CYANOBACTERIA

THE BLUE GREEN ALGAE

Cyanobacteria

- The division Cyanophyta includes a large number of Algae which are characterized by a low state of cell organization
- The cells lack well defined nucleus and characterized by a blue green coloration, the chief pigments being Chlorophyll *a*, Carotenes, Xanthophylls, *c*-Phycocyanin and *c*- Phycoerythrin
- The product of photosynthesis is glycogen
- These organisms lack flagellated reproductive bodies and sexual reproduction is totally absent

General Characters

- The most widely distributed of any group of algae and inhabit marine and freshwater environments, moist soils and rocks, either as freeliving or as symbiotic organisms Some planktonic forms can float owing to the presence of gas vacuoles, and most of the filamentous forms have gliding motility
- Structural range from unicells through branched and unbranched filaments to unspecialized colonial aggregations which are surrounded by a firm or amorphous mucilage
- Numerically these organisms dominate the ocean ecosystems and there are approximately 1024 cyanobacterial cells in the oceans
- Classified as obligate photoautotrophic organisms

- All blue-green algae are non-motile Gram negative eubacteria They lack a nucleus and organelles (chloroplast, mitochondria)
- Contain polyhedral bodies (carboxysomes) containing RuBisCo (ribulose bisphospate carboxylase/oxygenase, the enzyme that converts inorganic carbon to reduced organic carbon in all oxygen evolving photosynthetic organisms)
- Circular DNA, no chromosomes, no histone protein, 70S ribosomes, smaller than eukaryotic
- Cell walls characterized by a peptidoglycan layer
- Reproduction is strictly asexual, by simple cell division or fragmentation of the colony or filaments.

Habits

- Unicells
  - Singly- Synechocystis
  - Colonies of unicells- Aphanothece
- Rows of cells
  - Unbranched filaments without sheath (trichome)- Oscillatoria
  - Many trichomes in 1 large sheath- Microcoleus
  - Unbranched filaments with sheath- Lyngbya
  - Uniseriate branched filaments- Mastigocladus
  - Multiseriate branched filaments- Stigonema
  - Pseudo-branched filaments- Scytonema

Thallus Organization

Morphologically, two broad categories of thallus organization are made.

However, in both the forms -

The cell protoplast is clearly divisible into two parts,

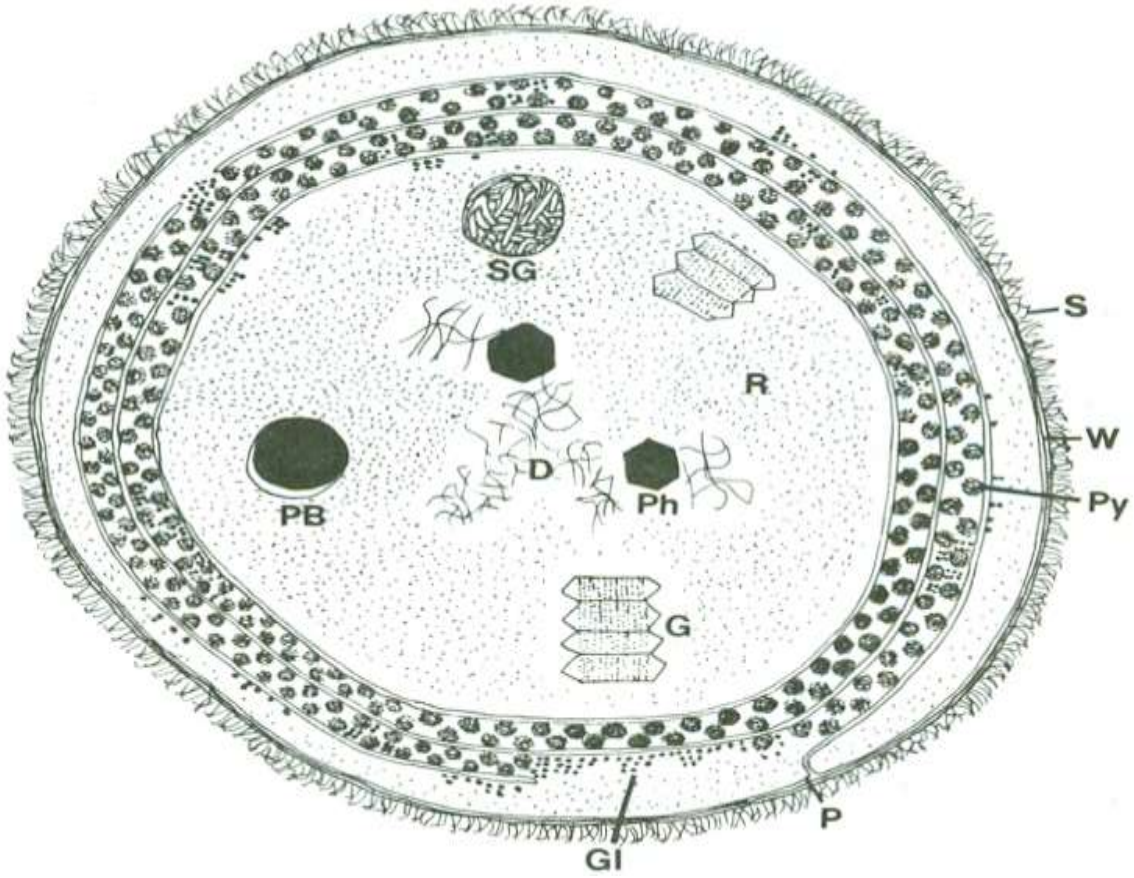
1. Peripheral pigmented region (chromoplasm)
2. Central colourless (centroplasm)

1.**Nonfilamentous** – These are mainly coccoid forms, having spherical, cylindrical or fusiform shapes.Repeated divisions lead to formation of a colony made up of many cells enveloped by one or more diffluent or firm mucilaginous sheaths

2. **Filmantous –** These are conditions which are made up of a long series of cells placed one over the other to form a long trichome. The trichome often secrete mucilaginous sheath of varying consistency, firm or flexible. The tricome is either straight, tips may be somewhat bent or whole trichome is spirally coiled. The cells of the trichomes are uniform (homocystous) or is interrupted at more or less regular intervals by special thick walled cells called heterocysts (heterocystous). The trichomes are either unbranched or branched.

Cyanobacteria

- **Cell Characteristics**
  - Chlorophyll A
  - Phycobilisomes
  - Thylakoids occur singly
  - 70s ribosomes
  - DNA microfibrils central
  - Polyhedral bodies
  - Gas vesicles



- **Habitat-** ubiquitous
- **Examples-** ***Anabaena, Nostoc, Oscillatoria, Lyngbya, Synechococcus, Synechocystis*.**

Cell organization

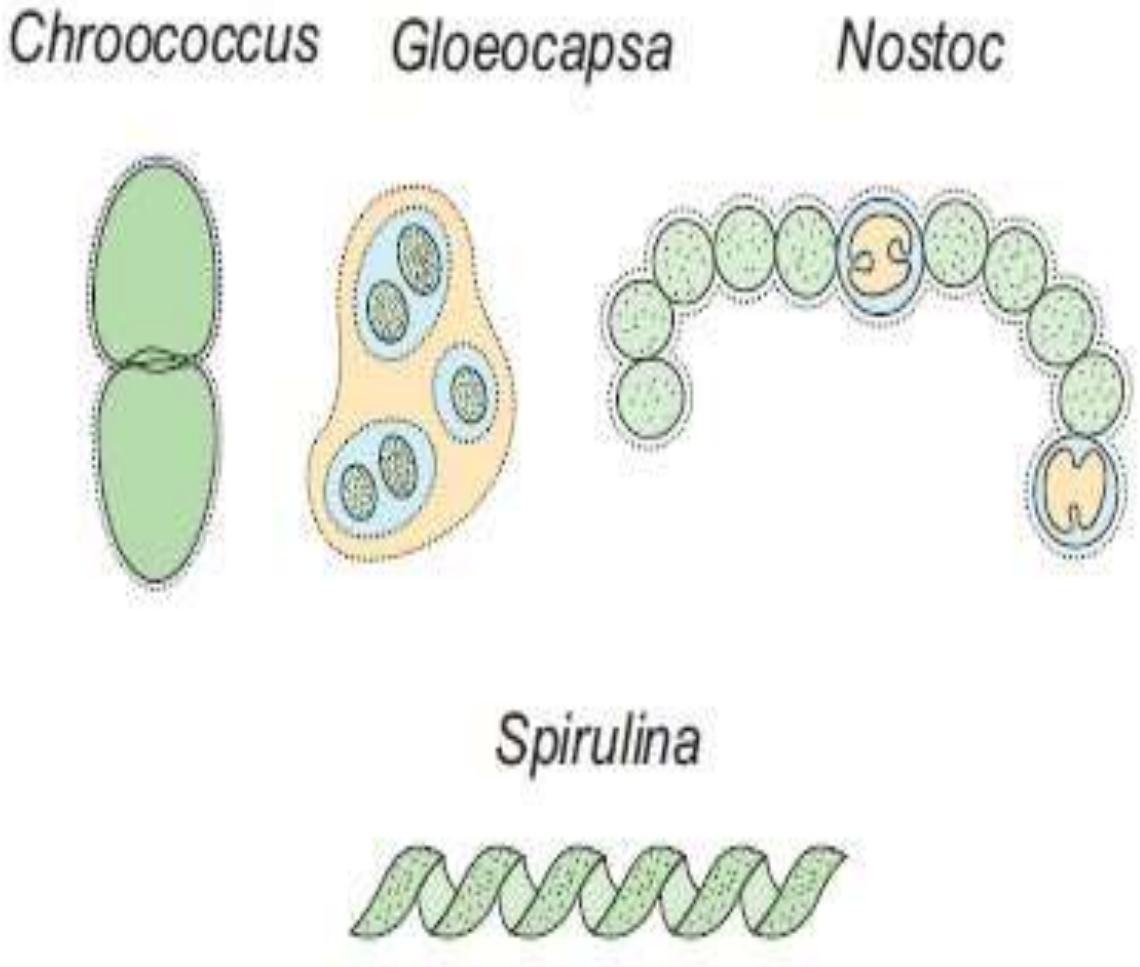
- Pigmentation of cyanobacteria includes chlorophyll a, blue and red phycobilins (phycoerythrin, phycocyanin, allophycocyanin, and phycoerythrocyanin), carotenoids and xanthophylls
- These accessory pigments lie in the phycobilisomes, located in rows on the outer surface of the thylakoids. The traditional name of blue-green algae for the Cyanophyceae is due to the presence of phycocyanin and phycoerythrin, which usually mask the chlorophyll pigmentation
- Their thylakoids, which lie free in the cytoplasm, are not arranged in stacks, but singled and equidistant, in contrast to prochlorophytes and most other algae, but similar to Rhodopyta and Glaucophyta

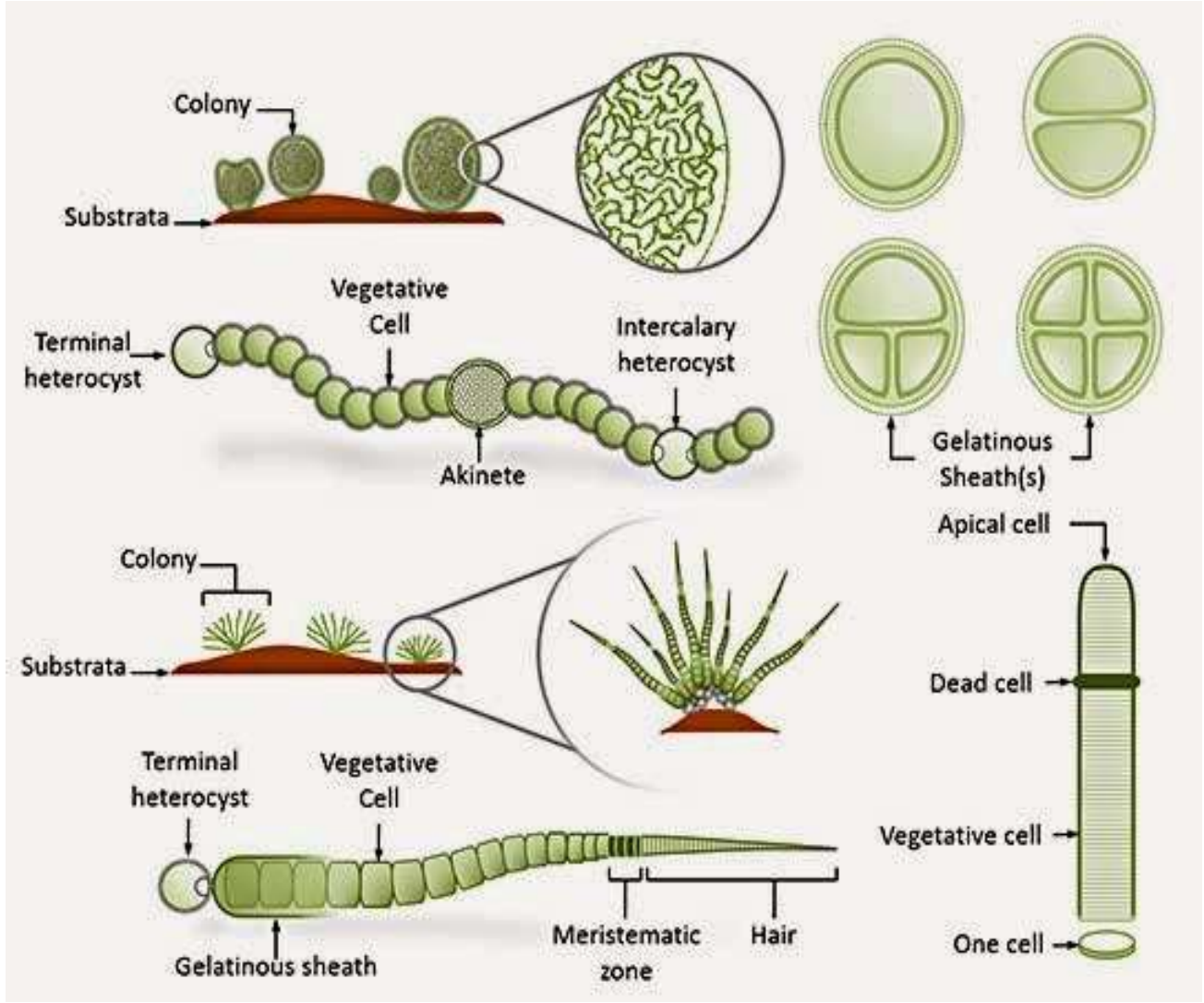
- The reserve polysaccharide is cyanophycean starch, stored in tiny granules lying between the thylakoids. In addition, these cells often contain cyanophycin granules, that is, polymer of arginine and asparagine.
- Some marine species contain gas vesicles used for buoyancy regulation.
- In some filamentous cyanobacteria, heterocysts and akinetes are formed
- Cyanobacteria in extreme habitats show Anoxygenic photosynthesis
- They lack photosystem II perform photosynthesis without O2 production and use hydrogen sulfide (H2S) as electron donor

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

- Some Thermophilic forms live in extremely high temperature of up to 70°C (Yellowstone Park)

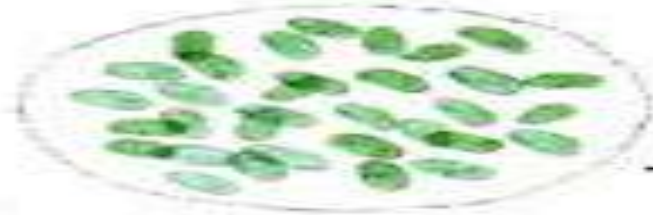
Cell organization





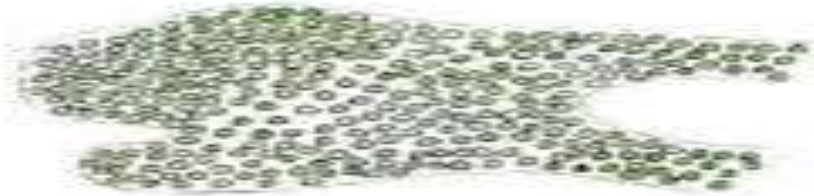
Cyanobacteria– unicellular & colonial

Synechococcus



Aphanothece

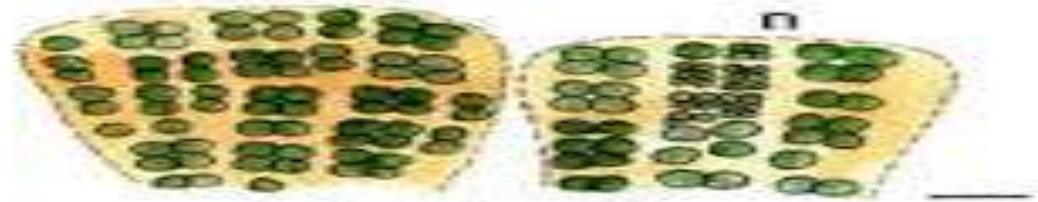
Gloeocapsa



Microcystis

g

Coelospaerium



n

Entophysalis

Dermocarpa

g b

b

Chamaesiphon

b baeocyte, g gas vacuolate, n nannocyte

Classification

Phylum Cyanophyta

Classs Cyanophyceae

1. **Order Chroococcales** – unicellular or colonial never trichome, No base/apex, no exospores

   Family Chroococcaceae – Unicellular or colonial

   Ex. *Microcystis, Gleocapsa*

   Family Entophysalidaceae – Pseudofilamentous

   Ex. *Entophysalis, Placoma*

2. Order Chamaesiphonales – Unicellular, base/apex organization, endo/ exospores present

A. Family Cylindiaceae – Cells spherical

Ex. *Chroococcidiopsis*

B. Family Chamesiphonaceae – Unicellular, attached with base/apex, exospores present

Ex. *Chamaesiphon*

C. Family Dermocarpaceae – Unicellular, attached with base/apex, endospores present

Ex. *Dermocarpa*

3. Order Pleurocapsales – distinctly filamentous, attached, no hormogones or heterocysts

A.Family Pleurocapsaceae – firm gelatinous membrane, filamentous, endospores

Ex. Myxosarcina

B.Family Hyellaceae – Filaments without hormogones, di/tetrachotomous, endospores

Ex. *Hyella*

4. **Order Nostocales** – Filamentous, hormogonalen, heterocysts, akinetes, exo/endospores, without true branching

   A. Family Oscillatoriaceae – Trichome single row of uniform broad cells, sometimes tapering, unbranched, firm mucilage sheath, heterocyst or spores absent, trichome may be spirally coiled

Ex. *Lyngbya, Oscillatiria, Spirulina, Phormidium, Trichodesmium*

   B. Family Nostocaceae – Filaments single or in a definite colony, heterocyst present, terminal or intercalary, single or more than one together

Ex. *Anabaena, Nostoc, Nodularia, Aulosera*

C. **Family Scytonemataceae** – Filaments with thick firm sheath, lamellated, false branching, heterocyst intercalary, many trichomes in a sheath

Ex. *Plectonema, Scytonema, Tolypothrix*

D. Family Microchaetaceae – Trichome with differentiation of base and apex, Unbranched, Sheath with single trichome, Heterocyst present

Ex. *Microchaete*

E. Family Rivulariaceae – Trichome with tapering apex, unbranched, Basal heterocyst, hormogones present

Ex. *Calotrix, Homoeothrix, Dichothrix, Rivularia, Gloeotrichia*

5. Order Stigonematales – Filamentous, hormogonalen, heterocysts, akinetes, exo/endospores, with true branching, dichotomy, with prostrate and erect arrengments

A. Family Capsosiraceae – Thallus attached, hemispherical, free irregular branches, filament with series of one or two cells, heterocyst present or absent

Ex. *Stauromatonema*

B. Family Nostochopsidaceae – Thallus made up of erect many bent filaments branched with two types of branches, long and with limited growth, terminal heterocyst

Ex. *Nostochopsis*

C. Family Mastigocladaceae – Trichome with reverse V shaped branching, intercalary heterocyst, endospores present

Ex. *Brachytrichia, Mastigocladus*

D. Family Mastogocladopsidaceae – Trichome with V shaped and lateral branching, Heterocyst lateral, terminal and intercalary

Ex. *Mastigocladopsis*

E. Family Stigonemataceae – Thallus with free variously bent filaments, irregularly branched, often prostrate and erect, lateral or intercalary heterocyst

Ex. *Hapalosiphon, Stigonema*

Vegetative Reproduction

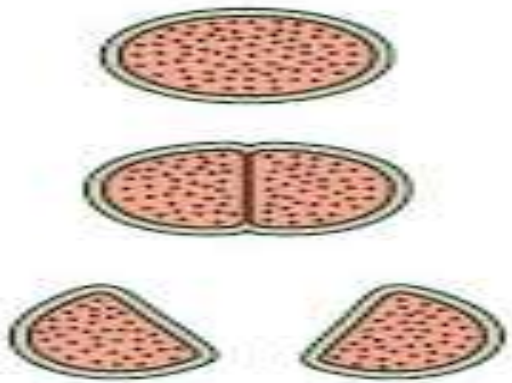
The vegetative reproduction is reported through

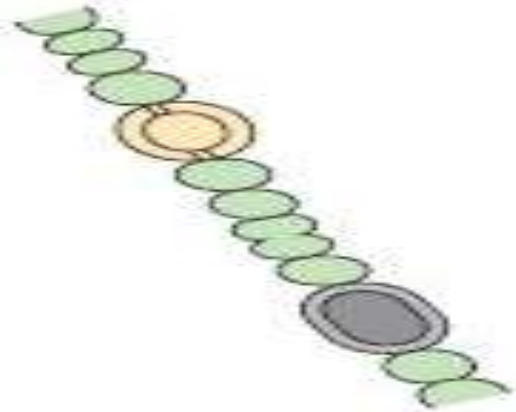
- Hormogones or Pseudohormogones- short sections of a trichome detach and form a new thallus.
- Endospores and Exospores - internal division of the protoplast results in a mass of spores
- Nanocytes – small cells under semi nurished environment
- Planococci or Akinetes - resting spores; cells that are resistant to unfavorable conditions
- Fragmentation- filament breaks into 2 parts, each of which forms a new thallus

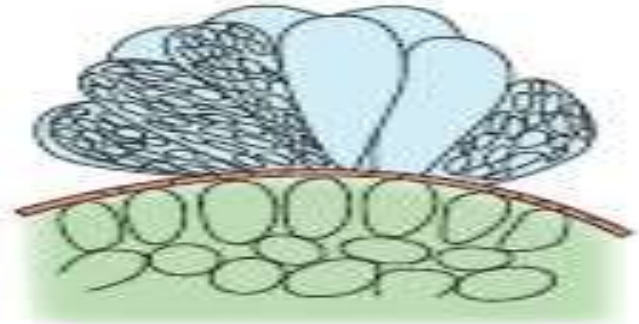
Fission
(Synechocystis)

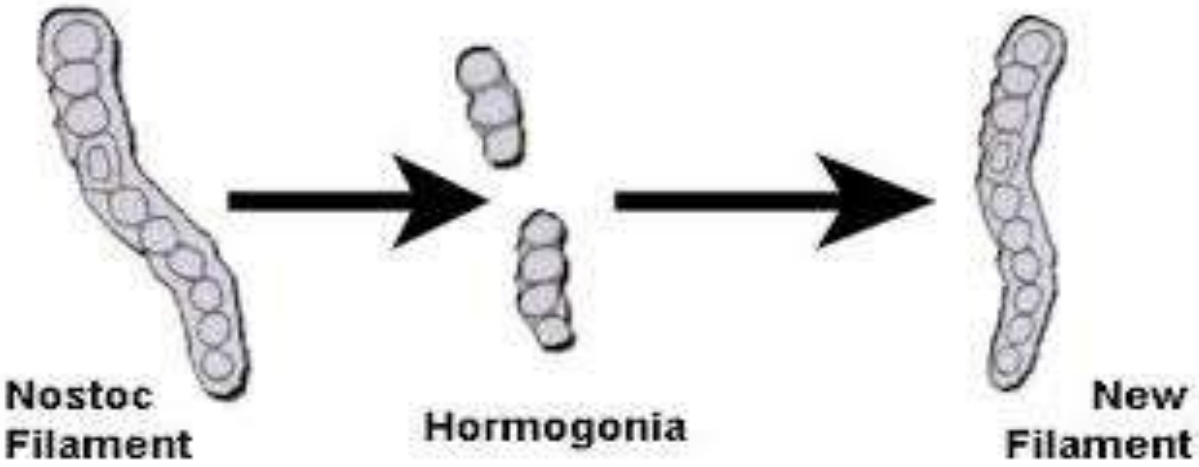
Akinete
(Anabaena)

Endospore
(Dermacarpa)

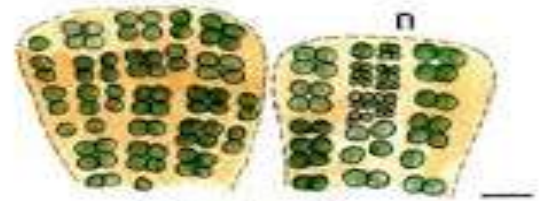






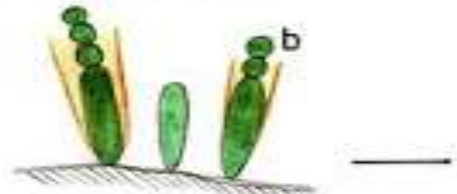


Coelospaerium



Entophysalis

Dermocarpa

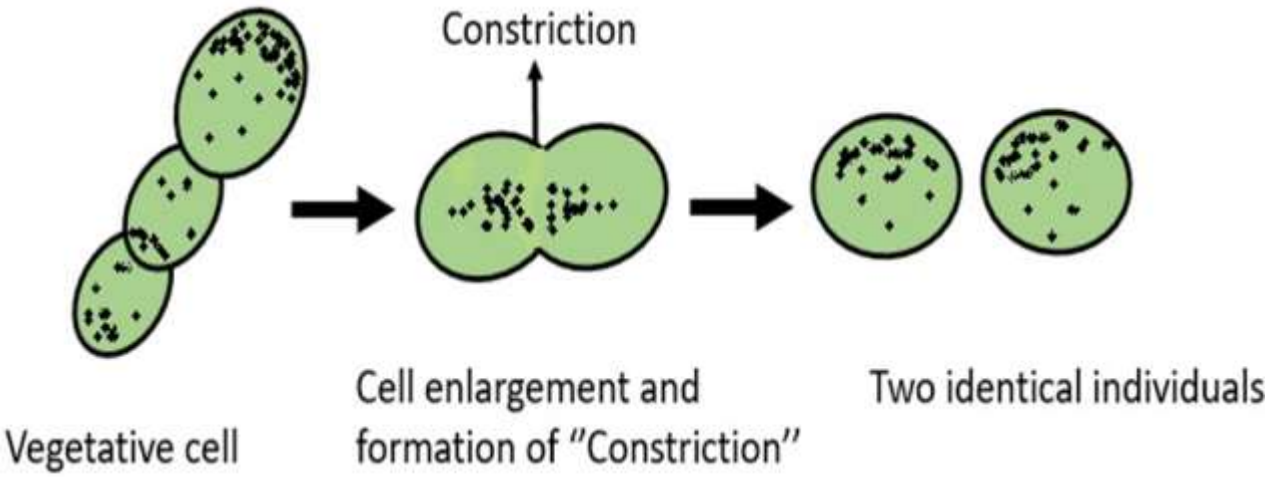


Chamaesiphon

b baeocyte, g gas vacuolate, n nannocyte

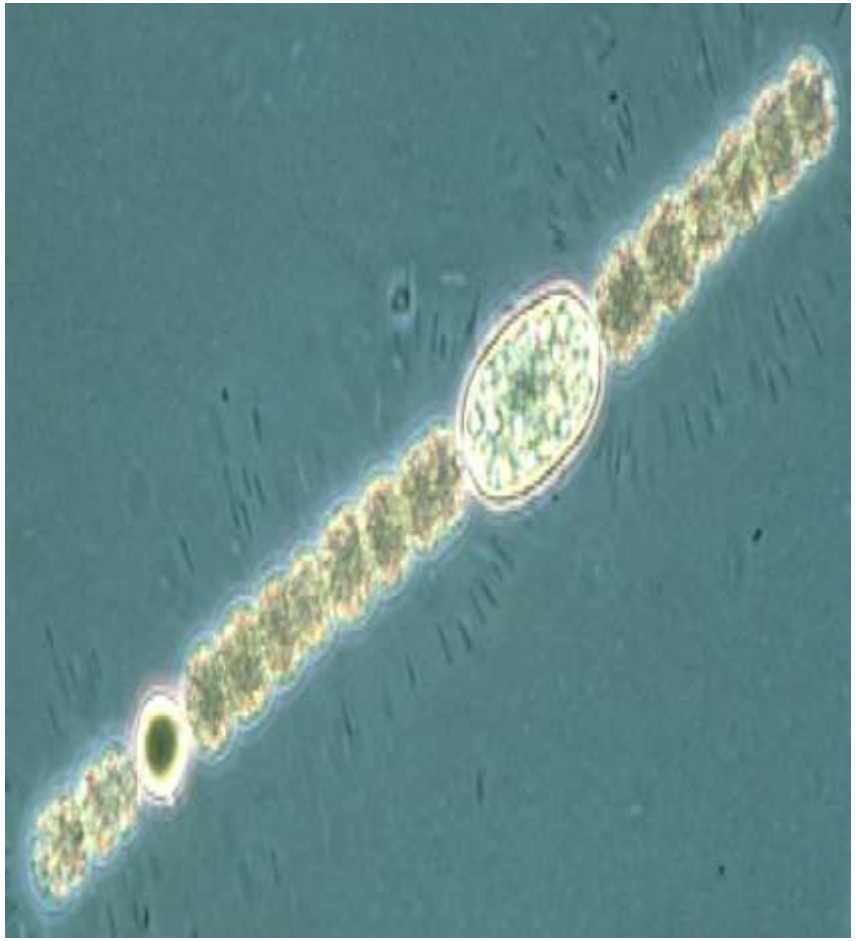
Asexual Reproduction

- **Binary Fission- division of a single-celled individual into two new single-celled individuals.**



Heterocyst

- A thick-walled large cell that fixes atmospheric nitrogen (diazotroph)
  - Photosynthetically inactive
  - Their formation is inversely related to nitrogen concentration
  - Microplasmodesmata- cytoplasmic connections that transfer metabolites and ammonium



- Heterocysts are vegetative cells (though they are larger) that appear empty in the light microscope (whereas akinetes appear full of storage products)
- Heterocysts have been drastically altered to provide the necessary anoxygenic environment which is ideal for nitrogenase enzyme necessary for the process of nitrogen fixation
- They are photosynthetically inactive because they loss of photosystem II thus they do not fix CO2, nor do they produce O2
- They also exhibit a high rate of respiratory O2 consumption

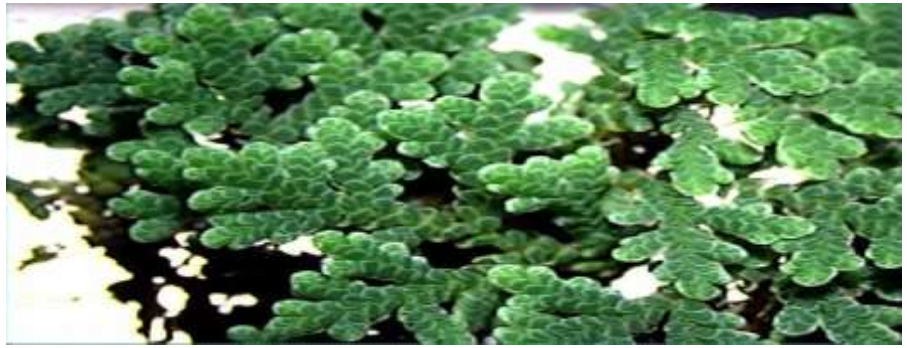
- They are surrounded by a thick, laminated, glycolipid cell wall that limits ingress of atmospheric gases, including O2
- Heterocysts are formed at regular intervals from vegetative cells by the dissolution of storage granules, the deposition of a multilayered envelope outside of the cell wall, the breakdown of photosynthetic thylakoids, and the formation of new membranous structures
- Some cyanobacteria produce potent hepatotoxin and neurotoxins

Movement in the Cyanobacteria

- Gliding- active movement of an organism in contact with a solid substrate.
  - Mechanism- mucilaginous layer of microfibrils generates waves.
- Swimming- active movement of an organism without contact with a substrate.
  - Mechanism- unknown
- Why?
  - Positively phototactic- dim light
  - Positively chemotactic- nutrients

Symbiotic Associations

- Lichens- cyanobacteria occur in about 8% of the species.
- Azolla- the water fern; contains Anabaena in the dorsal lobe of its leaf.
- Amoeba, protozoa, diatoms, green algae, mosses, liverworts, water molds, and vascular plants.



Ecological Importance

- Blue-greens are primary colonizers on bare soil and rock; by forming mats that bind to the soil surface, they reduce soil erosion
- As nitrogen-fixers, they contribute to soil fertility (e.g., growing in rice paddies, *Anabaena,* in association with the floating water fern, *Azolla,* increases rice production)
- Blue-greens contribute to the water plankton food chain; reef building, in tropical waters bluegreens precipitate calcium carbonate (limestone) out of water and build up rock layers;
- Toxins: “blooms” of dense concentrations in the sea kill marine fish, and in reservoirs, they may cause gastrointestinal diseases in cattle and humans

Cyanobacteria Produce Cyanotoxins

- Neurotoxins- alkaloids that target the nervous system
  - Anatoxin and saxitoxin

  Symptoms- staggering, muscle twitching, gasping, and convulsions

  Ex. Anabaena, Aphanizomenon, Oscillatoria
- Hepatotoxins- large compounds that target the liver
  - Microcystins and nodularins
  - Symptoms- weakness, vomiting, diarrhea

  Ex. Anabaena, Microcystis, Oscillatoria, Nodularia, Nostoc

Cyanophyta (Cyanobacteria / Blue-Green Algae)	Characteristic	Chlorophyta (Green Algae)
Typically 0.2 - 2.0 mm diameter	Cell Size	Typically 10-100 mm diameter
Many Toxic Species	Toxins	None
Many produce Geosmin & MIB	Taste & Odor	Some produce Geosmin & MIB
Binary fission (no meiosis)	Reproduction	Mitosis (meiosis involved)
Surface Blooms with many species	Blooms (Buoyancy)	Absent
Many Are	Nitrogen Fixers	No

Bacteria	Cyanobacteria
1. Cells are comparatively small.	1. Cells are comparatively longer.
2. They may possess flagella.	2. They lack flagella.
3. They are both autotrophic and heterotrophic.	3. They are autotrophic.
4. They are anoxygenic photosynthetic.	4. They are oxygenic photosynthetic.
5. They may be aerobic and anaerobic.	5. They are always aerobic.
6. Reserve food is glycogen.	6. Reserve food is cyanophycean starch.