Discipline Courses-I

Semester-I

Paper: Phycology and Microbiology

Unit-VI

Lesson: Cyanophyceae

Lesson Developer: Meenakshi Prajneshu

College/Department: Deshbandhu College, University of Delhi

Table of Contents

Introduction

Video: Role of **c**yanobacteria in evolution of life

Source: http://www.youtube.com/watch?v=DE4CPmTH3xg

The division Cyanophyta is included in Kingdom Monera and includes the blue-green algae. It is a primitive group of plants about 2.8 billion years old.

Living Fossils
Fossil records of **Stromatolites**- provide information about the origin of life 3.5 billion years ago. These are rock like structures formed in the shallow waters on the coasts with biofilms of microorganisms mainly the blue green algae (cyanophytes or members of cyanophyceae) entrapping the sediments and cementing them together. These fossilized microbes provide valuable information about the earth in the Precambrian times.

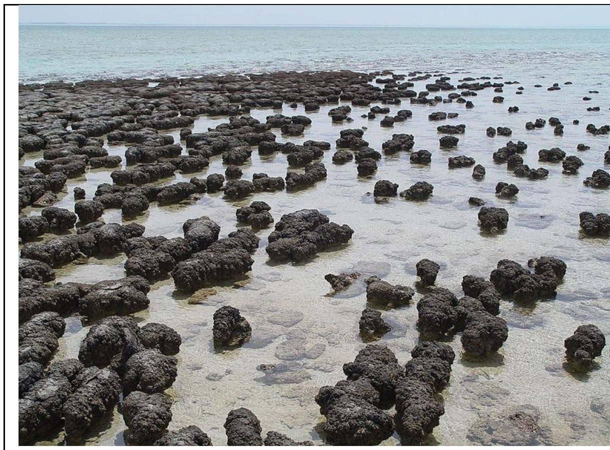


Figure: Stromatoliths in Shark bay Australia

Source: http://en.wikipedia.org/wiki/File:Stromatolites_in_Sharkbay.jpg

Also Visit: http://www.sharkbay.org/stromatolites.aspx

The division has only one class, i.e. Cyanophyceae or Myxophyceae. Cyanophyceae comprises of simplest members that are Gram-positive prokaryotes living autotrophically. The constituent genera are all microscopic. They have a wide range of tolerance to the environmental conditions and are considered as colonizers. They generally appear bluish-green due to the presence of blue, green and red pigments, namely phycocyanin, allophycocyanin, chlorophyll-a and phycoerythrin.

Cyanophyceae has ≈ 150 Genera and ≈ 2000 species

It is debatable as to whether cyanophyceae should be considered algae or bacteria. Blue-green algae or cyanobacteria are different from other bacteria in the following aspects:

(i) They contain chlorophyll-a
(ii) Free oxygen is given off in their photosynthesis
(iii) Some bacteria split H_2S as a source of electrons during their photosynthesis and contain bacteriochlorophyll pigment instead of chlorophyll-a.

They have some similarities with bacteria too:

(i) Cellular organization is same. They are prokaryotic as their organelles are not membrance-bound.
(ii) Lack cellulose in cell walls.
(iii) They have only haploid life cycle (i.e. no alternation of generation).
(iv) Reproduction through fission.
(v) DNA is not associated with histone proteins in their chromosomes.

Their photosynthetic pigment is different from other plants:

(i) Photosynthetic pigments are phycocyanin and chlorophyll-a
(ii) Phycocyanin functions as photosynthetic pigment in photosystem II. In plants, chlorophyll-b is the pigment in photosytem II.

Occurrence

General

Blue Green Algae have widest distribution as compared to all other types of algae. They are colonizers of rocks and virgin lands. They are commonly found in tropical countries and are quite common in the continental shelf waters off the Southeastern U.S. coast and also in the Northern Arabian Sea.

Figure: Buildings in the tropics coated by layers of blue-green algae (BGA).

Source: http://www.biologie.uni-hamburg.de/b-online/fo42/copacab.jpg

They have enormous variety of habitats: Frozen lakes, acidic bogs, deserts, volcanoes, alkaline-saline-acidic aquatic environments (fresh and polluted lakes, ponds, reservoirs, stagnant flowing, shallow, deep (30.4m) and fresh salt waters), In hot springs having very high temperatures (75^{0}C). They can be located in tropical soils (paddy fields, oil fields, plant pots, footpaths), in and on calcareous strata, on rocks, stones and even in the atmosphere. They grow as endophytes, as constituents of lichens, as endosymbiont in diverse animals.

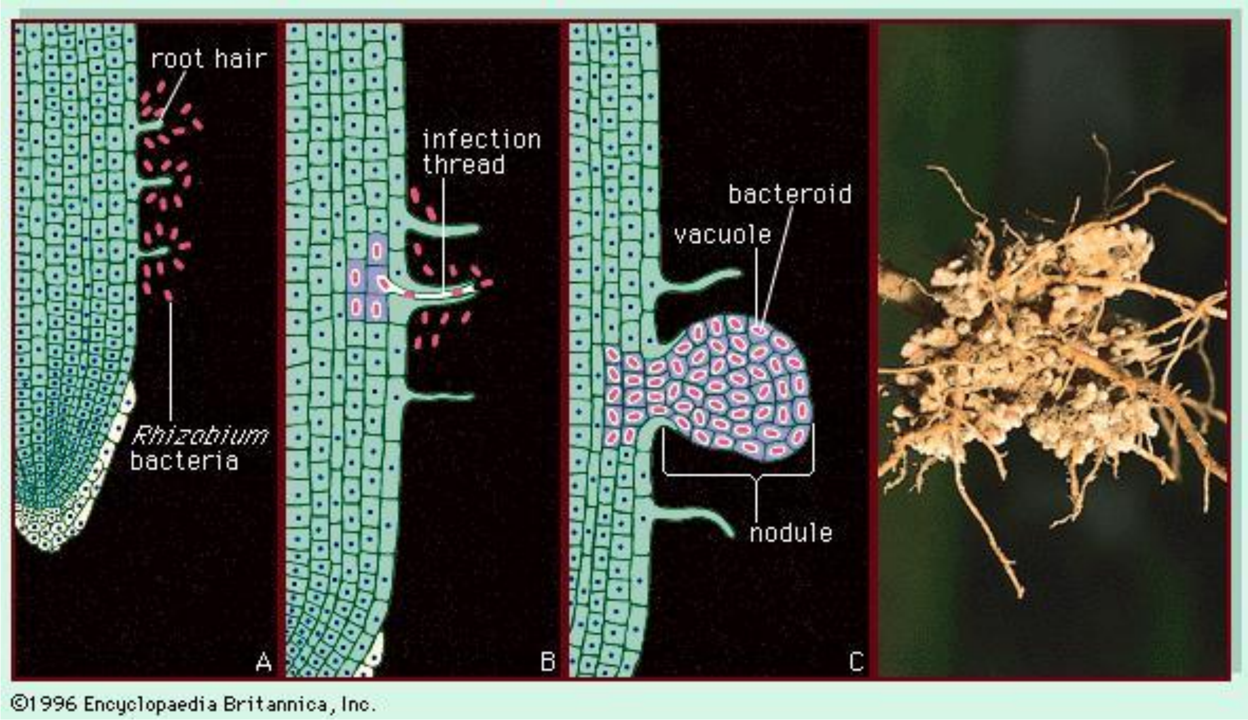


Figure: The bacteria *Rhizobium* enters through roots and establishes a symbiotic relationship with the higher plant.

Source:http://media-1.web.britannica.com/eb-media/38/6538-004-2E138DF9.jpg

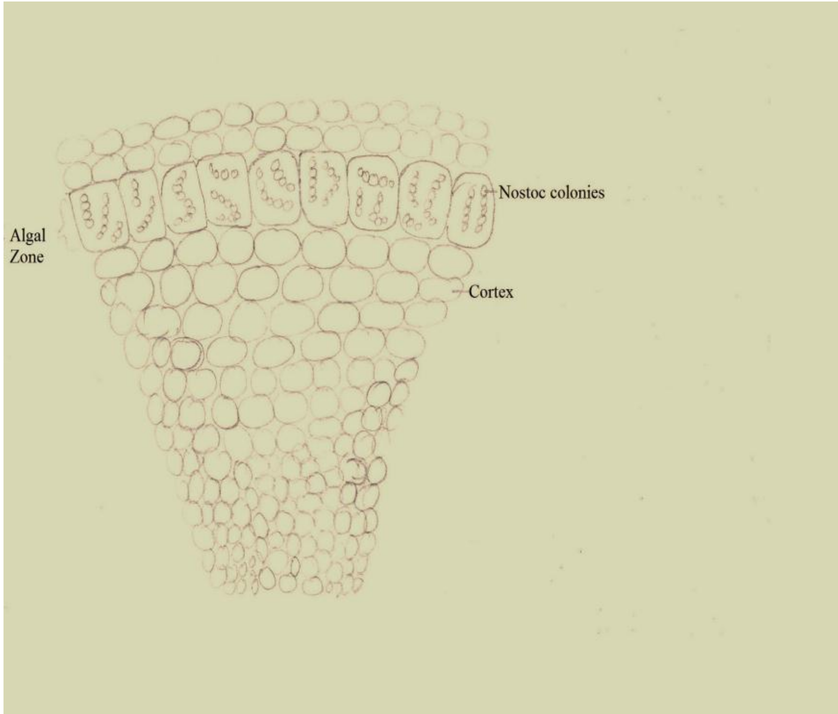


Figure: T.S. Cycas root showing Nostoc Filaments
Source: Author

They are responsible for the eutrophication of tanks, lakes, ponds, oceans and this makes them capable of increasing the fertility. Their blooms impart bluish-green colour to the tropical ponds "pea soup" type. Similar blooms are ephemeral in temperate ponds.

Specific:

1. As fossils: *Nostocites, Girvanella*
2. Endosymbiont in Bobtail Squids: *Vibrio Fischeri*

Most common algal group in terrestrial and symbiotic relationships

Figure: Mutual Beneficial Symbiotic Relationship with Squid

Source: http://farm5.staticflickr.com/4071/4559892992_1f80bfc56f_z.jpg

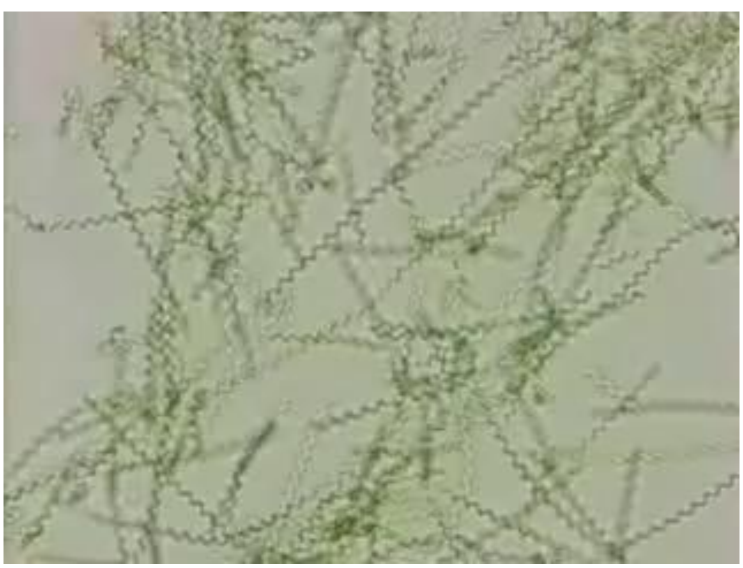
3. With Lichens: *Nostoc, Scytonema*
4. Epilithic: *Gloeocapsa, Scytonema*
5. Endophytes: (in *cycas* roots, *Nostoc, Anabaena Azolla, Anthoceros*)
6. Endozoic: *Oscillatoria, Simonsiella*
7. Thermophilic: *Phormidium, Mastigocladus*
8. Terrestrial: *Nostoc, Anabaena*
9. Marine: *Trichodesmium, Dermocarpus*
10. Fresh water: *Nostoc, Rivularia*
11. Cryophytes: *Phormidium*

Range of Thallus Organization

Figure: Different Forms of Cyanophytes

Source: http://www.botany.hawaii.edu/BOT201/Algae/Bot%20201%20Cyanophytes%20page.GIF

Thallus in Cyanophyceae is generally blue-green or olive-green coloured. Thallus has a range of organization from unicellular, to filamentous, to branched, to colonial. The filaments have mucin covering. Flagella are absent but some members move by gliding.



Video: *Spirullina* a cyanobacteria

Source: http://video.conncoll.edu/f/pasiv/lucid/Spirulina-900.html

Blue-green algae have three categories of forms in which thallus may be solitary or in a colony:

1. Unicellular, e.g. Coccoid and palmelloid genera
2. Filamentous, e.g. Unbranched and branced genera
3. Colonial, e.g. Any of the above forms held in common gelatinous matrix.

Unicellular: Thallus is unicell, spherical, or oval, e.g. *Synechocystis, Anacystis, Chlorococcus, Gloeocapsa.* Here daughter cells separate immediately after cell division.

Filamentous (Unbranched): Are called "trichome" of cells. Cells divide in single direction in one plane forming chain or a thread of cells. Cells are held together either by separation walls or common mucin sheath. The filament is a row of cells with gelatinous sheath, it may be straight or spiral. A mucin sheath may have one trichome or more.

Straight filaments: e.g. *Nostoc, Oscillatoria*

Spirally coiled filaments: e.g. *Arthrospira, Rivularia*

Mucin sheath with one trichome (a filament): *Nostoc.*

- Mostly with Mucin envelope
- Unicellular, filamentous (branched, unbranched)

Trichome may be of uniform diameter or taper from base to apex. Such genera usually have basal heterocyst, e.g. *Rivularia, Gloeotrichia.* Sometimes, trichome tapers at both ends, e.g. *Aphanizomenon.*

Filamentous (Branched): Cells divide in two planes. They may result into multiseriate or uniseriate filaments. Sometimes, branching is false. In such cases, fragments germinate *in situ* and their ends pierce out of the parent sheath in different directions.

Multiseriate branched filaments: e.g. *Stigonema*

Uniseriate branched filaments: e.g. *Hapalosiphon*

False branching: *Tolypothrix, Scytonema*

Colonial: In many species, cells are held together by their common gelatinous sheath or remain attached by their walls after division. This makes a loose type of organization and is called a colony. Colonies can be filamentous or non-filamentous.

Filamentous colonies: A gelatinous sheath with many trichomes, e.g. *Microcoleus vaginatus*

Non-filamentous colonies: These acquire various forms depending upon the plane and direction in which the cells divide. Correspondingly, they may be spherical, square, cubical, irregular and so on, e.g. *Microcystis, Eucapsis alpina, Aphanocapsa, Merismopedia.*

Also visit: http://www.biologie.uni-hamburg.de/b-online/library/webb/BOT311/Cyanobacteria/Cyanobacteria.htm

Cell Structure

Vegetative cells of blue-green algae are mostly up to 10μ in diameter, a characteristic of prokaryotes.

- **Absence of nucleus**
- **Circular DNA**
- **DNA histones lacking**
- **Chromosome is called genophore.**
- **Non-motile,no-flagella**

Table: Comparison between the prokaryotes (bacteria) and eukaryotes

Source: Author

Feature	Prokaryotes	Eukaryotes
Nucleus/Nucleolus	Absent (bacterial chromosome found as looping circular Nucleoid)	Present
Size (diameter)	1-10μm	10-100μm
Membrane Bound Organelles	None (bacteria do posses ribosomes)	Present
Cell Division	Binary Fission (simpler form of cell division)	Mitosis

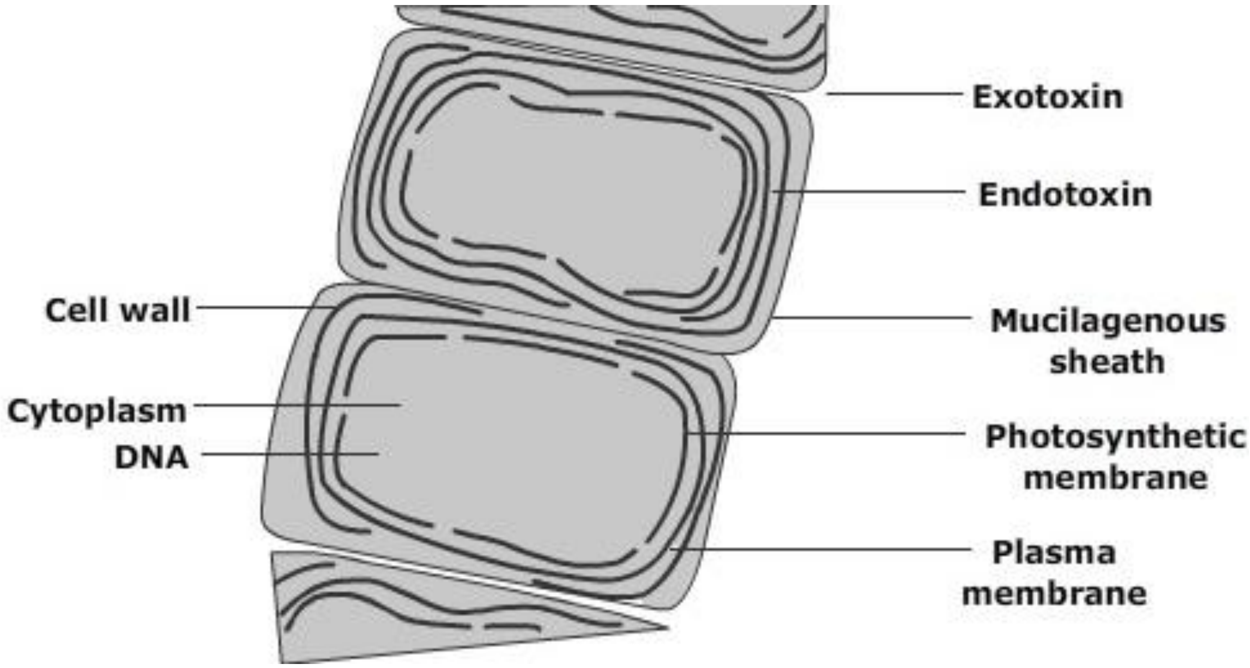


Figure: Multilayered cell wall

Source: Author

In cyanophyceae, vegetative cell is for photo- synthesis, spores make the resting stage and heterocysts, i.e. the specialized cells are meant for nitrogen fixation.

Chloroplast?

- Thylakoids present
- Single or paired
- Photosynthesis I & II

Light microscope reveals that the cyanophycean cells have two envelopes: Muciloginous sheath and cell wall. Mucin sheath may be absent in some forms. Cell wall surrounding the protoplasm is thin and firm. It is made up of two layers: Inner hemicellulosic and outer pectic. Inside it lies the plasma membrane. The sheath is thick and slimy. Cells may have individual sheath, e.g. spherical in *Chlorococous,* cylindrical in *Nostoc,* interrupted in *Oscillatoria.* The *sheath* is characteristic of blue-green algae and this is how they are called Myxophyceae, which means slime algae.

Because of slime sheath, blue-green algae are called Myxophyceae

Generally, it is quite thick, colourless and has a watery consistency. It is made up of pectic compounds. Sheath may be variously pigmented, lamellated or stratified. Sheath may be red, i.e. acidic, blue, i.e. basic and yellow/brown, i.e. with high salt content. It protects the cell against desiccation and against UV irradiation. Pectin secretion by the protoplast of cyanophyceae is a primitive character.

Under electron microscope, the sheath appears fibrillar and two-layered. Fibers are less dense in the outer part than the inner. Between the sheath and cell wall, there is a zone of low electric density. Cell wall appears three-layered, outer, middle and inner. Outer and middle are separated from each other by a clear space. Cytoplasmic membrane is proteinaceous and two-layered, electron-opaque.

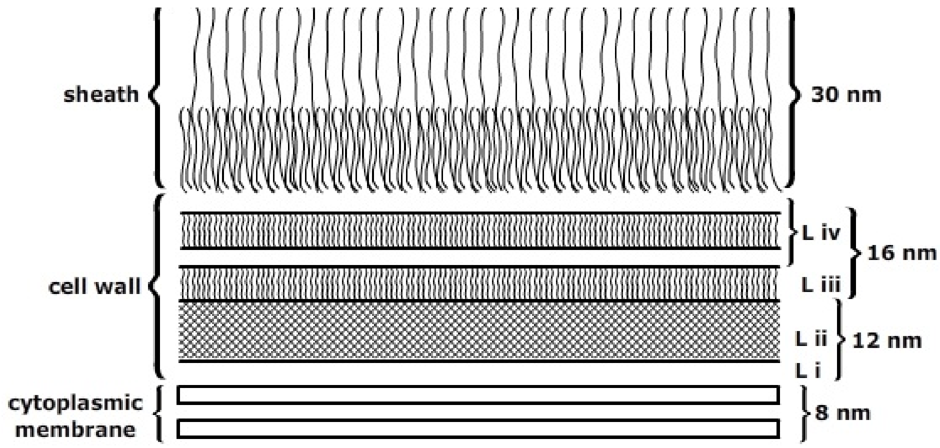
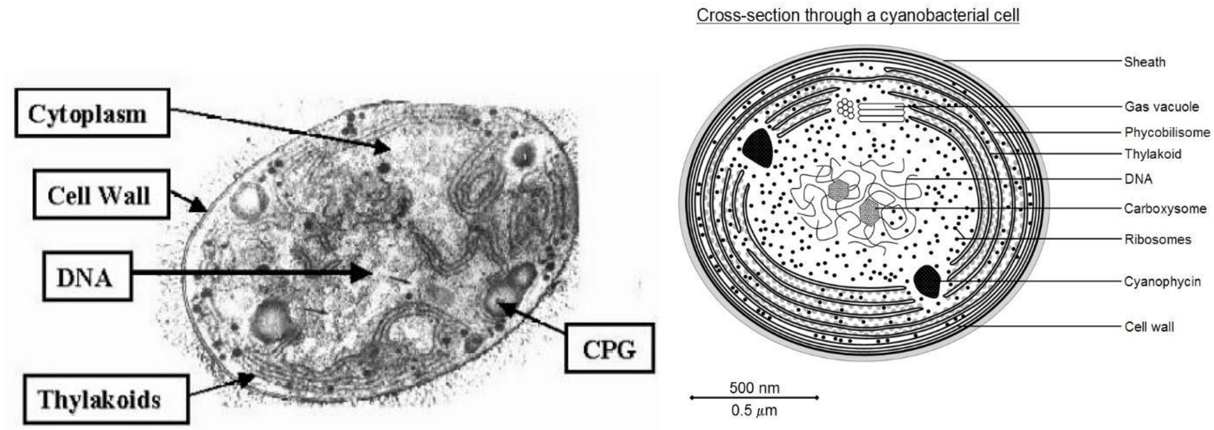


Figure: Myxophycean cell wall under electron microscope.

Source: Author

A less opaque lipid layer separates them. **Protoplast** has elementary internal structure. Lack of organized nucleus, plastids, mitochondria, Golgi apparatus and sap vacuoles. It has peripheral chromoplasm and central light area, centroplasm or central body, **Chromoplasm** or photosynthetic structure. It is made up of complex lamellar system, thylakoids. Generally present towards periphery, sometimes as in *Anabaena* throughout the protoplasm: Thylakoids are narrow tube like structures and apart from being photosynthetic, they are also seat of cellular respiration. Therefore, they are named as photosynthetic respiratory membranes. Particles of phycobilisome and phycobiliproteins are attached to these membranes .

Carbon storage or food storage is in the form of Cyanophycean starch



A B

Figure:A. Electron micrograph of an cyanophycean cell B.Diagrammatic section through a prokaryotic cell

Source: A. http://www.jochemnet.de/fiu/bot4404/CyanoCell.jpg B. http://cronodon.com/sitebuilder/images/cyanobacterium_structure_labeled-643x500.jpg

The *Centroplasm* contains cyanophycin granules, polyglucan granules, ribosomes many gas vesicles, polyphosphate bodies, lipid droplets and polyhedral bodies. The gas vesicles contain metabolic gases. They give buoyancy to species and are responsible for light shading role. Ribosomes are seats of protein synthesis. May be cyanophycean granules are copolymers of alanine and aspartic acid.

Gas vesicles are hollow cylinders made of proteins

- Low light, increase in gas vesicles gives buoyancy
- High light, decrease in gas vesicles– blue-green algae sink

Nucleoplasm area is more or less transparent (low electron opacity). Many fine threads of DNA microfibrils are present. Nucleolus, histones, protamines, nuclear membrane are absent.

Heterocyst

They are thick walled cells occurring in sideways position of cyanobacteria. They are permeable to nitrogen and impermeable to oxygen. They are seats of photophosphorylation but no photosynthesis. For survival, it depends on the adjacent cells. Often polar nodules are present at their ends. They contain 13 carboxylase enzymes, necessary for nitrogen fixation. The enzyme is sensitive to oxygen. The enzymes have

Heterocysts - Specialised cells for fixing nitrogen iron/sulphur (cofactor), and a heterometal (Fe Mo Co) (Fig. 8), which is easily 14arboxyl and destroyed by oxygen.

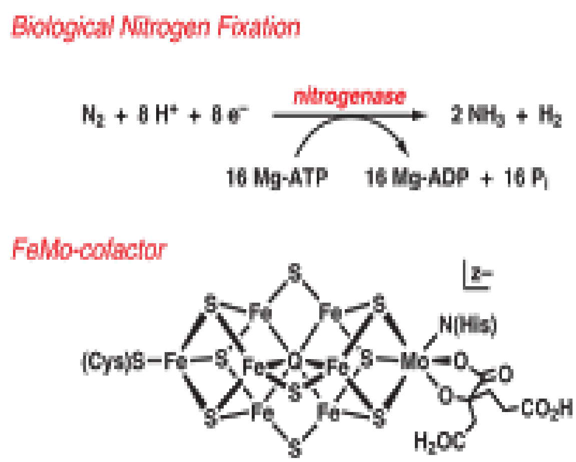


Figure: Nitrogenases enzymes have iron/sulphur (cofactor) with a heterometal (FeMoCo), a molybdenum and iron

Source: http://2.bp.blogspot.com/-z_N_WnKzaSQ/TdHhV0HiSCI/AAAAAAAAJMc/SajJkJanKR4/s1600/nitrogen+fixation.png

The thick wall of heterocyst prevents diffusion of oxygen. They have pale-yellow homogenous content. Heterocysts are not found in all filamentous Myxophyceae but occur in all members of Order Nostocales and Stigonematales except in family Oscillatoriaceae. They are terminal intercalary, basal, lateral (on the side of branch) and pedicellate (at the end of lateral branches).

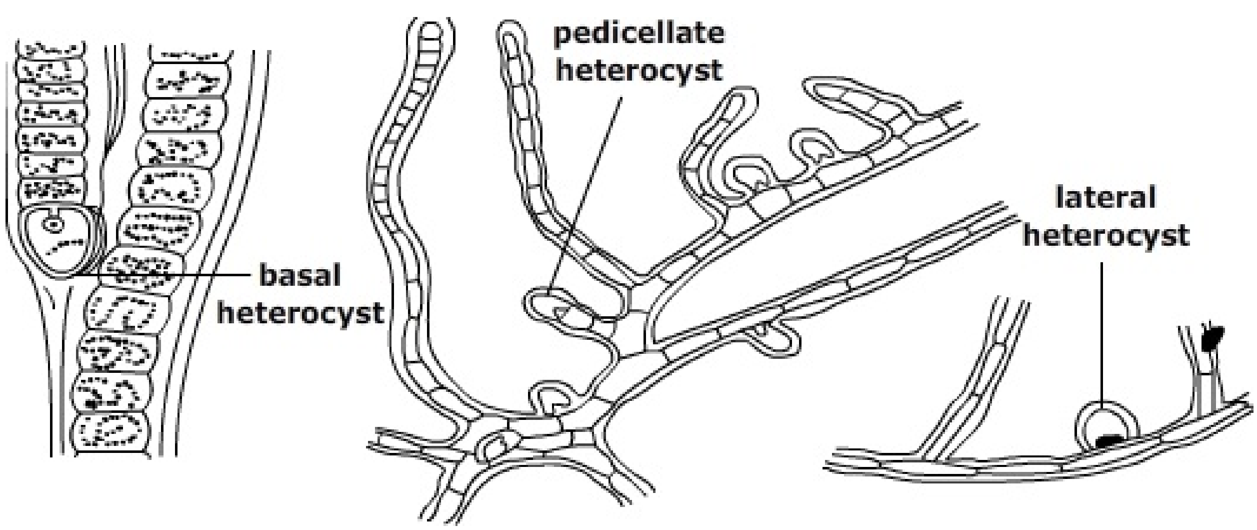


Figure: A. Basal heterocyst in *Tolypothrix distorta*; B. *Pedicellate heterocysts* in *Mastigocladus testarum*; C. Lateral heterocyst in *Nostochopsis lobatus*.

Source: Author

Figure: http://www.nature.com/nrmicro/journal/v8/n1/fig_tab/nrmicro2242_F1.html

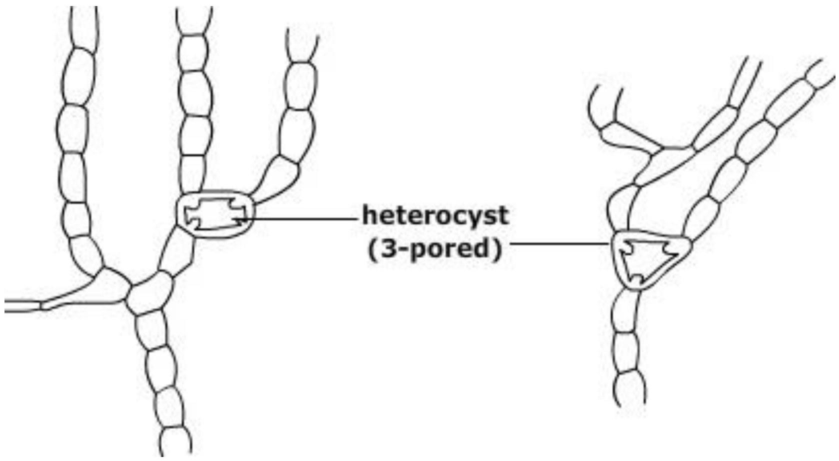
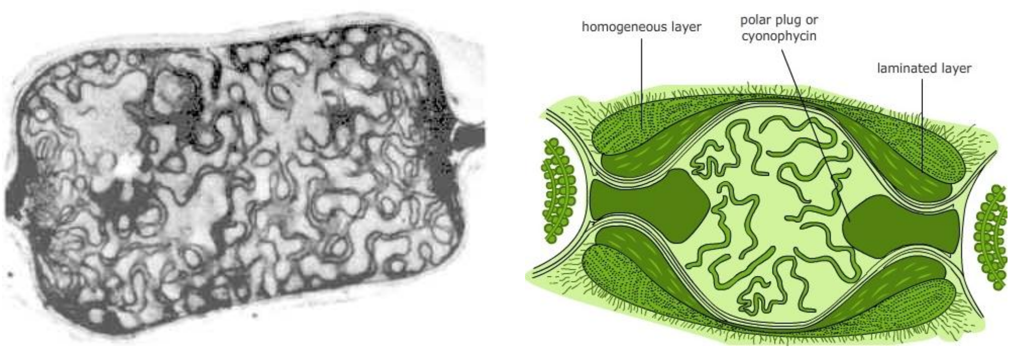


Figure: Three-pored heterocyst in *Brachytrichia balani*.

Source: Author

The wall of the heterocyst is two-layered. Outer layer is persistent, chemically pectin or cellulose. Inner layer is cellulosic. One (when heterocyst is terminal), two (inter-calary) or three pores *Brachytrichia balani*) perforate the heterocyst. These are the site of protoplasmic connections. A prominent polar granule or plug is present at each pore. Heterocyst matrix contains photosynthetic lamellae, some ribosomes and other granules.



A B

Figure: A. Electron micrograph of a heterocyst (http://www.biologie.uni-hamburg.de/b-online/library/webb/BOT311/Cyanobacteria/Heterocyst_small.jpg)

B. Diagrammatic representation of structure and contents of mature heterocyst.

For additional information

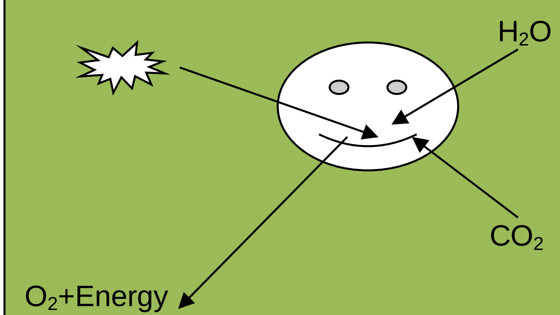
visit: http://www.sciencedirect.com/science/article/pii/S0966842X12001217, http://www.nature.com/nrmicro/journal/v8/n1/full/nrmicro2242.html

During transformation of a vegetative cell into heterocyst, volume of cell increases, cell wall becomes thick and adds layers to it, all pigments disappear except carotenoids, thylakoids reorganize and most granular bodies vanish. Components are replaced by two lipids, namely glycolipid and acil-lipid. Their functions are diverse, reproductive bodies which lost function, storage, mechanical, salt accumulation. They help in fragmentation as they are the points of breakage, related to frequency of cell division, stimulate production of akinetes, secondary reproductive organs, correlation with formation of gas vacuoles, responsible for sporulation of vegetative cells, can reproduce like other ordinary cells of trichome, can germinate to form new filaments, sites of nitrogen fixation. As such, they are a botanical enigma.

In low N_2 environments, cyanobacteria produces larger, thicker-walled heterocysts

Chromatic Adaptation

BGA with chlorophyll a can generate oxygen by oxidizing the oxygen present in water thus making the environment rich in oxygen which probably led to the evolution of aerobes on earth



Photosynthetic cell absorbing necessary things to generate O_2

Large number of photosynthetic pigments are located in the thylakoids, e.g. Chlorophyll-a, β carotene, myxoxanthophyll. Myxoxanthin and c-phycocyanin (blue),c-phycoerythrin (red), oscilloxanthin,zeaxanthin and lutein are also present but in smaller amounts. The proportion of red and blue pigments varies in different habitats. In high light intensity, they appear bluish-green whereas reddish in low light intensity. Red, blue and allophycocyanin pigments are together designated as phycobilins. They are all proteins. Phycobili proteins are arranged in phycobilisomes, which are spherical structures attached to photosystem II .

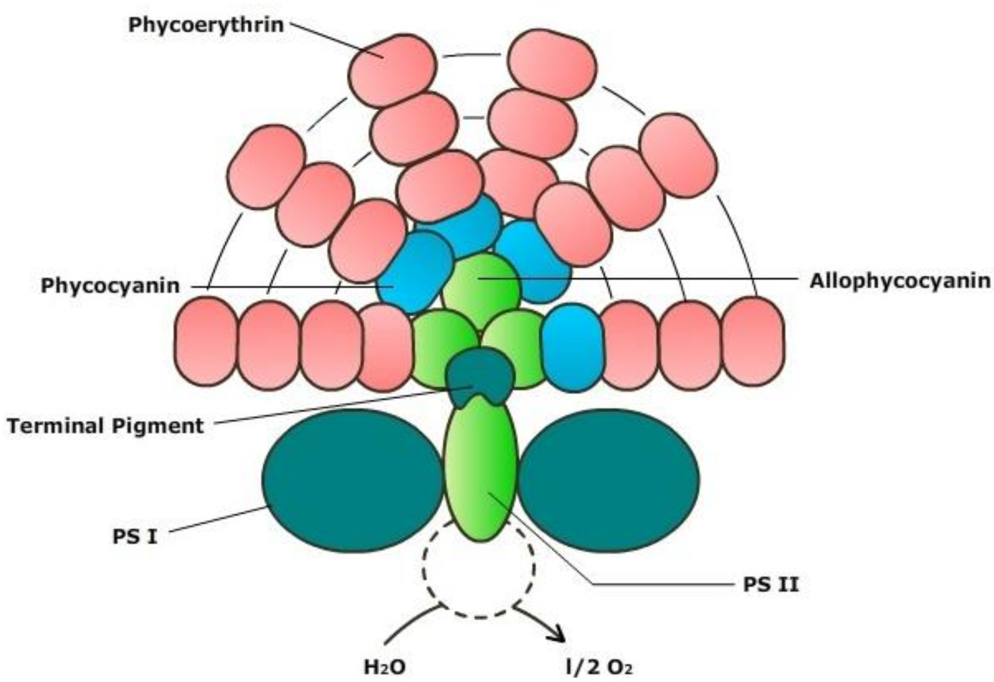


Figure: Phycobilisome structure

Source: http://www.jochemnet.de/fiu/bot4404/phycobilisome.gif

Cyanophyta have two distinct pigmentation patterns: Chlorophyll-a and phycobili proteins

Photosystem I has membrane-integral LHCs. Mostly cyanophyta are autotrophs with carbon in organic form and using light, they generate ATP. CO_2 is fixed and O_2 is released. Cyanophytes can survive in low CO_2 too by CCM (CO_2 concentrating mechanism). CCM transports and accumulates in organic carbon as HCO_3 and CO_2 within the cell. This creates a high CO_2 concentration pool around the CO_2-fixing enzymes (present in carboxisomes) Rubisco (ribulose biphosphate 17arboxylase-oixygenase). Rubisco converts CO_2 to sugars. Food storage is as cyanophycean starch.

Cyanophytes have two photosystems:

- Fe-S type
- Quinone type

Chromatic adaptation is the capabililty of cyanophytes to vary their pigment ratio especially phycobilins. In unilcellular and mixed cultures of *Synechoccus*, there is distinct change in ratio of phycocyanin to phycoerythrin. The red strain (rich in phycoerythrin) outcompeted the green strain in green light. Reverse was also true. This results into reduced inter strain competition and increases diversity of strains by complementarity. Similar to these mixed strain cultures, other remotely related strains (e.g. Tolypothrix) can also compensate for changes in available light. Blue-green algae *Calothrix* drastically changes phycobili protein composition, i.e. colour change in response to light quality.

Microbiologists are fascinated with a growing recognition that a number of cyanophyceans are capable of sensing and responding to different light colours. Both photosynthetic and non-photosynthetic prokaryotes have shown presence of genes encoding a super family of phytochrome-class photoreceptors. Members of Cyanophyceae, which are only photosynthetic, have large number of such genes. The mechanism and cellular role of most of these is yet to be elucidated.

Reproduction

Members of Cyanophyceae reproduce by simple and primitive methods, i.e. by vegetative means and asexually.

- No sexual reproduction
- Some DNA transfer observed
- Not conjugation

Vegetative reproduction is generally in four ways:

(i) Binary fission, e.g. in unicellular cells. A cell divides into two in roughly equal halves. Each grows to original form. Here nucleus divides mitotically first and then the cytoplasm. This is the most common type.

(ii) Fragmentation: Filaments break into small pieces. Each piece grows into new filament. Mostly occurs in colonial forms.

(iii) Hormogonia: Trichomes break up within the sheath into short segments called hormogonia or hormogones. Hormogones can be 2-3 cells to several cells long. Any portion of the trichome may get abstracted as a hormogone (e.g. in *Nostoc* and *Oscillatoria*). *Stigonema* forms hormogonia on special branches. Sometimes these are motile and move away from parent filament.

(iv) Hormocytes: These multicellular structures have a thick and massive sheath. They are intercalary or terminal. They can germinate from either end or both ends thereby forming new filaments.

Asexual reproduction – Cyanophyceae members reproduce by non-motile, asexual spores which are of following types:

(i) Akinetes: Are found close to heterocysts. Cells increase in size and a thick layer is formed around them. Under favourable conditions, new filaments are formed from them, e.g. *Cylindrospermum.* These are perennating (dormant) structures.

(ii) Nannocytes – In non-filamentous algae, like *Microcystis,* there is repeated cell-division unaccompanied by cell enlargement. Numerous cells are formed within the parent cell. These are naked protoplast. They are extremely small as compared to vegetative cells. They germinate *in situ* to give rise to new typical colonies.

(iii) Spores – In sporulation, any cell of an organism produces one or more reproductive cells inside its cell walls. These are produced by non-filamentous forms. They are produced in large numbers for rapid increase in population. This is the commonest type of asexual reproduction. Spores are of two types – **Endospores** are small, formed endogenously within a unicellular cell or cushioned form. One or more cells of parent plant increases in size. Their protoplast divide repeatedly forming a large number of small, uni-nucleate protoplasts. Each daughter protoplast secretes a wall around it and is called endospore. Wall is secreted on liberation from the parent cell, e.g. *Dermocarpa, Stichosiphon.* **Exospore** – Spores are successively cut of at the distant end of the protoplast by transverse division. These are exospores. Each spore is surrounded by a delicate membrane, e.g. *Chamaesiphon.*

Economic Importance

Cyanophytes are good as well as bad, which adjective suites best is a debatable question.To enumerate the positive features: important to agriculture, fix elemental nitrogen from the atmosphere thereby enhancing soil fertility; antiretroviral (extract of *Arthrospira platensis or spirulina*) inhibites replication of HIV-1 and AIDS virus in human beings, supports growth of healthy bacteria in human gut, saves patients with arsenic poisoning; *Aphanizomenon flos-aquae* and *Spirulina* are used as food and increases brain power, lowers cholesterol, controls tumor growth; preparation of ethanol to be used as bio-fuel; has substances which can be used to make anti-inflammatory and anti- bacterial medicines; source of renewable energy i.e. converts sunlight into electricity. Edible BGA reduce risk of cataract, mascular degeneration, and protect from liver damage. The negative aspects are: produce cynotoxins (stomach diseases caused by *Microcystis* and *Anabaena)* which can result into death of the patients. The cyto, endo, hepato and neurotoxins are also dangerous for animals and marine life.

Type Study – *Nostoc*

Kingdom: Monera

Cyanophyceae

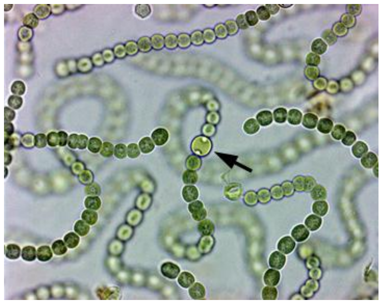
Class:	Cyanophyceae or Myxophyceae
Order:	Nostocales
Family:	Nostocaceae
Genus:	*Nostoc*

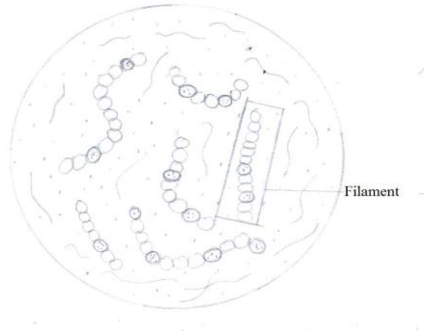
Morphology: Nostoc is a colonial cyanophyte. Colonies are ball-shaped.

Figure: Nostoc balls

Source: http://upload.wikimedia.org/wikipedia/commons/d/d3/CyanobacteriaColl1.jpg

Each colony contains several filaments. Each filament is composed of moniliform cells.





A B

Figure: Microscopic view of boll at 40X Magnification

Source: A. http://farm6.staticflickr.com/5042/5226800979_ab6d606e5a_o.jpg B. Author

Filaments are slender, long and appear like chain of beads. Filaments are interwoven but unbranched.

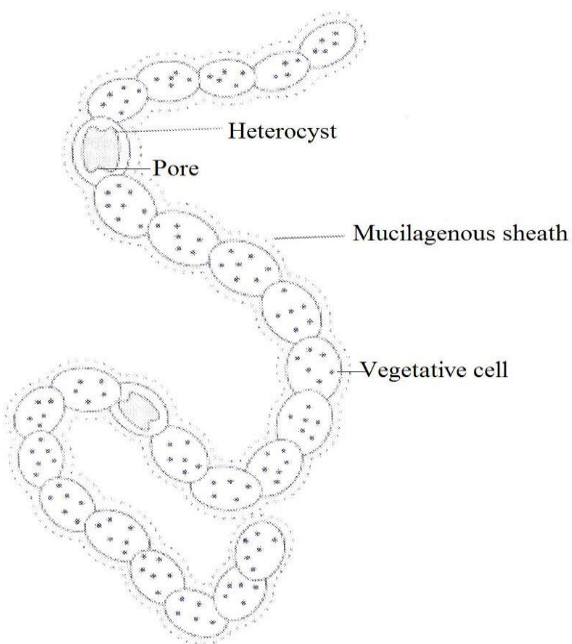


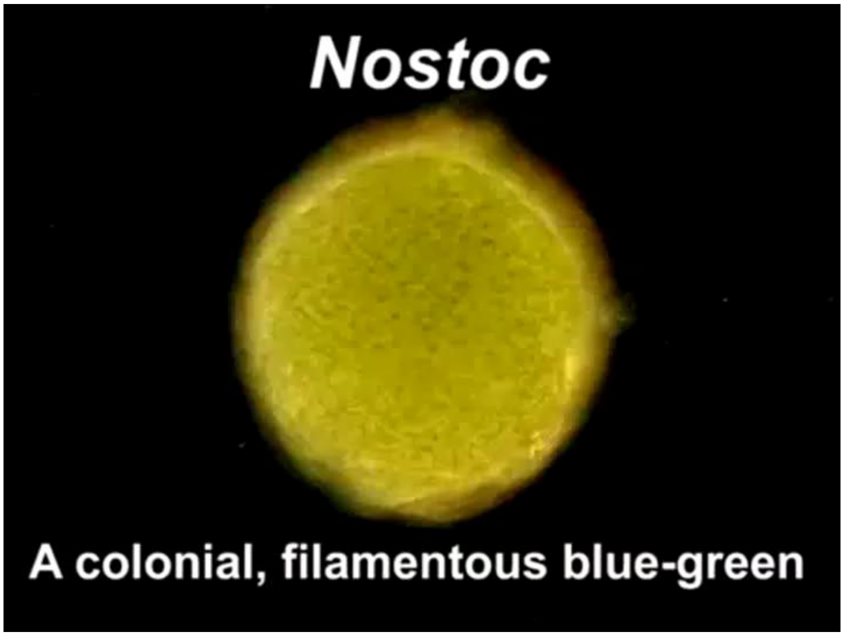
Figure: *Nostoc* Filament

Source: Author

Cells are rounded or oval. Apart from common mucilage covering the filaments, each filament is often enclosed in a gelatinous sheath. Vegetative cells have an outer coloured part (chromoplasm) and a central colourless region (centroplasm). Apart from simple vegetative cells, there are some cells, some specialized vegetative cells occur at regular intervals. These are bigger in size with thickened walls and pores at both the poles (intercalary) or on side adjoining simple vegetative cell (terminal). These are named heterocysts.

- When ingested, they produce neurotoxins
- Has heterocysts
- Fixes nitrogen

Cytoplasmic connections with the adjoining cells are maintained through the pores. At a later stage, pores are blocked by button like thickenings called polar molecule or nodule. The filament increases in length by cell division only in one plane.



Animation: *Nostoc* structure

Source: http://video.conncoll.edu/f/pasiv/lucid/Nostoc-500.html

Life cycle: No sexual reproduction and alternation of generation. Reproduction is by two means: Vegetative by fragmentation and formation of hormogonia; asexual by akinete formation mainly but sometimes endospores are also formed, e.g. *N. commune* and *N. microscopicum*. Hormogonia, akinetes and endospores germinate into fresh *Nostoc* filaments under favourable conditions. Heterocysts may also undergo divisions and germinate to form new filaments.

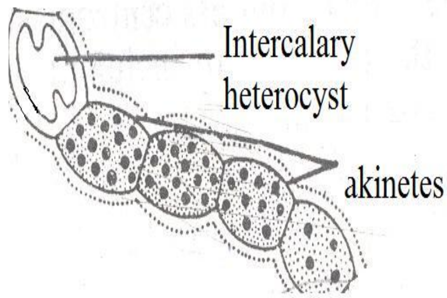


Figure: Nostoc akinetes

Source:Author

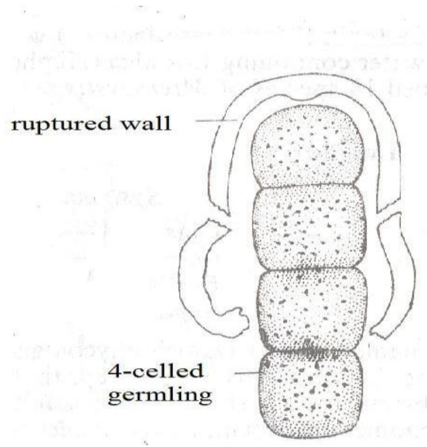


Figure: Germination of a heterocyst

Source: Author

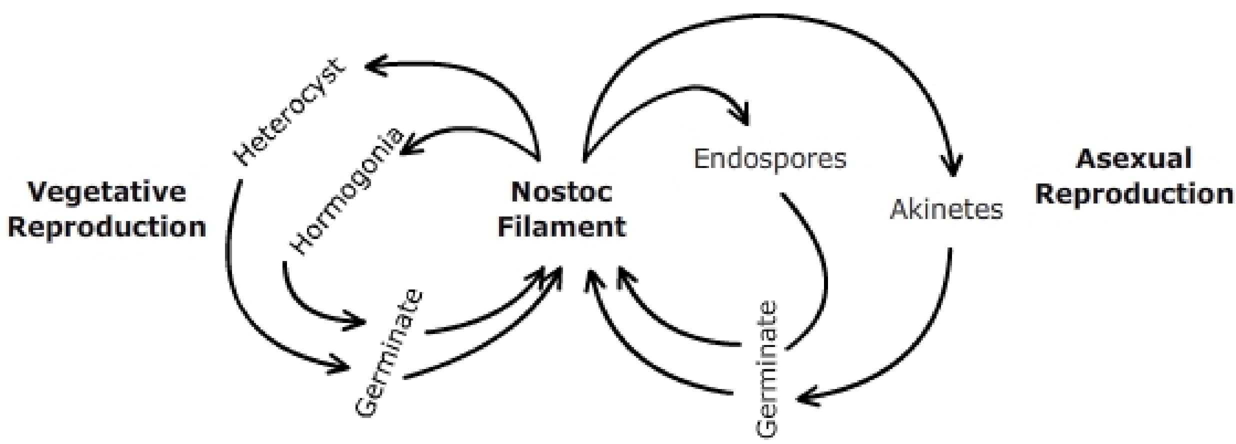


Figure: Diagrammatic Life cycle of *Nostoc*, filaments showing vegetative and asexual reproduction

Source:Author

Thank You (Poem)

O, Cyanophyta

I have laboured a lot

Writing about you

You may be bad and good

But I look at your goodness

As a colonizer, fertilizer

Oxygen releaser

Who made our existence

Possible on earth

Glossary

By complementarity:Absorbing different light spectra when confronted with light shading by one of the strains

Cryophytes: Growing On snow

Endophytes:Inside the plant

Endosymbiont:Mutual beneficial symbiotic relationship

Endozoic:In the intestine of man

Epilithic: On calcareous rocks

Eutrophic: Organically rich

LHCs:Light Harvesting Complexes

Moniliform:Beaded arrangement

Stromatolites:

Terrestrial:In damp soil

Themophilic: Tolerance to very high temperatures

Exercises

Q. 1. State True (T) or False (F):

(i) Cyanophyta is included under Monera

(ii) Cyanophyta has two classes

(iii) Cyanophyceae has about 2000 species

(iv) Blue-green algae occurs in symbiotic relationship
(v) Cyanophyta forms colonies
(vi) Nucleus is present in Cyanophyta
(vii) Gas vesicles perform light shading role
(viii) Thylakoids are narrow tube-like structures in blue-green algae
(ix) Nucleolus is absent in Cyanophyta
(x) Cytoplasmic membrane is two-layered in Cyanophyta.

Ans. (i) T, (ii) F, (iii) T, (iv) T, (v) T, (vi) F, (vii) T, (viii) T, (ix) T, (x) T

Q. 2 Fill in the blanks:

(i) Range of cell size in prokaryotes is ___________.
(ii) _________________ is an example of filamentous colony.
(iii) _______________ shows falls branching of the thallus.
(iv) ______________ is a freshwater Cyanophyta.
(v) Blue pigment of blue-green algae is called __________.

Ans. (i) 1μ-10μ, (ii) *Microcoleus vaginatus*, (iii) *Tolypothrix* or *Scytonema,* (iv) *Nostoc* / *Rivularia,* (v) Phycocyanin

Q. 3 Give one-word answers:

(i) Name the covering on cells of blue-green algae.
(ii) Name of red pigment in Cyanophyta.
(iii) Name of the pigment involved in photosystem II in blue-green algae.
(iv) A common sheath that covers many filaments.
(v) One most common method of reproduction in Cyanophyta.
(vi) Beaded arrangement of cells in *Nostoc.*
(vii) Cyanophyta growing on snow.
(viii) Name of cyanophytes occurring inside the plant.
(ix) Cyanophytes occurring in a mutually beneficial relationship.
(x) Absorbing different light spectra when confronted with light shading with one of the strains.

Ans. (i) Mucin or gelatinolus sheath, (ii) Phycocrythrin, (iii) Phycocyanin, (iv) Colony, (v) Fission, (vi) Moniliform, (vii) Cryophytes, (viii) Endophytes,

(ix) Endosymbiont, (x) Bycomplementarity/ Chromatic adaptation

Q. 4 Describe the range of thallus organization in the blue-green algae.

Q. 5 What are the various habitats of blue-green algae? Comment on their distribution.

Q. 6 Write details of the modes of reproduction in blue-green algae.

Q. 7 *Nostoc* is of common occurrence, elaborate upon its structure, morphology and life cycle.

Suggested Readings

1. Evolution and Oxygen. Hila Science Videos, 16 March, 2009.
2. Padmakumar, K.B., Menon, N.R. and Sanjeevan, V.N. (2010). Occurrence of endosymbiont *Richelia intracellularis* (Cyanophyta) within the diatom *Rhizosolenia hebetata* in the Northern Arabian Sea. *Int. J. Biodiversity Conservation,* **2,** 70-74.
3. Marshall, H.G. (1981). Occurrence of bluegreen algae (Cyanophyta) in the phytoplankton off the southeastern coast of the United States. *J. Plankton Res.,* **3,** 163-66.
4. Bold, H.C. and Wynne, M.J. (1985). *Introduction to the Algae: Structure and Reproduction*. 2nd ed. Prentice-Hall, New Jersey.
5. Clark, D.W., Moore, R. and Vodopich, D.S. (1998). *Botany.* 2nd ed. McGraw Hill, U.S.A.
6. Prescott, G.W. (1969). *The Algae: A Review.* Thomas Nelson and Sons, London, U.K.
7. E-Reference. Page 57, Tuesday, 17 May, 2011.
8. Fritsch, F.E. (1945). *Structure and Reproduction of the Algae.* Vol. 2. Cambridge University Press, London.
9. The Bigger.com
10. Sharma, O.P. (2004). *Textbook of Algae.* Tata McGraw Hill Publishing Company Ltd., New Delhi, India.
11. Kumar, H.D. and Singh, H.N. (1990). *A Textbook on Algae.* Affiliated East-West Press Pvt. Ltd., New Delhi, India.
12. Goodwin, T.W. (1974). *Carotenoids and Biliproteins.* Algae Physiology and Biochemistry. Stewart, W.D.P. (Ed.). University of California Press, Berkeley and Los Angeles, U.S.A.
13. Badger, L.R., Dieter, D.P., Klughammer, M. and Sultemeyer, B. (1998). The functioning of the CO_2 concentrating mechanism in several cyanobacterial strains. *Can. J. Botany*, Jun. 1998, 1-7.

14. Vierstra, R.D. (2005). Phytogenetic analysis of the phytochrome superfamily reveals distinct microbial subfamilies of photoreceptors. *Biochem. J.,* **392,** 103-16.
15. Bezy, R.P., Wiltbank, L. and Kehoe, D.M. (2011). Light-dependent attenuation of phycoerythrin gene expression reveals convergent evolution of green light sensing in cyanobacteria. *Proc. Natl. Acad. Sci. U.S.A.,* **108,** 18542-47.
16. Stomp, M.J., Huisman, F. de Jongh, Veraat, A.J., Gerla, D., Rijkeboer, M., Ibellings, B.W., Wollenzien, U.I.A. and Stal, L.J. (2004). Adaptive divergence in pigment composition promotes phytoplankton biodiversity. *J. Gen. Microbiol.,* **111,** 1-61.

Additional Links

http://www.jochemnet.de/fiu/bot4404/BOT4404_12.html

http://www.abdn.ac.uk/rhynie/cyano.htm

http://cronodon.com/BioTech/Cyanobacteria.html