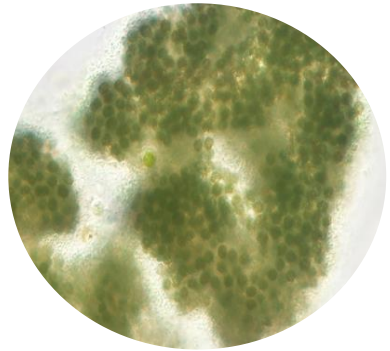


CyanoHAB training

PHYTOPLANKTON MONITORING NETWORK

JEN MAUCHER FUQUAY, M.S., PMN COORDINATOR

CSS CONTRACTOR, NOAA CHARLESTON LAB

Promoting a better understanding of Cyano Harmful Algal Blooms by way of volunteer monitoring

What is PMN?

Phytoplankton Monitoring Network (PMN) is a national volunteer organization that monitors for potential Harmful Algal Blooms

Train citizen scientists to:

- *Collect samples from coastal or freshwater environments*
- *Identify potentially harmful algal/cyanobacterial species*
- *Enter information into NOAA database*

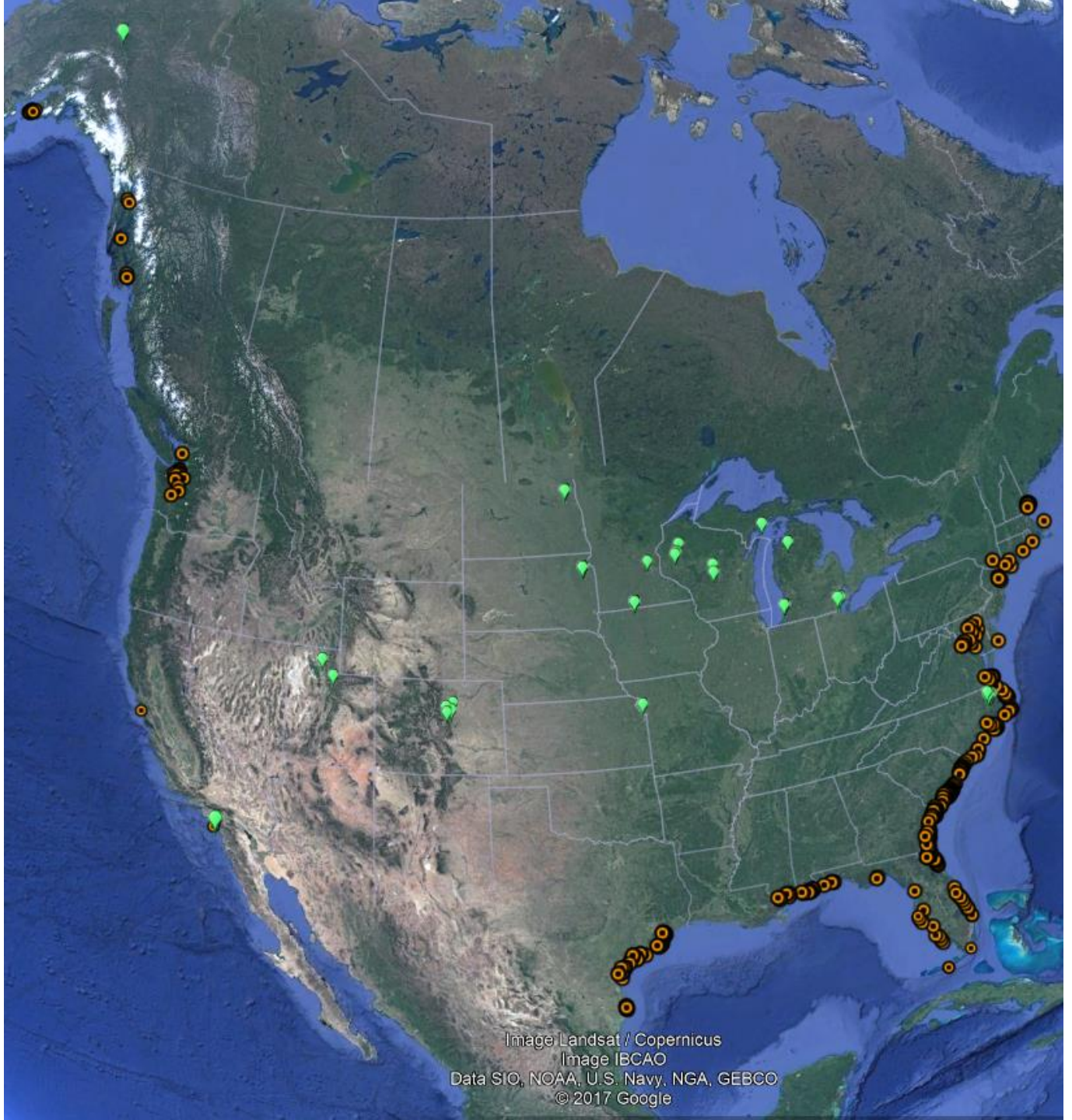
NOAA scientists can then:

- *Analyze water samples for HAB toxins*
- *Alert state/local agencies to presence of bloom*
- *Identify temporal and geographic HAB trends*

PMN sample sites

Participants include:

- **School groups**
- **Civic groups**
- **Aquariums**
- **Tribal communities**
- **National, State & local gov't entities**
- **Coast Guard Auxiliary**
- **Interested individuals**

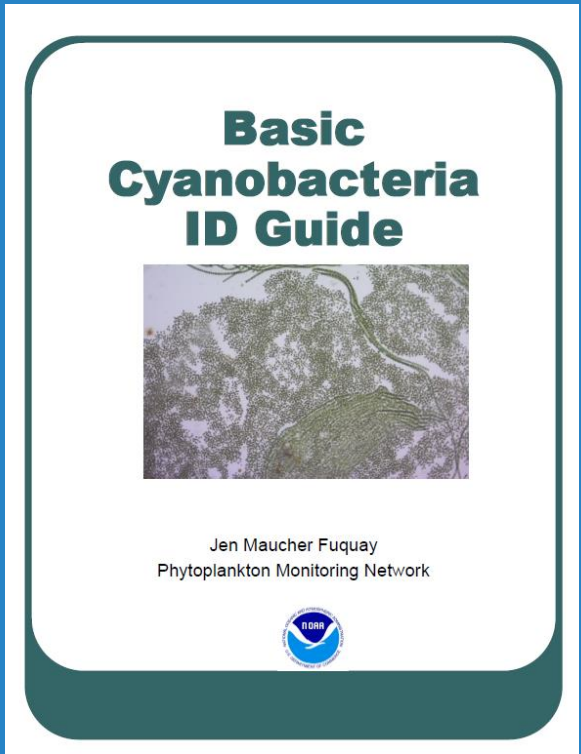


Volunteer Equipment

Volunteers are loaned all sampling equipment

- Thermometer
- 5 gridded slides
- Cover slips
- 1L & 125 mL bottles
- 30 mL of Lugol's for sample preservation
- Pre-paid overnight shipping label and shipping envelopes
- Identification sheets for target species

TRAINING

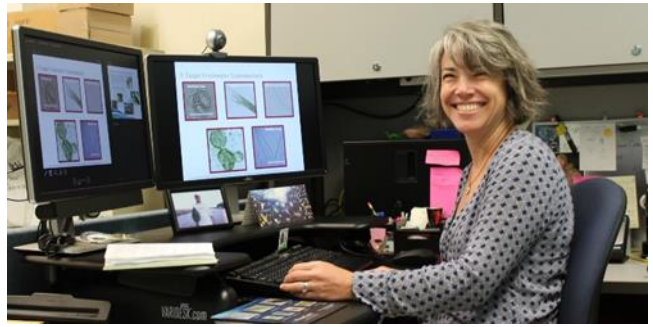


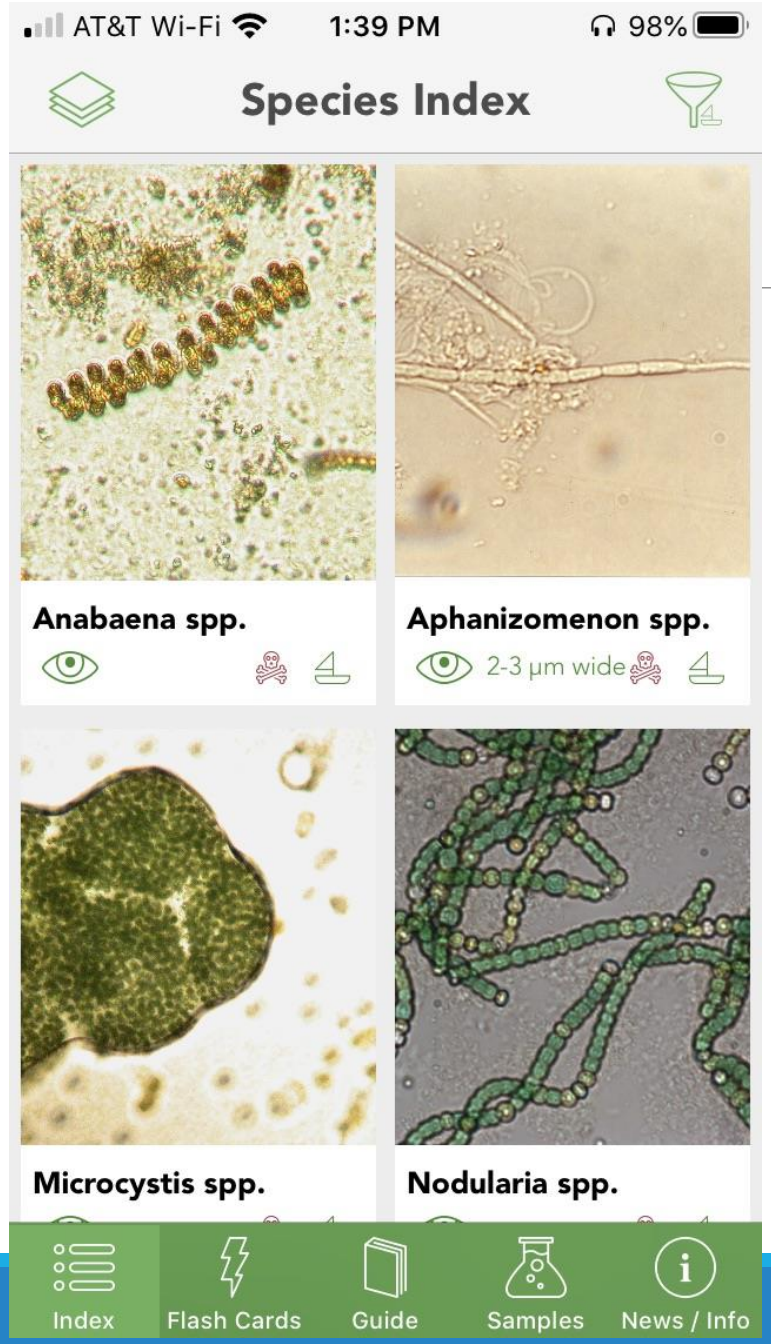
Remote or in person training covers:

- Background of HABs
- Sampling protocols
- How to ID target organisms

Feedback on IDs provided!!

Data entry QC'd by PMN





'PHYTO' app

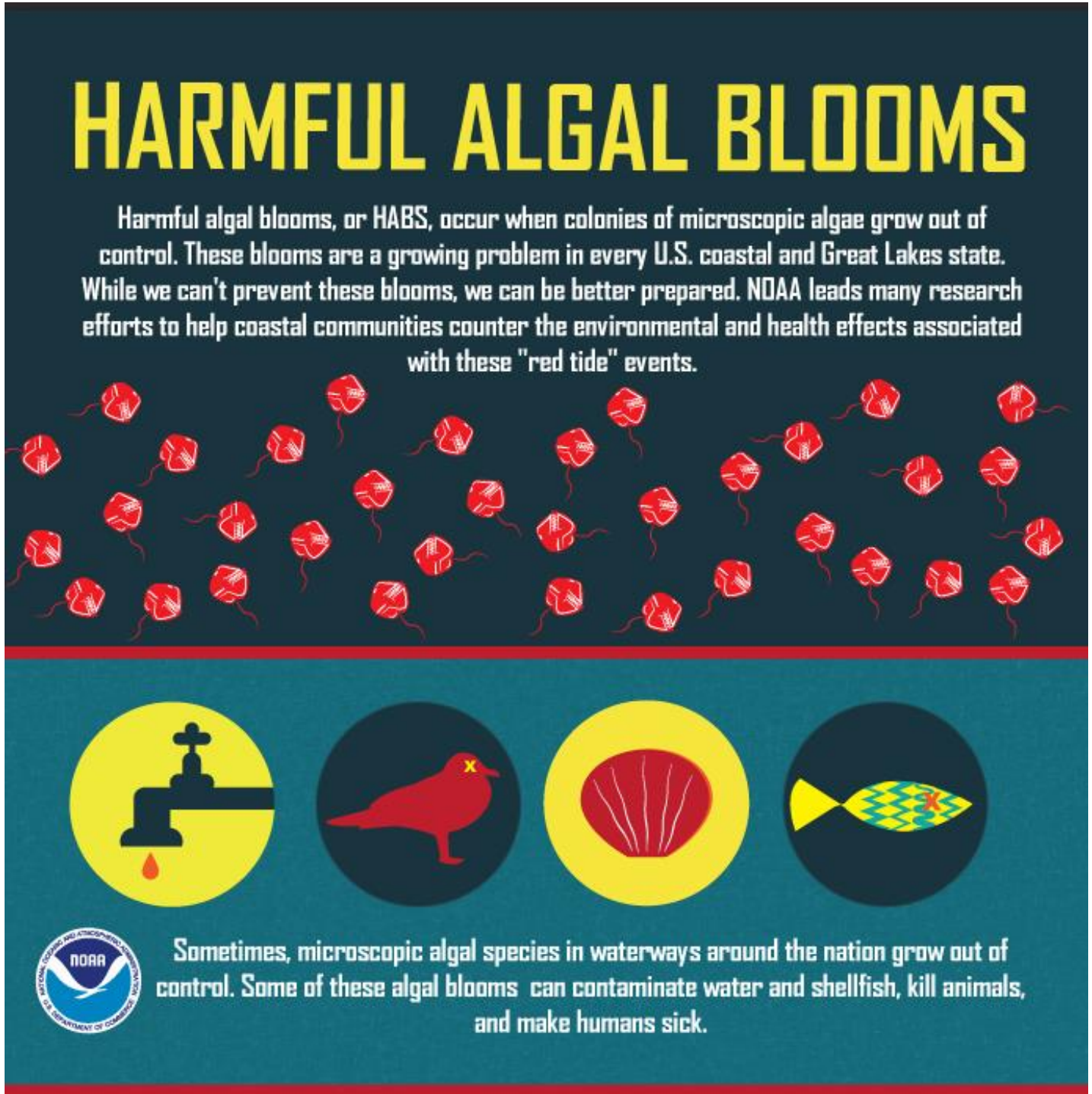
-Includes freshwater species!
-More pictures!
-More pronunciations!
-Can enter data from iPhone or iPad!
(sorry Android users… not quite ready yet!)

Developed by PMN volunteer Shawn Gano to assist with and improve volunteer's identification skills of marine algae & cyanos

http://youtu.be/ItzxoB06De0

WHAT IS A HAB?

Harmful Algal Bloom

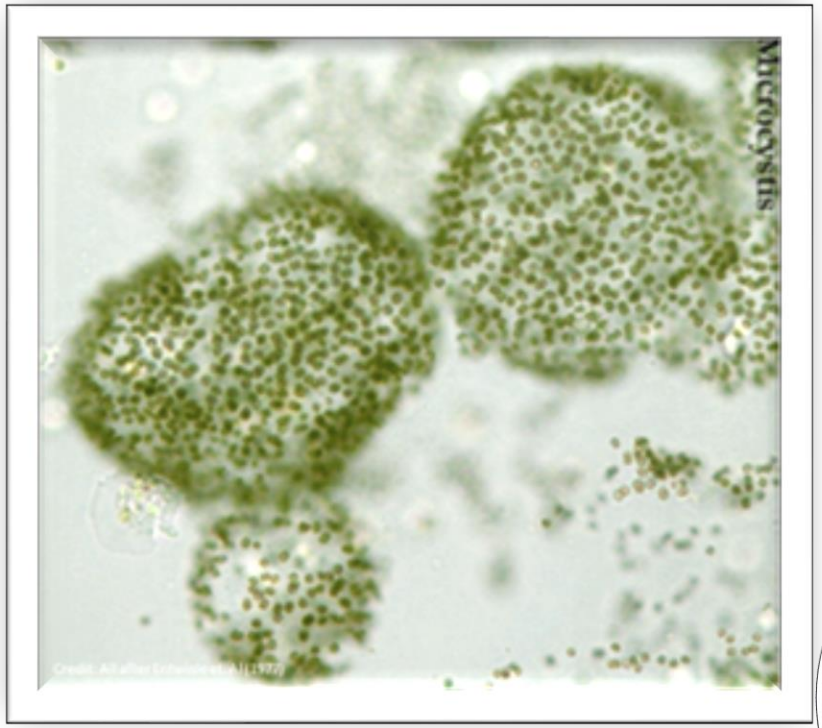


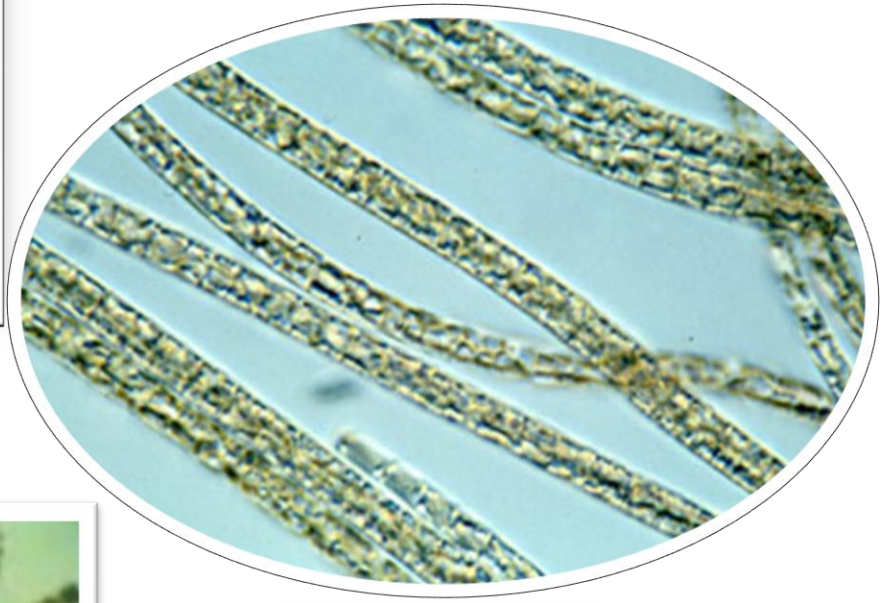
What are we looking for?

In freshwater environments the main culprits are **CYANOBACTERIA**

Not true algae, although we still call them HABs

CyanoHABs = Cyanobacterial Harmful Algal Bloom



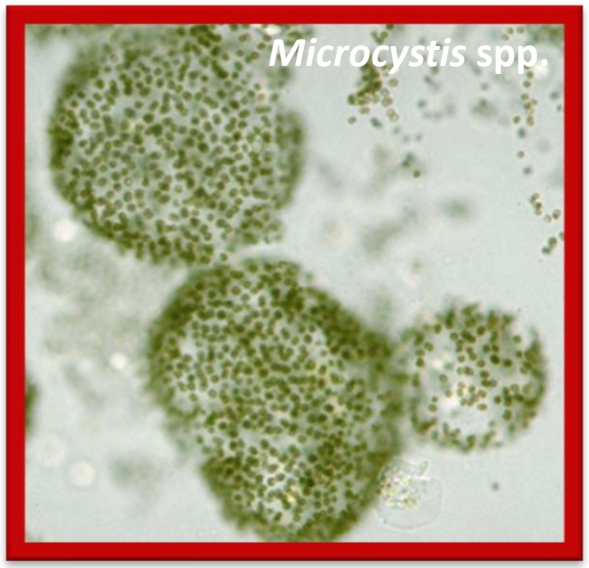


PMN Target Cyanobacteria

These 5 groups selected as they are generally found in surface waters, so they can be easily sampled. Many have mechanisms to keep them buoyant in the water column.

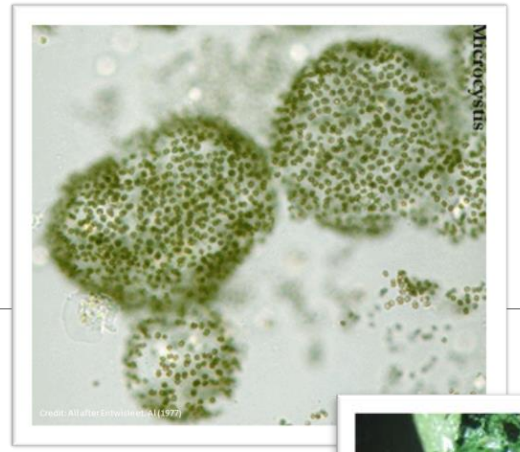
Have been several taxonomic (name) changes in the past few years.

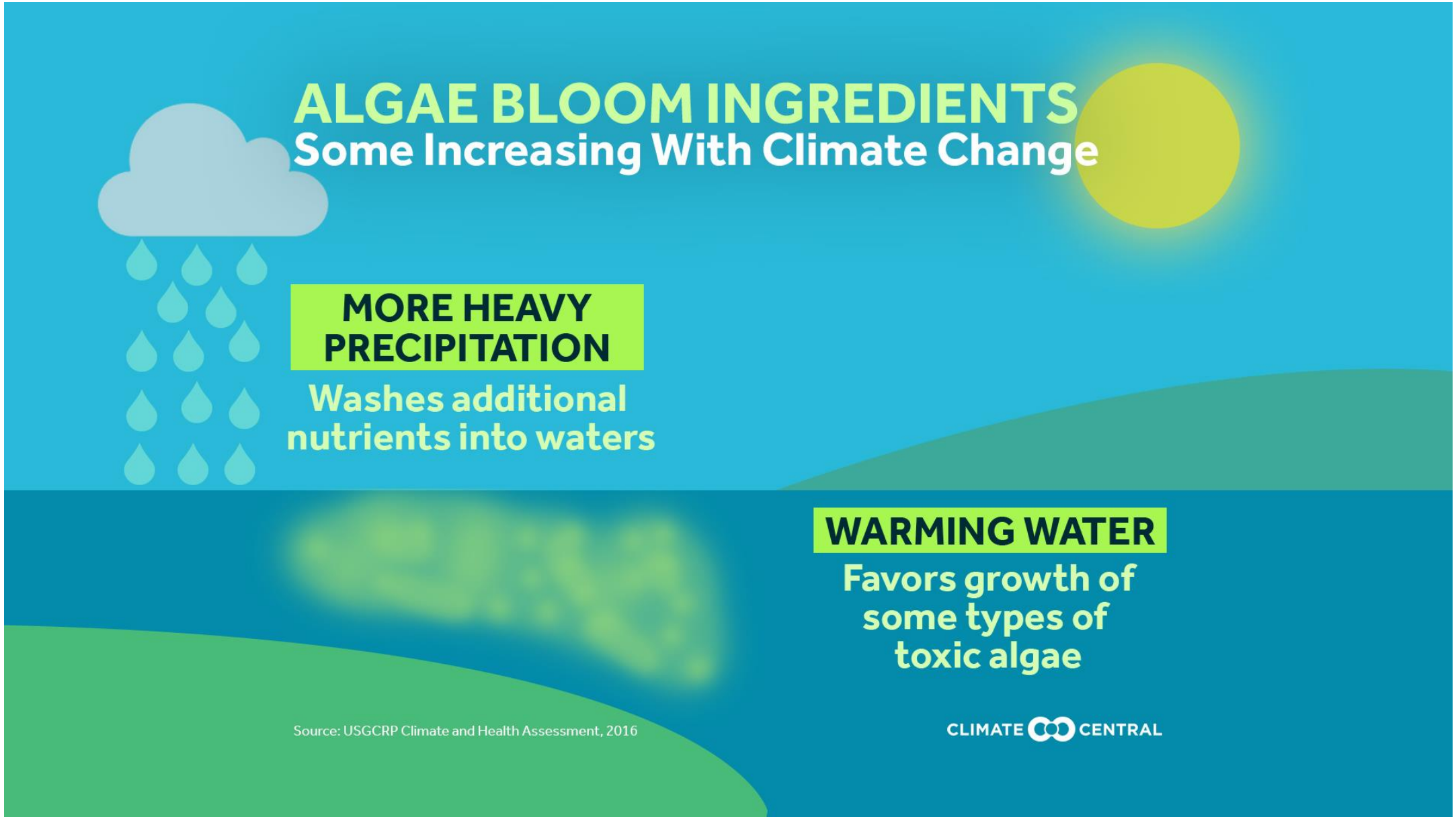
Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring, and management, World Health Organization, 1999



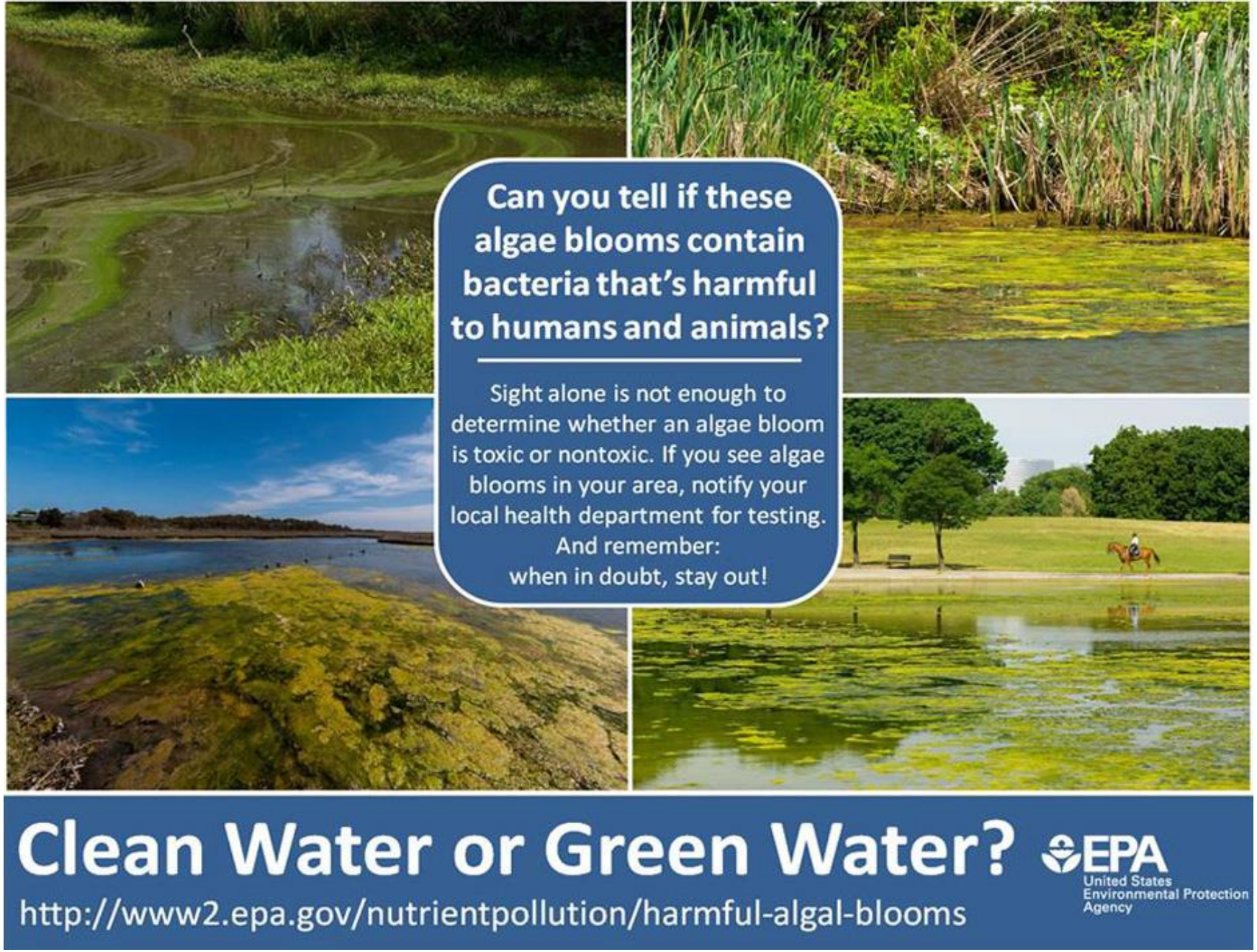
CYANOBACTERIA

- Formerly called blue-green algae
- Prokaryotic (primitive cell type)
- Microscopic
- Can photosynthesize
  - Beneficial oxygen producers for water and atmosphere
- Can form dense ‘blooms’ when conditions are right aka **cyanoHAB**





Cyanos like it still, hot and nutrient rich



Best to have microscopic identification to know what organisms are causing the bloom- not all are harmful

What do you mean by "harmful"?

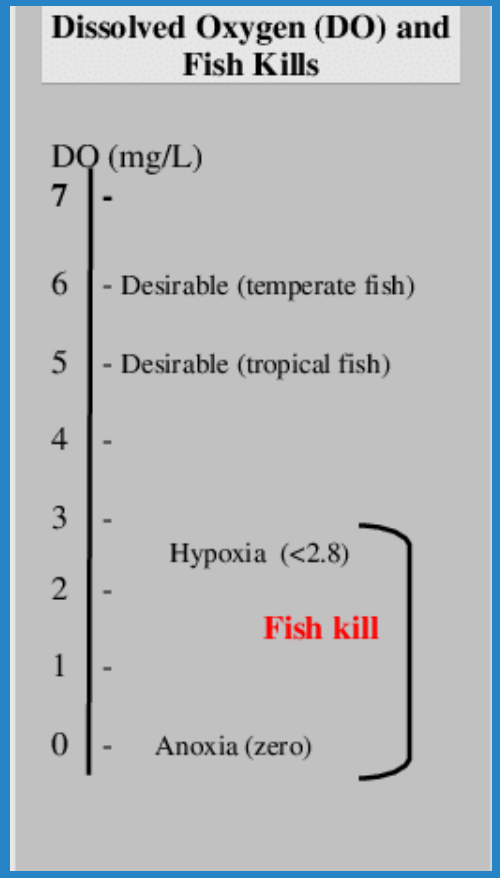


Figure source: Golam Kibria 2011; GM Water, Australia

- Scum can block sun to submerged plants & ↓dissolved O_2 (DO)
- Dying blooms also ↓ O_2

Hypoxia/anoxia can kill aquatic life

https://www.vdh.virginia.gov/environmental-epidemiology/waterborne-hazards-control-program/cyanobacteria/

What do you mean by "harmful"?

Salem extends water advisory for at least two more weeks

Updated Jan 30, 2019; Posted Jun 10, 2018

The city of Salem is extending its drinking water advisory for at least two more weeks.

OREGONLIVE
The Oregonian

Production of Toxins

- Drinking and recreational waters can be affected
- Human and animal illness/mortalities primarily through ingestion

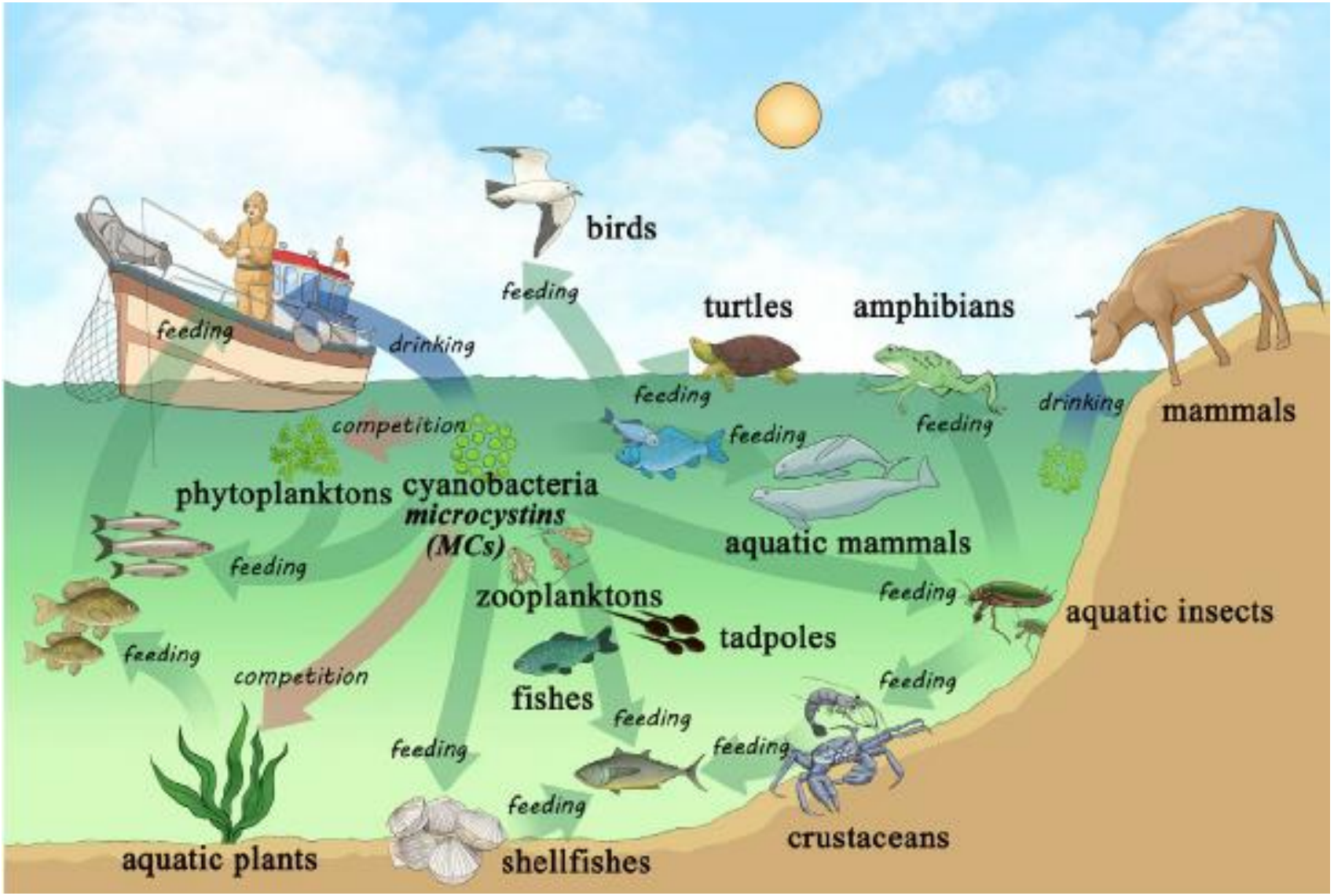
Toxic Algae Kills Dogs Across the Country

By Lindsay Kalter

https://pets.webmd.com/dogs/news/20190814/toxic-algae-kills-dogs-across-the-country

Cyanotoxins in the food web

Example of microcystins shown to demonstrate how various organisms can be exposed to cyanotoxins



A review of reproductive toxicity of microcystins, Chen et al., 2015

Many different groups (genera) of cyanos can potentially make toxins.

2 main classes of toxins:

- *Hepatotoxins affect the liver*
- *Neurotoxins affect the nervous system*

Some can potentially make more than one type of toxin

TABLE A1. CYANOBACTERIA AND THEIR ASSOCIATED CYANOTOXINS

Cyanobacterial Genera	Hepatotoxins		Neurotoxin	
	CYLINDRO-SPERMOPSIN	MICROCYSTINS	ANATOXIN	SAXITOXINS
Anabaena/Dolichospermum	x	x	x	x
Anabaenopsis		x		
Aphanizomenon	x		x	x
Aphanocapsa		x		
Cylindrospermopsis	x			x
Haplosiphon		x		
Lyngbya (Plectonema)	x			x
Microcystis		x		
Nostoc		x		
Oscillatoria (Planktothrix)		x	x	x
Phormidium			x	
Pseudanabaena		x		
Raphidiopsis	x		x	
Umezakia	x			
Synechococcus		x		
Synechocystis		x		

Information adapted from Jennifer Graham, USGS

HEALTH EFFECTS OF INGESTION, INHALATION & CONTACT WITH CYANOTOXINS

Every year, Americans fall ill after being exposed to harmful cyanotoxins. This contact can come in many forms, but most results from being in or around water that contains dangerous levels of algae. Below are examples of how cyanotoxins can affect you, based on the route of contact.

INGESTION
- Fever
- Headache
- Drowsiness
- Loss of Coordination

CONTACT
- Eye & Ear Irritation

INGESTION
- Vomiting
- Sore Throat
- Incoherent Speech

INHALATION
- Coughing
- Wheezing
- Difficulty Breathing

INGESTION
- Tingling
- Burning
- Numbness
- Muscular Twitching

CONTACT
- Skin Irritation
- Rash & Lesions

INGESTION
- Nausea
- Cramping
- Diarrhea

https://www.ewg.org/toxicalgalblooms/

Can you tell <u>toxins</u> are present just by the organism present or the water changing color?

NO!

Complicating factors:

1. Not all toxic blooms are discolored.
   - Water can be toxic but look normal
2. Not all species can produce toxins
3. Not all species that CAN make toxins always DO
4. Not just one form of toxin exists
   - Many different forms (congeners) of toxins exist
   - Toxicity of congeners can vary

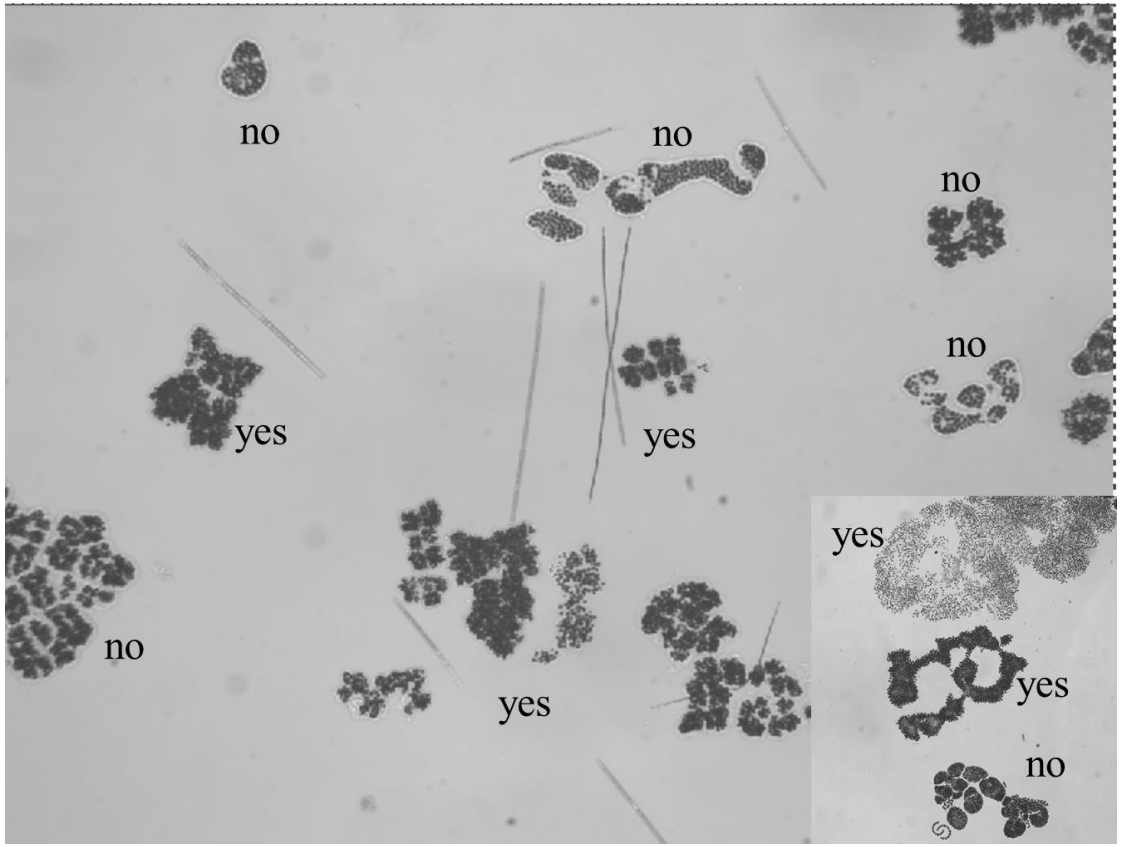
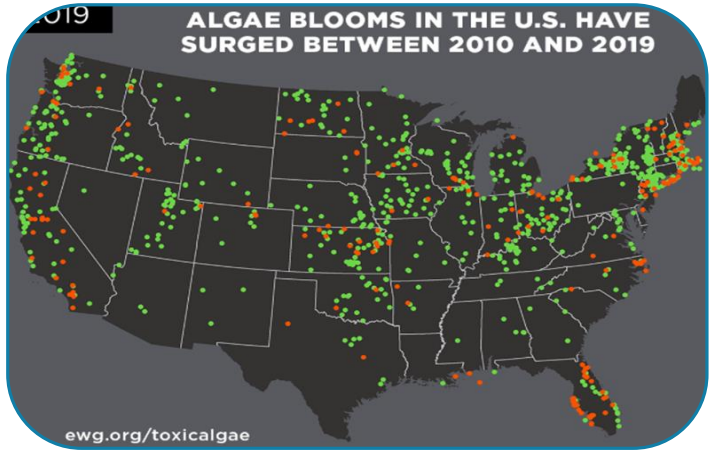
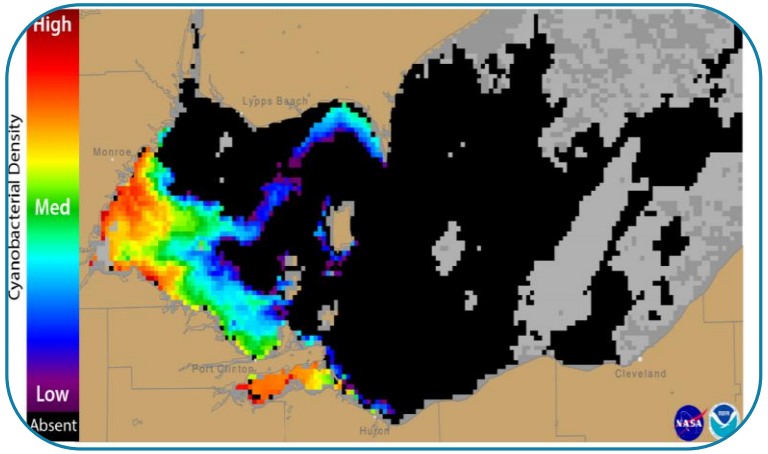


Photo blatantly stolen from Barry Rosen @USGS

Why We Monitor cyanoHABs



HABs are increasing in duration, frequency, and geographical distribution



Data helps us understand, forecast, and prepare for harmful algal blooms

Monitoring can act as early warning system for potential toxin exposure

Image courtesy of Todd Honeycut

Why PMN?

Problem: Very few government or private institutions have the capacity or capability to monitor thousands of lakes (and reservoirs), from the Great Lakes to small residential lakes annually impacted by HABs.

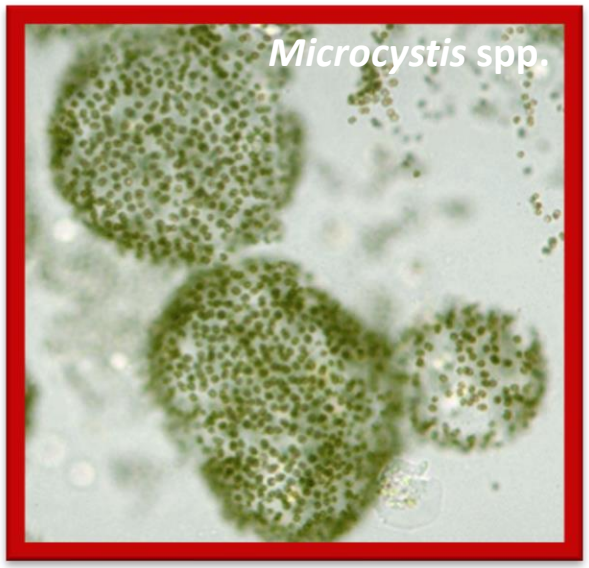
Solution: Engage local citizens in environmental monitoring of potentially harmful cyanobacteria to aid NOAA scientists and others in their research.

EPA Office of Water & PMN

- **Freshwater CyanoHAB monitoring started in 2015 as interagency agreement between EPA and NOAA**
- **Based on PMN's coastal marine monitoring program established in 2001**
- **Modified marine protocols for freshwater**
- **Looking for 5 target organisms**

PMN Target Cyanobacteria

Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring, and management, World Health Organization, 1999



MONITORING RESULTS

MARINE (2001-2019)

Volunteer Reported Blooms
> 200

Potentially toxic species= 57 events

Confirmed toxic events = 14

- 10 Domoic Acid (TX, MS, NC, AK)
- 1 Okadaic Acid (TX)
- 2 Saxitoxin (AK)
- 1 Microcystin (MS)

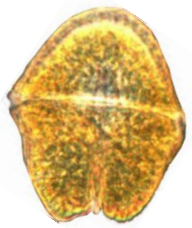
FRESHWATER (2016-19)

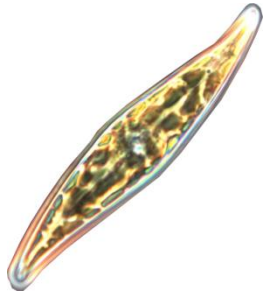
Volunteer Reported Blooms
37

Confirmed toxic events = 9

- Microcystis (ID, MI/OH, MN)
- Aphanizomenon (ND)
- Dolichospermum (GA, ID, CO)

PROTOCOLS





Phytoplankton Monitoring Network

Promoting a better understanding of Harmful Algal Blooms by way of Volunteer Monitoring

SITE SELECTION:

Where you sample is completely up to you.

Things to consider:

- Can you do it safely and legally?
- Can you get to the site on a consistent basis?
  - Minimum is every other week for one year/season (ice out to ice in)

Common criteria:

- Someplace you've seen blooms/discolored water before
- Someplace that is important to you or your community
  - Ex. Neighborhood pond/lake
- Just interested to see what is in your water

Don't necessarily need to sample on same day or same time

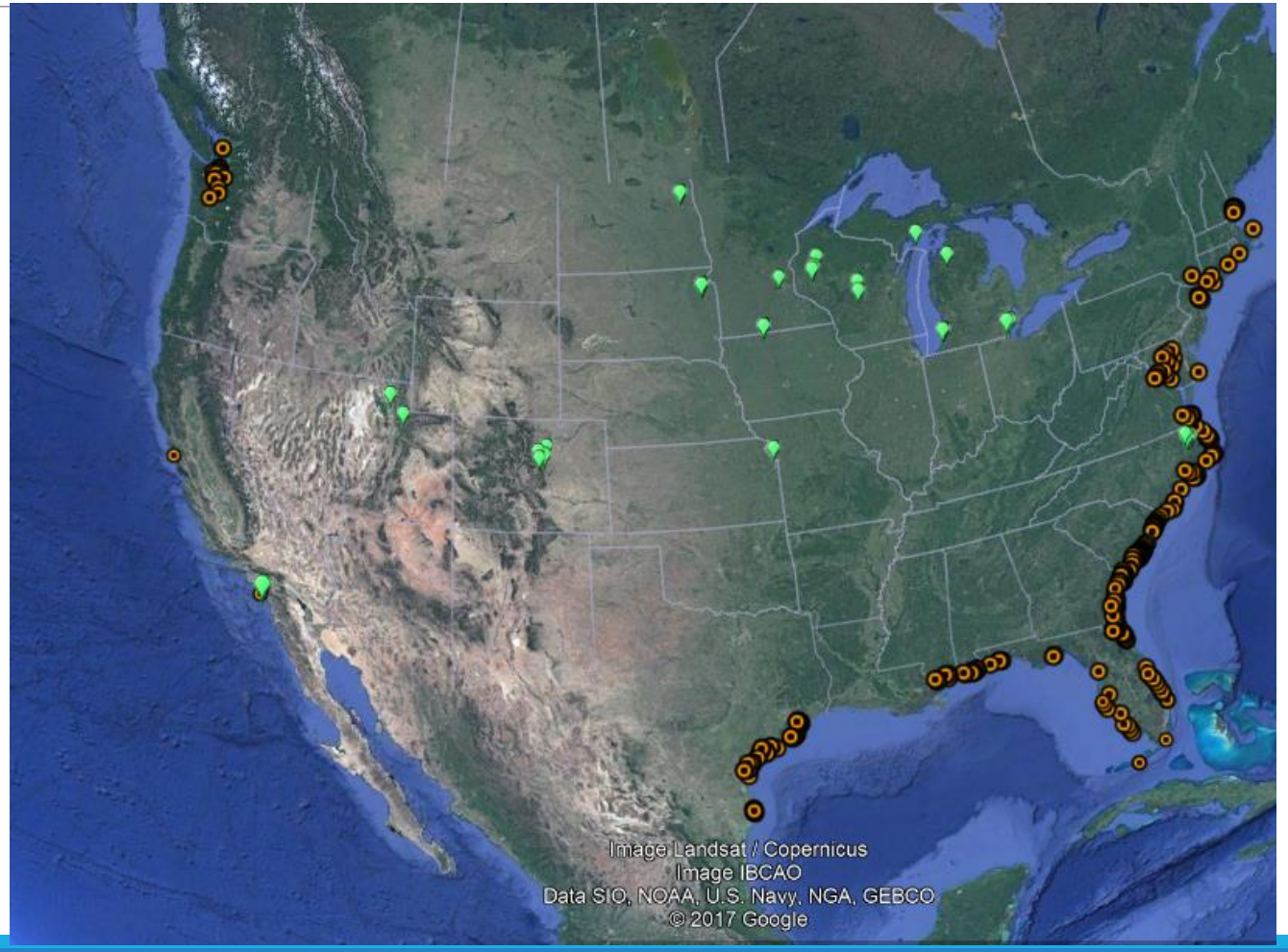
- Schedule according to what works best for you

WHAT WE NEED FROM YOU

1. A site name
2. GPS coordinates

Ex. Harrisville Harbor 44.6589, -83.2875

This allows us to get your site info into data entry portal and make you a dot on the map

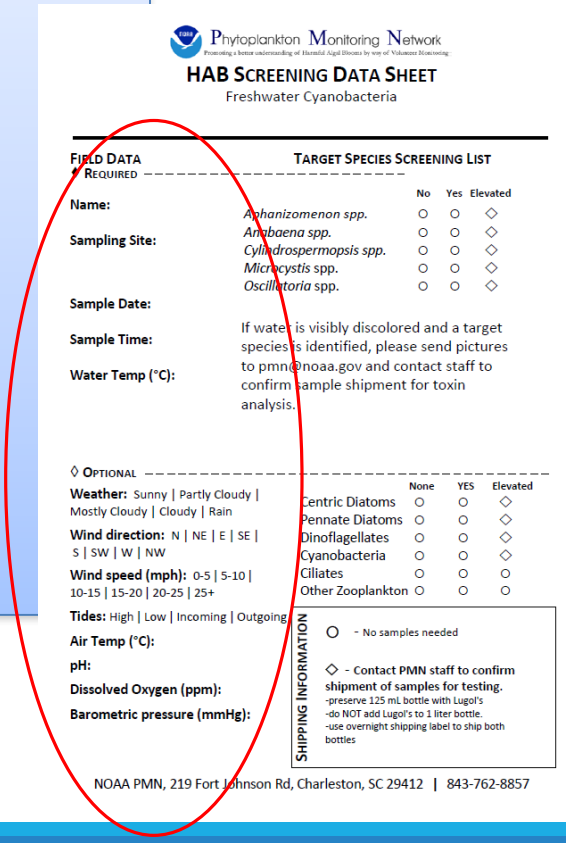


Sampling Overview

1) ***Collect sample*** at least once every two weeks during the sampling season (*1 year/season minimum*)
2) ***Analyze sample*** identifying target algae/cyanos
3) ***Take*** digital pictures to send into the PMN
4) ***Input*** data into the PMN database
5) ***Ship*** sample to PMN as required

1. Collect Sample

- 125 mL and 1 L bottles will be provided to volunteers
- Wear gloves when sampling
- Dip bottles to collect samples
- Collect air & water temperatures, optional weather data and note any other observations (water color, odor, etc)



Phytoplankton Monitoring Network

HAB Screening Data Sheet

Freshwater Cyanobacteria

Field Data

Required

Name:

Sampling Site:

Sample Date:

Sample Time:

Water Temp (°C):

Target Species Screening List

	No	Yes	Elevated
Aphanizomenon spp.	○	○	◇
Anabaena spp.	○	○	◇
Cylindrospermopsis spp.	○	○	◇
Microcystis spp.	○	○	◇
Oscillatoria spp.	○	○	◇

If water is visibly discolored and a target species is identified, please send pictures to pmn@noaa.gov and contact staff to confirm sample shipment for toxin analysis.

◊ Optional

Weather: Sunny | Partly Cloudy | Mostly Cloudy | Cloudy | Rain

Wind direction: N | NE | E | SE | S | SW | W | NW

Wind speed (mph): 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25+

Tides: High | Low | Incoming | Outgoing

Air Temp (°C):

pH:

Dissolved Oxygen (ppm):

Barometric pressure (mmHg):

	None	YES	Elevated
Centric Diatoms	○	○	◇
Pennate Diatoms	○	○	◇
Dinoflagellates	○	○	◇
Cyanobacteria	○	○	◇
Ciliates	○	○	○
Other Zooplankton	○	○	○

SHIPPING INFORMATION

○ - No samples needed

◇ - **Contact PMN staff to confirm shipment of samples for testing.**

-preserve 125 mL bottle with Lugol's

-do NOT add Lugol's to 1 liter bottle.

-use overnight shipping label to ship both bottles

NOAA PMN, 219 Fort Johnson Rd, Charleston, SC 29412 | 843-762-8857

Step 1:

Collect Whole Water Live Surface Samples 125 ml & 1 L

Freshwater Phytoplankton Monitoring Network

[1a. Preserve Sample]

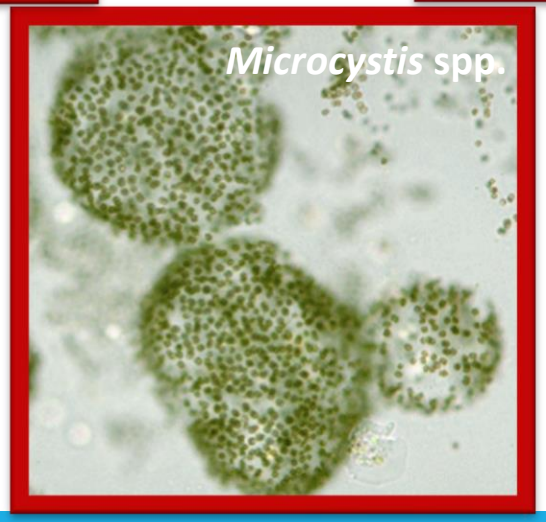
If samples cannot be analyzed within 8 hrs, you can preserve the 125mL sample on site.

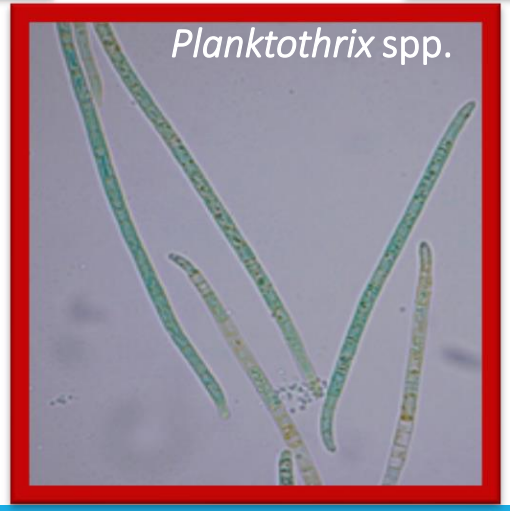
Lugol's solution:

Iodine
Potassium iodine
Glacial acetic acid

1. Add 2.5 mL to 125mL bottle
2. **NEVER** add Lugol's to live 1 Liter bottle!
3. Keep *ALL* sample bottles out of direct sunlight and heat.
   - Can bring small cooler with reusable ice pack

2. Sample analysis- Look for targets



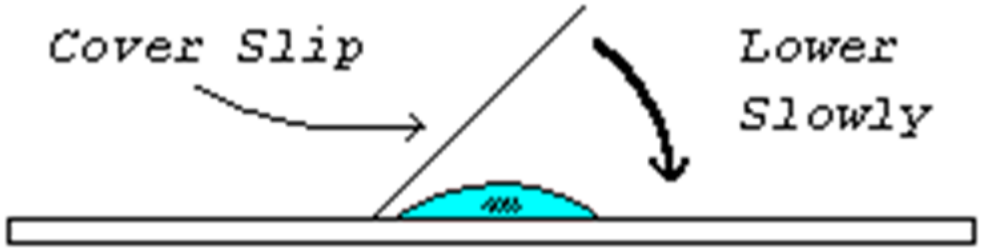


Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring, and management, World Health Organization, 1999

2. Sample analysis

A. Gently mix **125 mL bottle** by inverting 2x

B. Take sample from middle of bottle & add **2 drops** to gridded slide

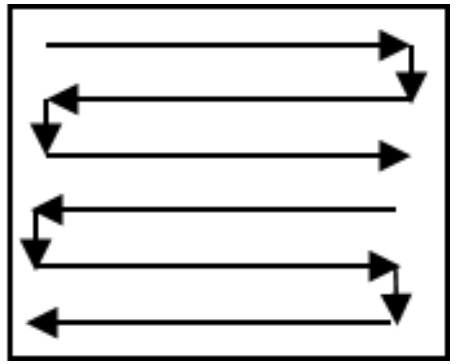


2. Sample analysis

C. Scan entire slide
   - Use **10X** objective to scan each square of grid
   - Go up to 40X objective when needed to ID
   - Use 'lawn mower method' to view ALL squares

D. Identify any **target species** that may be present and photograph (used to QC IDs made)

E. Keep track of how often you observe each target as you go



3. Photograph sample!!

A. Take photos of target organisms observed

- Use highest magnification (40X objective =400X total)
- May need multiple photos of one organism
- At least one photo for each target (need representative example of each target group seen to confirm ID)
- Can use cell phone camera- see this video on how!

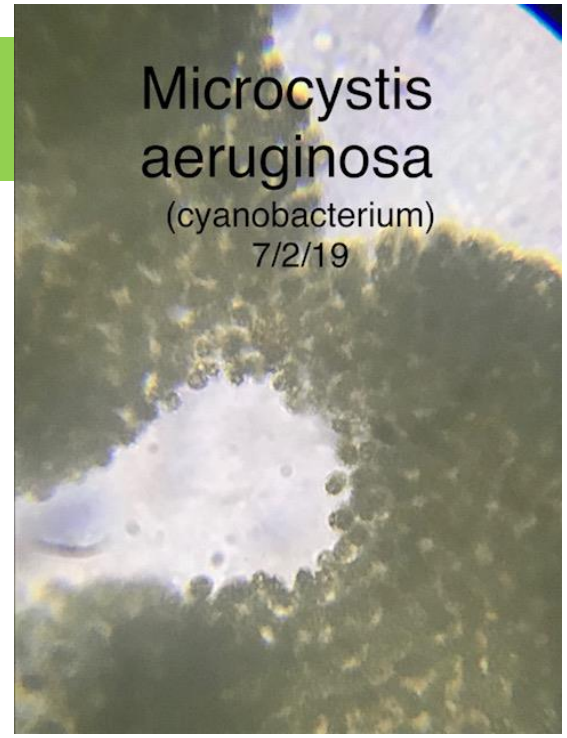
This is important for our data quality- IDs need to be confirmed by PMN staff

3. Photograph sample!!

B. Upload all photos into one file

- Can be Word doc, PowerPoint, PDF
- Be sure each photo is labeled with name of organism and total magnification used (40X objective= 400X total)
- File name/title page should include sample date

C. Email file to pmn@noaa.gov



Bob Carey
Marina del Rey, CA.
1/27/19
All photos 400X unless otherwise noted.

Image: www.microscopeworld.com

Credit: NOAA, Jeff Paternoster

Important to Remember…

You are *only* responsible for reporting on the 5 target freshwater algae species!

There may be lots of other "stuff" in the water - feel free to investigate, explore and have fun!

Keep in mind that sometimes you may not see any target species but data still needs to be entered every time!

4. Data Entry

At end of analysis you should have a relative abundance noted for how often you saw each target group.

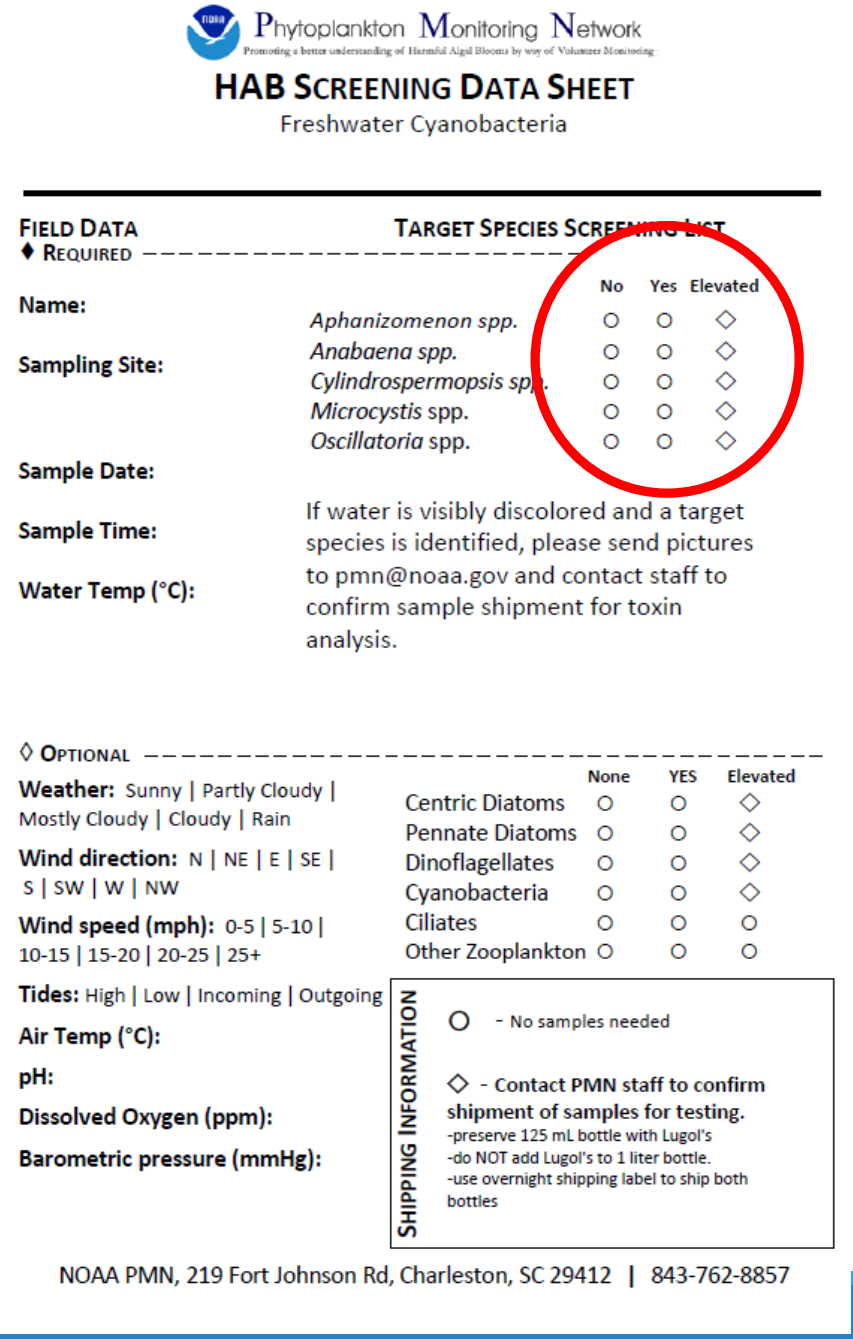
- **NO counting of cells/natural units**

  No= zip, zilch, zero

  Yes= 1-60% slide coverage

  Elevated = >60% with discoloration

None-Some-Lots



Phytoplankton Monitoring Network
Promoting a better understanding of Harmful Algal Blooms by way of Volunteer Monitoring

HAB SCREENING DATA SHEET
Freshwater Cyanobacteria

FIELD DATA ♦ REQUIRED

Name:

Sampling Site:

Sample Date:

Sample Time:

Water Temp (°C):

TARGET SPECIES SCREENING LIST

	No	Yes	Elevated
Aphanizomenon spp.	○	○	◇
Anabaena spp.	○	○	◇
Cylindrospermopsis sp.	○	○	◇
Microcystis spp.	○	○	◇
Oscillatoria spp.	○	○	◇

If water is visibly discolored and a target species is identified, please send pictures to pmn@noaa.gov and contact staff to confirm sample shipment for toxin analysis.

◊ OPTIONAL

Weather: Sunny | Partly Cloudy | Mostly Cloudy | Cloudy | Rain

Wind direction: N | NE | E | SE | S | SW | W | NW

Wind speed (mph): 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25+

Tides: High | Low | Incoming | Outgoing

Air Temp (°C):

pH:

Dissolved Oxygen (ppm):

Barometric pressure (mmHg):

	None	YES	Elevated
Centric Diatoms	○	○	◇
Pennate Diatoms	○	○	◇
Dinoflagellates	○	○	◇
Cyanobacteria	○	○	◇
Ciliates	○	○	○
Other Zooplankton	○	○	○

SHIPPING INFORMATION

○ - No samples needed

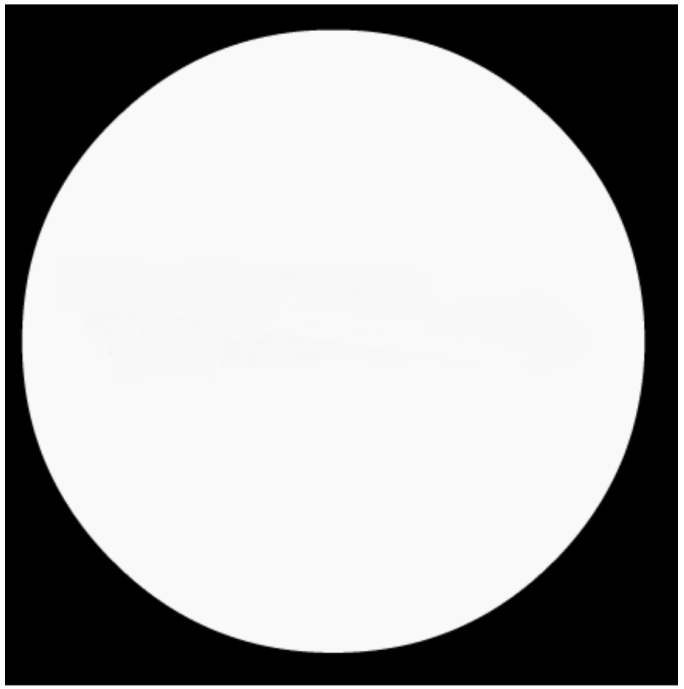
◇ - **Contact PMN staff to confirm shipment of samples for testing.**
-preserve 125 mL bottle with Lugol's
-do NOT add Lugol's to 1 liter bottle.
-use overnight shipping label to ship both bottles

NOAA PMN, 219 Fort Johnson Rd, Charleston, SC 29412 | 843-762-8857

Credit: NOAA, Jeff Paternoster

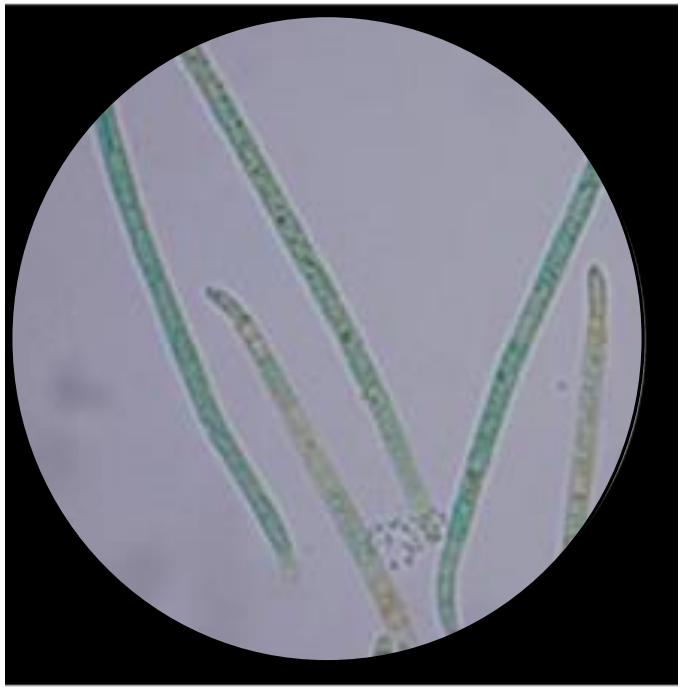
RELATIVE ABUNDANCE

NO= NONE



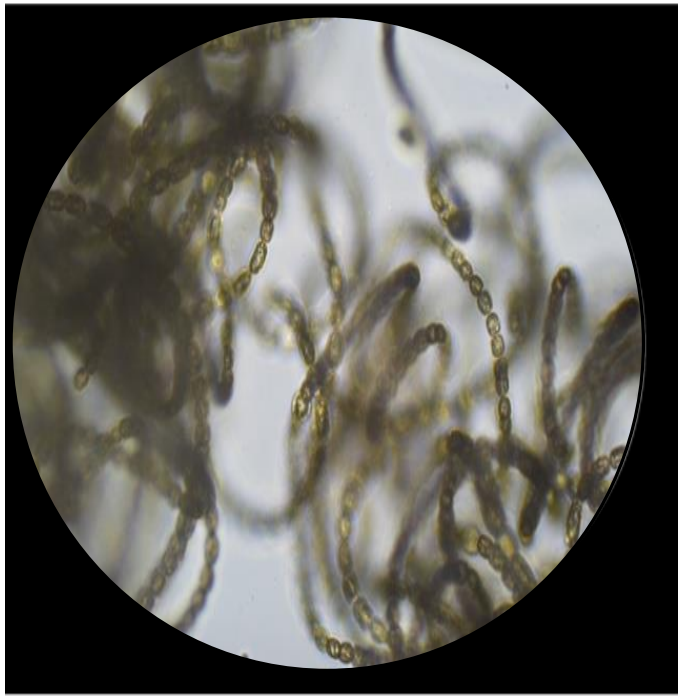
0%

YES= SOME



Present in 1-60% of grids
Even 1 present is a yes.
Sporadically seen across slide

ELEVATED= LOTS

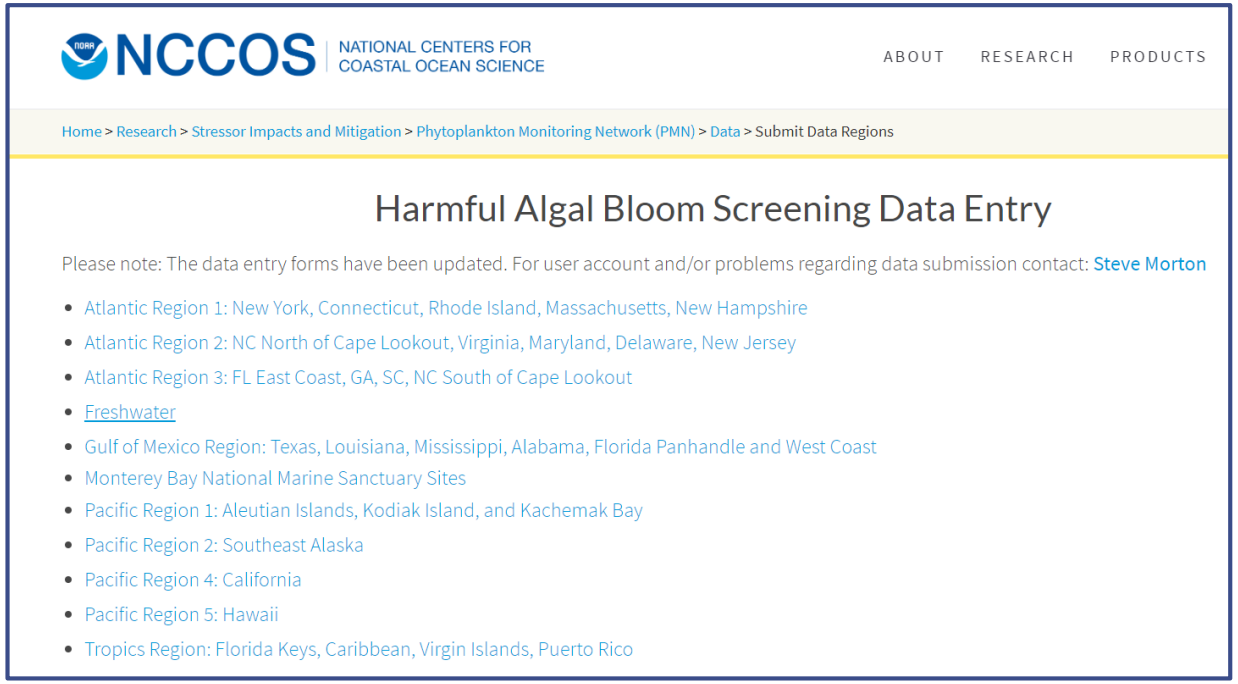


Present in >60% of grids
Target is dominant organism
Seen predominately across slide

4. Data Entry

Data entered online for each sample using the NOAA PMN website

- If NO targets are observed on slide, data still needs to be entered!



5. IF you have an obvious bloom

- If your state/organization already has toxin testing capabilities, you do not need to send us a sample
- Follow their shipping protocols
  - We would appreciate the sharing of results to keep track of toxic cyanoHAB events

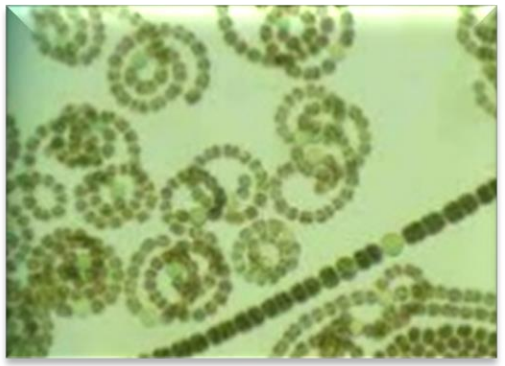
If you do NOT have any access to microcystins testing, then……

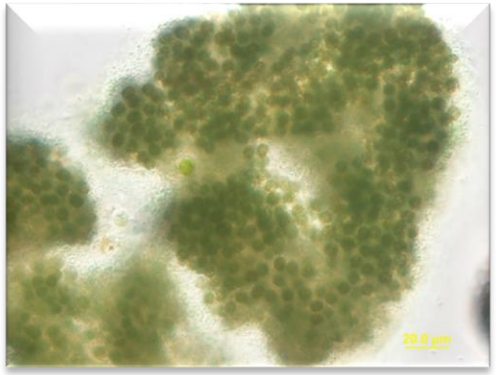
Sample bottle from August 2015 Microcystis bloom in Lake Erie (credit: Tom Green)

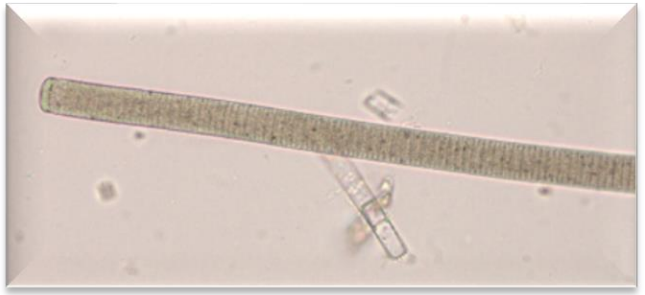
5. IF you have an obvious bloom

- Contact PMN immediately
- ***Freeze*** 1 L sample bottle
  - Leave headspace in bottle
  - DO NOT add Lugol's to this bottle!
- Photos used to confirm ID
- You will be given instructions on whether to mail sample for toxin analysis and how to prep samples

Dolichospermum, Microcystis, Planktothrix are all potential microcystins producers

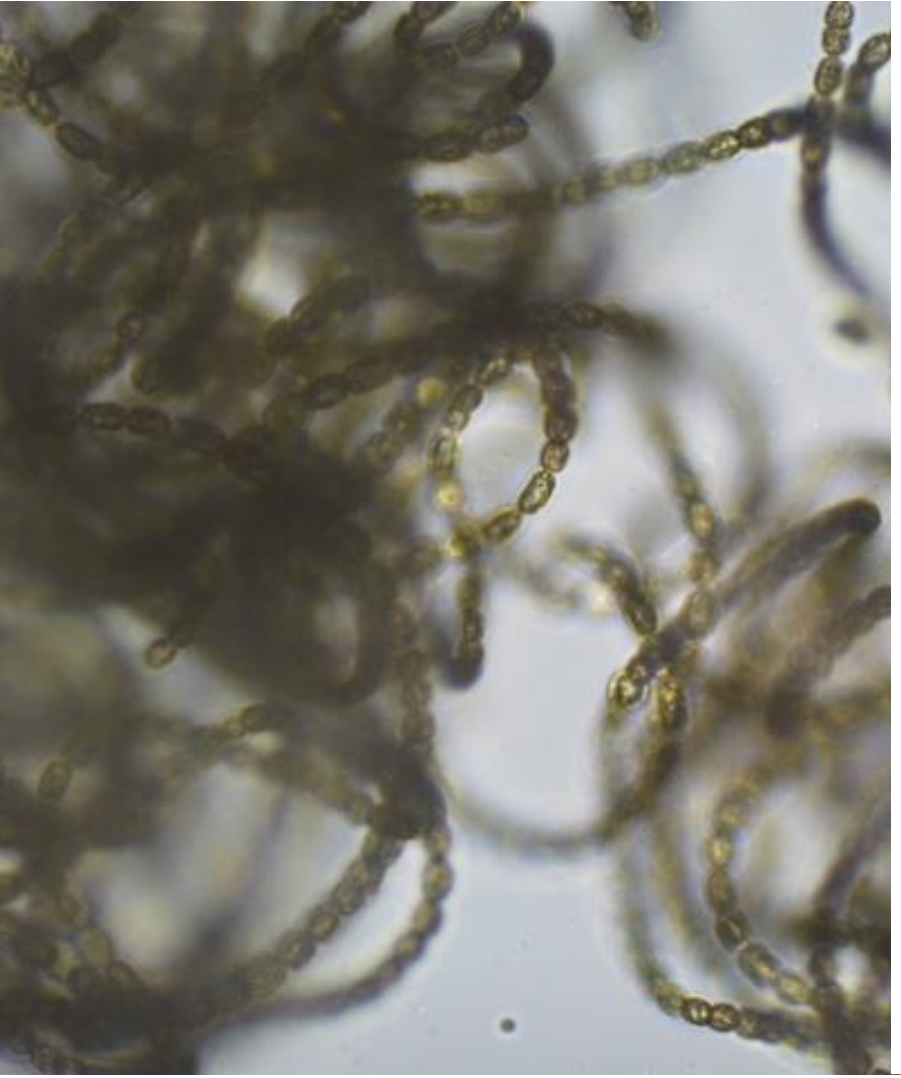


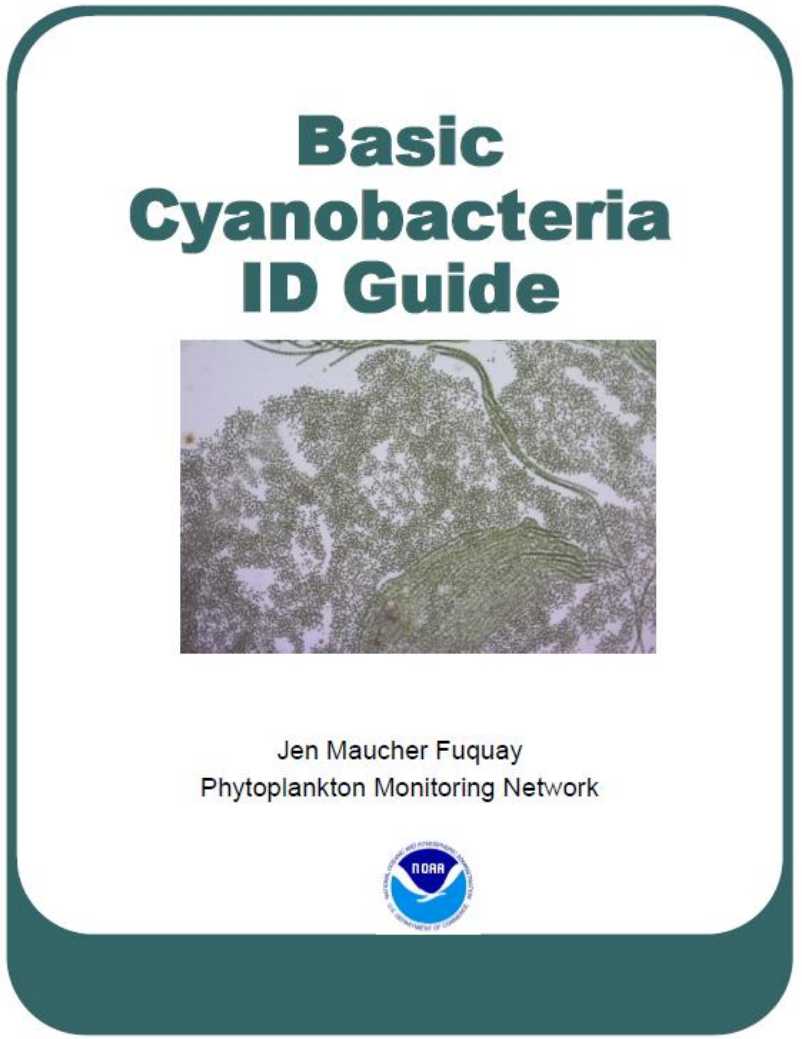




Sampling Summary

1) ***Collect sample*** at least once every two weeks during the sampling season (*1 year/season minimum*)
2) ***Analyze sample*** identifying target algae/cyanos
3) ***Take*** digital pictures to send into the PMN
4) ***Input*** data into the PMN database
5) ***Ship*** sample to PMN as required

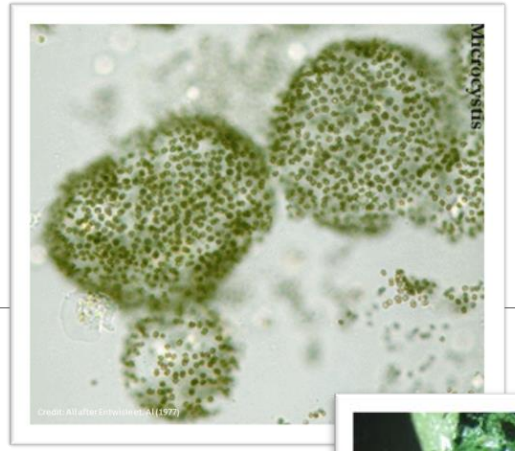




CYANOBACTERIA ID

CYANOBACTERIA

- Formerly called blue-green algae
- Prokaryotic (primitive cell type)
- Microscopic
- Can photosynthesize
  - Beneficial oxygen producers for water and atmosphere
- Live in fresh, brackish, marine water
- Unicellular, multicellular, colonial forms



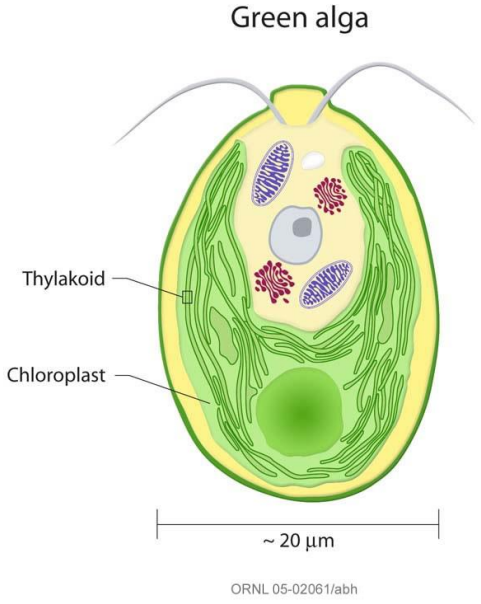
Algae vs Cyanos

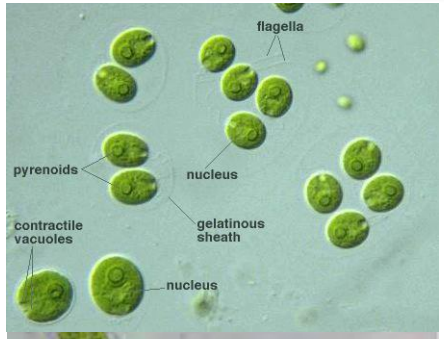
GREEN ALGAE

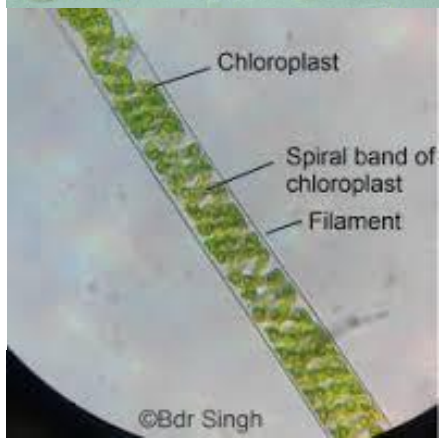
- Large cell size
- Have complex cell structures & organelles

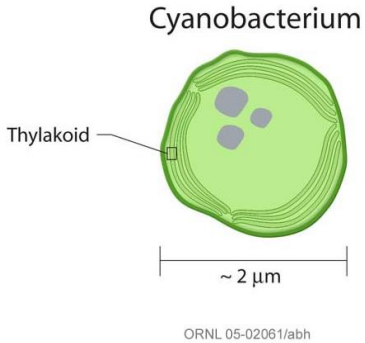
CYANOBACTERIA

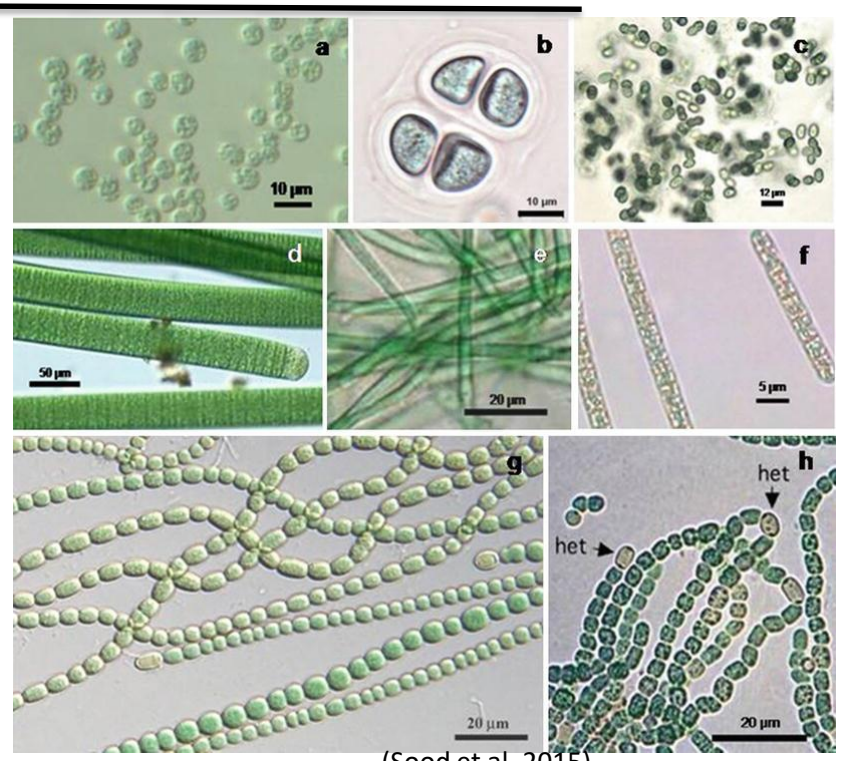
- Much smaller
- Lack membrane bound organelles











(Sood et al, 2015)

Morphology basics

Aerotopes- gas vesicles

Akinete(s)- thick walled resting spore

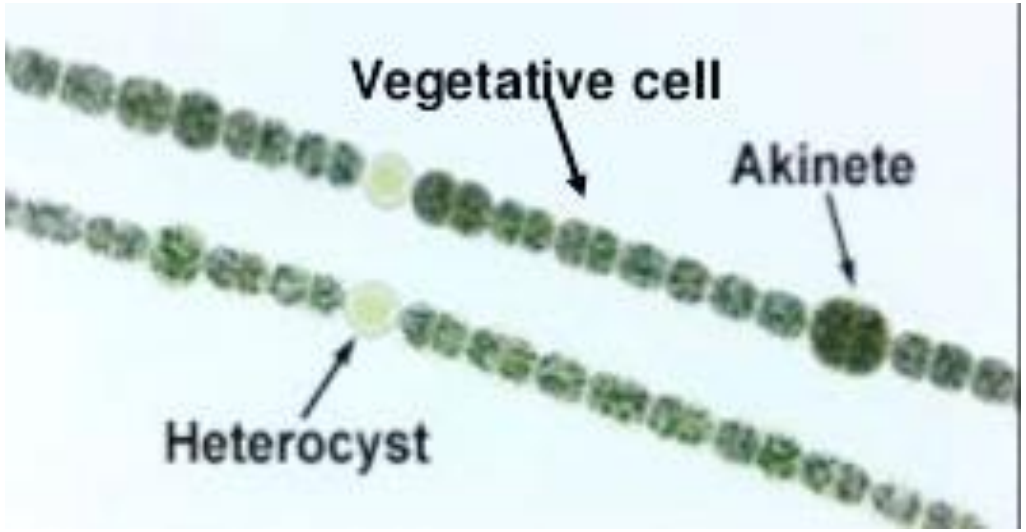
Heterocyte(s)- site of nitrogen fixation; also thick walled but clear

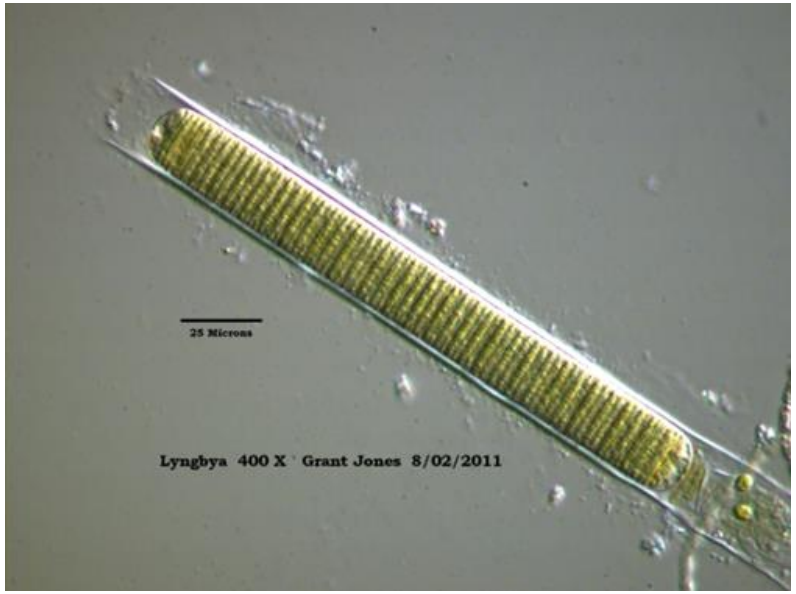
Trichome(s)- a row of cells which are connected

Unbranched- trichome does not have offshoots

Untapered- cells at end of trichome are generally same size as rest of cells

Sheath- outer covering of entire trichome made of polysaccharides



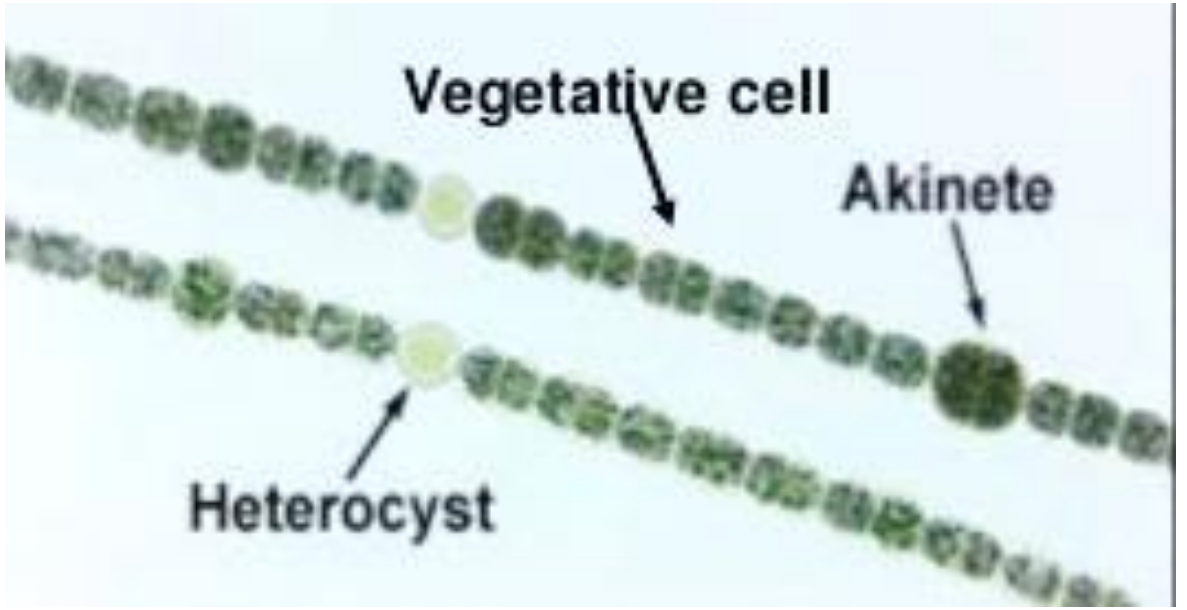


Dolichospermum spp.

N-Fixer

Some *Anabaena* has now been re-classified as *Dolichospermum*

- Filamentous
- Unbranched & untapered
- Trichomes usually solitary
- No sheath*
- Can be straight, curved or spirally coiled



DOLICHOSPERMUM

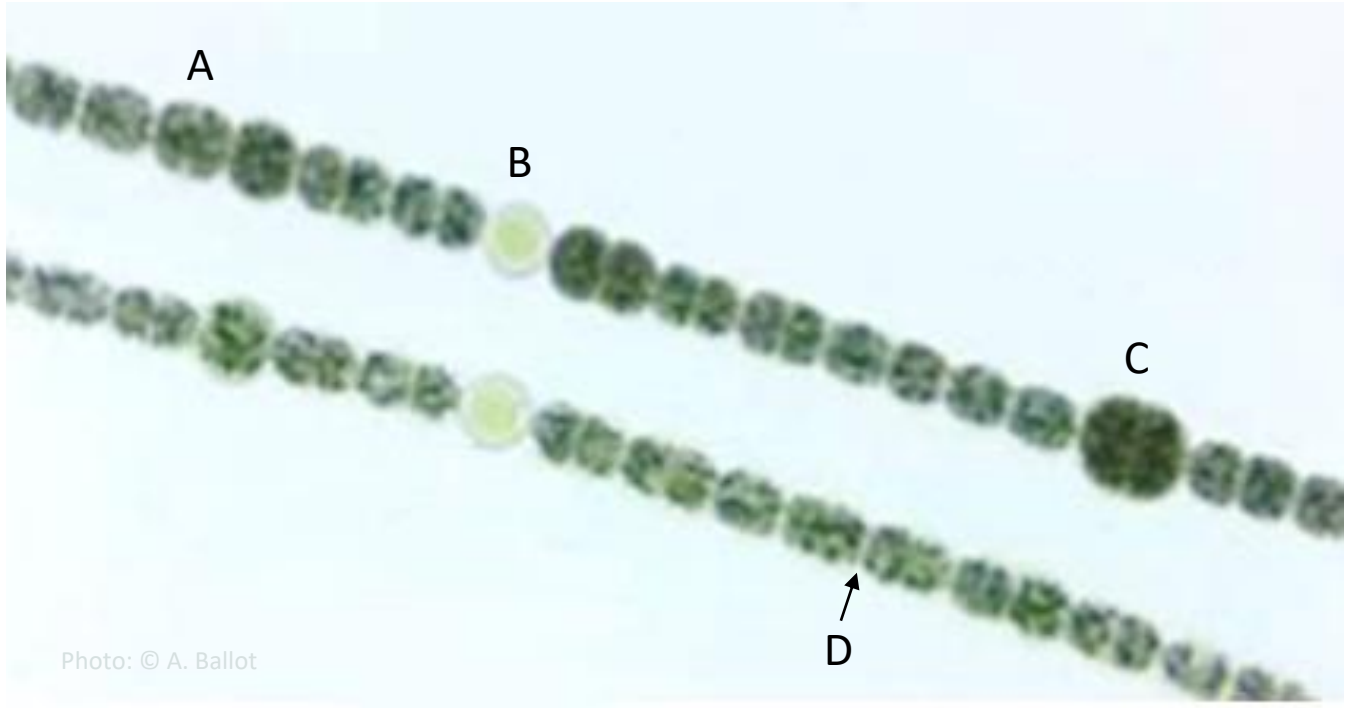
Things to look for:

A. Cells rounded or barrel shaped with aerotopes

B. Heterocytes are intercalary

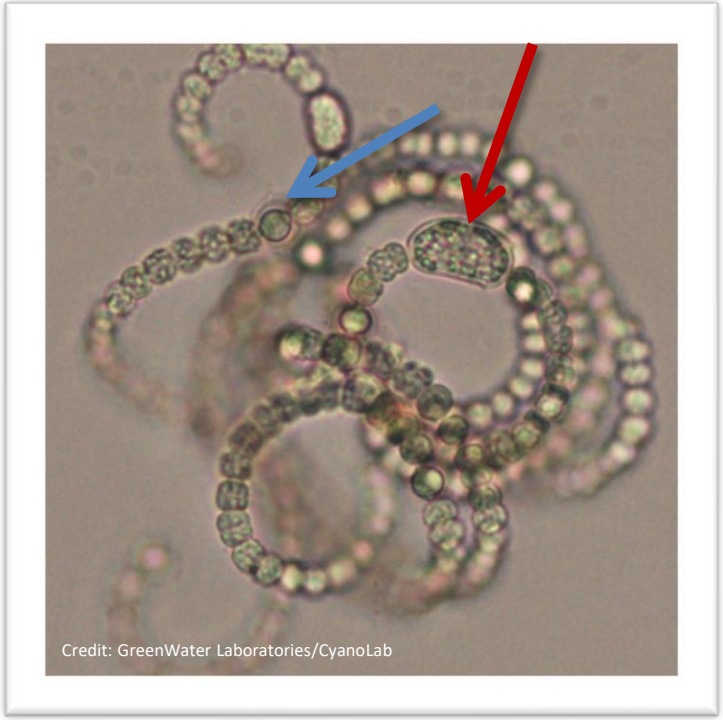
C. Akinetes are intercalary

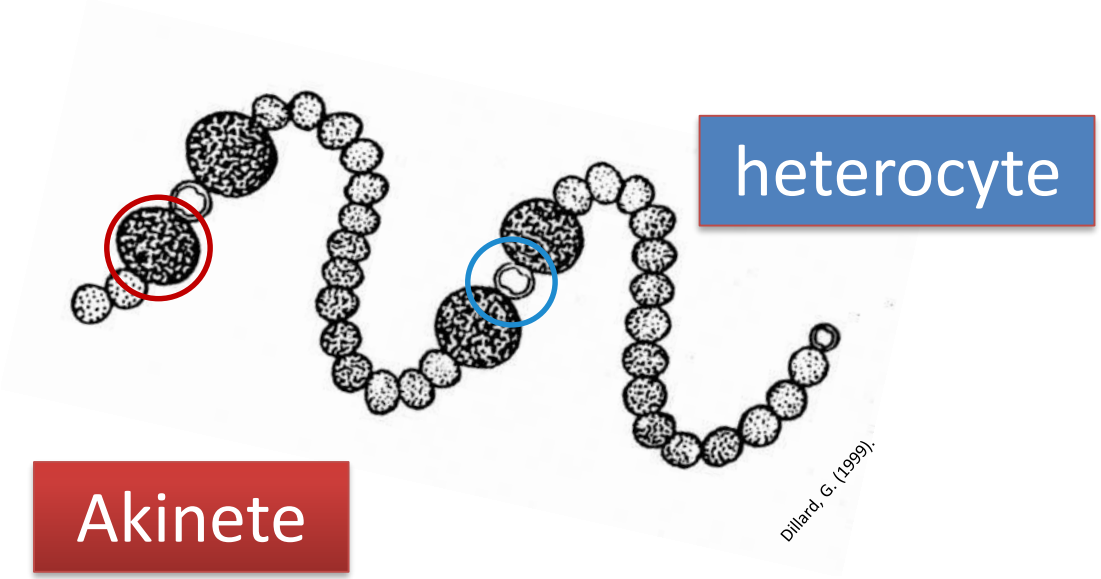
D. Cells constricted at cross walls



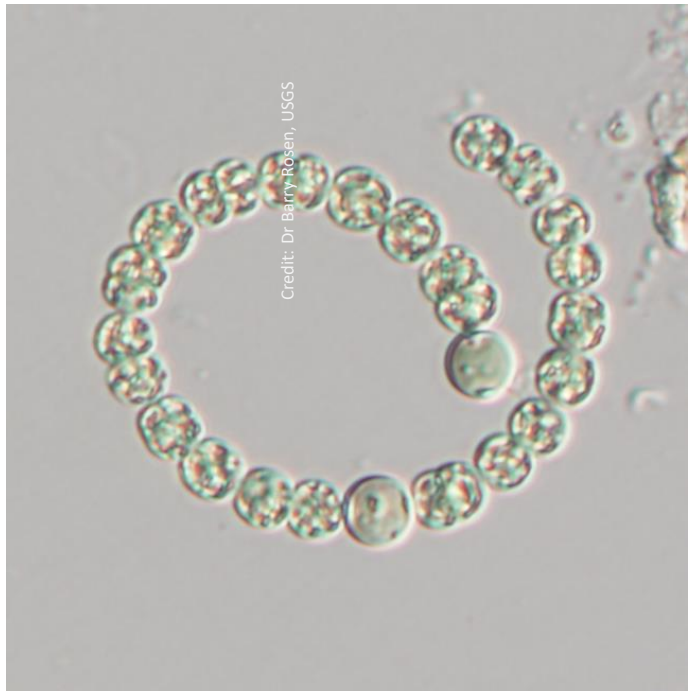
Dolichospermum spp.

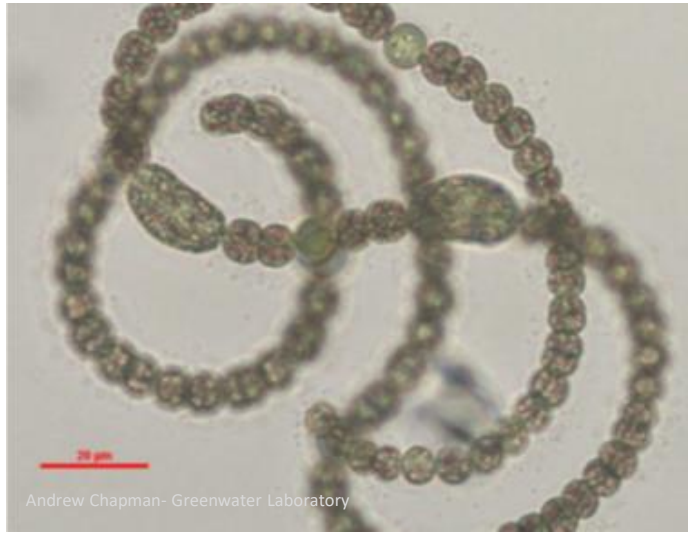
N-Fixer



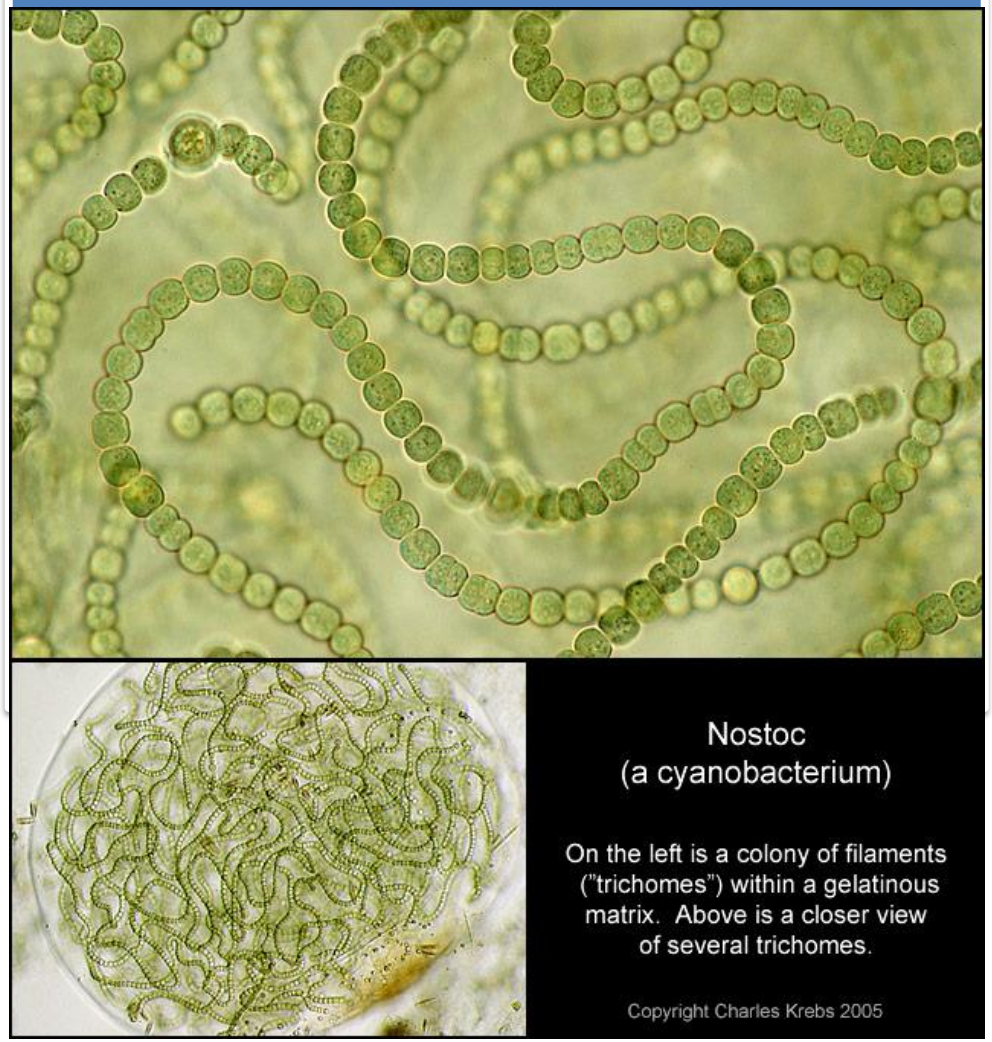


Akinetes known to survive more than 64 years in sediment





Dolichospermum can be confused with Nostoc, but Nostoc trichomes form colonies



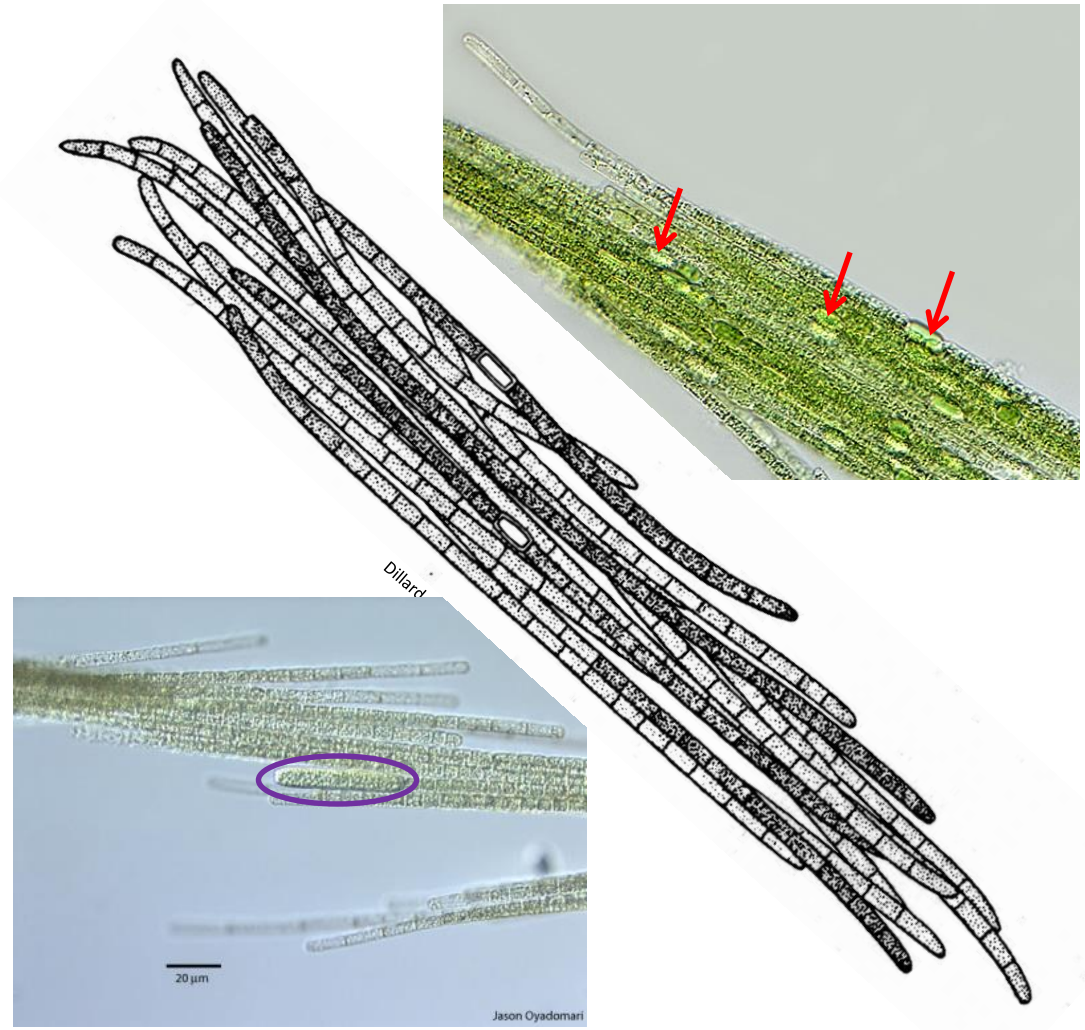
Freshwater Cyanobacteria

Aphanizomenon spp.

N-Fixer

Approximately 15 known species

- Filamentous, straight, unbranched trichomes
- Tapered at both ends
- No sheath
- Trichomes arranged in parallel layers.
- Has heterocysts and forms akinetes
- Can form winter & summer blooms



Akinetes known to survive more than 18 years in sediment

Aphanizomenon

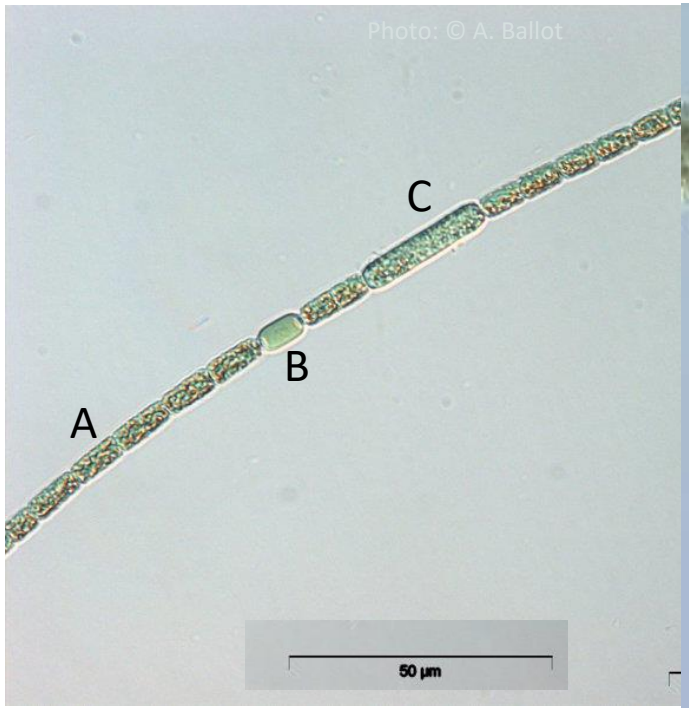
Things to look for:

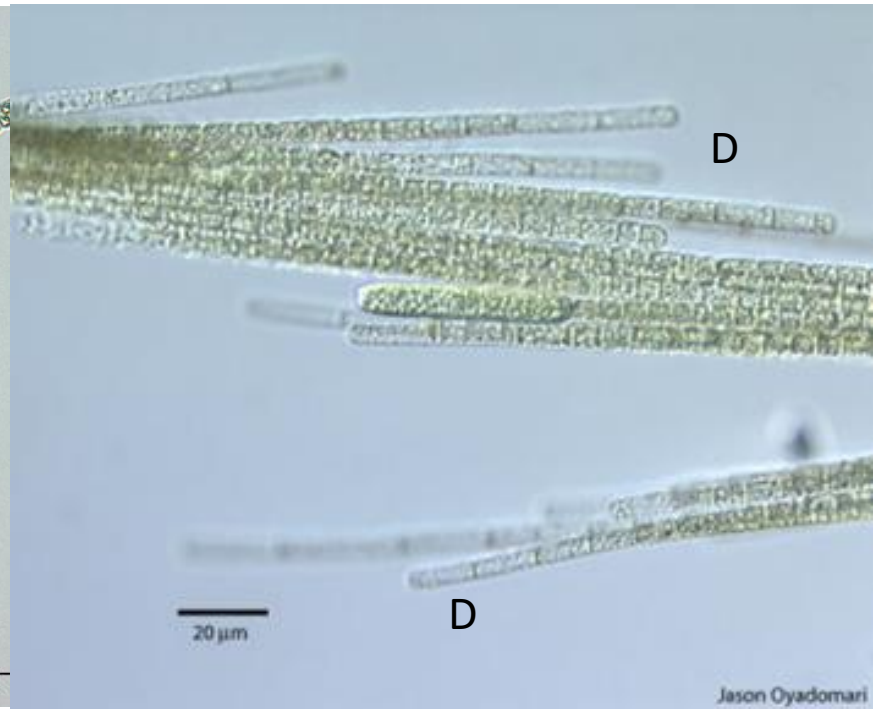
A. Aerotopes (facultative) in cylindrical shaped cells

B. Heterocytes are intercalary (facultative)

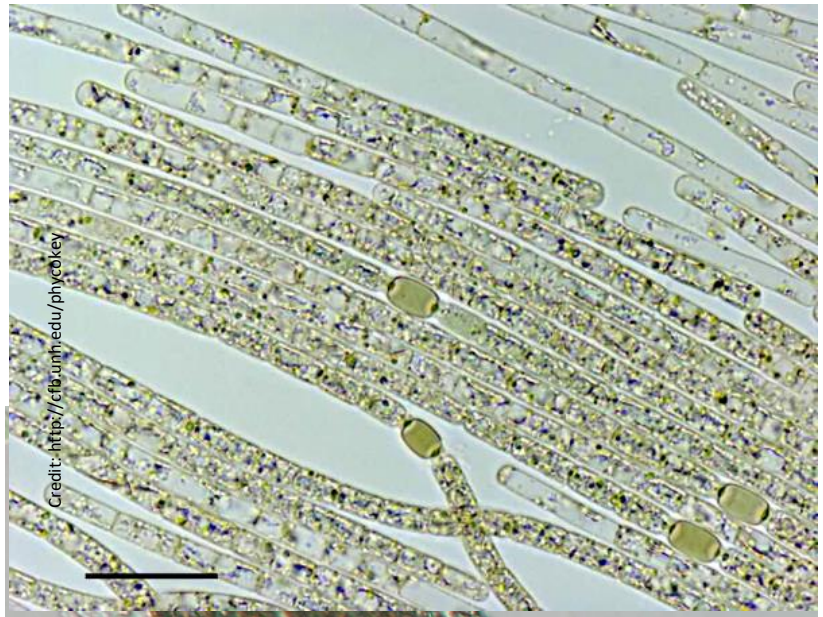
C. Akinetes usually cylindrical and intercalary

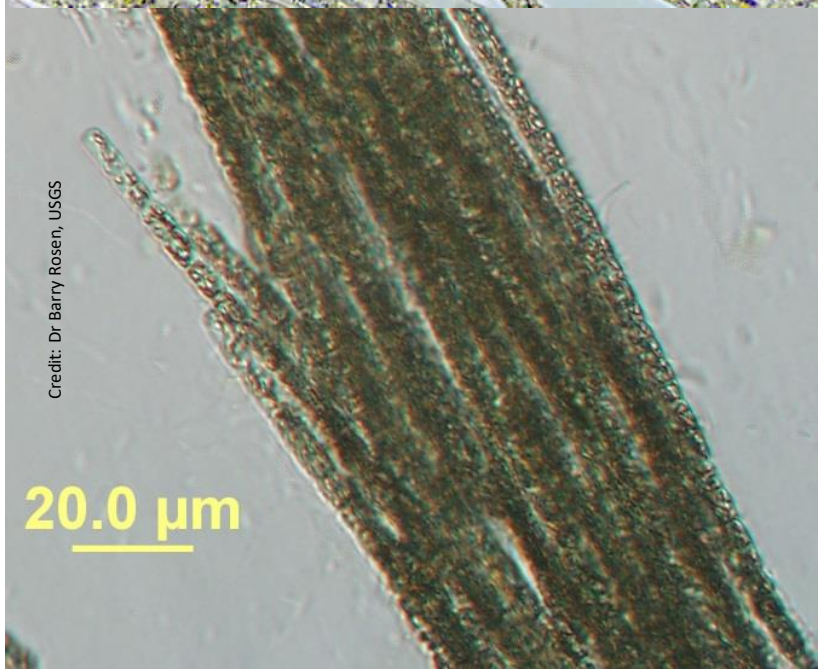
D. Terminal ends are elongated and may be “empty” looking





Aphanizomenon spp.





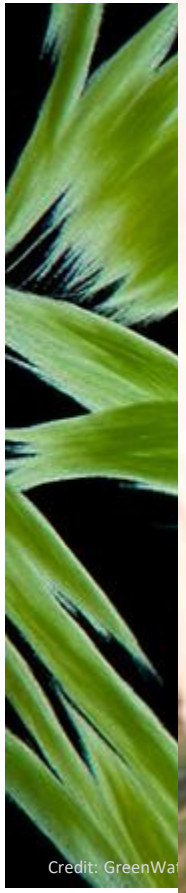
Can be confused with :

Planktothrix-

Can look similar to individual Aphan. trichomes, especially in absence of heterocytes.

Aphanizomenon bloom

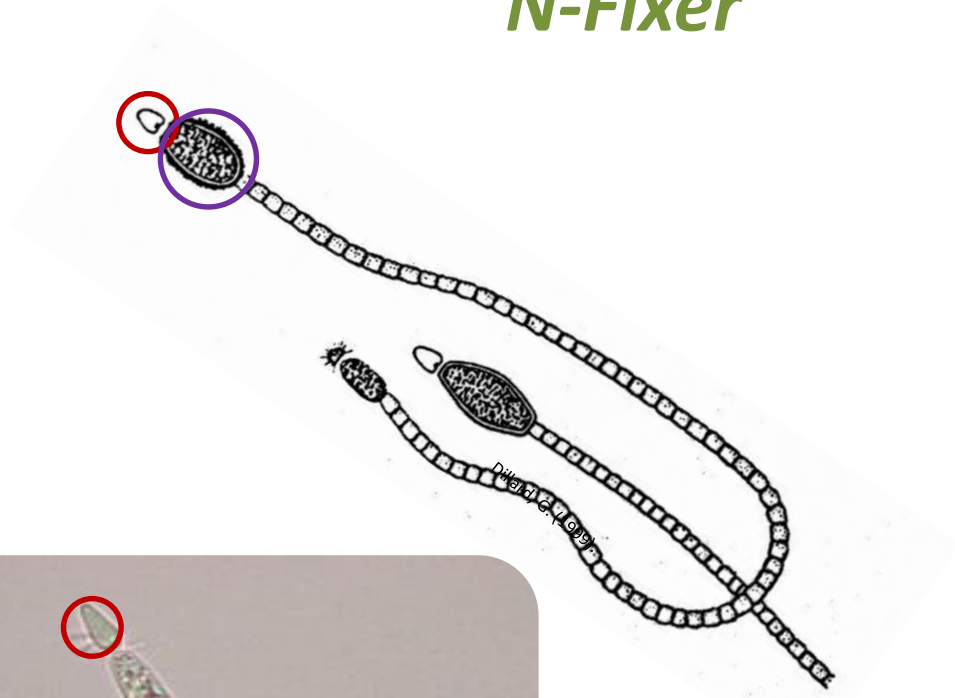
Will be filamentous



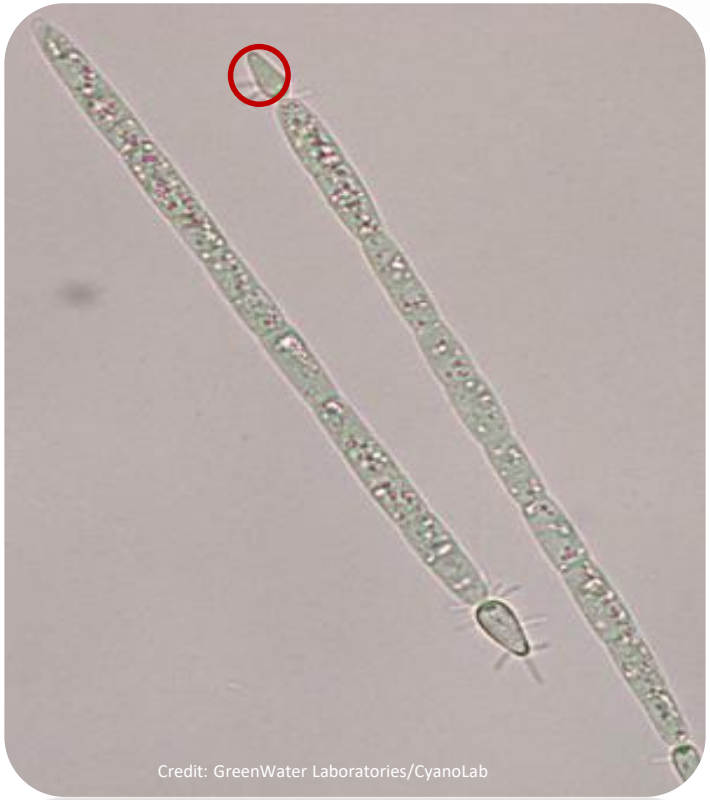
Raphidiopsis spp.

N-Fixer

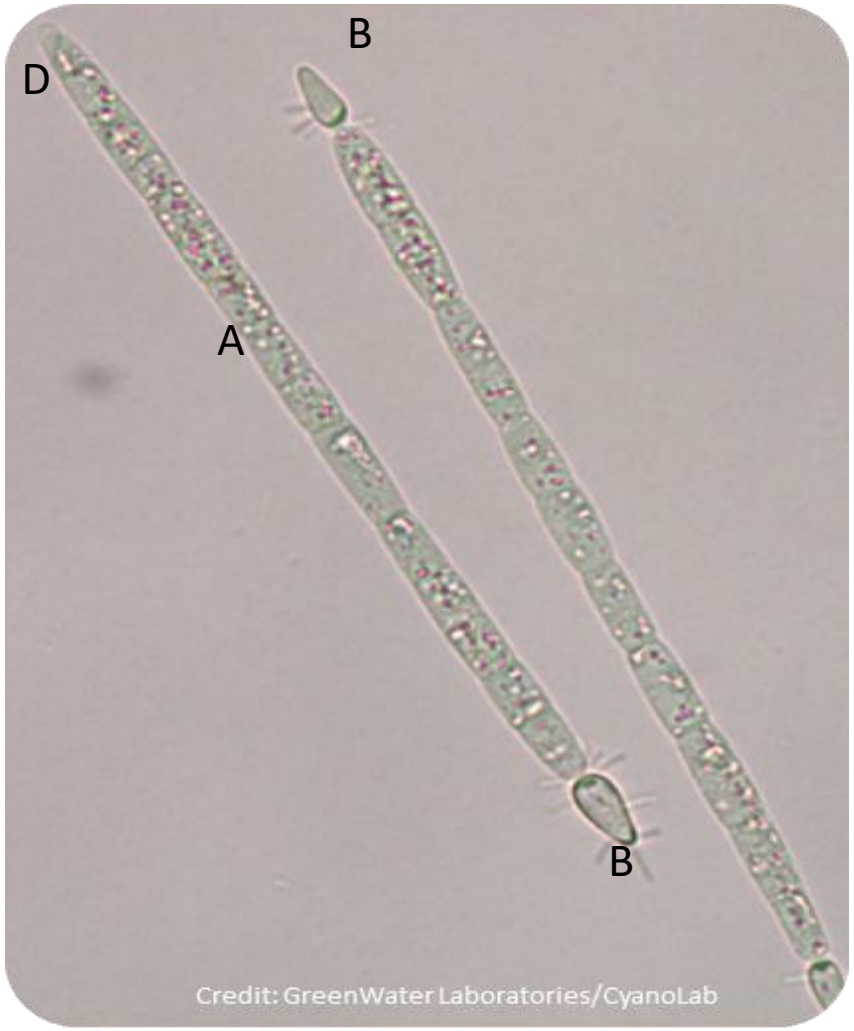
Cylindrospermopsis has now been re-classified as *Raphidiopsis*



- Filamentous, unbranched
- Trichomes are straight, curved or coiled; solitary
- No sheath
- Heterocysts always terminal!
- Akinetes form behind or slightly distant from heterocysts (gives asymmetric appearance)



RAPHIDIOPSIS



Things to look for:

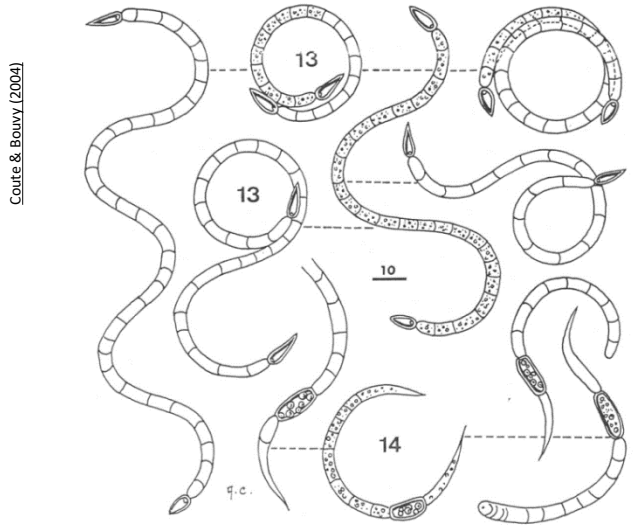
A. Cells cylindrical with aerotopes

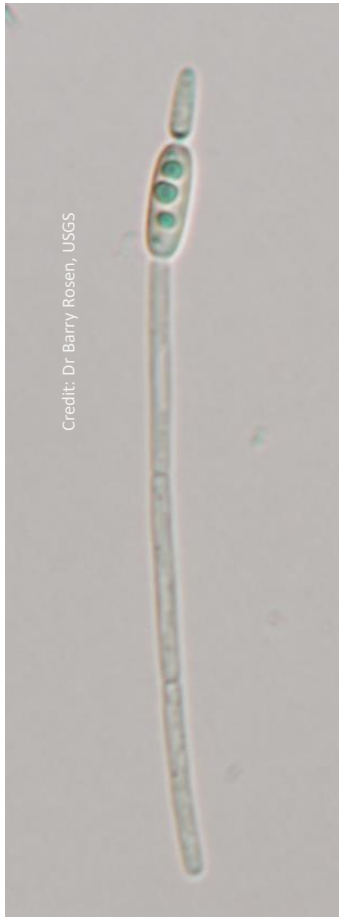
B. Heterocytes (when present) are always terminal at one or both ends

C. Akinetes (when present) usually 1-3 cells back from heterocytes

D. Terminal cells conical or pointy when lacking heterocyte(s).

Raphidiopsis spp.





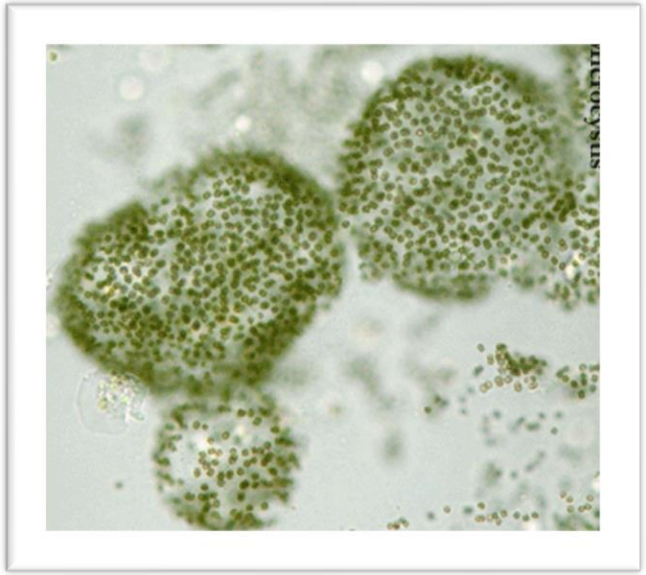
Used to be confused with but now related to:

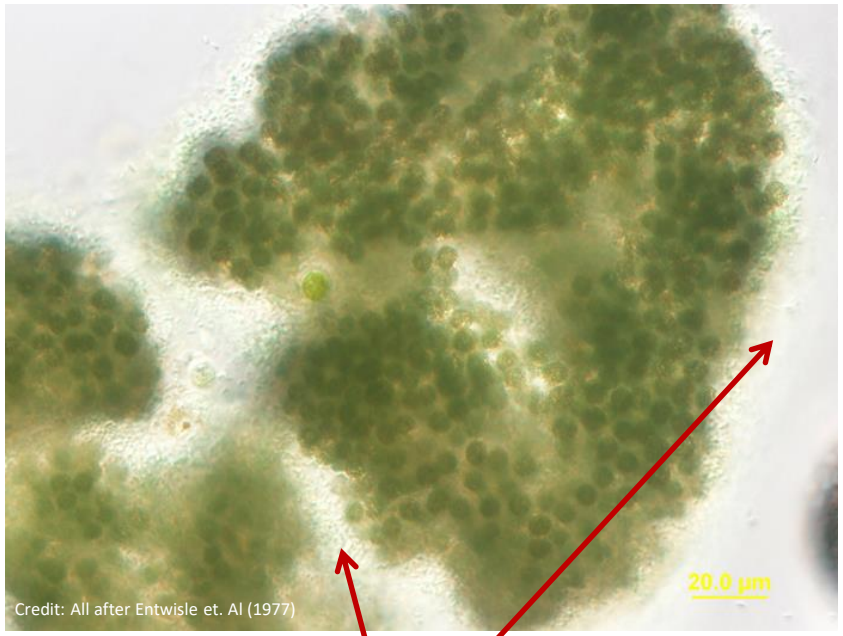
has tapered terminal cells, NO heterocysts, and any akinetes will always be near middle of chain, never at end

Microcystis spp.

Approximately 25 known species

- Colonial
- Unicellular but held together by snotty sheath
- Colonies are irregular, cloud-like (3D) with hollow spaces
- Buoyant due to gas vesicles
- Smells bad!
- Zebra mussels selectively reject Microcystis cells





Microcystis

Things to look for:

A. Rounded cells with aerotopes

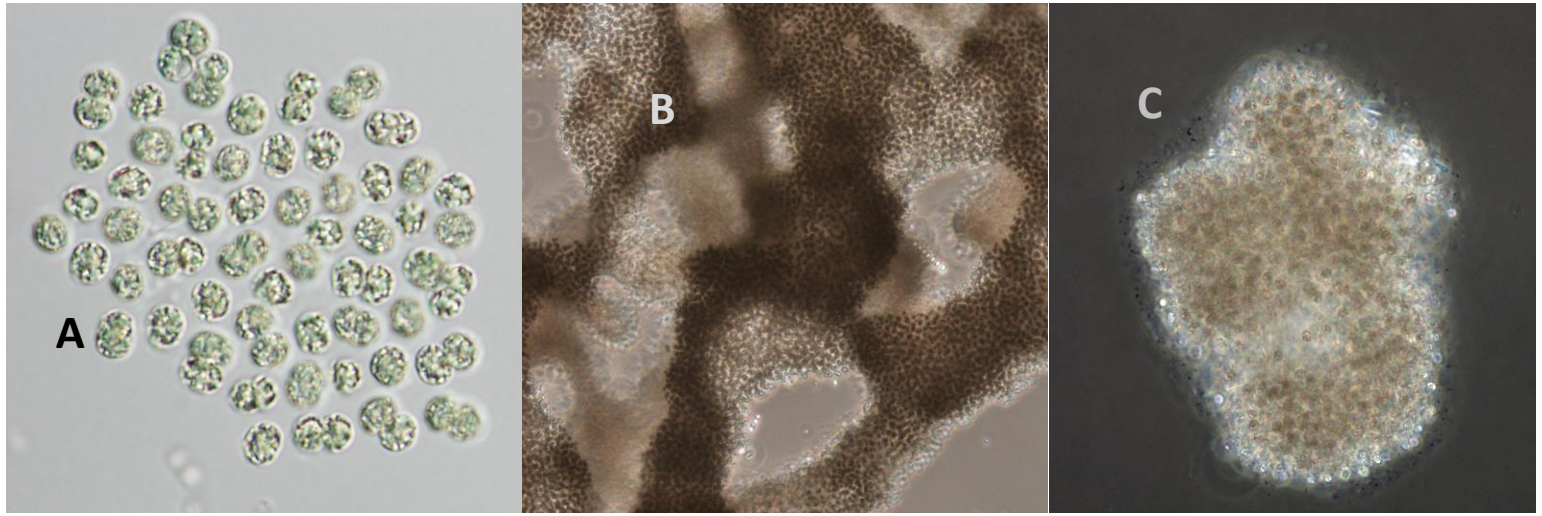
B. Cells in colony may be

   A. loosely associated

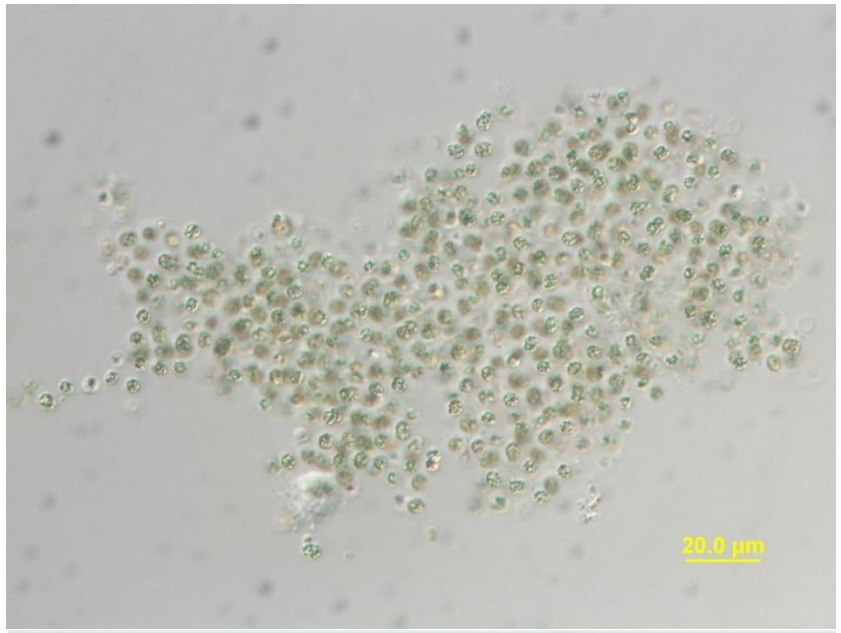
   B. clathrate

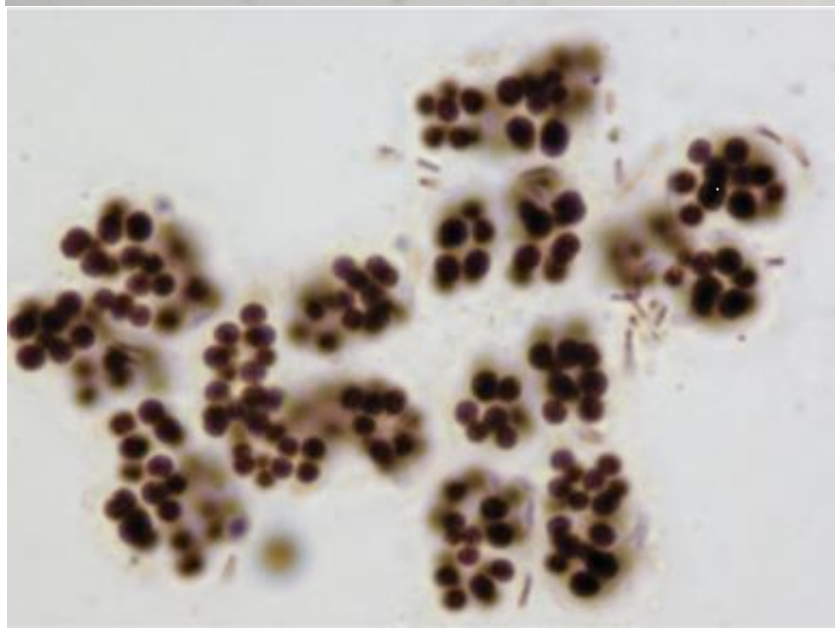
   C. densely packed

C. Mucilage can vary in thickness



Microcystis spp.





Credit: Dr Barry Rosen, USGS

Can be confused with :

Woronichinia sp.

Image by Jason Oyadomari

Woronichinia makes a hollow ball of cells

Microcystis bloom

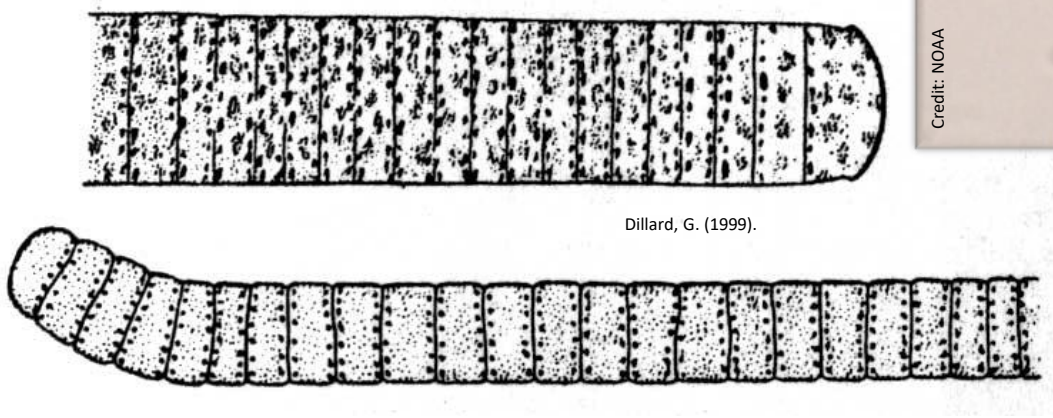
Will NOT be filamentous and will be quite stinky

Planktothrix morphotype

More than 100 known species

Formerly classified as Oscillatoria

- Filamentous, unbranched
- Trichomes cylindrical, straight or slightly wavy
- No sheath
- No heterocysts
- No akinetes
- Motile with gliding oscillations



Dillard, G. (1999).

PLANKTOTHRIX

Things to look for:

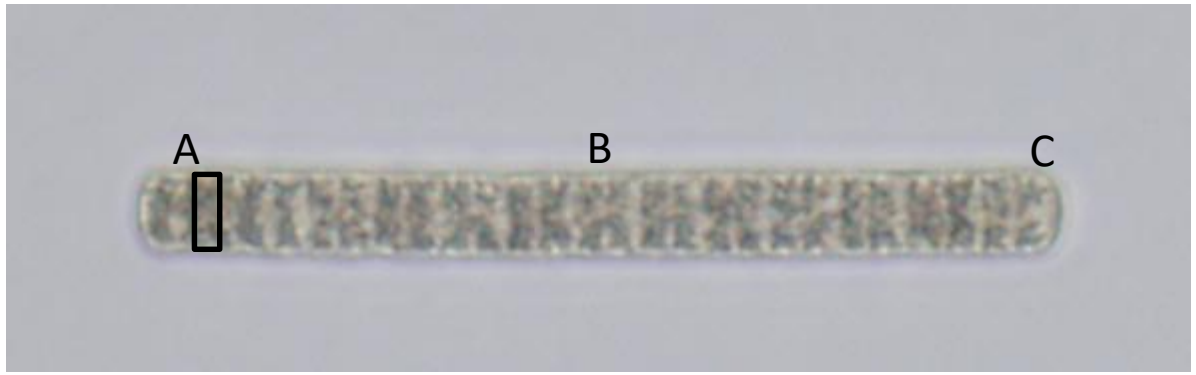
A. Cells cylindrical; mostly wider than long

B. LOTS of aerotopes throughout cells

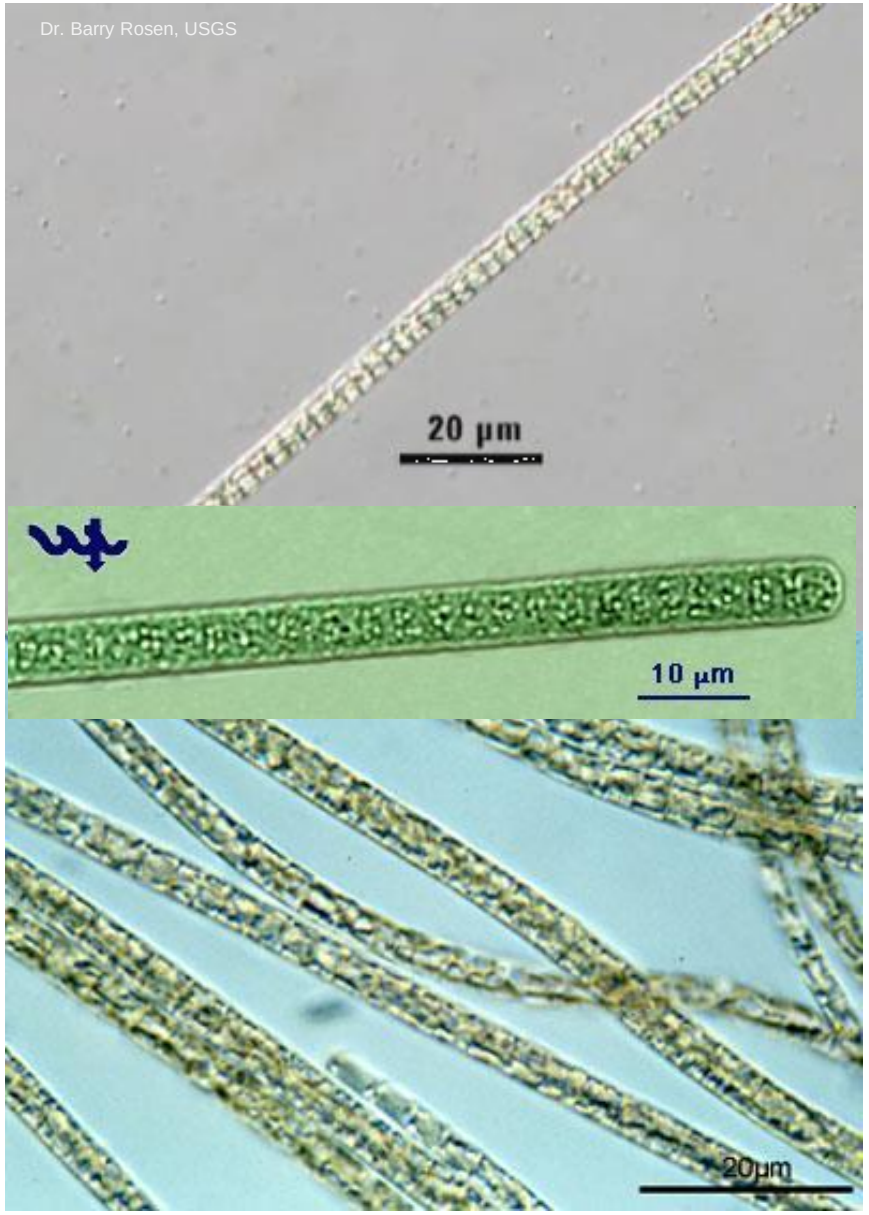
C. Terminal cells rounded

- No heterocytes (not a N_2 fixer)

- No akinetes

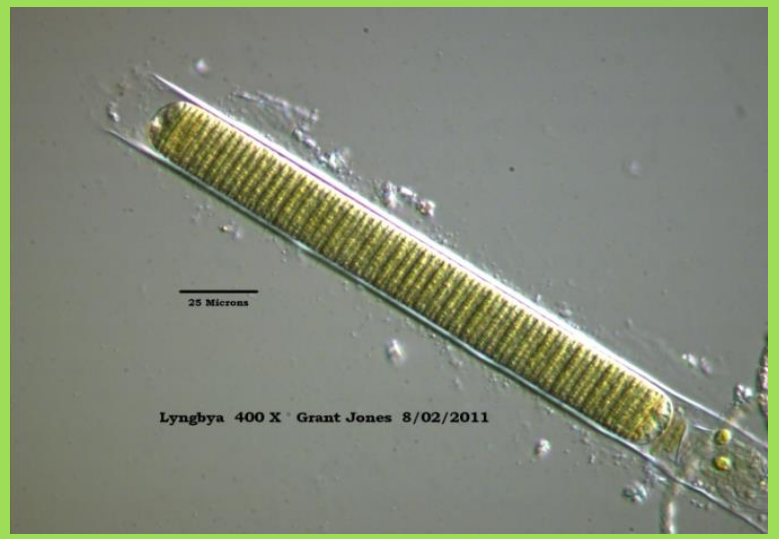


Planktothrix morphotype.



Can be confused with :

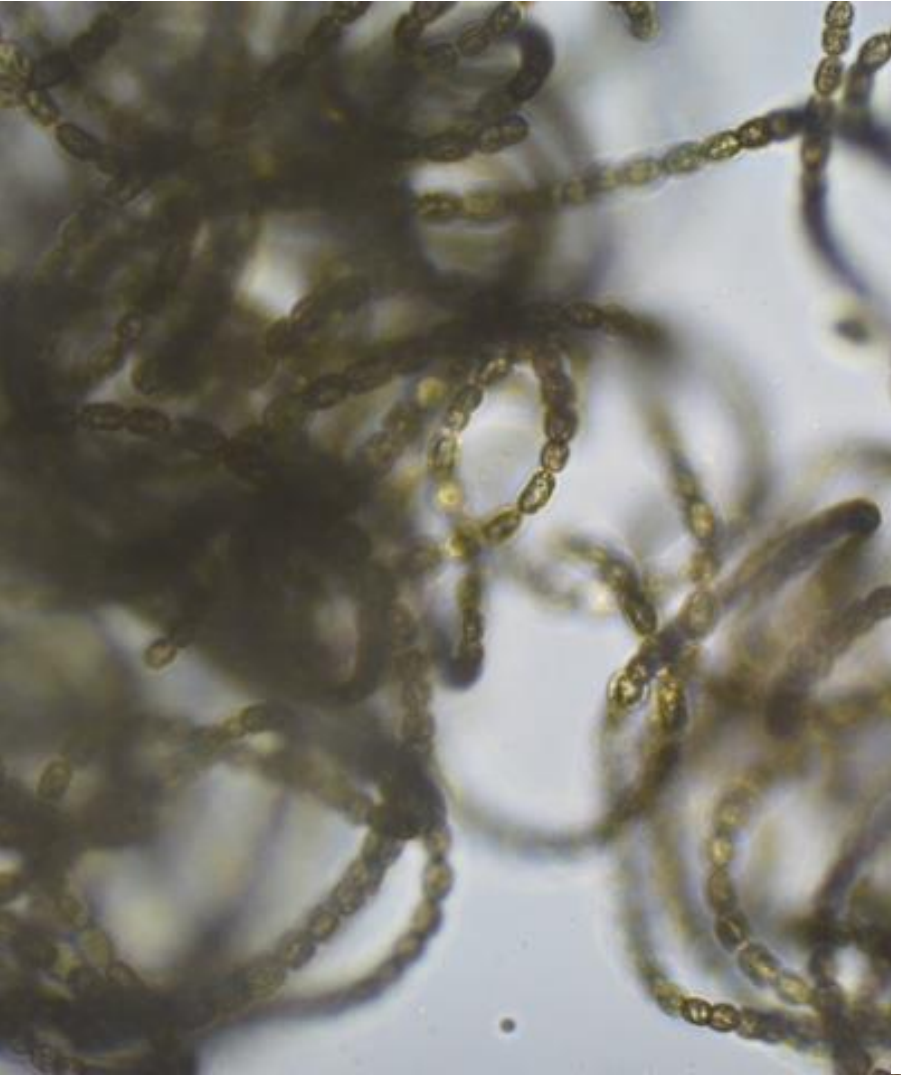
Lyngbya-
Has a visible sheath

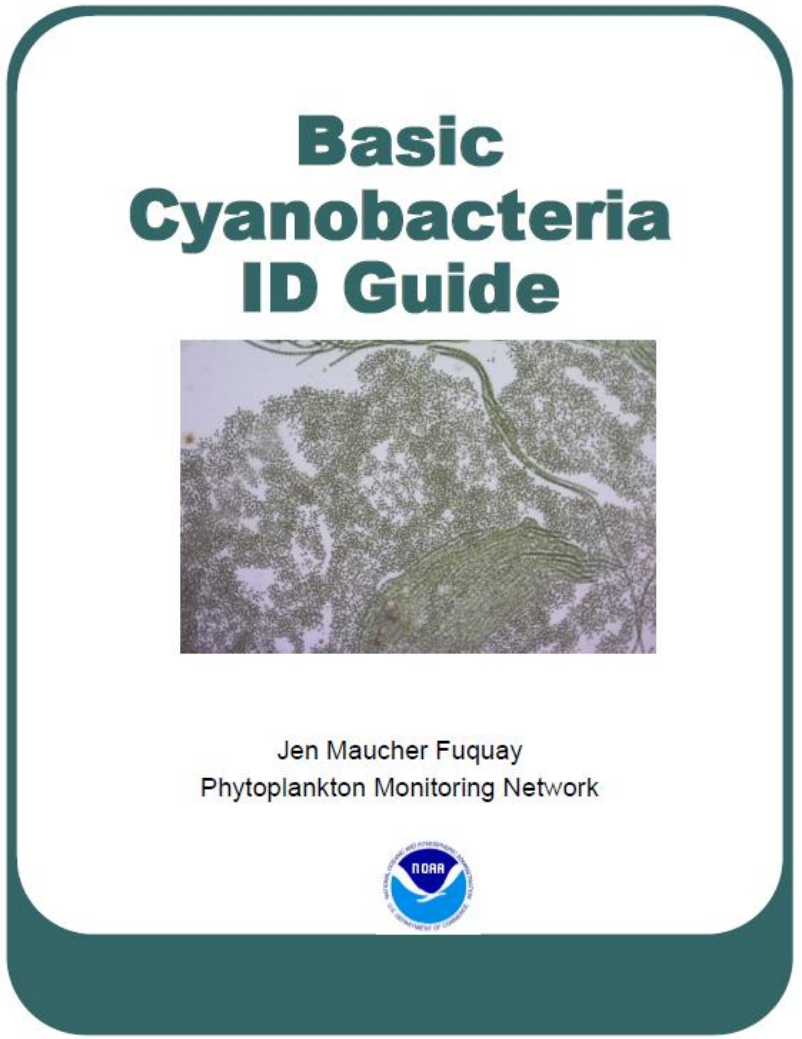


Planktothrix bloom

Filamentous
Can be red or green depending on species

Planktothrix rubescens





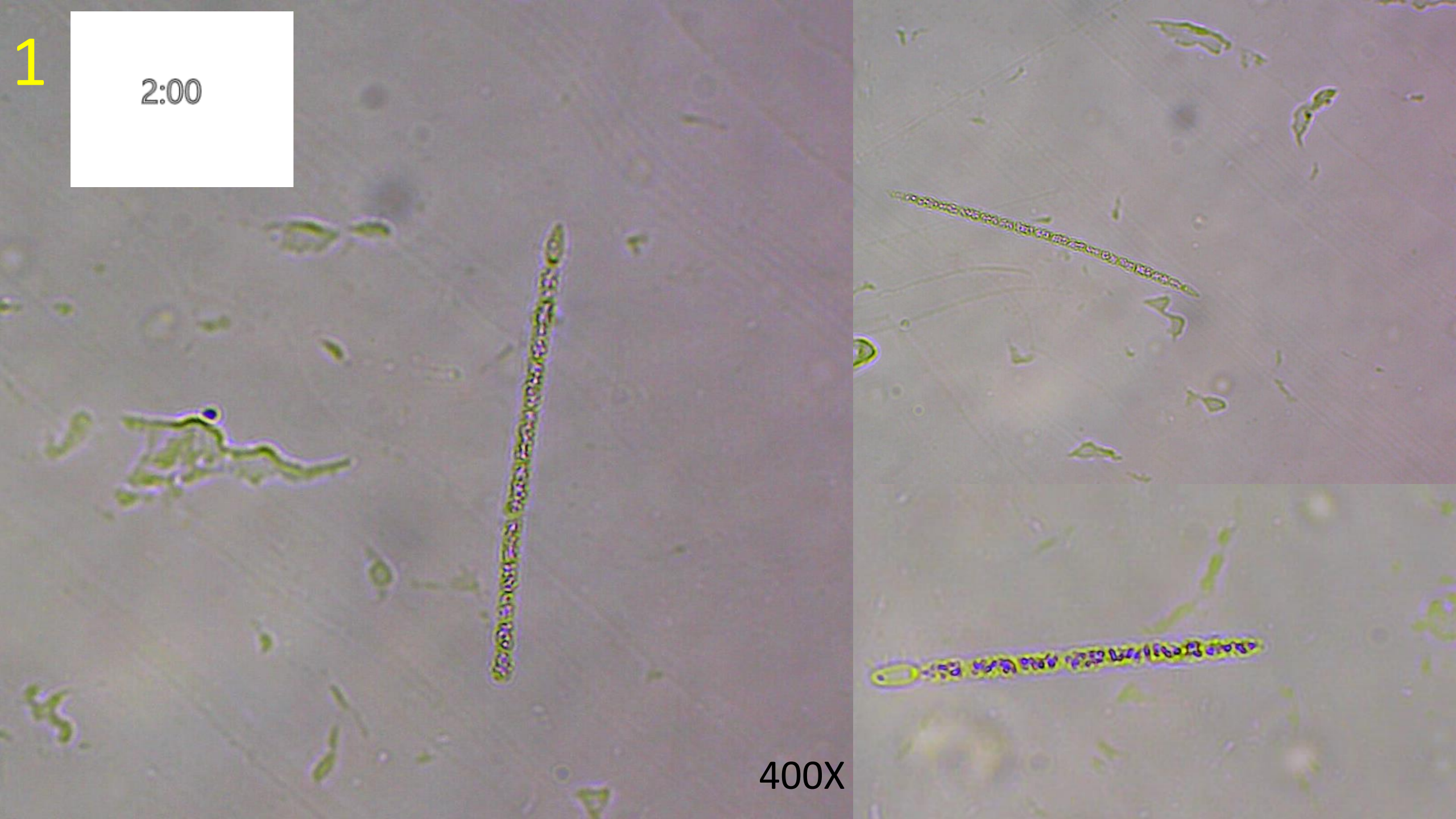
CYANOBACTERIA PRACTICE

Phytoplankton Monitoring Network
Promoting a better understanding of Harmful Algal Blooms by way of Volunteer Monitoring

ID PRACTICE

- Slides are fixed in glutaraldehyde (no color) or Lugol's (all brown)
- Have your ID guide handy if you have one
- There will be 2 minutes for each target to figure out what it is
  - Do not type in answer in chat box or turn on microphone!
  - Write down what you think each one is
- We will go over that target then move on to the next one
- Bonus environmental sample at the end!

Thank you to Andrew Chapman (Greenwater Labs) for samples!


1
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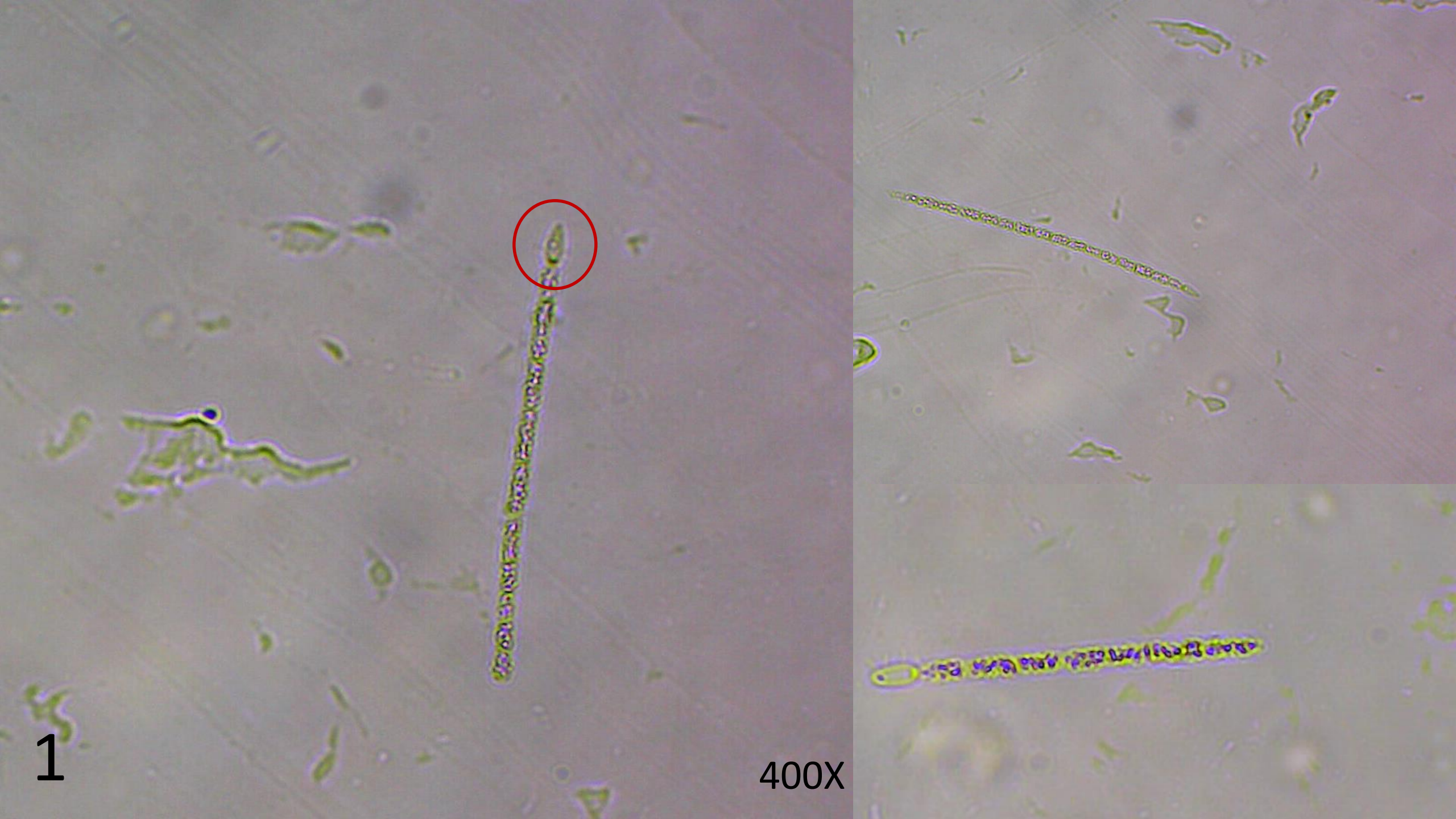
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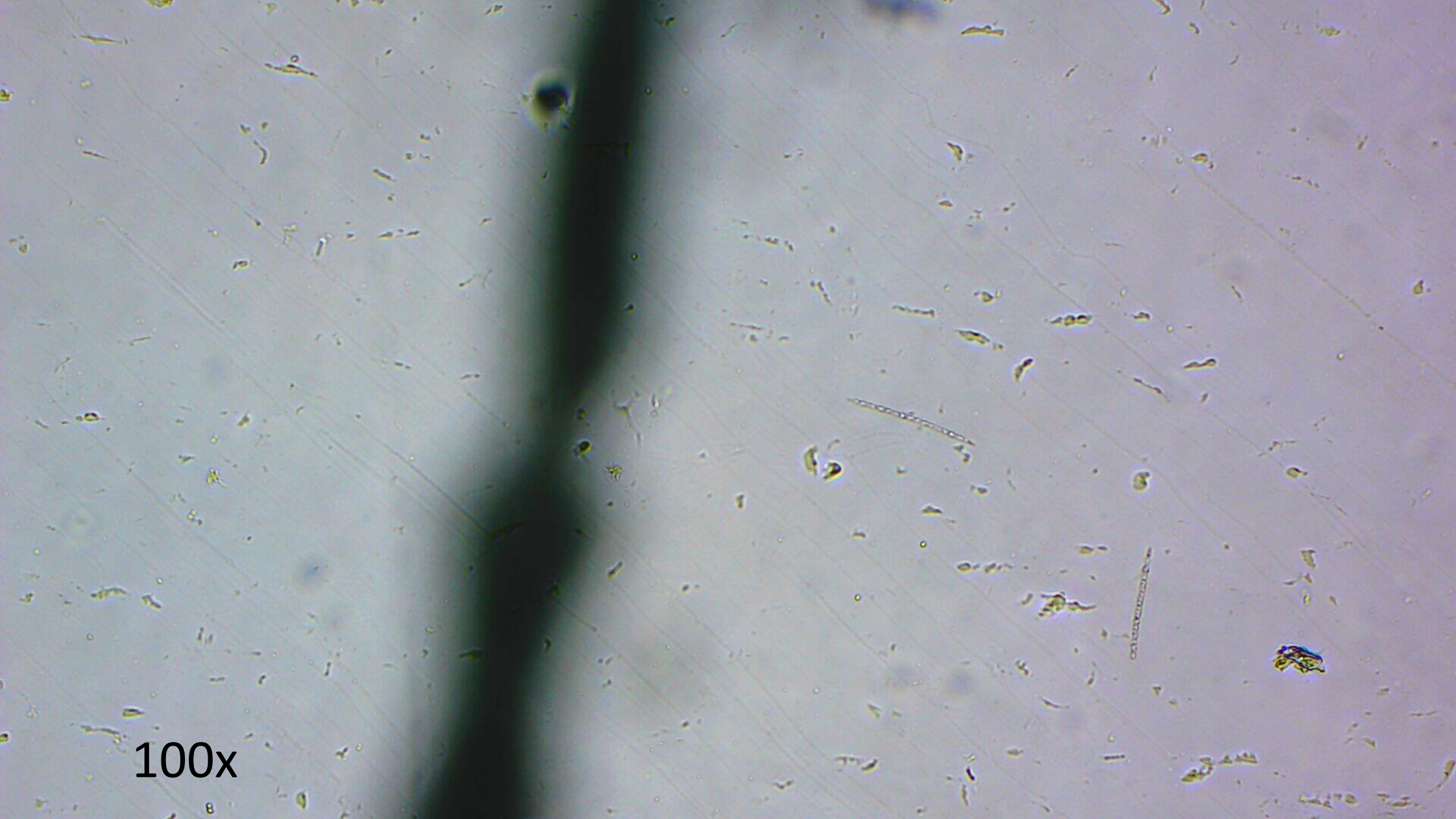
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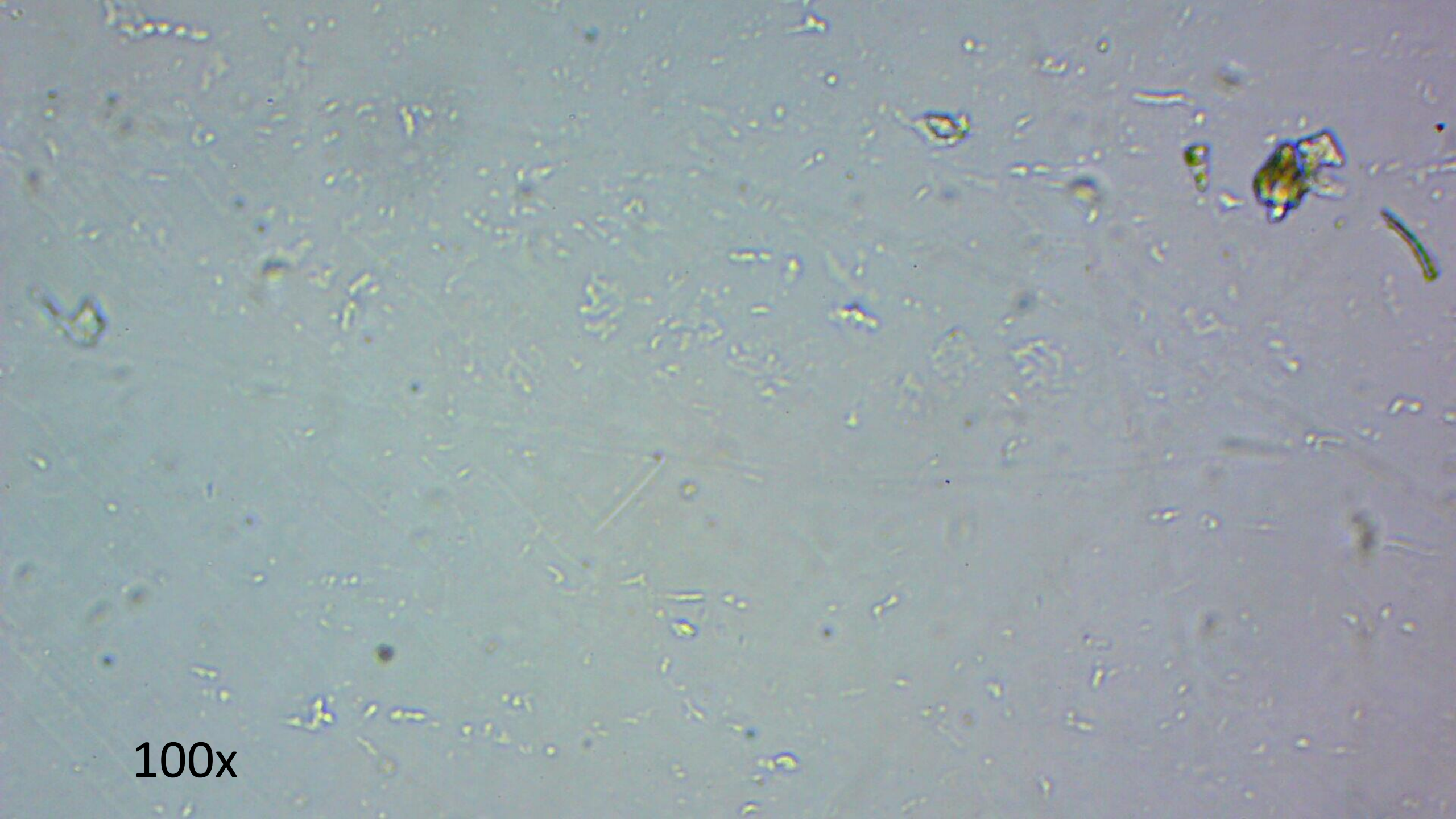
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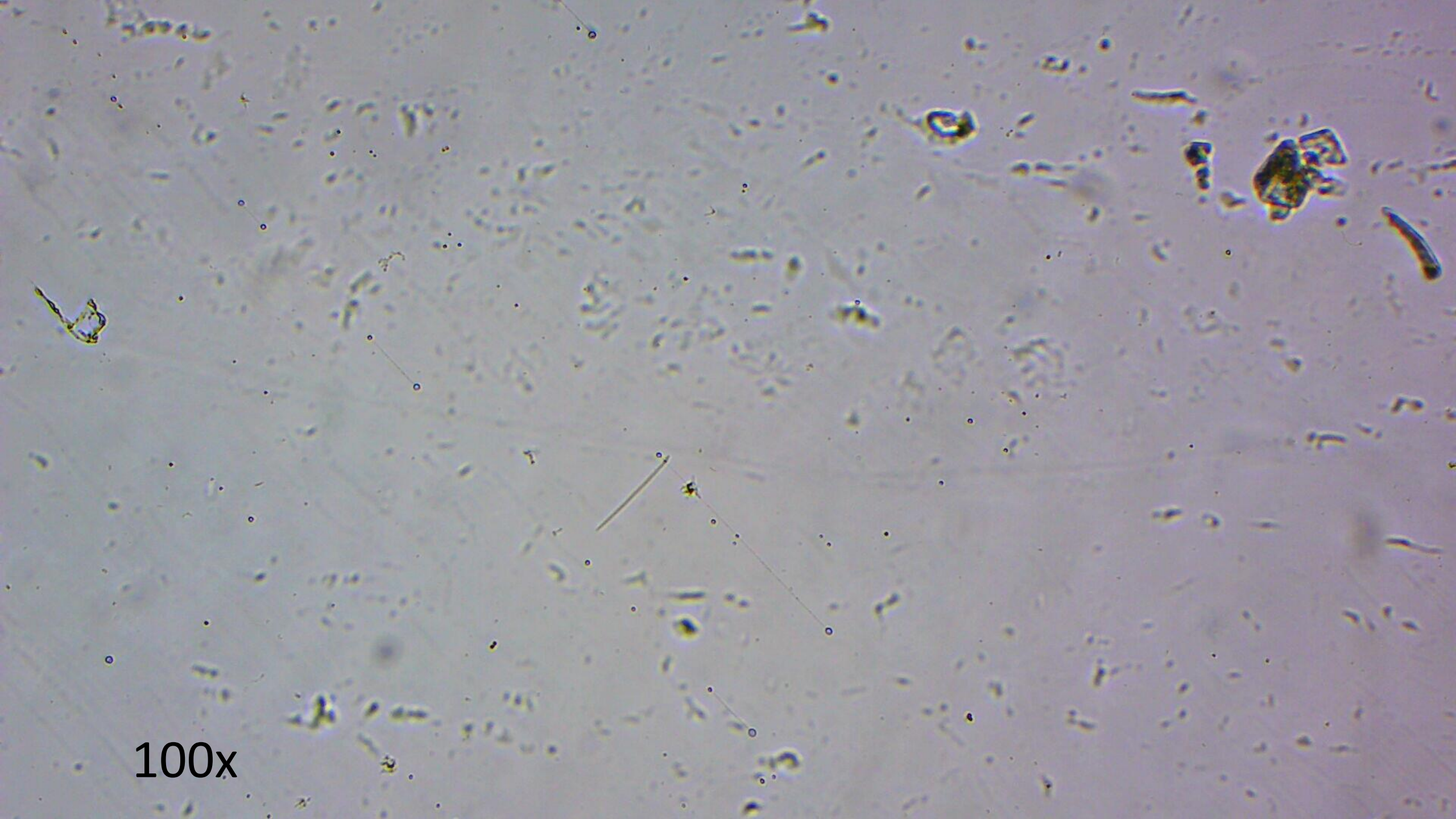
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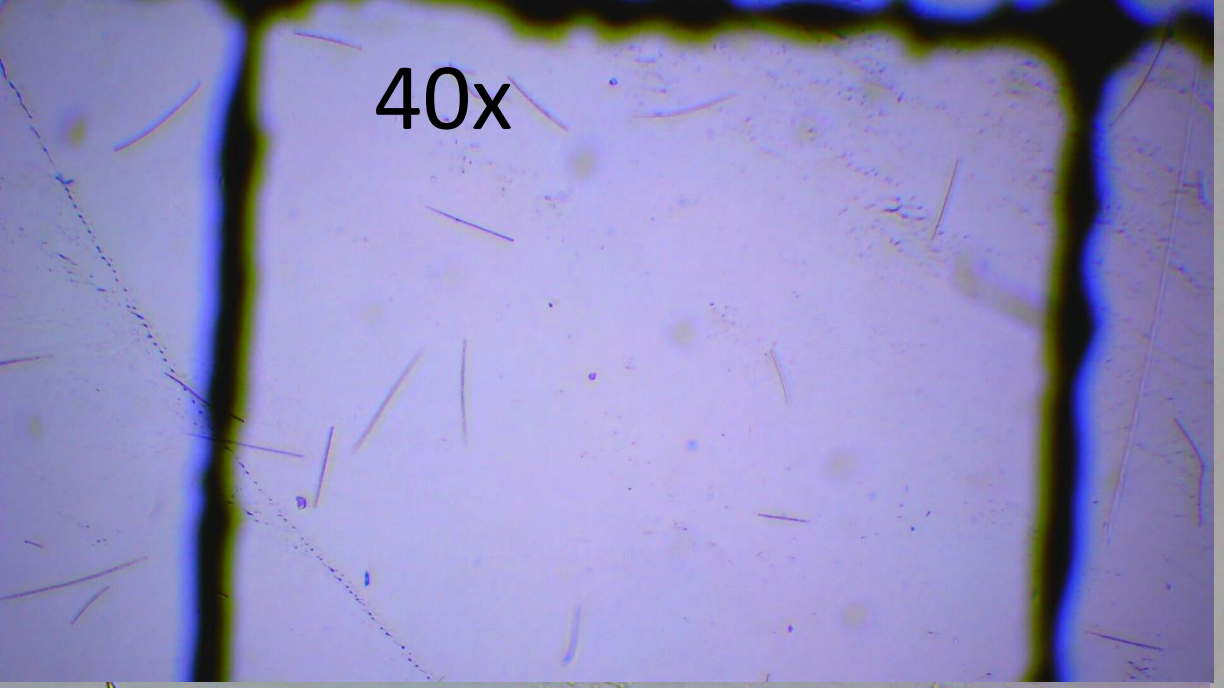
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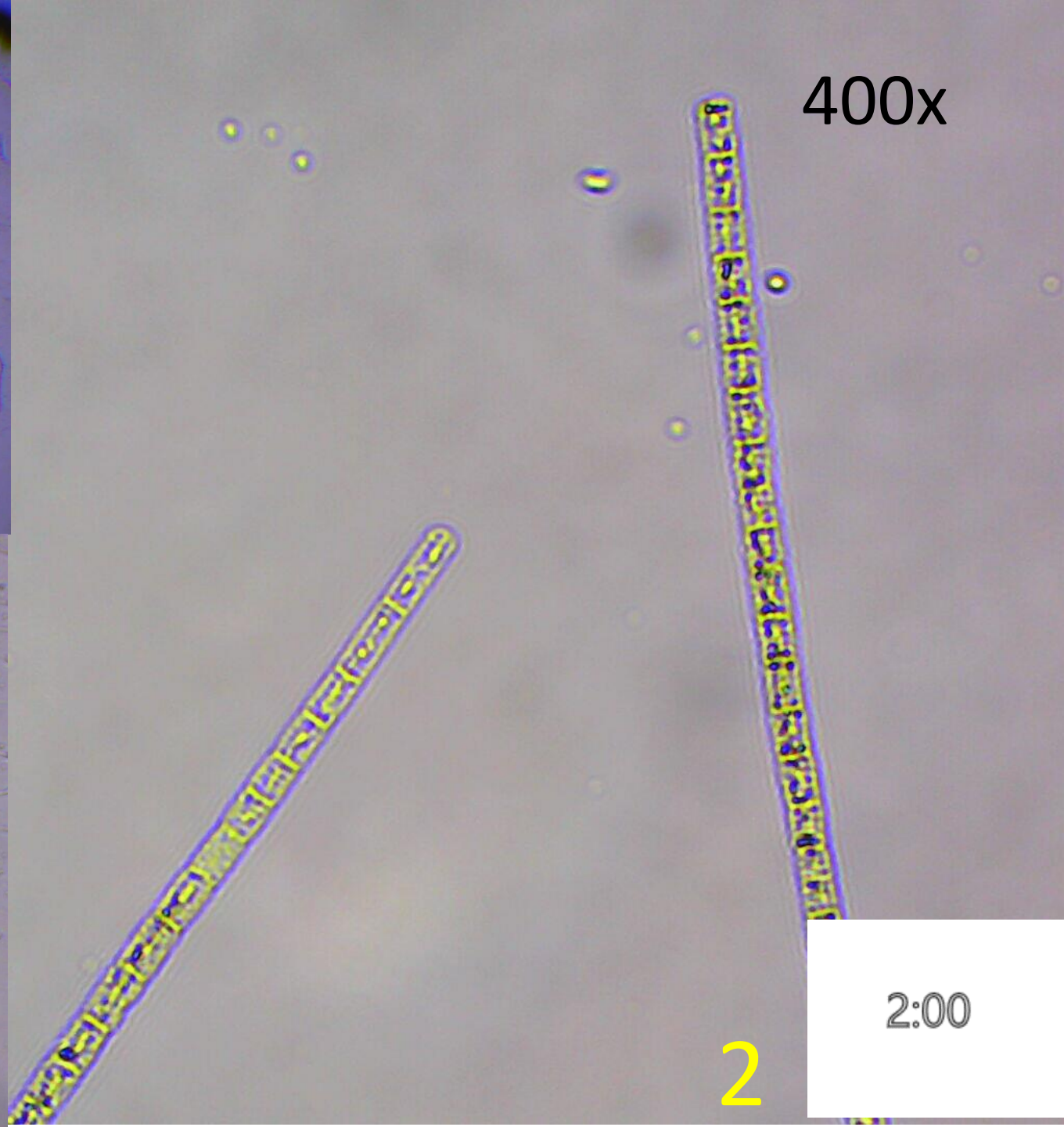
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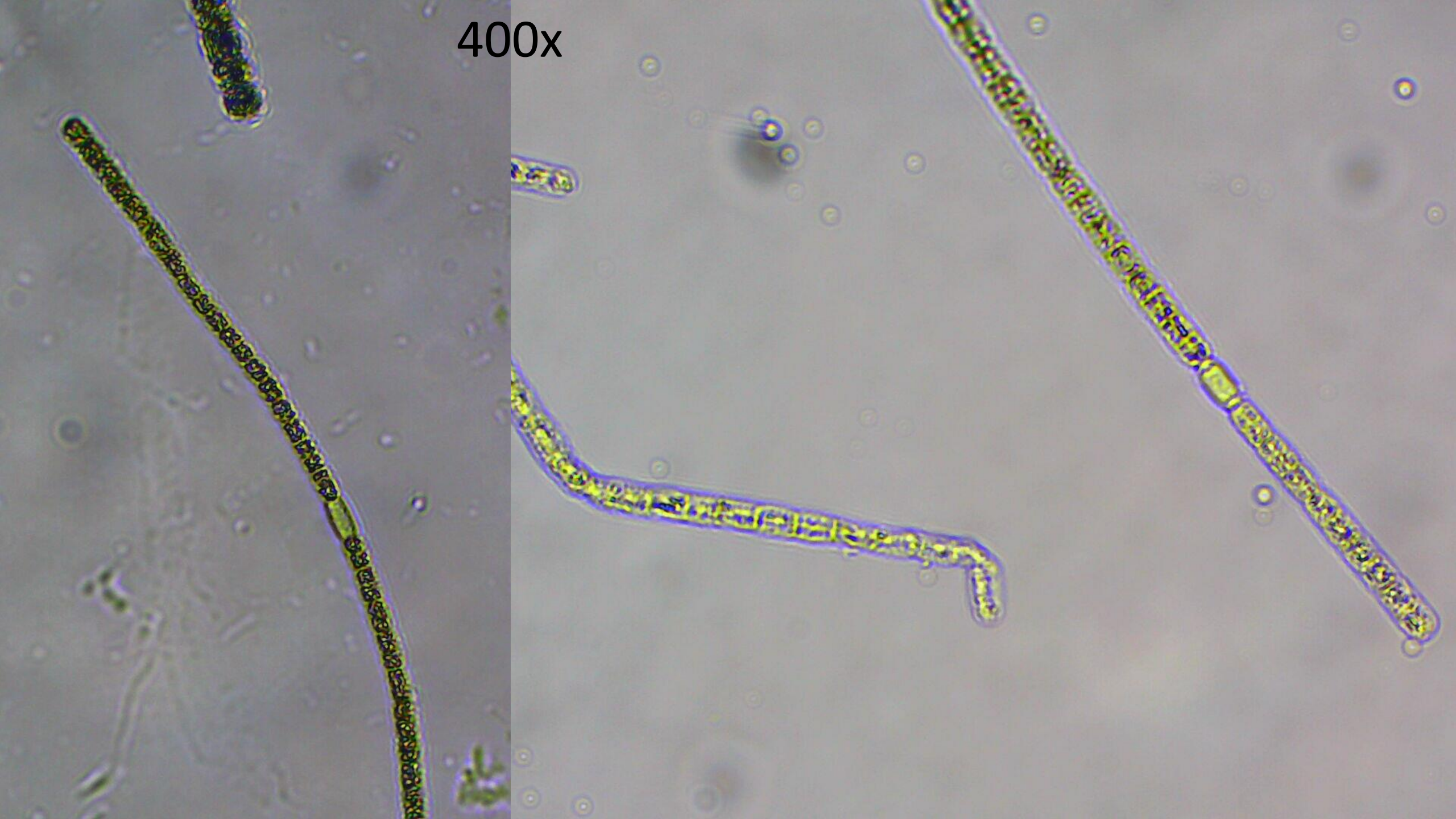
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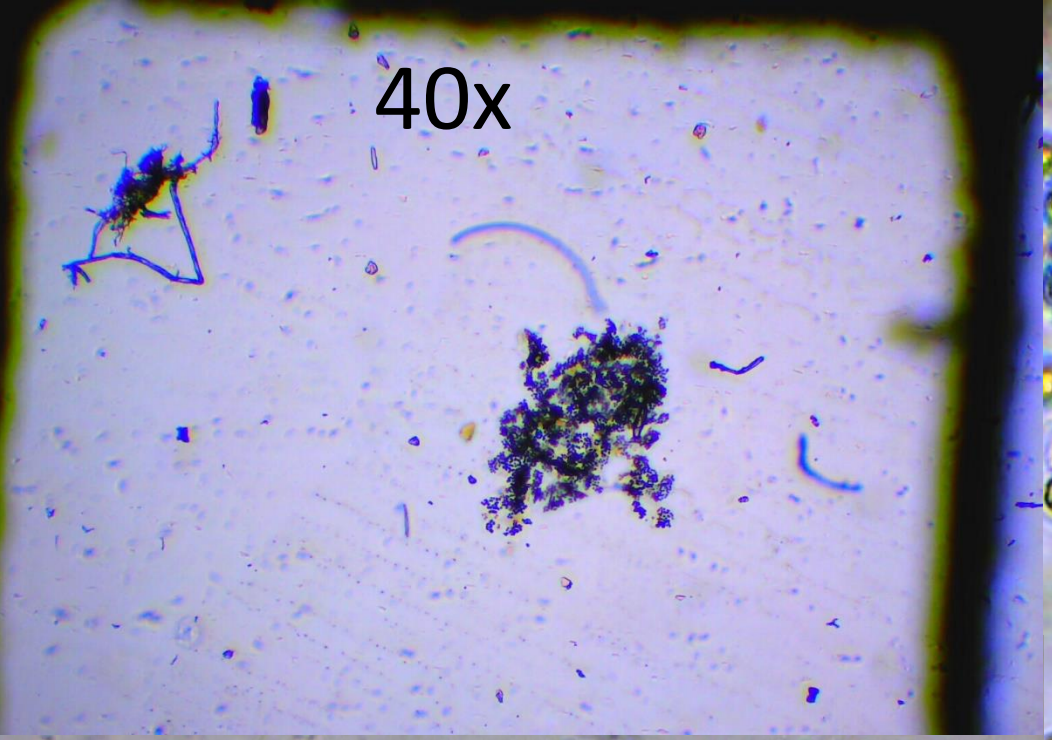
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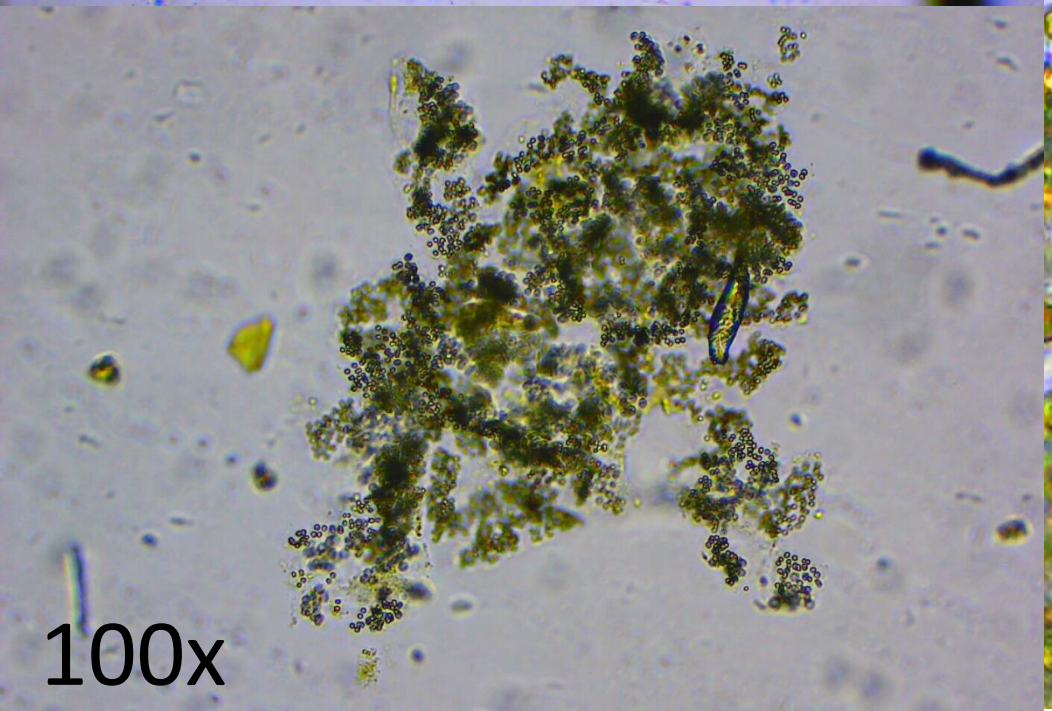
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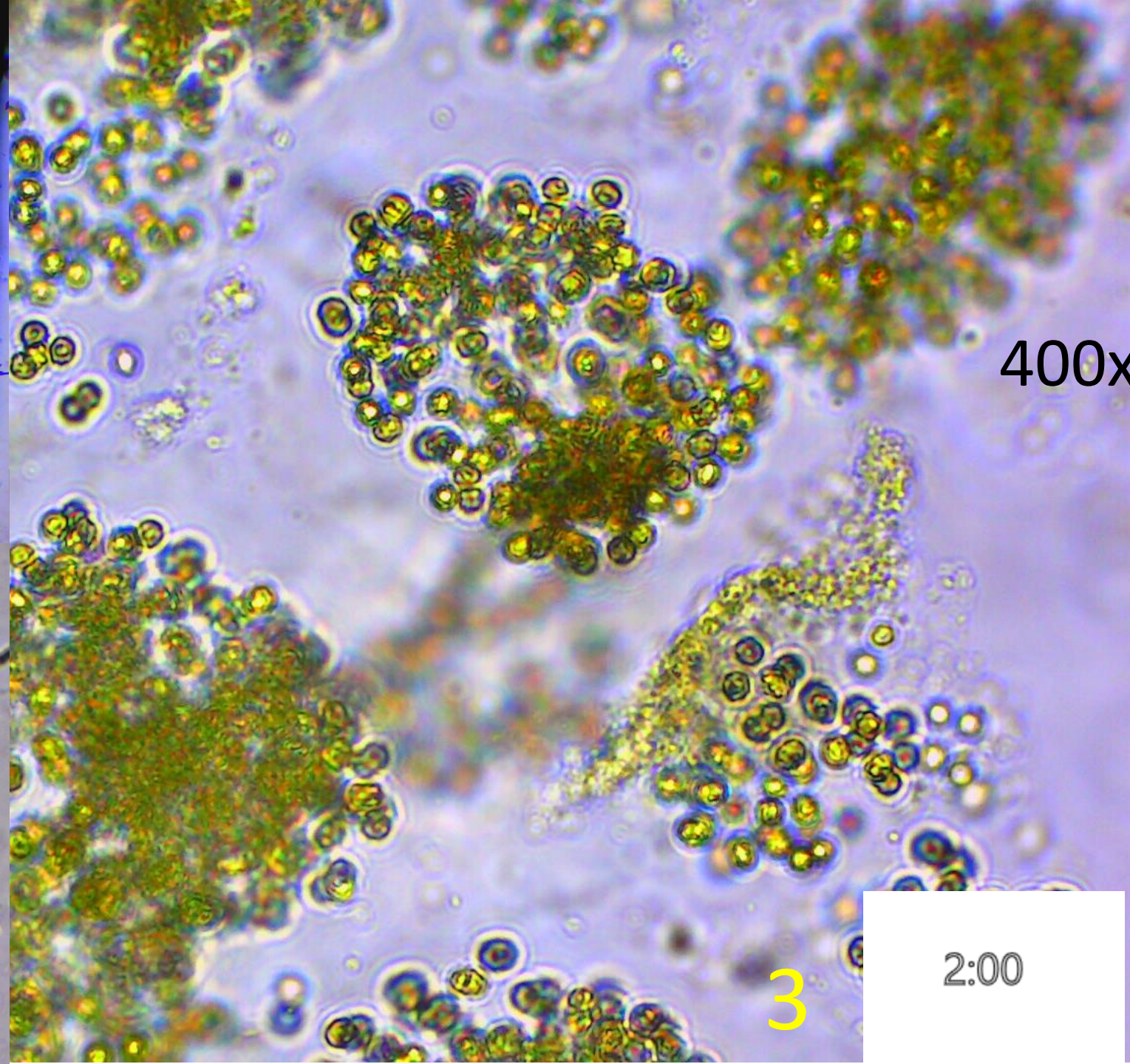
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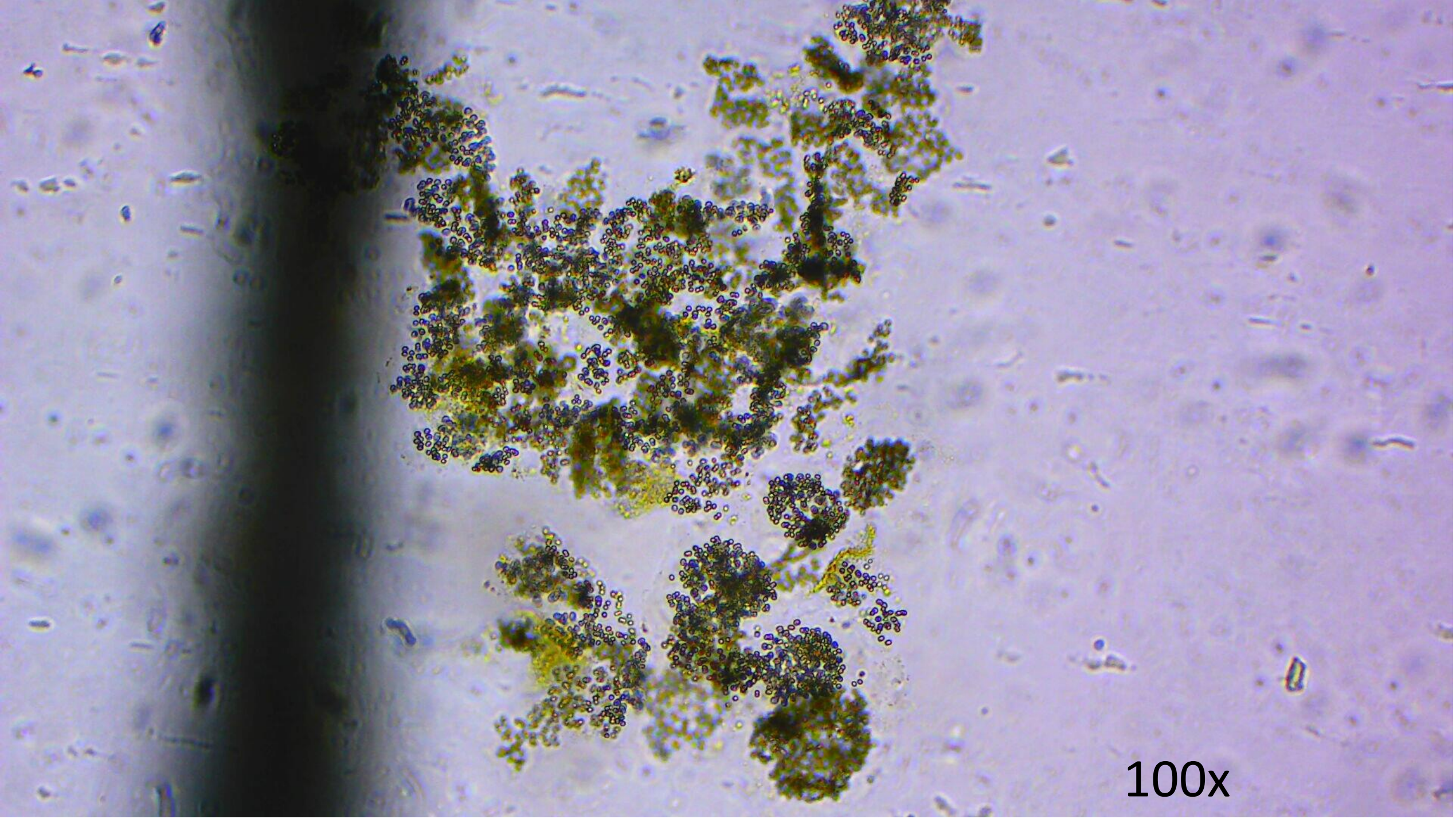
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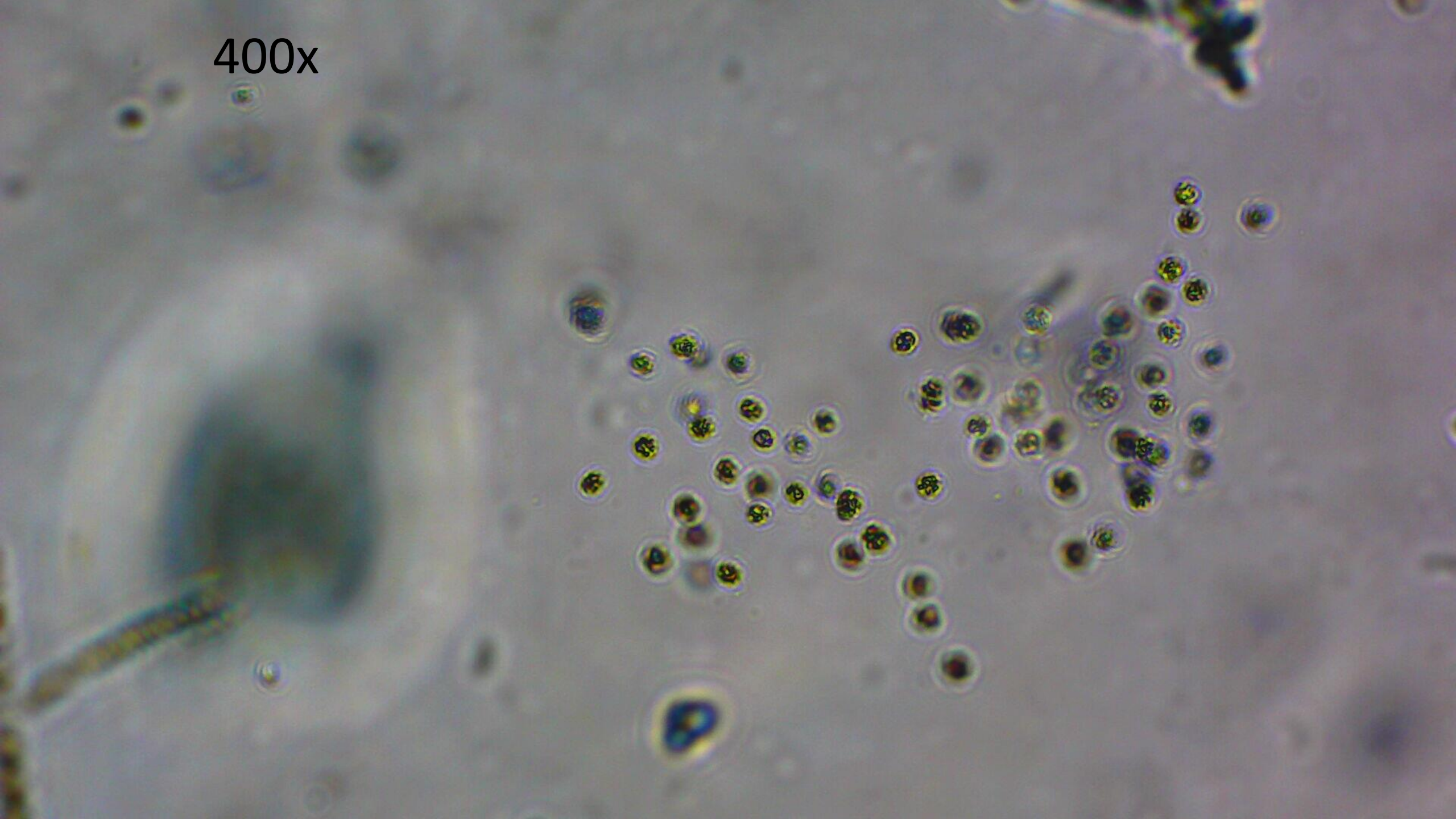
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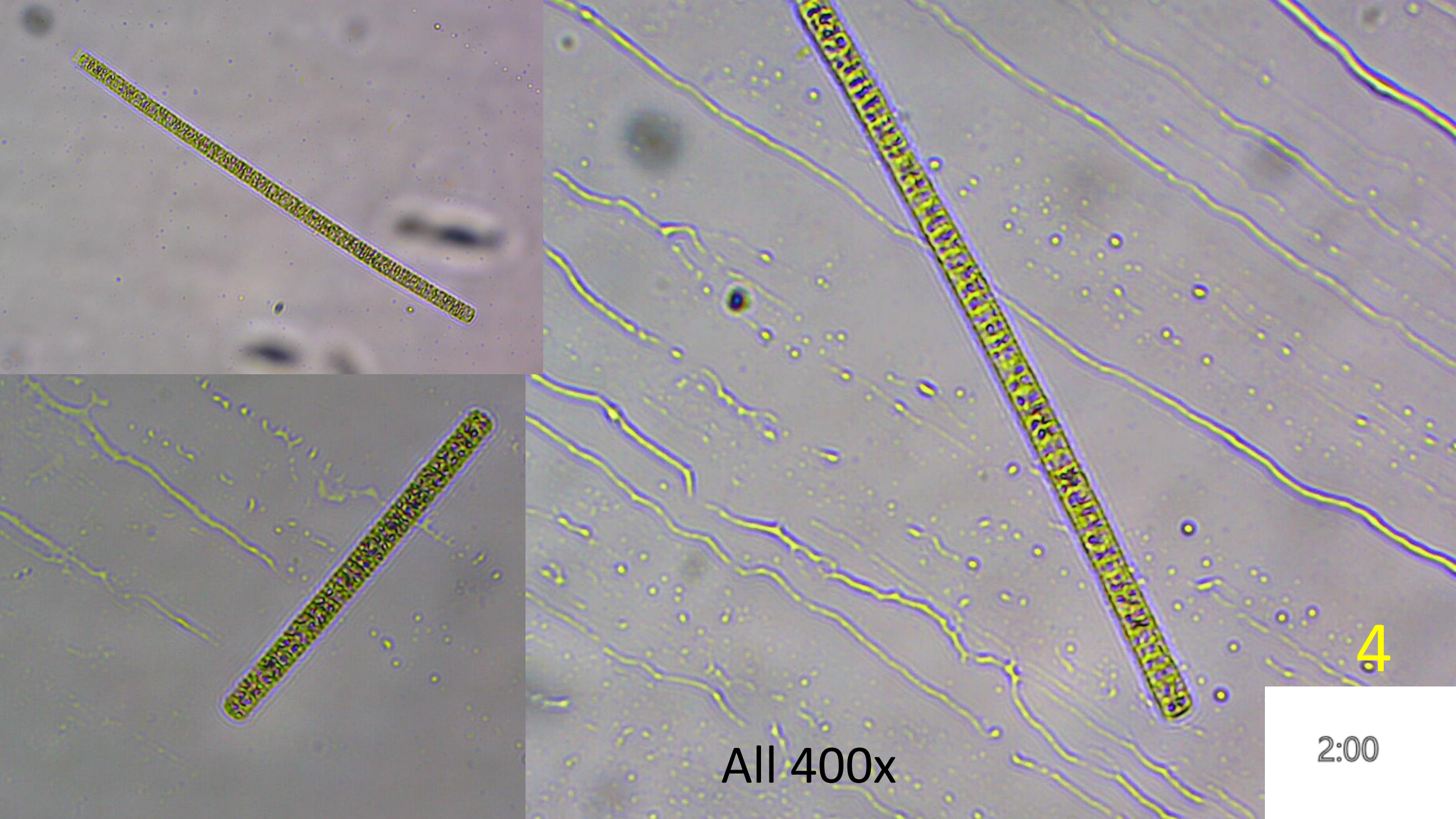
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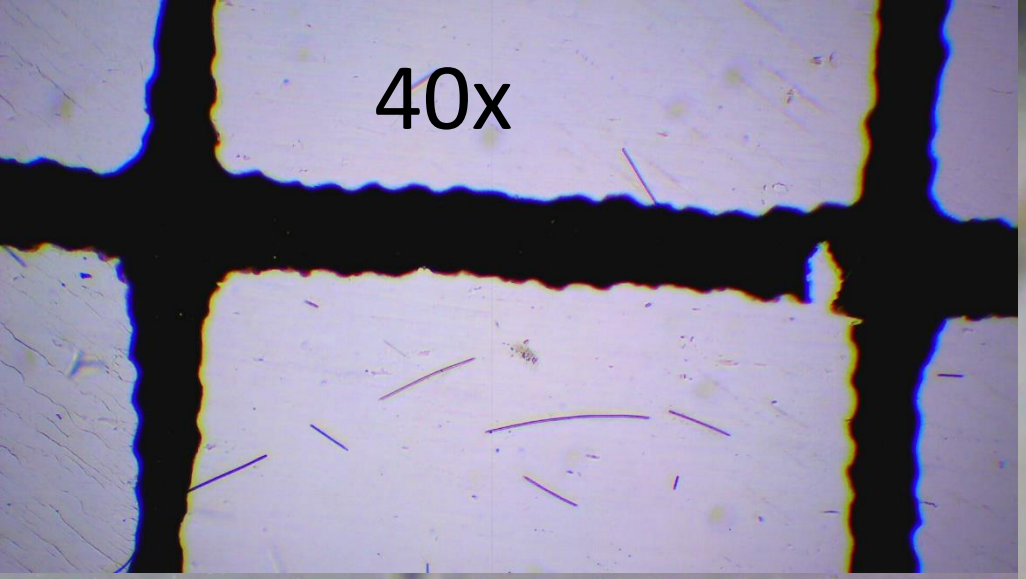
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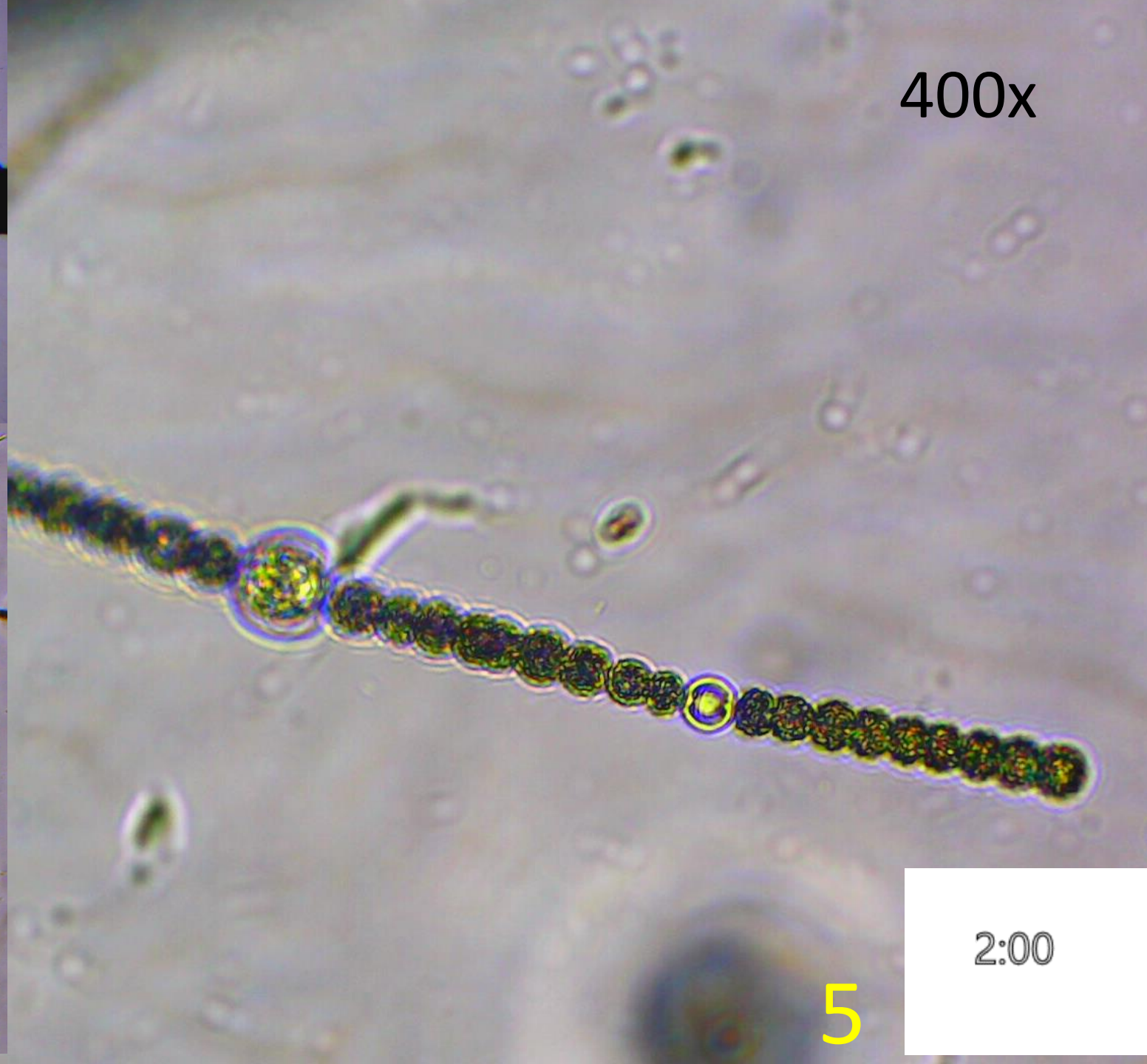
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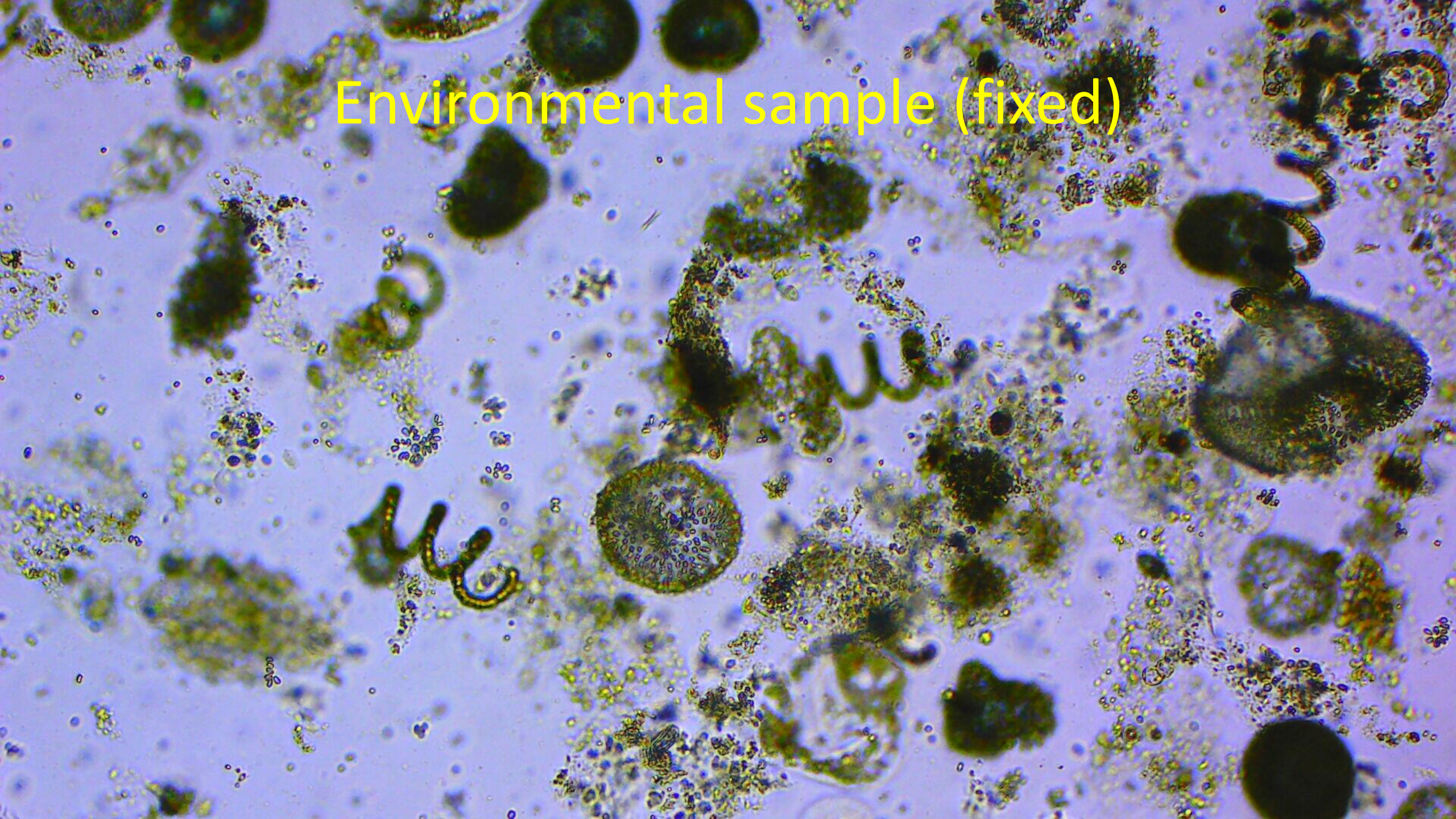
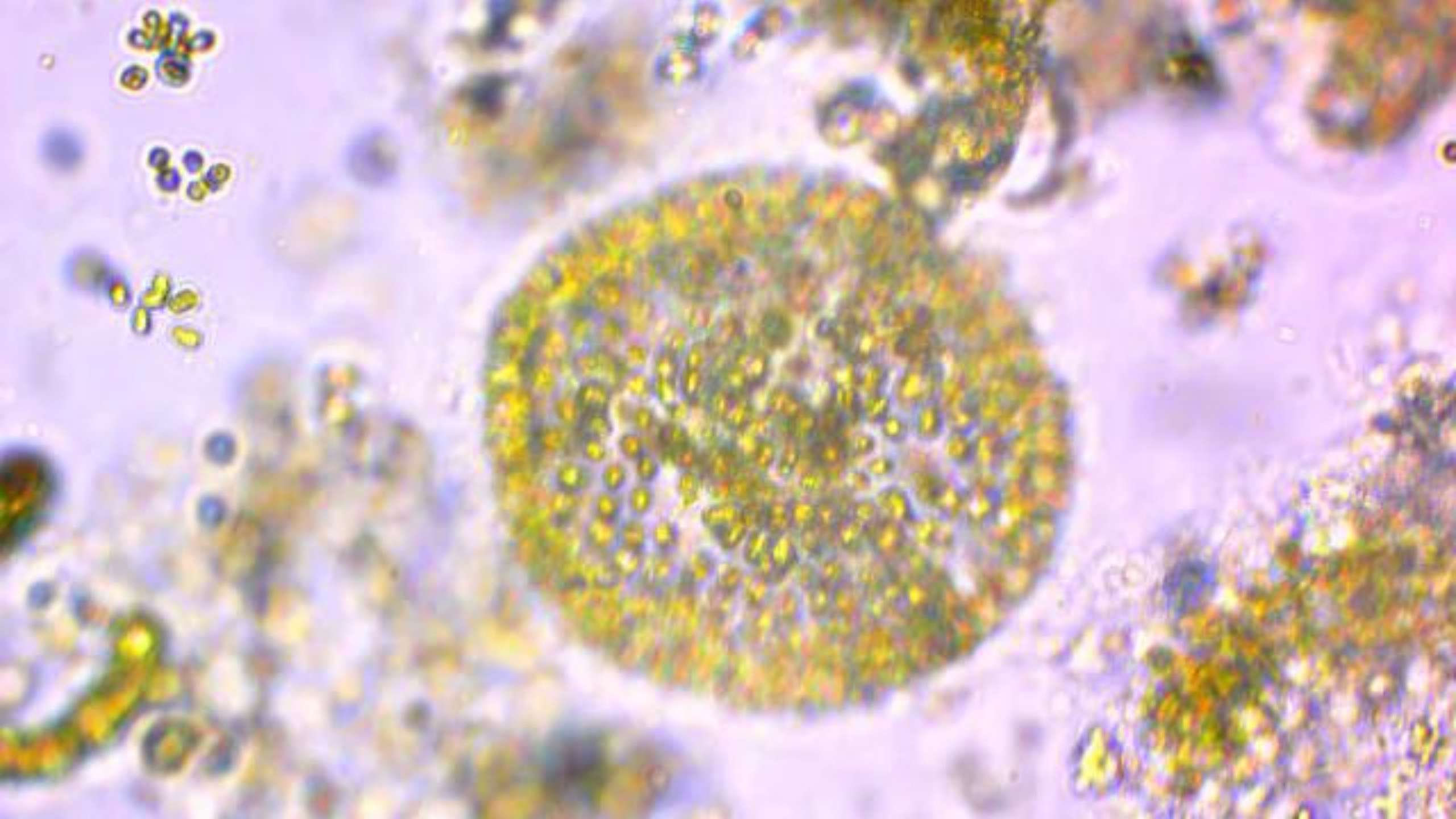

Environmental sample (fixed)




Woronichinia
Microcystis

Staurastrum (Desmid)

Pediastrum (Sphaeropleales)

Funding partners

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Links:
https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/pmn/- PMN website
http://youtu.be/ItzxoB06De0- Phyto app demo