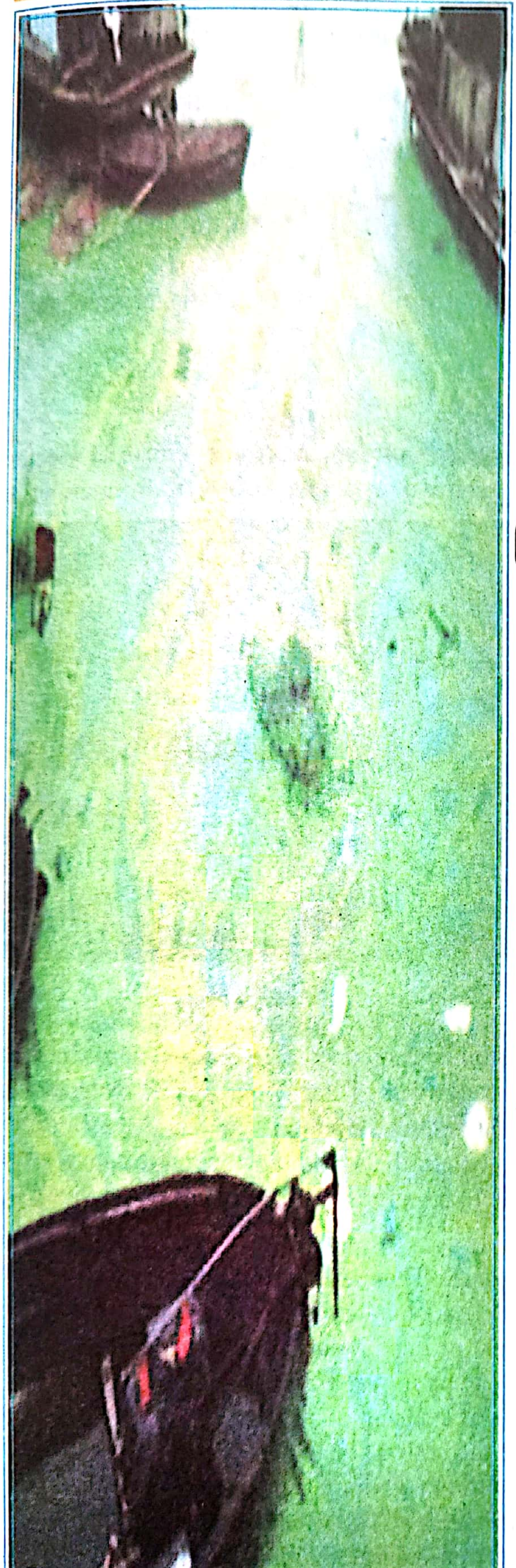
Blue green algal bloom
(Afflicting Taihu lahe in China)

CHAPTER 2

# DIVISION : CYANOPHYTA (*Cyanophycophyta*) Class : *Cyanophyceae*



## GENERAL CHARACTERISTICS

This division includes the blue-green algae which are the only known oxygen producing prokaryotes. It is a small primitive group comprising of about 2,500 species placed under 150 genera. All of them are included in a single class **Cyanophyceae** or **Myxophyceae**. The members of this class are considered the simplest, living autotrophic plants. Individually all the blue-greens are microscopic. The diagnostic features of the division and the class are:

(*i*) The cells constituting the thallus are **prokaryotic;**

(*ii*) The flagella are entirely lacking (even the reproductive cells are non-flagellated);

(*iii*) Where locomotion occurs, it is of gliding, jerky type;

(*iv*) The phycobilin pigments unique to this class are blue *C-phycocyanin* and *C-phycoerythrin*; in addition to *chlorophyll-a*, *B-carotene* and unique, xanthophylls, namely, *myxoxanthin* and *mycoxanthophyll;*

(*v*) There are no membrane bound chromatophores;

(*vi*) The unique food-storage compounds are the *myxophycean starch* and a proteinaceous material *cyanophycin;*

(*vii*) Many filamentous blue-greens possess specialised cells of disputed function known as the **heterocysts**;

(*viii*) Sexual reproduction is completely absent. Recently indications of genetic recombination which fulfil the function of sex have been reported in a few cases.

## TRIBE : HORMOGONEAE : ORDER 2 : NOSTOCALES

*Family* **Nostocaceae.** The trichomes are composed of a row of similar cells and are either free or embedded in a common matrix of mucilage. Certain cells in the trichome form heterocysts and some akinetes. The former are intercalary, rarely terminal in position and occur either singly or more than one together. Reproduction is by hormogonia and in some by spores in addition. The important genera included in the family are *Nostoc, Aulosira, Nodularia, Anabaena* and *Aphanizomenon*. Here *Nostoc* is taken as a type.

## NOSTOC (VAUCHER, 1803)

**Occurrence.** It is filamentous form of both terrestrial and aquatic habitats. It does not occur in single filaments but grows in large colonies of closely packed trichomes embedded in a firm matrix of gelatinous material. Nostoc colony thus forms a mucilaginous lump or thallus which occurs floating or attached. The thalli are of various sizes and shapes and may be solid or hollow. They may be balls of a jelley-like substance (Fig. 2.24A) or may be irregularly shaped. In size they may be microscopic, pea-size, walnut sized or as large as a plum. Sometimes they may reach a diameter of eight centimetres. The colour may be olive-green or blue-green and the surface of the colony warty or smooth. Terrestrial species, *Nostoc commune* grows on damp soil and forms leathery or rubbery sheaths. It is common in the Arctic and alpine meadows. Aquatic species occur either as free floating thalli in the sunny pools, ponds and lakes or lying at the bottom attached to submerged vegetation. A few species favour running water, especially fast flowing mountains streams. There they are found attached to stones along the stream beds. *Nostoc* also occurs in symbiotic association with fungi to form lichens. A certain species of *Nostoc* occurs in the thalli of *Anthoceros*. One species (*N. punctiforme*) occurs in the underground stems of *Gunnera manicata* (Angiospermic marsh plant). Some species of *Nostoc* have been reported to fix atomspheric nitrogen and tend to maintain fertility of paddy fields in which these forms regularly occur. Large colonies of terrestrial species are eaten in the orient.

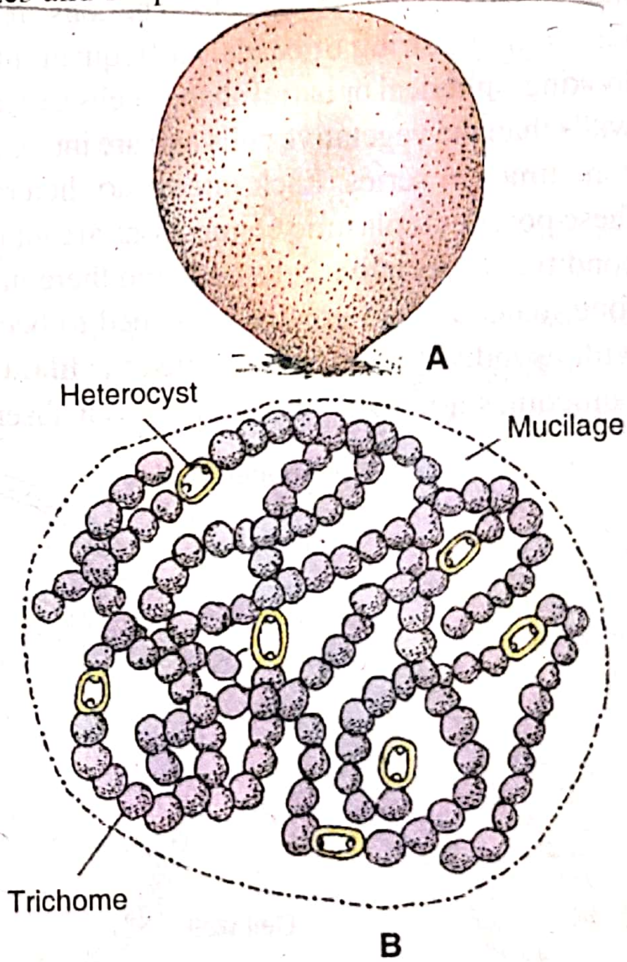


**Fig. 2.24 (A-B).** *Nostoc* sp. (A) Colony; (B) Portion of the colony as seen under low power of microscope.

**Structure of the Colony** (Fig. 2.24 B). Innumerable chains of bead-like cells (trichomes) of varying lengths are intricately tangled in a copious gelatinous matrix to form a colony (B). Each trichome (Fig. 2.25) is usually enclosed by its own mucilaginous sheath and is called a **filament**. The numerous filaments in the colony are held together by a soft mucilaginous envelope formed by the fusion of the individual trichome sheaths and also secreted copiously by the component cells. The mucilage lump is bounded externally by a firm, tough, pellicle-like bounding membrane to form a definite colony. Each colony appears like a bluish green or yellowish mass of jelly. Young colonies are small and microscopic. The mature ones are large. Enclosure of several colonies growing in the neighbourhood, within a common gelatinous mass results in the formation of a macroscopic, mucilaginous lump or thallus. It may be called a **compound colony**. Frequently the compound colony breaks open as it gets large and forms a flat expanse with lacerated margins.

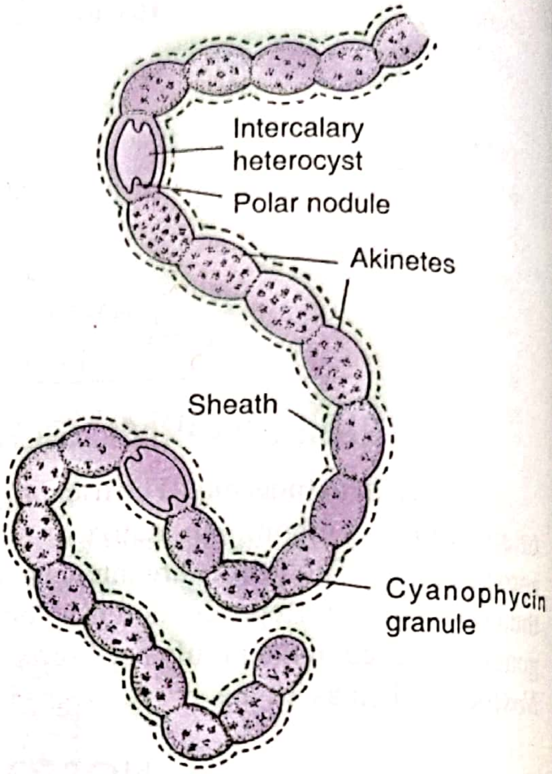


**Fig. 2.25.** *Nostoc* sp. A filament with a single trichome.

**Structure of the Trichome** (Fig. 2.25). The trichomes are much contorted, moniliform and intertwined. They wind about in every direction in the gelatinous matrix. They are more crowded towards the periphery of the colony to form a dense limiting layer. Each trichome is composed of numerous rounded or oval cells. The cells are joined loosely from end to end into a trichome somewhat resembling a string of beads. At frequent intervals along with trichome are found colourless, empty looking, spherical or barrel shaped cells called the **heterocysts**. They are slightly large and have thicker walls than the vegetative cells and are intercalary, sometimes terminal (*N. linckia*). They occur singly, sometimes in series. Each intercalary heterocyst, when first formed, has two polar pores. Through these pores cytoplasmic connections are maintained with the adjacent vegetative cells. Under certain conditions vegetative cells here and there in the trichome may become greatly enlarged, stored with food materials and greatly thickened to become resting bodies called the **akinetes**. Each trichome with its individual sheath is called the **filament** (Fig. 2.25). The sheath may be hyaline or coloured. Sometimes it is very indistinct or even absent.

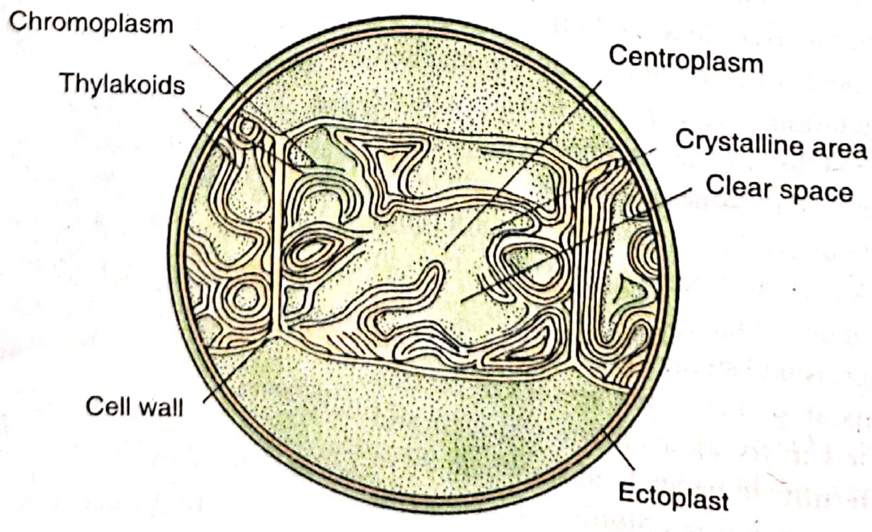


**Fig. 2.26.** *Nostoc muscorum*. Showing cell structure as revealed by electron microscope (Based on Menke).

**Cell Structure** (Fig. 2.26). The cell consists of the **cell wall** surrounding the **protoplast**. The protoplast, as usual in the cyanophycean cell, is vaguely defined into the outer pigmented cytoplasmic region called the **chromoplasm** and the inner colourless **centroplasm**. The chromoplasm has the usual pigments (phycocyanin, chlorophyll a, etc.) located in the lamellae which form a system of peripheral area of parallel paired membranes embedded in the granular matrix. There is no chromoplasm without lamellae. It also contains the colourless granules of myxophycean or cyanophycean starch and the cyanophycin granules of proteinaceous nature. The centroplasm is not separated from the chromoplasm by any kind of membrane.

**Reproduction**. *Nostoc* reproduces entirely vegetatively by the following methods:-

**1. Colony Fragmentation**. The *Nostoc* colony as it gets larger frequently breaks up into flat expanses as a result of storms and other disturbances. Each of these grows up to the size of the parent colony.

**2. Hormogonia** (Fig. 2.12 C). Hormogone formation is very common in *Nostoc*. The trichome ruptures at places where a heterocyst and the vegetative cell adjoin. This junction is the weakest link in the chain. In fact some algologists believe that heterocysts represent a mechanism for the fragmentation of the trichome. In this way, short segments of living cells called the **hormogonia** became isolated. The hormogonia slip out of the enclosing gelatinous matrix and establish new colonies by division (Fig. 2.27 A-B). The terminal cells of the hormogonia differentiate as heterocysts (B). The intercalary cells then divide in a plane parallel to the axis of the trichome (B) forming a packet of cells (C). This is the *aseriate stage*. Sometimes the hormogones develop into fresh trichomes without being liberated from the colonial sheath and increase the number of trichomes in the adult colony.

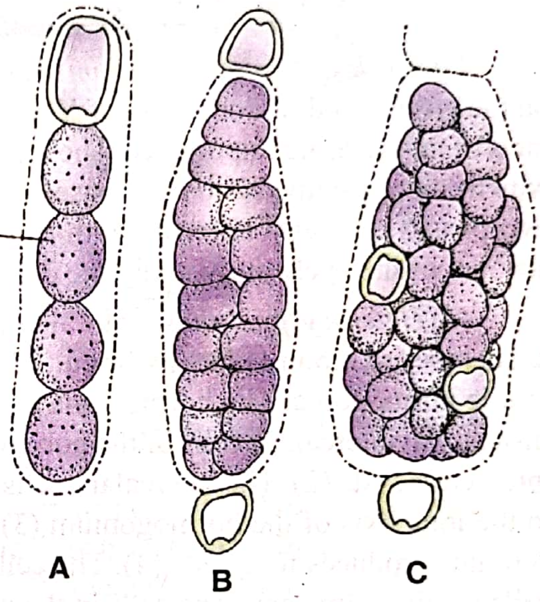


**Fig. 2.27 (A-C)**. *Nostoc*. Stages in germination of a hormogone to form a new colony (C).

**3. Resting spores or akinetes** (Fig. 2.25). Under certain conditions any cell or some of the vegetative cells of the trichome become enlarged and each secretes a thick, highly resistant wall around it. They get gorged with reserve food materials. Such specially modified vegetative cells are called the **akinetes** or **resting spores**. These are well adapted to survive unfavourable conditions such as water shortage and unsuitable temperature. It is not unusual to find all the cells between two heterocysts and occasionally the entire trichome converted into akinetes. With the return of favourable season each akinete germinates to form a new filament of *Nostoc*. Recently Tewari (1979) discovered a new species of *Nostoc* described as *N. spinosa* which produces akinetes with spinose spore walls.

4. In exceptional cases (*N. commune*) the heterocyst may become functional (A). It germinates to form a new filament (Fig. 2.28). At first, a 2-celled (B) and later, a 4-celled germling is formed (C). It escapes either by the rupture of the heterocyst wall at the equatorial region or by gradual dissolution and widening of the pore.

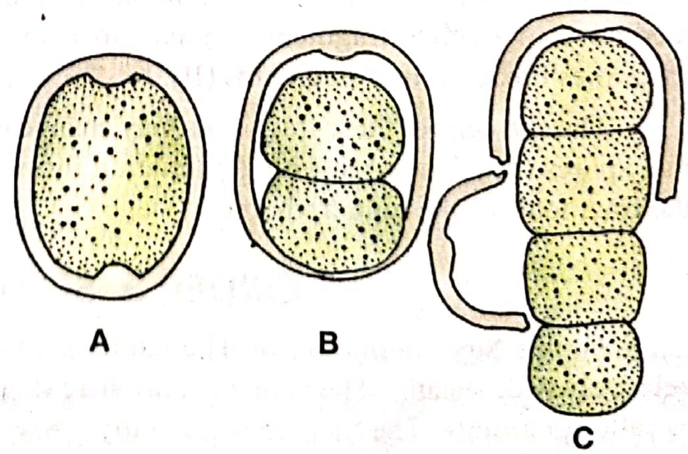


**Fig. 2.28 (A-C)**. *Nostoc*. Stages in germination of heterocyst (After Geitler).

5. **Endospore formation**. Brand (1901) and Spratt (1911) reported that the contents of the heterocysts in *Nostoc commune* and *N. microscopicum* divide to produce **endospores**. The endospores, on liberation, give rise to new filaments.

**Taxonomic Position:**

| | | |
|---|---|---|
| Division | : | **Cyanophyta** (Cyanophycophyta) |
| Class | : | **Cyanophyceae** |
| Tribe | : | **Hormogoneae** |
| Order | : | **Nostocacales** |
| Family | : | **Nostocaceae** |
| Genus | : | *Nostoc* |
| *Species* | : | *muscorum* |

*Life cycle of Nostoc muscorum* (Fig. 2.29). Observations of Lazaroff and Vishaniac (1961, 1962) on the growth and reproduction of *N. muscorum* under cultural conditions have revealed interesting facts of far-reaching importance. The alga passes through a regular sequence of development changes which can be grouped into two phases, namely, **heterocystous phase** and sporogenous phase. These two phases regularly alternate with each other in the developmental cycle. Following is the brief account of the cycle as given by the discoverers:

(*a*) *Heterocystous phase*. The alga passes through this phase in complete darkness with glucose or sucrose as carbon source in the culture medium. The trichomes break up at the heterocysts to form motile hormogonia. The hormogonia do not grow into normal heterocyst containing trichomes (1). Instead the intercalary cells of the hormogonia increase in size and the terminal cells metamorphose into heterocysts (2). The intercalary cells of the hormogonium separate and divide in a plane parallel to the long axis of the hormogonium (3). The division is suggested to be meiotic. Each intercalary cell thus produces four cells (4). The cells divide further so that a packet of several undifferentiated cells results from each. The cells in the packet may occur singly (5) or in chains of two or three (6). This is the *aseriate stage*. The developmental cycle is arrested at the aseriate stage in the dark. On exposure to light the cells of each packet of the aseriate stage form a single trichome. The 2 or 4-celled fragments anastomose. The products of anastomosis may grow in lengths by cell division and develop intercalary heterocysts (7). The liberated filaments break up into heterocysts and hormogonia. These seven growth stages constitute the heterocystous phase of the developmental cycle.

(*b*) *Sporogenous phase*. This phase in the cycle starts with two or four cell long chains of the aseriate stage (6). On exposure to light and with carbon dioxide as source of carbon in the culture medium 2 to 4-celled fragments (6) may grow to form long trichomes without heterocysts (I). The trichomes break up into fragments (II).

The end cells of these fragments may change into heterocysts (III). The intercalary cells develop into spores (IV). The spores on germination form 2 or 3-celled germlings (V) apparently similar to the fragments of the long trichome of stage (II).