Blue-green algae in Wisconsin: their identification, potential health effects, and determination of safe levels for recreation

2017 Wisconsin Lakes Partnership Convention Workshop

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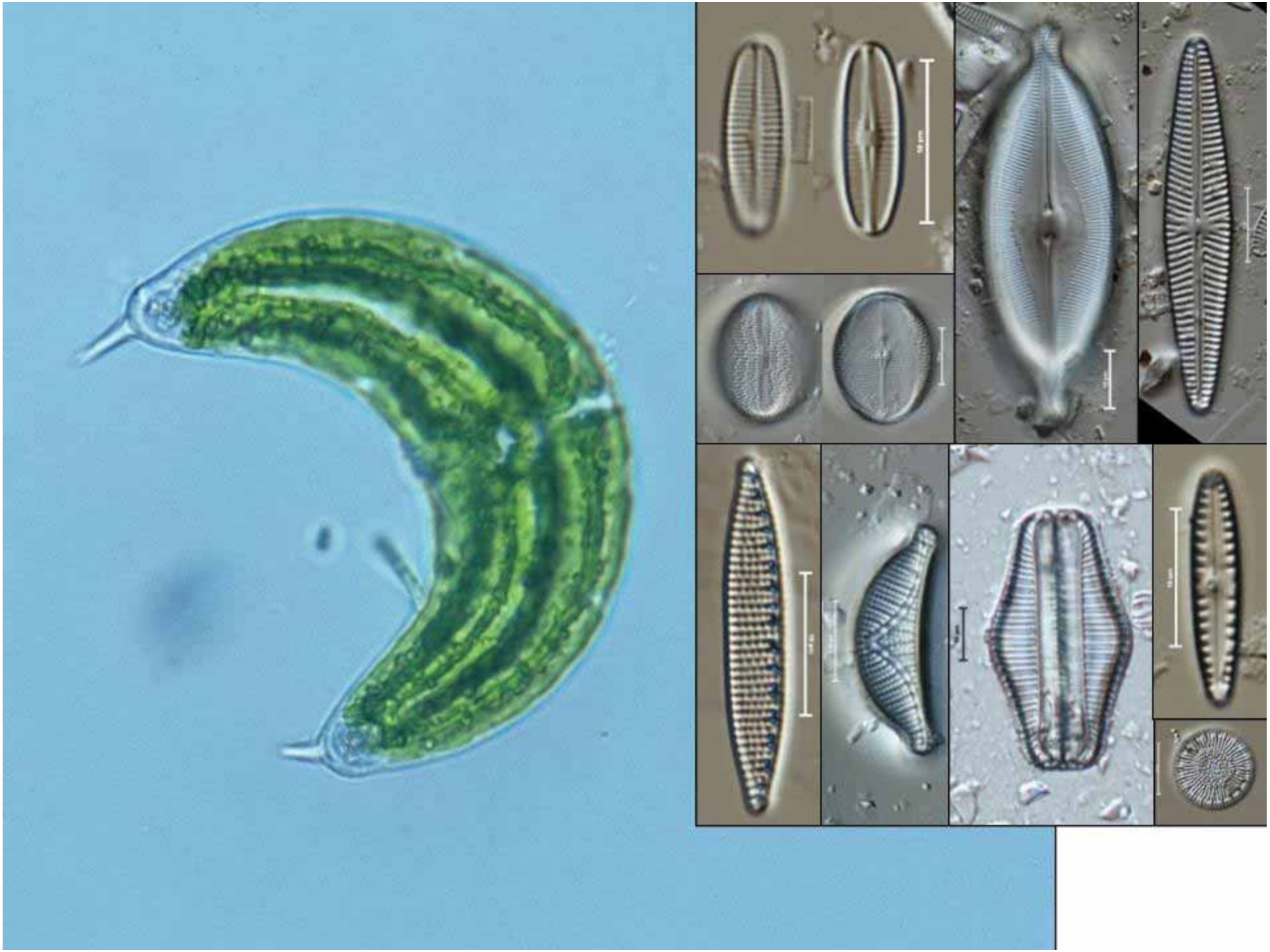
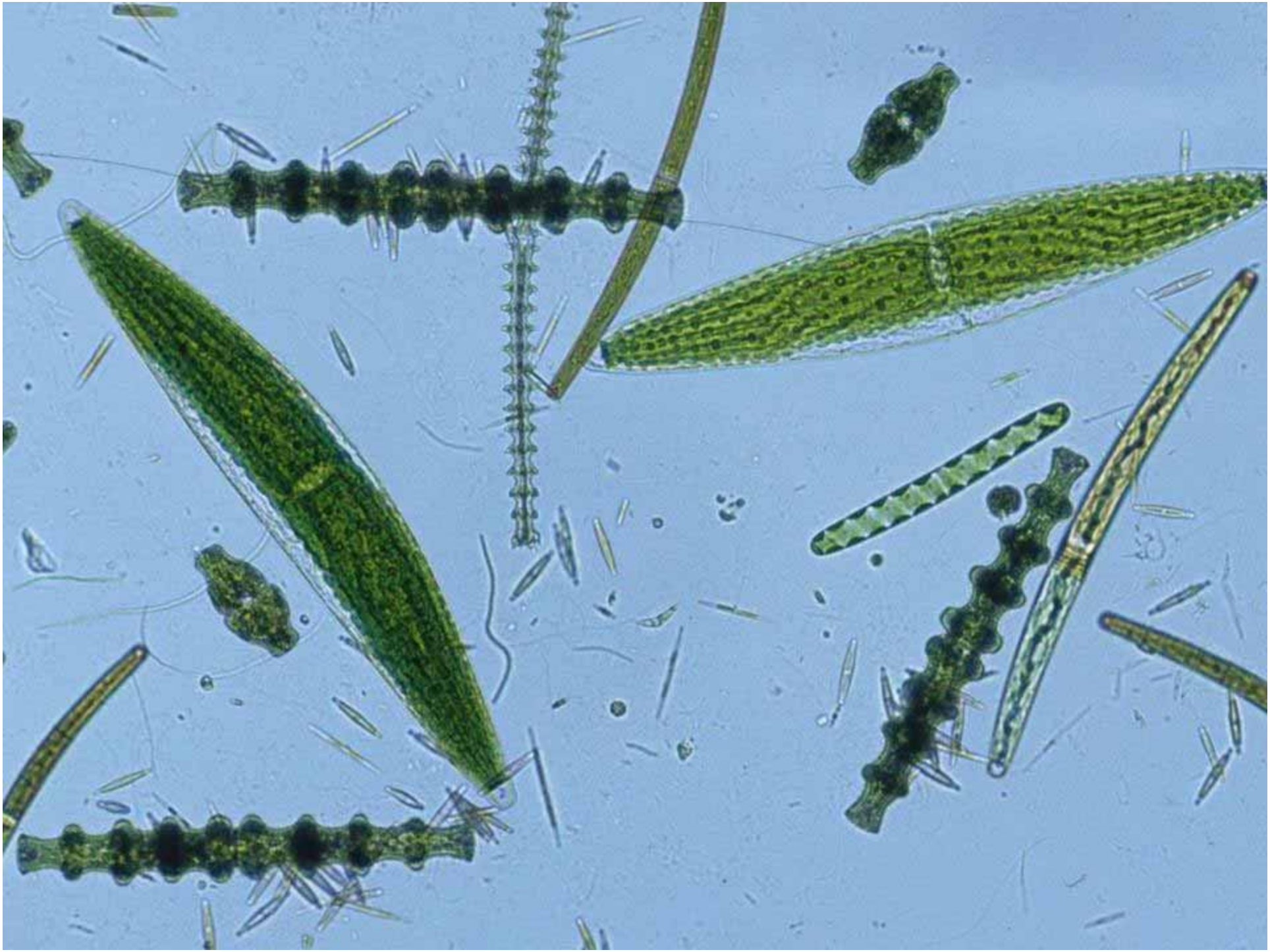
All photos by Gina LaLiberte unless otherwise attributed.

Workshop Agenda

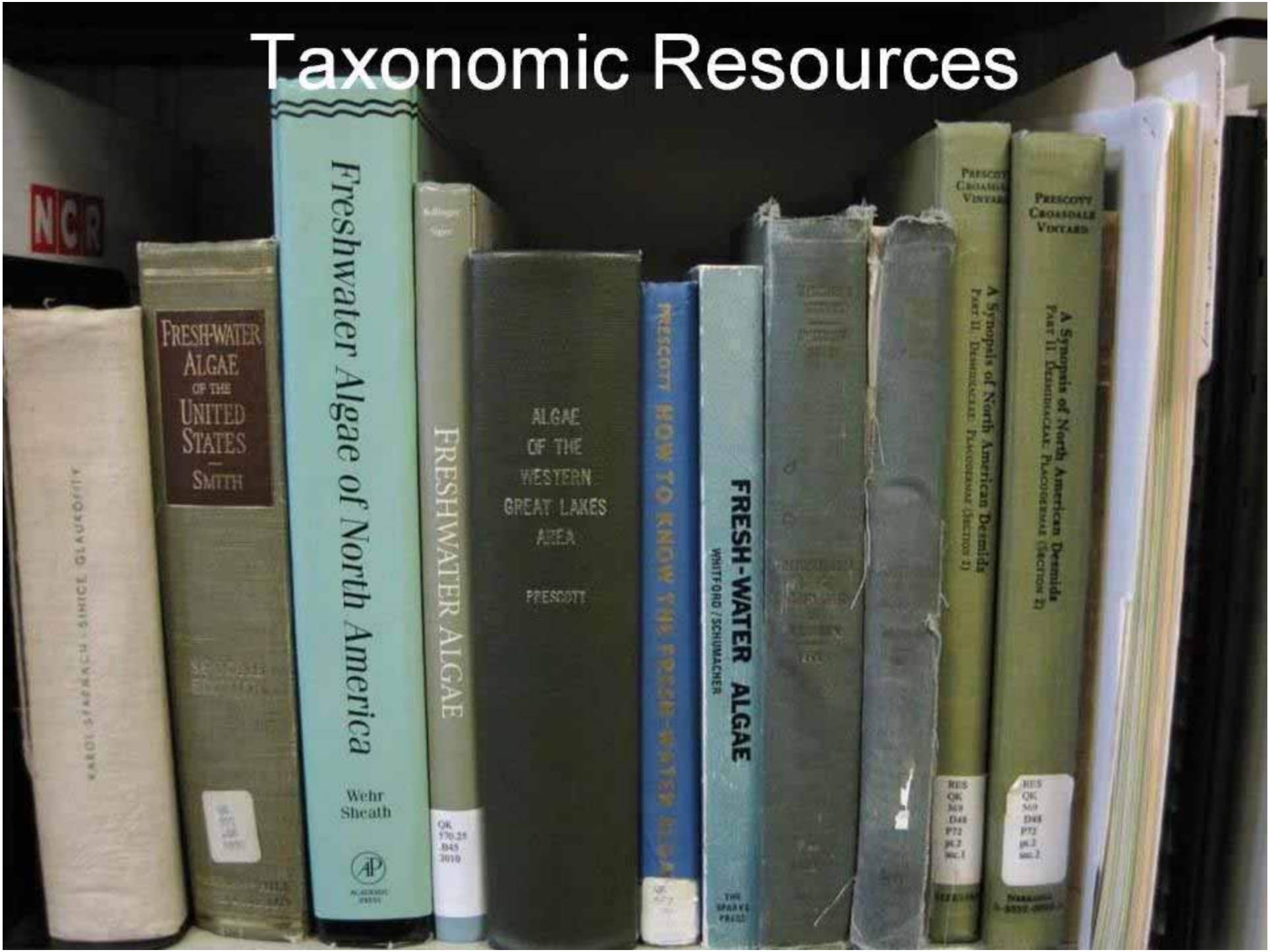
- Introductions
- Resources
- Caveats
- Cyanobacteria & algae background
- Hands-on
- Health impacts & recreational guidelines




T. Johnson



Taxonomic Resources



How To Know

THE FRESH-WATER ALGAE

An illustrated key for identifying the more common Fresh-water Algae to genus, with hundreds of species named and pictured and with numerous aids for their study.

by

G. W. PRESCOTT, Ph.D.
Professor of Botany
Michigan State University

Pictured-Key Nature Series

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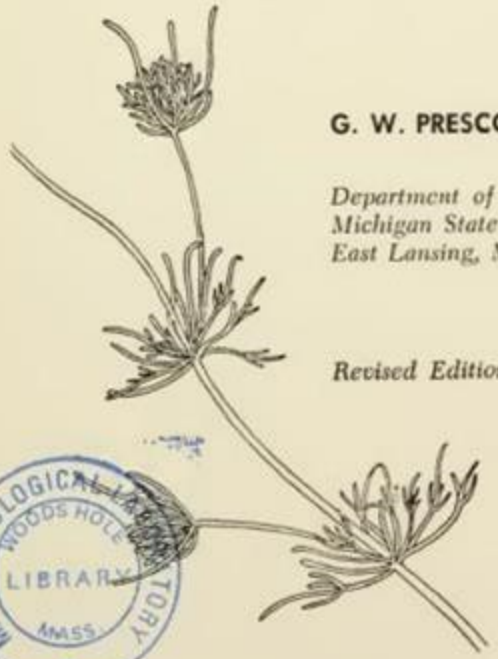
ALGAE

OF THE WESTERN GREAT LAKES AREA

With an Illustrated Key to the Genera of Desmids and Freshwater Diatoms



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Department of Botany and Plant Pathology
Michigan State University
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Revised Edition

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Freshwater Algae

Identification, Enumeration and Use as Bioindicators

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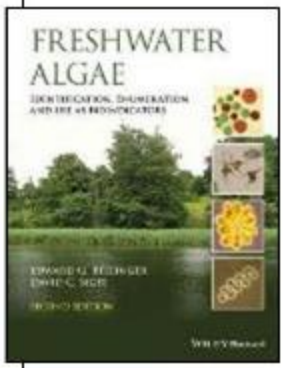
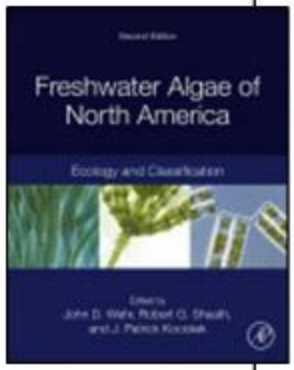


WILEY Blackwell

Freshwater Algae of North America

Ecology and Classification



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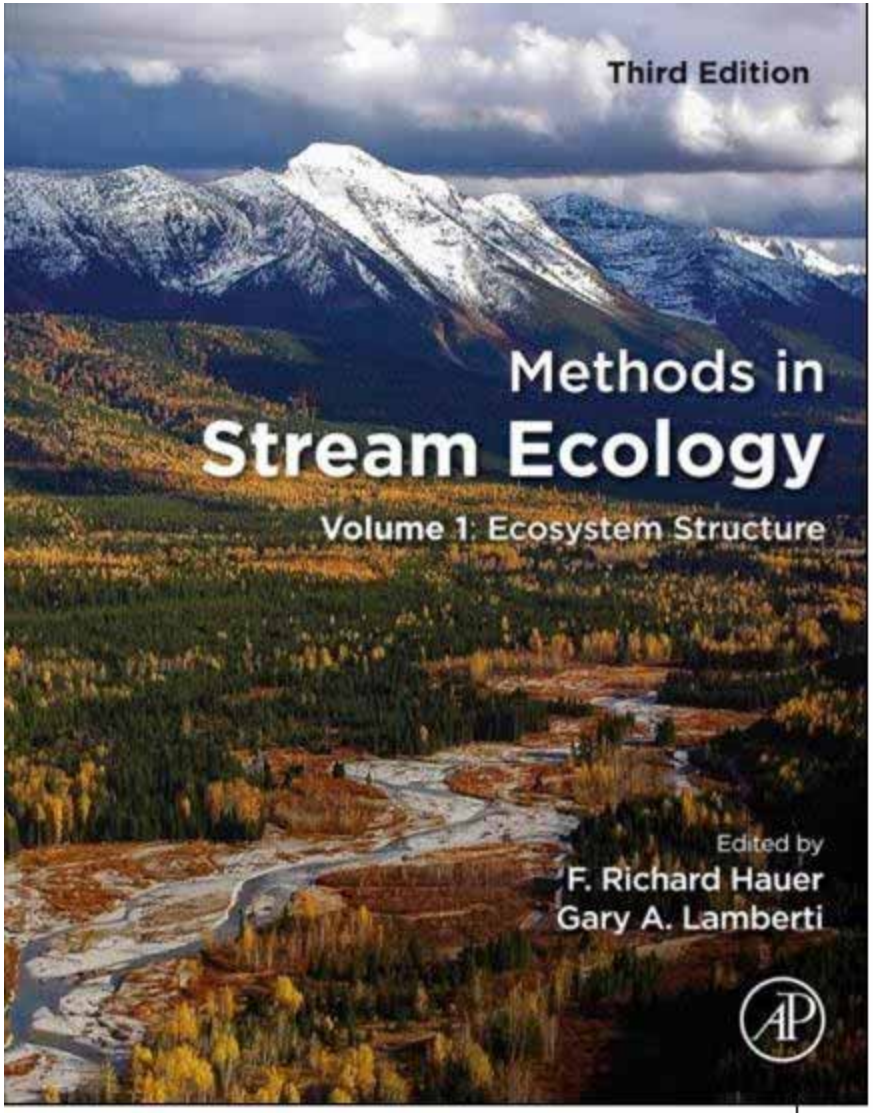
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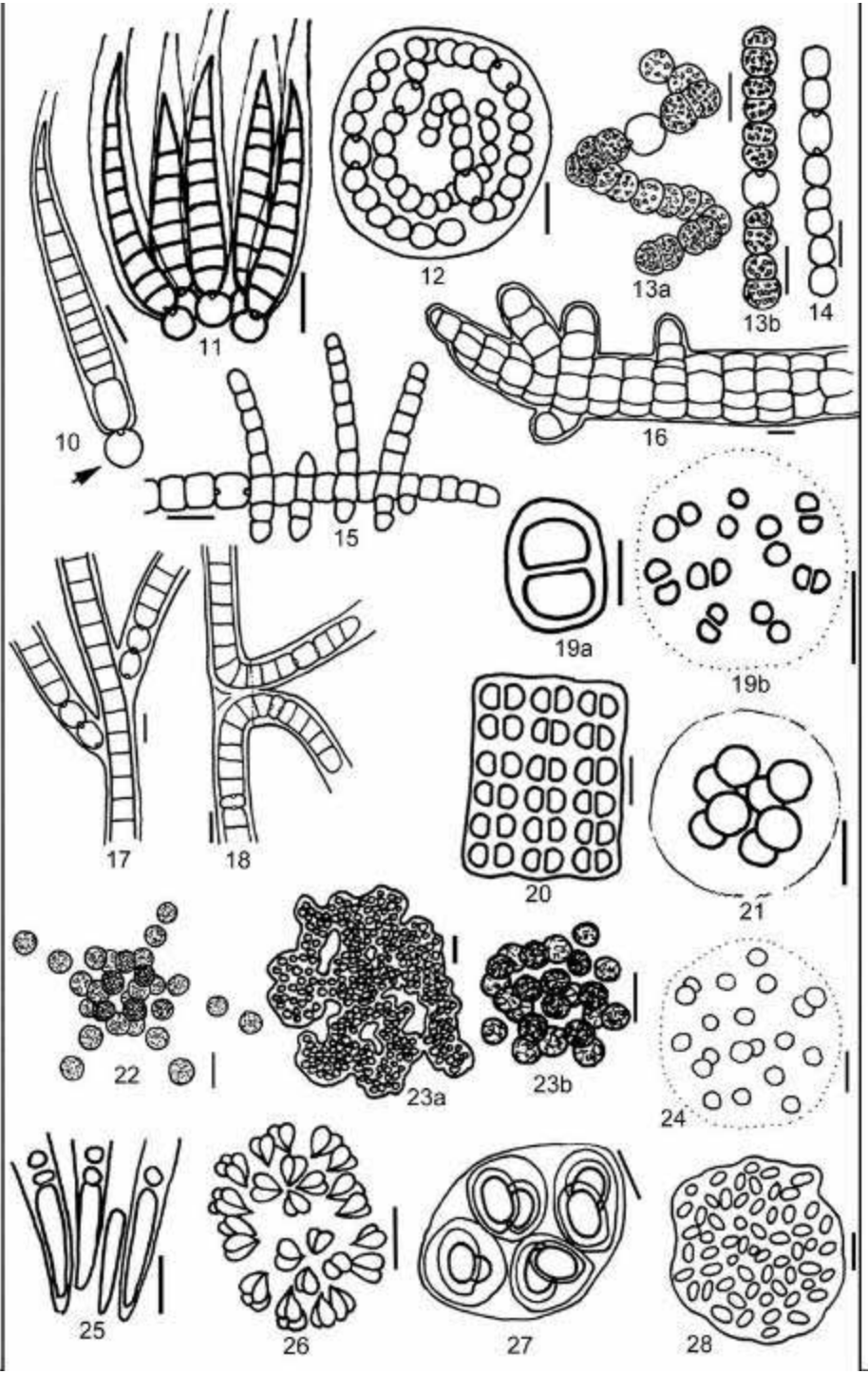
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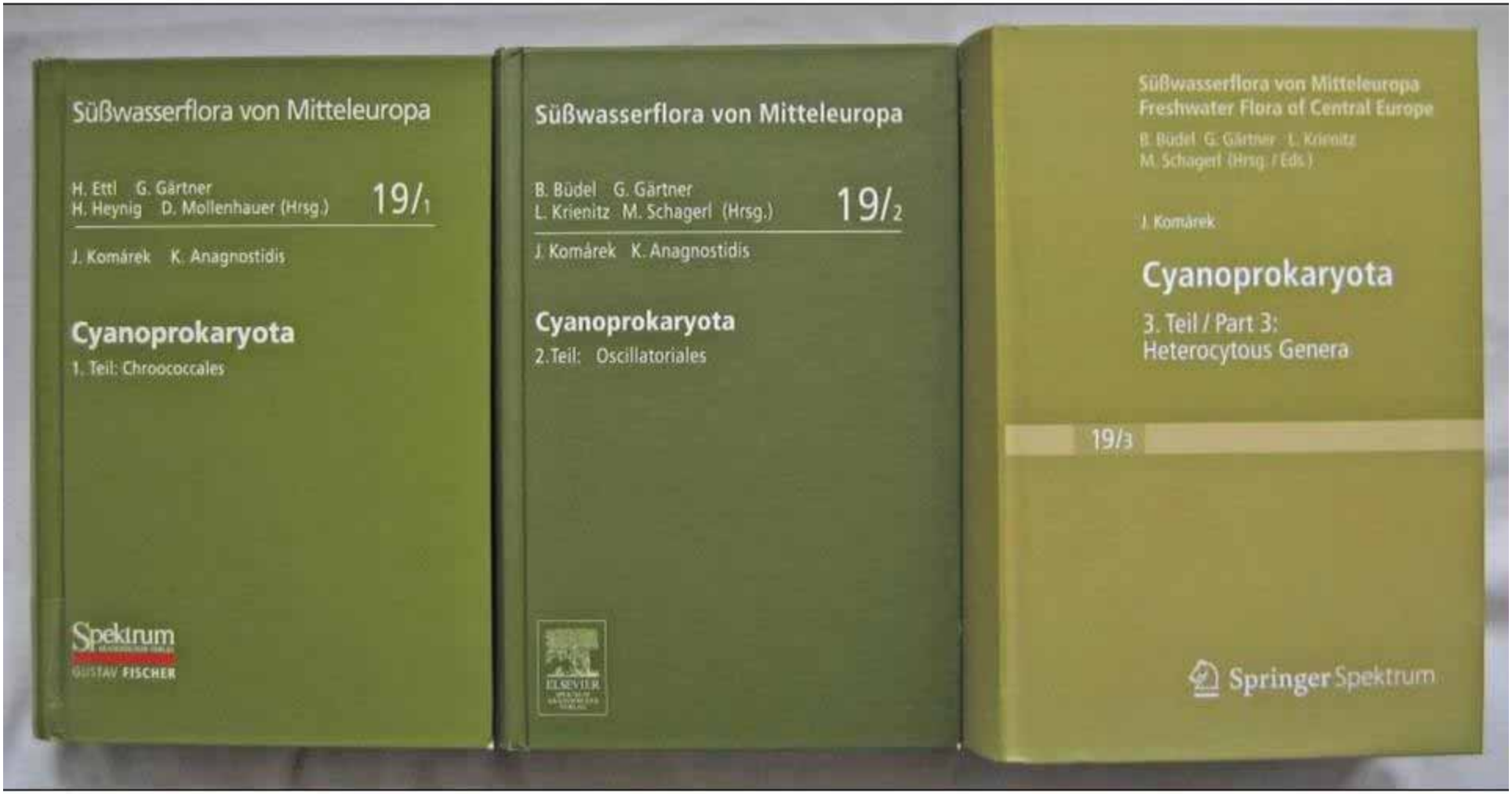
USGS
science for a changing world

Field and Laboratory Guide to Freshwater Cyanobacteria Harmful Algal Blooms for Native American and Alaska Native Communities

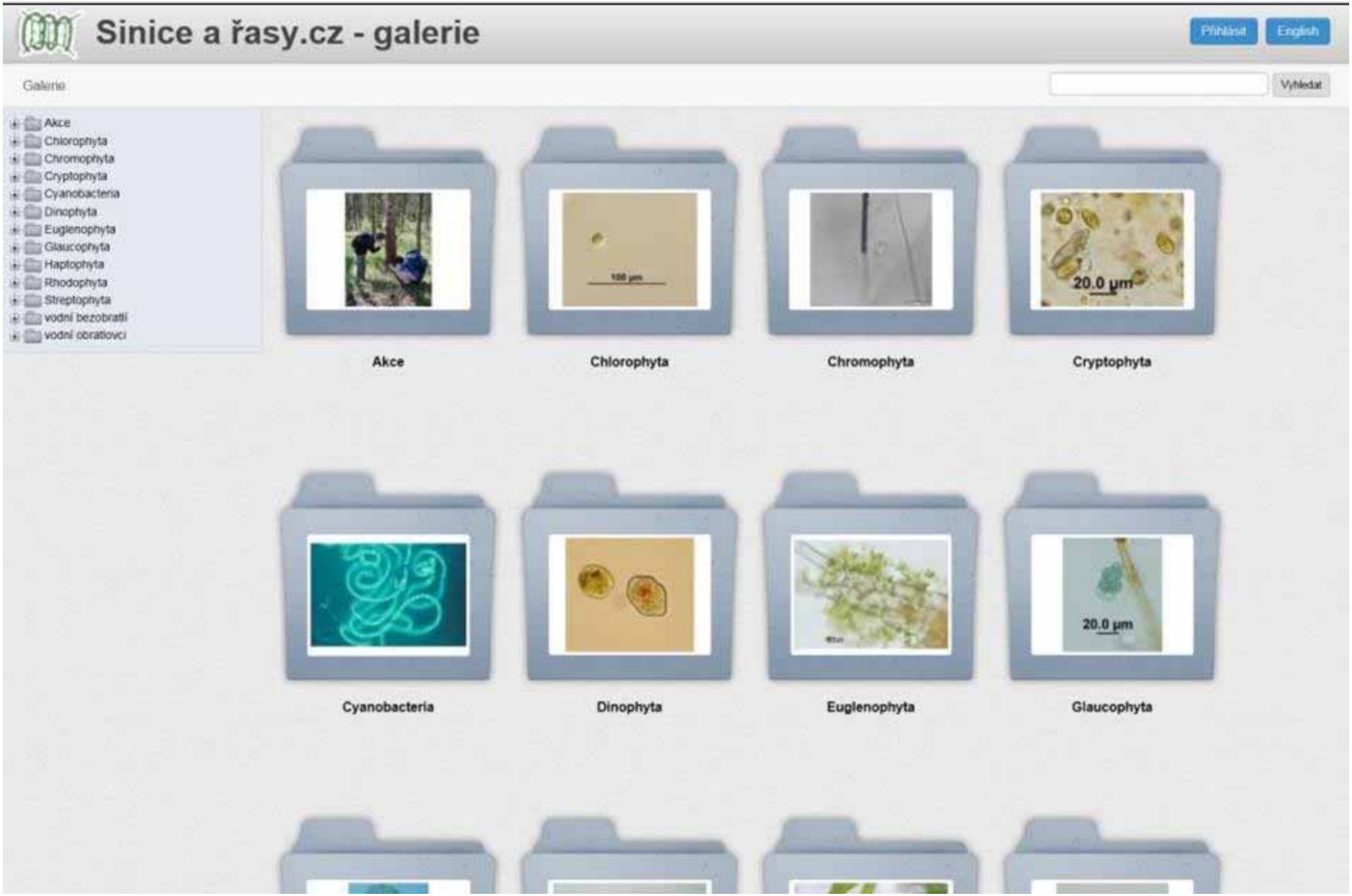
Open-File Report 2015–1164

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

Süßwasserflora von Mitteleuropa: Cyanoprokaryota
Komárek & Anagnostidis 2008-2013



Online Resources



Species Search

Search results

For more detail, click on the name or the currently accepted name.

Name	Current accepted name (if different)
Anabaena flosaquae f. lemmermannii (P.G.Richter) Canabaeus	Dolichospermum lemmermannii (Richter) P.Wacklin, L.Hoffmann & J.Komárek
Anabaena lemmermannii f. laxa (Skuja) G.Cronberg & J.Komárek - Unchecked	
Anabaena lemmermannii P.G.Richter	Dolichospermum lemmermannii (Richter) P.Wacklin, L.Hoffmann & J.Komárek
Anabaena lemmermannii var. minor (Utermöhl) Komárková	

4 Found - Displaying **1** through **4**

Recent Species

Anagnostidinema tenue **(Anisimova) Strunecky *et al.***

Anagnostidinema lemmermannii **(Woloszynska) Strunecky *et al.***

Anagnostidinema lacus-solaris **(S.E.Campbell & Golubic) Strunecky *et al.***

Anagnostidinema ionicum **(Skuja) Strunecky *et al.***

Anagnostidinema epiphlocophyticum **(Anagnostidis) Strunecky *et al.***

Anagnostidinema exile **(Skuja) Strunecky *et al.***

Anagnostidinema deflexum **(West & G.S. West) Strunecky *et al.***

Anagnostidinema acutissimum **(Kufferath) Strunecký, Bohunická, J.R.Johansen & J.Komárek**

Anagnostidinema amphibium **(C.Agardh ex Gomont) Strunecký, Bohunická, J.R.Johansen & J.Komárek**

WI Cyanobacteria Resources

dnr.wi.gov and dhs.wisconsin.gov
Search for “algae”

Microscopes

Caveats

- Introduction to cyanobacteria
- Tools to ID cyanobacteria *vs.* other algae
- Resources for accurate communication

What are algae?

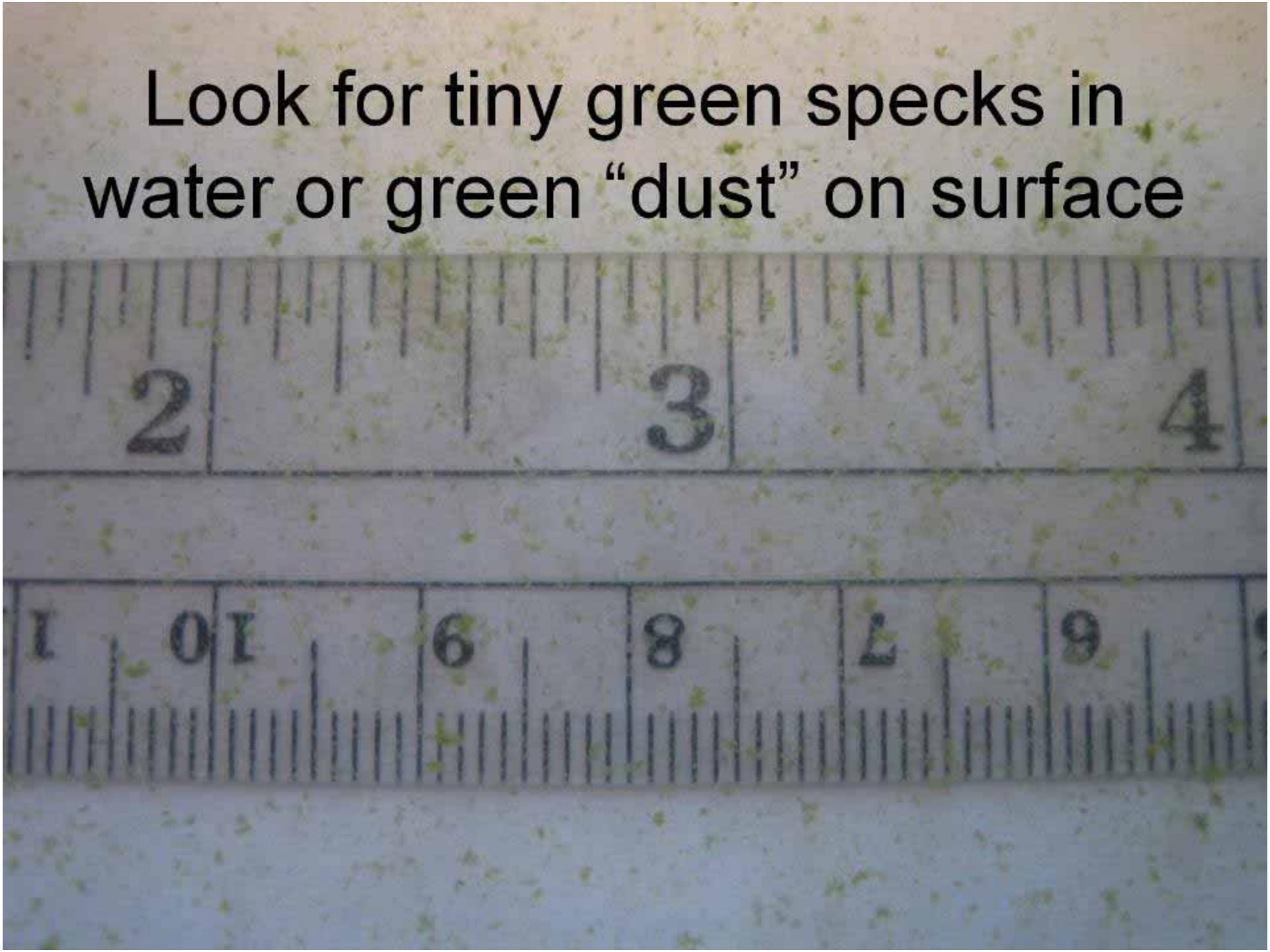
- Have chlorophyll, like plants
- Lack specialized tissues, unlike plants
- They grow everywhere, even in deserts
- From tiny unicells to giant kelp

Species vs. Strains

- Cyanobacteria (blue-green algae) are true bacteria
- Bacteria only divide – no sexual reproduction
- Different genetic makeups can evolve – these are strains.

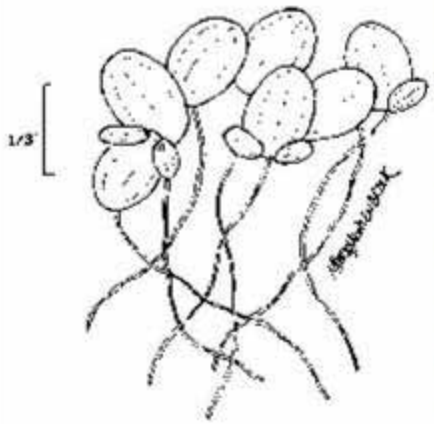
Key features for identification

- Color. All algae have chlorophyll-a. Many have additional pigments.
- Texture: stringy and hair-like? Tiny particles in water? Does it drape over your fingers or run right through them?
- Shape of colonies
- In most cases, light microscopy is necessary.


Look for tiny green specks in water or green “dust” on surface

Don’t mistake duckweeds or watermeal for blue-green algae

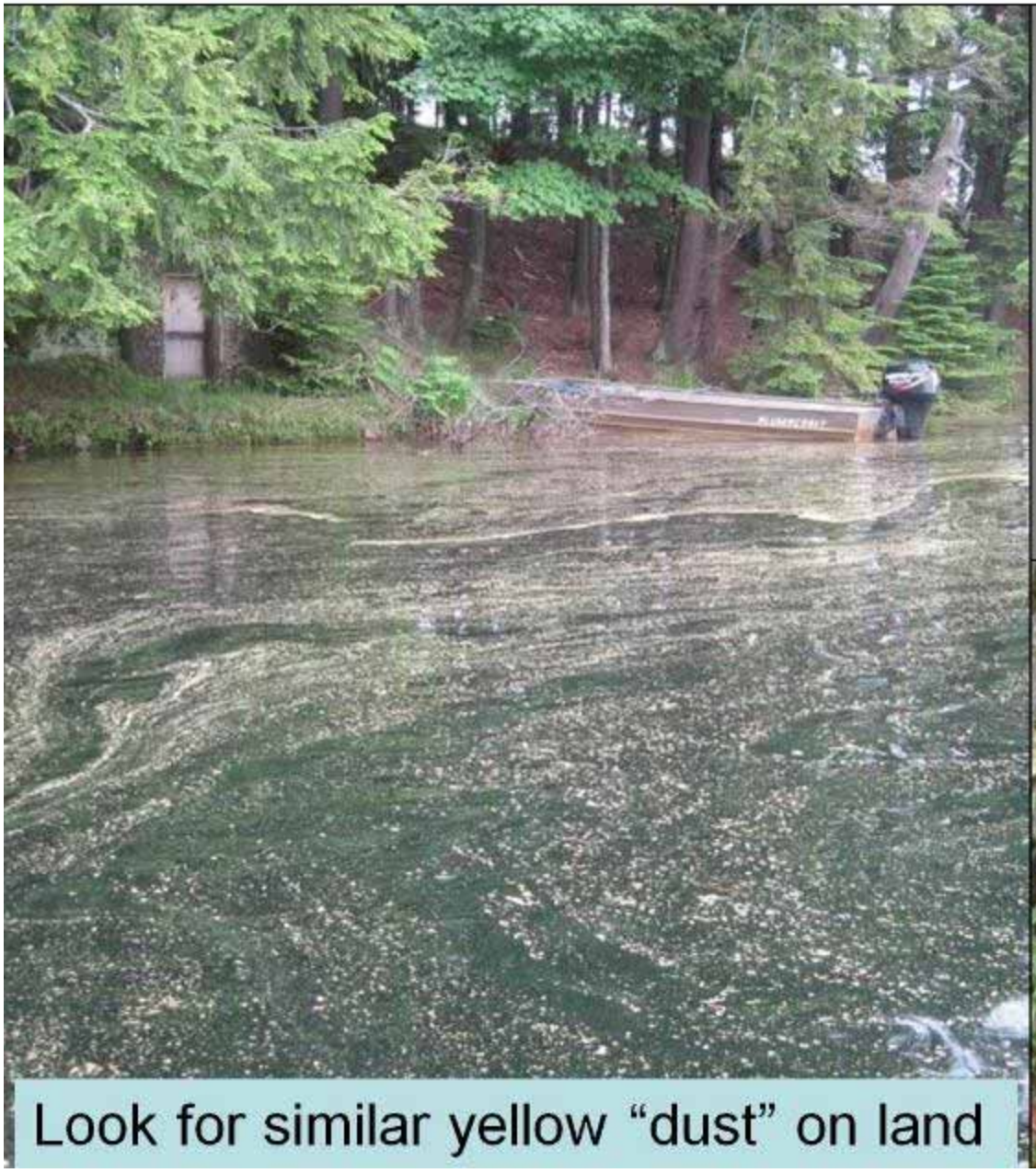
Duckweeds (*Lemna*, *Spirodela*) have roots



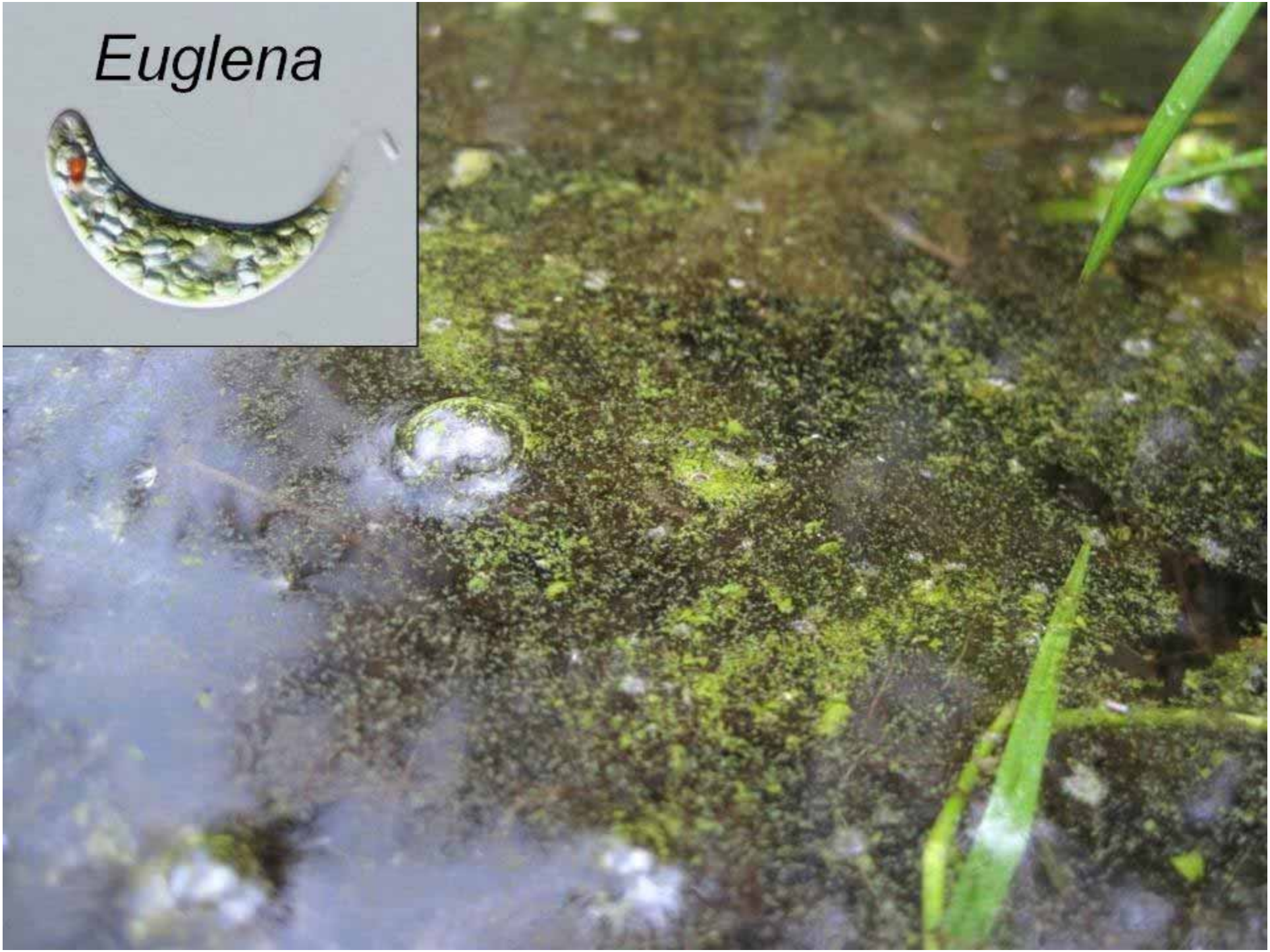
Lemna, *Spirodela*, *Wolffia*

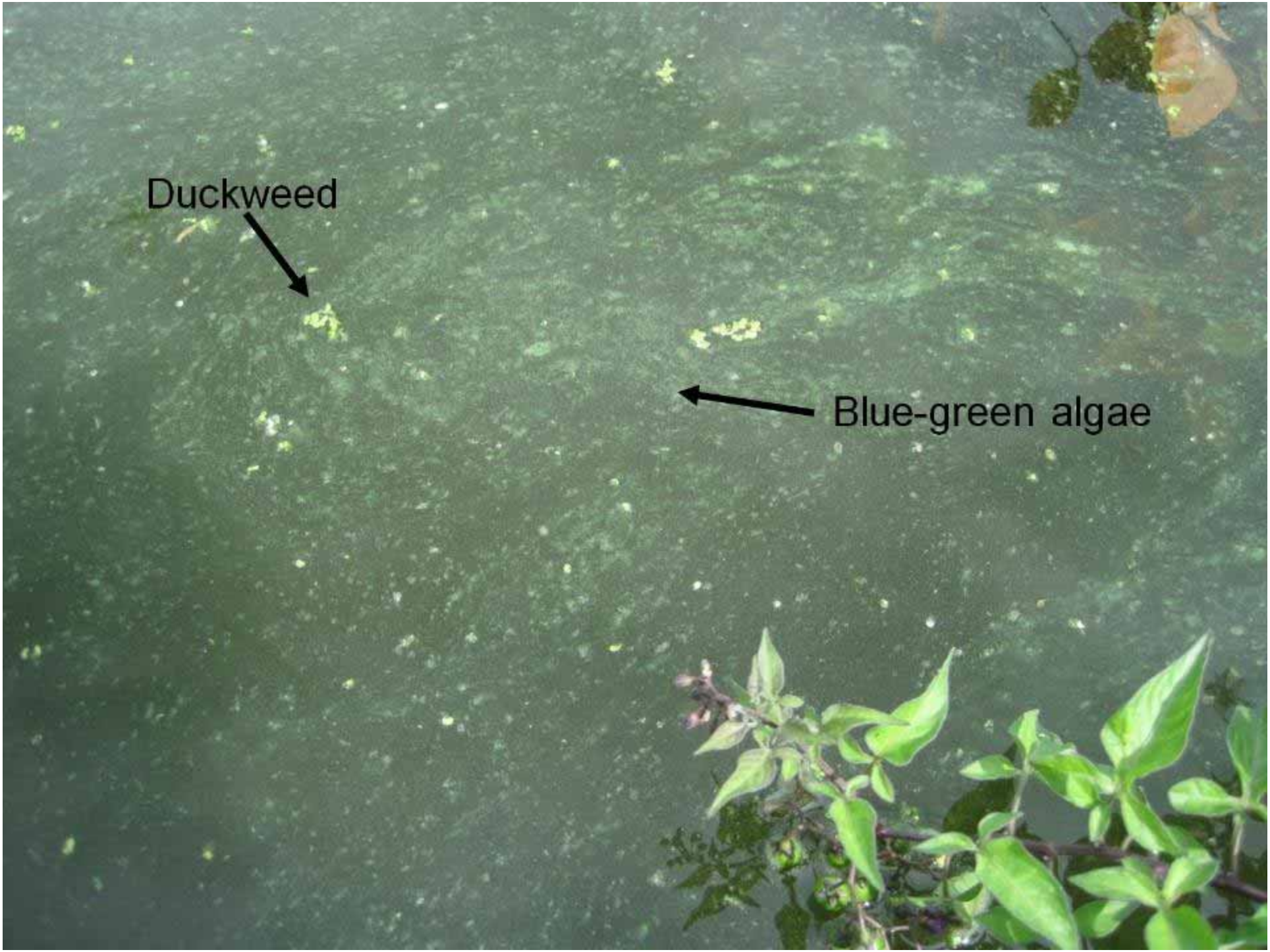
Watermeal (*Wolffia*)
Tiny, firm, grainy

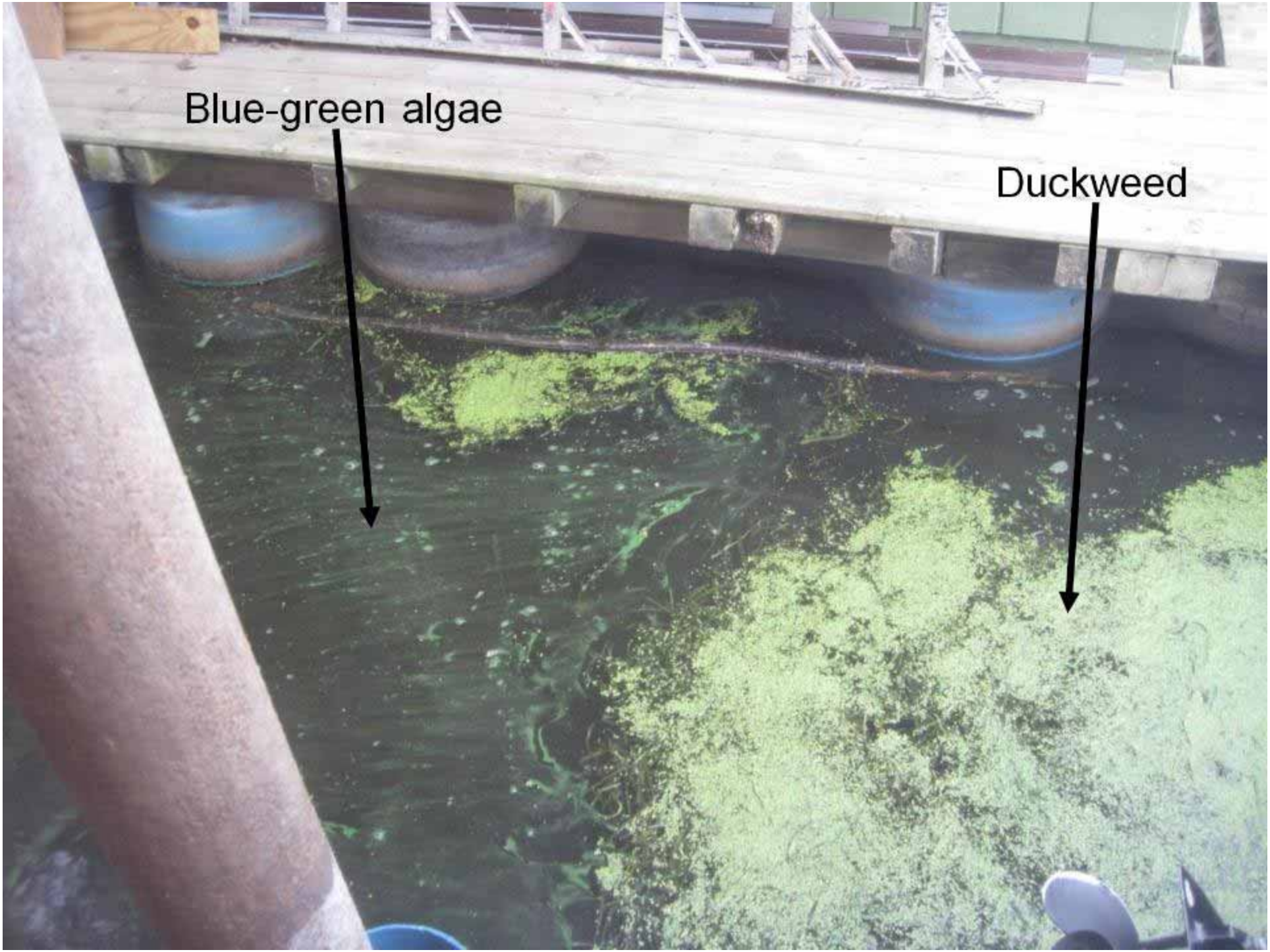
Don’t mistake yellow pollen for blue-green algae



Look for similar yellow “dust” on land


Euglena


Duckweed
Blue-green algae


Blue-green algae
Duckweed

Don’t mistake filamentous green algae for blue-green algae

“Blue-green” is misleading

Growing blooms are most often green in color.

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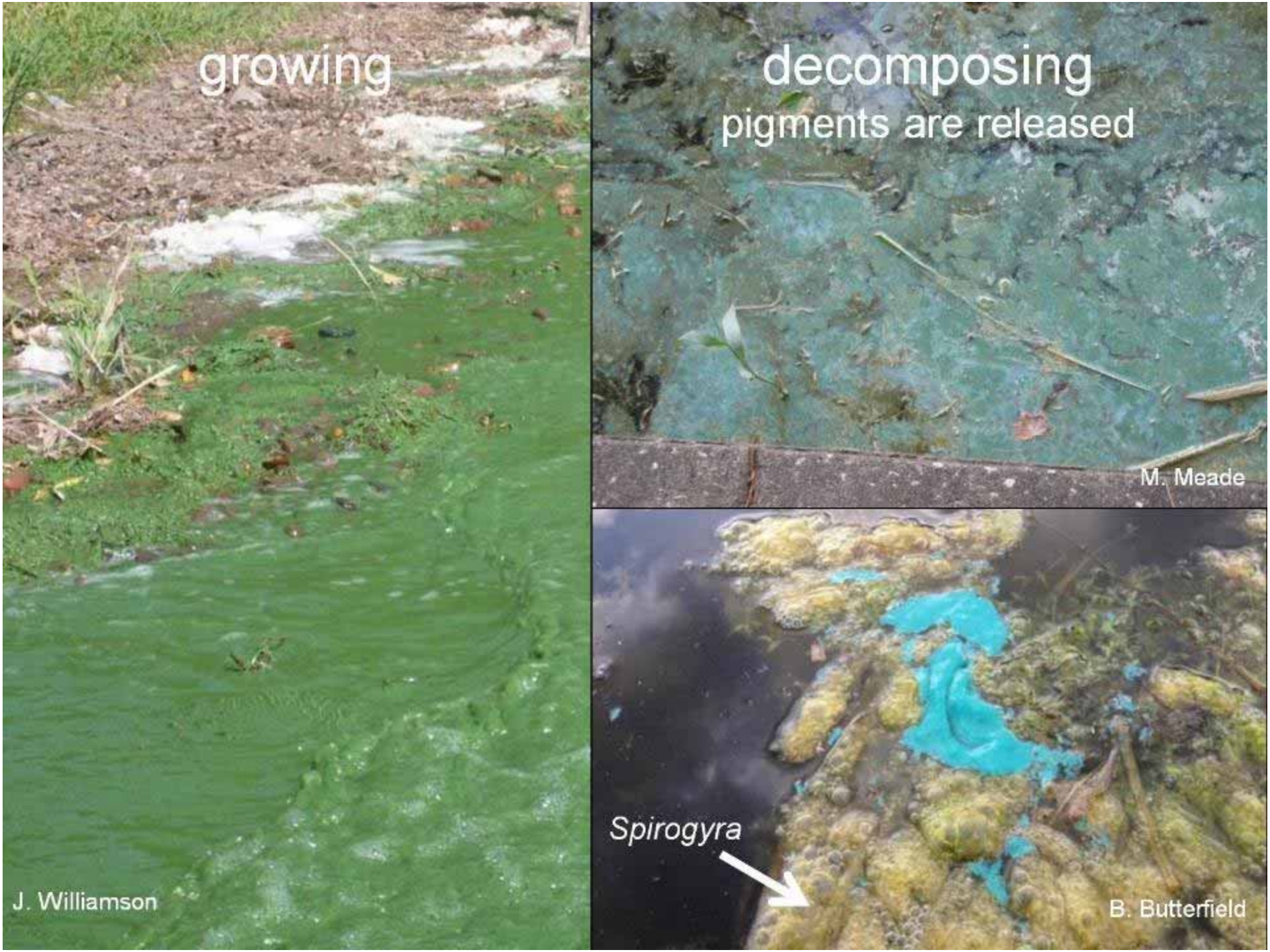
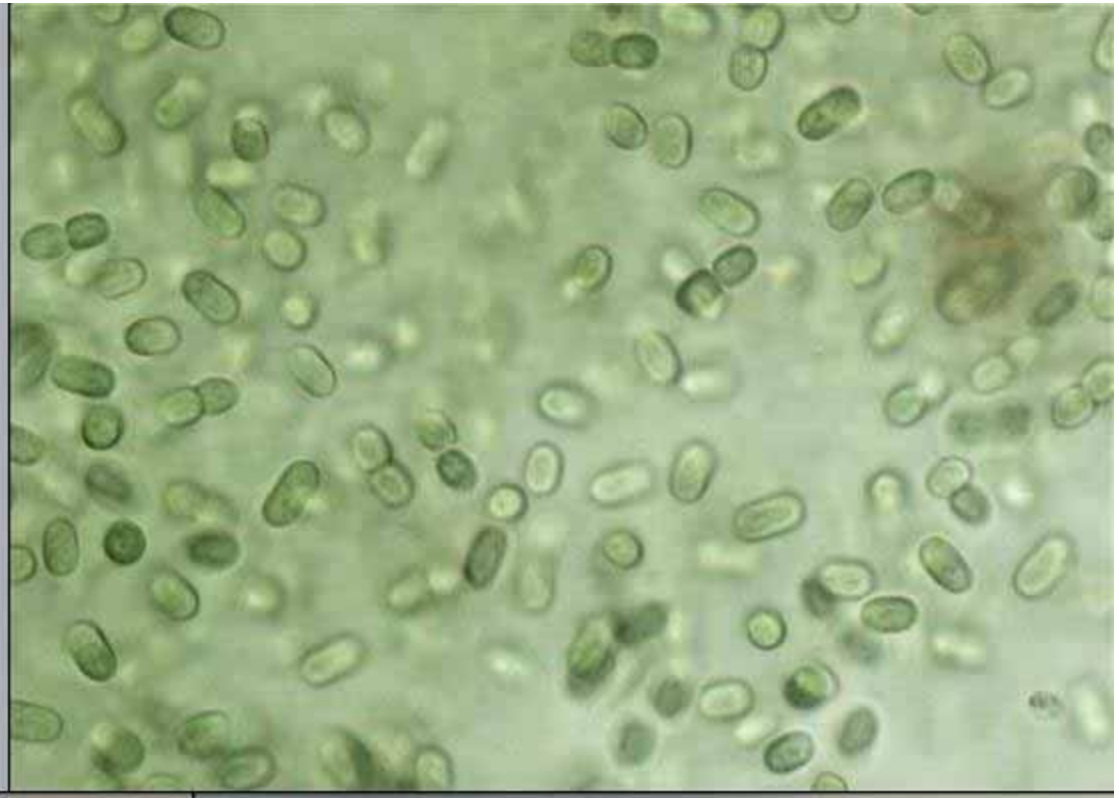

growing
J. Williamson
decomposing
pigments are released
M. Meade
Spirogyra
B. Butterfield

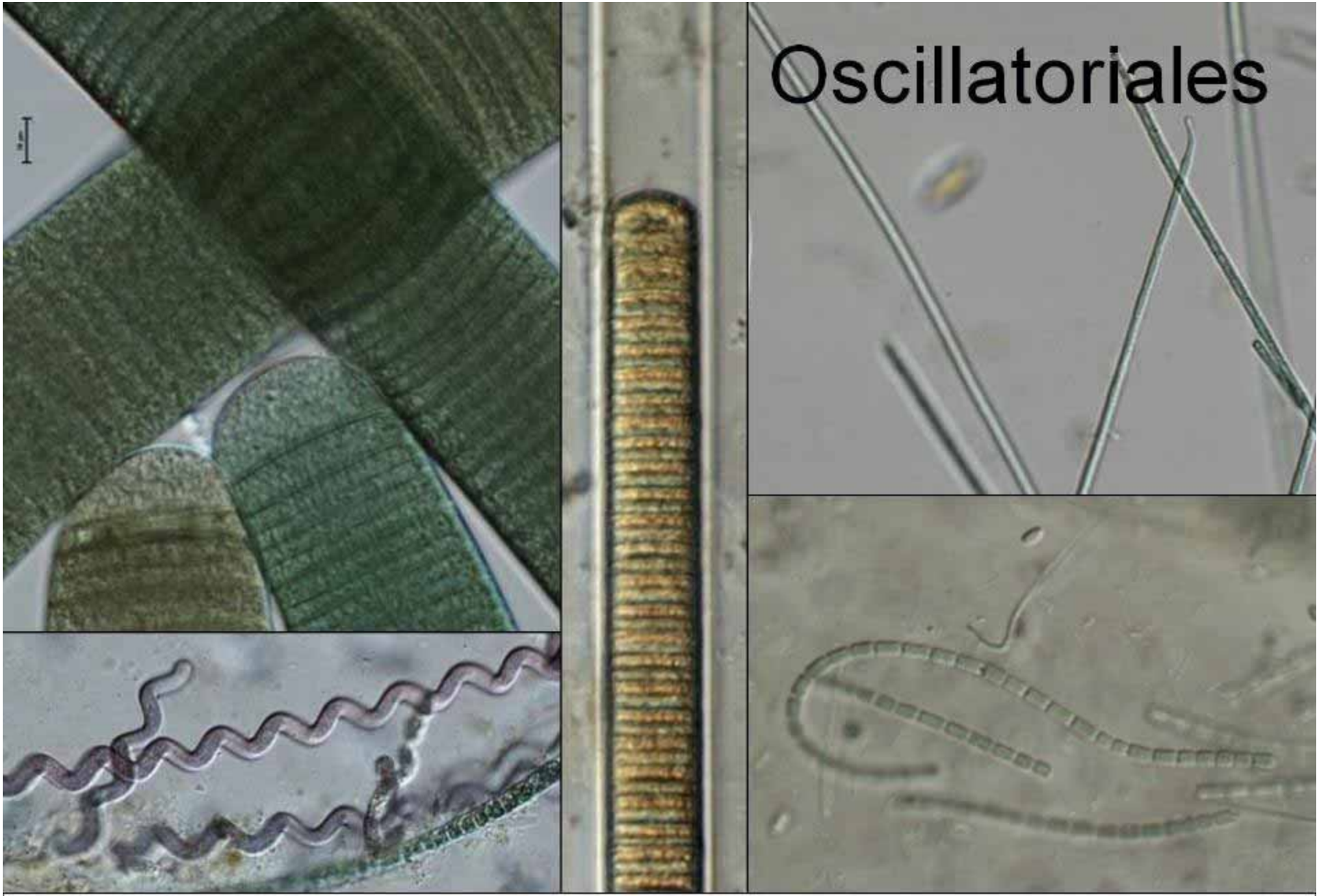

R. McLennan
N. Trombly
J. Williamson
T. Moris
R. McLennan
WDHS
J. Williamson
A. Dryja

Orders of Cyanobacteria

Chroococcales



Single cells or colonies of (mostly) spherical or ovoid cells

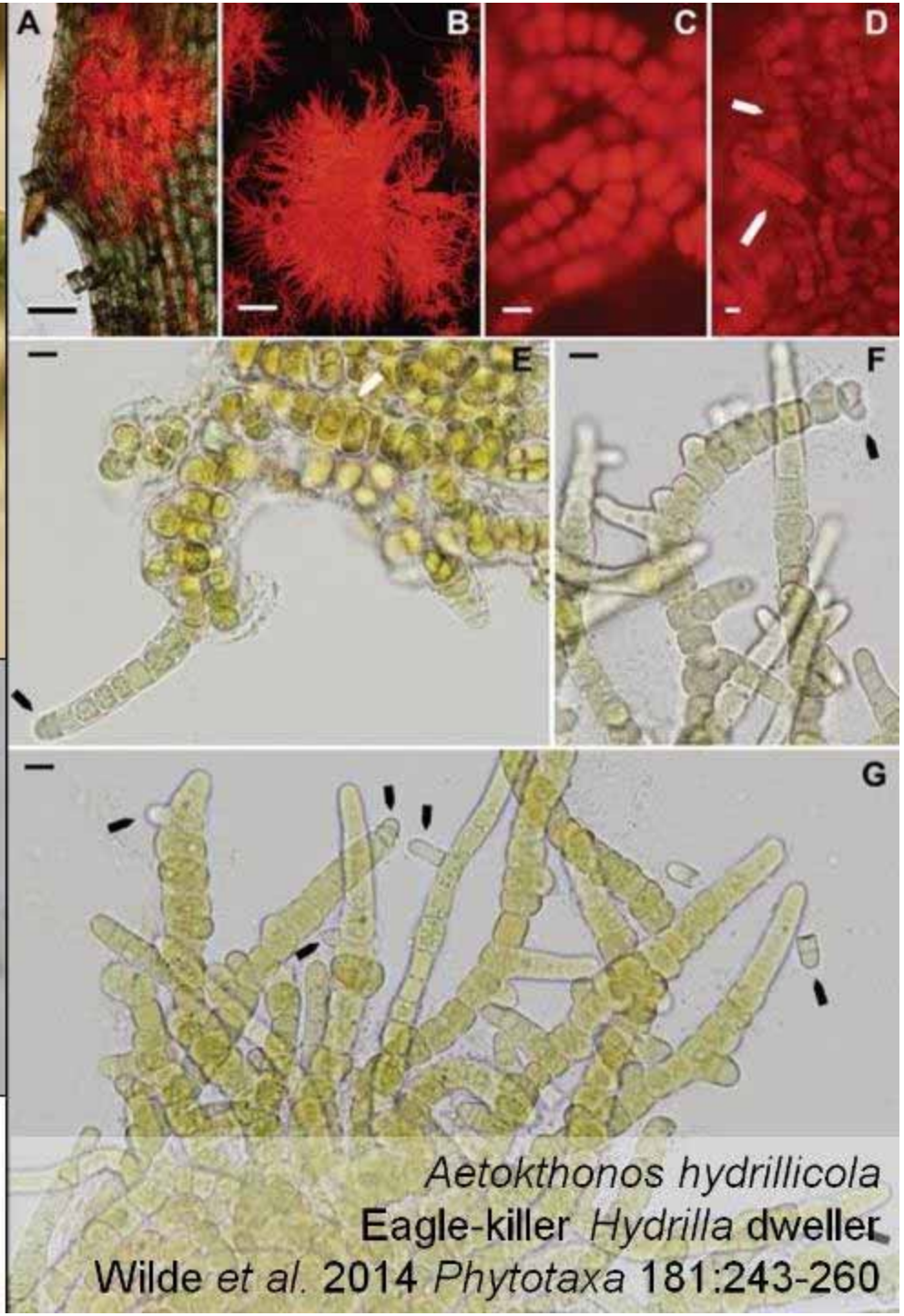


Uniseriate, unbranched trichomes (filaments)

Heterocytes for N_2 fixation, false branching, uniseriate

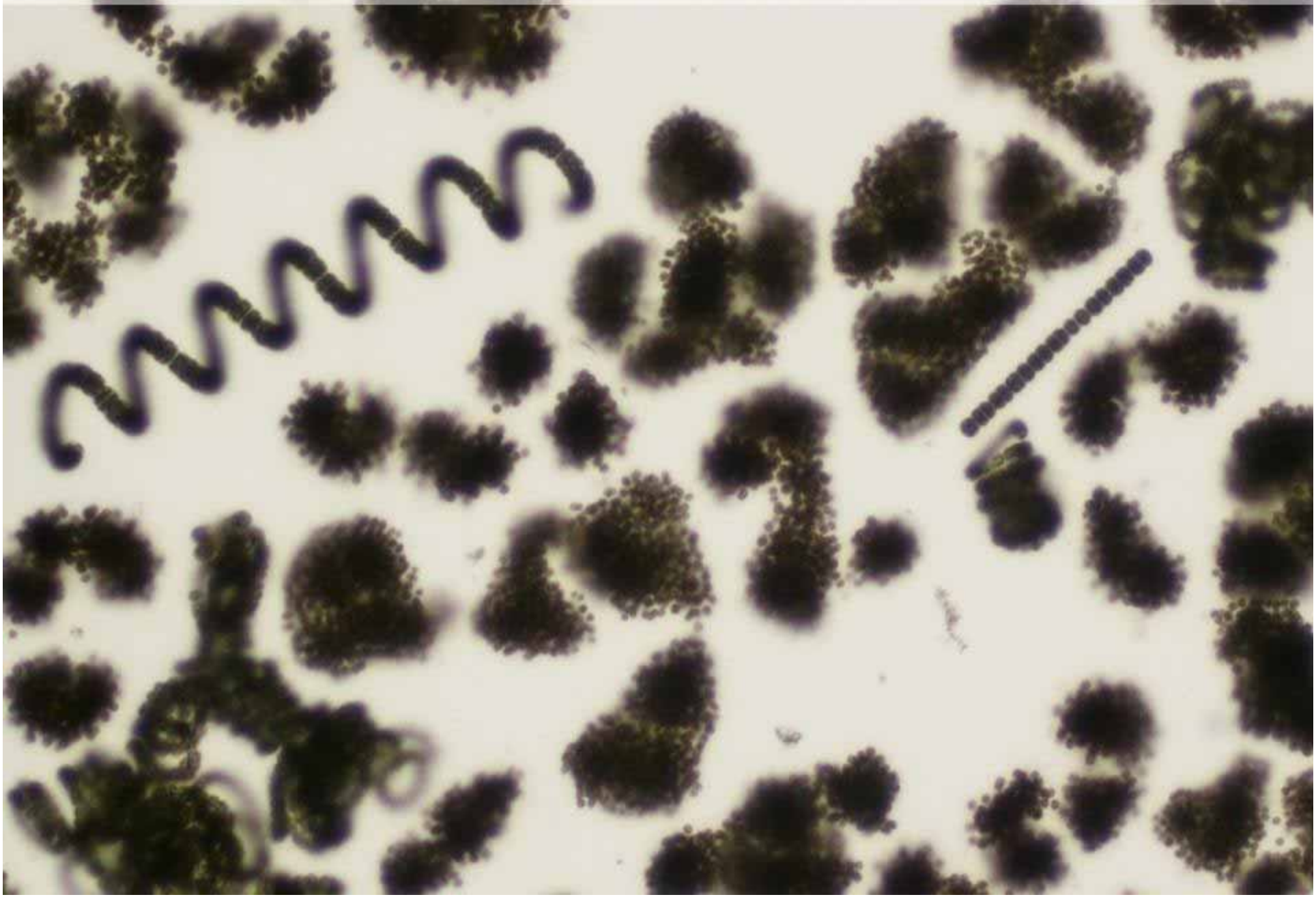
Stigonematales

Heterocytes for N_2 fixation, true branching, multiseriate



Aetokthonos hydrillicola
Eagle-killer *Hydrilla* dweller
Wilde *et al.* 2014 *Phytotaxa* 181:243-260

PLANKTONIC BLOOMS: *Microcystis* and other buoyant species appear black when viewed with a microscope, due to light refraction by the gas vesicles in the cells.



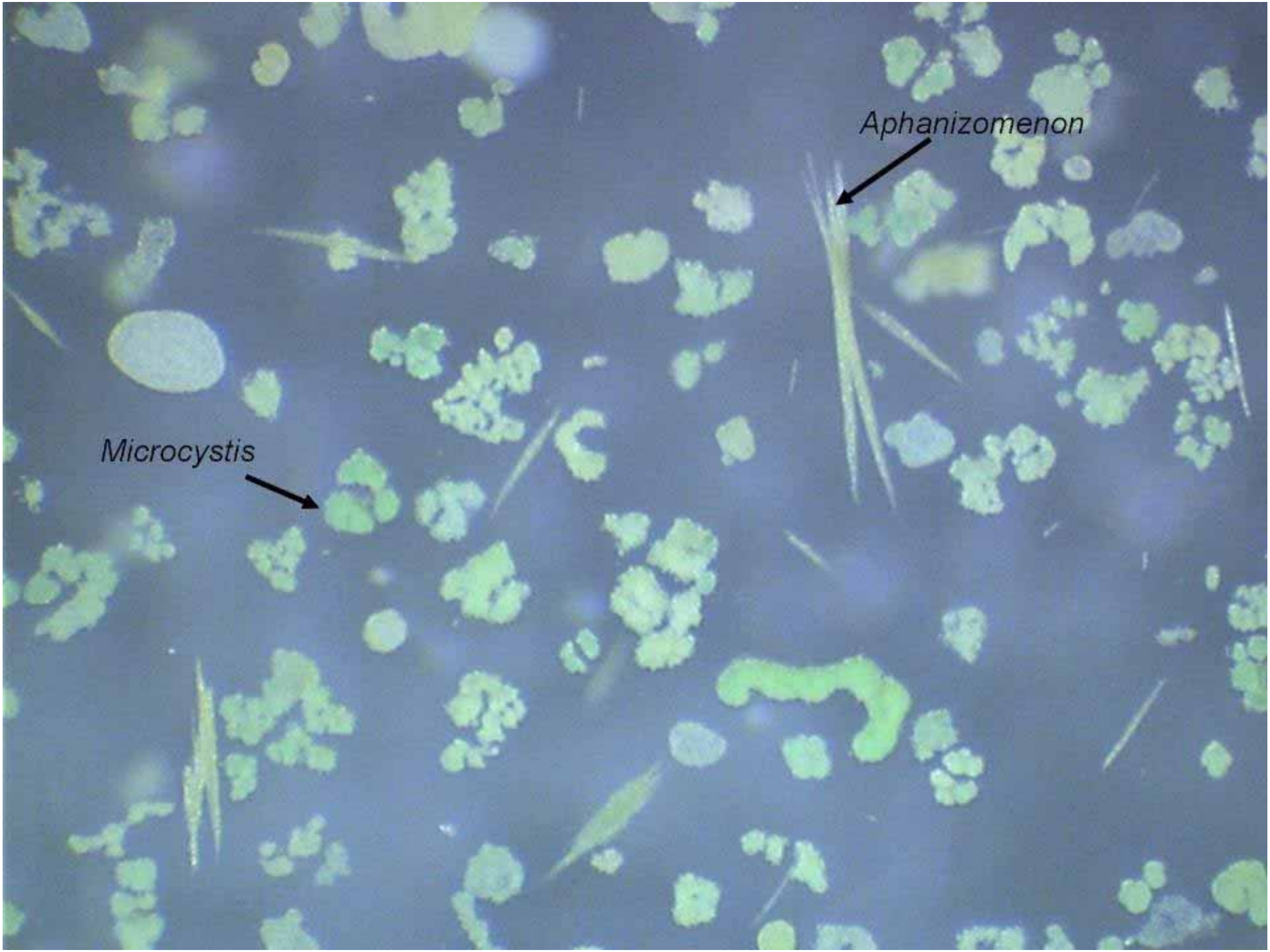
Microcystis

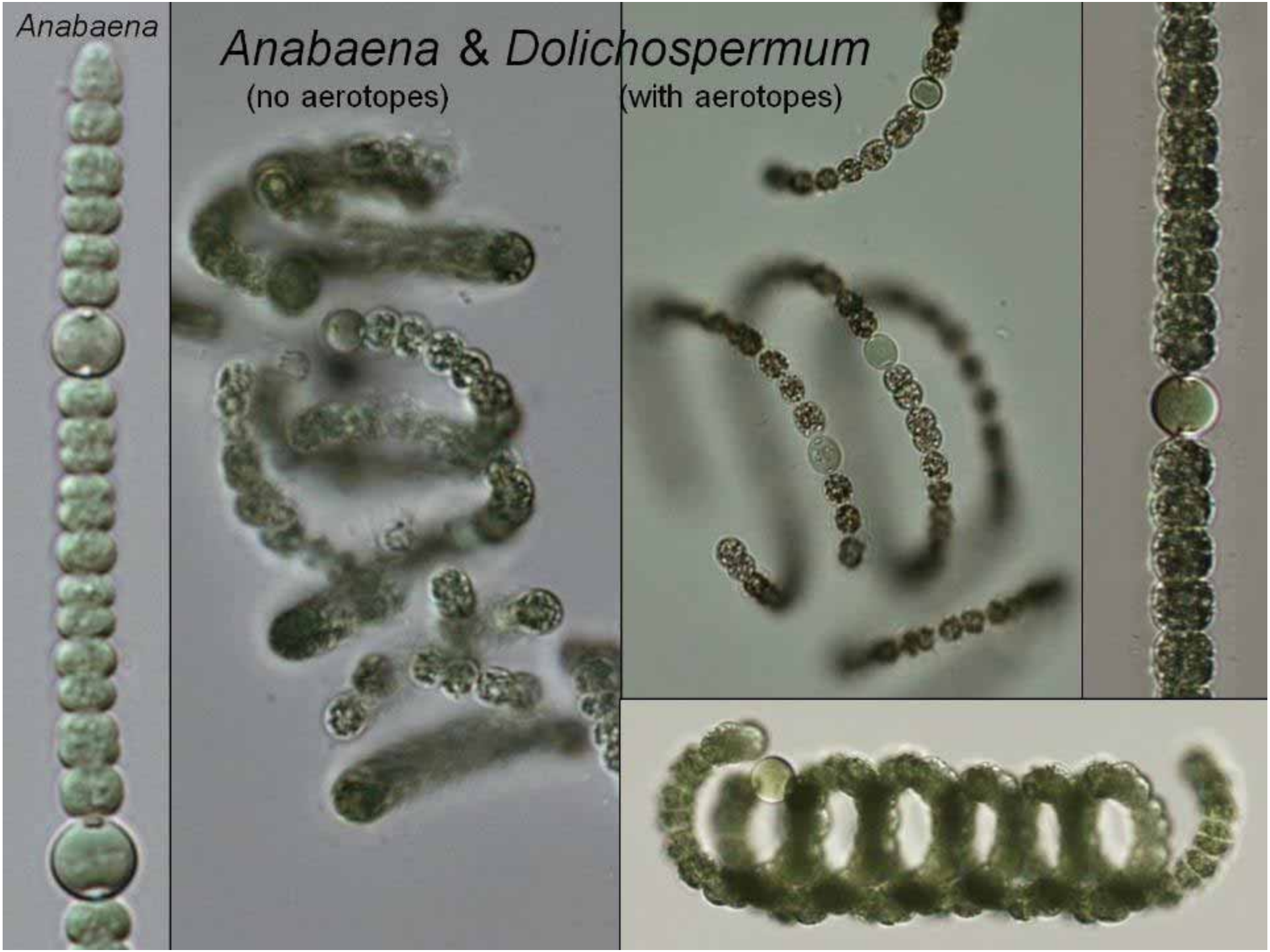
The most common bloom-forming cyanobacteria genus in Wisconsin lakes

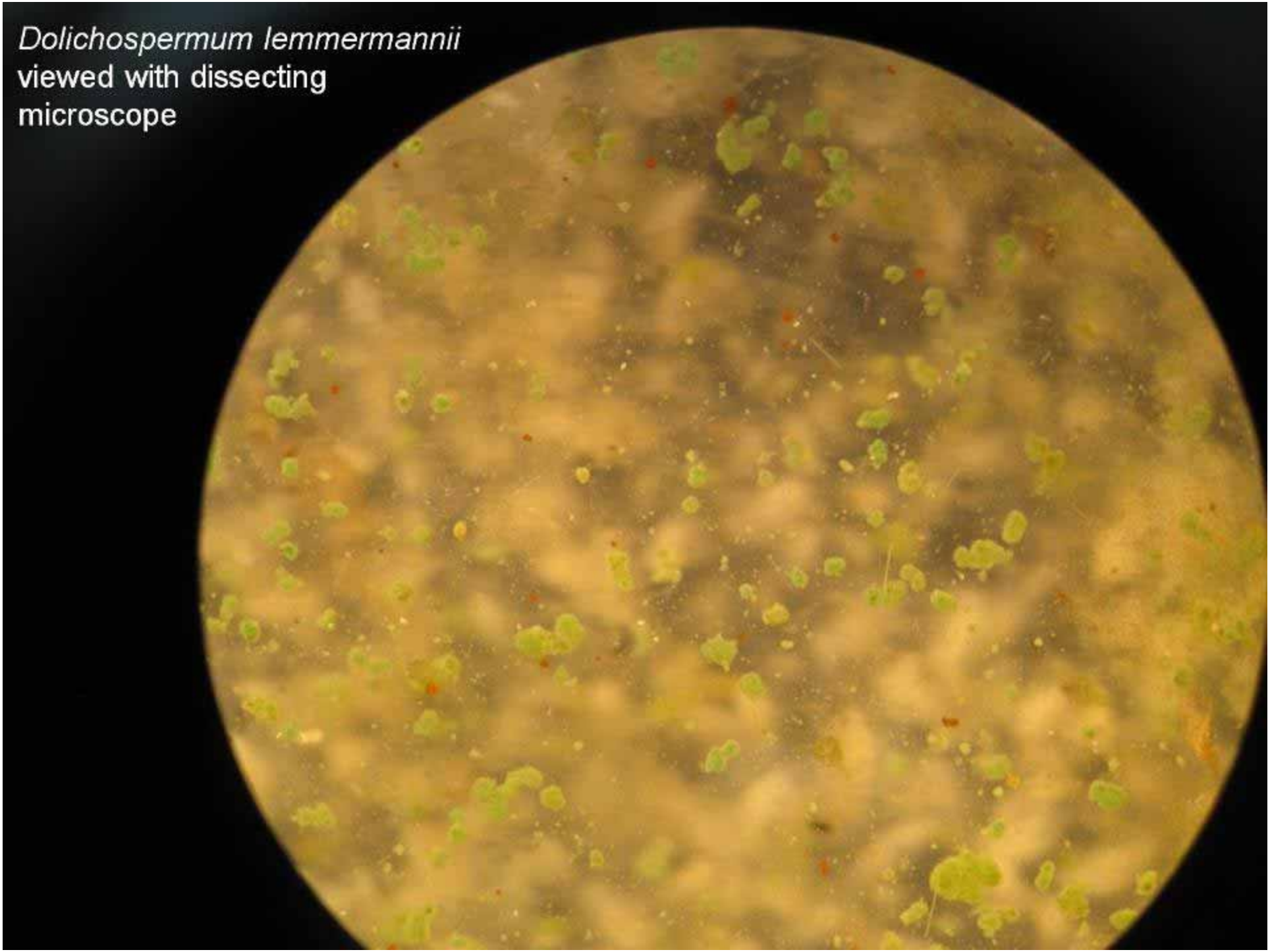
Aphanizomenon

Tiny grass clippings

C. Carlson


Aphanizomenon
Microcystis

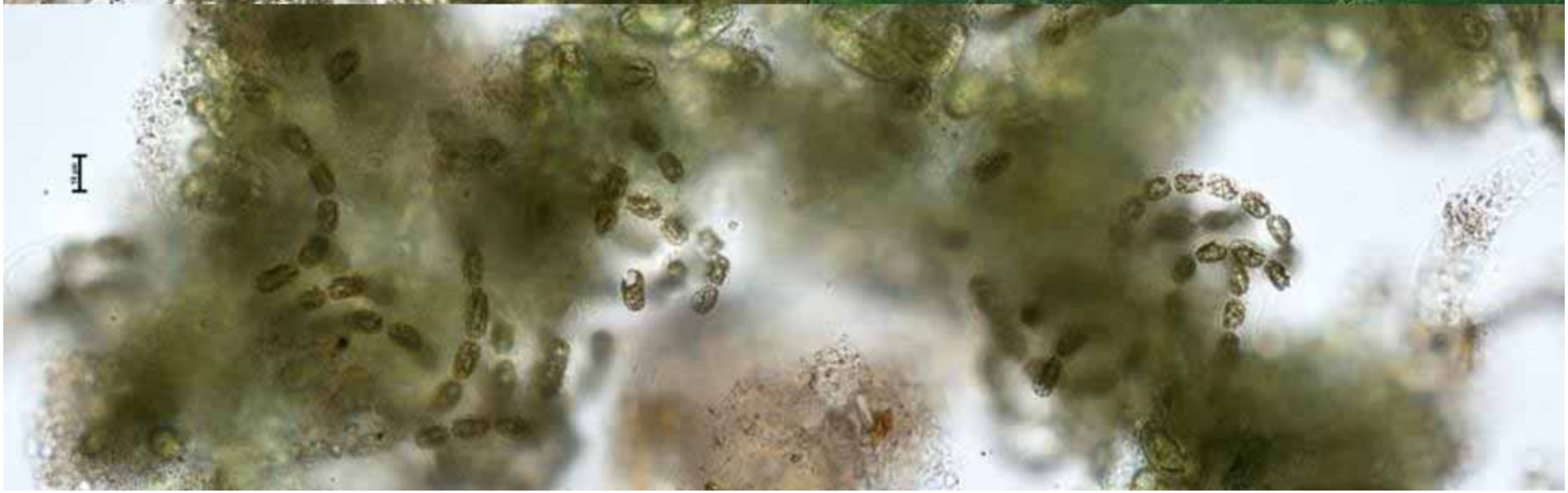

Anabaena
Anabaena & Dolichospermum
(no aerotopes)
(with aerotopes)


Dolichospermum lemmermannii
viewed with dissecting
microscope

Dolichospermum lemmermannii
(previously *Anabaena*)

J. Lamers, Pickerel Chain Lake Association

Dolichospermum lemmermannii bloom Lake Superior July 2012




Dolichospermum lemmermannii
Sea caves, Apostle Islands National Lakeshore
B. Moraska Lafrancois, NPS


Gloeotrichia echinulata
Not usually associated with toxic bloom events, although some populations have been shown to produce microcystin at low levels.
Blooms may be increasing, even in low-nutrient lakes.
Resting cells overwinter in lake sediments.

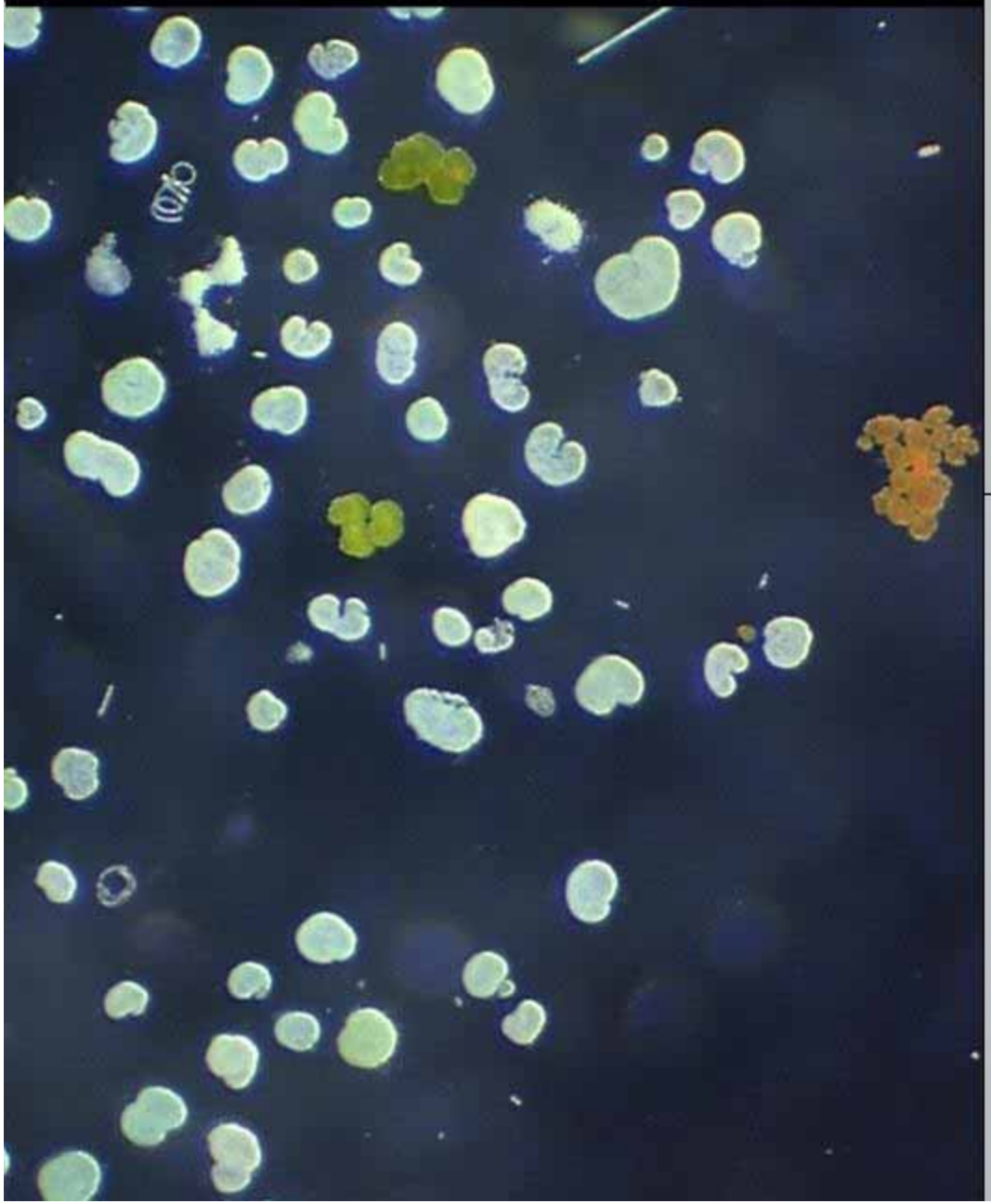
Dense *Gloeotrichia* colonies
J. Williamson, Polk County Land & Water Resources Department


cm 1
G. LaLiberte


G. LaLiberte


Gloeotrichia echinulata
Clean Lakes Alliance Monitoring Volunteer

Woronichinia
(formerly *Coelosphaerium*)

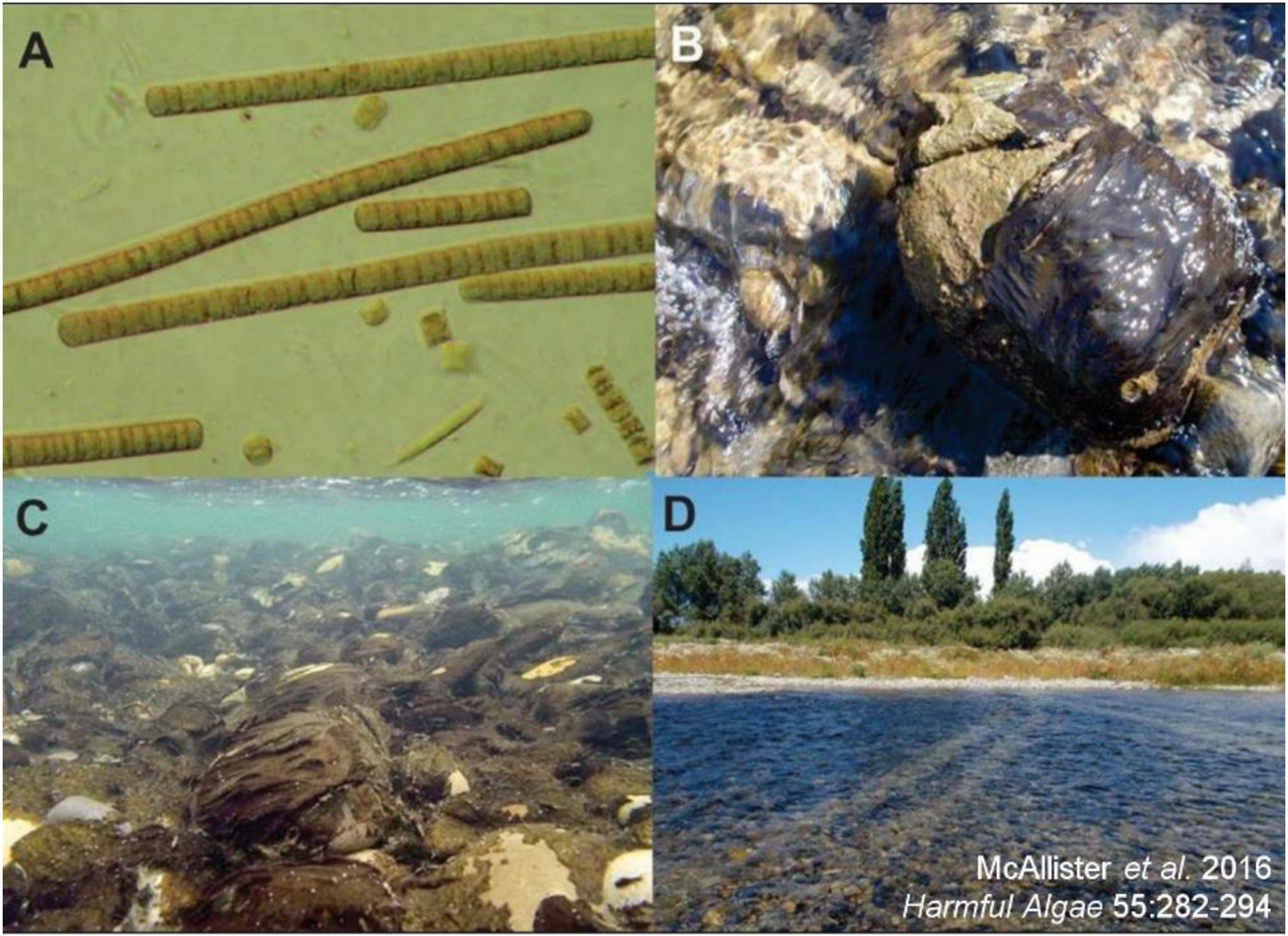


Cylindrospermopsis raciborskii

Blooms may occur at depth

NR40 Prohibited species; subtropical but expanding its range in temperate regions

Floating Benthic Algal Mats:
Oscillatoria, Lyngbya, Plectonema, Planktothrix


A
B
C
D
McAllister *et al.* 2016
Harmful Algae 55:282-294


Oscillatoria princeps mats
E. Evensen

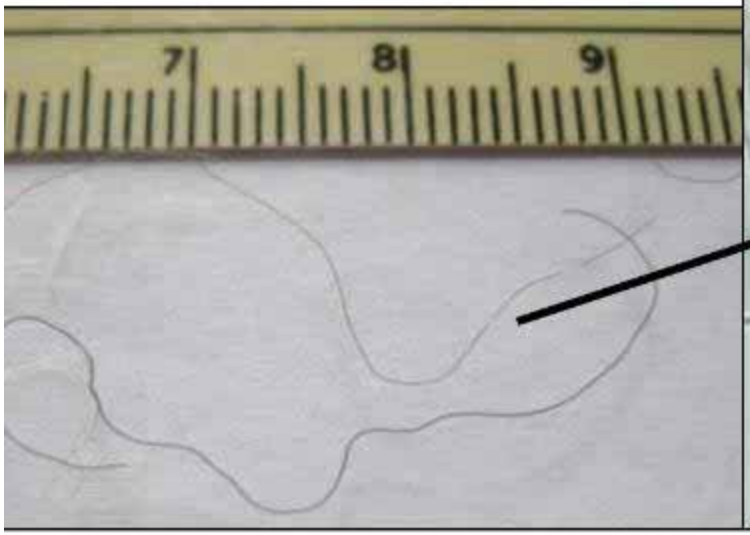

Cyanobacterial mat material received for identification
G. LaLiberte

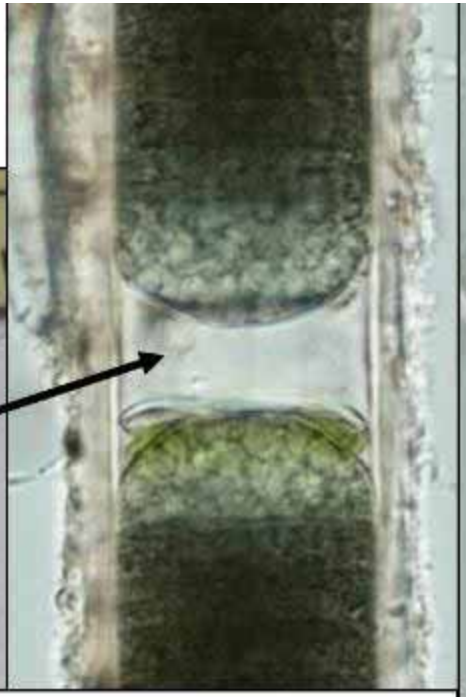

Filaments are more evident in water.
These filaments are very long for cyanobacteria – up to 10 mm.
G. LaLiberte


Oscillatoria princeps filaments
under the microscope
G. LaLiberte

Microseira wollei

(formerly *Lyngbya*, *Plectonema*)

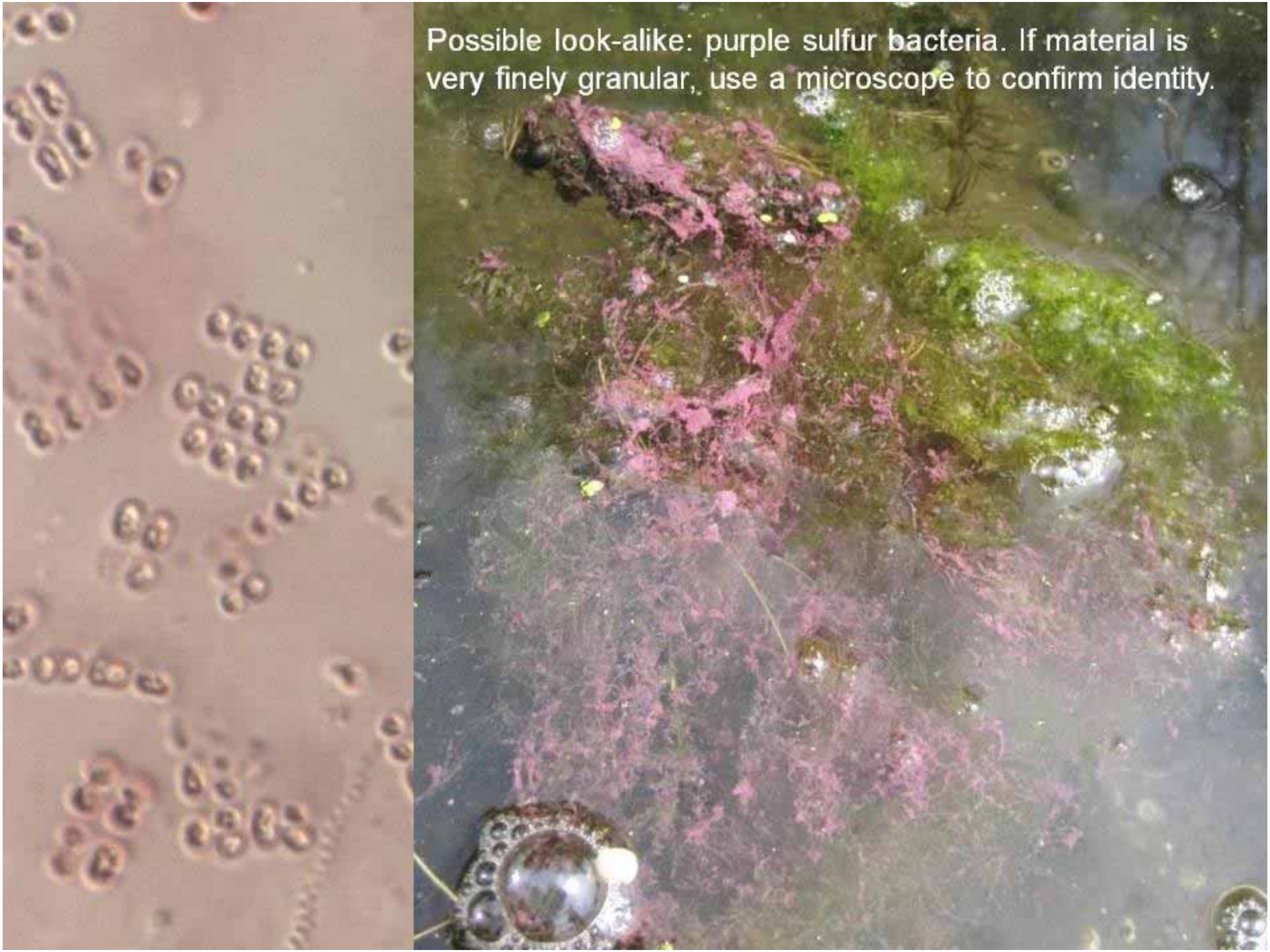




Up to several cm long - huge for a cyanobacterium.
"Breaks" are gaps between trichomes inside sheath.

False branching
may occur


D. Daulton
J. Klosiewsk


Possible look-alike: purple sulfur bacteria. If material is very finely granular, use a microscope to confirm identity.

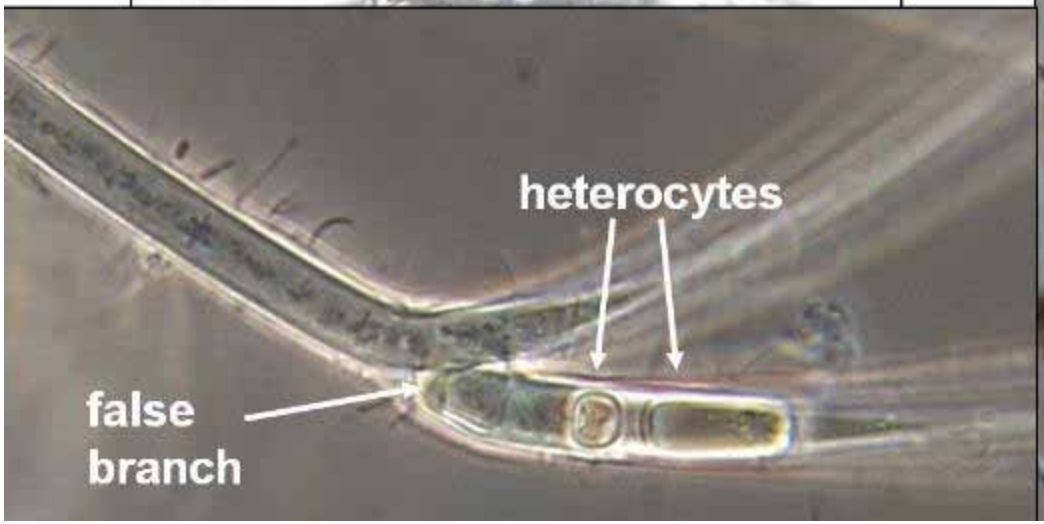
Tolypothrix

Can form balls on lake bottoms that later float to surface

Microscope needed for identification

False branching; heterocyte at branch

Olive-green to brown color




D. Blumer

Aphanothece & *Aphanocapsa*

Colonies consist of small spherical or ovoid cells

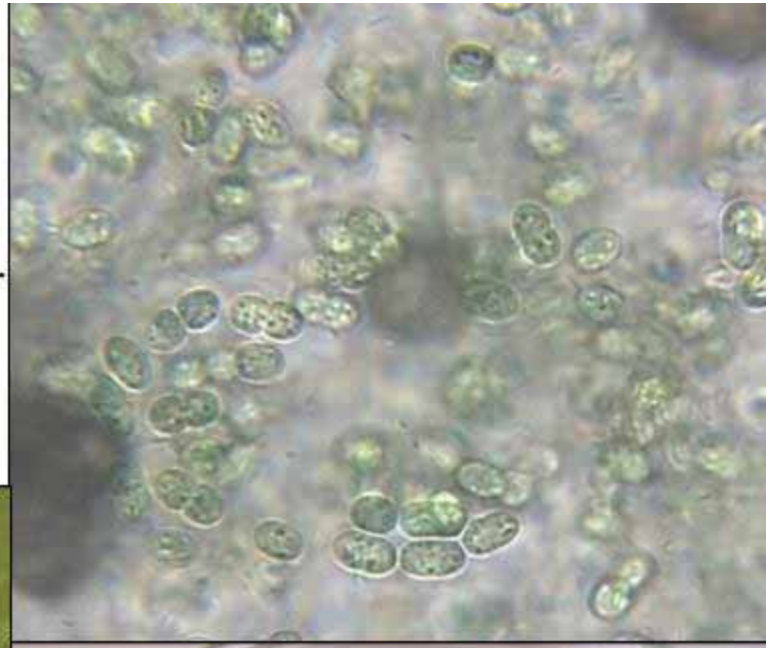
Difficult to identify to species – microscope necessary

Aphanothece stagnina:

Globular or irregular colonies up to a few cm diameter

May form large masses on lake beds, or float

May contain calcite crystals



P. Skawinski

Aphanothece stagnina


www.bio.no

Nostoc

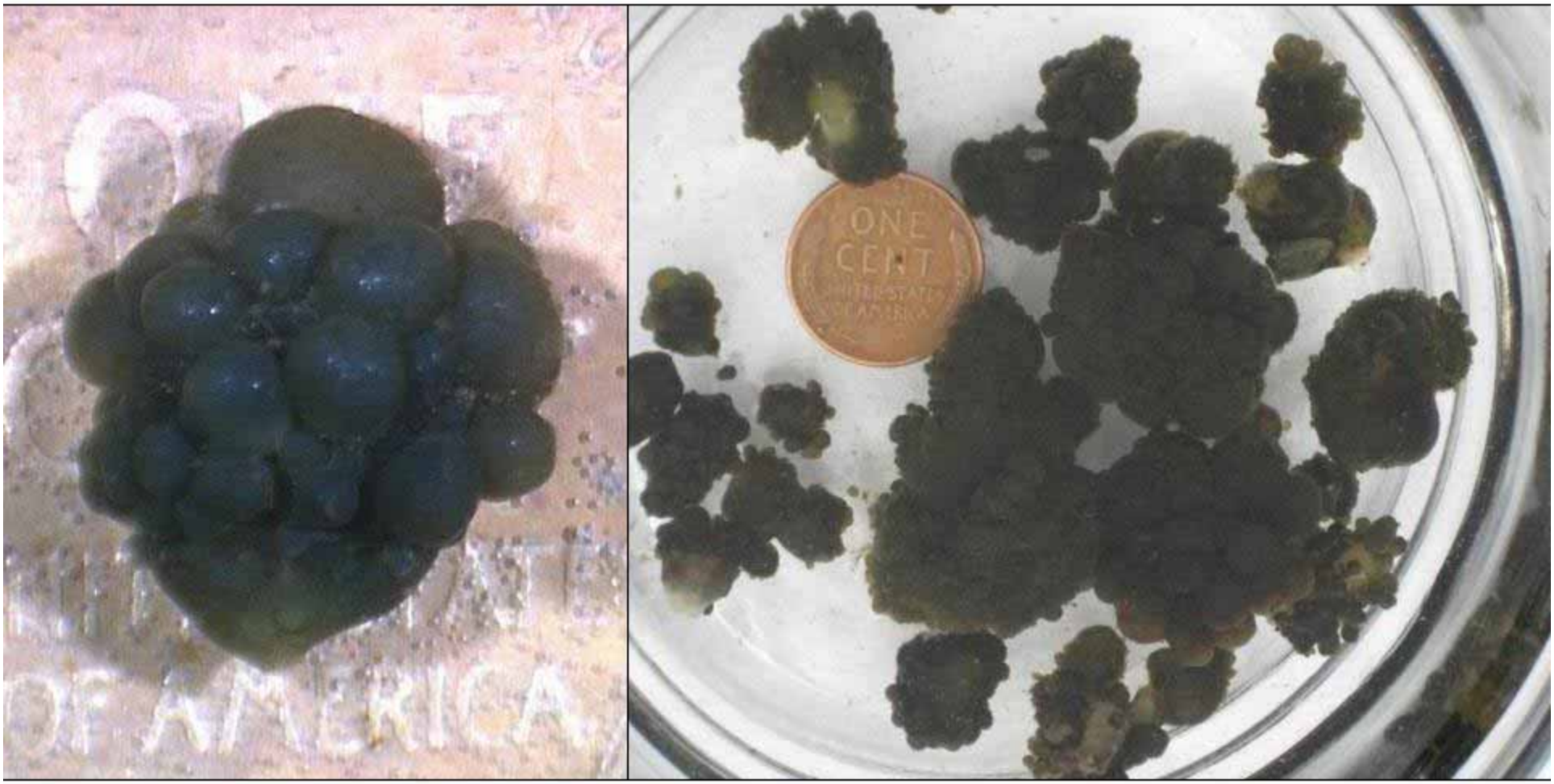
Aquatic species: pinhead to egg-size, on lake bottom or floating

N. pruniforme: "lake plums," "mare's eggs"

Colonies consist of unbranched filaments in a firm gelatinous matrix

Filaments have heterocytes – *Nostoc* uses them to fix atmospheric nitrogen

Nostoc zetterstedtii: "lake blackberries"
Rare! Red-list species in Europe
Prefers *Lobelia* & *Isoetes* lakes (oligotrophic, clear water)
Replaced by *N. pruniforme* as lake water becomes more eutrophic



Please let me know if you find *N. zetterstedtii* or *N. pruniforme*! Gina.LaLiberte@wisconsin.gov

Nostoc commune

Terrestrial!

Star jelly, witches' butter
French: Crachat de lune
(moon spit)

Outer mucilage layer
often dark yellow

Black and crispy when
dehydrated
Rehydrates & is more
noticeable after rain

COULD BE MISTAKEN FOR NOSTOC: *Ophrydium versatile*

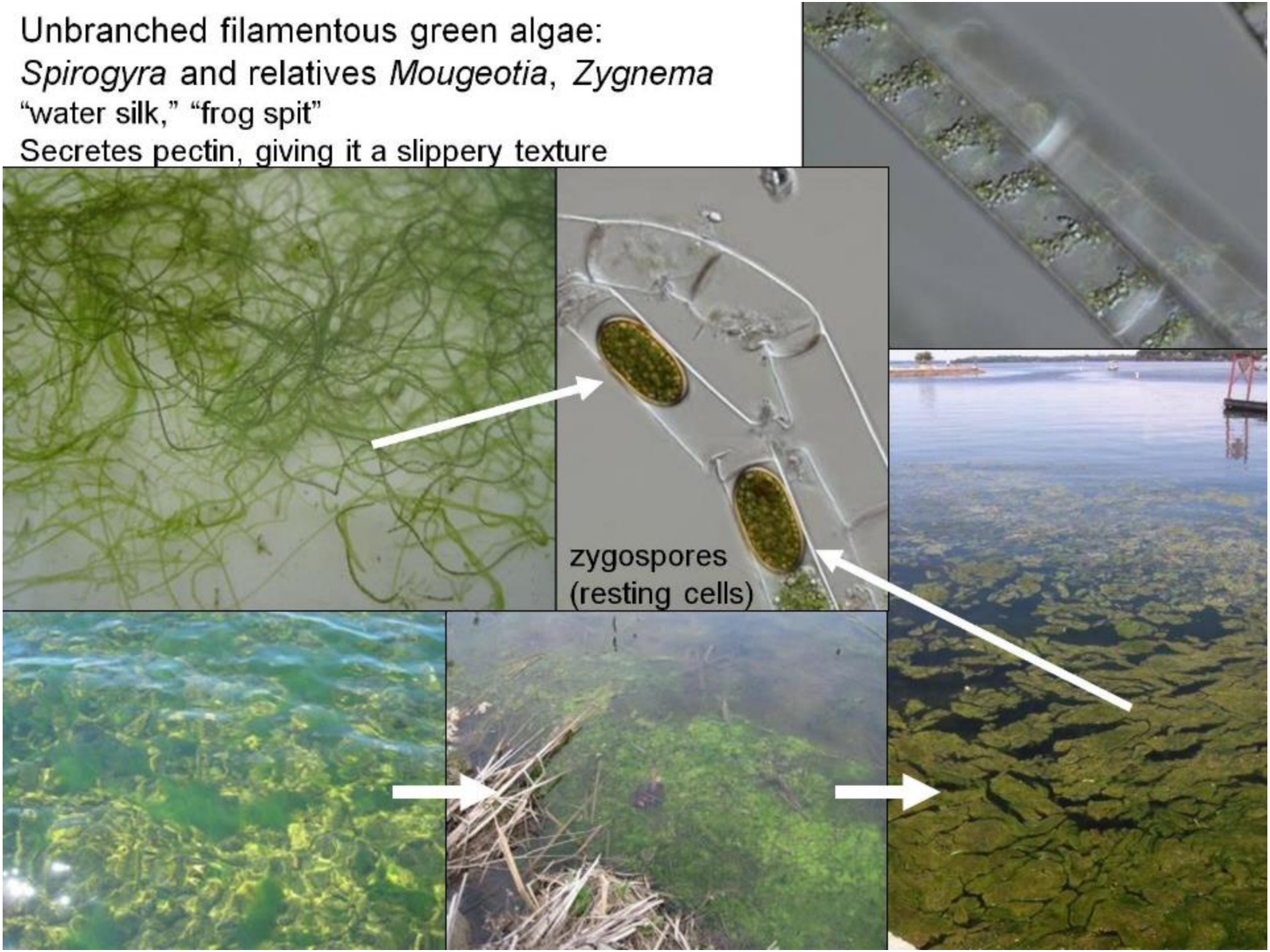
Colonial protozoan

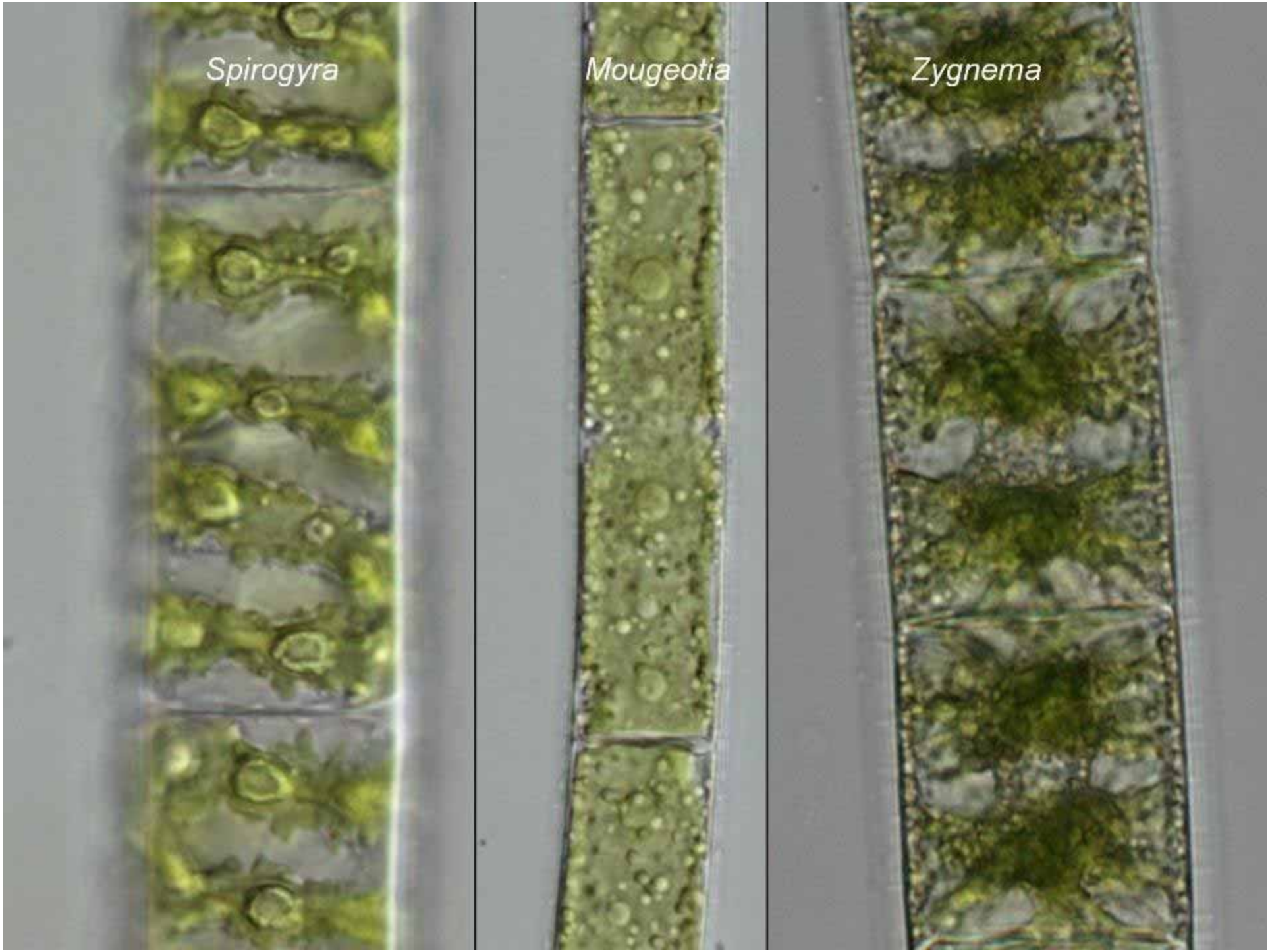
Internal symbiotic algae (*Zoochlorella*) give colonies their green color

Soft, gelatinous texture

Colony may be attached to plants, on the lake bottom, or broken free and floating

Unbranched filamentous green algae:
Spirogyra and relatives *Mougeotia*, *Zygnema*
"water silk," "frog spit"
Secretes pectin, giving it a slippery texture




Spirogyra
Mougeotia
Zygnema

Unbranched filamentous green algae: *Oedogonium*

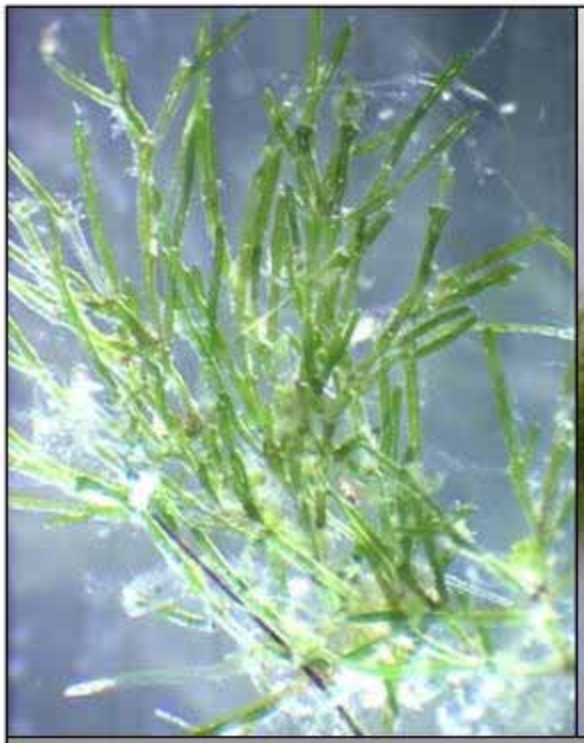
Often covered with epiphytic algae and mixed in with other filamentous greens

Microscope needed for identification

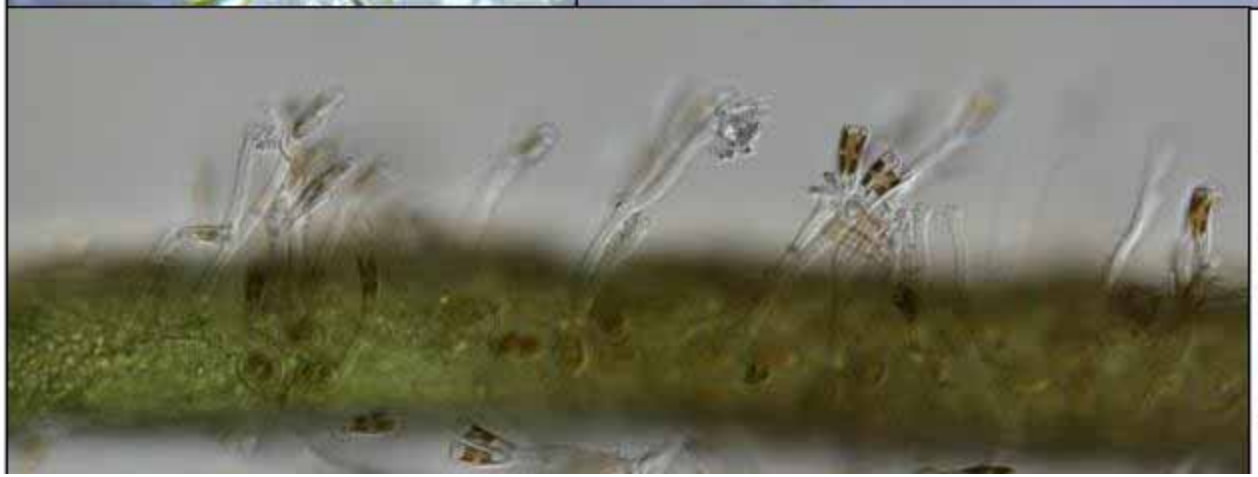
Rings of apical caps from cell division are a key diagnostic feature

Branched filamentous green algae: *Cladophora*

Microscope needed for identification, but cottony, highly branched greens on hard substrates at lake margins are usually *Cladophora*



On rock in splash zone



Can be highly branched or have minimal branching.

Older portions are often covered with algal epiphytes. Diatoms make it appear to be a golden-brown color

Branched filamentous green algae: *Cladophora* & *Rhizoclonium*

Microscope needed for identification

Phenotypically plastic so they are difficult to identify to species

Cladophora species with minimal branching are confused with related *Rhizoclonium*

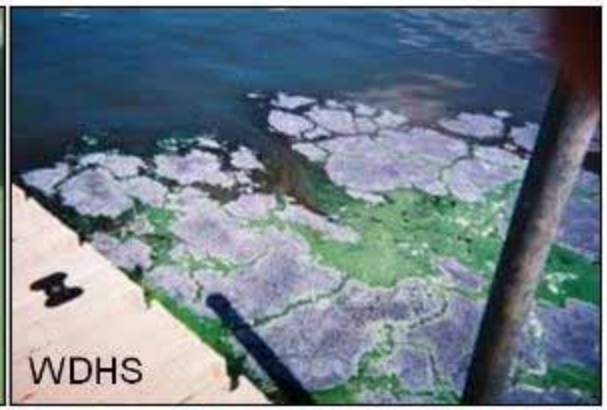
Often entangled with macrophytes or forming nuisance growths

Large, coarse filaments (>40 μm diameter) are most likely *Cladophora*

Branched filamentous green algae: *Pithophora*
Microscope needed for identification
Branching and coarse, rough texture.
Also known as “horsehair algae.”
Branches are at right angles and cells are long. Resting cells appear as dark ovals. Notorious for forming nuisance growths entangled in plants or floating.

Hazards of blue-green algae blooms

- They may form nuisance blooms.
- Blooms impact aquatic life.
- Some strains can make liver, cell, or nerve toxins if conditions are right.
- Toxins may irritate the skin in sensitive individuals; swallowing or inhaling them in water can cause illness.
- **Not all blue-green algae make toxins, and toxins are not made all the time.**



What causes harmful blooms?

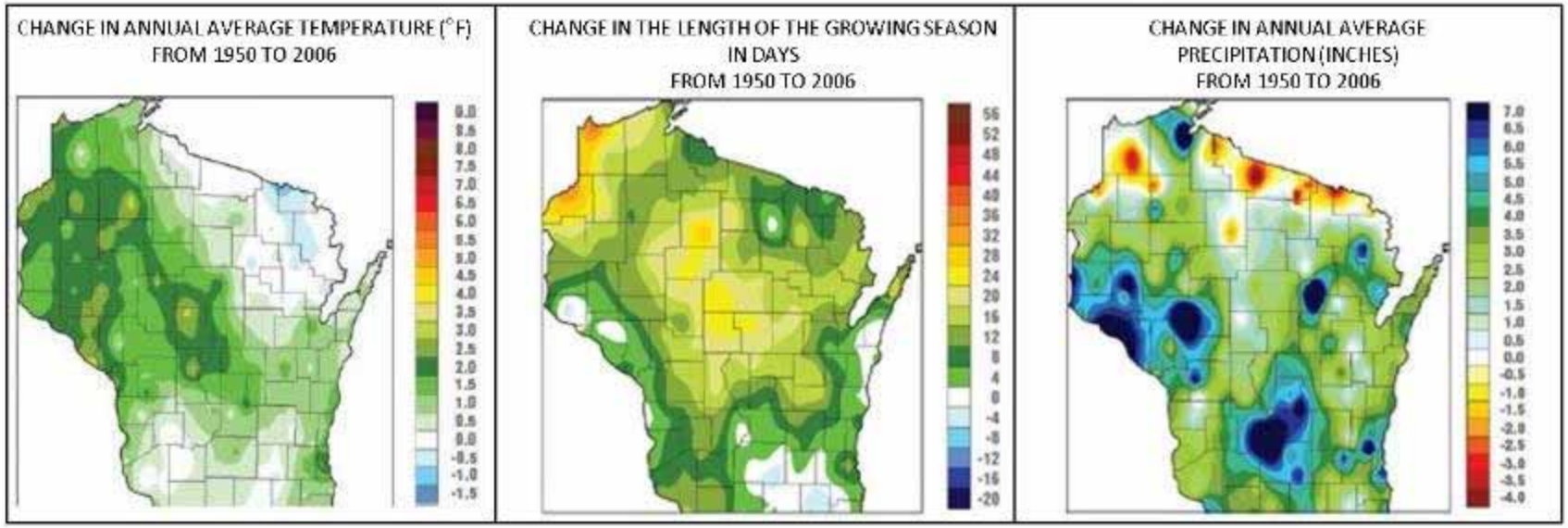
- Excess nutrients are fertilizer for growth
- Primarily P, but N can be important too
- Warm water and calm weather

The details are more complicated…

- Species and strains
- Cell biochemistry
- Micronutrients (iron)
- Dissolved carbon
- Zebra & quagga mussels
- Nutrients & cells from lake sediments
- Herbicides?

"Favorable environmental conditions"
– Mark Vander Borgh, NCDENR

Are blooms more frequent?



- Yes – worldwide evidence
- Heavy rains & snowmelt: extra nutrients
- Drought –lower, warmer water
- Earlier warming & extended warming may lead to blooms

Figures from Wisconsin Initiative on Climate Change Impacts 2011: *Wisconsin's Changing Climate: Impacts and Adaptations*

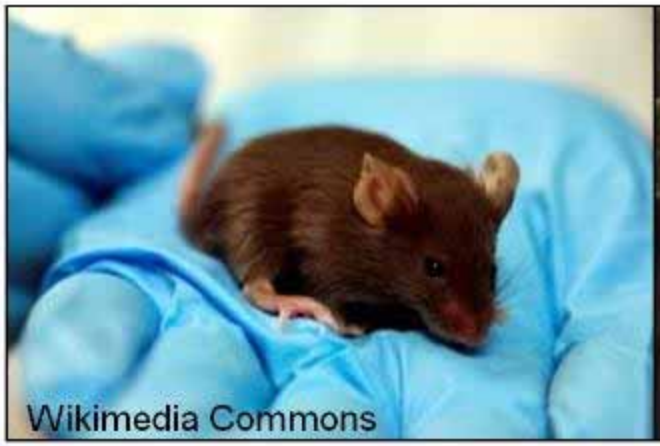
How do I get rid of it?

- Chemical treatment usually not permitted – killed cells can release toxins in 1 big dose.
- Other "solutions" are often ineffective or treat the symptom, not the cause.
- Reduce nutrient input, but internal loading can continue to fuel blooms.

T. Johnson

Are blooms more toxic?

- New technology means we continue to learn more
- Ongoing research to identify toxins and their production pathways



Toxins

- We have a good idea of what common planktonic species contain strains that can make toxins.
- We know much less about uncommon or infrequently occurring species.
- About 2700 described species worldwide.
- Research carefully – unless you know the full story, inadequate information may cause you undue concern.

Toxin information online

- Assess your information sources.
- Papers – “toxic bloom-formers” without testing for toxins, or non-toxic taxa lumped in with toxic.
- E.g. *Nostoc zetterstedtii*.

How to tell if it's safe?

- What does the water look like?
- Can you see your feet?
- How does it smell?
- For pets, does the water look like something YOU would want in your mouth?

- Has there been a recent heavy rain? (higher bacteria levels)

Who is at risk

- Children, especially small children.
- People with compromised immune systems.
- People with allergies may have greater sensitivity.

Can I do my own testing?

- Yes – Wisconsin State Laboratory of Hygiene
- Keep in mind bloom may change significantly between time of collection and when results are available – concentration, toxin production
- Posting advisories should be left to public health officials

Who issues advisories?

Chapter 254.46 Beaches. The department or a **local health department** shall close or restrict swimming, diving and recreational bathing if a human health hazard exists in any area used for those purposes on a body of water and on associated land and shall require the posting of the area.

DNR has the responsibility for advisories at State Park and State Forest properties.

US EPA Draft Recreational Guidelines

Draft Recreational Advisory Levels for Cyanotoxins	
Microcystins (MC)	**Cylindrospermopsin (CYN)**
4 µg/L	8 µg/L

Swimming Advisory: not to be exceeded on any day
(also dually proposed as Ambient Water Quality Criteria)

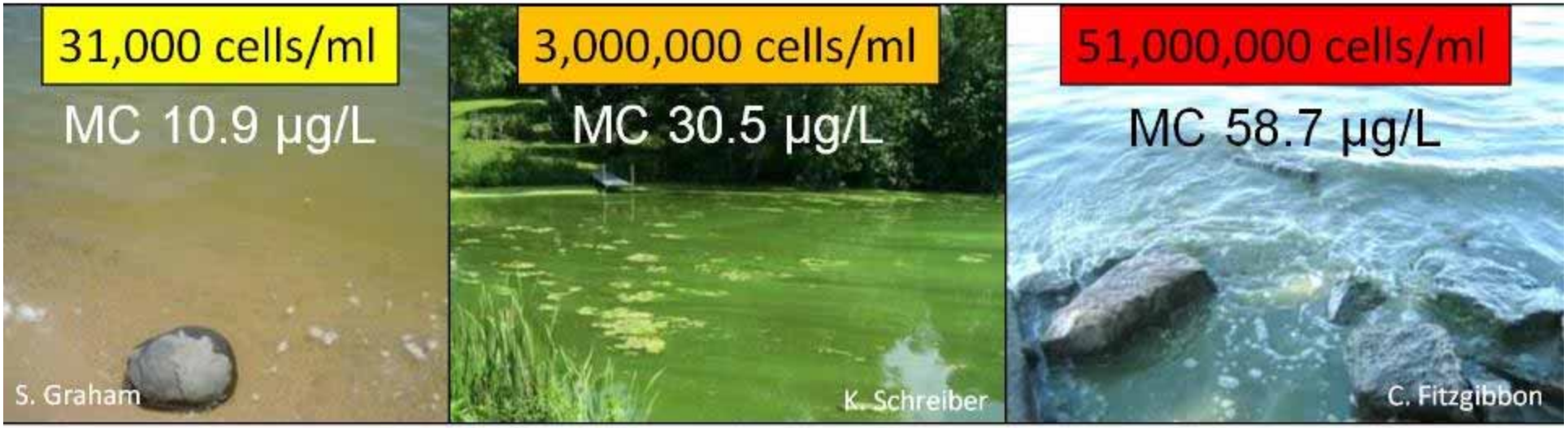
Based on toxins' chronic effects on target organs (liver, kidney), not on acute effects (e.g., allergic reactions, gastrointestinal upset)

	Samples	Detects	Exceeded
2004-2016 MC	511	292	57
2007 & 2012 EPA NLA MC	92	47	5
2004-2016 CYN	117	2	1
2007 EPA NLA CYN	35	0	0

WHO Recreational Guidelines

Probability of Adverse Health Effects	Cell Density (cells/ml)	Microcystin-LR (µg/L)	Chlorophyll (µg/L)
Low	< 20,000	< 10	< 10
Moderate	20,000-100,000	10 – 20	10 – 50
High	100,000-10,000,000	20 – 2,000	50 – 5,000
Very High	> 10,000,000	> 2,000	> 5,000

Graham *et al.* 2009, based on WHO 2003 *Guidelines for Safe Recreational Water Environments*



Signage – Mixed Interpretation by Public?

CAUTION

WATER QUALITY ADVISORY

This water may contain blue-green algae capable of producing toxins that can be dangerous to humans and pets.

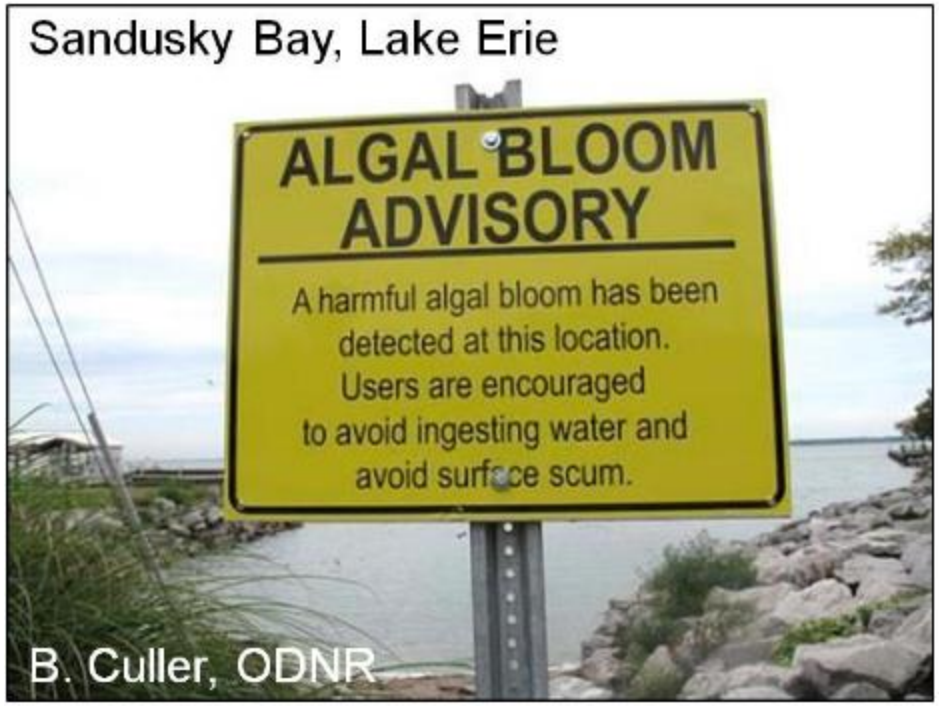
FOR YOUR SAFETY

- If water is cloudy, looks like green paint or pea soup, or has a floating scum layer or floating clumps
  - -Do not swim or swallow water
  - -Do not allow pets to swim or drink
  - -Do not allow children to play in scum layer from shoreline
- Rinse off after swimming

For more information please contact the

LOCAL HEALTH DEPARTMENT at (___) ___-_____

Sandusky Bay, Lake Erie



B. Culler, ODNR

HEALTH ALERT

Toxic blue-green algae may be present in this area.

Avoid swallowing lake water and do not touch algal scums. Keep pets away from the water.

Do not swim in areas where you cannot see your feet in knee-deep water.

Be alert! Avoid water that:

- **Looks like pea soup or spilled paint**
- **Is discolored or has colored streaks**
- **Has surface scums, mats, or films**
- **Has green dots or globs floating below the surface**

For more information, call your local health department or visit http://dnr.wi.gov or http://www.dhs.wisconsin.gov

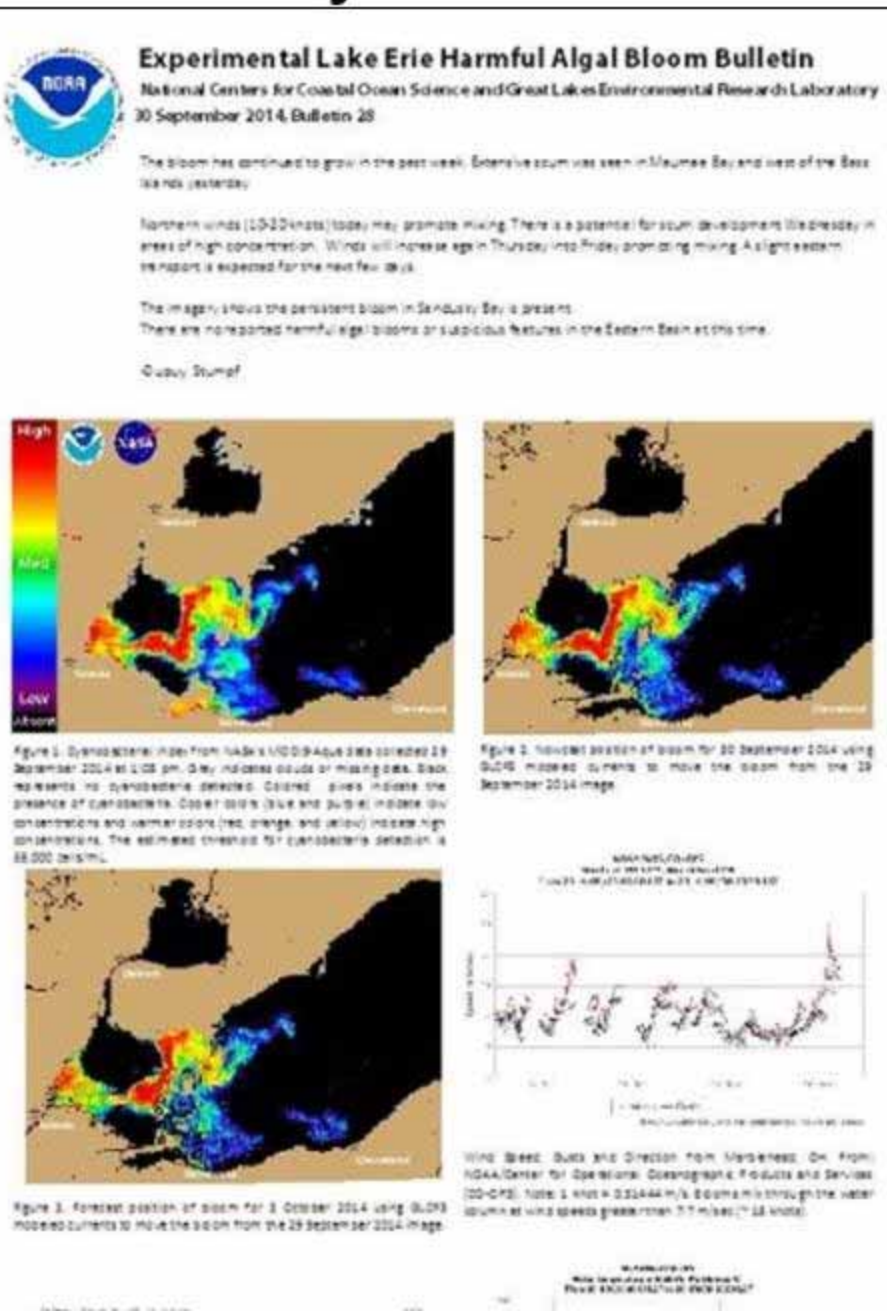
DEPARTMENT OF HEALTH SERVICES, Division of Public Health
Bureau of Environmental and Occupational Health, P-01082 (08/2015)

Are they toxic? Can I even go in the water?

Can't we test more?

Blooms change rapidly
Results delayed
Expensive!
Where to test on a large lake?

Are they toxic? Can I even go in the water?



Experimental Lake Erie Harmful Algal Bloom Bulletin

National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory

30 September 2014, Bulletin 28

The bloom has continued to grow in the past week. Extensive scum was seen in Maumee Bay and west of the Bass Islands yesterday.

Northern winds (10-20 knots) today may promote mixing. There is a potential for scum development like already in areas of high concentration. Winds will increase again Thursday into Friday, promoting mixing. A slight eastern component is expected for the next few days.

The imagery shows the persistent bloom in Sandusky Bay is present.
There are no reported harmful algal blooms or suspicious features in the Eastern Basin at this time.

-Dubuy Stumpf

Figure 1. Cyanobacteria index from NASA's MODIS-Aqua data collected 29 September 2014 at 1:05 pm. Gray indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate high concentrations. The estimated threshold for cyanobacteria detection is 50,000 cells/mL.

Figure 2. Forecast position of bloom for 30 September 2014 using GLCFS modeled currents to move the bloom from the 29 September 2014 image.

Figure 3. Forecast position of bloom for 3 October 2014 using GLCFS modeled currents to move the bloom from the 29 September 2014 image.

Wind Speed, Gusts and Direction from Vanderhoef, OH. From NOAA/Center for Operational Oceanographic Products and Services (CO-OPS). Note: 1 knot = 0.51444 m/s. Boom is through the water column at wind speeds greater than 7.7 m/sec (~15 knots).

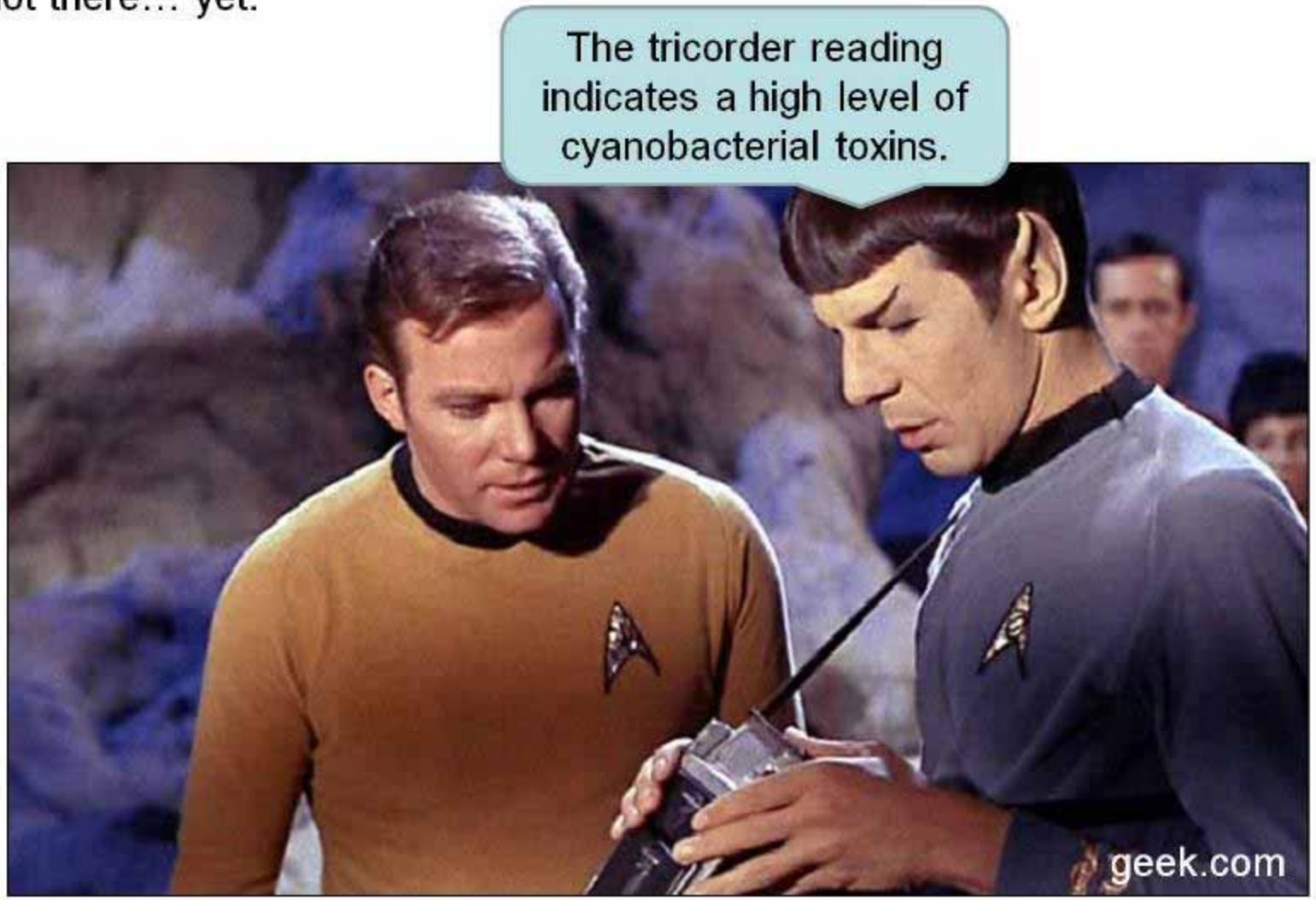
Many inland lakes are too small for satellite monitoring

Toxins cannot be assessed via remote sensing

Lots of data needed for forecasts

Are they toxic? Can I even go in the water?

Knowing instantaneously if toxins are not present, or if the cyanobacterial population does not have toxin genes, is the only way to be certain that it is safe.
We're not there… yet.



For now, common sense applies.

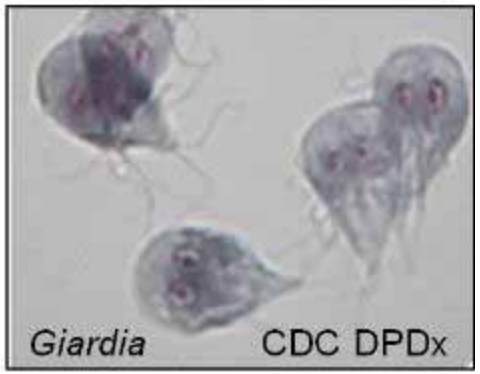
Can you see your feet in knee-deep water?

Avoid water that resembles a green milkshake, pea soup, or paint.

Smell earthy or musty odors? Toxins might be present.

Graham et al. 2010: geosmin & MIB co-occurred with toxins http://bit.ly/1dPjZGC

Cyanotoxins can still be present without odors



Choose the clearest water possible for swimming. Try to avoid swallowing water, no matter how clean it looks, especially after a rainstorm!


Sometimes the risk is obvious.
2014 North Carolina
Division of Water Quality

What about other situations?

- Bloom close to shore or patchy?
- Chunks of material floating?
- Things on lake bottoms?
- Only a fine dusting of material?
- These are judgment calls for you. Take into account health vulnerabilities. Smaller doses may make small children ill. Dogs will not hesitate to drink water containing algae or eat algae clumps.

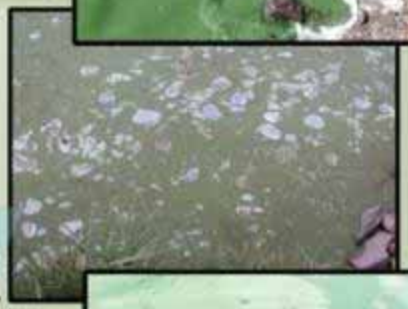
Sometimes it is more difficult to gauge risk.

Communication Caveats

- DON'T terrify your audience.
- Know who has the responsibility for issuing advisories. ALWAYS work with local public health officials (county or municipal) if there is a need to communicate risk to the public for a given water body.
- Be absolutely certain that a "bloom" is actually cyanobacteria!
- Recognize that conditions can change

Should you let your kids or pets play in this?

BAD IDEA!



Algae are common in lakes and rivers. But at high concentrations a type called "blue-green" algae can make people and animals sick.

What to look for:

- Does the water look "pea soupy"?
- Does it smell swampy?

Blue-green algae can:

- irritate skin, eyes and nasal passages and make you sick.
- poison your pets or livestock – animals have died from it.

If you or your pets have come in contact with blue-green algae, **wash thoroughly.** Think you or animals are sick from it? Call a doctor or veterinarian immediately.

When in doubt, best keep out!

This poster prepared by the Minnesota Interagency Work Group on Blue-Green Algae.

In Wisconsin - http://dnr.wi.gov/lakes/bluegreenalgae/

dnr.wi.gov and dhs.wisconsin.gov
Search for “algae”

- DHS and DNR are trying to track blooms and illnesses.
  Please let me know about bloom events!
- Illnesses – report via DHS website.
- DNR cannot respond to each case, but knowledge of blooms helps us to track where HABs are a public health burden.