Division: Cyanophyta

(blue-green algae or cyanobacteria)

- Single class: Cyanophyceae
- ~150 genera
- ~2000 species

Classification……

Scientists debate on how to classify:
→ more closely related to bacteria than eukaryotic algae

Orders based on:

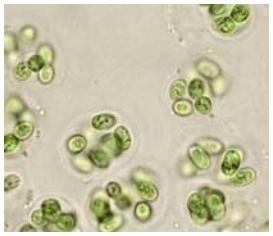
- filamentous vs. non-filamentous types

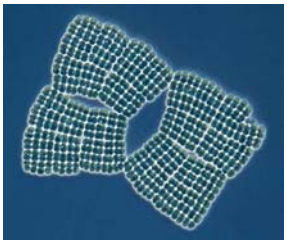
- within filamentous:
  - simple or branched
  - specialized cells or not (heterocysts and akinetes – will discuss later)

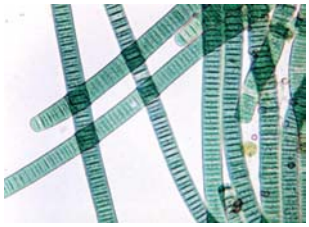
Cellular Structure…….

•individuals are microscopic

• unicells in mucus envelope, colonies, and filaments; most complicated form → Branched filament.







Cellular Structure (cont.)…….

•Kingdom – Monera

•Nucleus – none, circular DNA, lack histones

•Chloroplasts – no complex organelles (chloroplasts, mitochondria, golgi, etc) …….but do have thylakoids which contain photosystems I & II (respiration – in thylakoids too!)

•Pigments – Chl a, b and phycobiliproteins

•Thylakoids – single or paired (one species lacks thylakoids altogether – Ps pigments in cell membrane)

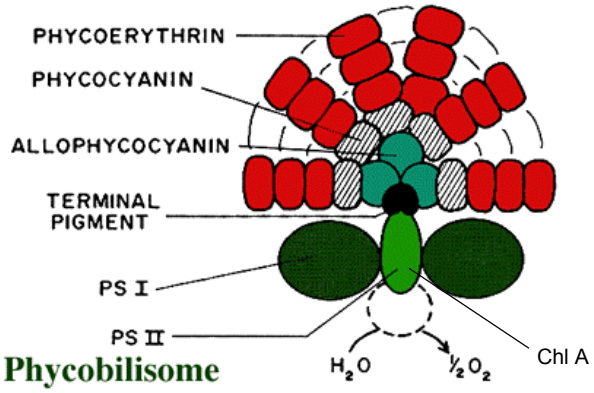
•Carbon storage - starch

•Flagella – none

• Carboxysomes – contain RuBisCo

Light Capturing "Antennae"

• phycobiliproteins act as both light antennae and reserves of cellular nitrogen



Side note→ phycocyanin gives blue-green coloration

Chromatic adaptation: green light ↑ phycoerythrin, red light ↑ phycocyanin

Morphology of Cyanobacteria

• cell wall made of peptidoglycan (not cellulose), similar to gram-negative bacteria (more complex cell wall than gram-positive)

• row of cells = **trichome**

• trichome within a **mucilaginous sheath** = **filament**

• possible to have > 1 trichome within a filament

• mucus sheath involved in motion (gliding) and protection against desiccation and UV irradiance (sometimes pigmented)

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

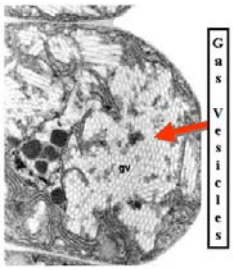
Movement……..

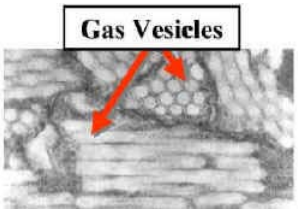
1. "Gliding" against a solid substrate -no change in shape or obvious pushing; no ability to steer, sometimes trichome rotates within sheath, and sheath is left behind as the trichome moves forward
2. Jet propulsion = excrete mucus
3. Helical species (e.g. *Spirulina*), use waves of contraction
4. Swimming?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

Buoyancy:

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

- *low light?* decreased Ps → metabolism of polysacharides → increase in vacuoles → float upward
- *high light?* Increased Ps → Accumulation of polysacharides → cell pressure increases → vacuoles shrink → sink





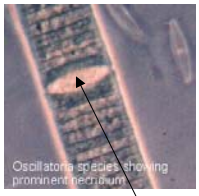
Reproduction:

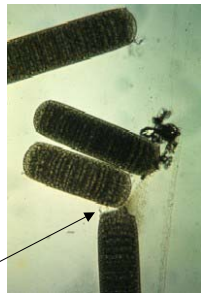
- ✓ No sexual reproduction
- ✓ Assexual reproduction through:

1) **Binary fission – dividing in two**
2) **Fragmentation of colonies**
3) **Endospores/exospores**

Reproduction (cont.)

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





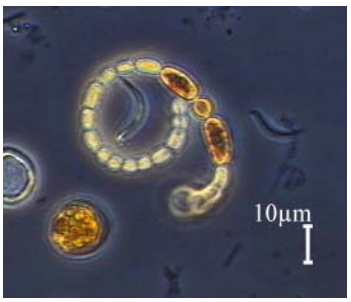
Separation disk or "Necridium" = funky dead cell where detachment occurs

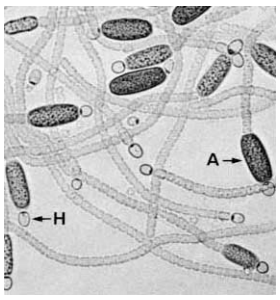
Reproduction (cont.)

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

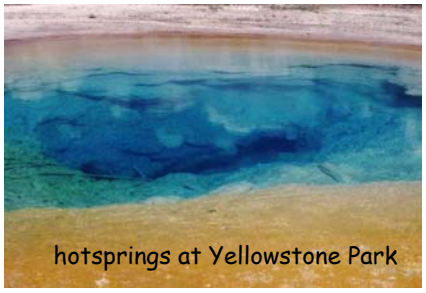
   Packed with energy reserves; dense = sink to the bottom when released.

   Resists unfavorable conditions, can remain viable for years.





Wide Range of Habitats……


hotsprings at Yellowstone Park

•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

endolithic species (= inside rocks!)

Hyella stella: a cyanobacterium that lives in marine limestone

Sheath color usually varies with environment

- red = acidic
- blue = basic
- yellow/brown = high salinity

Origins of Photosynthesis……

- first prokaryotes were anaerobic heterotrophs (explains ubiquitous presence of glycolysis pathways in most groups of organisms)

- first metabolic pathway was anaerobic (fermentation)

- Competing hypotheses: (Photosynthesis Evolution)

(1) Photosynthesis may have evolved independently many times (photosynthetic groups scattered among many branches of prokaryote phylogeny)

(2) Photosynthesis evolved once in an ancestor common to the diverse prokaryotic groups that use photosynthesis today (Molecular machinery for photosynthesis very complex)

Origins of Photosynthesis……(cont.)

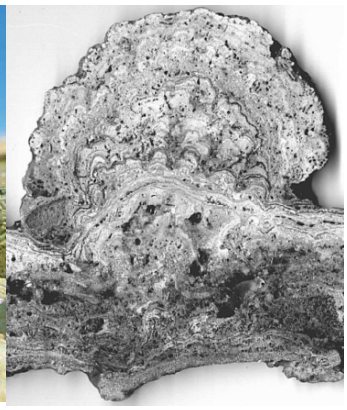
• some modern prokaryotes perform "simpler" photosynthesis (single photosystem to extract electrons from H_2S, instead of splitting water

•cyanobacteria are the only autotrophic prokaryotes that release O_2 by splitting water during the light reactions

• transformed early earths atmosphere - oxygen revolution – bad for some, good for others

• it is likely that cellular respiration evolved from photosynthetic equipment for a new function

Earliest evidence of Cyanophyta comes from stromatolites: 3.5 BYA



• layered calcareous mounds that contain fossils of prokaryotes that look like cyanobacteria

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)

•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)

Cyanophyta are important because……

• first algae to evolve

• only autotrophic prokaryotes that release O2 by splitting water during the light reactions

• first terrestrial photosynthetic organism of any kind

• instrumental in transforming early earths atmosphere from a reducing one to an oxidizing one

•cyanophyta thought to be the endosymbiont(s) that led to chloroplasts in other algal groups

• simplest organisms to have circadian clocks

• most common algal group in terrestrial systems and symbiotic relationships

Some cyanos are: "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 → Water (O2 produced)

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

Anaerobic conditions? Electron donor → Hydrogen sulfide (no O2 produced)

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

- As facultative chemoautotropes, cyanobacteria fill important niche in environments where aerobic/anaerobic conditions fluctuate

Example: Solar Lake, Israel

- In winter high levels of hydrogen sulfide are found in the anaerobic bottom layers of the thermally stratified lake

Cyanophyta also include both obligate phototrophs (=energy only from photosynthesis) and heterotrophs (= external source of carbon)

Another big reason Cyanophyta are cool and ecologically important……**Nitrogen fixation**

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

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

Only cyanophyta and prokariotic bacteria can fix N; BUT cyanophyta also produce O_2 during photosynthesis

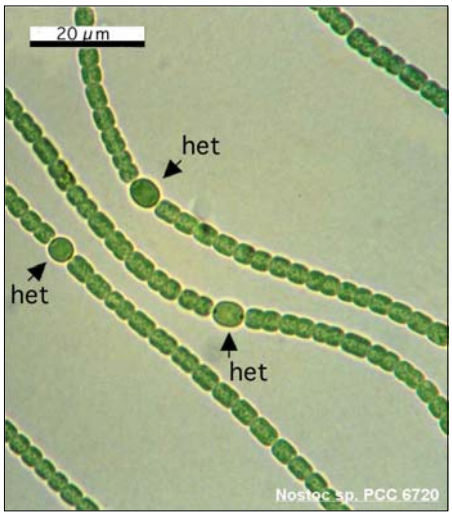
This is a trick, because O_2 inactivates nitrogenase

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



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)!

Ecological Importance…….

✓N-fixing cyanobacteria hugely important in rice paddies

✓Black film in upper intertidal zone? You guessed it. Important source of N in intertidal communities.

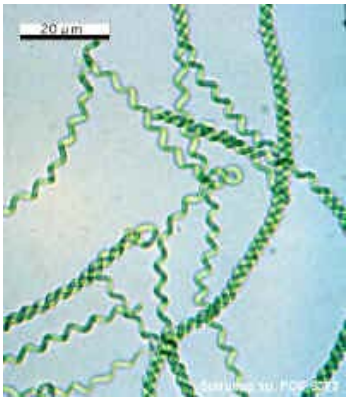
✓In terrestrial soils, also prevent erosion by binding sod particles; maintain moisture; biofertilizer to enrich soil nitrogen

Medical Importance…….

✓Antibiotic and pharmaceutical compounds from Cyanophyta:

- Compounds developed from Cyanophyta currently used against: herpes, pneumonia, HIV
- Antifungal drugs
- Some compounds used in cancer treatment (reduce tumor growth rates)

Spirulina…….



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Spirulina……

Dietary Benefits:

- Contains all essential amino acids in perfect balance for human consumption.
- Contains highest percent vegetable protein at 58%.
- Highest known chlorophyll level.
- Composed of soft cell wall made of polysaccharides and proteins.
- Rich in beta-carotene, carotenoids, antioxidants, vitamin B12, and iron.

Medical Benefits:

- Boosts immune system by increasing cytokines.
- Spirulina therapy shrinks tumors in mice.
- Spirulina binds to heavy metals and can detoxify liver and kidneys through process called Chelation.

Human History and *Spirulina*

•Documentation of Aztecs using Spirulina in 16th century.

•Indigenous use in Africa (Chad and Niger).

•Today mass commercial production in Oregon and Hawaii.

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)