Division: Cyanobacteria

blue-green algae

- Single class: Cyanophyceae
- ~150 genera
- ~4037 species

1

Brief history of photosynthetic organisms on earth

3.45 bya = Cyanobacteria appear and introduce photosynthesis

1.5 bya = first Eukaryotes appeared (nuclear envelope and ER thought to come from invagination of plasma membrane)

0.9 bya = first multicellular algae (Rhodophyta - Red algae)

800 mya = earliest Chlorophyta (Green algae)

400-500 mya = plants on land – derived from Charophyceae

250 mya = earliest Heterokontophyta (Brown algae)

100 mya = earliest seagrasses (angiosperms)

2

DOMAIN

1.Bacteria- cyanobacteria (blue green algae)
2.Archae
3.Eukaryotes

Groups (Kingdom)

1. Alveolates- dinoflagellates
2. Stramenopiles- diatoms, heterokonyophyta
3. Rhizaria- unicellular amoeboids
4. Excavates- unicellular flagellates
5. Plantae- rhodophyta, chlorophyta, seagrasses
6. Amoebozoans- slimemolds
7. Fungi- heterotrophs with extracellular digestion
8. Choanoflagellates- unicellular
9. Animals- multicellular heterotrophs

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Domain Bacteria- unicellular, lacking a nucleus, ribosomes, tRNA, peptoglycan in the cell wall

Phylum Low-GC Gram-positive- staph infections & antrax
Phylum High GC- Gram-positive- tuberculosis & antibiotics
Phylum Hyperthermophilic bacteria- live at high temperatures
Phylum Hadobacteria-live at high temps, consume nuclear waste
Phylum Cyanobacteria- blue green algae, origin of the chloroplast
Phylum Spirochetes- syphilis & lime disease
Phylum Chlamydias- intercellular parasites
Phylum Proteobacteria- pathogens, nitrogen fixers, autotrophs, origin of mitochondria

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Cyanobacteria are important because:

• Cyanobacteria are modern representatives of the very first photosynthetic organisms on Earth.

•First organisms to have 2 photosystems and to produce organic material and to give off O_2 as a biproduct.

•Instrumental in transforming early earths atmosphere to an oxidizing one → **the oxygen revolution**

• Most common algal group in terrestrial systems and symbiotic relationships

Cyanobacteria Cellular Structure:

•**Nucleus?**

•**Chloroplasts?**

• **Pigments**?

• **Carbon storage**?

• **Flagella?**

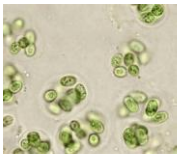
Cyanobacteria Cellular Structure

No complex organelles

Thyllakoids- photosystems I & II

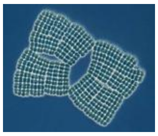
Carboxisomes- bacterial microcompartments that contain enzymes involved in carbon fixation
- concentrate CO_2 for RuBisCo

Cellular Structure: microscopic

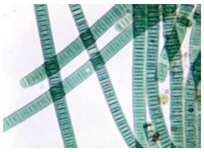


• Unicells in mucus envelope

• Colonies



• Filaments, Branched filaments→ most complicated form



Cyanophyta Cellular Structure

vegetative cells- photsynthesize

spores- resting stages

heterocysts- specialized cells for fixing nitrogen

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"facultative chemoautotropes"

•Many spp have the ability to photosynthesize under both aerobic and anaerobic conditions

Difference is where the electrons come from:

Aerobic conditions? Electron donor is Water → O_2 produced

$$CO_2 + H_2O \longrightarrow CH_2O + O_2$$

Anaerobic conditions? Electron donor is Hydrogen sulfide → Water is produced

$$2H_2S + CO_2 \longrightarrow CH_2O + 2S + H_2O$$

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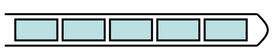
Morphology of Cyanophyta

- Cell wall made of peptidoglycan, polymer consisting of sugars and amino acids (not cellulose), similar to gram-negative bacteria
- **Trichome**- Row of cells
- **Filament**- Trichome within a **mucilaginous sheath**
- **Mucilaginous Sheath**- layer of mucilage outside of cell wall



- Possible to have > 1 trichome within a filament

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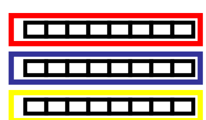
Mucilaginous Sheath –

-motion (gliding)
-protection against desiccation
- protection against UV irradiance

Sheath is often colored:

Red = acidic
Blue = basic
Yellow/Brown = high salt



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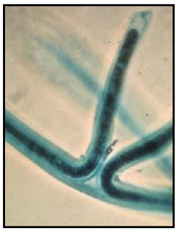
False branching =

outgrowth of filaments adjacent to dead or specialized cells; filament curves



True branching =

outgrowth from cells that change their axis of division, 90 degrees from axis of trichome

Movement

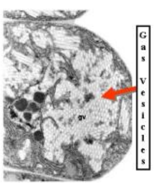
1. "Gliding" against a solid substrate -no change in shape or obvious pushing; no ability to steer, sometimes trichome rotates within sheath, and sheath is left behind as the trichome moves forward
2. Jet propulsion = excrete mucus
3. Helical species (e.g. *Spirulina*), use waves of contraction
4. Swimming? No idea how they do this, but evidence of chemotaxis and phototaxis.
5. Changing buoyancy

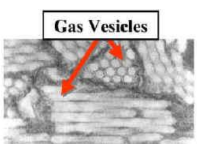
Buoyancy:

Cells contain gas vesicles or gas vacuole
= hollow cylinders made of protein

•*low light?* Decreased Ps → metabolism of polysaccharides → increase in gas vacuoles → float upward

•*high light?* Increased Ps → Accumulation of polysaccharides → cell pressure increases → gas vacuoles shrink → sink





Reproduction:

- ✓ No sexual reproduction → some DNA transfer has been observed, not conjugation per se.
- ✓ Asexual reproduction through:

1-Binary fission – dividing in two

2-Fragmentation of colonies

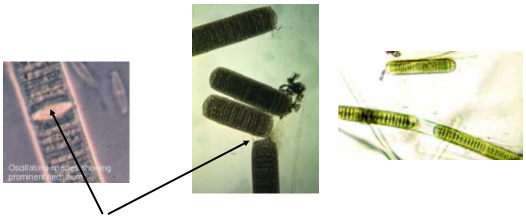
3-Endospores/exospores

4-Hormogonia

5-Akinetes

Reproduction

4. **Hormogonia** = short piece of trichome that detaches from parent filament and glides away



Separation disk or "Necridium" = funky dead cell where detachment occurs

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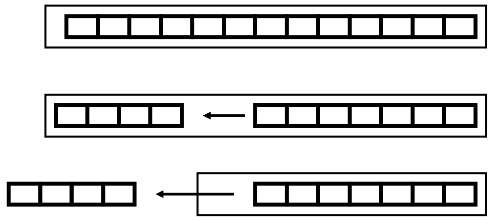
Asexual Reproduction

Hormogonia – short piece of trichome found in filaments. It detaches from parent filament and glides away



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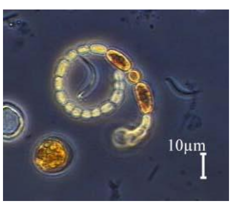
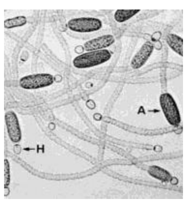
Reproduction

5. **Akinetes** = thick-walled resting spores.

   Packed with energy reserves; dense = sink to the bottom when released.

   Triggered by unfavorable conditions, can remain viable for years.





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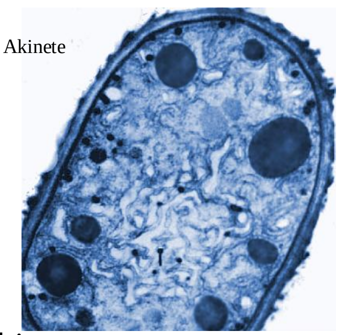
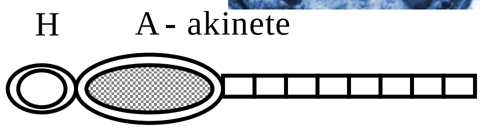
Akinete





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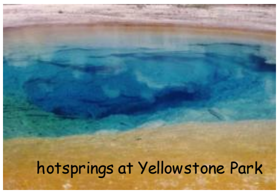
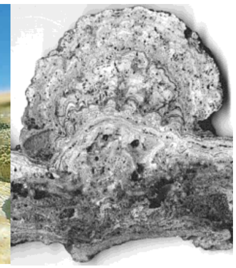
Wide Range of Habitats



- Freshwater lakes
- Terrestrial soils
- Marine systems (intertidal, open ocean)
- **Extreme** environments (e.g. salt flats, hot springs, glaciers, etc.)
- Endosymbiotic: diatoms, sponges, tunicates, lichens, polar bear fur, bryophytes, gymnosperms, angiosperms

Earliest evidence of Cyanobacteria comes from stromatolites: Precambrian- 3.5 BYA



- Layered calcareous mounds that contain fossils of cyanobacteria that look like Oscillatoria

Stromatolites

- Stromatolites are produced by successive deposition through "grain trapping" or calcification:
  - **Mucilaginous** sheath of cyanos physically blocks the movement coarse gain sediments and laminates it to the surface of the stromatolite
  - Attract and bind Ca ions to negatively charged sites
- Locations : **hypersaline seas** (Shark Bay,western Aus.), **frozen lakes** (Antarctic), **hot springs** (Yellowstone), the Caribbean
- Most cyano's active during the day= layers count the numbers of days
- Also they grow up toward the sun and are directional toward the sun (=can document annual motion of sun)

Another big reason Cyanobacteria are cool and ecologically important: **Nitrogen fixation**

Many are able to fix nitrogen = convert atmospheric N_2 ($N \equiv N$) to a usable form (Ammonium: NH_4+) using enzyme nitrogenase

N can be limiting; necessary for the production of amino acids

Only cyanobacteria and proteobacteria can fix N;
BUT cyanobacteria also produce O_2 during photosynthesis

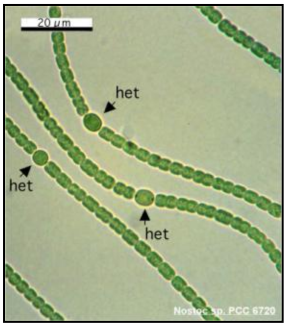
This is a trick, because O_2 inactivates nitrogenase

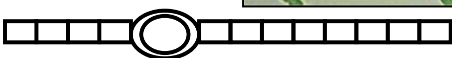
How do they do it???

1. Spatial separation of functions:

Heterocyst = special cells for N fixation.

- Thick-walled, and larger than other vegetative cells; hollow looking
- Not capable of dividing
- Not photosynthetic, so no CO_2 fixation or O_2 production
- Microplasmedesmata connect to other cells in filament





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2. Temporal separation of functions:

- Fix N in the dark, Ps in the daytime;

Every N-fixing cyanobacteria fits into these two categories **except:**

Trichodesmium = marine, colonial species; fix nitrogen under aerobic conditions in the light through division of labor among cells within a filament (no heterocysts)!

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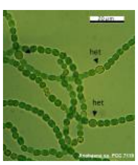
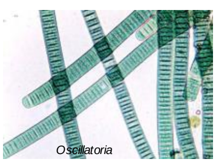
The dark side of cyanobacteria?

Cyanobacterial blooms = death and destruction

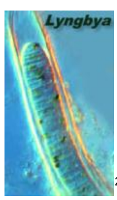
Swimmer's itch = *Lyngbia* → releases chemicals

Cyanotoxins: released by animal ingestion → neurotoxins (e.g. *Anabaena, Oscillatoria*) and hepatotoxins (e.g. *Microcystis, Nostoc*) (death to mammals, birds, fishes , no known human deaths)





Oscillatoria



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Domain Bacteria- unicellular, lacking a nucleus, ribosomes, tRNA, peptoglycan in the cell wall

Phylum Cyanobacteria- 4037 species

Class Cyanophyceae- 4037 species, 7 orders

Order Chroococcales- 954 species
filamentous, no specialized structures

Order Oscillatoriales -926 species
filamentous, no specialized structures

Order Nostocales- 1,297 species
filamentous, specialized structures, may have true branching

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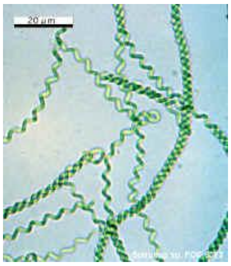
Order Chroococcales

Genus Spirulina

- Filament is spiral
- Major food source for flamingos
- Commercial food source
- No heterocysts or akinetes
- benthic or plantonic, freshwater, thermal & mineral springs, coastal & brackish waters
- 52 species



Domain Bacteria- unicellular, lacking a nucleus, ribosomes, tRNA, peptoglycan in the cell wall

Phylum Cyanobacteria- blue green algae, origin of the chloroplast

Class Cyanophyceae-

Order Chroococcales- filamentous, no specialized structures

Order Oscillatoriales -filamentous, no specialized structures

Order Nostocales- filamentous, specialized structures, may have true branching

Order Oscillatoriales

Genus Oscillatoria

- Unbranched filaments
-No readily identifiable sheath, but is present
-No specialized cells
-Fix nitrogen
-Early precambrian fossil stromatolites
-Planktonic, form mats on mud, stone, sand, in freshwater, brachish, marine
-137 species

Order Oscillatoriales

Genus Trichodesmium

- Important marine N fixer
- Segregates N fixing within colonies (lacks heterocysts)
- More Phycoerythrin than Phycocyanin
  → Red color, gave the Red Sea its name
- Strictly planktonic- marine & fresh water
-10 species

Domain Bacteria- unicellular, lacking a nucleus, ribosomes, tRNA, peptoglycan in the cell wall

Phylum Cyanobacteria- blue green algae, origin of the chloroplast

Class Cyanophyceae-

Order Chroococcales- filamentous, no specialized structures

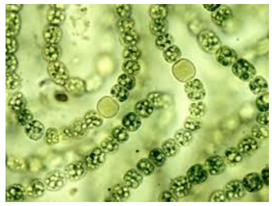
Order Oscillatoriales -filamentous, no specialized structures

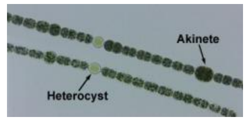
Order Nostocales- filamentous, specialized structures, may have true branching

Order Nostocales

Genus Nostoc

- Fixes nitrogen
- Has heterocysts in the middle of filaments
- Akinates midway between heterocysts
- 94 species
- Freshwater

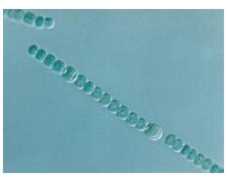


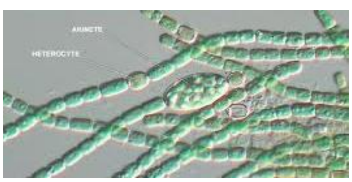


Order Nostocales

Genus Anabaena

- Produces neurotoxins that become release when they are ingested by animals
- Fixes nitrogen
- Has heterocysts in the middle of filaments
- Akinates adjacent to heterocysts
- Planktonic, or periphytic, benthic, soils,
- 117 species





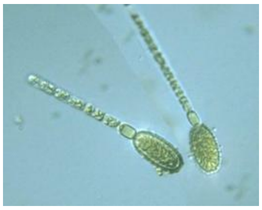
Order Nostocales

Genus Calothrix

- Fixes nitrogen
- Has heterocysts, often at the base of filaments
- Filaments taper at ends
- Periphytic on algae, aquatic plants, stone, wood, high intertidal
- 132 species

Order Nostocales

Cylindrospermum



- Produces neurotoxins that are released when they are ingested.
- Fixes nitrogen
- Has heterocyst at the base of large akinetes
- Periphytic or soils
- 49 species

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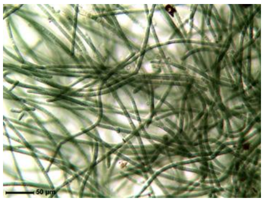
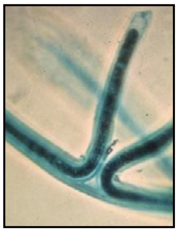
Order Nostocales

Genus Tolypothrix



- Fixes nitrogen
- Has heterocysts
- Exhibits false branching
- 60 species
- Mainly submerged, also aerophytic habitats



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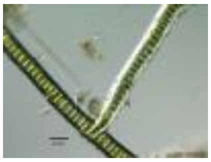
Order Nostocales

Stigonema

- Has heterocysts
- Exhibits True Branching
- Often found as phycobiont in lichens, terrestrial & soil, freshwater
- 62 species



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