HARMFUL ALGAL BLOOMS (HABS)

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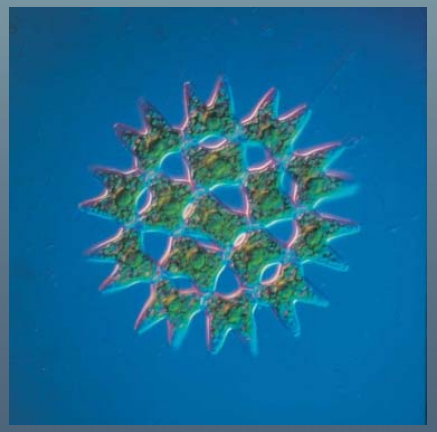
The Term “Algae”

- ✓ More of an ecological term than a taxonomic one since algae include both eukaryotes and prokaryotes (blue-green algae, also known as cyanobacteria)
- ✓ Most algae provide valuable ecosystem services
- ✓ Base of the food web; primary productivity
- ✓ Contribute toward oxygenating the water
- ✓ Sequester carbon
- ✓ May be a source of biofuel and have some pharmacological values
- ✓ However, some algae can be problematic

Main types of freshwater algae

- ✓ Phytoplankton (free floating algae)
- ✓ Filamentous Mat Algae (benthic algae)
- ✓ Macro-algae (stoneworts)



Harmful Algal Blooms (HABs)

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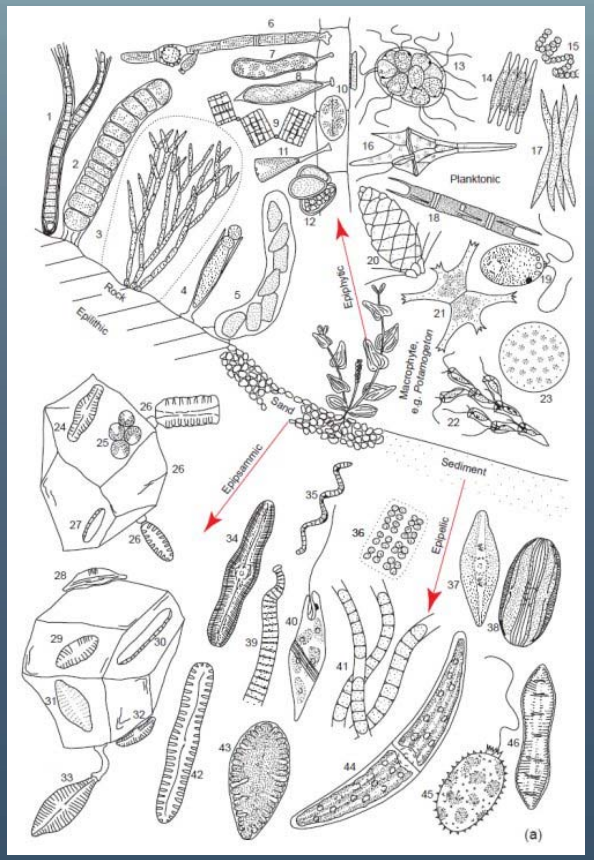
Common Freshwater Algal Groups

- ✓ Green algae
- ✓ Chrysophytes
- ✓ Diatoms
- ✓ Dinoflagellates
- ✓ Euglenoids
- ✓ **Blue-green algae**
- ✓ Others



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Cyanobacteria (blue-green algae)

- ✓ Photosynthetic bacteria
- ✓ Very old organisms so they are very well adapted to their environments
- ✓ The dominant nuisance group of algae in freshwater ecosystems
- ✓ Responsible for nuisance scums, negatively impact recreational usage, potable water supplies and ecological value
- ✓ Can produce **cyanotoxins** and taste / odor compounds.
- ✓ Many are not grazed by zooplankton

Adaptations of Cyanobacteria

- ✓ Can photosynthesize in a variety of light intensities
- ✓ Some can fix gaseous nitrogen (heterocysts)
- ✓ Some can regulate their position in the water column through gas vacuoles
- ✓ Generate colonies and cyanotoxins that make them unpalatable

Akinetes

- ✓ Resting cells that form from one cell or fusion of two or more neighboring cells.
- ✓ Thick cell walls and store “food.”
- ✓ Tend to be produced toward the end of the growing season.
- ✓ Basically used to survive harsh conditions.
- ✓ When a lake mixes, it can transport the akinetes back to the surface where they germinate

Heterocysts

- ✓ Specialized cells that produce thick, multi-layered cell walls that are air tight.
- ✓ Maintain an micro-environment in the heterocyst that is anoxic (no oxygen)
- ✓ The cell then has the ability to "fix atmospheric nitrogen.
- ✓ Thus, they are not dependent on external sources of nitrogen (nitrate-N or ammonia-N).

Heterocysts

- ✓ Studies have shown that the appearance and frequency of heterocysts on the filament of a blue-green is dependent on the availability of dissolved inorganic nitrogen (nitrate-N and ammonia-N).
- ✓ However, fixing nitrogen is a very energy demanding biological process so blue-greens tend to need more phosphorus relative to other algal groups.

Gas Vacuoles and Gas Vesicles

- ✓ Gas vacuoles (also called aerotopes) are membrane-bound organelles in the blue-green algal cell that fills with gas.
- ✓ Gas vacuoles are clusters of gas vesicles.
- ✓ Essentially provide a means for planktonic blue-green algae to control / regulate their position in the water column through buoyancy.

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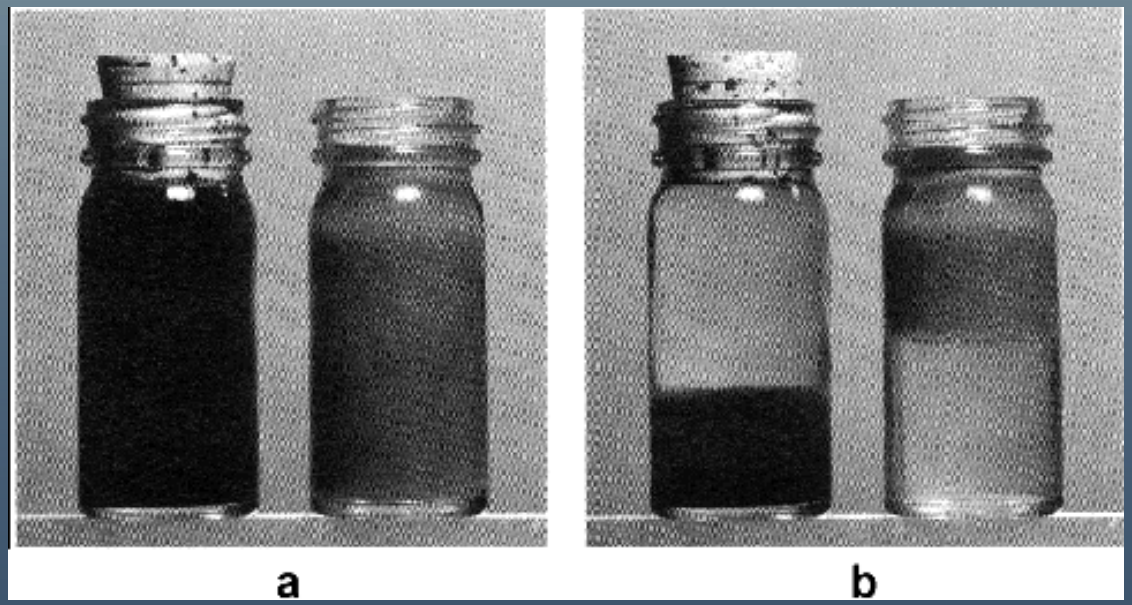
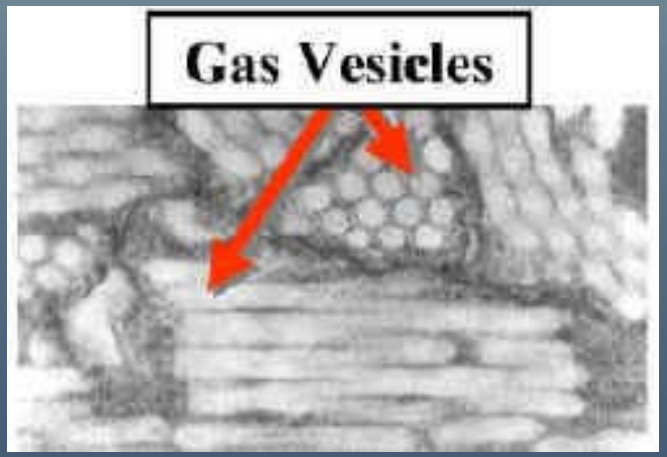
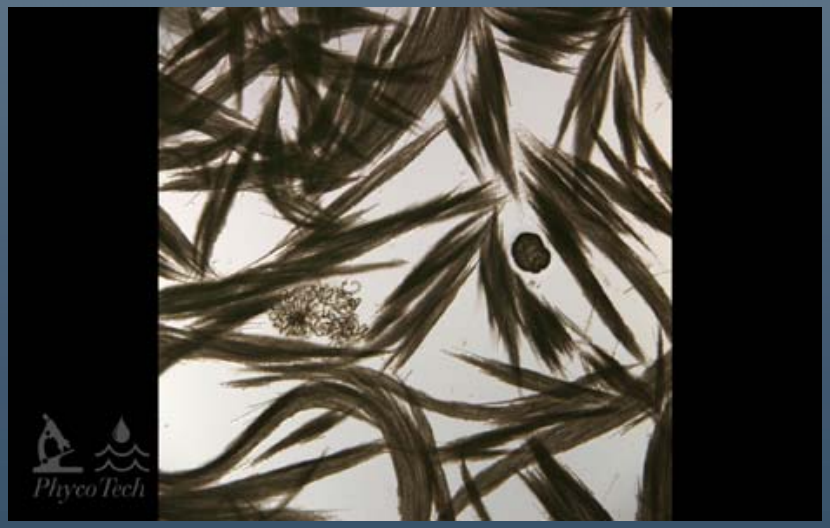
Gas Vacuoles and Gas Vesicles





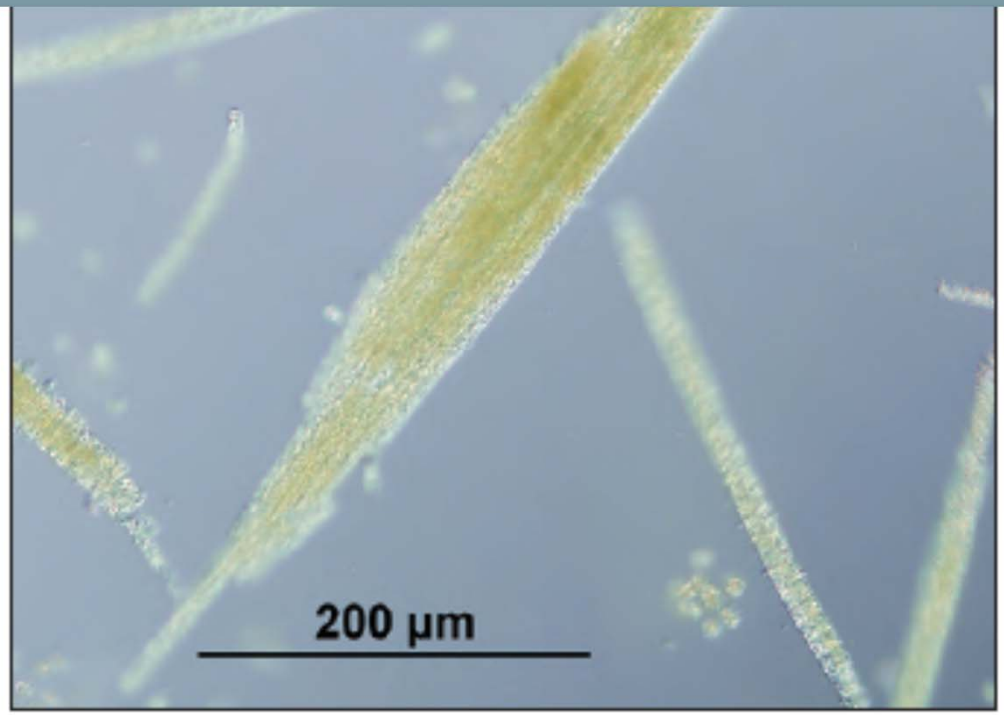
Blue-green algal blooms



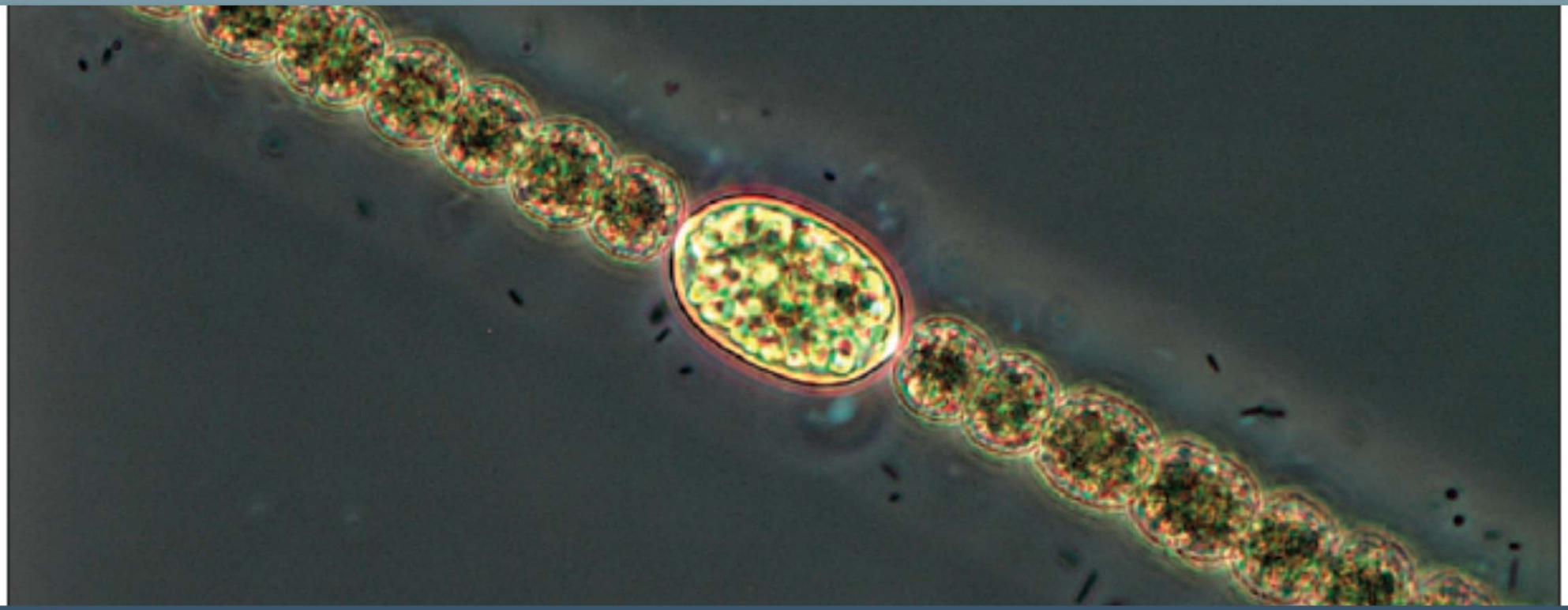
Common Nuisance Blue-green Algae

- ✓ *Anabaena* or *Dolichospermum* (Annie)
- ✓ *Aphanizomenon* (Fanny)
- ✓ *Microcystis* (Mike)
- ✓ *Coelosphaerium* or *Woronichinia* (Celia)
- ✓ *Oscillatoria*
- ✓ *Lyngbya*
- ✓ *Cylindrospermopsin*

Aphanizomenon



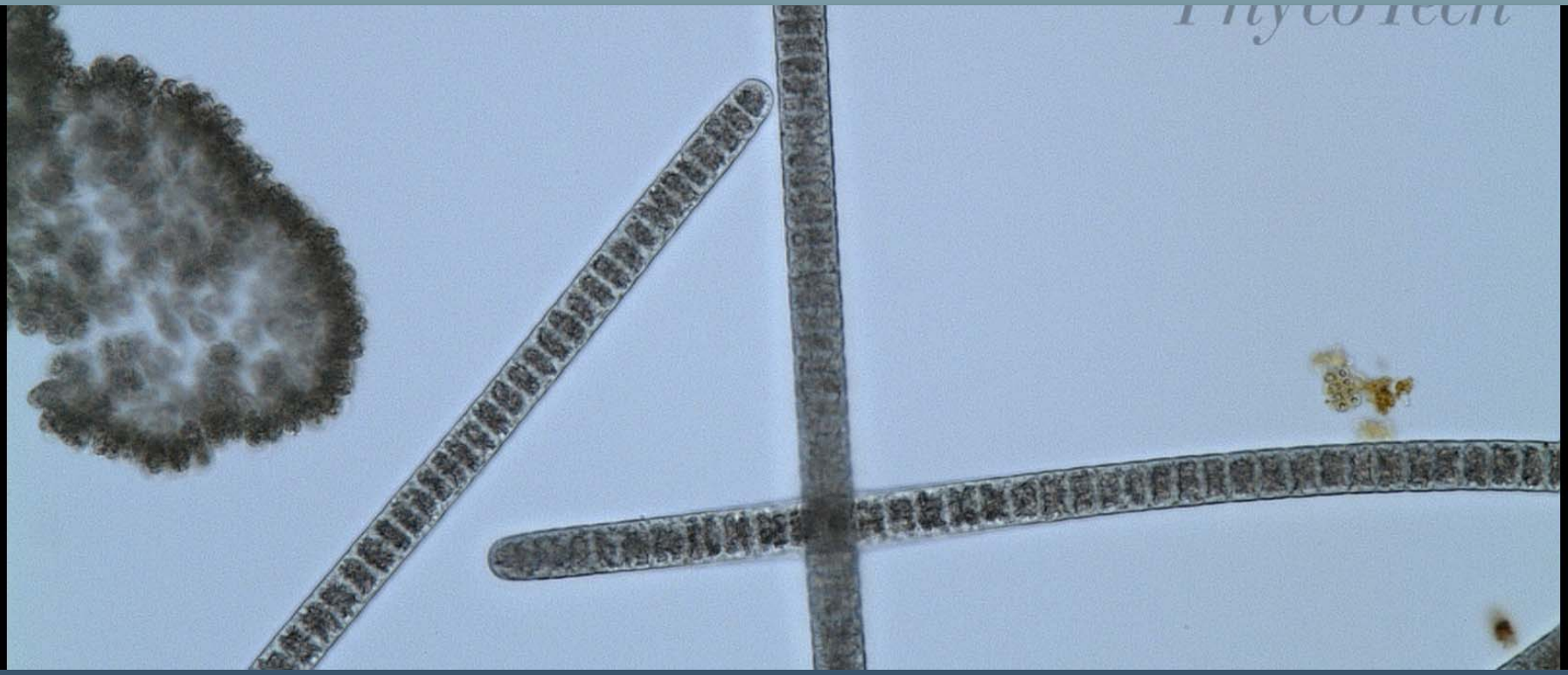
Anabaena or *Dolichospermum*



Cylindrospermopsis

Microcystis

Oscillatoria



Additional information on blue-green algae

- ✓ Most prefer higher water temperatures and bloom during the summer months
- ✓ Tend to thrive in phosphorus enriched waters (TP concentrations > 0.03 mg/L)
- ✓ Can move through the water column so prefer still water habitat
- ✓ Do not do well in acidic waters
- ✓ Generally more susceptible to copper sulfate than other algae; however, over use of copper can increase tolerance

Conditions that Result in an Blue-Green Algal Bloom

- ✓ High seasonal temperatures
- ✓ Still water conditions / thermal stratification
- ✓ Total Phosphorus concentrations as low as 0.03 mg/L can generate nuisance blooms / scums

So Can Blue-Green Algae Bloom in Rivers?

- ✓ Since blue-green algae tend to thrive and bloom in still water habitats and use gas vacuoles to move through the water column, one might assume that such blooms would be very rare in riverine systems.
- ✓ However, blue-green algal blooms have been well documented to occur in riverine systems, particularly under low flow conditions over the summer and fall seasons.

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Algal Bloom on the Schuylkill River? (No, it was duckweed)

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Schuylkill River

- ✓ The duckweed “bloom” occurred in early August 2016.
- ✓ That summer / fall our region experienced a severe drought.
- ✓ Isolated storms washed the duckweed into the river and the lower seasonal flows allowed the plant to bloom.
- ✓ However, this does not mean that blue-green algal blooms could not occur in the Schuylkill River.

Potable Water Intakes

- ✓ There are three major potable water intakes for the Philadelphia area: Philadelphia Water Department, Aqua Pennsylvania and the Pennsylvania American Water Company.
- ✓ Combined they serve more than 1.5 million people in the Philadelphia area.
- ✓ However, there are other water intakes in the Schuylkill River watershed.

HABs - Not As Simple As It Sounds

- ✓ “Typical conditions” don’t always cause bloom.
- ✓ Blooms with elevated cyanotoxin levels may be experienced under much different conditions.
- ✓ Not all cyanobacteria cause HABs.
- ✓ Not all cyanobacteria produce cyanotoxins.
- ✓ Cyanotoxin producers may not always produce cyanotoxins even during bloom conditions.

Cyanotoxins are NOT Taste and Odor Compounds

- ✓ Cyanotoxins are colorless, tasteless and odorless compounds
- ✓ Taste and odor compounds such as Geosmin and MIB can be produced by cyanobacteria (blue-green algae) and some actinobacteria
- ✓ Blue-green algae can produce T&O compounds and not produce cyanotoxins and they can produce cyanotoxins but no T&O compounds

What are Cyanotoxins?

- ✓ Diverse group of chemical substances produced by blue-green algae which show specific toxic impacts on vertebrates.
- ✓ Some are **neurotoxins** (anatoxin-a, anatoxin-a(s), saxitoxins)
- ✓ Some are **hepatotoxins** (**microcystins**, nodularin and **cylindrospermopsin**)
- ✓ Dermotoxins (lyngbyatoxins and aplysiatoxins)
- ✓ Documented impacts on humans, livestock and pets

More Information on Cyanotoxins

- ✓ Exposure …drinking, bathing or contact recreational activities.
- ✓ Even at low concentrations, recreational contact may cause skin rashes (even for dogs and livestock), ear/throat infections and gastrointestinal distress.
- ✓ Increased attention being given to possible links between cyanotoxins and neurodegenerative diseases (Parkinson's, ALS, and Alzheimer's).

Lake Erie and Toledo, Ohio

- ✓ Early August of 2014 massive cyanobacterial algal bloom in the western end of Lake Erie.
- ✓ The cyanotoxin microcystin was found in dangerous levels in the finished municipal water.
- ✓ Half a million people were warned not to drink the water.

Lake Erie, August 2014

What Defines a Health Concern?

- Currently no PA DEP State standard.
- ✓ World Health Organization (WHO) provisional DW guideline 1 µg/L **microcystin-LR**.
- ✓ NYDEC
  - Drinking Water - 1 µg/L
  - Contact recreation - warning > 4 µg/L

  > 20 µg/L beach closure

US EPA's Concern Over Cyanotoxins

- ✓ In May of 2015 US EPA developed Health Advisories for two cyanotoxins in drinking water supplies
- ✓ In November 2016 EPA released Draft Human Health Recreational Ambient Water Quality criteria and/or Swimming Advisories for freshwater recreational waterbodies
- ✓ Monitoring under EPA's Unregulated Contaminant Monitoring Rule (UCMR-4) will occur between 2018 and 2020.

What Defines a Drinking Water Health Advisory?

- ✓ 10-Day Drinking Water Health Advisories (HAs) for microcystins and cylindrospermopsin.
- ✓ Children (younger than 6) > 0.3 µg/L for microcystins and > 0.7 µg/L for cylindrospermopsin
- ✓ Others (adult) >1.6 µg/L microcystins and 3.0 µg/L for cylindrospermopsin.
- ✓ HA is not legally enforceable federal standard
- ✓ 10-day HAs reflect exposures and effects for a 10 kg (22 lbs) child consuming 1 liter of water per day.

Stepwise Monitoring for Cyanotoxins

- ✓ **General observations** (color / appearance of water; water clarity measured with Secchi disk)
- ✓ **Collection of sample –** identification of algae
- ✓ **Quantification of sample –** if blue-green algae present, at what concentrations? Typically, 15,000 cells / mLs is the threshold when a cyanotoxin sample is collected
- ✓ **Field cyanotoxin measurement**
- ✓ Possibly collect sample for **laboratory analysis of cyanotoxins**. Raw and finished water

Algal Identification and Enumeration

- ✓ Focus the counts (cells / mLs) on the blue-green algae
- ✓ While most blue-green algae appear to have the ability to generate cyanotoxins, not all can
- ✓ Multiple cyanotoxins

WHO CYANOBACTERIA CELL COUNT ACTION LEVEL	
SPECIES	**ACTION LEVEL**
Microcystis spp. or another singular genus	2,000 cells/mL or 5,000 cells/mL
Combination of all potentially toxic cyanobacteria species present	15,000 cells/mL

US EPA Health Advisories for Drinking Water Supplies

10-DAY EXPOSURE LEVELS VIA ORAL EXPOSURE ONLY

Microcystins	Cylindrospermopsin
0.3 µg/L for bottle-fed infants	0.7 µg/L for bottle-fed infants
1.6 µg/L for adults	3 µg/L for adults

Monitoring Cyanotoxins

- ✓ Abraxis test strips
- ✓ Abraxis field meter
- ✓ ELISA analyses
- ✓ Full laboratory analyses (HPLC)

Management Options for Raw Water Supplies - Proactive

- ✓ Nutrient control within the water
- ✓ Controlling external sources (watershed-based)
- ✓ Controlling internal sources (anoxic sediments)
- ✓ Modifying depth of withdrawal
- ✓ Separating blooms from intake areas (floating curtains)
- ✓ Using alternative sources of water
- ✓ Preemptive flushing

Management Options for Raw Water Supplies - Reactive

- ✓ Copper-based algicides
- ✓ Alternative products (oxidizers like GreenClean)
- ✓ Other potential technologies
- ✓ Use alternative sources of water
- ✓ Avoid blooms by withdrawing water from alternative depths
- ✓ Nutrient stripping of water column (proactive and reactive)
- ✓ Increase existing flushing rates

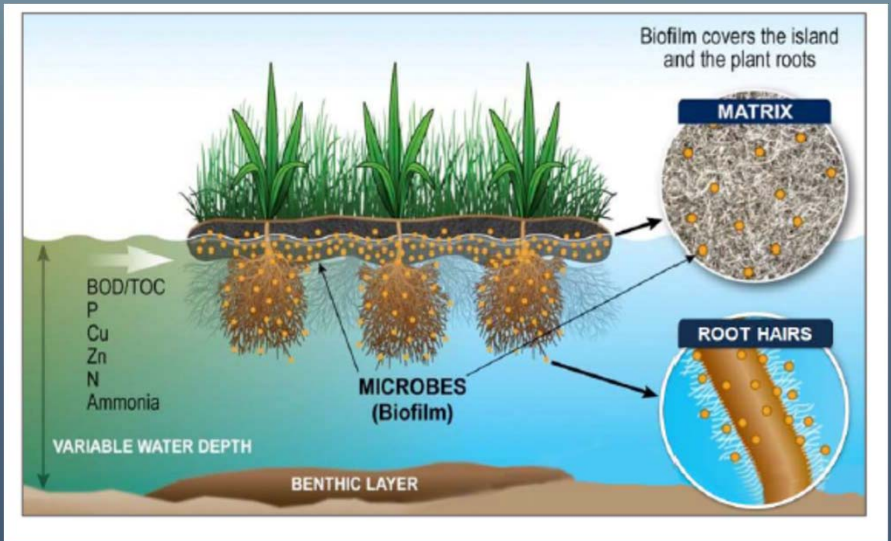
Nutrient Control (External Sources)

- ✓ Reducing point and non-point source (NPS) pollution entering the waterway or waterbody.
- ✓ Watershed-based measures (stormwater management, green infrastructure, septic / wastewater management, agricultural BMPs) are effective, long-term solutions.
- ✓ However, does the water purveyor own the land where the NPS pollution is being generated?
- ✓ Frequently, land ownership is limited to immediately along the shoreline.

Nutrient Control (External Sources)

- ✓ Focus on shoreline / streambank stabilization
- ✓ Measures that can remove nutrients from the water column (not necessarily internal loading)
- ✓ Phosphorus Stripping
- ✓ Floating Wetland Islands
- ✓ Separating the blooms and surface scums from the intakes

Floating Wetland Islands



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Floating Wetland Islands

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Frances Slocum Lake
September 2017

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Installation of De-stratification / Aeration System

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Algicides (Reactive Strategies)

- ✓ Most, but not all, are copper-based products.
- ✓ Immediately effective and can quickly control nuisance densities of both planktonic and mat algae.
- ✓ Relatively low in product and application costs.
- ✓ Permitted activity (need a certified applicator to file a permit with the State and need to use approved products).

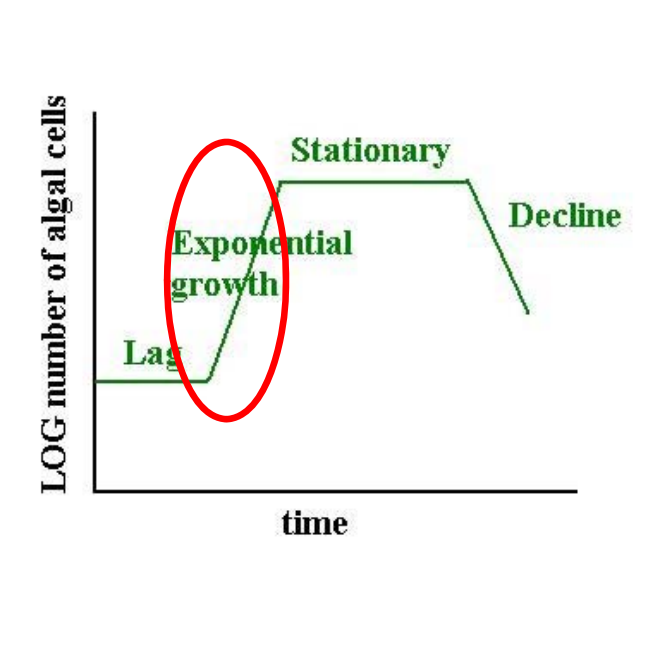
Algicides (Reactive Strategies)

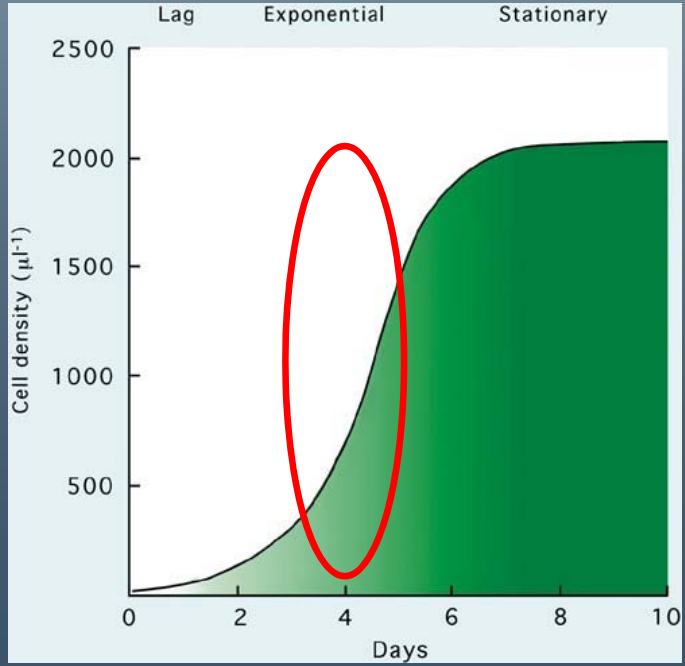
- ✓ Relatively short duration of improvement.
- ✓ Can produce secondary algal blooms.
- ✓ Long-term applications favor more copper resistant species / strains.
- ✓ Impacts non-target organisms.
- ✓ Accumulates in the sediments.
- ✓ Potential to contribute toward fish kills.
- ✓ **Can release cyanotoxins and T&O compounds into the water column**

Algicides – impacts on cyanotoxins and T&O compounds

- ✓ If a bloom has a measurable amount of cyanotoxins in the water, copper-based algicides should be avoided.
- ✓ If the majority of the cyanotoxins are within the algal cells (dissolved vs. total microcystins), depend on in-plant measures to reduce the cyanotoxins (e.g. settling).

A “Proactive” Approach





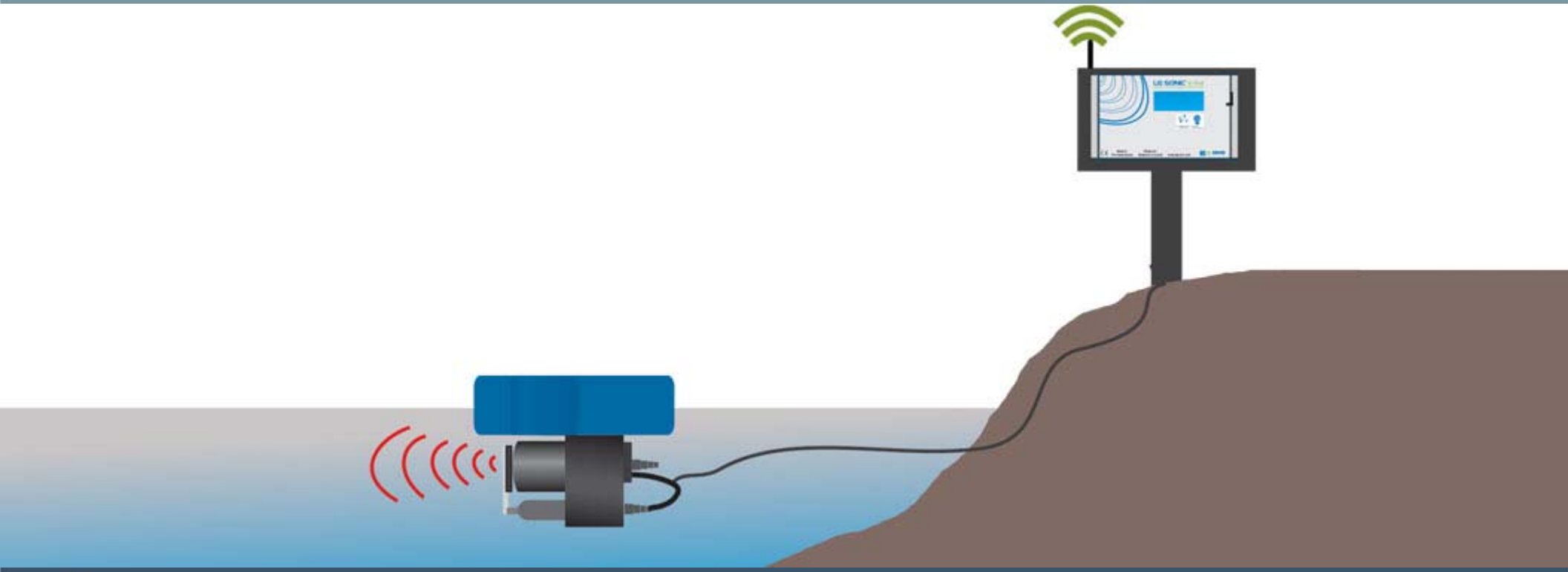
Alternative Products

- ✓ Strong oxidizers (GreenClean)
- ✓ More expensive than copper-based algicides but do not product or introduce any toxic materials (e.g. copper)
- ✓ In contrast to copper-based algicides, tends to be added on a more routine basis
- ✓ **Possibly effective at reducing both cyanotoxins and T&O compounds.**

Ultra-Sonic devices

- ✓ Non-chemical means of controlling algae, particularly blue-green algae.
- ✓ Forces the collapse of blue-green alga gas vacuoles so they can not migrate through the water column.
- ✓ Need stable source of power.
- ✓ Somewhat expensive.
- ✓ Not a large amount of data on the effectiveness of the systems.

Ultra-Sonic devices



Avoiding the Blooms

- ✓ Taking advantage of multiple intakes.
- ✓ Withdrawing water from multiple depths or sources, depending on the season or even the time of day.
- ✓ Avoid deep water blooms by withdrawing from the surface, particularly in the spring.
- ✓ Avoid surface blooms by withdrawing from the deeper intakes during the summer.
- ✓ Daily changes in depth specific withdrawals.

Monitoring, Management and Treatment (MMT) Plan

- ✓ A Monitoring, Management and Treatment (MMT) Plan is an objective means of being both proactive and reactive to the potential occurrence of blue-green algal blooms and the generation of cyanotoxins.
- ✓ **Monitoring** – water quality monitoring data (focusing at the intake structure) as well as the collection of weather data and cyanotoxin data.

Monitoring, Management and Treatment (MMT) Plan

- ✓ **Management** – long-term planning and assessment (bathymetric survey, pollutant loading analyses, management measures, in-treatment planning)
- ✓ **Treatment** – measures to implement when a bloom occurs (copper and non-copper based products, multiple intakes, in-treatment operations).

QUESTIONS?

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THANK YOU!

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