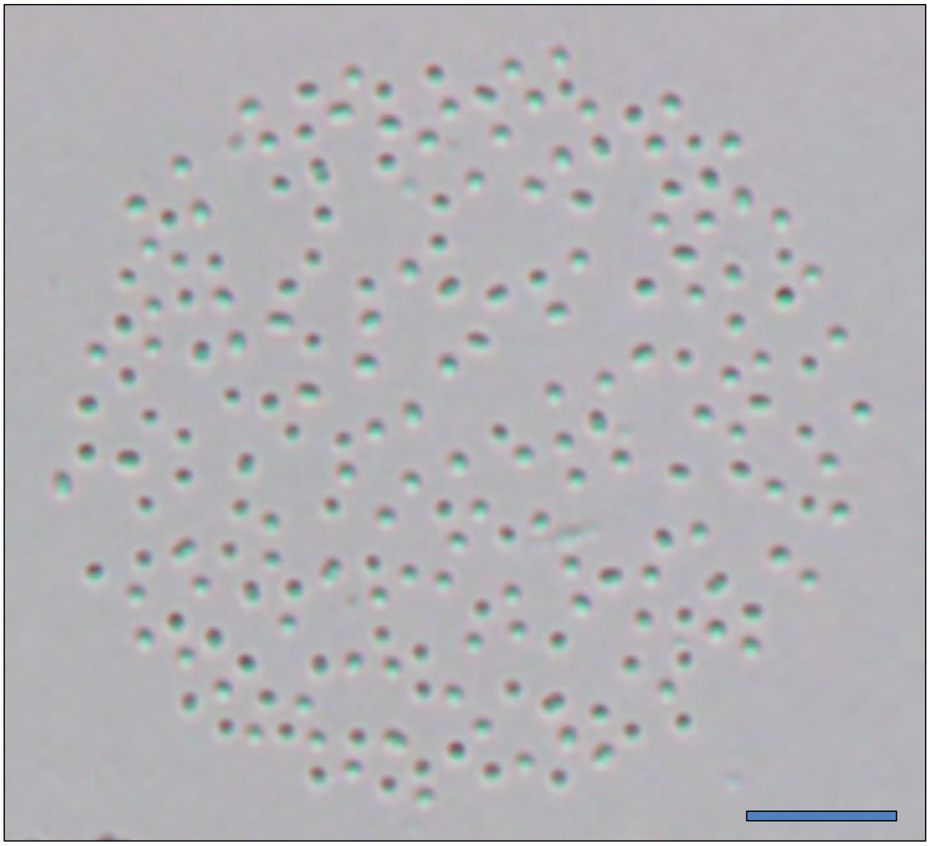

Figure 21. *Aphanocapsa delicatissima* West and G. S. West; bar is 10 µm in length (Komárek and Anagnostidis, 1998, fig. 171).

Figure 21 illustrates *Aphanocapsa delicatissima,* a colonial form, with very small spherical cells, under 1 µm in diameter, loosely packed into a colony. Cells appear elongated before cell division.

Order Synechococcales
Family Merismopediaceae
Genus *Aphanocapsa*

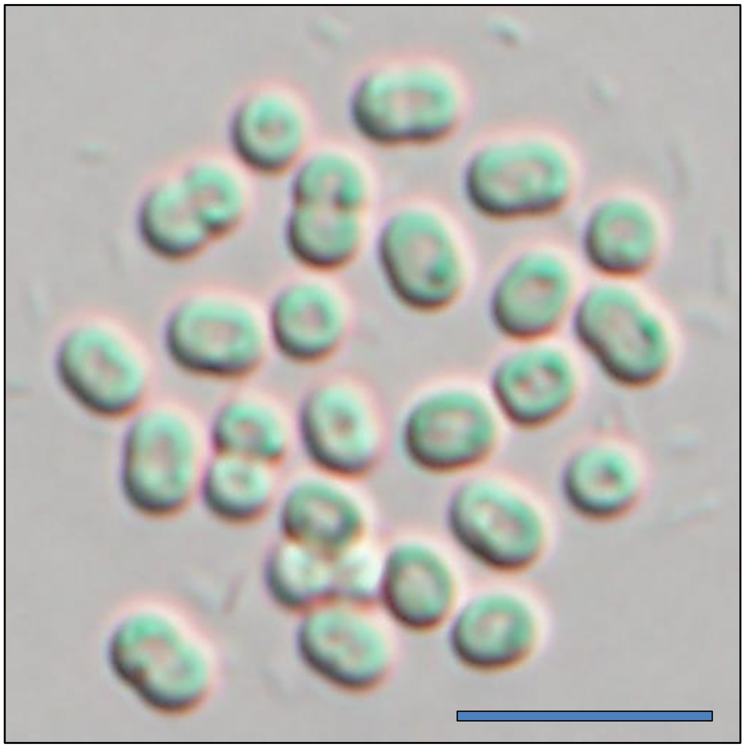

Figure 22. *Aphanocapsa* cf. *planctonica* (G. M. Smith); bar is 10 μm in length (Komárek and Anagnostidis, 1999, fig. 184).

Figure 22 illustrates *Aphanocapsa* cf. *planctonica,* a colonial form, with small spherical cells, 2.75 μm in diameter, packed tightly into a colony. Cells appear elongated before cell division.

Order Synechococcales
Family Merismopediaceae
Genus *Aphanocapsa*

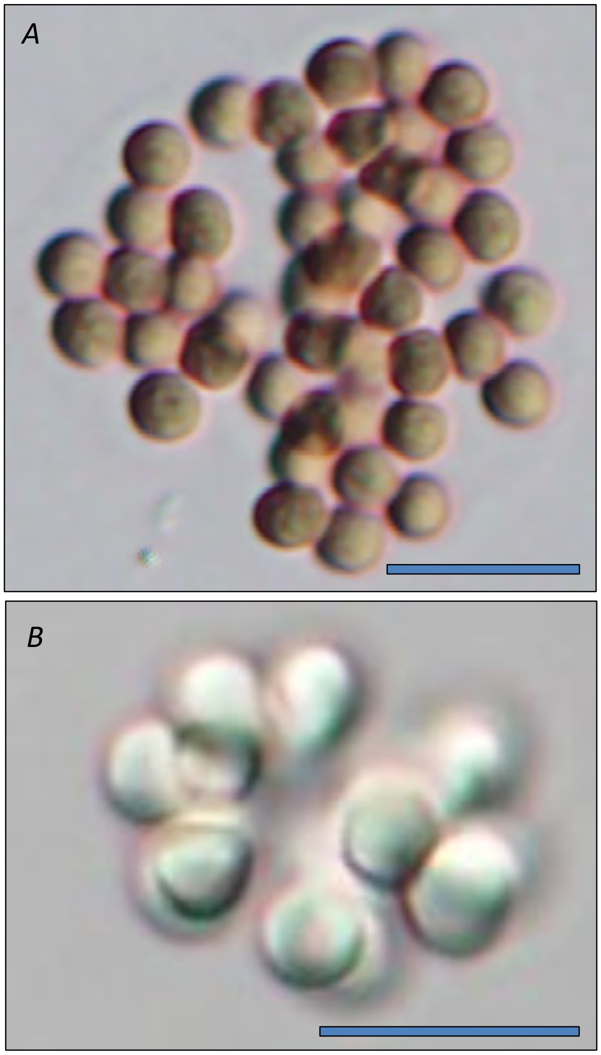

Figure 23. *Aphanocapsa grevillei* (Berkeley) Rabenhorst; bars are 10 μm in length (Komárek and Anagnostidis, 1998, fig. 194).

Figures 23*A* and 23*B* illustrate *Aphanocapsa grevillei,* a colonial form, with spherical cells, 3.5 μm in diameter, packed tightly into a colony. Fig. 23*A* was preserved in Lugol's iodine (the only image in this document in which a preserved sample was used).

Order Synechococcales
Family Merismopediaceae
Genus *Merismopedia*

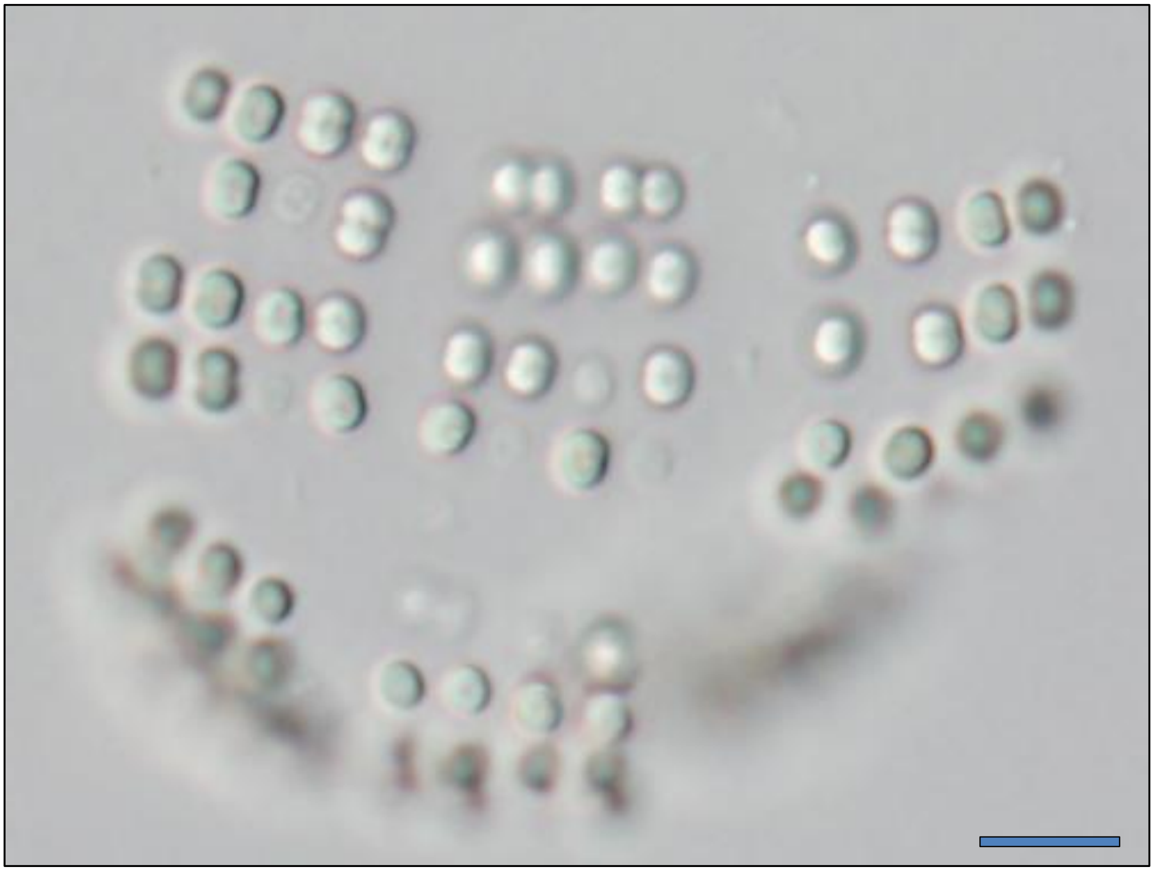

Figure 24. *Merismopedia punctata* Meyen; bar is 10 µm in length (Komárek and Anagnostidis, 1999, fig. 222).

Figure 24 illustrates *Merismopedia punctata,* a colonial form, with small hemispheric and spherical cells, spaced evenly and regularly from one another, forming a flat sheet of cells. Cells appear elongated before cell division.

Order Synechococcales
Family Pseudanabaenaceae
Genus *Limnothrix*

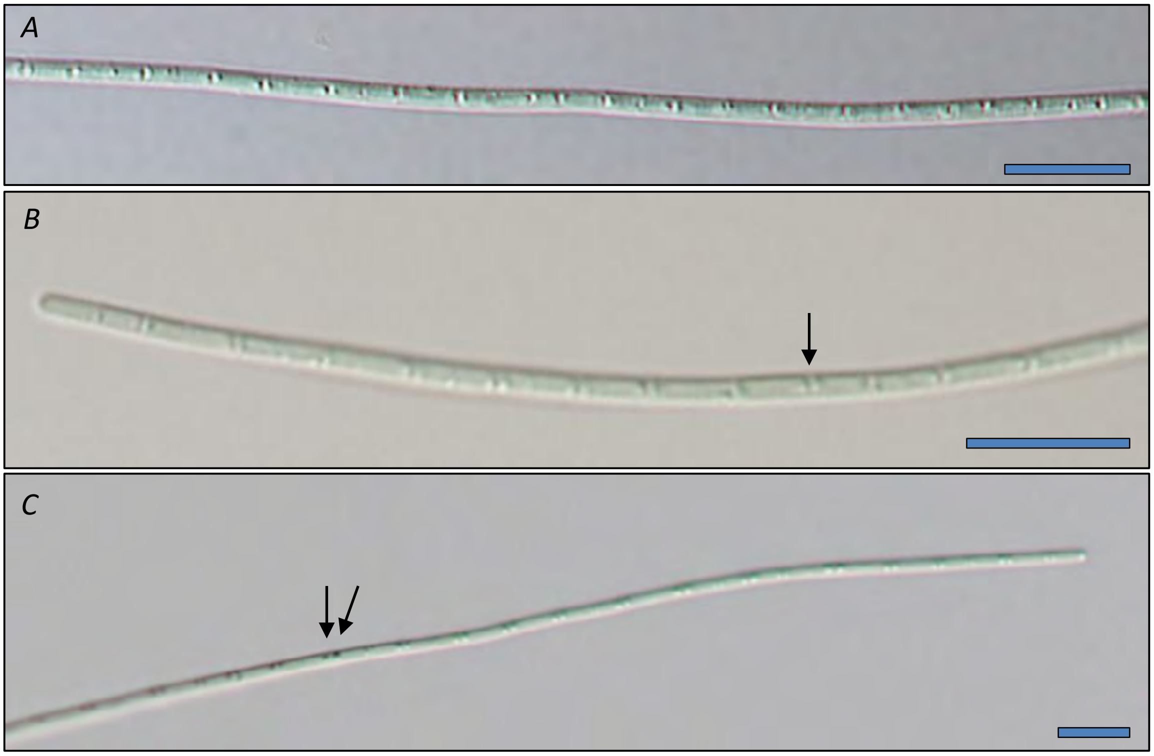

Figure 25. *Limnothrix redekei* (Van Goor) Meffert; bars are 10 μm in length (Komárek and Anagnostidis, 2005, fig. 82).

Figures 25*A*–25*C* illustrate *Limnothrix redekei,* a filamentous form that is straight to slightly curved. Cells are longer than they are wide, with distinct cross-walls (clear space at arrow) and inclusions adjacent to the cross-wall (double arrow).

Order Synechococcales
Family Pseudanabaenaceae
Genus *Pseudanabaena*

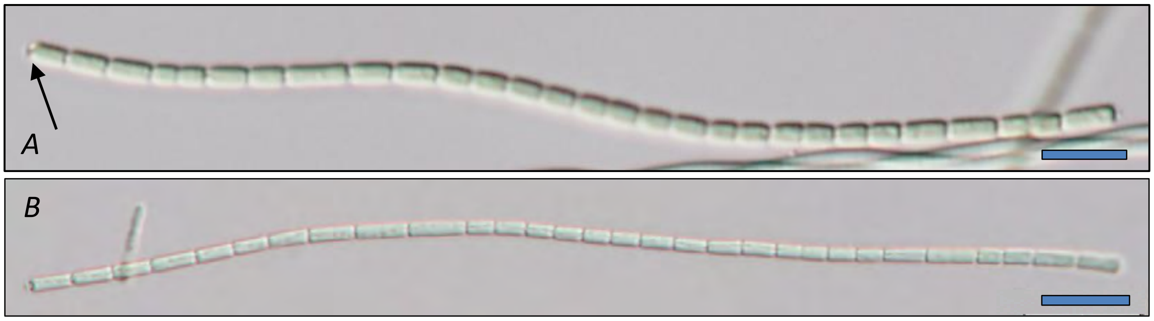

Figure 26. *Pseudanabaena* cf. *galeata* Böcher; bars are 10 µm in length (Komárek and Anagnostidis, 1998, fig. 67).

Figures 26*A* and 26*B* illustrate *Pseudanabaena* cf. *galeata,* a filamentous form that is slightly curved. Cells are longer than wide, deeply constricted at the cross-walls, and with a distinct terminal cell with a clear inclusion (at arrow).

Order Synechococcales
Family Pseudanabaenaceae
Genus *Pseudanabaena*

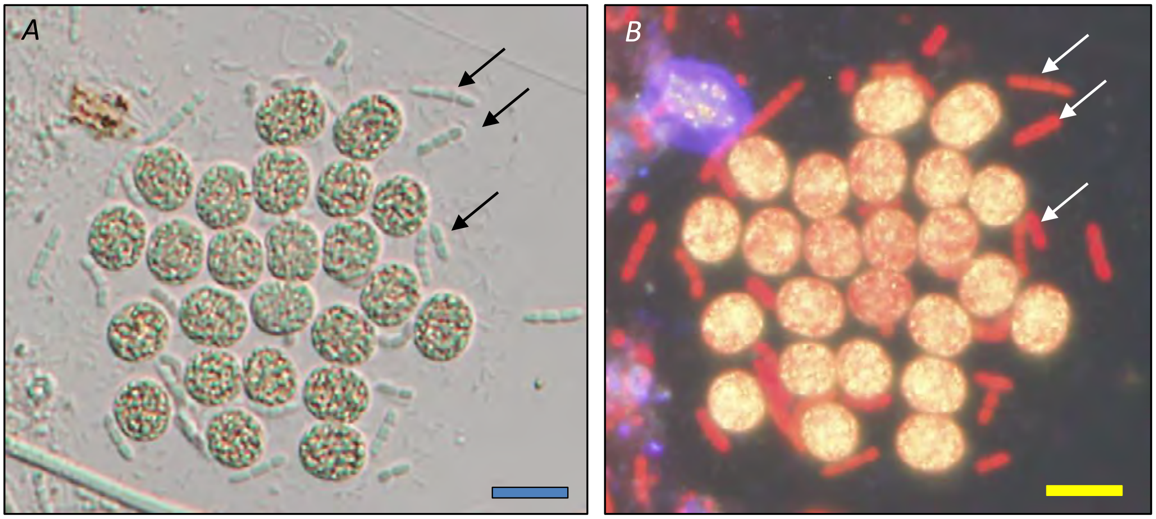

Figure 27. *Pseudanabaena mucicola* (Naumann and Huber-Pestalozzi) Schwabe (at arrows) in the *Microcystis* colony; bars are 10 μm length (Komárek and Anagnostidis, 2005, fig. 51).

Figures 27*A* and 27*B* illustrate *Pseudanabaena mucicola* (at arrows), a filamentous form that lives in association with *Microcystis* and other cyanobacteria and algae. Filaments of *P. mucicola* are 2–8 cells long, deeply constricted at the cross-walls, and with a conical terminal. Fig. 27*B*, illuminated by UV epifluorescence, shows the deep red color of *P. mucicola,* whereas the *Microcystis* cells appear granular and yellow because of the presence of aerotopes.

Order Synechococcales
Family Pseudanabaenaceae
Genus *Pseudanabaena*

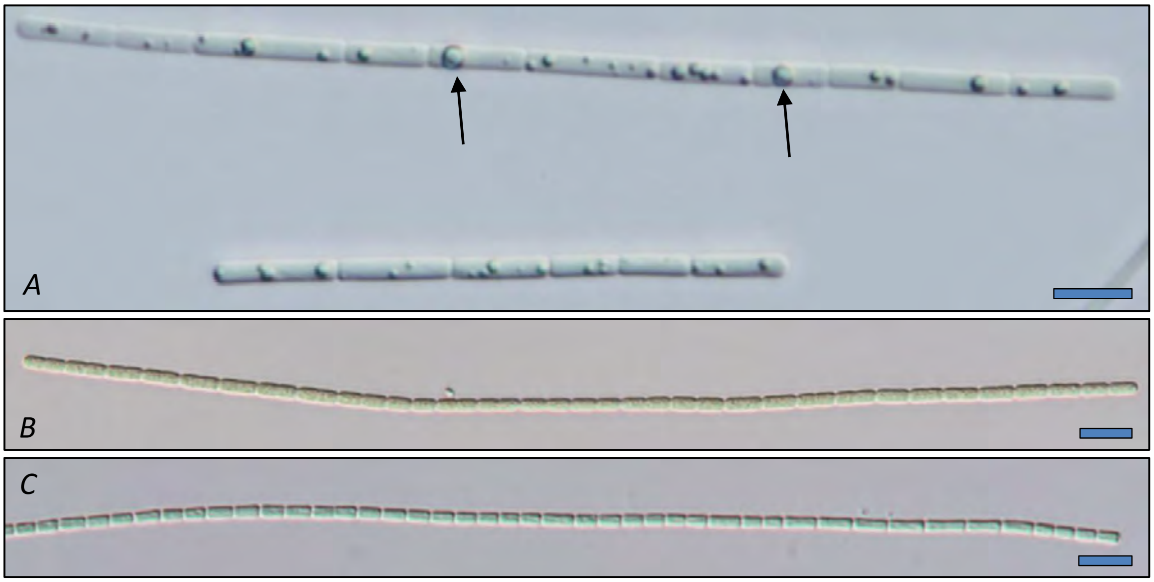

Figure 28. *Pseudanabaena* sp. Lauterborn; bars are 10 μm length (Komárek and Anagnostidis, 2005).

Figures 28*A*–28*C* illustrate *Pseudanabaena* sp., a filamentous form that is straight to slightly curved. Cells are longer than they are wide, deeply constricted at the cross-walls. Fig. 28*A* shows cellular inclusions (at arrows) that may function as aerotopes.

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