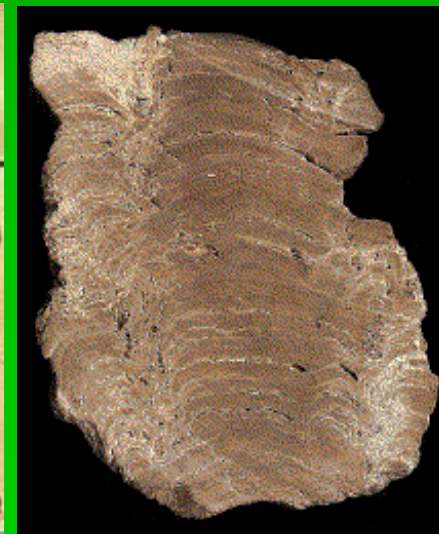
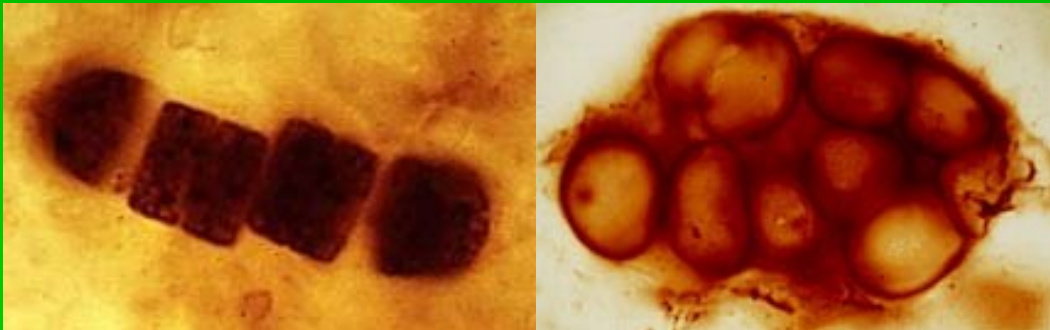


Stromatolites

- stromatolites – trapping and binding of the sediments as well as carbonate precipitation in cyanobacterial sheaths (from 2.5 mld Proterozoic) or „sediment trapping“ – Precambrium - 3,5 mld years old



Stromatolites

heliotropic –
grow toward
sunlight

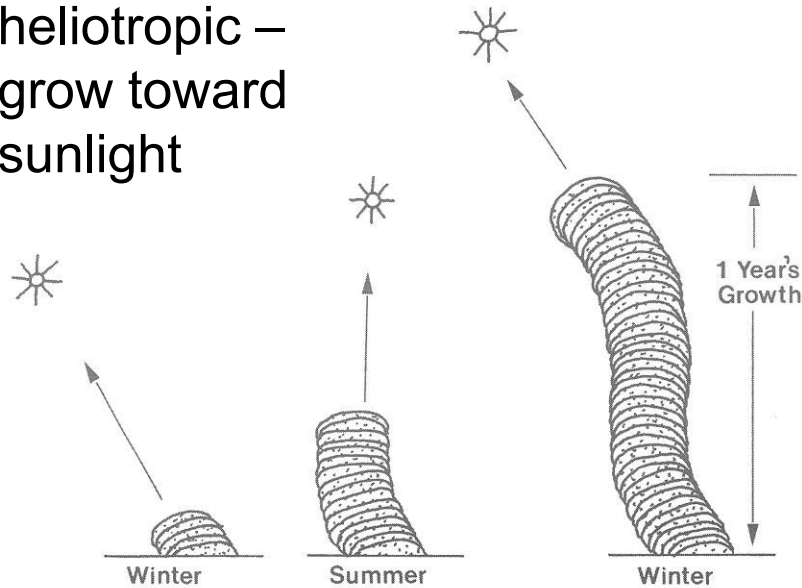
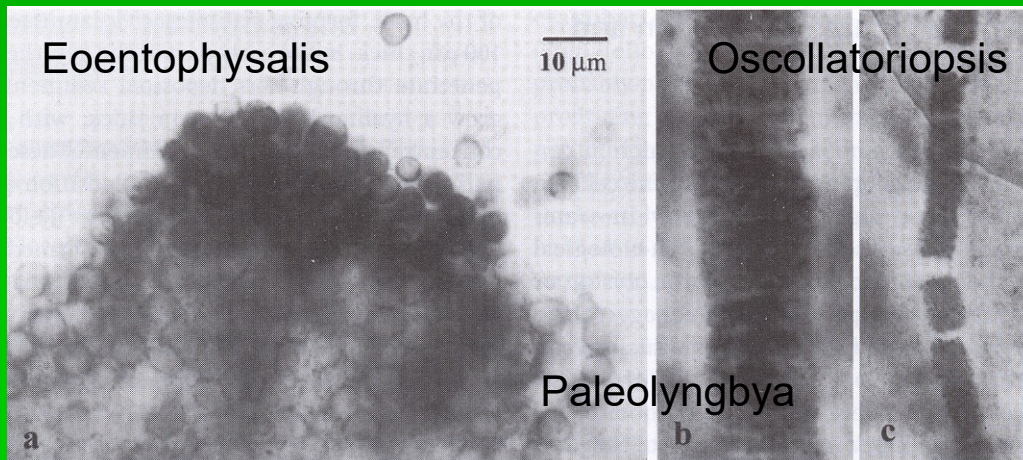


Fig. 2.55 Diagrammatic representation of the growth of a stromatolite over the period of a year. A year's growth is represented by an S-shaped curve.

Circadian clock

Counting of the
number of laminae



solar year varied considerably
1 billion y ago – 435 days

fossil cyanobacteria from the stromatolite, 1.4 mld years old

Stromatolites

- live stromatolites – Western Australia, Shark's Bay



hypersaline



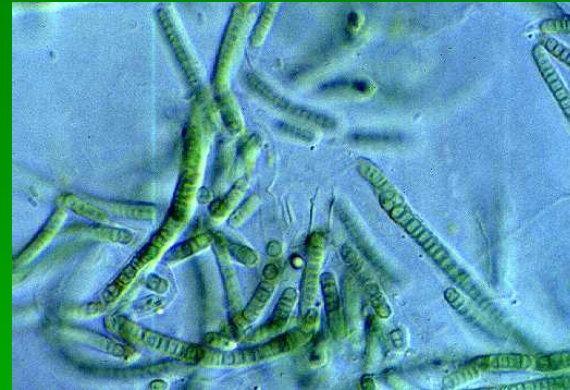
maximum in number and
diversity at 1 mld years ago - no
grazers



Stromatolites

- live stromatolites – southern Florida, Bahamas

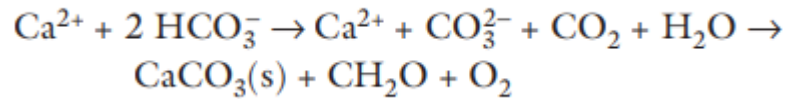
Schizothrix



high tidal current

living
freshwater
stromatolites

(Garcia-Pichel et al.
2004)

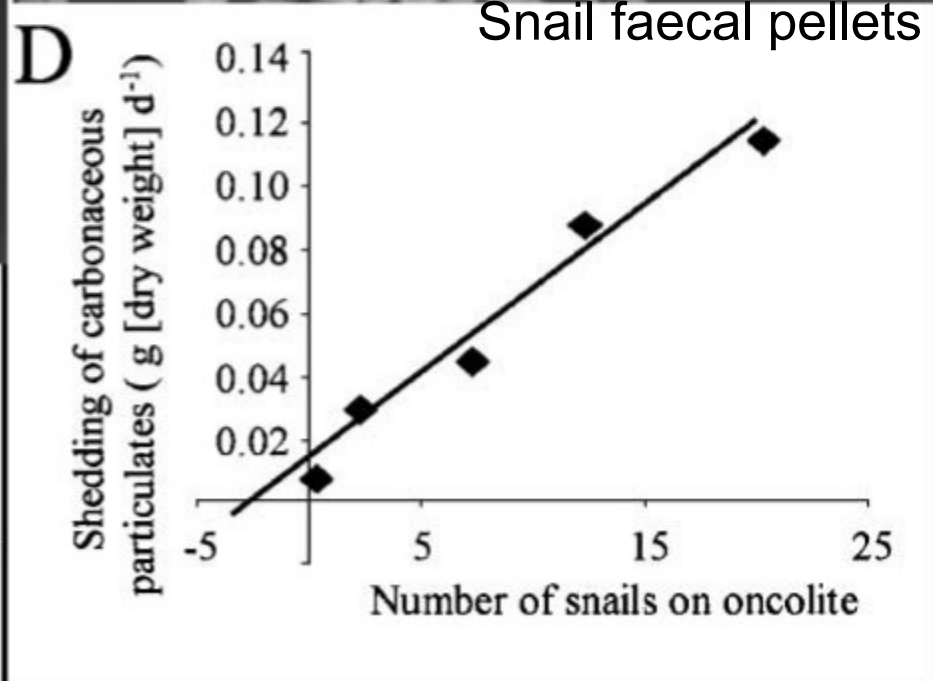
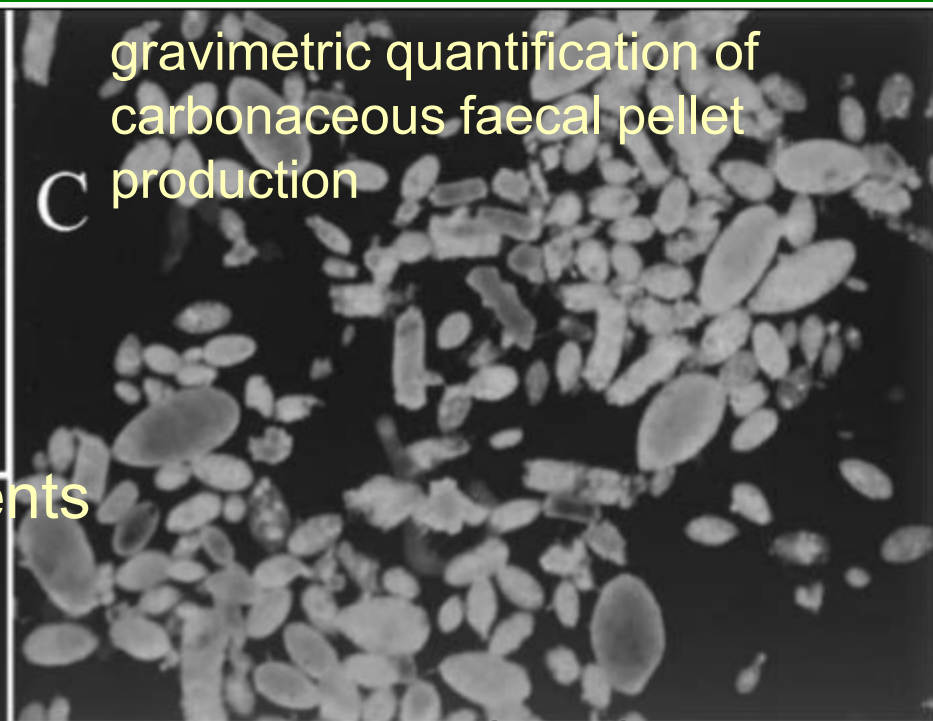
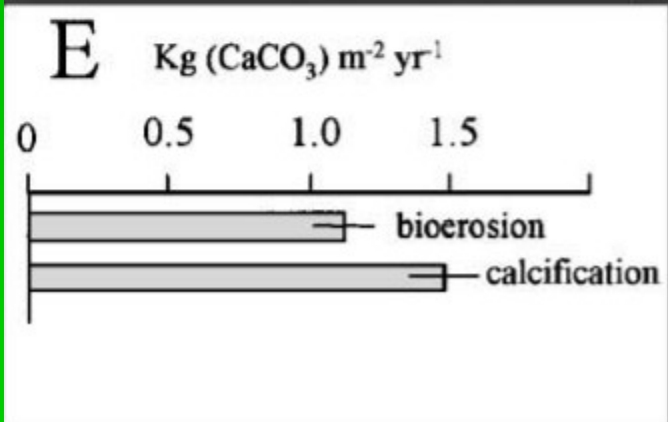
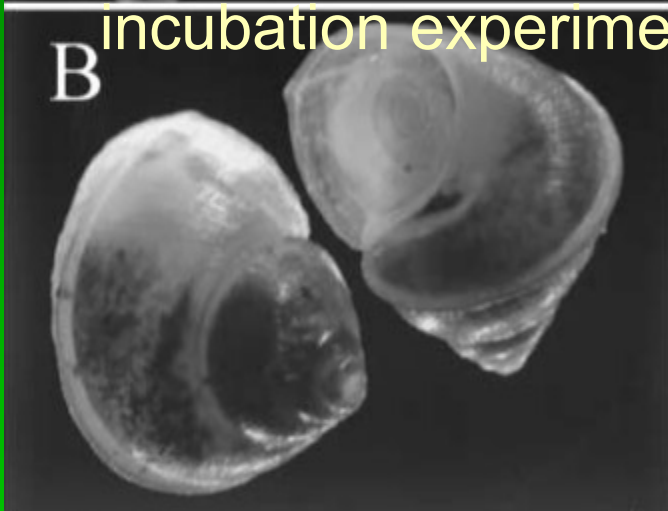
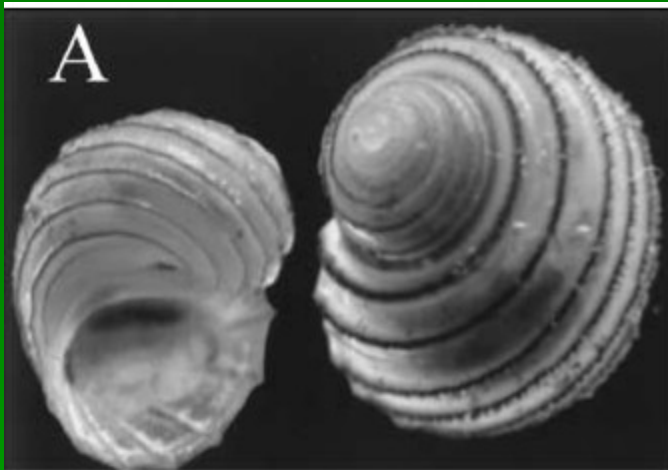


Rio Mesquites, Cuatro Ciénegas,
Coahuila, Mexico



concurrent processes of
microbial calcification and
metazoan bioerosion
(hydrobiid gastropods)





incubation experiments

Snail faecal pellets

Ekology of Cyanobacteria

- ubiquists, predominantly freshwaters, but also marine – pikoplanktonic, extreme biotopes (glaciers, desert soil crusts, hot springs)
- colonization success → they may survive in low light intensities in epilimnium, phenoplastic, produce toxins

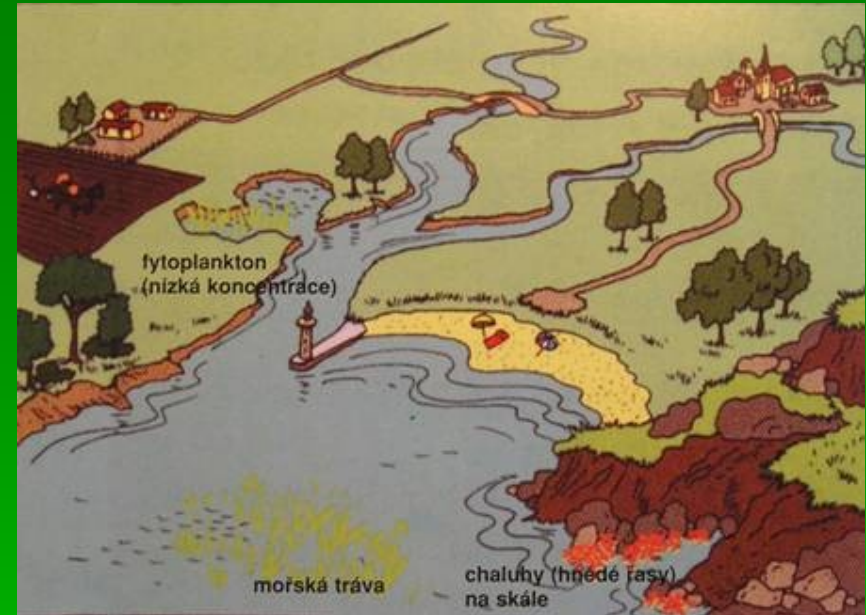
Why there are predominantly small species in the sea?

Eutrophication

- nutrient excess
- freshwater – P- limiting nutrient
- marine env. – N – limiting nutr.
- nutrient runoff from human activities:

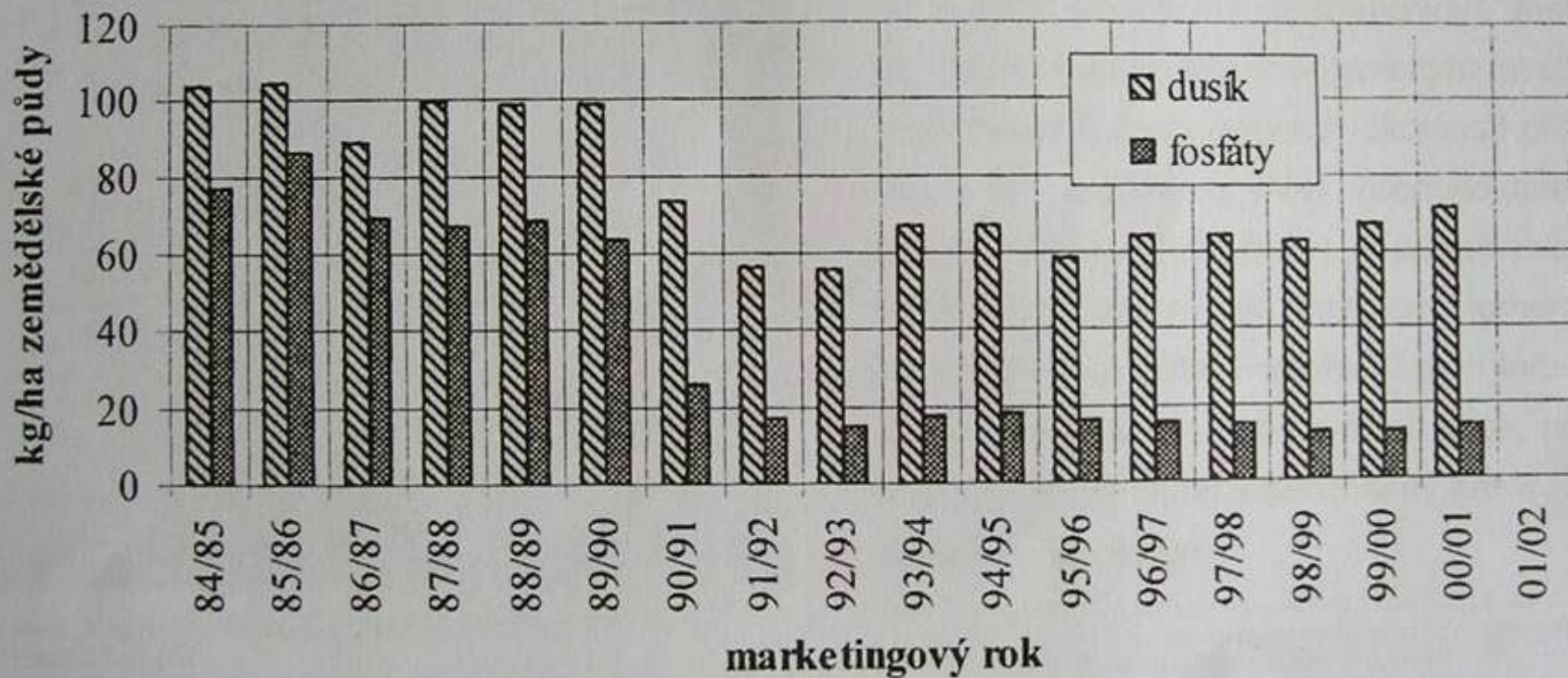
N – surface runoff, erosion

P – industry, household



Eutrophication

- Czech Republic 1985 - 2002



Water blooms



Centrum pro cyanobakterie
a jejich toxiny

www.sinice.cz



<http://www.sinice.cz/>

Cyanotoxins

- **alkaloid neurotoxins (block transmission of the signal from neuron to muscle)**

anatoxin, saxitoxin, aphanotoxin

- **alkaloid hepatotoxins**

cylindrospermopsin

- **peptidic hepatotoxins**

microcystin, nodularin

- **lipopolysaccharides**

component of cell walls in all cyanobacteria, alergen

Cyanotoxins – over 50 species produced them

Genus	Produced toxins
<i>Dolichospermum</i>	anatoxins, microcystins, saxitoxins, LPS
<i>Aphanizomenon</i>	saxitoxins, cylindrospermopsins, LPS
<i>Raphidiopsis</i> = <i>Cylindrospermopsis</i>	cylindrospermopsins, saxitoxins, LPS
<i>Hapalosiphon</i>	microcystins, LPS
<i>Lyngbya</i>	aplysiatoxins, Lyngbyatoxin-a, LPS
<i>Microcystis</i>	microcystins, LPS
<i>Nodularia</i>	nodularins, LPS
<i>Nostoc</i>	microcystins, LPS
<i>Phormidium</i> (<i>Oscillatoria</i>)	anatoxins, LPS
<i>Planktothrix</i> (<i>Oscillatoria</i>)	anatoxins, aplysiatoxins, microcystins, saxitoxins, LPS

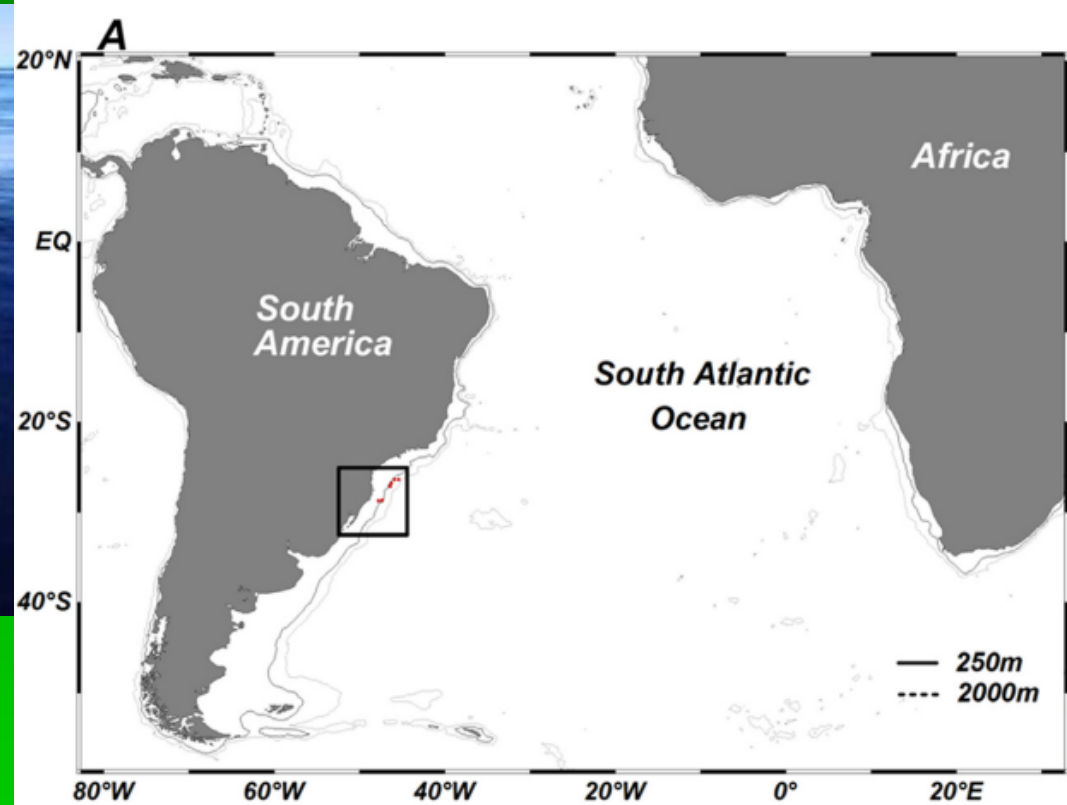
- anti-herbivore chemicals
- allelopathic interactions (affection of growth of other organisms)

investigations into anatoxin-a, also known as "Very Fast Death Factor", began in 1961 following the deaths of cows that drank from a lake containing an algal bloom in Saskatchewan, Canada.

Cyanotoxins

- *Trichodesmium* –saxitoxin, continental slope of the southwestern South Atlantic Ocean, toxins are harmful to shrimp larvae and plankton

nutrient poor waters

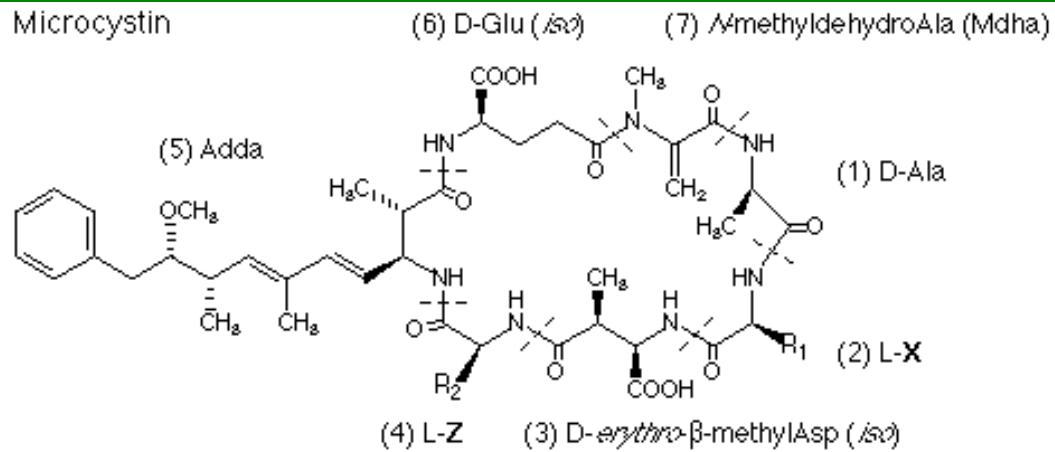


alkaloid neurotoxin

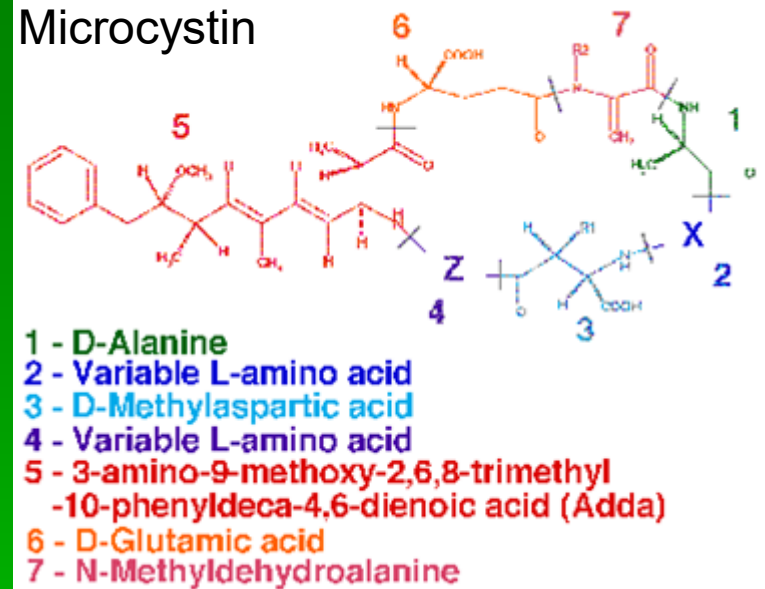
(Detoni et al. 2016)

Cyanotoxins

Microcystin



Microcystin

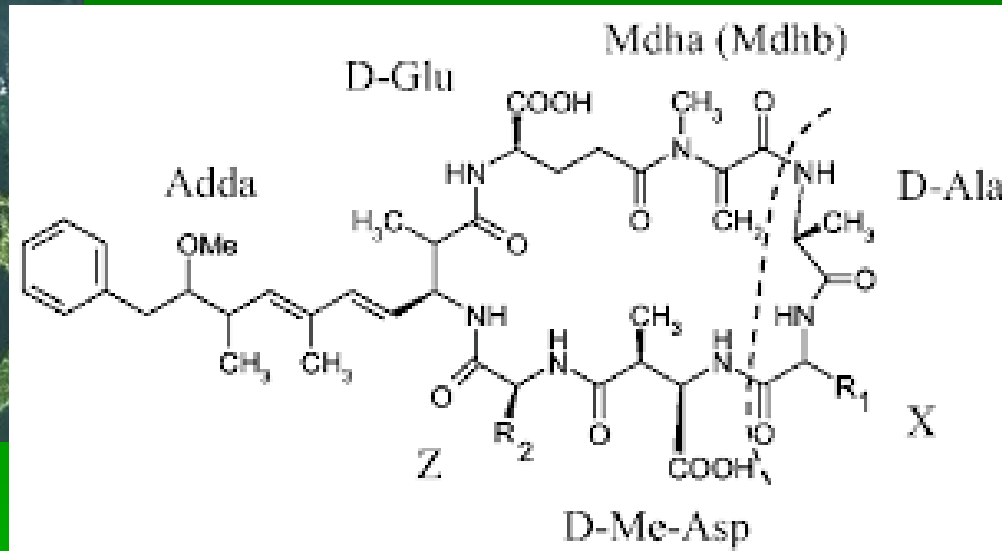


Microcystis a *Anabaena*

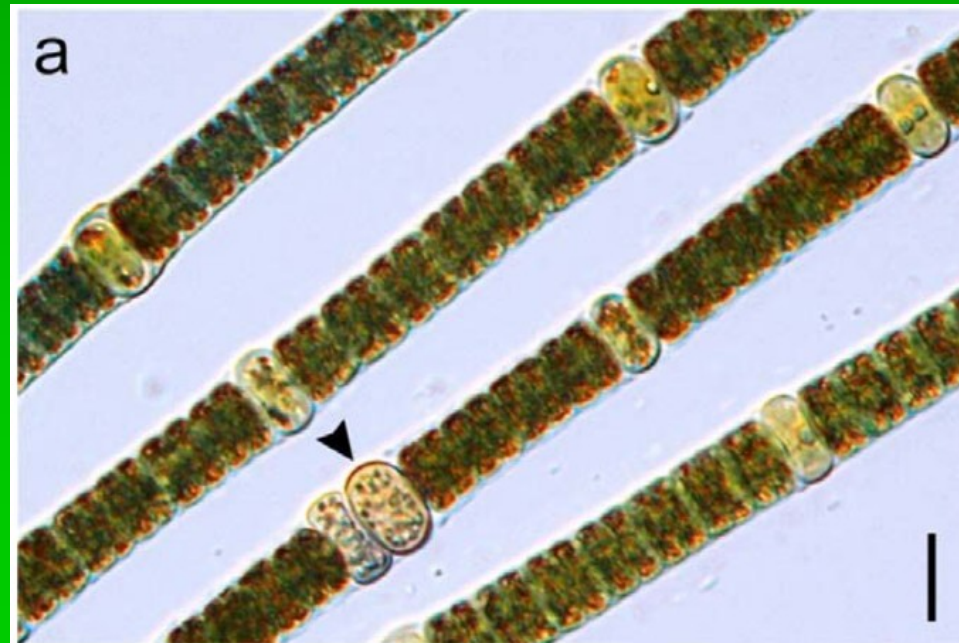
peptidic hepatotoxin

Cyanotoxins

peptidic hepatotoxin

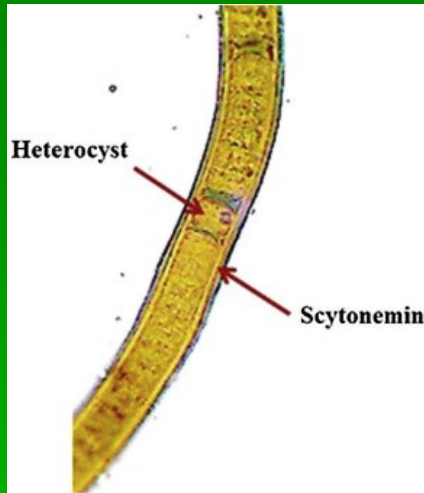


nodularin

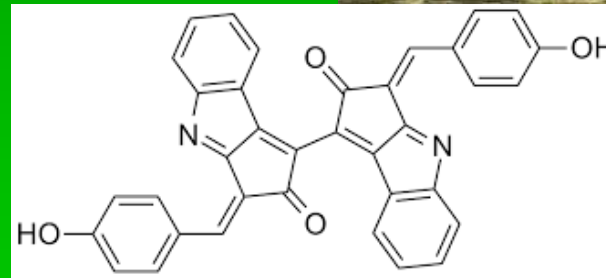
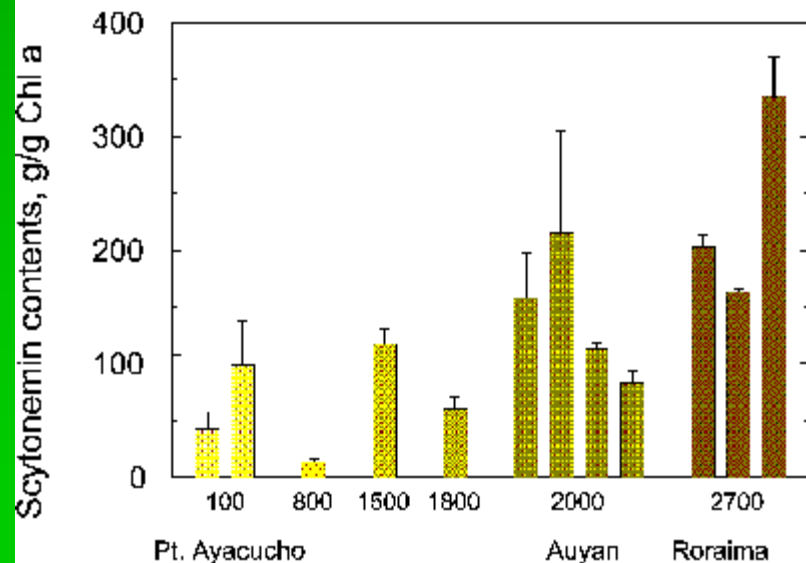
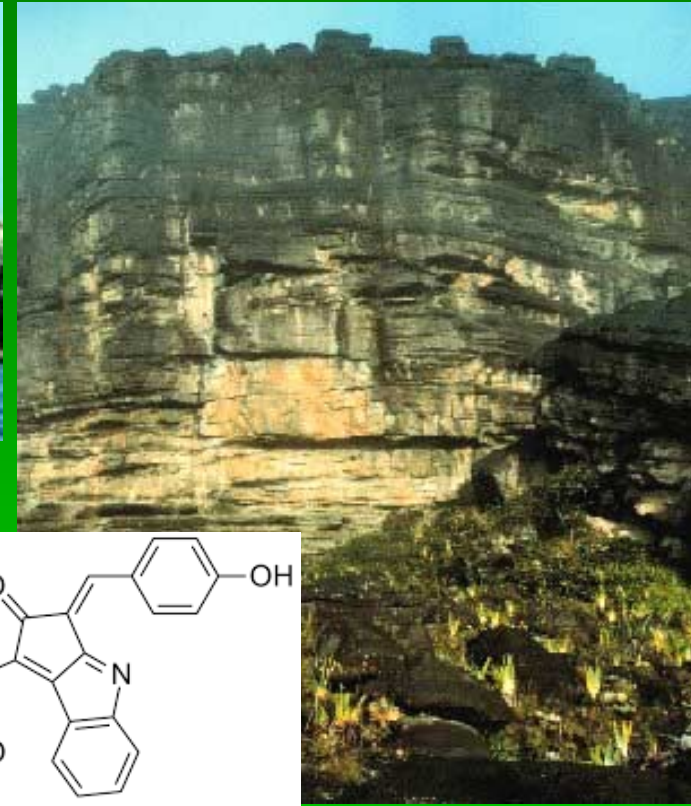


Epilithic cyanobacteria

- dark colour, UV protection



is compared to altitude

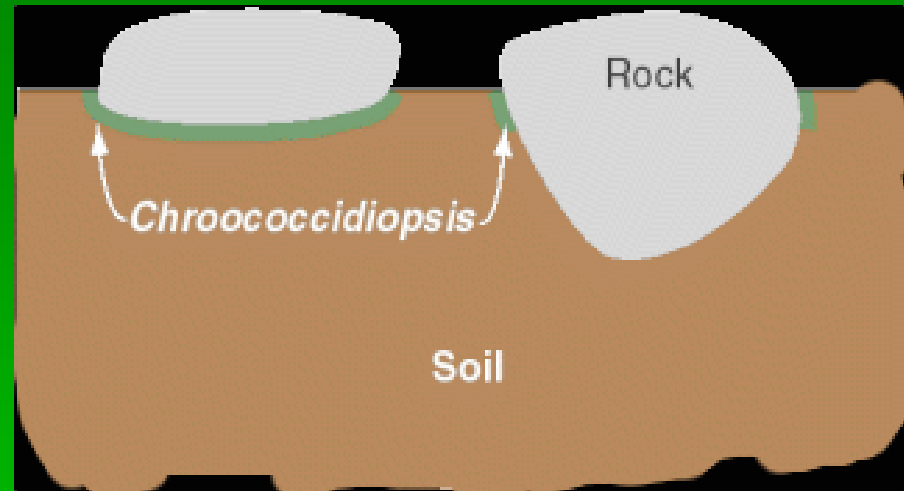
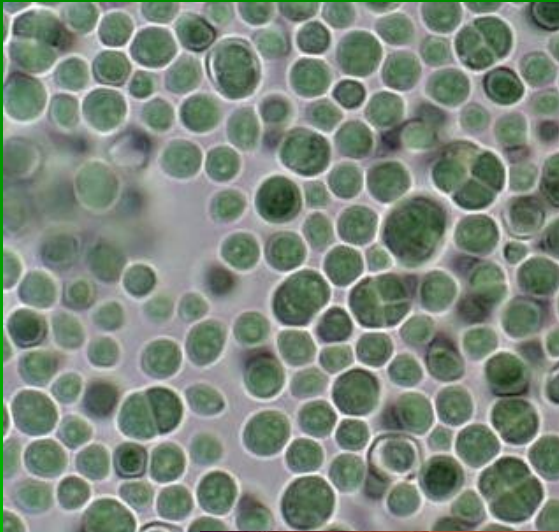


aromatic indole alkaloid

High scytonemin content (UV A protection) correlated with the magnitude

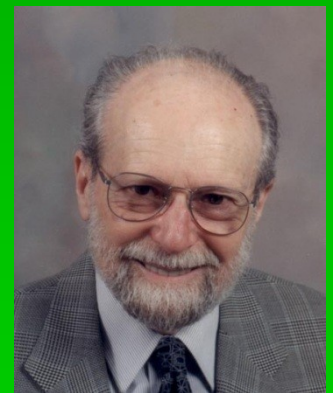
Epilitic cyanobacteria

- *Chroococcidiopsis* –able to survive extreme environments; NASA project – Mars colonization, E.I.Friedmann, astrobiologist



lives in deserts under the translucent stones (humidity collectors, UV protection)

Microbial ecology of absolute extreme environments

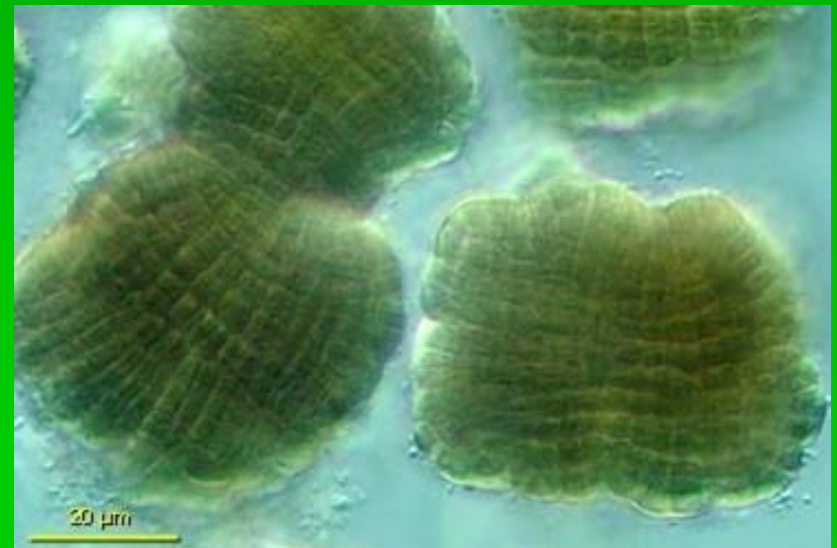


Grilli-Caiola, M., D. Billi and E. I. Friedmann. 1996. Effect of desiccation on envelopes of the cyanobacterium *Chroococcidiopsis* sp. (Chroococcales). *Eur. J. Phycol.* **31**:97-105.

Endolithic cyanobacteria



- *Chroococcidiopsis* – underside of translucent stones



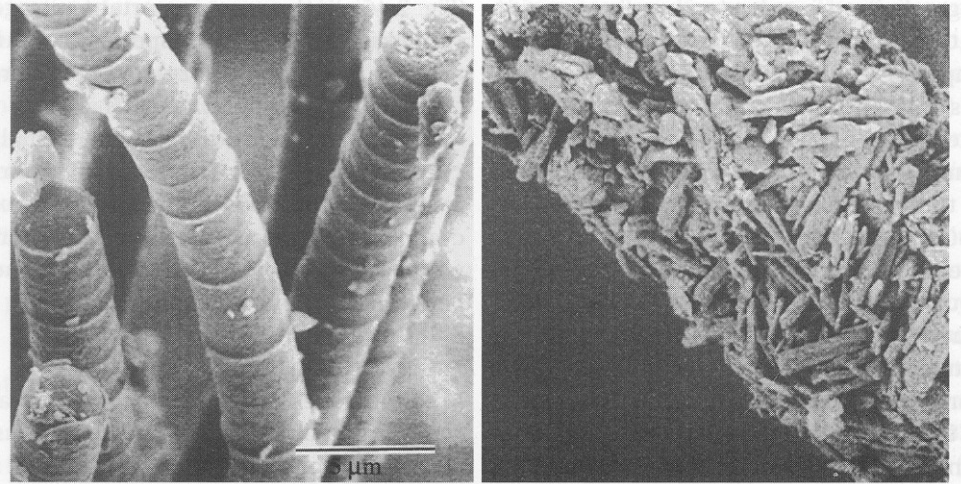
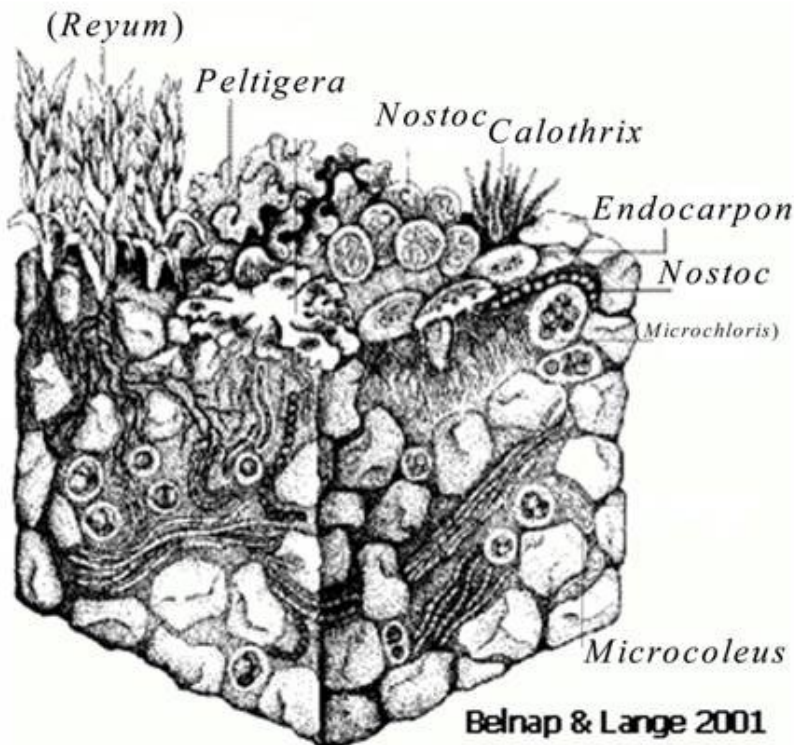
Cyanobacteria in microbial crusts

- bind particles – soil stabilisation → prevent erosion
- retain humidity, warming of the soil surface
- nitrogen enrichment of the soil (10-25 kg/ha/year) → nutrient input



Soil crusts

- cyanobacteria, algae, mosses, lichens, fungi
- cyanobacteria and lichens dominant in hot deserts
- cyanobacteria to algae ratio changes with pH ($\downarrow$ pH – green algae dominate)
- typical genera: *Scytonema*, *Lyngbya*, *Oscillatoria*, *Microcoleus*, *Nostoc*, *Calothrix*, *Aphanocapsa*, *Chroococcidiopsis*



Microcoleus vaginatus

Termophilic cyanobacteria – hot springs

extreme 70-73°C
enzymes stable at higher temp.

Synechococcus

green non-sulphur bacteria

Synechococcus, *Phormidium*



Octopus Spring, Yellowstone NP



Phormidium



Mushroom Spring

60°C

Synechococcus

Mastigocladus laminosus

Miller et al. 2007, APPLIED
AND ENVIRONMENTAL
MICROBIOLOGY



M. laminosus is found in thermal areas
throughout the world

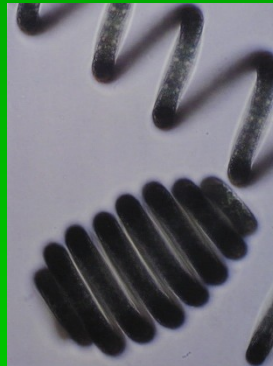
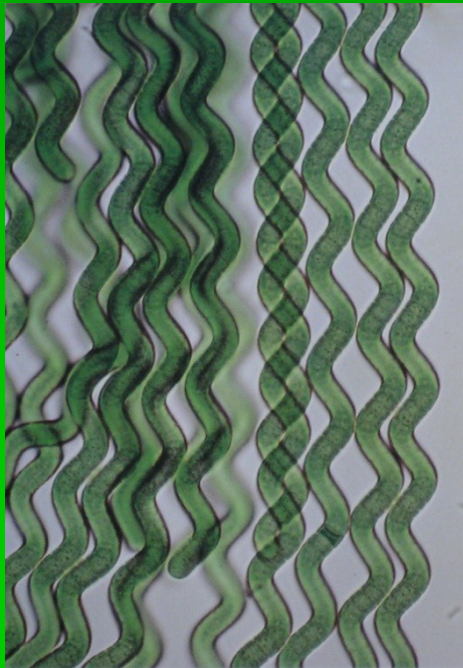
populations are typically genetically
differentiated on local geographic scales
suggests the existence of dispersal barriers

conclusion corroborated by evidence for
genetic isolation by distance



Limnospira (Arthrospira)

tropical lakes, large-scale cultivations, dietary supplements



Limnospira

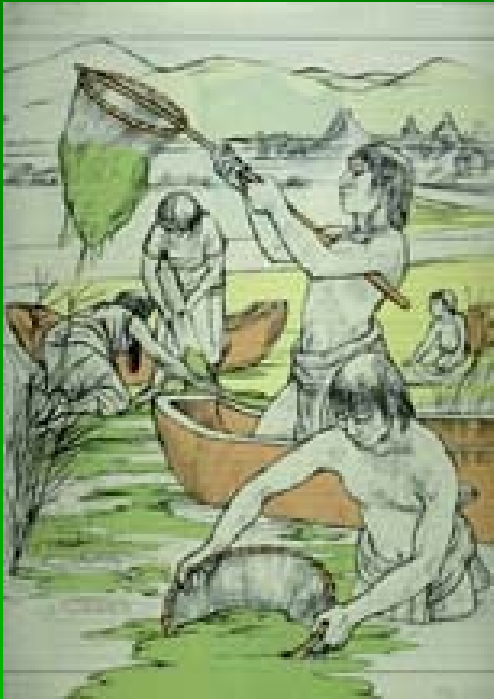
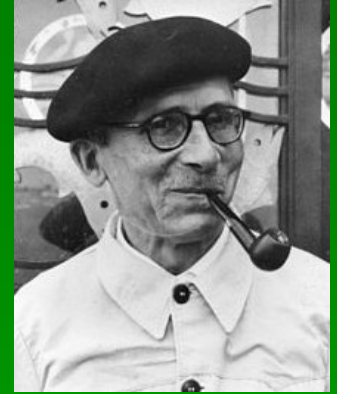


Illustration from the Florentine Codex (1540 - 1585) showing how the Aztecs collected spirulina (*Limnospira*) from the surface of lakes using ropes

The Aztecs collected spirulina on the surface of lakes in the Valley of Mexico
Drawing in Human Nature, March 1978.



„dihe“ cakes Lake Chad



French phycologist Pierre Dangeard was the first to recognize Spirulina in “dihe” cakes produced by local people from Kanembu tribe





India



USA Hawai - Cyanotech



contains essential amino-acids, high protein and chlorophyll content
digestible cell wall, vitamins (B₁₂), carotenoids, Fe

Symbiotic interactions

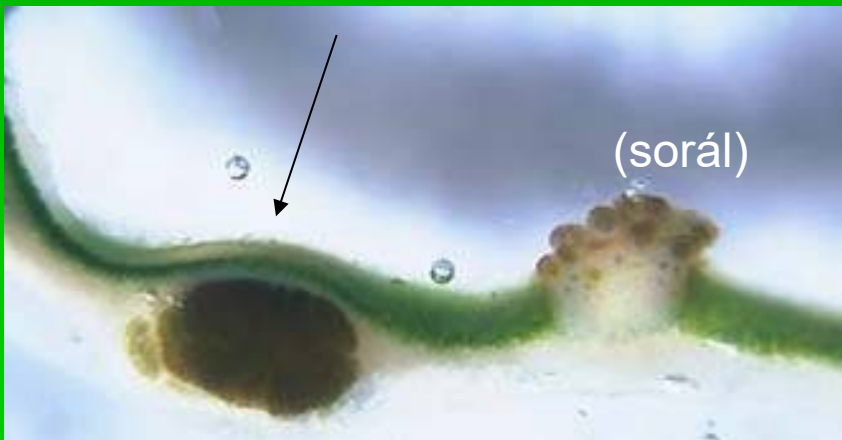
- origin of plastids
- with algae – diatoms, dinophytes, Glaucophyta (cyanels)
- with fungi – lichens, *Geosiphon*
- with Bryophytes – *Blasia*, hornworts
- with ferns – *Azolla*
- with cycas
- *Gunnera*
- different degree of assimilation, it may be isolated into the culture

Symbiotic interactions

- with fungi – lichens



Lobaria – cephalodium, *Nostoc*



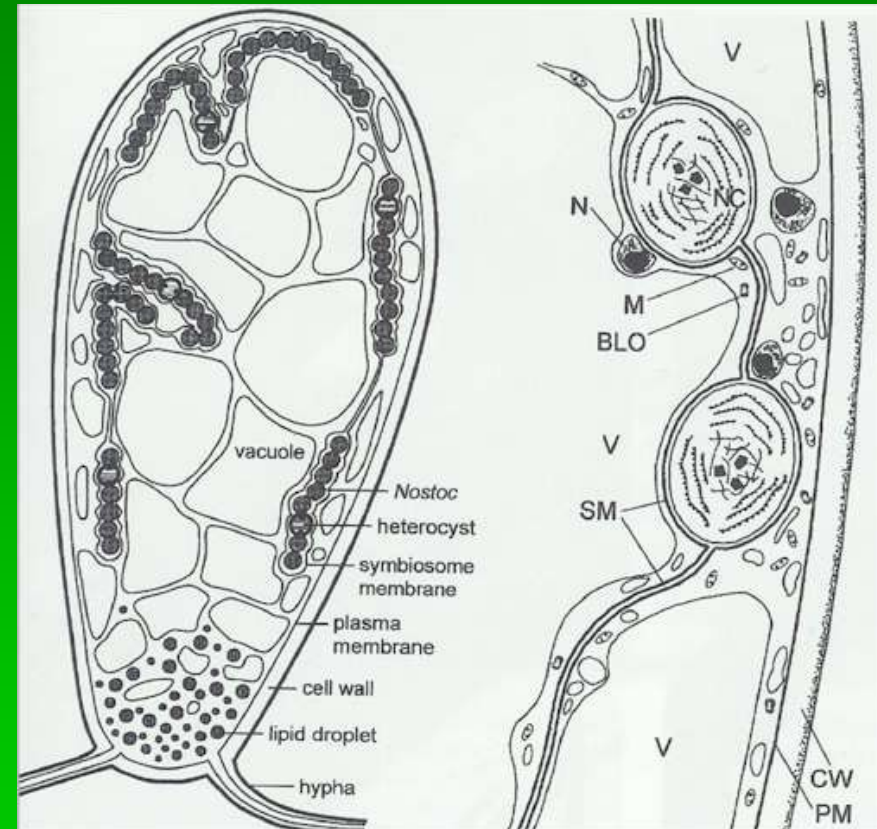
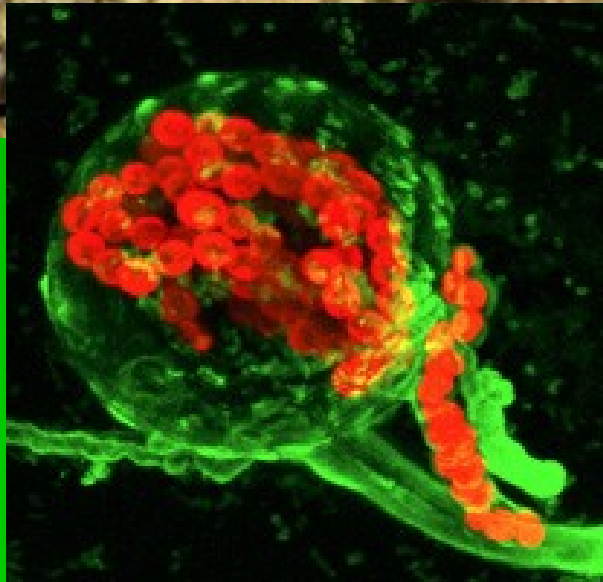
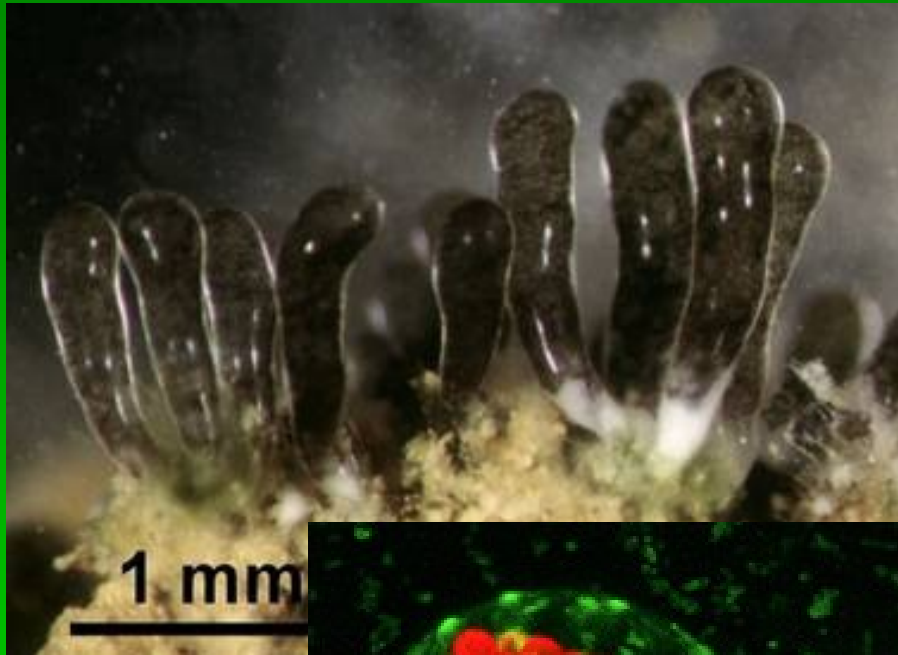
Collema - *Nostoc*



Peltula - *Chroococcidiopsis*

Symbiotic interactions

- with fungi– *Geosiphon* – Glomeromycota



Symbiotic interactions

- with Bryophytes – *Blasia*, hornworts *Anthoceros*



Blasia



Anthoceros

liverworts and hornworts

Symbiotic interactions

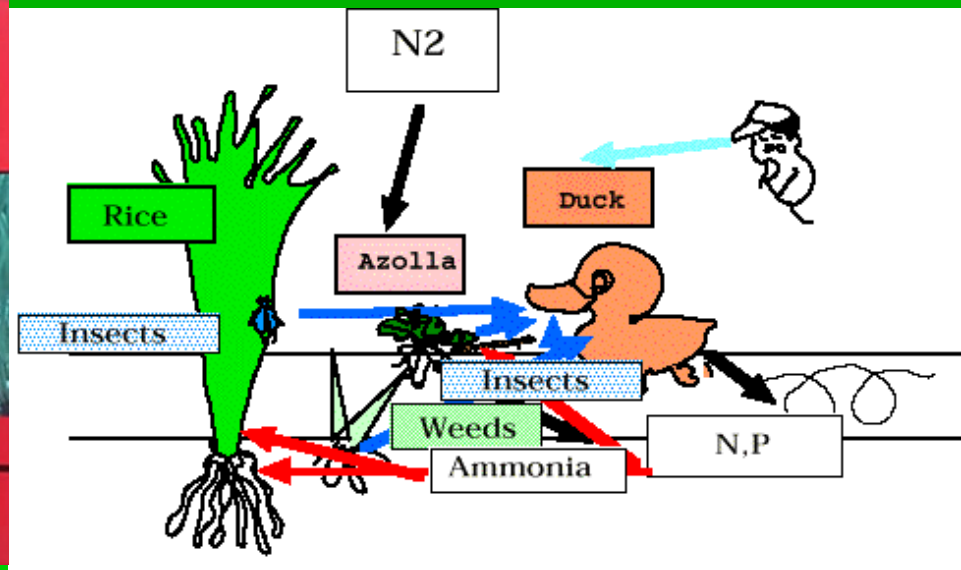
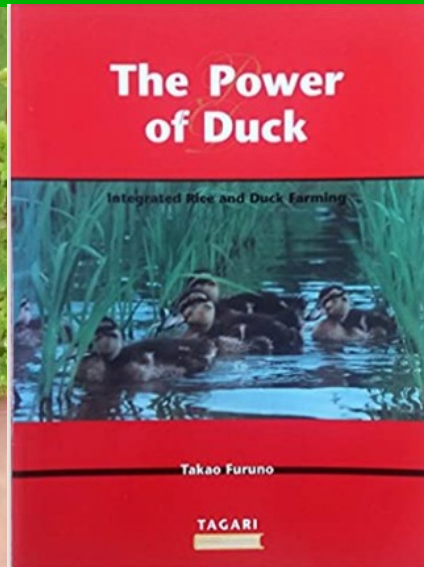
- with ferns – *Azolla* has *Nostoc* in meristems



biofertilizer in rice
paddies, fixation 20 x
higher within *Azolla*,



Rice fields 'fertilized' with Azolla fern (carries a symbiotic cyanobacterium) – growing organic rice without artificial fertilizers and pesticides.



Azolla event

From greenhouse Earth to icehouse Earth



Hypothetical scenario: Middle Miocene (around 49 million years ago) Azolla covered the entire Arctic Ocean.

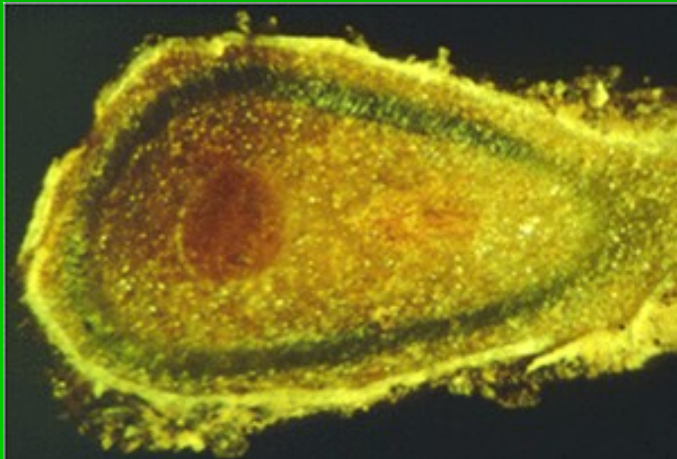
At the end of each growing season, it sank into the sediment annually for 800,000 years – a carbon trap (CO_2 sequestration – reducing concentration by 80% in less than a million years; from 3500 ppm to 650 ppm; today 421). Cooling effect on the Earth's climate.

Symbiotic interactions

- with cycases (*Nostoc*) cortex of aboveground roots



Cycas - roots



Neurotoxin BMAA produced by *Nostoc*



beta-
methylamine L-
alanin

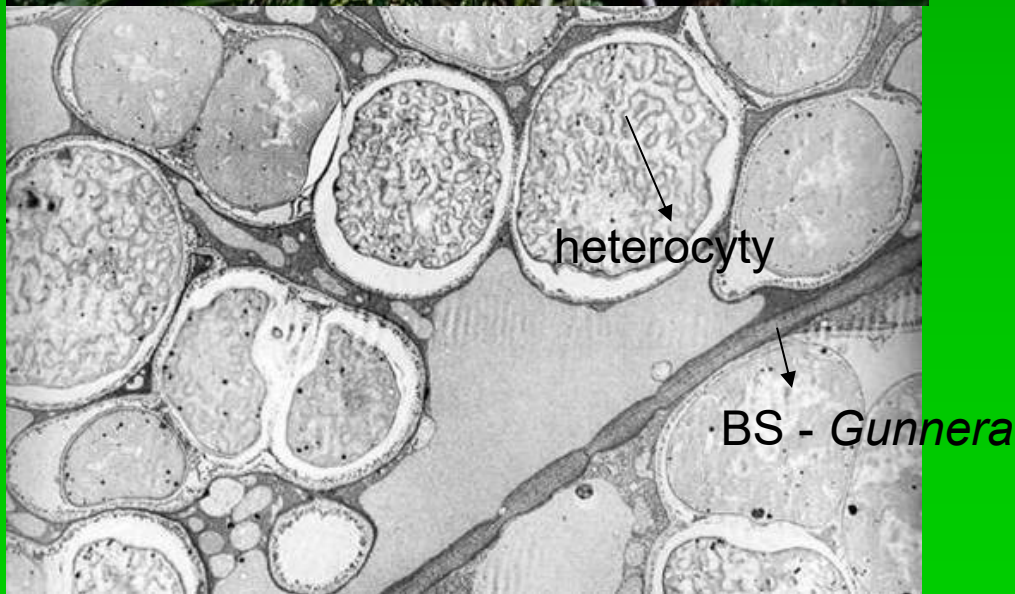
BMAA: mechanism for its biomagnification (10-240x) through increasing trophic levels. Within brain tissues, the endogenous neurotoxic reservoir can slowly release free BMAA, thereby causing incipient and recurrent neurological damage over years or even decades

Murch et al. 2004



Symbiotic interactions

- *Gunnera chilensis* (mucilage-filled glands in the stems)- *Nostoc*





Prochloron and ascidians:

The tunic contains mycosporins which filter out ultra-violet radiation and protect the symbiotic cyanobacteria from damage in strong sunlight

cloacal cavity

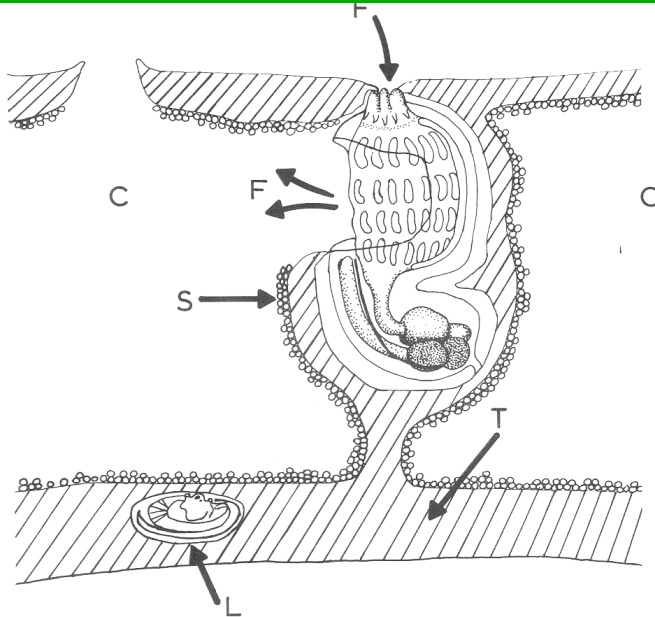
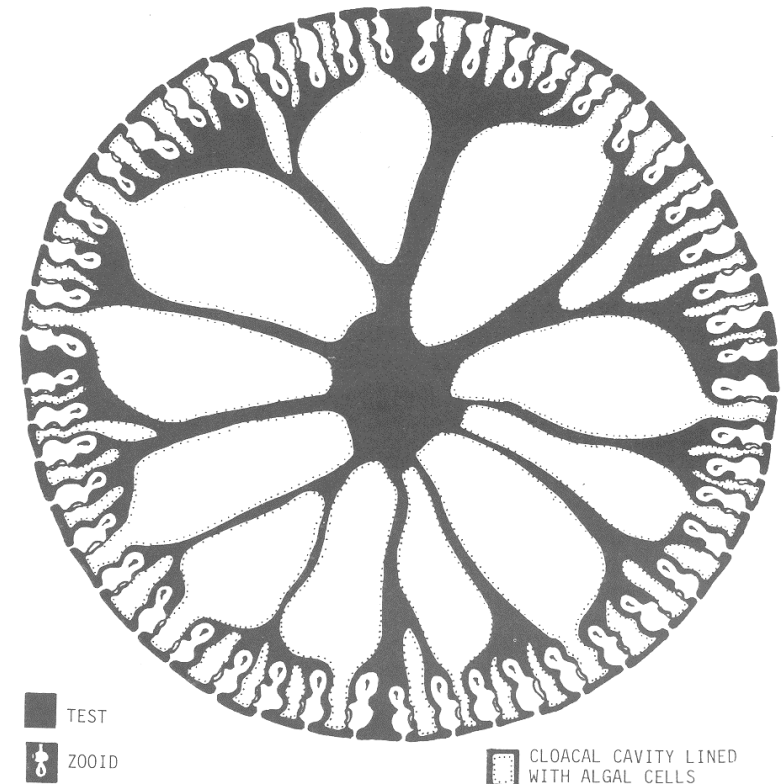


Fig. 3. Diagram of a single zooid showing its position within the test and relationship to the cloacal canals and symbiotic algae. F, direction of water flow; C, common cloacae; S, algal symbionts; T, test matrix; L, larva. (From Kott 1982).



Prochloron and ascidians

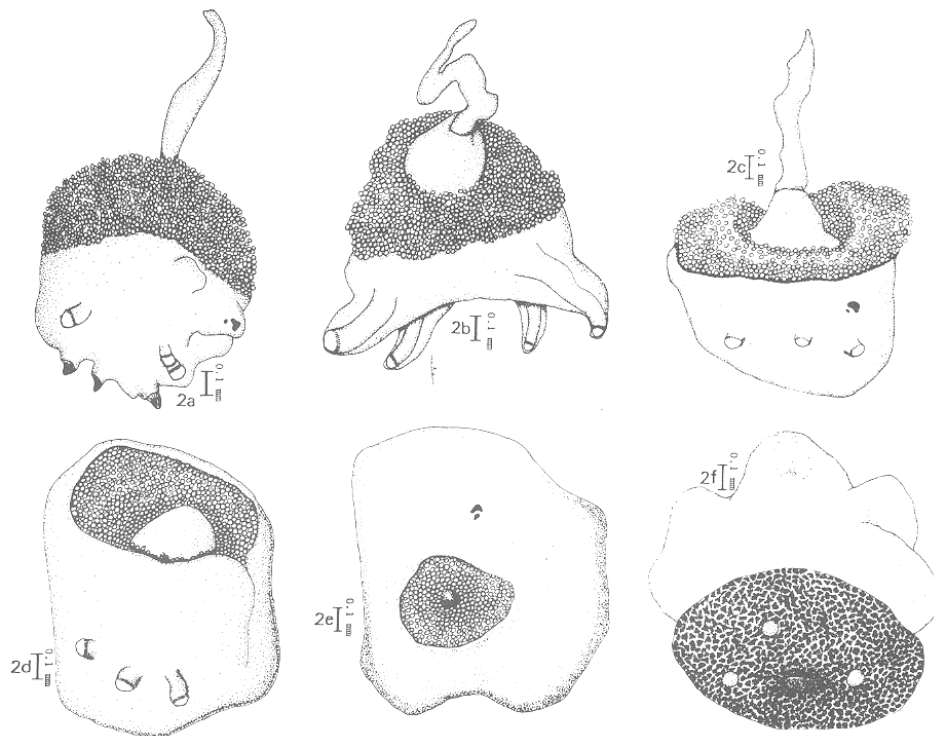


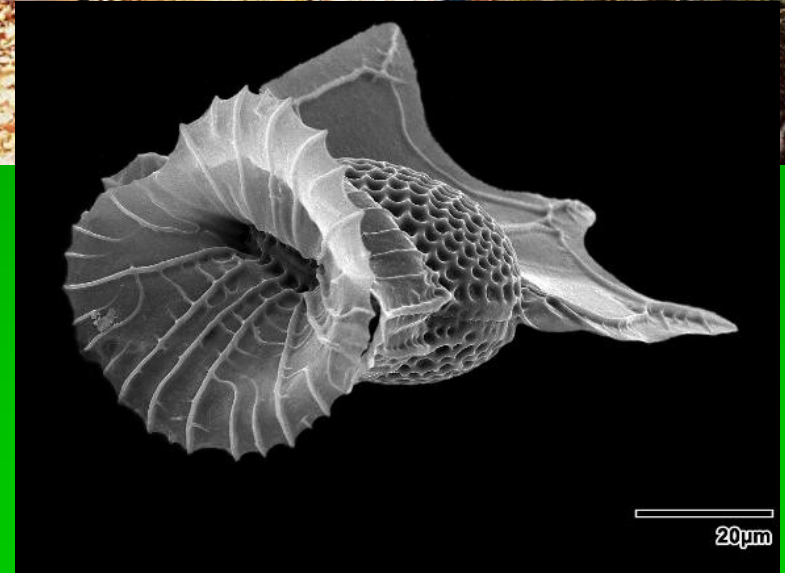
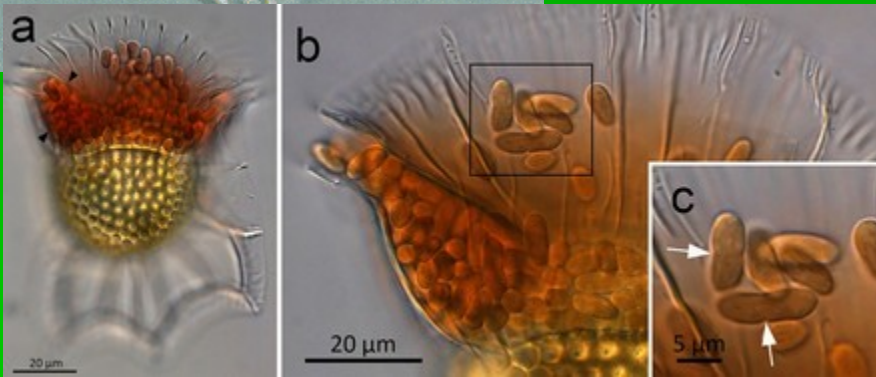
Fig. 5. Series of diagrams showing the metamorphosis of a didemnid larvae. Note how the tissue overgrowth brings about encapsulation and internalization of the symbiotic algae. The view in e is from above looking down into what will be the cloacal cavity. The diagram in f shows a ventral-lateral view of a colony variant which has a pigmented base. (From Kott 1982).



Prochloron + *Didemnum* (Chordata, Tunicata)



Tropical marine heterotrophic dinoflagellates *Ornithocercus*



Synechococcus/Synechocystis – suitable microaerobic environment for nitrogenase functioning, provision of fixed C. *Ornithocercus* were in effect growing their own “vegetables” and likely consuming the bacteria via a peduncle

Why are cyanobacteria important?

- the only prokaryotes, that produce O_2 by water splitting in the light reaction of photosynthesis
- first terrestrial organisms
- ability of cyanobacteria to perform oxygenic photosynthesis is thought to have converted the early reducing atmosphere into an oxidizing one
- cyanobacterial ancestor – actor of endosymbioses → chloroplast of other algal groups (including vascular plants)
- the simplest organisms with circadian rhythm
- favourite symbiosis partners

The systematics of Cyanobacteria

Castenholz (1992): only genera, so called „static evolution“

Van den Hoek et al. (1995): 2000 species in 150 genera

Komárek & Anagnostidis (1999): thousands of species

the frequency of horizontal gene transfer (HGT) and homologous recombination (HR) decreases with the genetic distance – there seem to be coherent evolutionary lineages, which might be called species

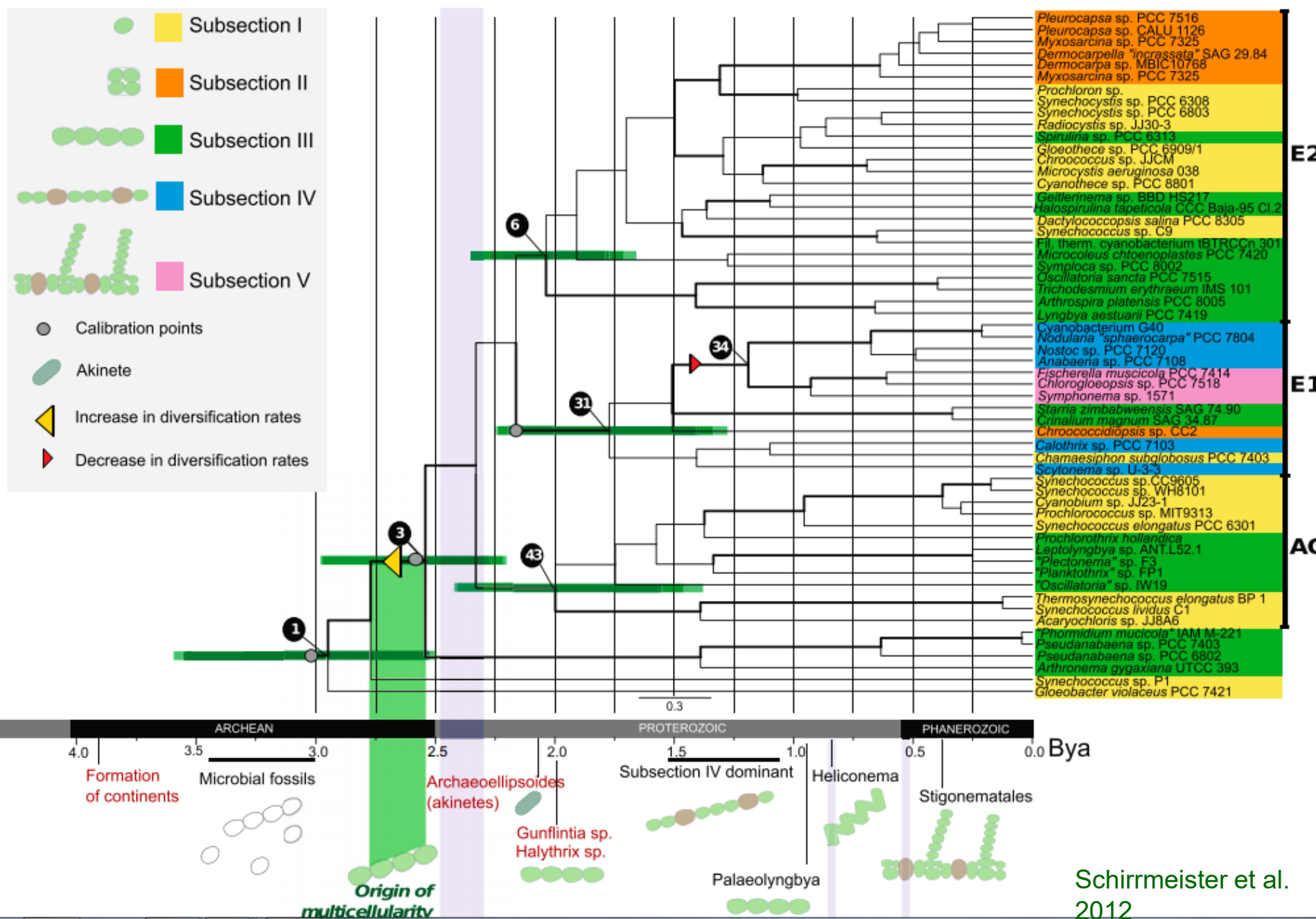
The systematics of Cyanobacteria

Taxonomic scheme according to Bergey's Manual of Systematic Bacteriology 2nd Edition

D.R. BOONE, R.W. CASTENHOLZ, G.M. GARRITY (eds), 2001.

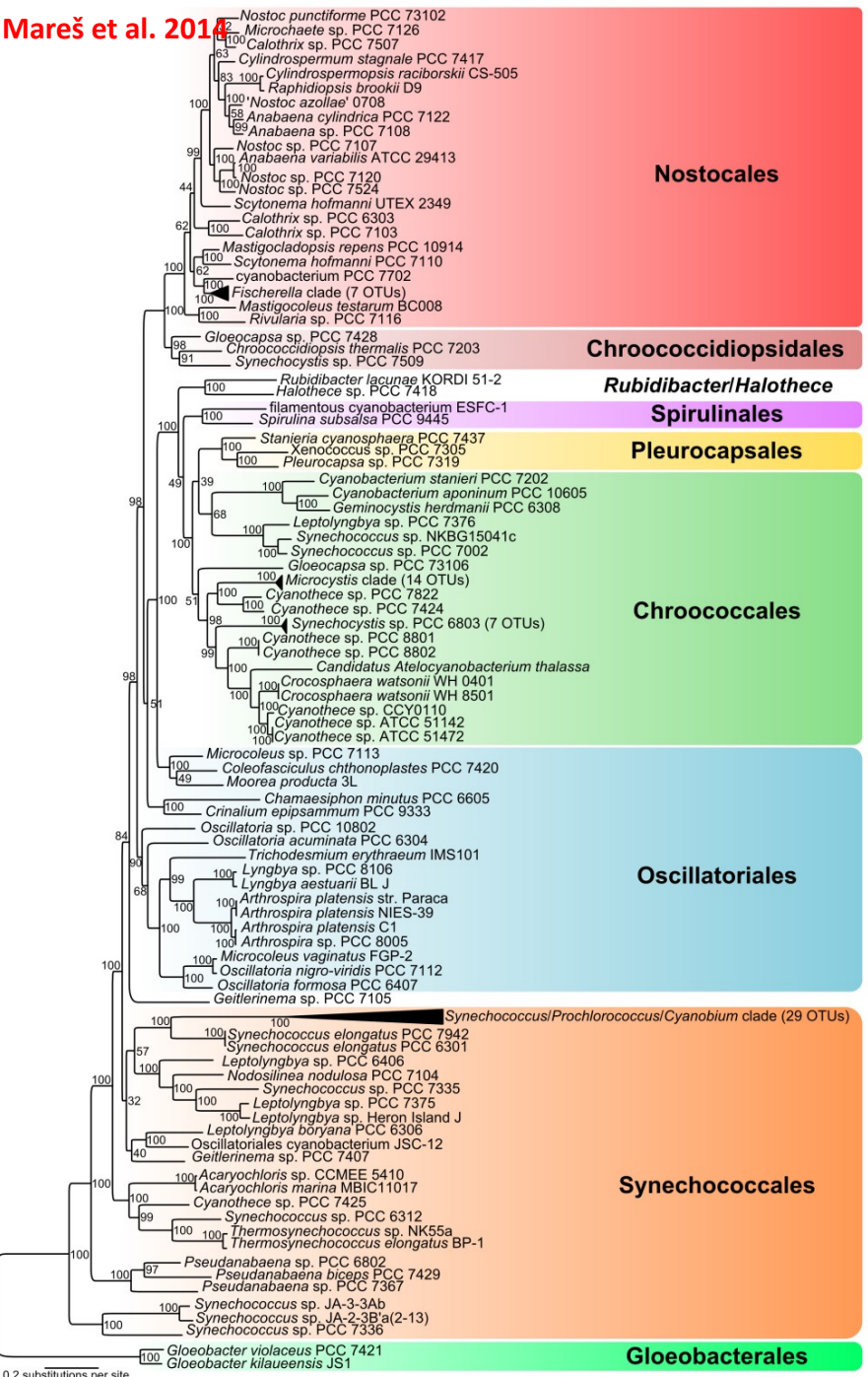
not congruent with a molecular phylogeny

- I. **Chroococcales** – single celled, free living or colonial, binary fission
- II. **Pleurocapsales** – multiple fission, baeocytes
- III. **Oscillatoriales** – simple filamentous cyanobacteria without heterocysts and akinetes
- IV. **Nostocales** - filamentous cyanobacteria with heterocysts and akinetes, some of them with false branching
- V. **Stigonematales** - filamentous cyanobacteria with heterocysts and true branching



Great Oxidation Event 2.45-2.32

Schirrmeister et al.
2012



Filamentous types with complicated cytology and development of heterocytes, akinetes, resp. arthrospores. Facultative false or true branching.

Complicated coccoid types with baeocytes.

Coccoid; often baeocyte production.

Coccoid types with complicated cytology (incl. thylakoidal system).

Filamentous types without heterocytes and akinetes; with complicated cytology, particularly thylakoidal system.

Simple coccoid and simple filamentous types with parietal arrangement of thylakoids. Phylogenetic differences are indistinct.

Coccoid types with lacking thylakoids.

I. GLOEOBACTERIALES

Gloeobacteraceae
- polar granules

ABSENT



II. SYNECHOCOCCALES - parietal thylakoids

Synechococcaceae

- division in one plane



Merismopediaceae

- division in two planes



Prochloraceae

- division in one plane
- chlorophyll b



Coelosphaeriaceae

- division in two planes, polarized cells



Acaryochloridaceae

- division in multiple planes
- chlorophyll d



Chamaesiphonaceae

- asymmetrical binary fission
- sedentary, polarized cells



Romeriaceae

- sheaths absent, loose filaments



Pseudanabaenaceae

- sheaths absent, regular filaments



Leptolyngbyaceae

- single filaments with sheaths



Schizotrichaceae

- clusters of filaments
- common sheath



Heteroleibleiniaceae

- single filaments with sheaths
- heteropolar filaments



III. SPIRULINALES

Spirulinaceae

- parietal thylakoids
- sheaths absent, coiled filaments



V. PLEUROCAPSALES

Hydrococcaceae

- irregular cell division
- pseudo-filamentous or - parenchymatous



Dermocarpellaceae

- division in multiple planes
- baeocytes
- polarized colonies



Xenococcaceae

- irregular cell division
- baeocytes
- polarized cells



Hyellaceae

- division in multiple planes
- baeocytes
- polarized pseudo-filaments



VII. CHROOCOCCIDIOPSIDALES

Chroococcidiopsidaceae

- division in three or more planes
- baeocytes



IV. CHROOCOCCALES

Microcystaceae

- division in three planes
- colonial, aerotopes present



Aphanothecaceae

- division in one plane, colonial



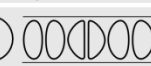
Cyanobacteriaceae

- division in one plane, not colonial



Cyanothrichaceae

- division in one plane
- pseudo-filaments (sheaths)



Stichosiphonaceae

- asymmetrical binary fission
- sedentary, polarized cells
- exocytes



Chroococcaceae

- division in three or more planes
- colonial, aerotopes absent



Gomphosphariaceae

- division in two planes
- spherical colonies
- polarized cells



Entophysalidaceae

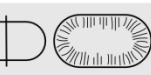
- division in three or more planes
- heteropolar colonies



VI. OSCILLATORIALES

Cyanothecaceae

- division in one plane
- unicellular, keritization
- special cell wall structure



Borziaceae

- obligatory short filaments



Coleofasciculaceae

- parietal to irregular thylakoid arrangement



Microcoleaceae

- radial thylakoid arrangement



Oscillatoriaceae

- short cells
- irregular thylakoid arrangement



Gomontiellaceae

- short cells
- special thylakoid arrangement
- special cell wall (cellulose)



Homoeotrichaceae

- polar filaments
- false branching

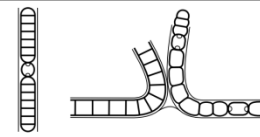


VIII. NOSTOCALES

see Fig. 2
heterocytes

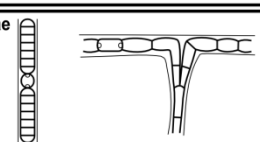
Scytonemataceae

- isopolar filaments
- false branching



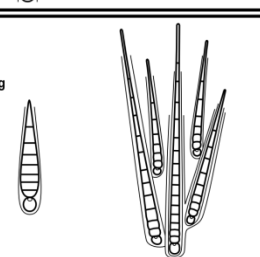
Symphyonemataceae

- isopolar filaments
- Y-type true branching



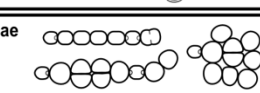
Rivulariaceae

- heteropolar filaments
- tapering trichomes
- facultative false branching



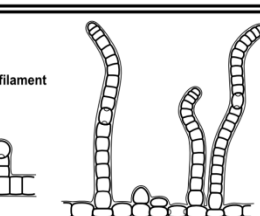
Chlorogloeopsidaceae

- isopolar filaments
- cell aggregates
- true branching???



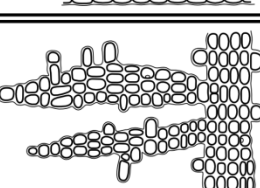
Hapalosiphonaceae

- isopolar filaments
- T-type true branching
- uni- or multiseriate main filament with uniseriate branches



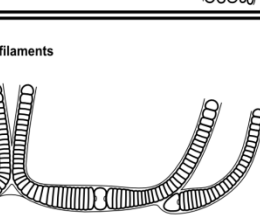
Stigonemataceae

- T-type true branching
- uni- or multiseriate filaments and branches



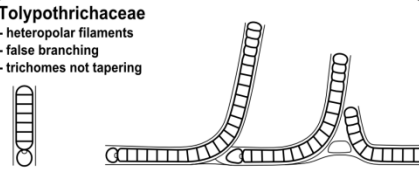
Godleyaceae

- isopolar and heteropolar filaments
- false branching
- tapering



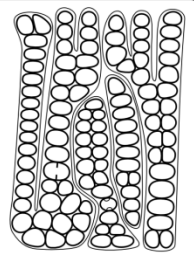
Tolypothrichaceae

- heteropolar filaments
- false branching
- trichomes not tapering



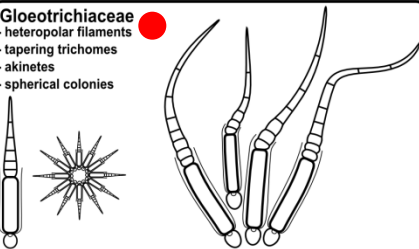
Capsosiraceae

- cell aggregates and filaments
- true branching
- polar growth of colonies



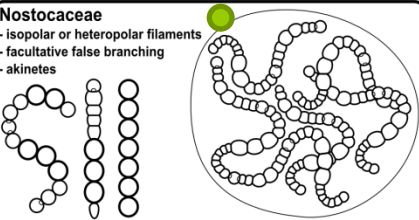
Gloeotrichaceae

- heteropolar filaments
- tapering trichomes
- akinetes
- spherical colonies



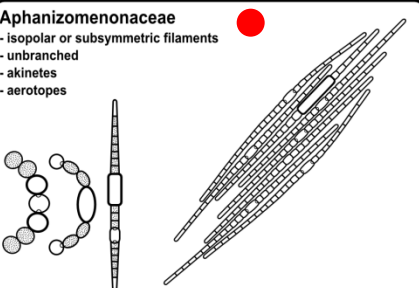
Nostocaceae

- isopolar or heteropolar filaments
- facultative false branching
- akinetes



Aphanizomenonaceae

- isopolar or subsymmetric filaments
- unbranched
- akinetes
- aerotopes



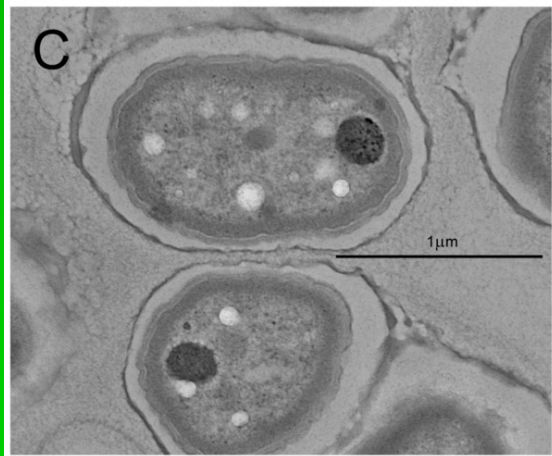
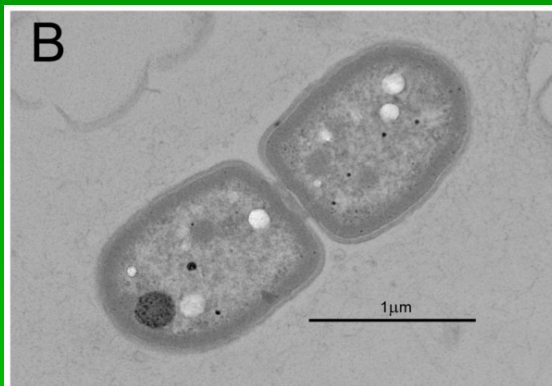
- containing planktic species
- with species, facultatively occurring in plankton

Mareš et al. 2014, Preslia

- I. Gleobacterales
- II. Synechococcales
- III. Spirulinales
- IV. Chroococcales
- V. Pleurocapsales
- VI. Oscillatoriales
- VII. Chroococcidiopsidales
- VIII. Nostocales

I. Gleobacterales

- *Gleobacter* - unique among in not having thylakoids, instead, the phycobilisomes sit on the inside of the plasma membrane
- *G. violaceus* – limestone rock in the Swiss Alps
- *Gleobacter kilaueensis* - from an epilithic biofilm in a lava cave in Kilauea Caldera, Hawaii.



raised bumpy purple colonies

Saw et al. 2013

The cyanobacteria mat on Kilauea cave wall

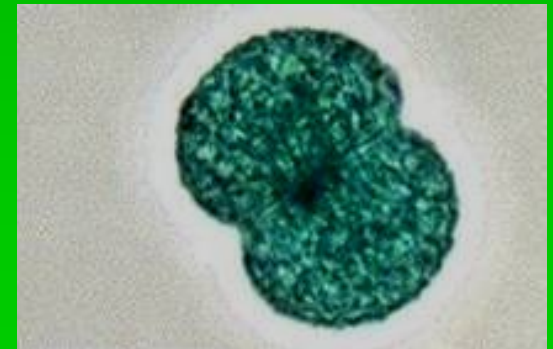
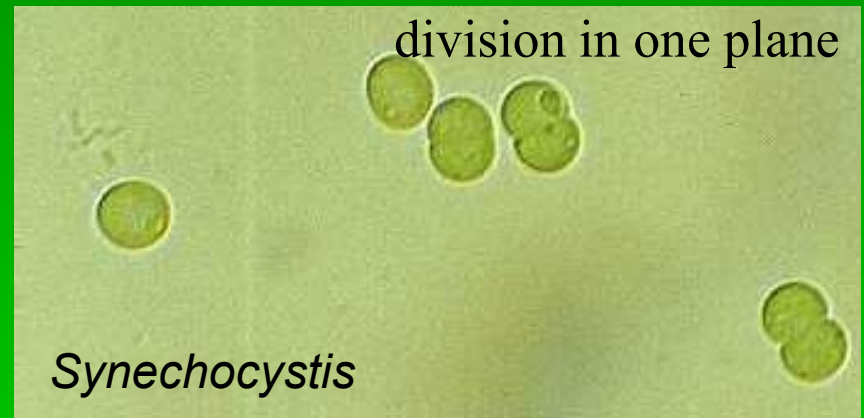
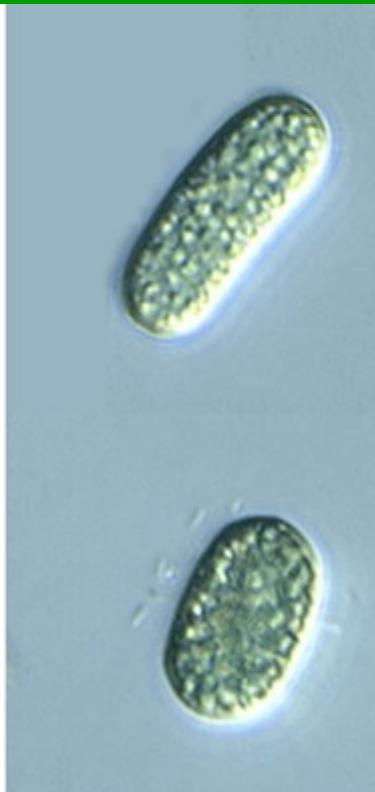
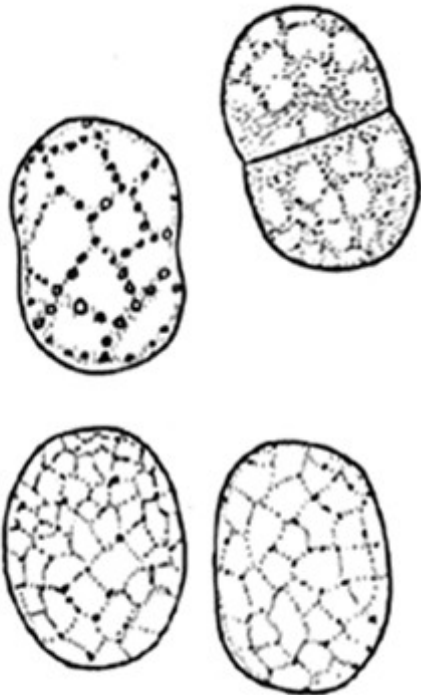


II. Synechococcales

- *Synechococcus* –picoplanktonic, freshwater/marine, eutrophic,
- *Synechocystis* – marine/mineral waters, *Synechocystis* sp. PCC 6803 – well studied model organisms

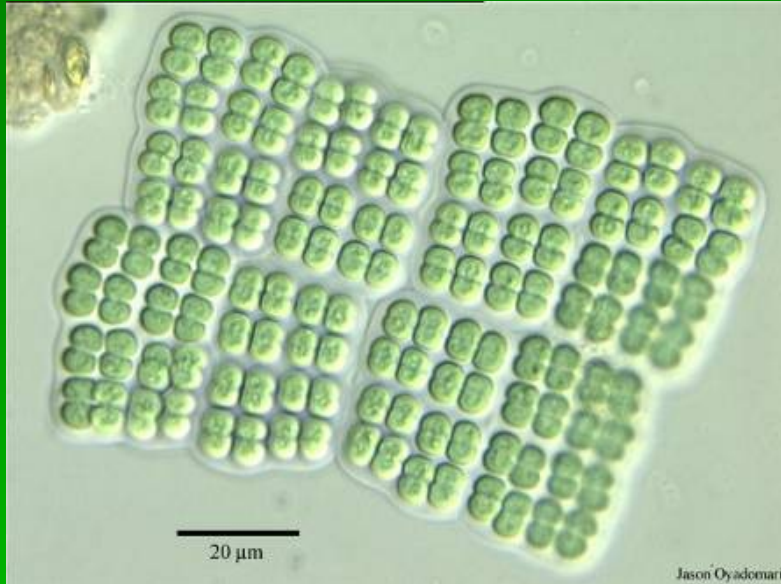
Synechococcus - a few cells to 10^6 cells per ml in virtually all regions of oceanic euphotic zone, prefer eutrophic waters

Synechococcus



II. Synechococcales

Merismopedia – division in two planes, phytobentos



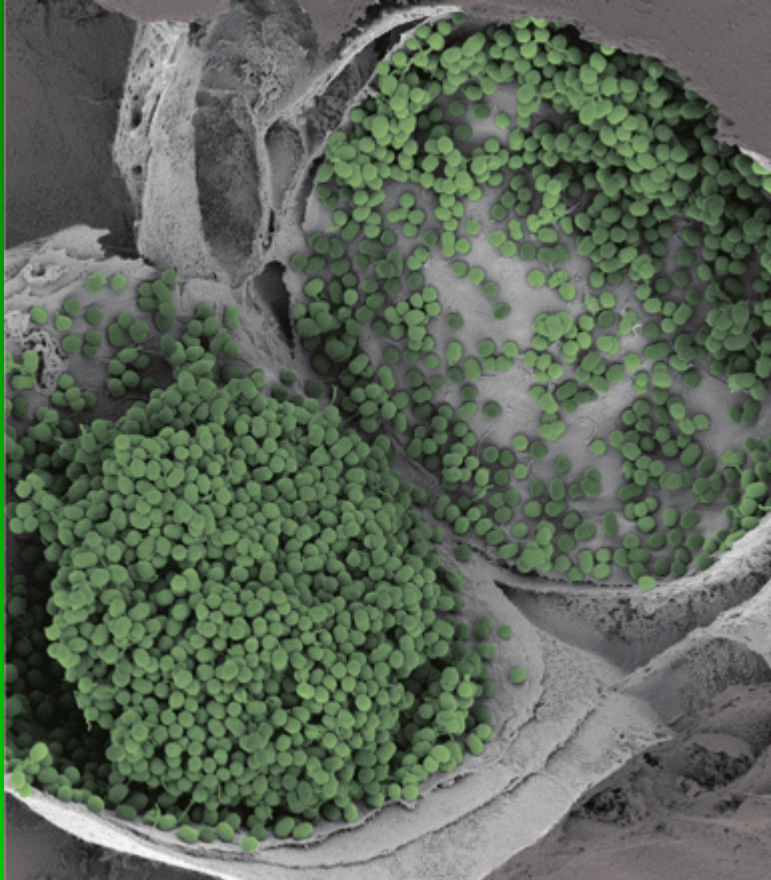
Prochloron didemni – division in one plane, Chlorophyll b



symbiont of
ascidians

II. Synechococcales

Acaryochloris marina – chlorophyll d



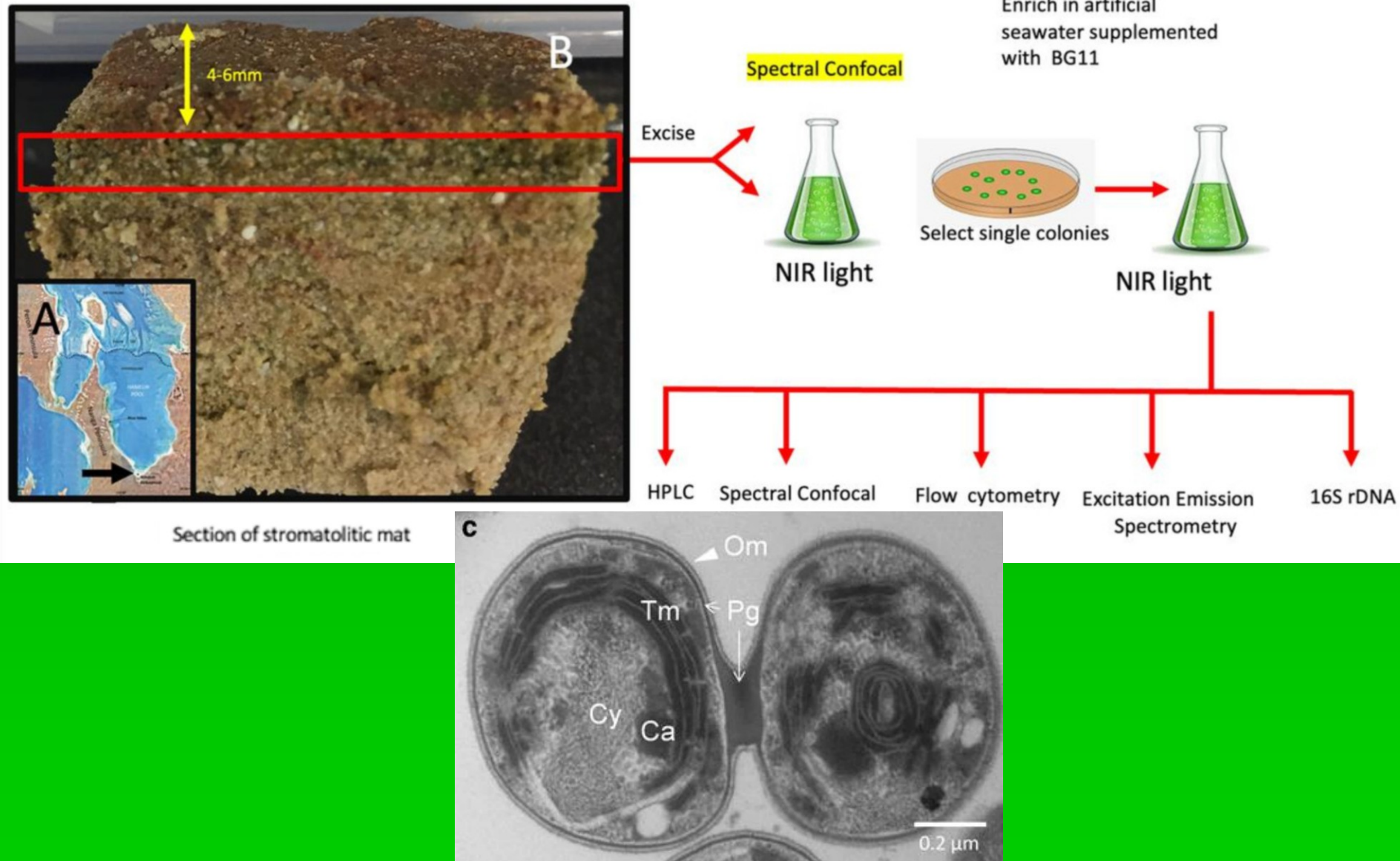
This unique cyanobacterium is the only known phototroph that has exchanged its Chl *a* for Chl *d*

oxygenic photosynthesis using near-infrared radiation (NIR).

In nature, *Acaryochloris* thrives in biofilms colonizing microniches experiencing strong depletion of visible light, while sufficient NIR prevails.

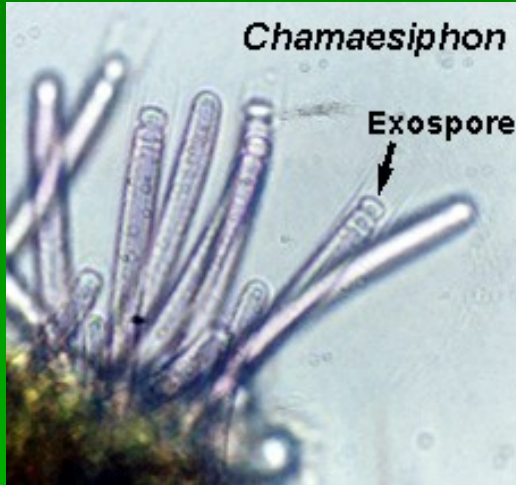
Behrendt et. al 2012, Appl. Environ. Microbiol.

new *Acaryochloris marina* strain isolated from an NIR-enriched stratified microbial layer 4–6 mm under the surface of stromatolite mats located in the Shark Bay, Australia



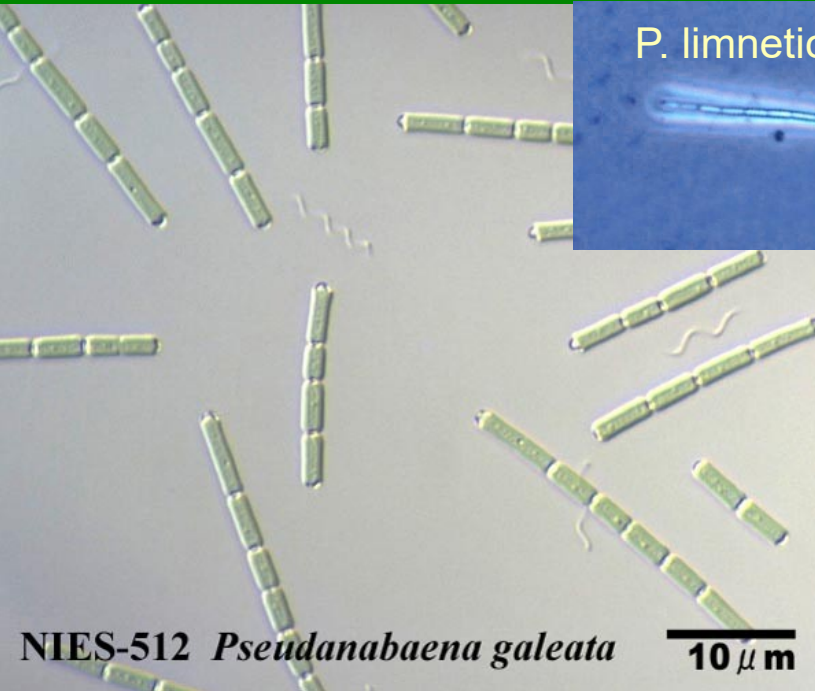
II. Synechococcales

Chamaesiphon – freshwater, pear-shaped cells, stones in fast-flowing streams



II. Synechococcales

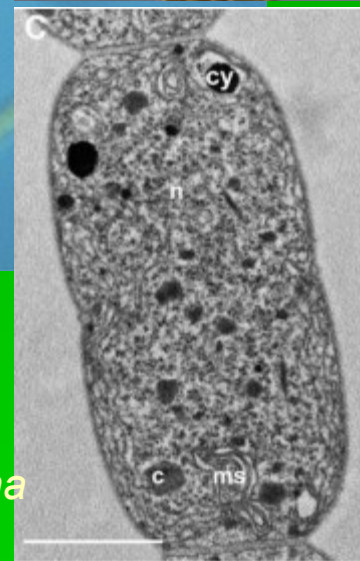
Pseudanabaena – sheaths absent, loose filaments



- nonheterocystous cyanobacteria
- characterized by simple trichomes with a width less than 4 μ m
- cells are longer than wide, possess parietal thylakoids, contain polar gas vesicles and the cross walls are conspicuously constricted

- some strains are capable of anaerobic N_2 fixation

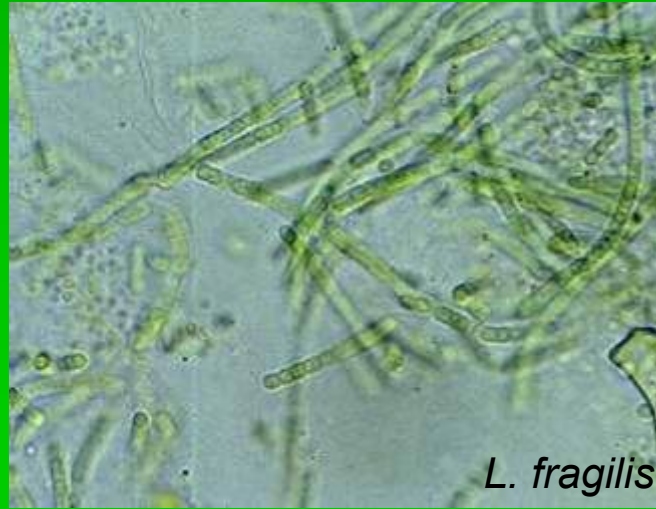
Pseudanabaena rutilus-viridis



II. Synechococcales

Leptolyngbya – single filaments in sheaths, thin filaments (0.5 to 3.5 μm wide) and parietal location of the thylakoids, ubiquitous, benthic, subaerophytic, on wet rocks, on soil

L. valderiana - poly(3-hydroxybutyrate) (PHB) sustainable production of biodegradable bioplastics .

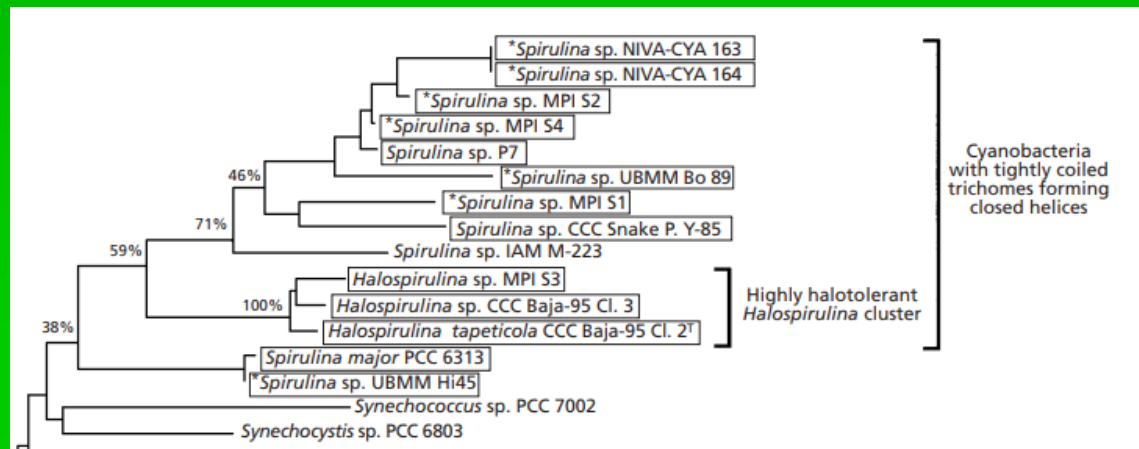
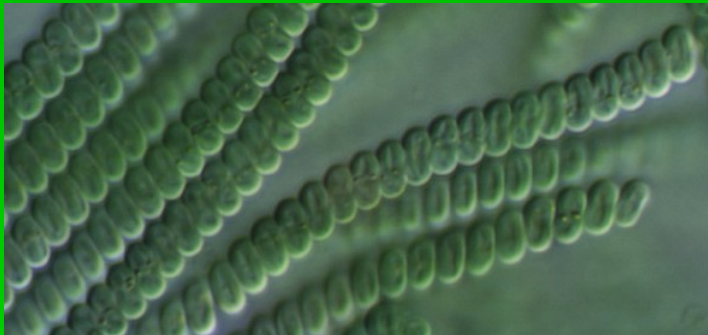
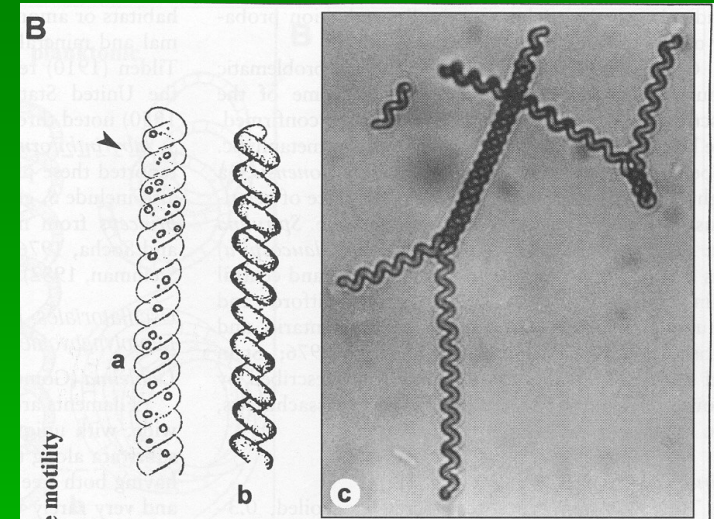


III. Spirulinales

Spirulina – parietal thylakoids, sheath absent, coiled filaments

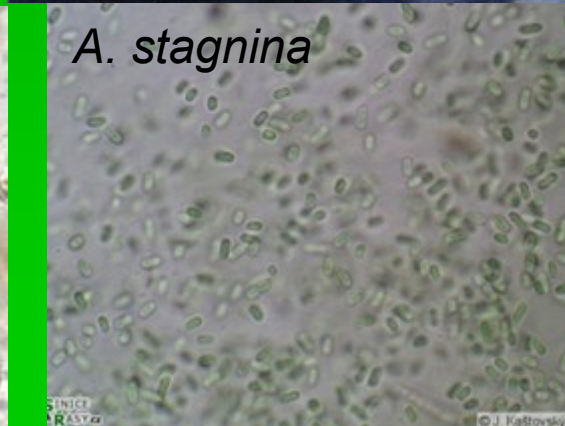
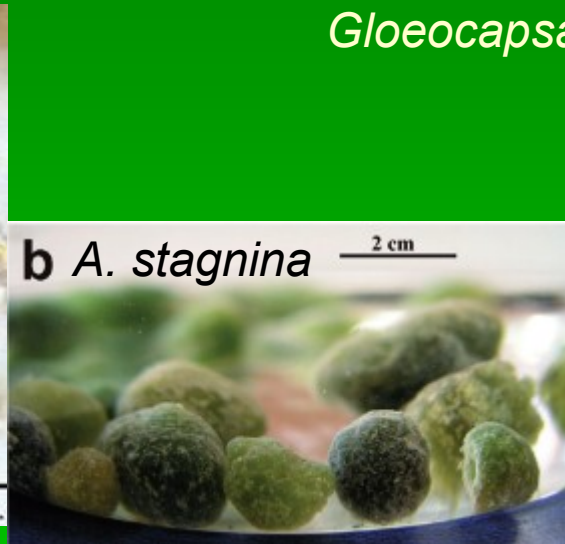
filaments unbranched, always without sheaths, rarely solitary (free floating), usually in clusters or in fine mats which are to macroscopically visible and covering the substrate, regularly screw-like coiled along the whole trichome length

Several species are benthic or grow in metaphyton of freshwater biotopes, usually in not heavy artificially polluted waters, in detritus among water plants. Several species prefer thermal and mineral springs, or halophilic biotopes (marine coastal and brackish waters) - *Halospirulina*.



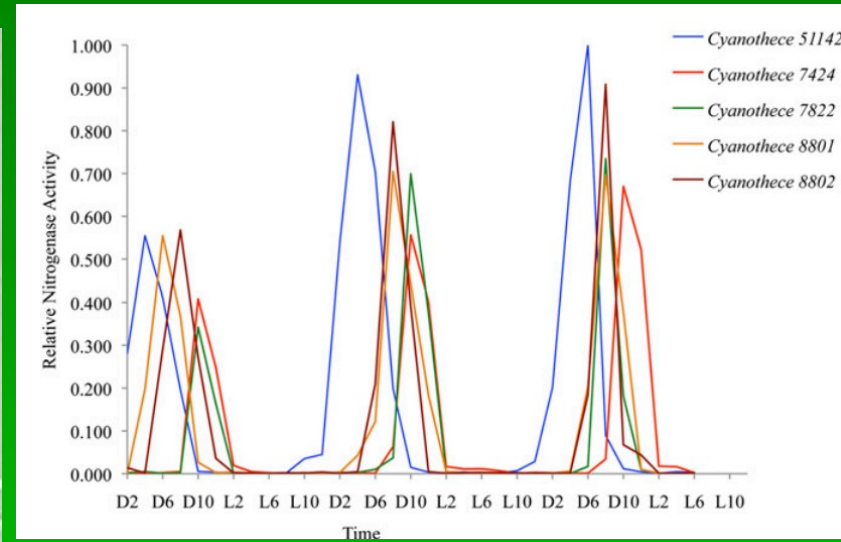
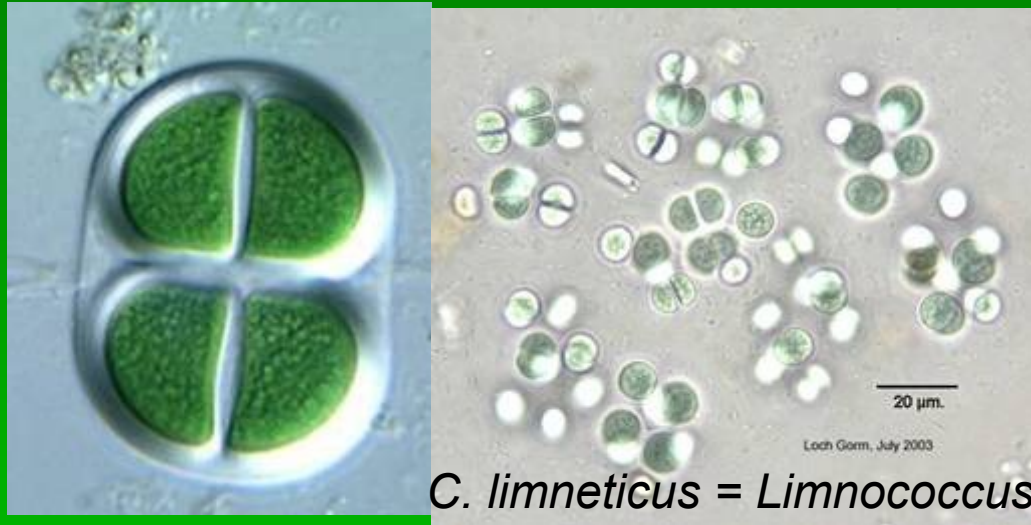
IV. Chroococcales

- *Aphanothece* – mucilage colonies, from various freshwater habitats
- (*A. castagnei*, lime stone), benthos (*A. stagnina*, eutrophic ponds) (*A. microscopica*, acidic waters)
- *Gloeocapsa* – concentrically layered slime, damp rocks (granite)

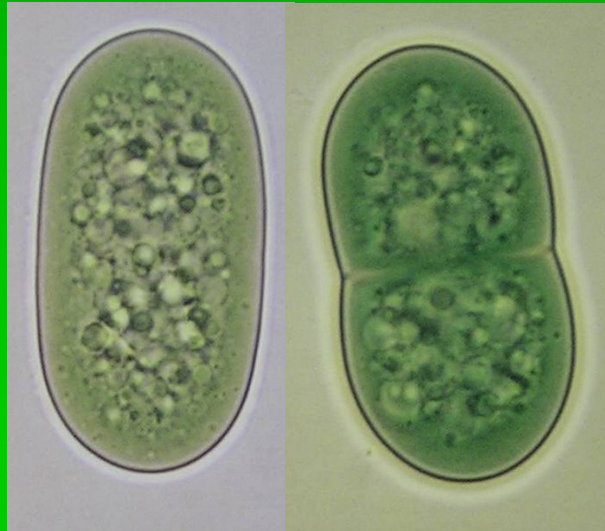
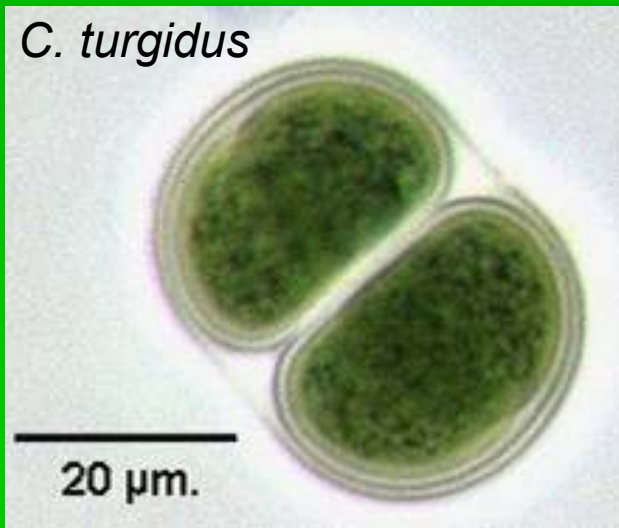


IV. Chroococcales

- *Chroococcus* – marine/freshwater, soil, damp rocks
- *Cyanothece* – peat bogs, diazotroph, diurnal activities N –fix.



C. turgidus



IV. Chroococcales

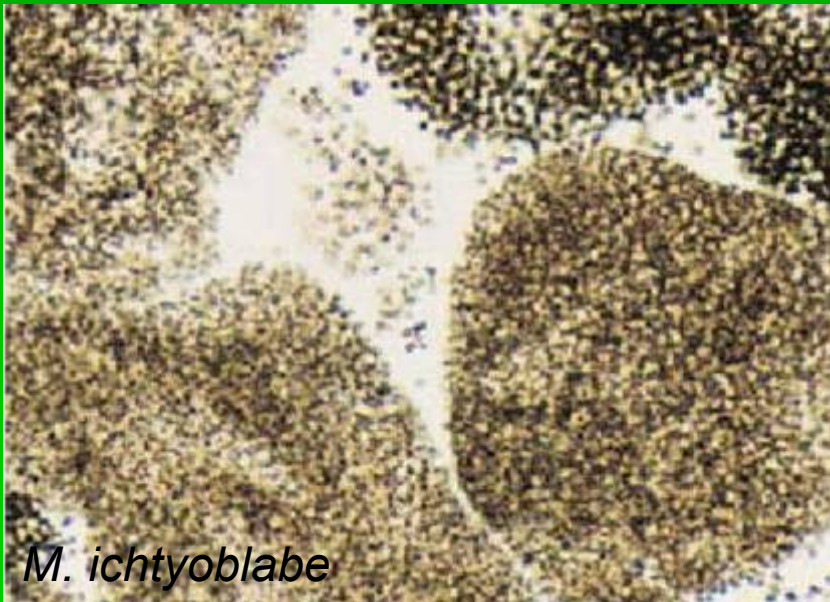
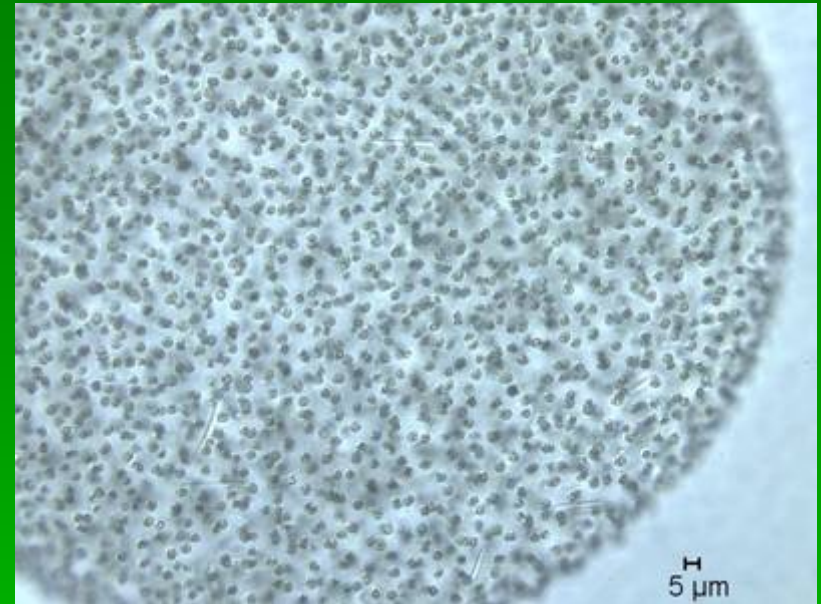
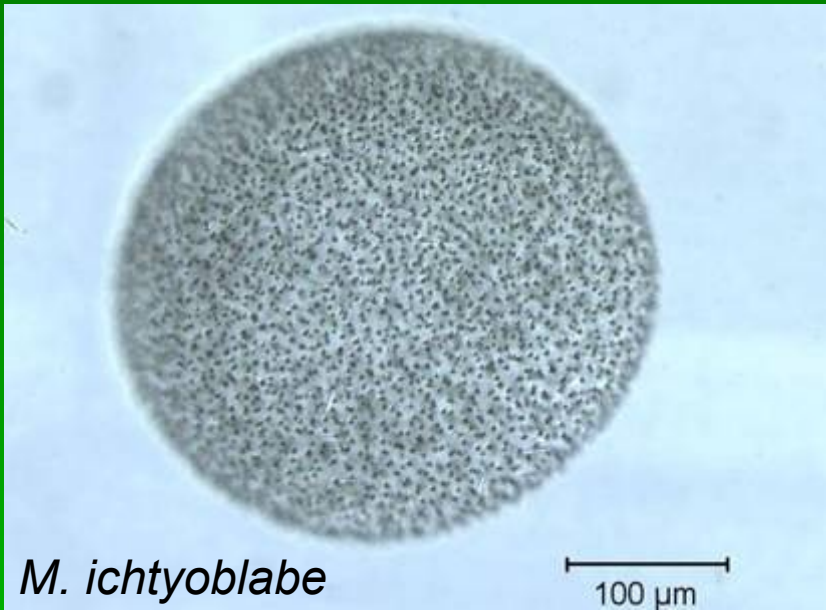
- *Microcystis* – irregular colonies in mucilage, aerotopes, only planktonic, cyanotoxines, water blooms

Kombinace znaků při určování morfotypů *Microcystis*

	Vel. b.(um)	Tvar kolonií	Sliz	Nahuštění b.	Morfotyp/toxicita
A	2 – 3,2	nepravidelně sférické	rozplývavý, nezřetelný	pravidelně rovnoměrně, zprvu velice hustě	SILNĚ TOXICKÝ ↑ ⇒ <i>M. ichthyoblabe</i>
B	4 – 7	krychlovité	kopíruje okraje skupin b.	nepravidelně Baličkovité shluky	TOXICKÝ ↑ ⇒ <i>M. viridis</i>
C	4 – 6	laločnaté, otvory	rozplývavý	pravidelně rovnoměrně	TOXICKÝ ↑ ⇒ <i>M. aeruginosa</i>
D	5 – 9	laločnaté, otvory	zřetelně hraničený, oddálen od b.	náhodně rozmístěné b.	NETOXICKÝ ↑ ⇒ <i>M. wesenbergii</i>



IV. Chroococcales



Otsuda et al. 2001 (IJSEM)

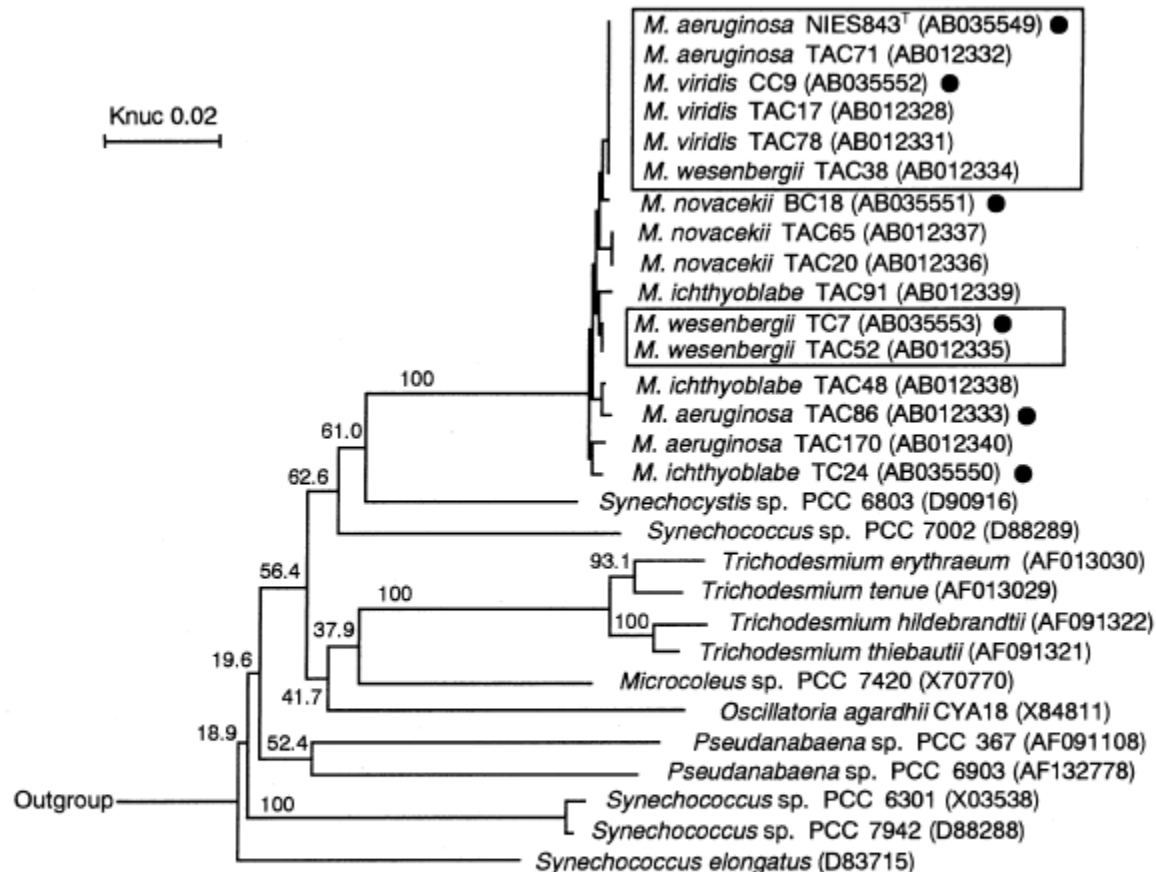
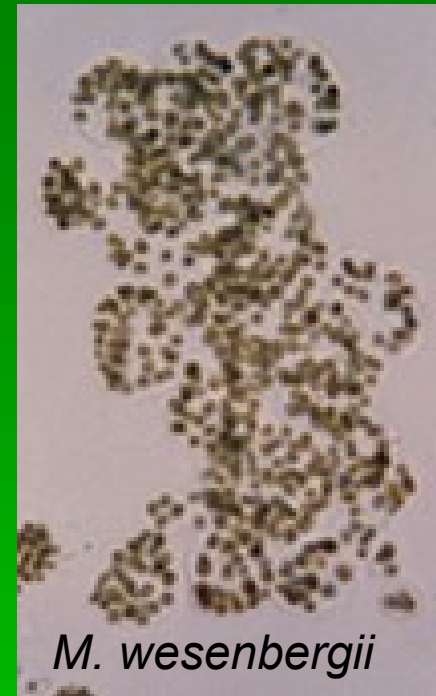
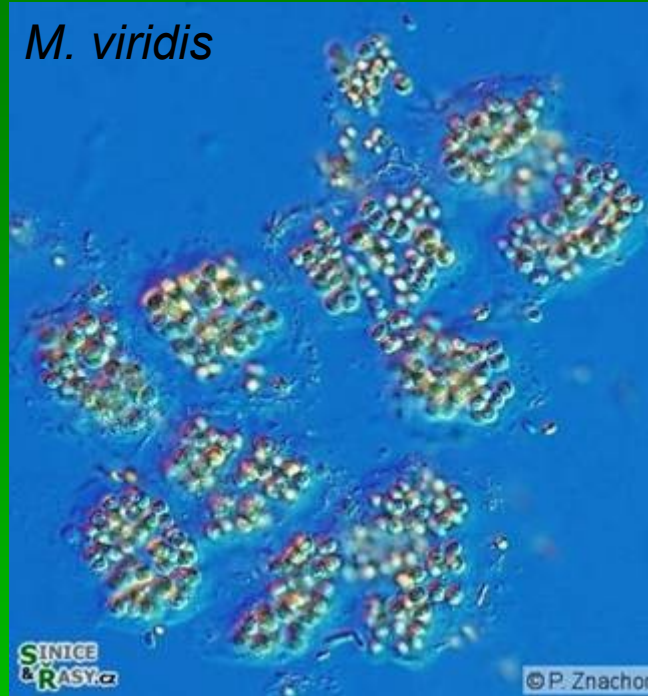


Fig. 1. Neighbour-joining tree of the *Microcystis* strains and related organisms. An alignment of 1347 nt after excluding positions with gaps was used. Local bootstrap probabilities (for branches except those within the *Microcystis* cluster) are indicated at nodes. Strains marked with a black circle were used for DNA-DNA hybridization and strains in each rectangle have an identical sequence. Accession numbers in the DDBJ/EMBL/GenBank databases are indicated in parentheses. *E. coli* (accession no. E05133), used as an outgroup, is not shown.

proposed to unify these five species into *M. aeruginosa* under the Rules of the Bacteriological Code

IV. Chroococcales



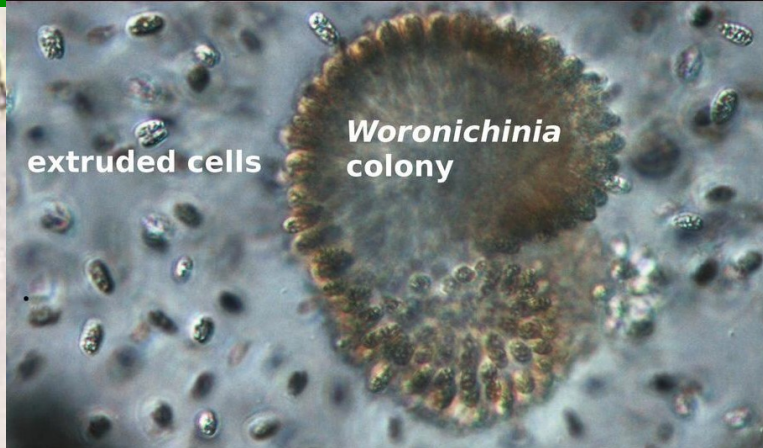
Chroococcales

- *Woronichinia* – toxic, water bloom, does not fix N, gas vesicles
- *Gomphosphaeria* – free-living (mainly in the metaphyton), usually enveloped by narrow, indistinct, fine and diffluent mucilage

Woronichinia naegeliana



anatoxins, microcystins



very efficient in taking up ammonium and urea



Gomphosphaeria



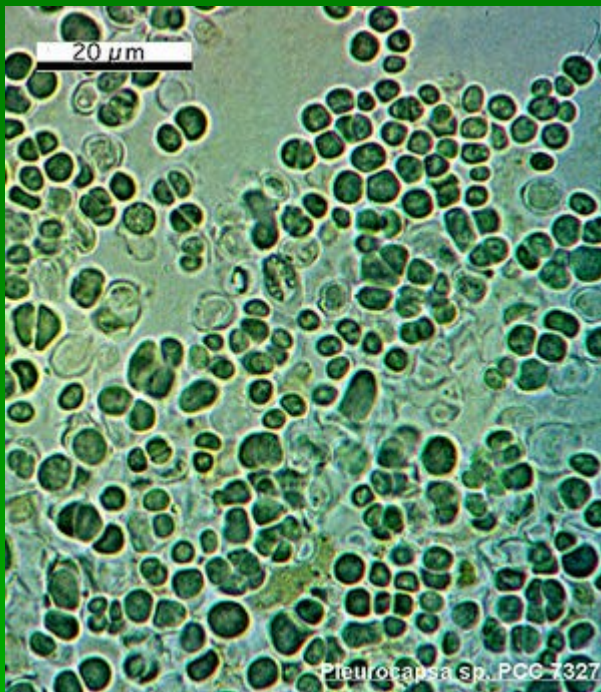
Gomphosphaeria



G. semen-vitis

V. Pleurocapsales

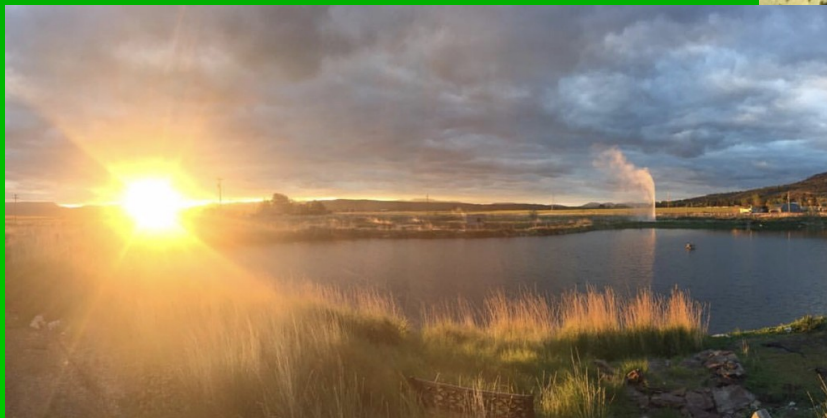
Thermopsis thermophile
thermophilic ostracod micro-
crustacean, active up to 47-48 °C



Pleurocapsa



Pleurocapsa/Calothrix were dependent on
grazers - the springs without ostracods
were overgrown with *Geitlerinema*



Geothermal Spring, Hunter's
Hot Springs, Oregon

freshwater/marine, in alkalic waters calcification
– stromatolite-like structures, contains
scytonemin

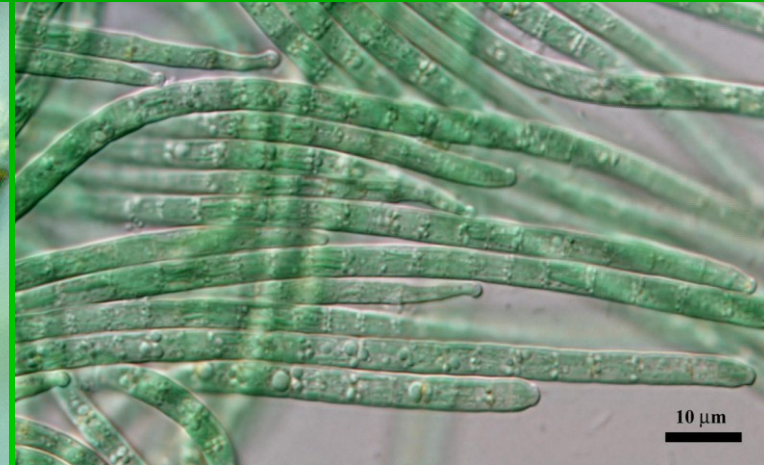
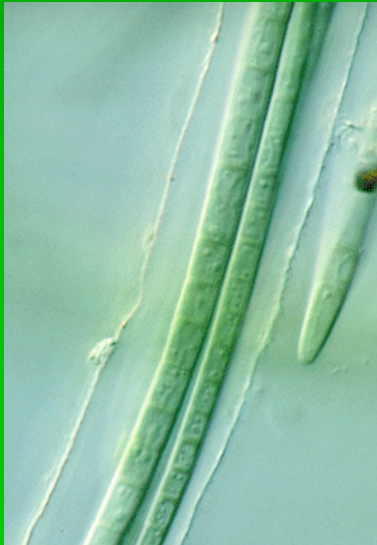
VII. Oscillatoriales

Microcoleaceae

some species e.g. , *Ph. amoenum*, *Ph. autumnale*,

Ph. favosum were transferred to the genus *Microcoleus* according to molecular data and cytomorphology of trichomes)

Microcoleus – bunches of filaments with thin sheaths, slightly motile, without hormogonia, calyptra, typical for saline waters, in soil *M. vaginatus*

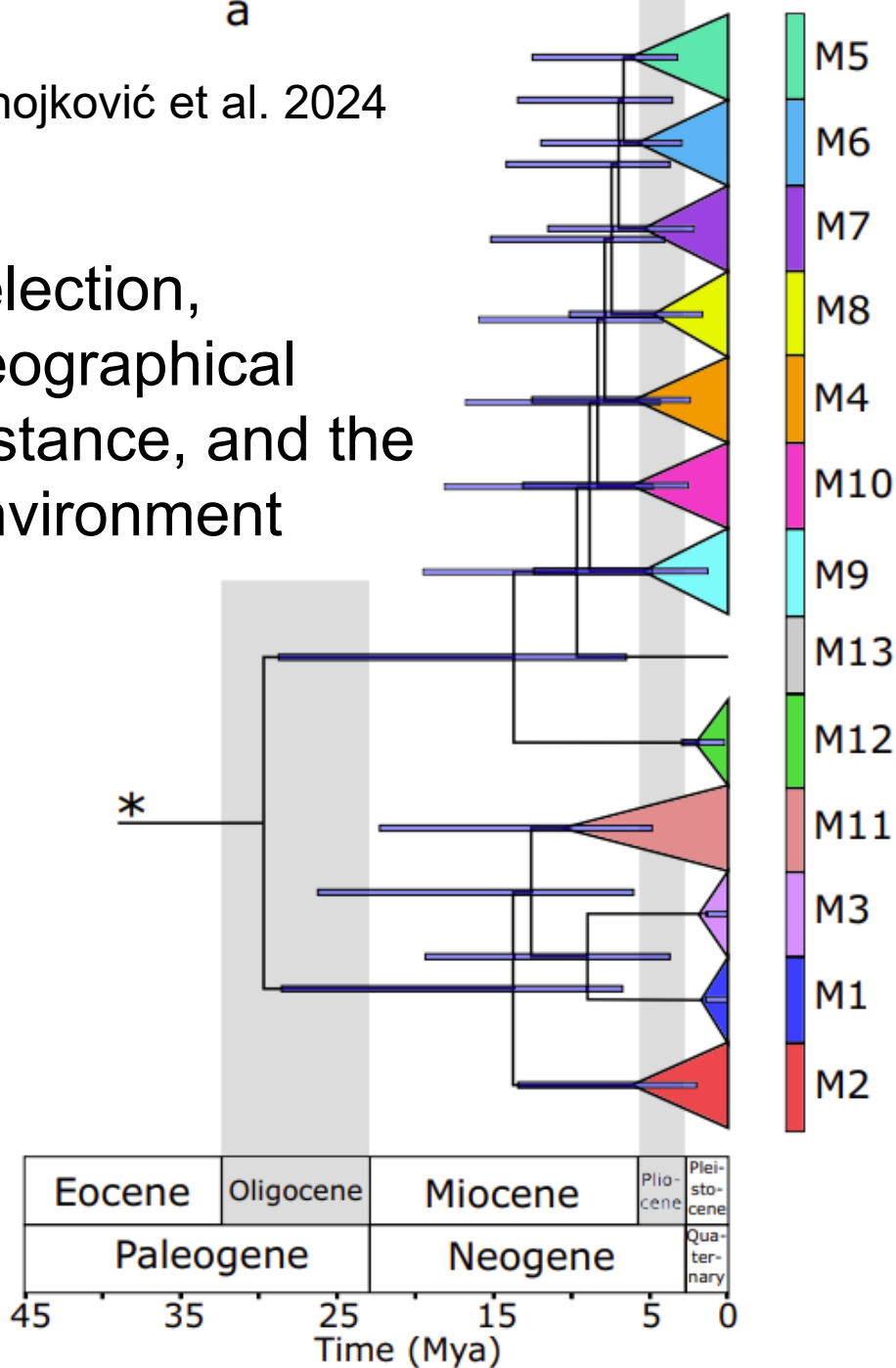


Ph. autumnale = *M. autumnale*

a

Stanojković et al. 2024

selection,
geographical
distance, and the
environment



Phylogenetic relationships
and divergence times of the
13 *Microcoleus* lineages
(indicated as M1-M13)

diversification of the nearly
ubiquitous soil cyanobacterium
Microcoleus. *Microcoleus*
represents a global speciation
continuum of at least 12
lineages, which radiated during
Eocene/Oligocene aridification
and exhibit varying degrees of
divergence and gene flow.

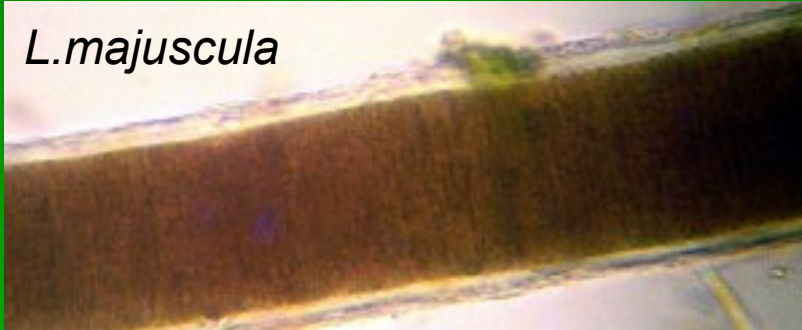


VII. Oscillatoriales

Oscillatoriaceae

- *Lyngbya* – metafyton, sladk., hodně moř., povlaky, toxické, široká pochva (nad 1 μm), trichomy nad 8 μm

L. majuscula

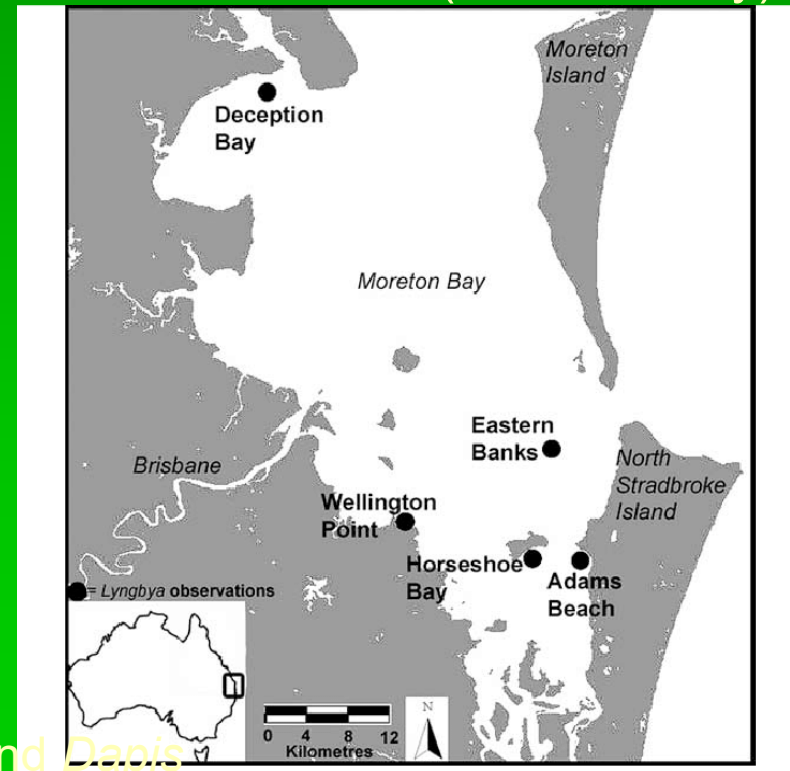
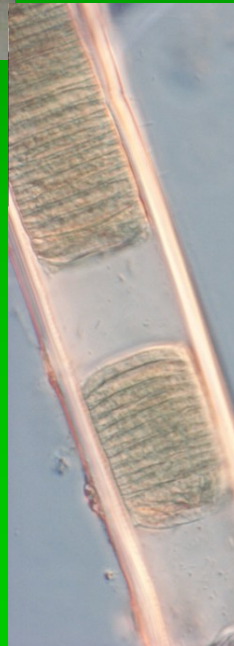


growing attached to seagrass, corals and other shallow substrates. On occasions it can grow rapidly to form an algal bloom Queensland coastal waters (Moreton Bay)

L. majuscula



K. Ahern, UQ



new genera were erected from this genus:
e.g., *Moorea*, *Limnoraphis*, *Okeania*, *Microseira*, and *Dapis*

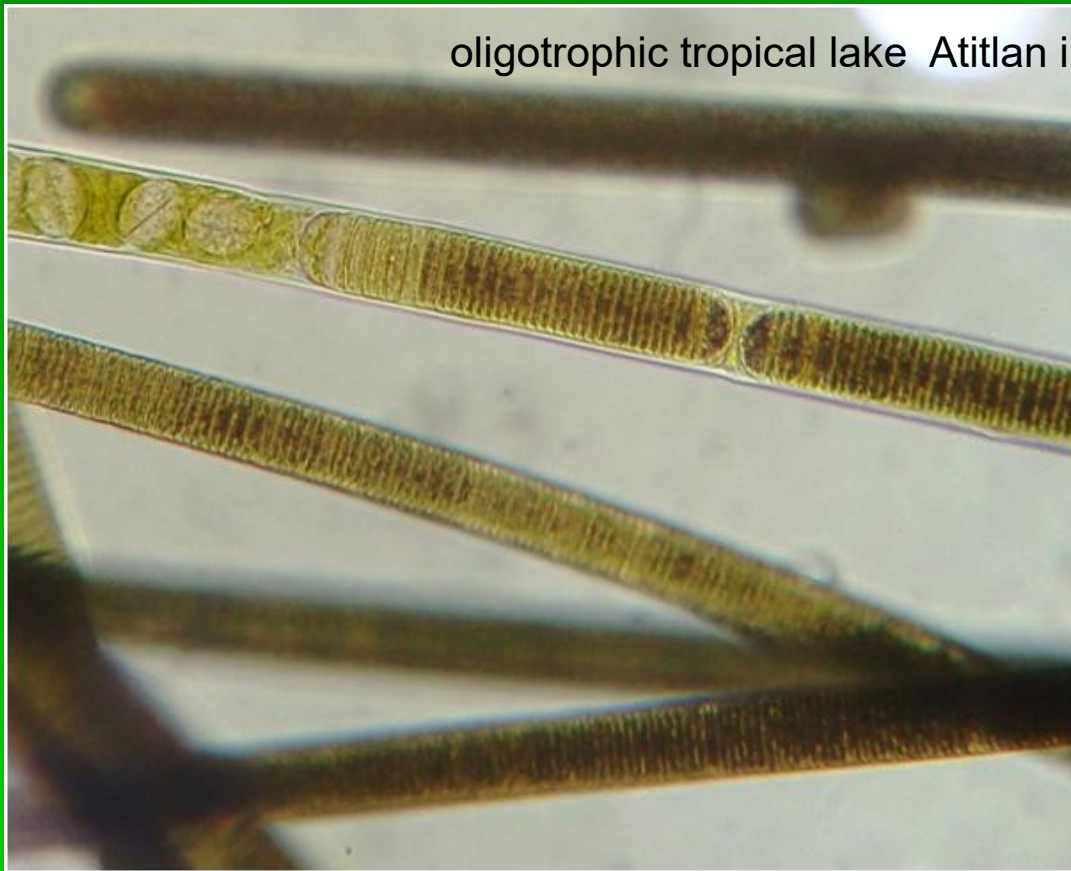
Lyngbya majuscula - Queensland, lyngbyatoxins



VII. Oscillatoriales

Oscillatoriaceae

Limnoraphis robusta forms recently water blooms in tropical and subtropical lakes near west coasts of Central and South America, since 2008

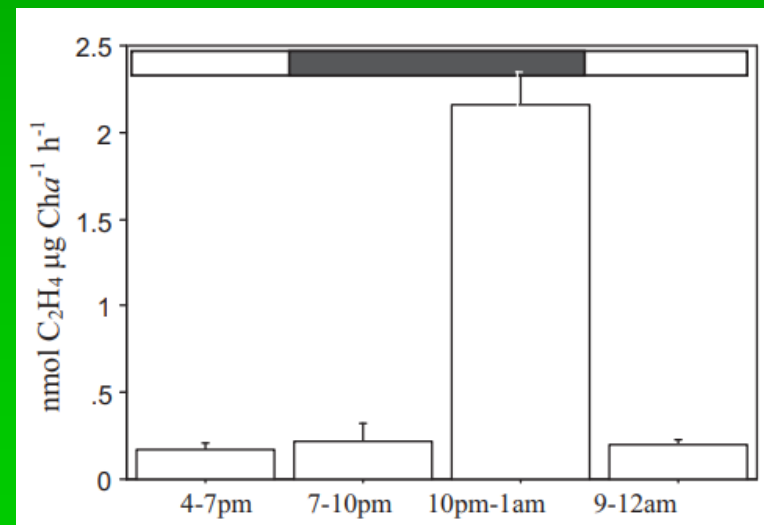
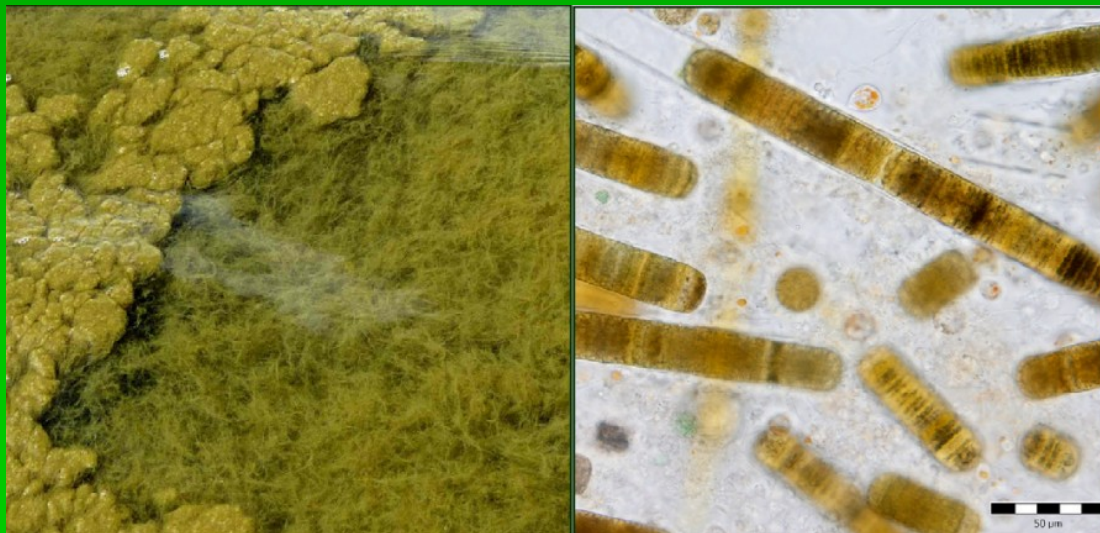
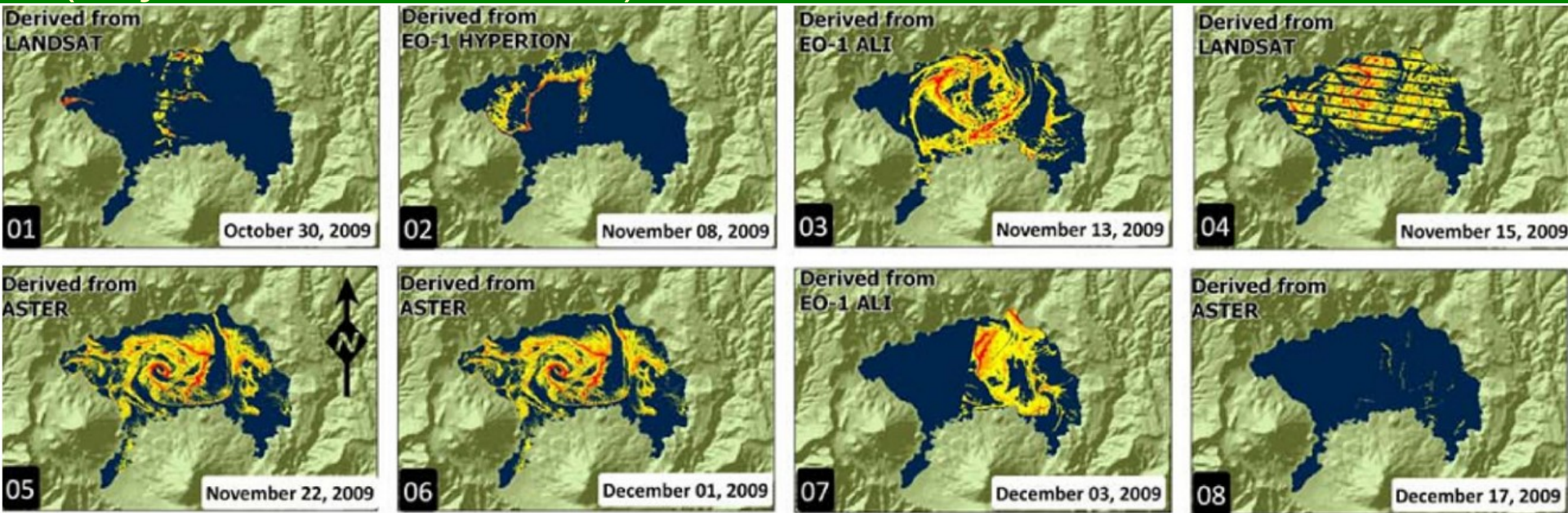


oligotrophic tropical lake Atitlan in Guatemala.



Aerotopes, N-fixing (day/night),

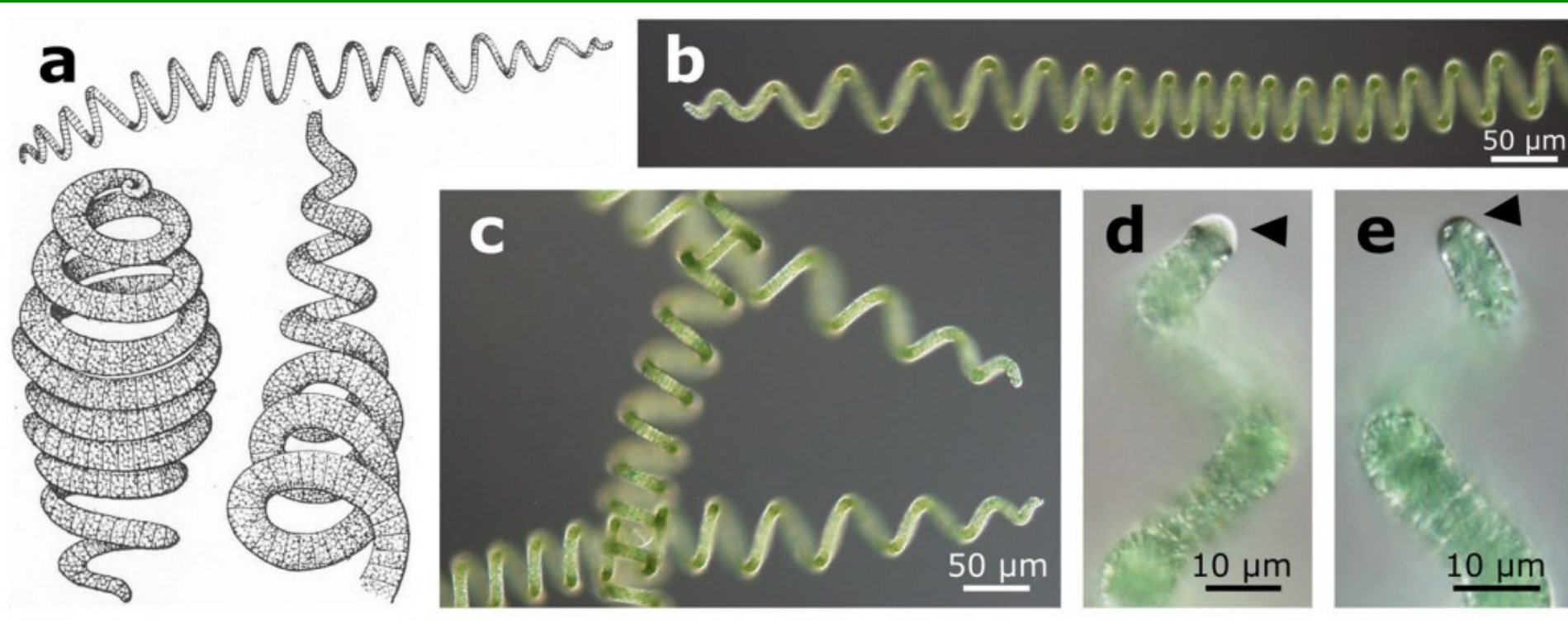
(Rejmankova et al. 2011)



nitrogenase activity

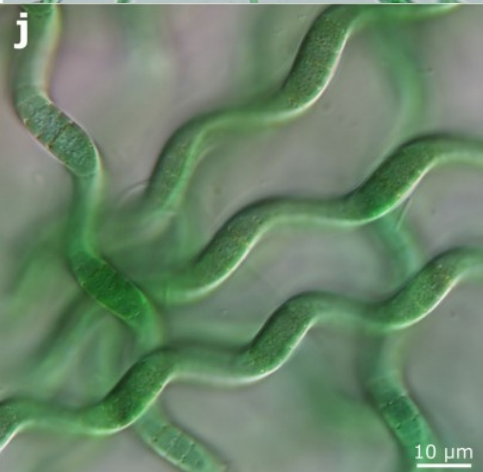
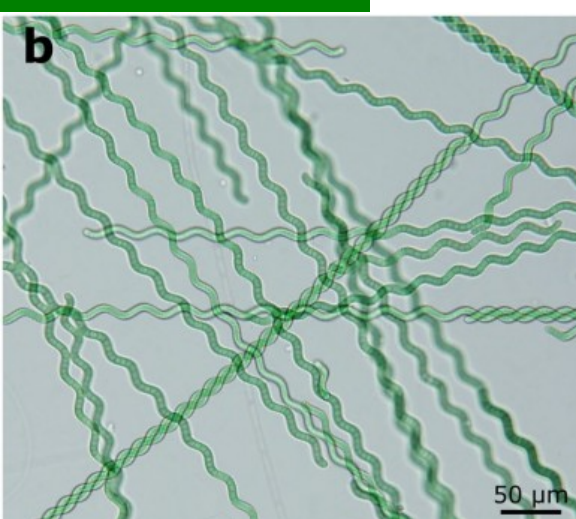
VII. Oscillatoriales

Limnospira fusiformis

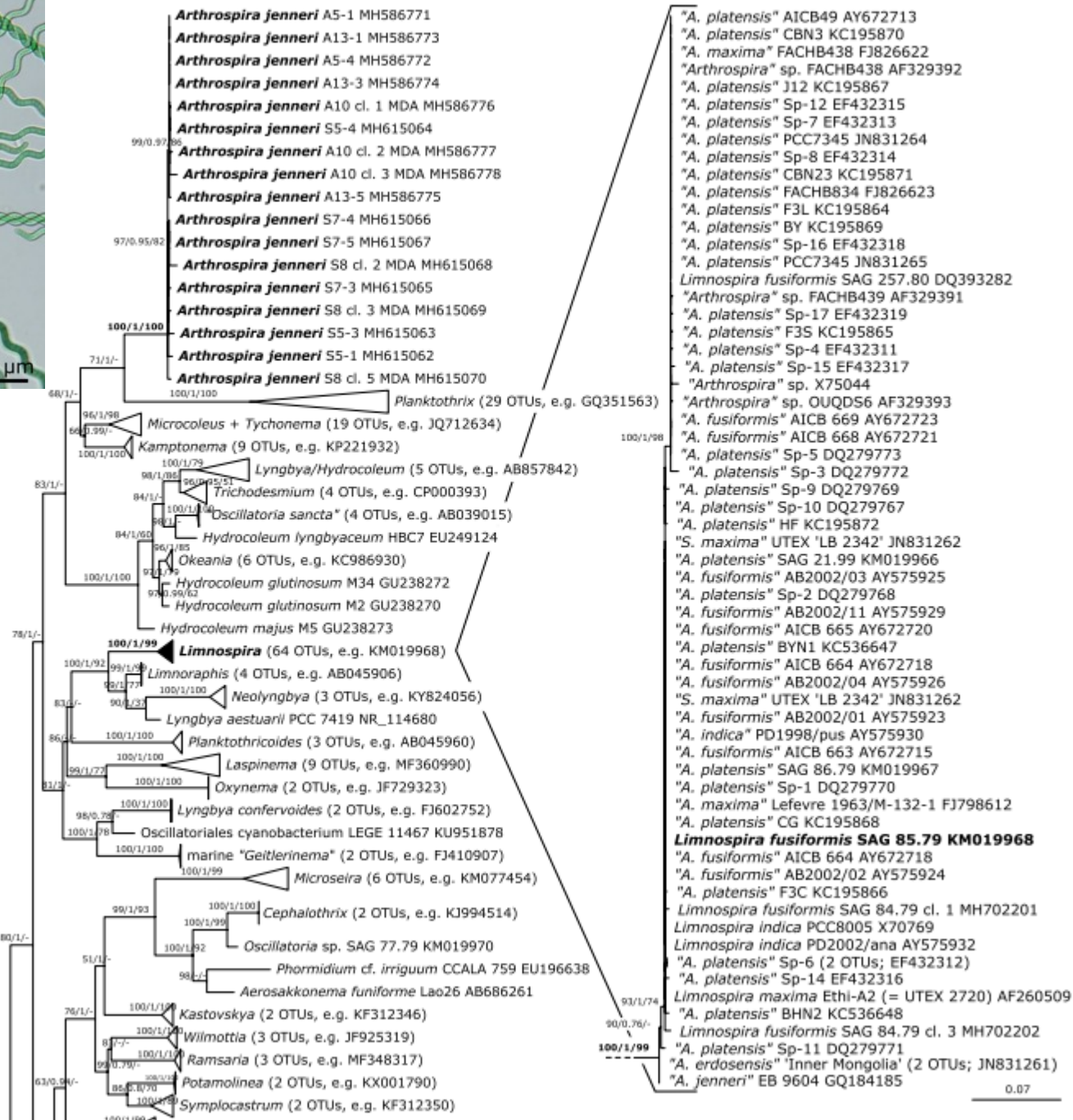


separation of commercially grown taxa (*Arthrospira platensis*, *A. maxima*, and *A. fusiformis*) into the new genus *Limnospira*

Nowicka-Krawczyk et al. 2019



Arthrospira jeneri
Microcoleaceae
Oscillatoriales



VII. Oscillatoriales

Planktothrix rubens

Burgundy-blood phenomenon

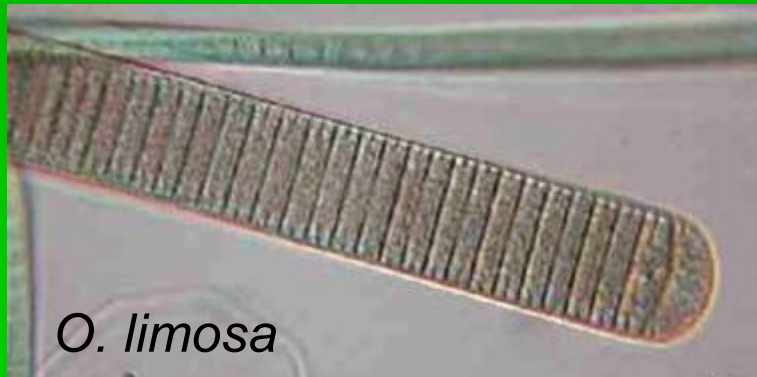
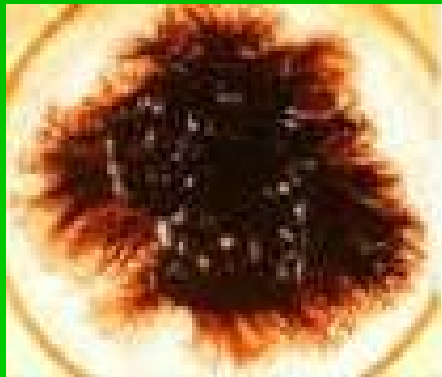
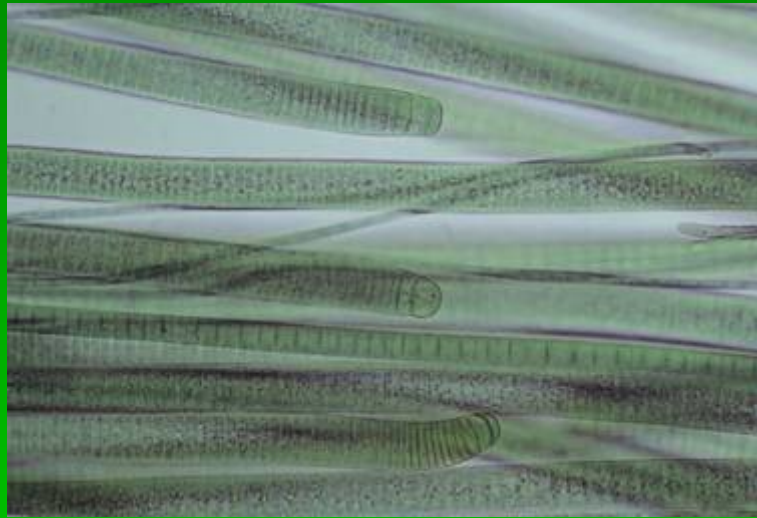


April 2021 water bloom, quarry Holetin (Hlinsko)



VII. Oscillatoriales – neperzistující pochvy, b. kratší než širší

- *Oscillatoria* – motile filaments, sheaths under stress, metaphyton, gliding filaments, water blooms



VII. Oscillatoriales

- *Trichodesmium* – first described by Cook 200 years ago, extensive water blooms (10 – 100 km wide), nitrogen fixer (1/2 of nitrogen fixation in marine systems), oligotrophic waters

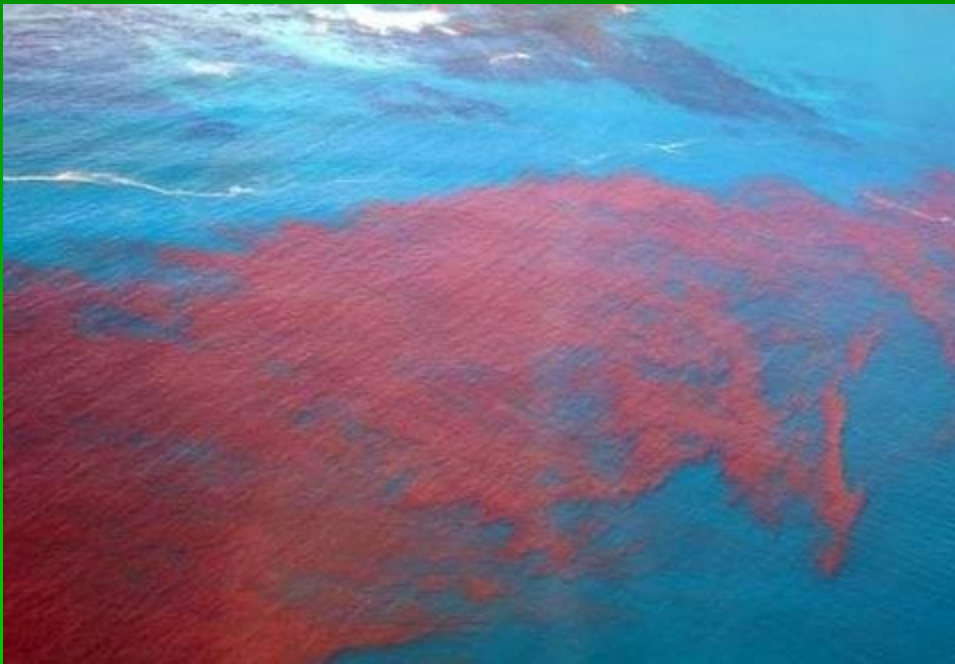
high energy, low nutrient environm.

limited by Fe and phosphate, gas vesicles – vertical movement to harvest nutrients



VII. Oscillatoriales

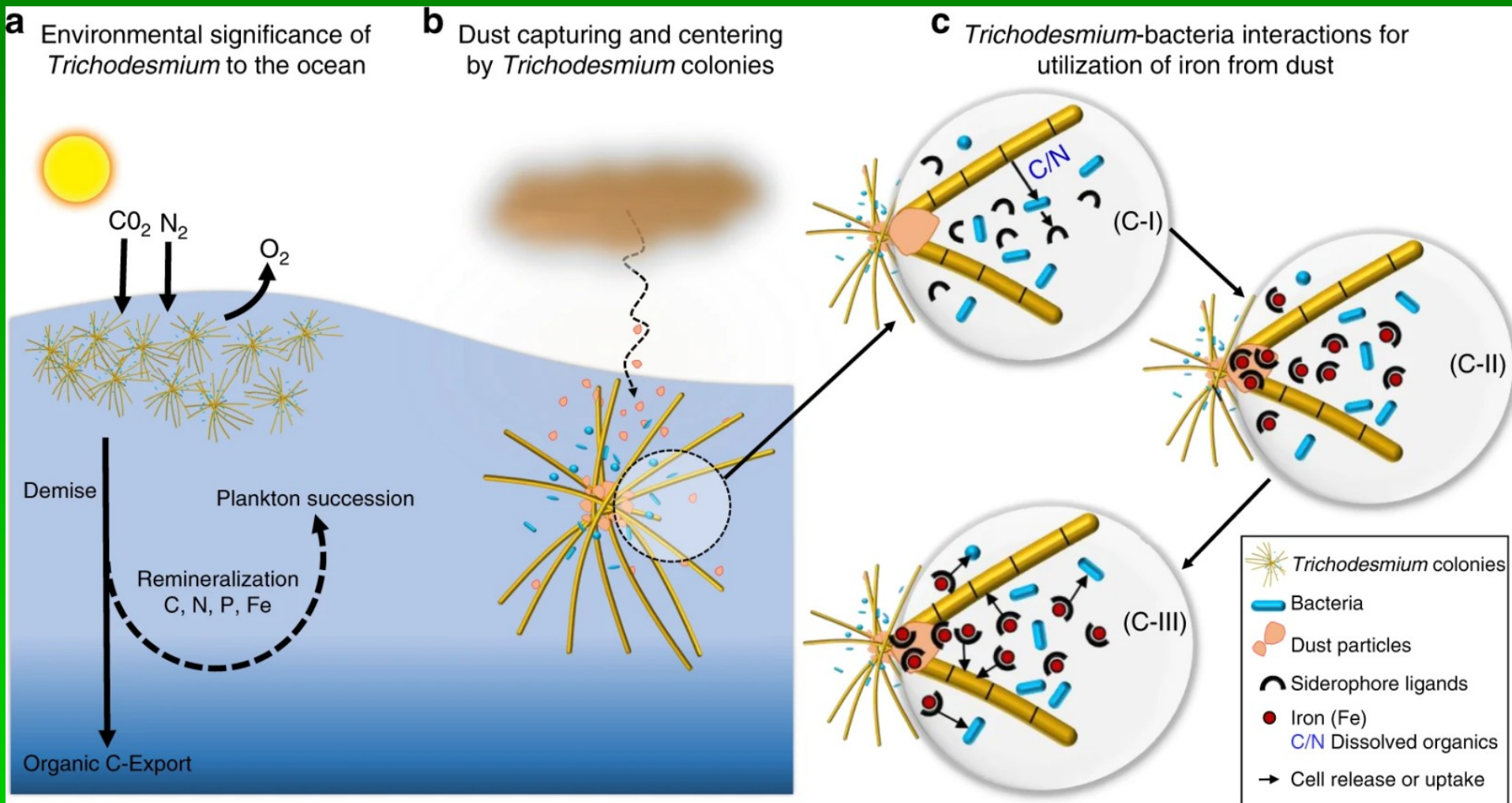
Why the Red Sea red?



filled with blooms of cyanobacteria
Trichodesmium erythraeum.

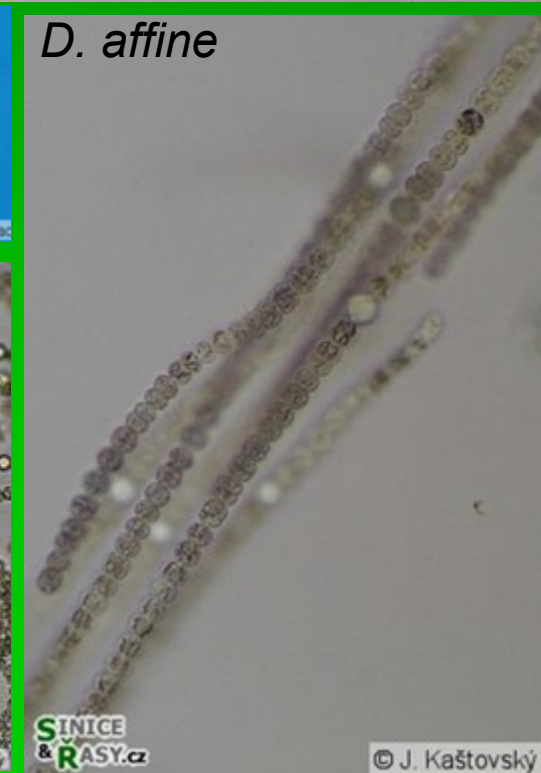
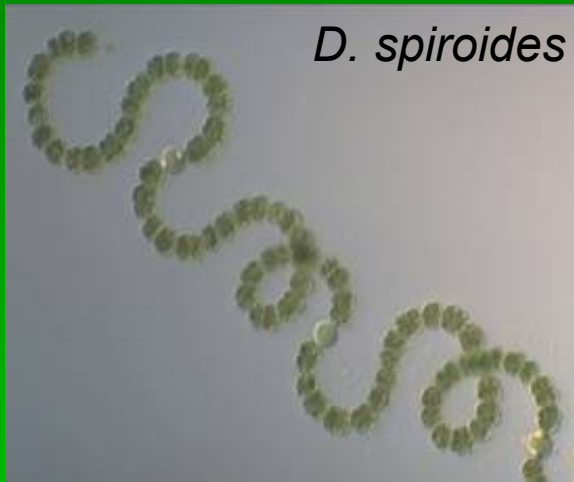


Colonies of marine cyanobacteria *Trichodesmium* interact with other bacteria to acquire iron from dust



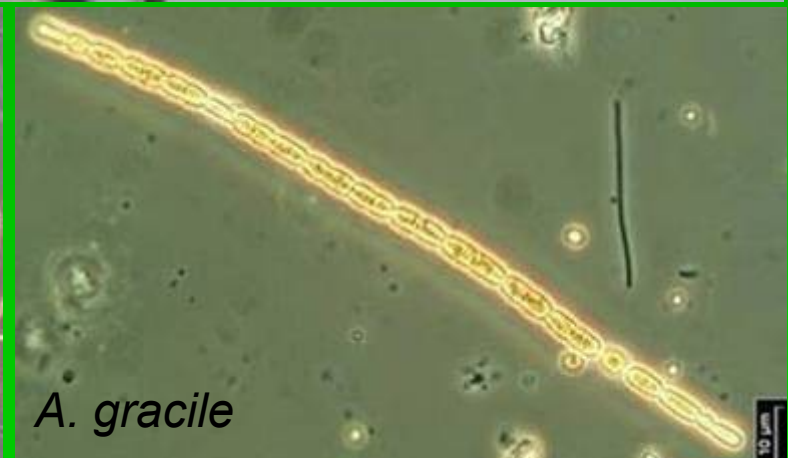
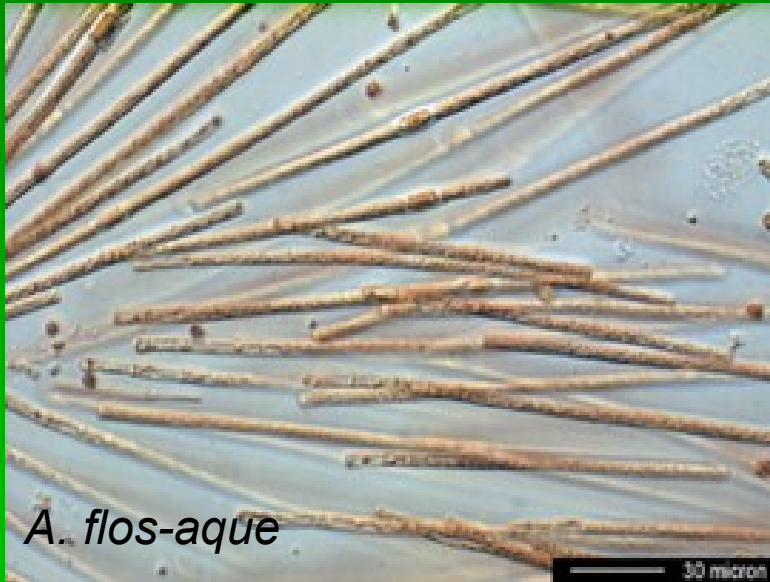
VIII. Nostocales – heterocytes intercalary

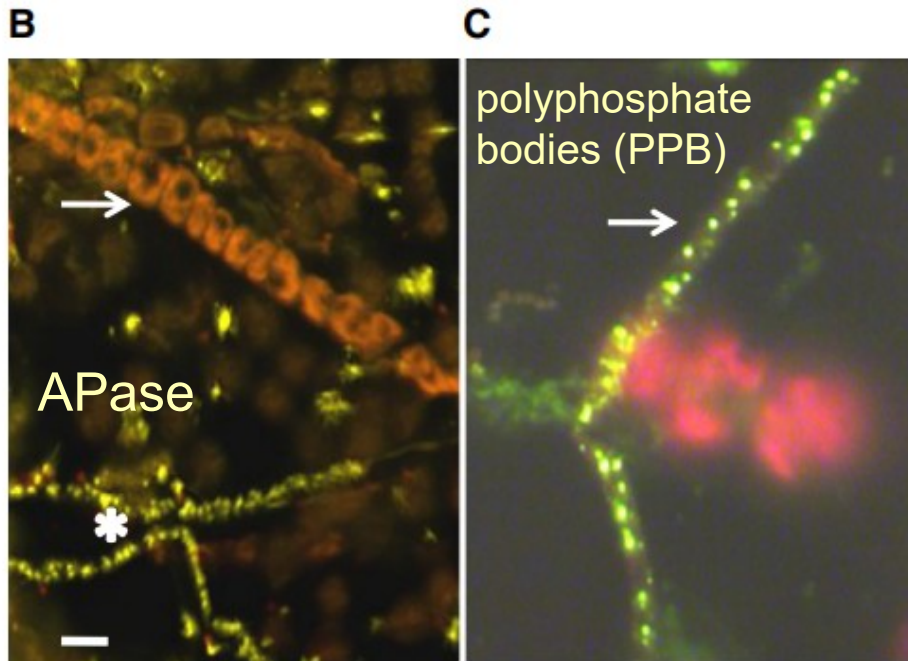
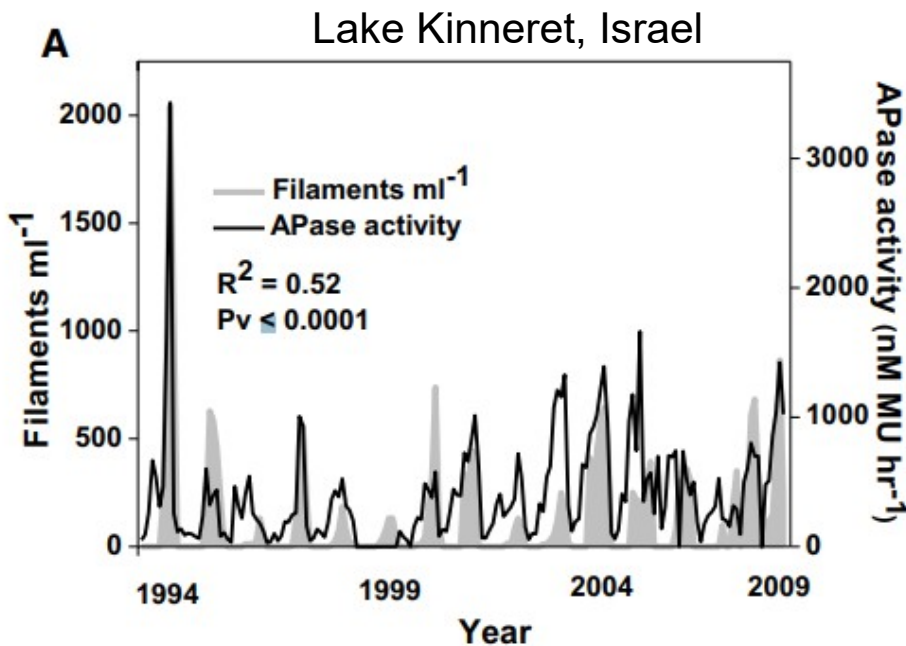
- *Dolichospermum* - planktonic (aerotopes), water bloom, some toxic, *Anabaena* – benthic species; fertilization, reservoirs



VIII. Nostocales – heterocytes intercalar

- *Aphanizomenon* – filaments evenly tapered at the ends, water bloom 'needles on the surface' – *A. flos-aque*,





Enslavement in the Water Body

Aphanizomenon ovalisporum

- ability to induce phosphate availability to itself through release of cylindrospermopsin
- Cylindrospermopsin causes other phytoplankton to increase their alkaline phosphatase activity, increasing inorganic phosphate availability in the water to *Aphanizomenon* during times when phosphate becomes limiting.

VIII. Nostocales – interkalární heterocyty

- *Nostoc* – s form colonies composed of filaments in a gelatinous sheath of polysaccharides, freshwater, soils, symbiotic



Nostoc flagelliforme



Facai



Desert crusts, North and North-west China



Fa Cai (Faai Choy) – in Cantonese, it sounds the same as 'meet good fortune.'



VIII. Nostocales – interkalární heterocyty

- *Nodularia* – cells short and wide, akinetes arranged in a row, benthic and planktonic, toxic

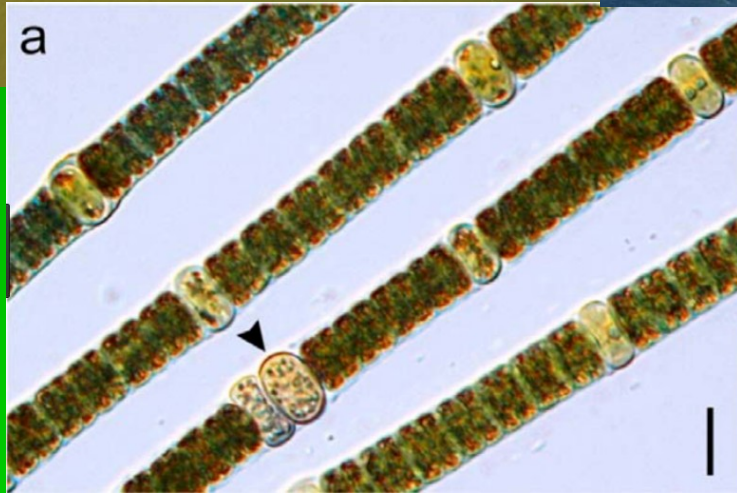
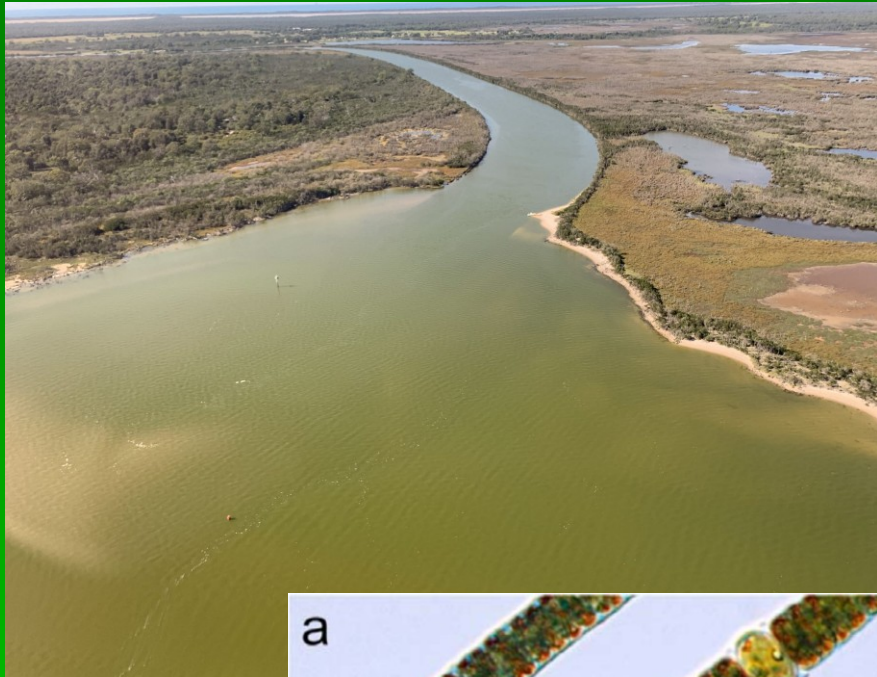


Soos – Císařský spring, in the Cheb basin



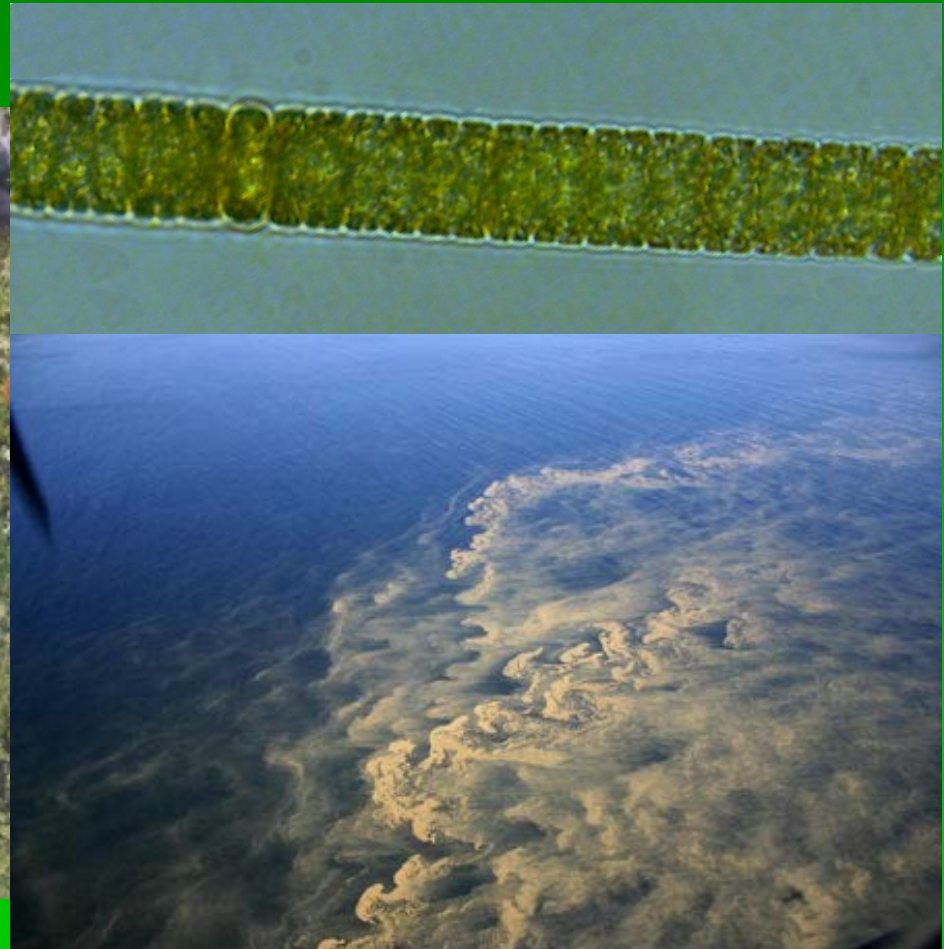
N. harveyana

Nodularia spumigena (mostly in brackish waters)



Nodularia spumigena bloom, January 2002, in the Gippsland Lakes, Victoria, Australia

Nodularia spumigena – Baltic Sea, brackish water, hepatotoxin (nodularin), max. toxicity with nitrogen deficiency and phosphorus excess



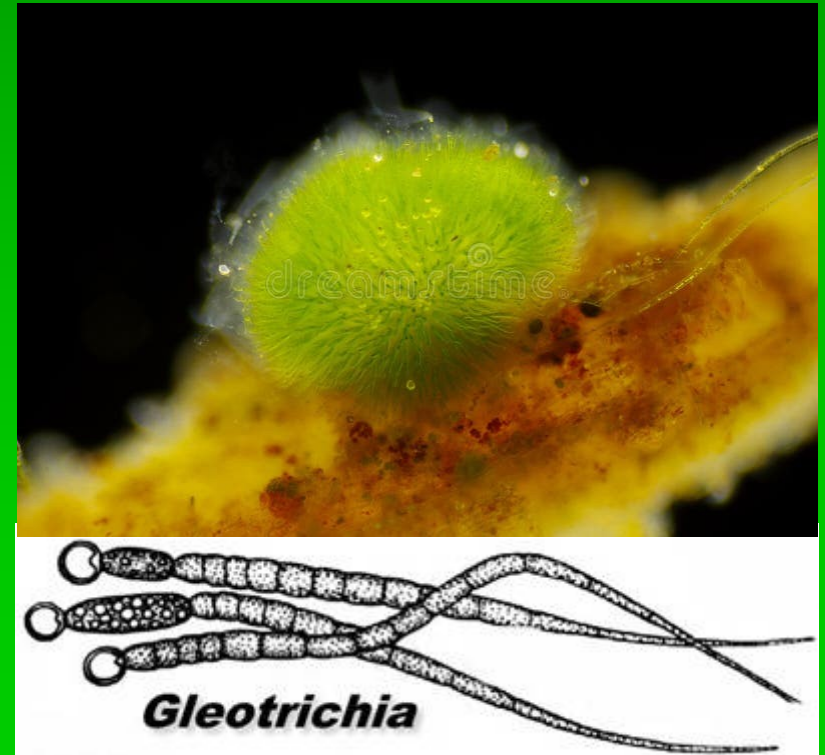
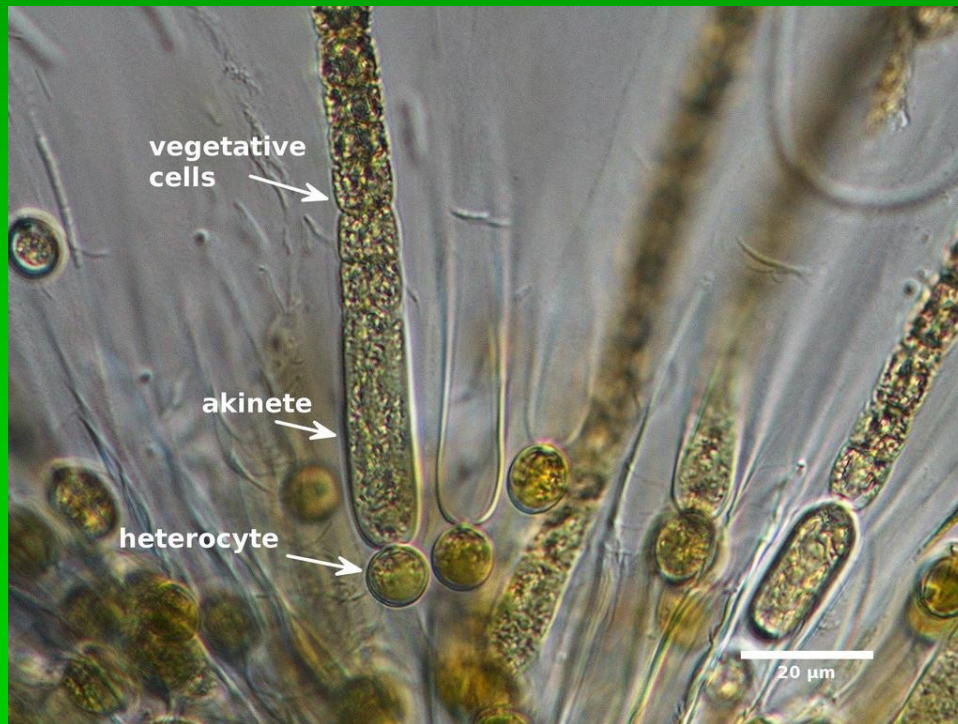
The wide blue-green algal accumulations were observed in the Åland Sea in July 2005. Photo Finnish Frontier Guard.

VIII. Nostocales – heterocytes basal

- *Gloeotrichia* – spherical colonies, macroscopic (2mm), submerged substrates, also in plankton, N fixer

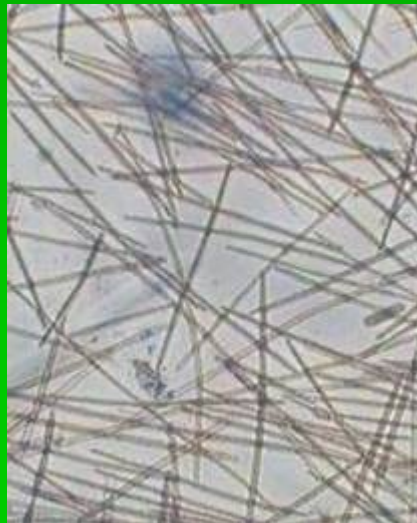
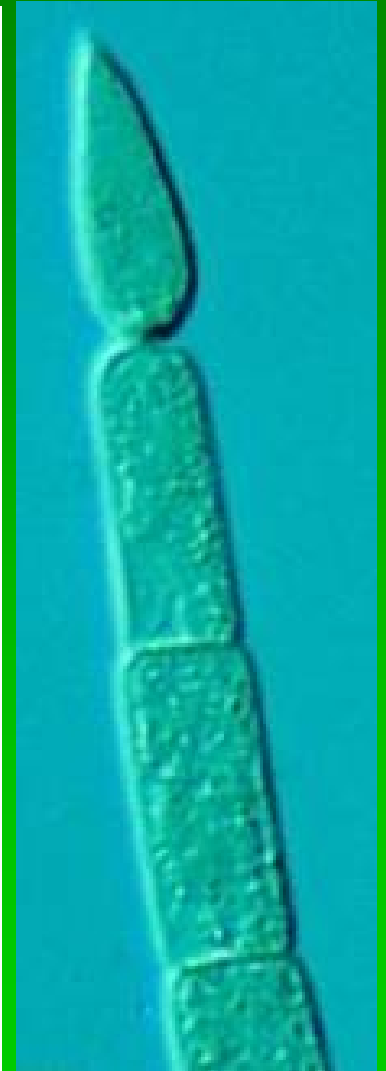
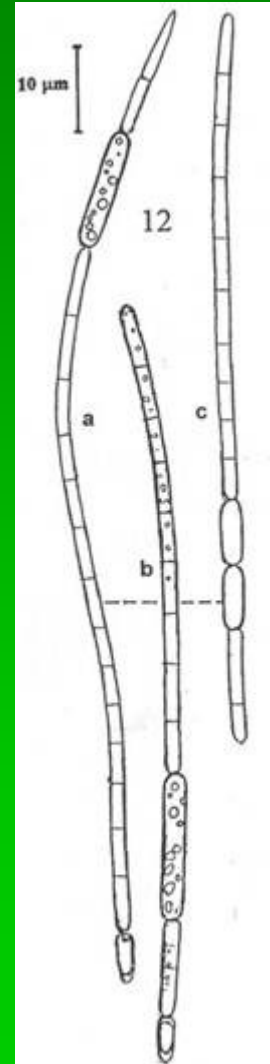


colonies develop in the bottom waters where sediment mineralization releases a portion of its phosphate, then adjust their buoyancy by elongating gas vesicles and rise to the surface - push lakes towards eutrophication



VIII. Nostocales – term. heterocyty

- *Raphidiopsis* (*Cylindrospermopsis*) – Heterocytes conical, asymmetric division of terminal cells, eutrophic waters, temperate zone to tropics, water bloom, toxic

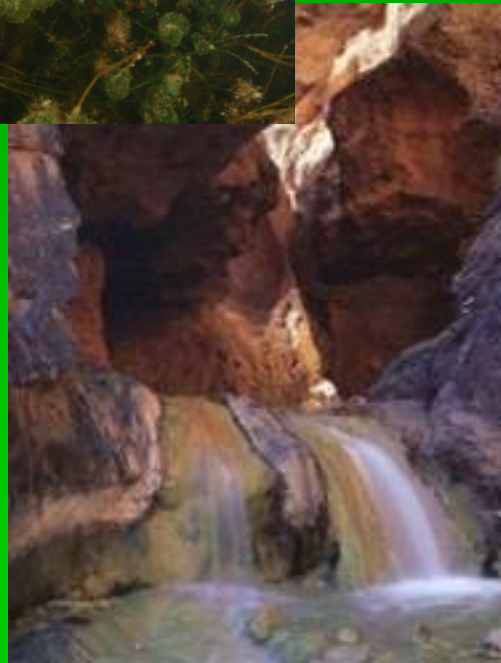
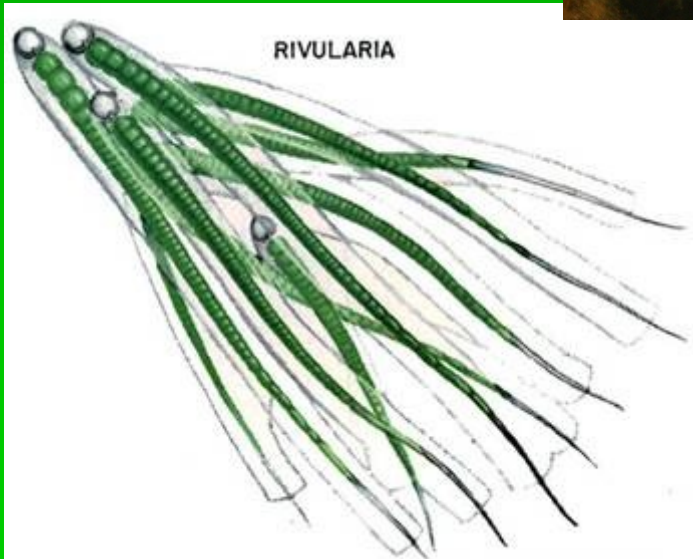


VIII. Nostocales – basal heterocysts

- *Rivularia* – Solid spherical colonies, macroscopic, submerged substrates, calcification → crusts, travertine

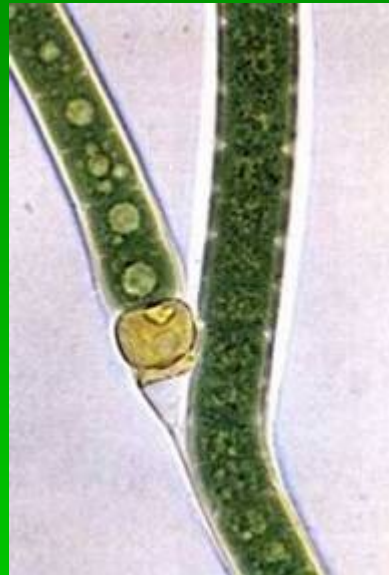


Baltic sea-Hiddensee



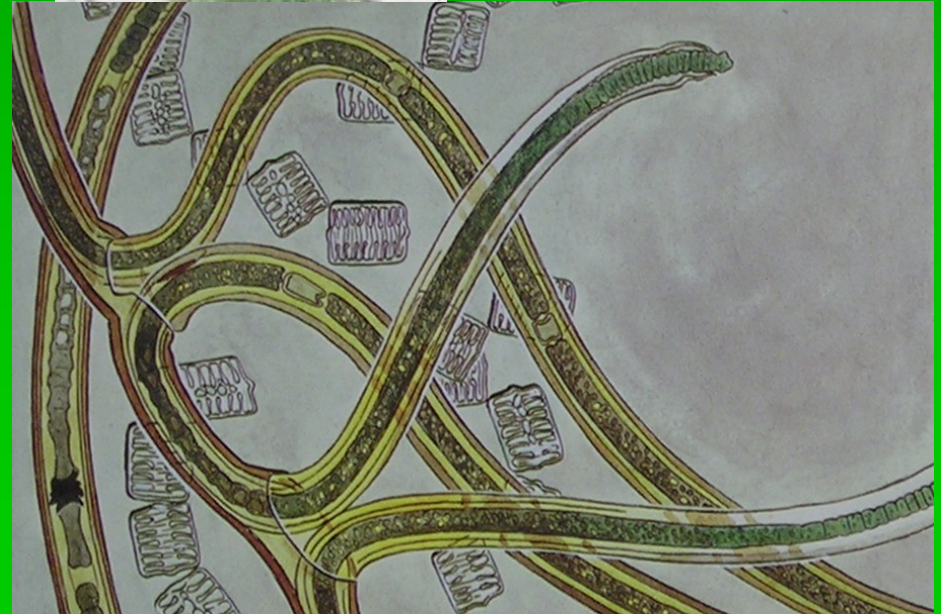
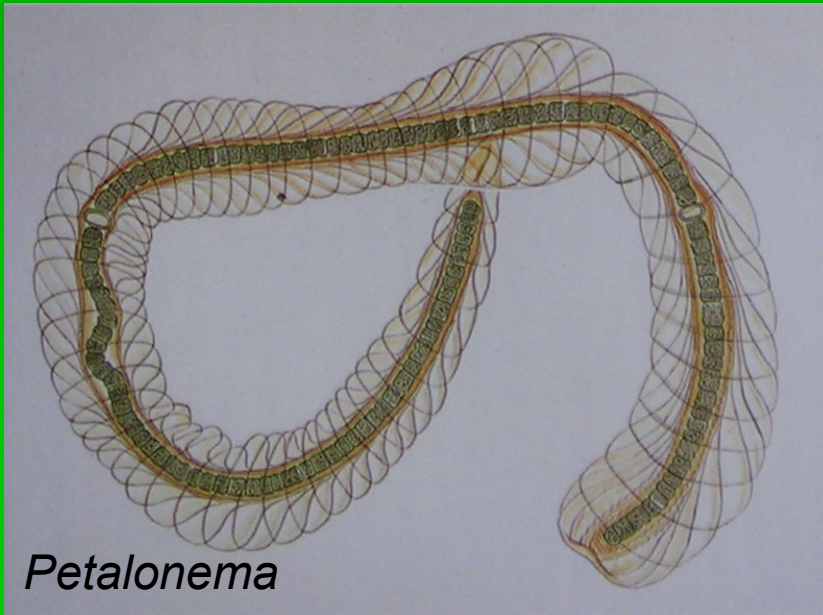
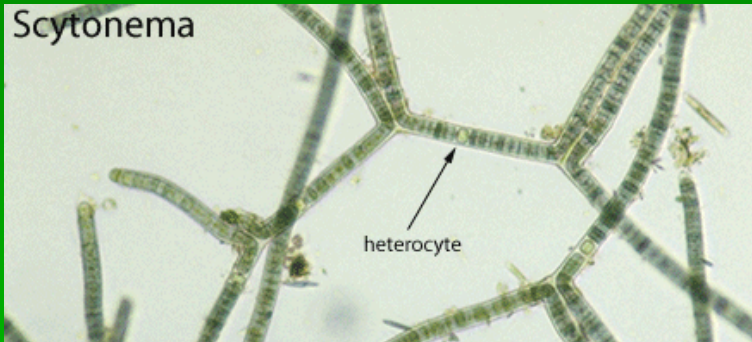
VIII. Nostocales – false branching

- *Tolypothrix* – Lateral filaments grow one by one, longitudinally layered sheath or without sheath, epiphyte, stream stones, submerged plants
- *Hasallia* – rare, aerophytic, cooling towers



VIII. Nostocales – false branching

- *Scytonema* – mucilaginous sheath, lateral branches in pairs, occasionally one by one, predominantly freshwater, CaCO_3 incrustation → travertine
- *Petalonema* – obliquely layered sheath, apically hormogonia



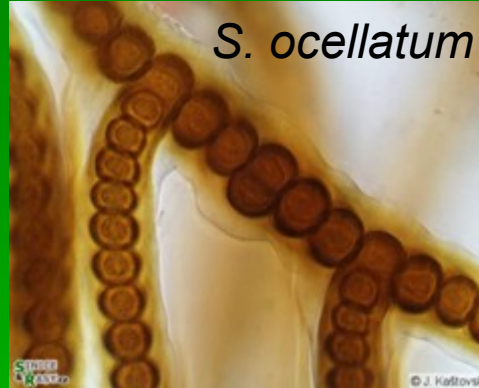
VIII. Nostocales – true branching

- *Stigonema* – prominent mucilage, uniseriate or multiseriate filaments, branching in all directions, subaerial, soil, growths, mainly in the tropics

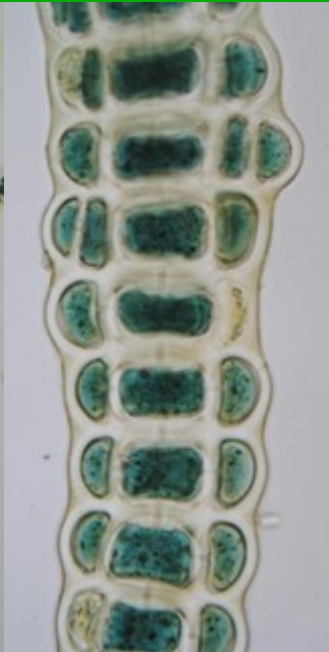
S. ocellatum



S. ocellatum



S. ocellatum



VIII. Nostocales – true branching

- *Mastigocladus* – uniseriate filaments, irregularly coiled, *M. laminosus* is an obligate thermophile (t from 45 to 60°C, pH > 7.5, low salinity), 1862 Karlovy Vary

