Cell Structure of Cyanobacteria

5. Cytoplasmic Inclusions:
Several glycogen granules, oil droplets and other inclusions are dispersed in chromoplasm as well as in centroplasm regions:

(i) Cyanophycin:
The cyanobacteria accumulate nitrogenous reserve material called cyanophycin or cyanophycian granules when grown at conditions of surplus nitrogen. These are built with equal molecules of arginine and aspartic acid. These represent as much as 8% of total cellular dry weight. They can be observed under a light microscope as they accept neutral red or carmine.

(ii) Gas Vacuoles:
In many cyanobacteria e.g. Anabaena, Glocotrichia, Microcystis, Oscillatoria, etc. the gas vesicles of viscous pseudo vacuoles of different dimensions are found. The cytoplasm lacks vacuoles. The vesicles are hollow, rigid and elongated cylinders (75 nm diameter, 200-1000 nm long) covered by a 2 nm thick protein boundary. The ends of vacuoles are conical. The protein boundary is impermeable to water and freely permeable to gases. Under pressure they get collapsed, and therefore, lose refractivity.

The function of gas vesicles is to maintain buoyancy so that the cell can remain at certain depth of water where they can get sufficient light, oxygen and nutrients. Floating and sinking phenomenon is a key feature found in free floating cyanobacteria. Through this mechanism they can escape from harmful effect of bright light.

(iii) Carboxysomes:
Carboxysomes are the polyhedral bodies containing 1, 5-ribulose bi-phosphate carboxylase (Rubisco).

(iv) Phosphate Bodies:
Phosphate bodies seen in volutin granules of bacteria.
(v) Phycobilisomes:
Some phototrophic organisms (i.e. cyanobacteria and red algae) contain two accessory pigments such as carotenoids and phycobilins (also called phycobiliproteins), in addition to chlorophyll or bacteriochlorophyll pigments. The carotenoids play a photo-protective role, whereas phycobilins serve as light harvesting pigments.

Phycobilins are the main light-harvesting pigments of these organisms. Phycobiliproteins are red or blue in colour. These compounds consist of an open-chain tetrapyroles derived biosynthetically from a closed porphyrin ring. The tetrapyroles are coupled to proteins.

Phycobiliproteins are aggregated to form a high molecular weight darkly stained ball-like structure called Phycobilisomes. The phycobilisomes are attached to the outer surface of lamellar membrane.

Phycobiliproteins includes three different pigments:
(i) A red pigment phycoerythrin which strongly absorbs light at 550 nm,

(ii) A blue pigment phycocyanin which absorbs light strongly at 620 nm, and

(iii) Allophycocyanin which absorbs light at 650 nm.

The pigments in phycobilisomes are arranged in such a way that allophycocyanin is attached to photosynthetic lamellar membrane. Allophycocyanin is surrounded by the molecules of phycocyanin and the latter by phycoerythrin.

Phycoerythrin and phycocyanin absorb shorter (high energy) wavelength of light and transfer energy to allophycocyanin. Allophycocyanin is closely linked to the reaction centre chlorophyll. Thus energy is transferred from allophycocyanin to chlorophyll a. Presence of phycobilisomes makes the cyanobacterial growth possible at the region of lowest light intensities.

(vi) DNA Matrix:
Like other prokaryotes the cyanobacteria also contain naked DNA fibrils dispersed in the centroplasm. DNA material lacks nucleoplasm, and like E. coli contains a histone like protein that binds with DNA. The total number of genomes is yet not known but in Agmenellum 2 to 3 genomes have been reported.
However, base composition of DNA in different cyanobacteria varies, for example in chroococcales (35-71 moles percent G + C), Oscillatoriales (40- 67 moles percent G + C), Pleurocapsales (39-47 moles percent G + C) and heterocystous forms (38- 47 moles percent G + C). The molecular weight ranges from $2.2 \times 10^9$ to $7.4 \times 10^9$ Daltons. Like eubacteria, cyanobacteria also have 70S ribosomes. Similar to bacteria cyanobacteria contain covalently closed non-functional, circular plasmid DNA. These are called cryptic plasmid as the function of cyanobacterial DNA is not known.

6. Specialized Structures of Cyanobacteria:
There are certain specialized structures viz., hormogones, exospores, endospores, Nano cysts, heterocysts, exospores, endospores, akinetes, etc. which are produced in cyanobacteria.

(i) Hormogones and Hormocysts:
Hormogones are the short segments of trichomes produced in all filamentous cyanobacteria. Hormogones are produced by several methods such as fragmentation of trichomes into pieces (e.g. Oscillatoria, delimination of cells into intercalary groups (Glocotrichia), fragmentation and round off the end cells (Nostoc) (B), formation of separating disc or necridia and their subsequent degradation (Oscillatoria, Phormidium). The hormogones show gliding movement. Each hormogene may develop into a new individual.

Some other cyanobacteria produce hormocysts or hormospores which function similar to hormogones. Hormocysts are produced intercalary or terminal in position. They are highly granulated and cells are covered by a thick mucilaginous sheath. In the cells of hormocysts a large quality of food material is accumulated. During favourable condition hormocysts develop into a new plant.

(ii) Endospores, Exospores and Nanocysts:
The non-filamentous cyanobacteria generally produce endospores, exospores and nanocysts, for example Chamaesiphon, Dermocapsa and Stichosiphon. The endospores are produced inside the cell. During endospore formation, cytoplasm of the cell is cleaved into several bits which are converted into endospores.

After liberation each endospore germinates into a new plant, for example Dermocapsa. When the size of endospores is smaller but larger in number, they are called Nano spores or nanocysts. Some of the cyanobacteria (e.g. Chamaesiphon) reproduce by budding exogenously. The spores produced through this method are called exospores.
(iii) Akinetes:
The members of Stigonemataceae, Rivulariaceae and Nostocaceae are capable to develop the vegetative cells into spherical perennating structures called akinetes or spores such as Nostoc, Rivularia, Gloeotrichia, etc.

During unfavourable conditions, the vegetative cells accumulate much food, enlarge and become thick walled. These are formed singly or in chains. Akinetes possess cyanophycean granules hence these appear brown in colour. Under favourable conditions the akinetes germinate into vegetative filaments.

(iv) Heterocysts:
Heterocysts are the modified vegetative cells. Depending on nitrogen concentration in the environment, hetero- cyst formation occurs. During differentiation several morphological, physiological, biochemical and genetical modifications take place in heterocyst.

They are slightly enlarged cells, pale yellow in colour containing an additional outer investment. They are produced singly or in chains and remain intercalary or terminal in positions. These are found most frequently in Oscillatoriaceae, Rivulariaceae, Nostocaceae and Scytonemataceae.

In heterocysts, total amount of thylakoids gets reduced or absent. The photosystem II that generates oxygen becomes non-functional. The amount of surface proteins that combine with oxygen and create oxygen tense environment is increased.

Rearrangement in $nif$ gene (nitrogen fixing gene) cluster takes place and expression of nitrogenase and nitrogen fixation are accomplished. In addition, these take part in perennation and reproduction as well.

![Fig. 4.33: An enlarged view of different components of wall layer of the cell of a cyanobacterium (diagrammatic).](image)
Fig. 4.34: Phycobilisomes attached to the lamellar membrane (A); arrangement of phycobiliproteins in a phycobilisome attached to lamellar membrane (B); arrows show the direction of transfer of energy (diagrammatic).

Fig. 4.35: Diagrams of a Gloeotrichia (A), Nostoc (B) and Oscillatoria (C).
Nostoc sp. showing heterocysts.