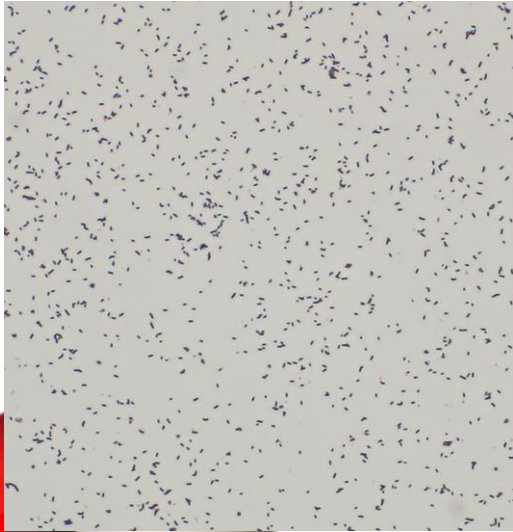


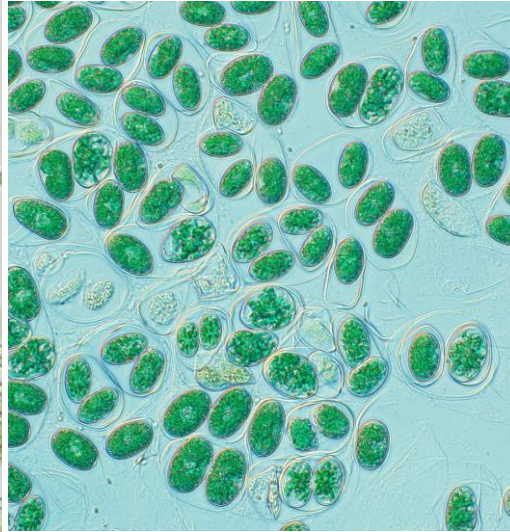
MICROORGANISMS – BLUE-GREEN ALGAE / CYANOBACTERIA



Bacteria



Cyanobacteria



Green Algae

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FBMI ČVUT, 2023

Innovation of Teaching of
Natural Science Subjects
at CTU FBMI

GRAM-NEGATIVE BACTERIA – CYANOBACTERIA

- Cyanobacteria **are a unique group of Gram-negative bacteria** - autotrophic prokaryotic organisms capable of photosynthesis.
- DNA freely in cytoplasm, ribosomes 70S, storage substances - cyanobacterial starch, volutin, some representatives **have gas bladders (so-called aerotypes)**.
- Main photosynthetic pigment – chlorophyll a - thylakoids - photosynthesis with PS I and PS II. PS II - water photolysis - oxygen is released - oxygenic photosynthesis.
- **Origin of oxygen atmosphere on Earth.**
- Phycobilisomes - light-harvesting antennae.
- Some - **ability to fix airborne nitrogen - heterocytes** (not heterocysts!).
- Production of secondary metabolites - cyanotoxins. More toxic than curare!

GRAM-NEGATIVE BACTERIA – CYANOBACTERIA

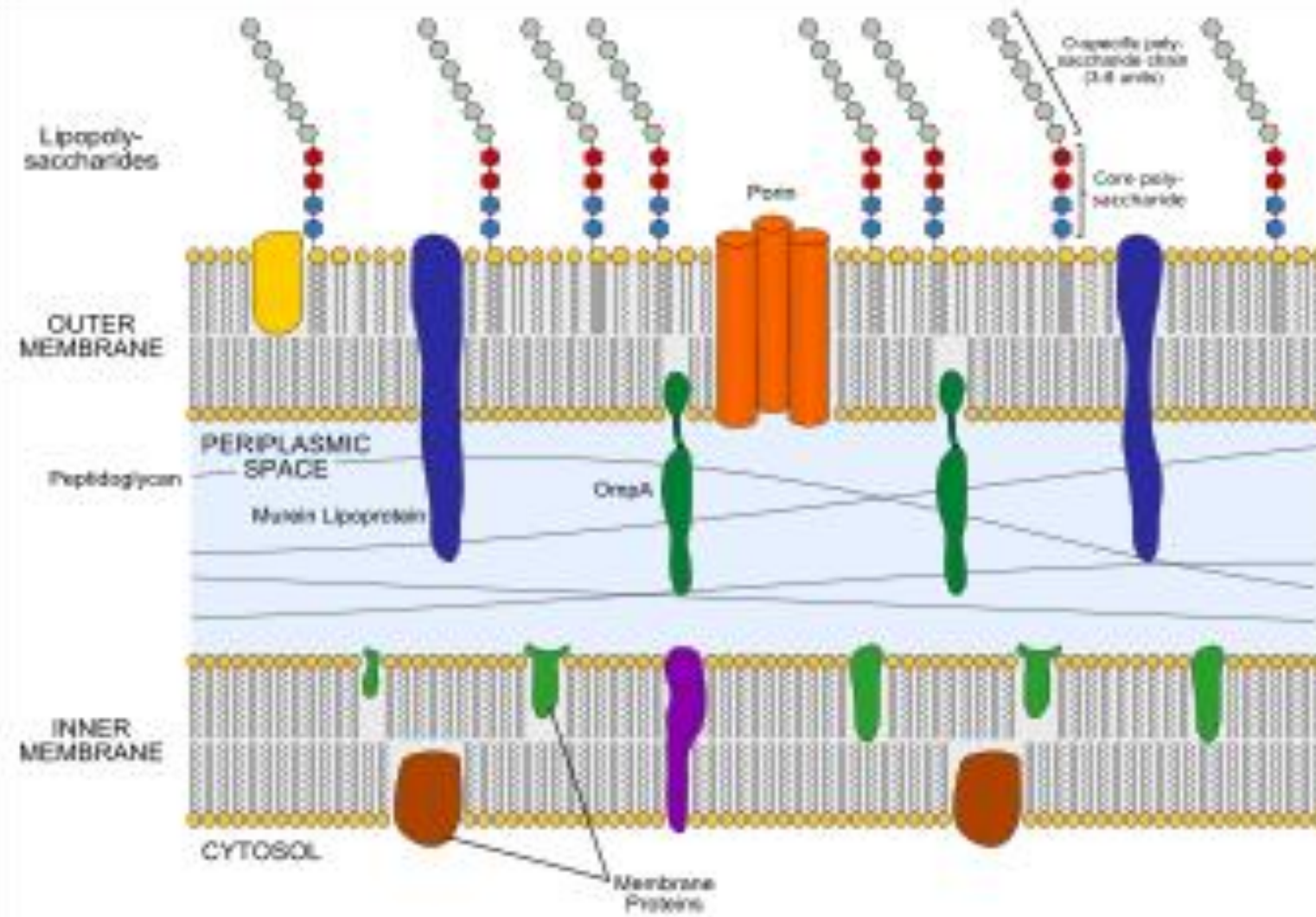
Cyanobacteria **contain photosynthetic pigments** (chlorophyll a, blue phycocyanins and red phycoerythrins, collectively called phycobilins and carotenoids).

Their relative proportions depend on light and nutrition and determine the resulting colour, which ranges from olive green to grey-blue, red-violet, dark green-blue and black.

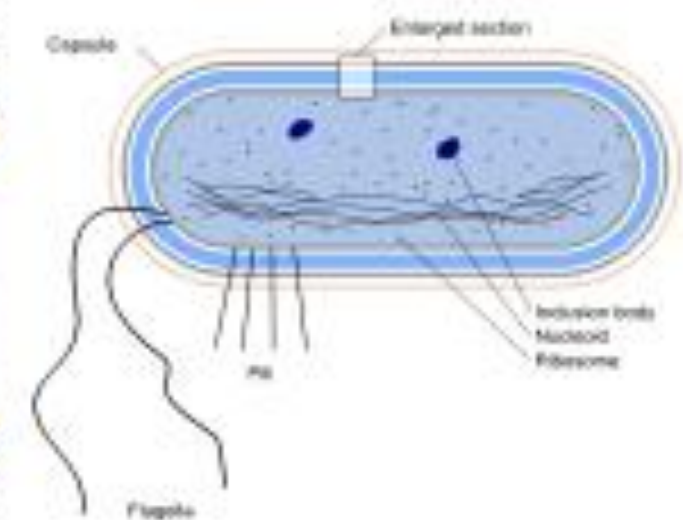
Cyanobacteria may have cells or colonies of cells surrounded by mucus, movement.

Cyanobacteria contain potent toxins, **cyanotoxins** (e.g. microcystins), which are allergenic, neurotoxic and hepatotoxic to humans.

Cyanobacteria are highly observable by optical microscopy.



Gram Negative Bacterial Cell Wall



https://en.wikipedia.org/wiki/Gram-negative_bacteria

TAXONOMY OF CYANOBACTERIA

Individual Orders

- Gloeobacteriales – primitivní sinice

Chroobacteria

- Chroococcales
- Pleurocapsales
- Oscillatoriales

Hormogonaea

- Nostocales
- Stigonematales

Domain

Bacteria

Phylum

Cyanobacteria
Stanier ex Cavalier-Smith, 2002

Class

Cyanophyceae
Schaffner, 1909

STROMATOLITE

- **Stromatolite** is a calcareous **biogenic sediment of a loose to hemispherical shape**.
- A number of microorganisms were involved in their formation during the Precambrian period, but the most important component is cyanobacteria.
- At that time, these were microorganisms that were among **the first photosynthesizing organisms** and enriched our planet's atmosphere with oxygen during their metabolism, thus contributing to the formation of an **oxygen atmosphere** on Earth.
- Stromatolites are among **the oldest fossils, they are about 3.5 to 3.7 billion years old**, today we can see them in Australia, Bolivia, etc.

DIVISION FOR IDENTIFICATION IN EXERCISES

Coccal ad 1, filamentous ad 2,3,4

- 1) Unicellular representatives, living alone or associating in colonies** - representatives of the orders Gloeobacterales, Chroococcales (Microcystis, Woronichia), Chroococcidiopsidales, Pleurocapsales and Synechococcales (Merismopedia)
- 2) Simple filamentous cyanobacteria** - representatives of the orders Oscillatoriales (Oscillatoria), Synechococcales and Spirulinales (Spirulina)
- 3) Filamentous cyanobacteria with heterocytes, with occasional irregular divisions** - some representatives of the order Nostocales (Anabaena/Dolichospermum, Aphanizomenon/Cuspidothrix, Nostoc)
- 4) Filamentous cyanobacteria with heterocytes, with true divisions** - part of the representatives of the order Nostocales

The following presentation contains only some selected species of cyanobacteria; use other recommended resources for self-identification during the exercises.

MICROCYSTIS

Class: Cyanophyceae

Order: Chroococcales

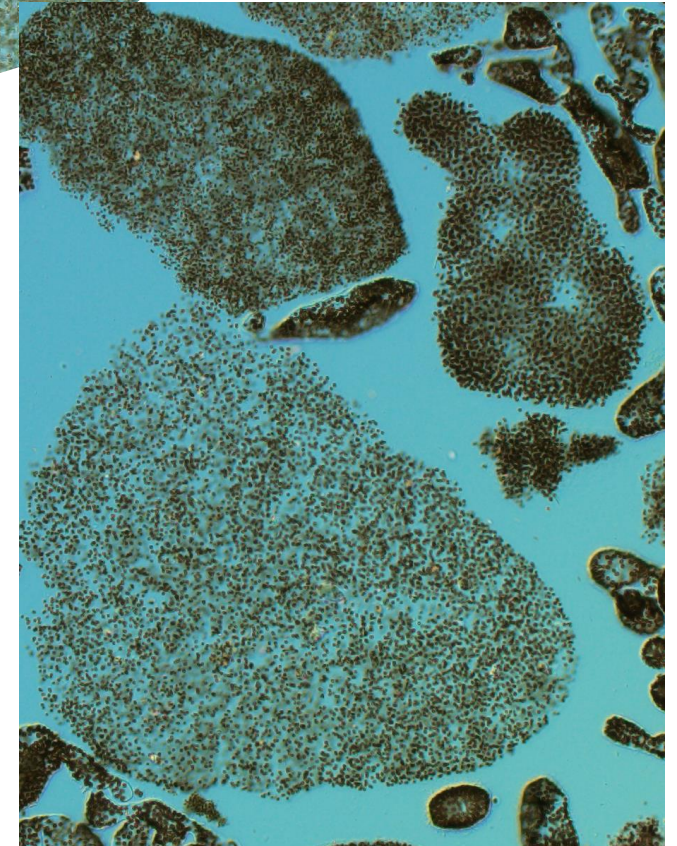
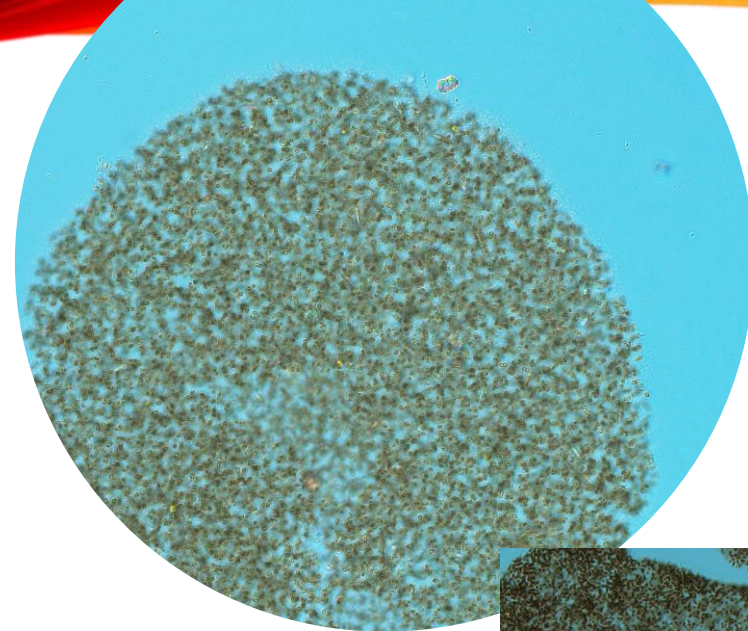
Representative: *Microcystis aeruginosa*
Microcystis flos-aquae

The genus *Microcystis* is one of the most important genera producing **cyanobacterial aquatic blooms**. It consists of approximately 20 described species, many of which are found in tropical regions.

Cyanobacterial species are important for their large biomass production and also for the production of cyanotoxins.

Cyanotoxins are products of bacterial metabolism and are toxic to warm-blooded animals and humans.

Their name is microcystins, cyanopeptolins and they are neurotoxic, hepatotoxic.



WORONICHINIA

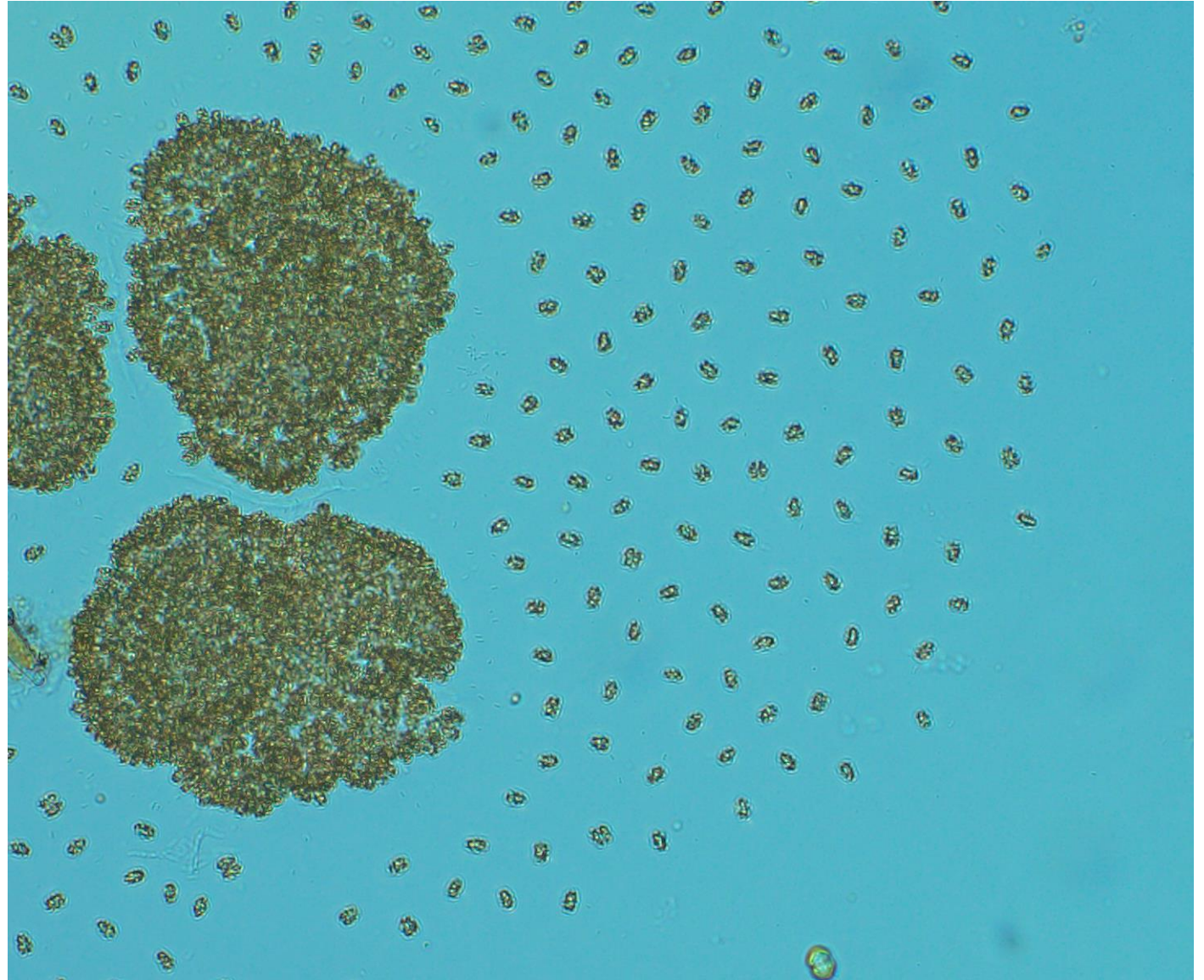
Class: Cyanophyceae

Order: Chroococcales

**Representative: Woronichia
naegeliana**

Planktonic species, cells connected by mucilaginous pedicels into a colony.

Reproduces by ejectile cells.



MERISMOPEDIA

Class: Cyanophyceae

Order: Synechococcales

Representative: *Merismopedia tenuissima*

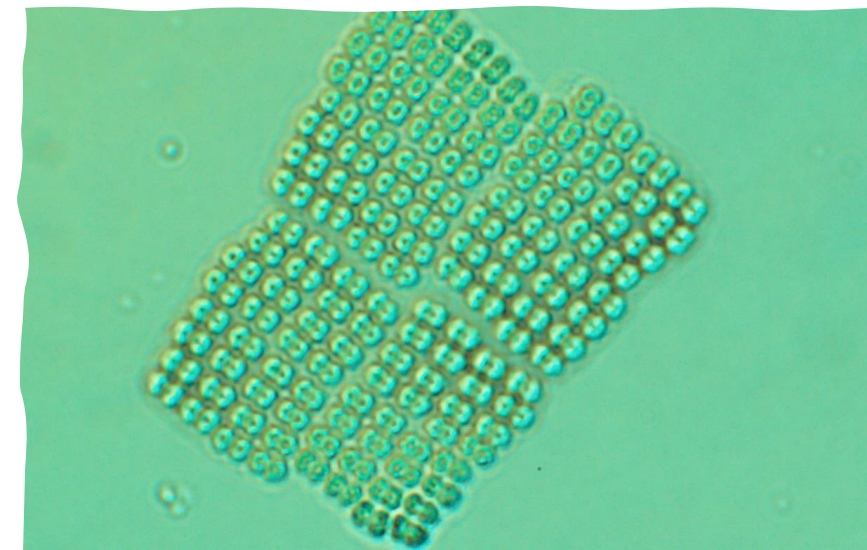
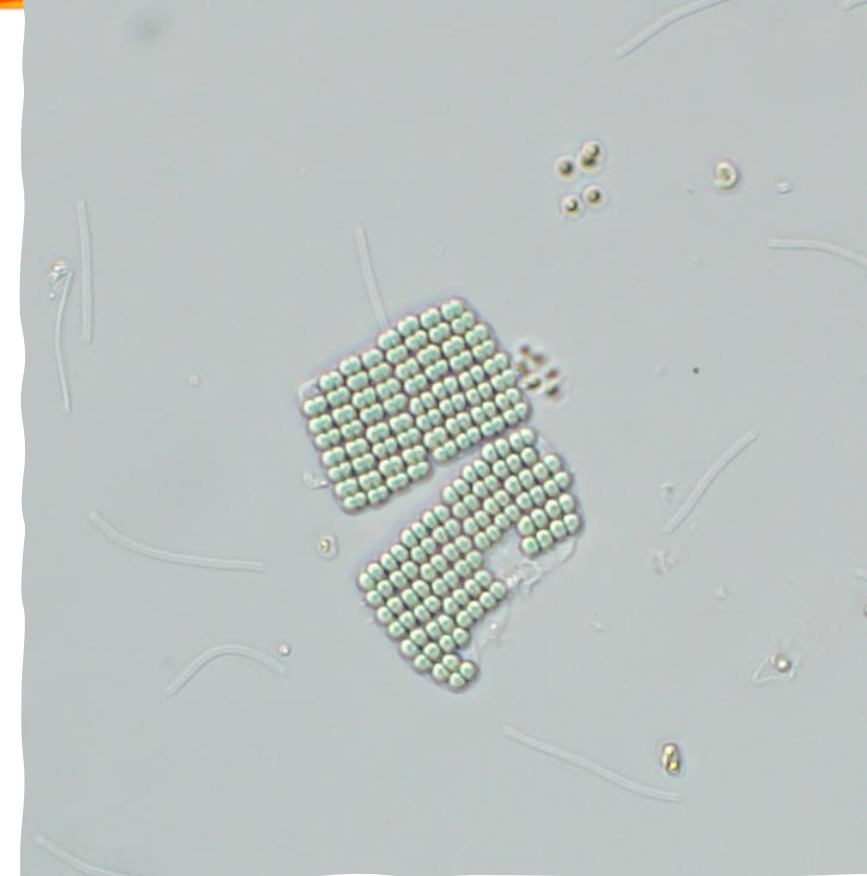
Merismopedia punctata

Merismopedia glauca

Cyanobacteria form plate-like colonies of 8-64 cells.

Colonies are formed by binary cell division in two perpendicular planes.

Cyanobacteria are found in freshwater plankton, eutrophic waters.



OSCILLATORIA

Class: Cyanophyceae

Order: Oscillatoriales

A genus of cyanobacteria which is referred to in Czech as Drkalka, after its movement.

Representative: *Oscillatoria limosa*

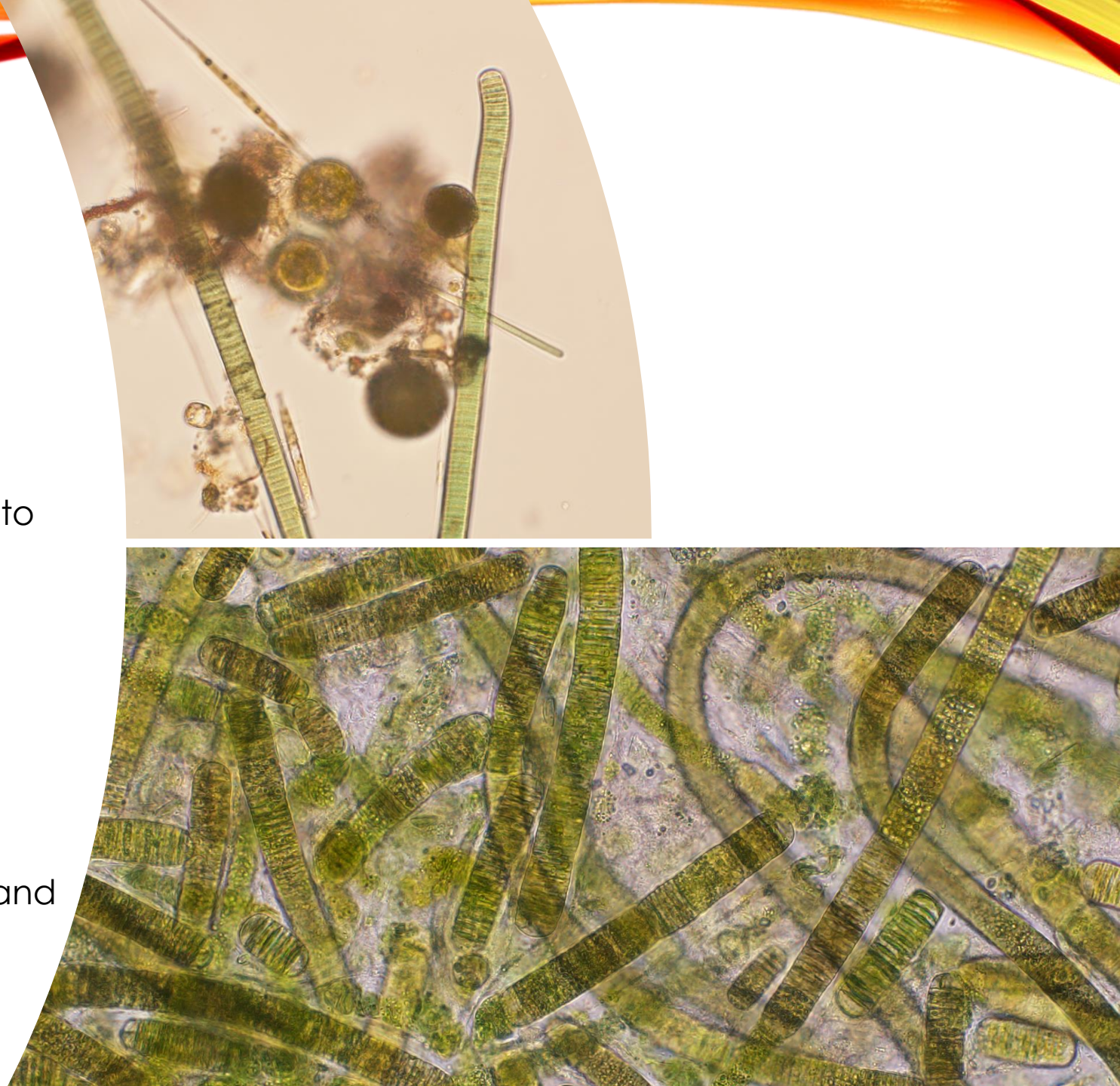
Oscillatoria major

The cyanobacteria can actively move in a peculiar grating, rotating motion while producing large amounts of slime.

It does not form heterocytes.

It divides binary.

It is also found in moist soil, objects of study and soil microbiology.



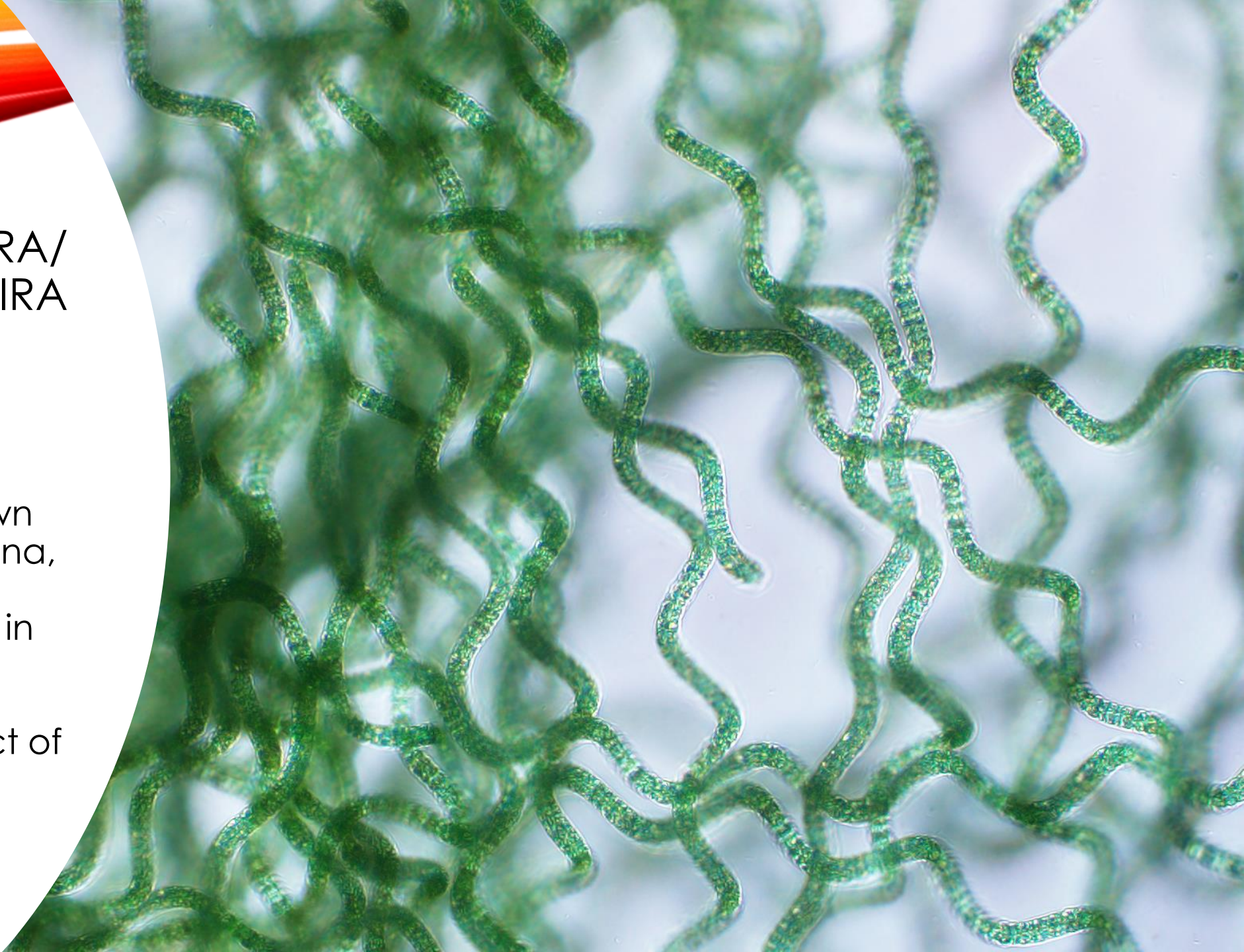


LIMNOSPIRA/ ARTHROSPIRA

Class: Cyanophyceae

Order: Spirulinales

Cyanobacteria is known commercially as Spirulina, a representative of ***Spirulina magna***, used in dietary supplements. However, its effects on humans are the subject of further research and many experts do not recommend its use!



ANABAENA, (DOLICHOSPERMUM)

Class: Cyanophyceae

Order: Nostocales

The representative of
Anabaena flos-aquae is a
filamentous cyanobacterium
capable of gliding.

Its filaments can occur in
coiled spirals in the water.

It produces cyanotoxins
(anatoxin-a).



THE GENERA ANABAENA, (DOLICHOSPERMUM)

- Class: Cyanophyceae
- Order: Nostocales
- The taxonomy of representatives of the genus *Anabaena* is difficult to determine by non-experts. (Komárek and Zapomělová, 2007)
- The representative ***Anabaena sigmoide*** is a filamentous cyanobacterium.
- Its filaments can occur in coiled spirals in the water.
- It produces cyanotoxins (anatoxin-a).



SPECIALISED CELL TYPES AND FILAMENTS

Heterocytes - thick-walled cells -
fixation of air nitrogen

Akinetes - formation from one or
more vegetative cells, larger than
heterocytes. Survival in adverse
conditions, through the
winter...Occurrence - only in some
species of cyanobacteria.

Hormogonium, n.s. Hormogonia are
motile mucus-connected filaments
of cells produced by some
cyanobacteria of the family
Nostocaceae, by which they can
reproduce.



APHANIZOMENON/CUSPIDOTHRIX

Class: Cyanophyceae

Order: Nostocales

Cyanobacteria of the genera *Aphanizomenon* play an important role in the nitrogen cycle because they can perform nitrogen fixation.

Representative: *Aphanizomenon flos-aquae*, *A. yezonse*

Much of the fixed nitrogen can be released into the surrounding water, providing an important source of bioavailable nitrogen for the ecosystem.

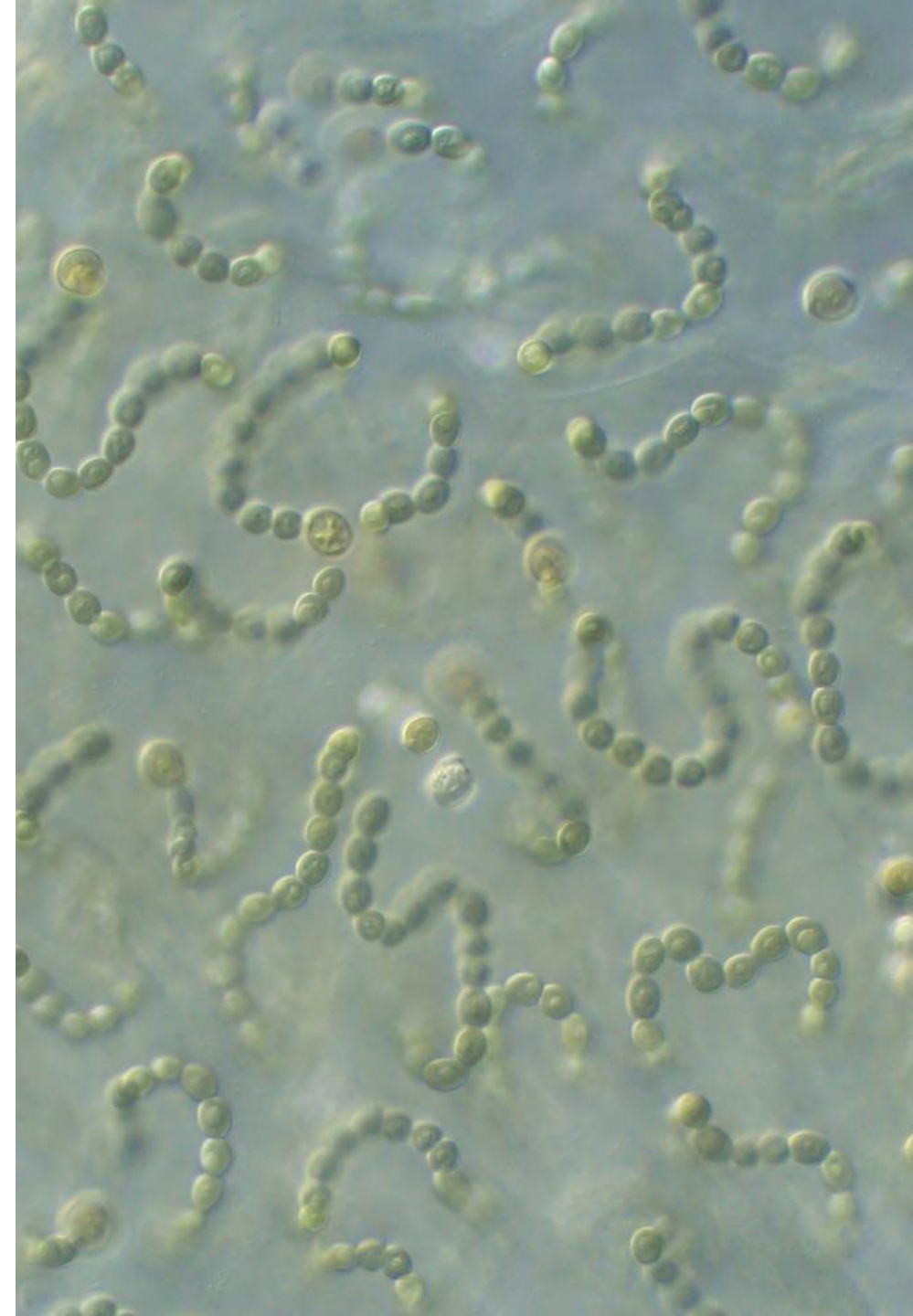
Cyanobacteria are characterized by the formation of linear (unbranched) filaments called trichomes.

Parallel trichomes can then further join together to **form bundles of filaments** - flakes (Puman 2011).



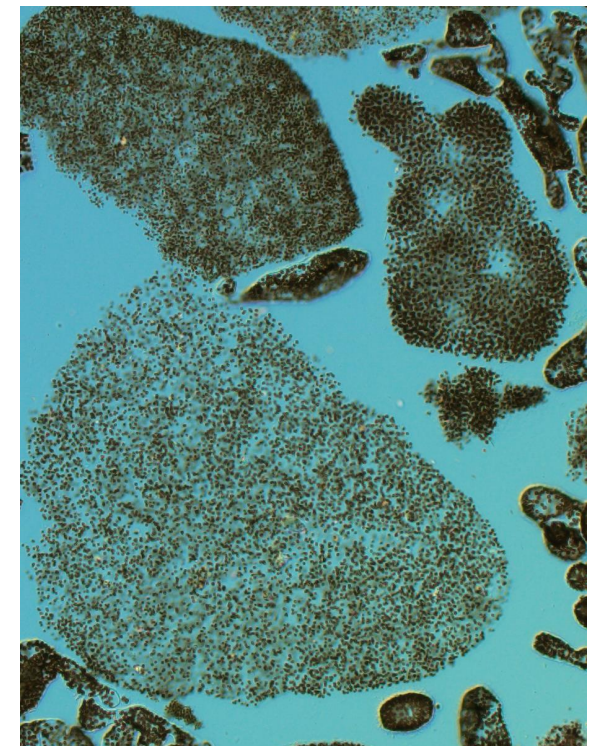
NOSTOC

- Class: Cyanophyceae
- Order: Nostocales
- **Representative: *Nostoc calcicola*, *Nostoc commune*, *Nostoc punctiforme***
- Their blue-green cells form mucilaginous colonies - unbranched filaments resembling strings of beads.
- The filaments may contain **heterocytes** in which **airborne nitrogen is fixed**.
- The quiescent stages of the cells are referred to as akinetes.
- Nostoc can grow symbiotically inside the cells of the aquatic fern Azolla.
- Cosmopolitan occurrence, even in cold environments - Antarctica.



WATER BLOOM

- Water bloom refers to the striking green colouration of water caused by an overgrowth of microorganisms in the water, especially cyanobacteria.
- It is most common in late summer in August and September, but due to current climate changes it can be seen as early as June.
- The main representatives of cyanobacteria in aquatic blooms are the genera **Microcystis**, **Aphanizomenon** and **Anabaena**.
- Water blooms are associated with **eutrophication**, the process of enriching water with nutrients, mainly nitrogen and phosphorus.
- Photographs of a natural water source with water bloom and microphotographs of cyanobacteria.





IMPORTANCE FOR HUMANS

Positive:

Part of the diet in eastern countries (Asia, Japan, China)

Biofuel production

Source of B vitamins and carotenes

Biomedical research, use of cyanobacterial compounds to inhibit the growth of other bacteria, cancer therapy

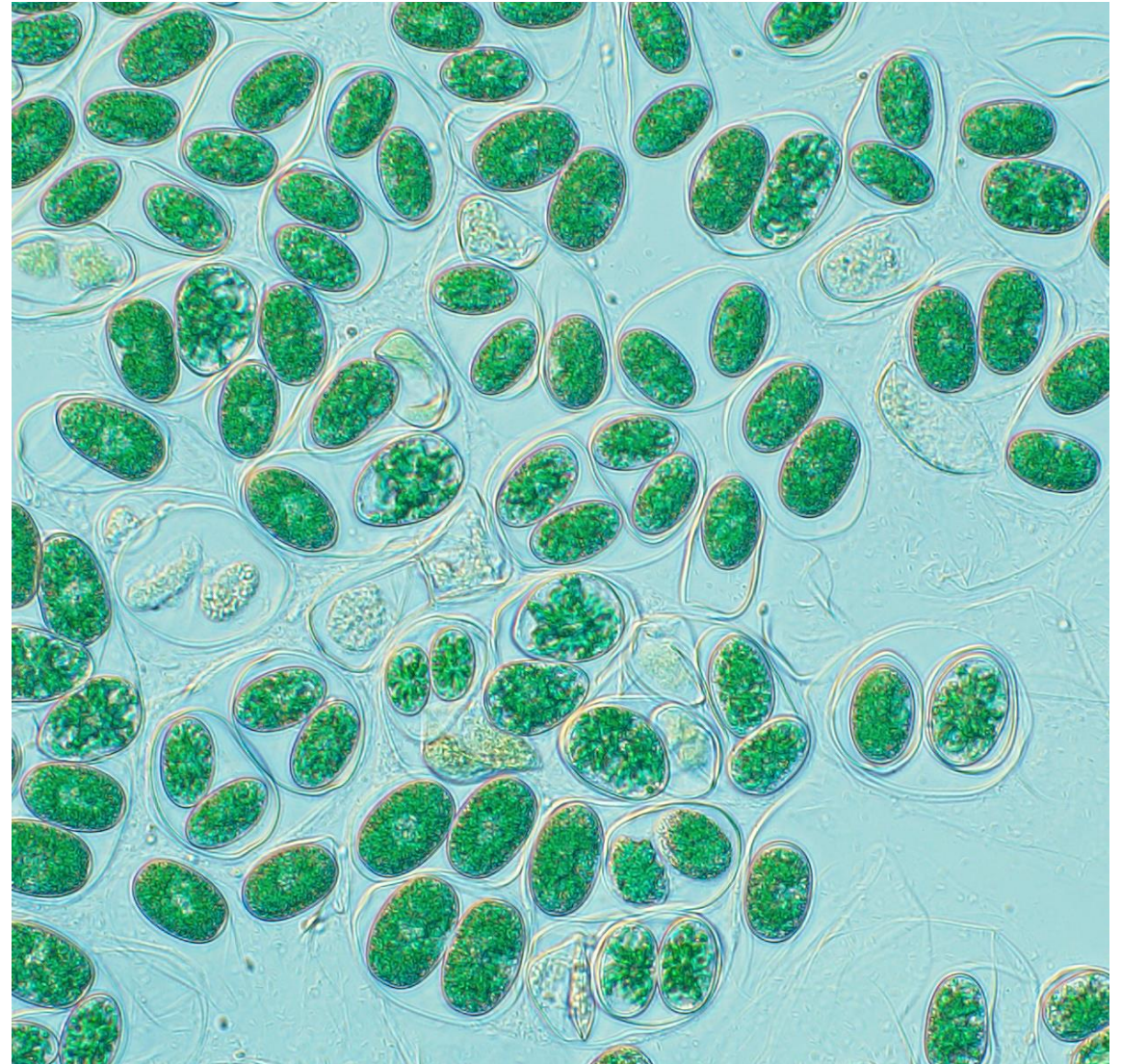
Negative:

Cyanotoxins

Water bloom

GLAUCOCYSTIS NOSTOCHIARUM

- The freshwater alga ***Glaucocystis nostochinearum*** has interesting plastid organelles called **cyanelles**.
- These organelles are bounded by peptidoglycan.
- This leads to the speculation that in this case, **according to the endosymbiotic theory**, the cyanobacteria penetrated the cells of the original glaucophytes.
- Peptidoglycan is found in the surface structures of bacteria.



QUESTIONS TO PRACTICE

- 1) How can you characterize cyanobacteria?
- 2) What is a stromatolite?
- 3) What do cyanotoxins cause, what is their toxicity?
- 4) Explain the concept of an aquatic bloom.
- 5) In what genus of cyanobacteria do you find microcystins?
- 6) Explain what it is, and what is the purpose of an akinete?
- 7) What is the function of heterocytes?
- 8) What is the purpose of hormogonia?
- 9) What are cyanelles, where do we find them?
- 10) State the main differences between cyanobacterial cells and green algal cells.

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9. Author of all microphotographs in the presentation, photos of water with water bloom - Mgr. V. V. Vymětalová, Ph.D., the samples for the preparation of the slides are from natural sources at P6 and P7, the genus *Arthrospira* is a culture from the Faculty of Science of Charles University.