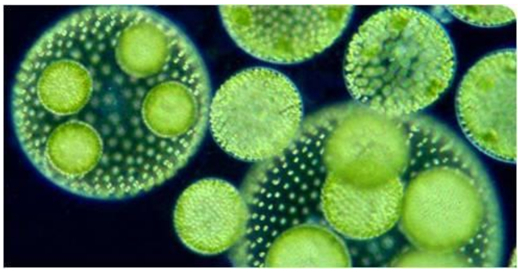
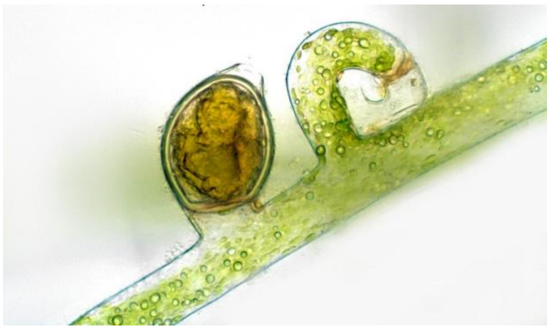
Ecology of Algae

For 3rd year

Chemistry & Microbiology Students

Faculty of Science





By

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Phycology

Definition of Algae

Algae are a diverse group of simple, plant-like organisms. Like plants, most algae use the energy of sunlight to make their own food, a process called photosynthesis. However, algae lack the roots, leaves, and other structures typical of true plants. Algae are the most important photosynthesizing organisms on earth. They capture more of the sun's energy and produce more oxygen (a byproduct of photosynthesis) than all plants combined. Algae form the foundation of most aquatic food webs, which support an abundance of animals. Algae vary greatly in size and grow in many diverse habitats. Microscopic algae, called phytoplankton, float or swim in lakes and oceans. Phytoplanktons are so small that 1000 individuals could fit on the head of a pin. The largest forms of algae are seaweeds that stretch 100 m (300 ft) from the ocean bottom to the water's surface. Although most algae grow in fresh water or seawater, they also grow on soil, trees, and animals, and even under or inside porous rocks, such as sandstone and limestone. Algae tolerate a wide range of temperatures and can be found growing in hot springs, on snow banks, or deep within polar ice.

Habit and Habitat

The algae are predominantly aquatic and are found in fresh or salt waters. Fresh water forms occur abundantly in ponds, lakes, slow flowing streams and water reservoirs. In habit they may be free swimming, free floating or attached to the bottom in the shallow water. Some are terrestrial and grow in wet situations, such as, on damp soil, damp shaded sides of trees and walls or even rocks and thus have adapted themselves to a life in the air. They may live as epiphytes as well as epizoics. A few occur in association with fungi. Some algae are endophytic whereas a few live in symbiotic relationship with the higher plants. Most of the marine forms are *Sea Weeds.* They inhabit vast area of the ocean. Some of the marine forms are free floating. A few are attached. The free floating and free swimming initiate algae together with similar other organizations constitute the *plankton* of the ocean and lakes.

According to the habitat, the algae may be classified as follows:

1. Aquatic algae
2. Terrestrial algae
3. Aerophytes
4. Cryophytes
5. Thermophytes
6. Algae of unusual habitats

1. Aquatic algae: Majority of the algal genera are aquatic and found either completely submerged or free floating on the surface of water. Aquatic algae usually occur in ponds, pools, tanks, ditches, streams or in slow running rivers and are called fresh water forms. Marine algae are found in sea and macroscopic large thalli of brown algae are commonly known as "sea weeds". Fresh water algal forms like *Chlamydomonas, Volvox, Hydrodictyon* are found in stagnant waters, whereas *Cladophora, Oedogonium, Ulothrix* and few species of *Vaucheria* occur in slow running water bodies. Most of the members of Phaeophyceae and Rhodophyceae are found in sea either floating on the surface of sea water or attached with rocks or any other substratum. The free floating and free swimming microscopic algal forms together with other similar organisms constitute the *Planktons* of water bodies. Plankton forming algae may either be free floating from very beginning and are never attached (Euplanktons) *e.g., Microsystis, Chlamydomonas, Scenedesmus* and*, Cosmarium* or in the beginning may be attached but later on they get detached and become free floating (Tychoplanktons) *e.g., Zygnema, Oedogonium, Cladophora, Cylindrospermum, Rivularia* etc.

2. Terrestrial algae: Many algal genera are found on or beneath the moist soil surface are called terrestrial algae. The algal forms occurring on the surface of soil *e.g.* few species of *Vaucheria, Botrydium, Fritschiella* and *Oedocladium* are called *Sapophytes* while algal genera having subterranean habit *e.g.,* few species of *Nostoc, Anabaena* and *Euglena* are known as *Cryptophytes.*

Factors affecting the soil algae: A number of factors have been found to be associated with the growth and diversity of soil algae.

Moisture: it is one of the important factors for the growth of soil algae which is required to complete the life cycle.

Temperature: Many blue-green algal forms can tolerate temperature between 60-90 ^{0}C and due to this they are common in tropical soils. Diatoms can survive very low temperatures.

Light: Although many algae can withstand bright sunlight but their growth is maximum in less bright light.

pH and salinity: pH has an important role in determining the algal groups. Many green algae can be found in a wide range of pH while blue-green algae prefer neutral or alkaline pH. Blue-green and diatoms do not prefer acidic soils.

Soil texture and chemical composition: The chemical properties and the texture of soil are important factors which decide the type and growth of algal flora.

3. Aerophytes: Such algal forms as are adapted for aerial mode of life and occur on the trunks, moist walls, flower pots, rocks, and get their water and carbon dioxid requirements completed directly from atmosphere are called Aerophytes. *Trentepohlia* is found the bark of trees in moist and humid climatic conditions while *Phormidium, Scytonema* & *Hapalosiphon* have been observed to grow on bark of trees along with Bryophytes.

4. Cryophytes: These algae are found on the mountain peaks covered with snow and impart attractive colours to the mountains. *Haematococcus nivalis* gives red colour to Arctic and Alp regions while *Chlamyodomonas yellowstonensis* along with some species of *Ankistrodesmus* is responsible for the green colour of the snow of the mountain of European countries particularly in Arctic region.

a) Those algae which are found on snow and not on ice *e.g.,* some species of *Raphidone* and *Chlamydomonas.*

b) Those algae which can grow only on ice and result in "ice bloom" *e.g., Ancyclone, Mesotaenium.*

c) Those algae which can grow on snow and ice both *e.g.,* and *Cylmdrocys*

d) Those algae which are not true cryophytes and have their temporary growth on ice snow e.g., *Phormidium* and *Gloeocapsa*.

5. Thermophytes: The algal genera occurring in hot springs at quite high temperature are called thermophytes. There are certain algae which are known to tolerate the temperature up to 85 ^{0}C e.g. few genera belonging to family Chroococcaceae and Oscillatoriaceae. *Oscillatoria brevis, Synechococcus elongatus* and *Haplosiphon lignosum* are some common examples of thermophytes which can survive up to a temperature of 70°C at which generally plant life is not possible.

6. Algae of unusual habitats: Many algae are found at various interesting places and according to their habitats may be of following types:

a) Halophytic algae. These algae are found in saline water containing high percentage of salts e.g., *Dunaliella, Stephanoptera* and *Chlamydomonas chrenbergii*.

b) Lithophytic algae. Usually the members of Cyanophyceae grow on moist rocks, wet and other rocky surfaces. Blue green algae *Rivularia* and *Gloreocapsa* occur on exposed rocks, whereas *Nostoc* is found growing in damp shady habitats. Several marine belonging to Rhodophyceae and Phaeophyceae are lithophytic in habit and grow on submerged rocks or rocky surface *e.g., Ectocarpus, Polysiphonia* etc.

c) *Epiphytic algae.* Such algal forms which grow on the other aquatic plants are called *Epiphytic algae.* Green algae *Chaetonema* has been found growing on *Tetraspora* and *Batrachospermum. Rivularia* are observed to grow on Angiospermic plant.

d) *Epizoic algae.* Many algae grow on the shells of molluscs, turtles and fins of fishe are known was *epizoic algae. Cladophora* is found on snails and shells of bivalves.

e) *Endozoic algae.* Contrary to epizoic algal forms endozoic algae are found inside the aquatic animals *e.g., Zoochlorella* is found inside *Hydra viridis* while *Zooxanthe* known to occur inside the fresh water sponges.

f) *Parasitic algae. Cephaleuros virescens* which causes 'red rust of tea' is a striking example of parasitic algae and causes heavy damage to tea foliage. *Chlorochytrium* and *Phyllosiphon* are other examples of parasitic algae. *Polysiphonia festigata* a member of Rhodophyceae is reported as semiparasite on *Ascophyllum nodosum.*

g) *Symbiotic algae.* Several members of Cyanophyceae grow in association with other plant and lichens exhibit good example of it. Almost all the plant groups are known to have symbiotic association with blue green algae *e.g., Nostoc* is found within the thalli of *Anthoceros* and *Notothylas, Anabaena cycadeae* is reported in the coralloid roots of Cycas, *Anabaena azollae* occurs in *Azolla* etc. The association of *Chlorella* with nitrogen fixing bacterium *Azotobactor chrooccocum,* and with that of certain species of *Ceratophyllum* and mosses are other examples of symbiotic algae.

Organisation of the thallus

The algae exhibit a great diversity in the organisation of the plant body. The simplest forms are motile or non-motile unicells (*Chlamydomonas* and *Chlorella*). In many species, the cells are grouped into aggregations called colonies *e.g., Volvox* and *Pediastrum.* These assume various forms and may be a hollow sphere, a flat plate or a filament. The filamentous types are usually multicellular and the filament may be simple *e.g., Ulothrix, Zygnema* or branched or an aggregation of filaments or a*,* highly organised thallus of a large size. In some multicellular forms the cells may perform both functions, vegetative and reproductive as in *Oedogonium,* while in others special reproductive cells or organs may be developed, e.g., *Chara*, *Sargassum* etc.

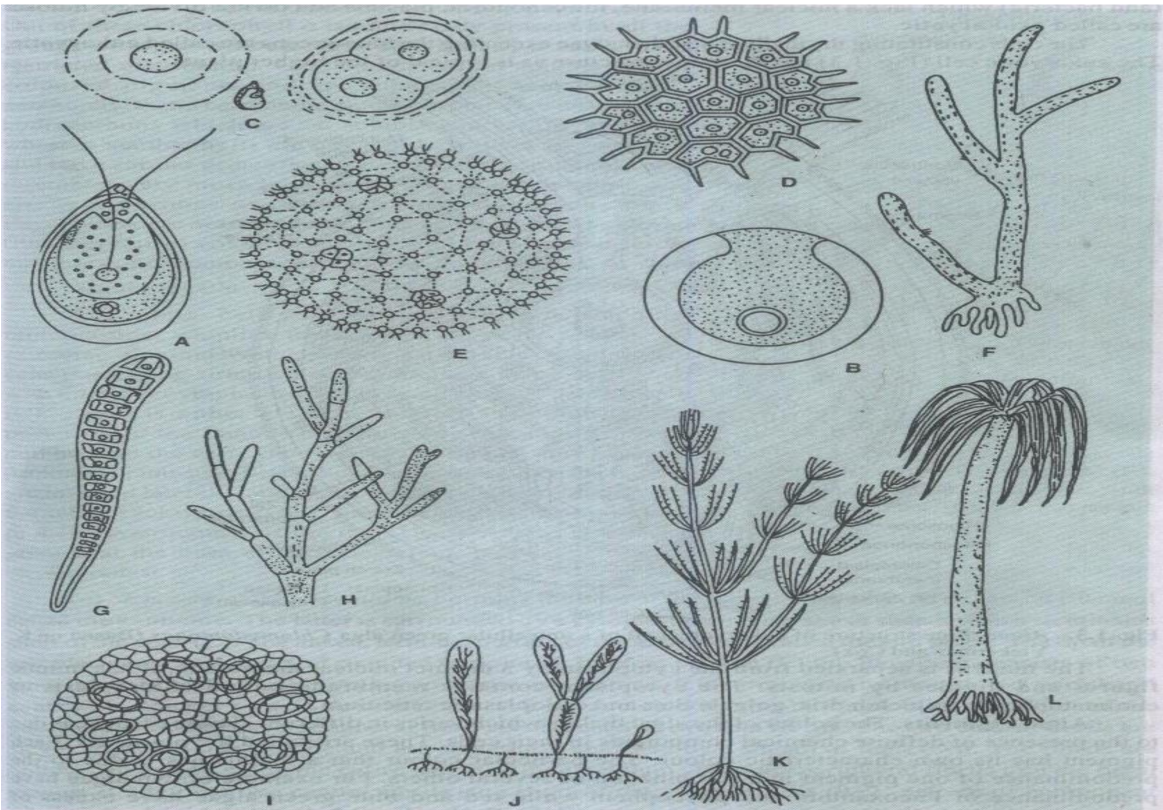


Fig. 1.2. Range of thallus organisation in Algae. (A). *Chlamydomonas*, (B). *Chlorella*, (C). *Gloeocapsa*, (D). *Pediastrum* (E). *Volvox* (F). *Vaucheria* (G). *Ulothrix* (H). *Cladophora*, (I). *Coleochaete* (J). *Caulerpa* (K). *Chara* (L). *Postelsia*

Structure of algal cell

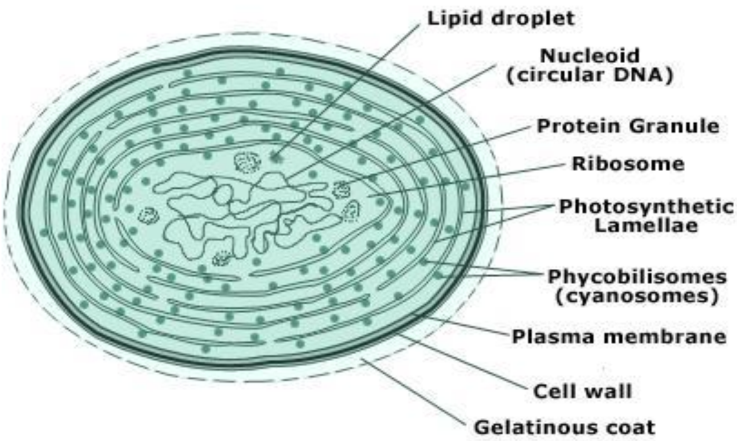


Fig.2. Cell Structure of Cyanophyta

The cells constituting the algal thalli are basically of two kinds, prokaryotic and eukaryotic. The prokaryotic cells (Fig.2) which constitute thalli of cyanophyta (blue-green algae) have a cell wall which contains a specific strengthening component not found in the cell walls of other algae. The central nucleoid has many irregularly arranged fine strands of DNA.

The chlorophyll-pigment is bound to photosynthetic lamellae or thylakoids which may be arranged in parallel layers in the periphery of the cytoplasm or form a network extending throughout the cell cytoplasm. They are not organised into grana. The chloroplasts are thus absent and so are the mitochondria, golgi body and endoplasmic reticulum. The ribosomes are, however, present. The nuclear division does not take place by mitosis and no cell plate is formed. Such simple cells of blue-green algae (and bacteria) which lack a nuclear membrane, mitochondria, and plastids and do not divide by mitosis are called prokaryotic. The cells constituting the thalli of all other algae excepting the blue-greens are called eukaryotic. The eukaryotic cell (Fig.3) has the same structure as is typical of the higher plants.

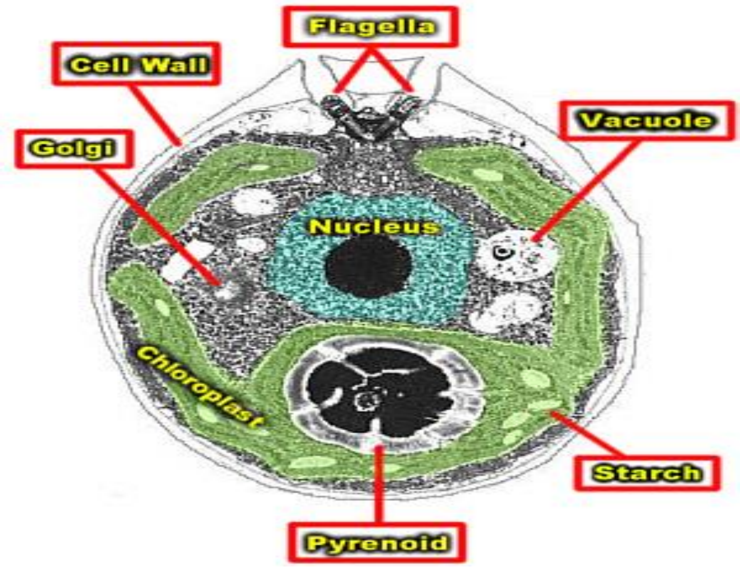


Fig.3. Cell structure of green algae

The nucleus is separated from the cytoplasm by a distinct nuclear membrane. It has mitotic figures and divides by mitosis. The cytoplasm contains membrane bound chloroplasts or chromatophores, mitochondria, golgi bodies and endoplasmic reticulum.

Algal pigments

The colour of the algal thallus which varies in different classes of algae is due to the presence of definite chemical compounds in their cells. These are called the pigments; each pigment has its own characteristic colour. The particular colour that a thallus has is due to the predominance of one pigment in a combination of several others. For example brown algae have predominance of Fucoxanthin and phycophein while red and blue green algae have excess of phycoerythrin and phycocyanin pigments respectively. Each group of algae has its own particular combination of pigments and a characteristic colour which is not found in the other algal groups. In fact the various algal groups show striking differences of colour. Thus the nature of the pigments present in the algal cells forms a quick guide to the primary classification of algae into divisions. The photosynthetic pigments in algae are of three kinds, namely, **chlorophylls, carotenoids** and **phycobilins** or **biliproteins**. The algal chlorophylls are characterized by green colour and in solution they show the phenomenon of fluorescence and emit red light.

1. Chlorophyll pigments are fat soluble compounds and are of five different types. chlorophyll a, b, c, d, and e. Out of these chlorophyll a is universally present in all the groups of algae whereas chlorophyll b, c, d and e have restricted distribution.

Chlorophyll a - present in all higher plants and algae.

Chlorophyll b - present in all higher plants and green algae.

Chlorophyll c - diatoms and brown algae.

Chlorophyll d - red algae.

Chlorophyll e - xanthophyta.

(Chlorophyll a is present in all photosynthetic organisms that evolve O_2.)

2. Carotenoids are fat soluble yellow coloured pigments and are subdivided into carotene, xanthophylls and carotenoid acids.

a) Carotens are unsaturated hydrocarbons which are fat soluble and yellow in colour.

b) Xanthophylls are oxygen derivatives of carotenes and have similar properties like carotenes.

c) Carotenoid acid resembles very much with carotenes and xanthophyll, and are hydrocarbons consisting a chain of carbon atoms.

3. Phycobilins are water soluble blue (phycocyanin) and red (Phycoerythrin) coloured pigments and are present in the members of Cyanophyceae and Rhodophyceae.

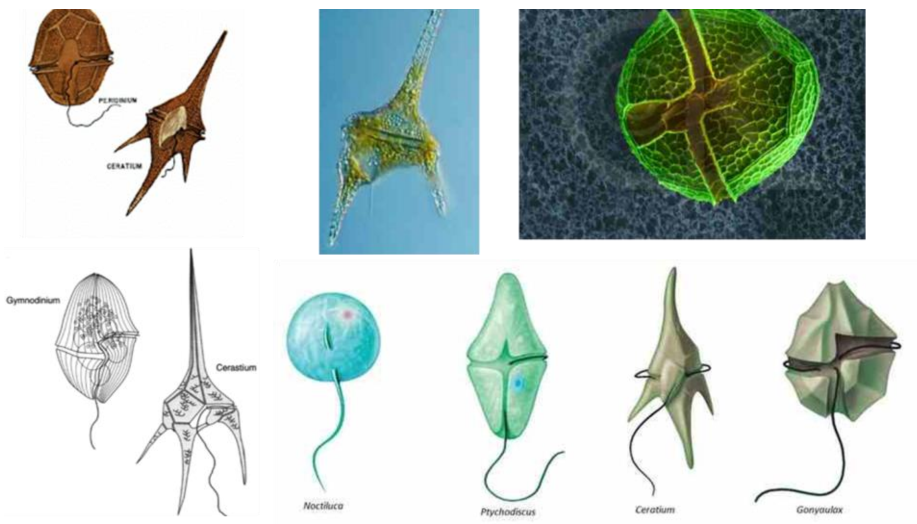
Taxonomic Group	Photosynthetic Pigments
Cyanobacteria	chlorophyll *a*, phycocyanin, phycoerythrin
Green Algae (Chlorophyta)	chlorophyll *a*, chlorophyll *b*, carotenoids
Red Algae (Rhodophyta)	chlorophyll *a*, chlorophyll d, phycocyanin, phycoerythrin, (phycobilins)
Brown Algae (Phaeophyta)	chlorophyll *a*, chlorophyll c, fucoxanthin and other carotenoids
Golden-brown Algae (Chrysophyta)	chlorophyll *a*, chlorophyll c, fucoxanthin and other carotenoids
Dinoflagellates (Pyrrhophyta)	chlorophyll *a*, chlorophyll *c*, peridinin and other carotenoids

Dinoflagellates

About 75% of the known toxic marine algal species are dinoflagellates which are microscopic. Dinoflagellates are mostly unicellular. The cell wall of these algae is only present when in the cyst stage. Most species of dinoflagellates have two flagella. One typical flagellum extends behind the cell. The other, usually shorter flagellum lies in a groove encircling the cell.

Dinoflagellates are an important component of plankton, the primary producers of organic material in the oceans. While this makes them important as a food source, some species of dinoflagellates are poisonous.

Some dinoflagellate species are photosynthetic, some eat other organisms and some do both. There are around 2,000 species of dinoflagellates in the world. While most species are not harmful, about 30 dinoflagellates produce potent neurotoxins that are capable of producing poisoning in human consumers of contaminated seafood. Some species can grow rapidly, accumulating near the sea surface and discoloring the water in a phenomenon called a red tide. While red tides usually have benign effects, some species produce toxins as they redden the sea. Other algal species produce toxins but do not discolor the sea at all The Red Tides common off the coasts of Florida and Mexico are caused by dinoflagellates and can kill millions of fish.



Algal flagella

The motile cells of algae are provided with fine, protoplasmic, whiplike threads, the flagella (A). They are extremely fine and hyaline emergencies of the cytoplasm. In cells possessing firm cell walls, the flagella are connected with the inner cytoplasm through small pores in the cell wall (C). There is either a single anterior flagellum (rarely posterior) or the flagella occur in pairs (A), rarely in great numbers on the cell. The flagella on the cell may be equal **(**isokont**)** or unequal **(**heterokont**)** in length. When the flagella are inserted laterally one is directed forwards in motion and the other backwards. They function as the locomotory or propelling structures of the cell. Usually there is a single granule at the base of each flagellum. It is known as the blepharoplast.

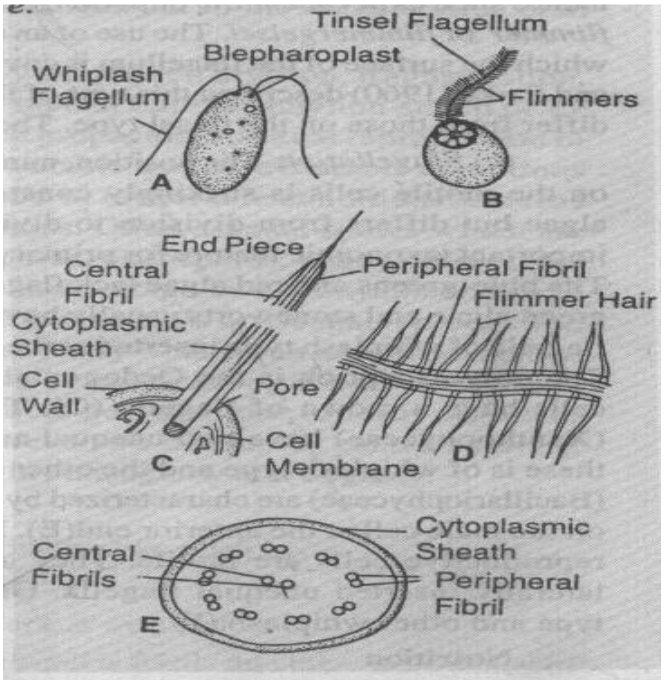


Fig. 1.4. (A-E). *Algae*. Kinds of Flagella and their structure. (A), Whiplash; (B). Tinsel; (C), L.S. Whiplash Flagellum; (D), L.S. Tinsel Flagellum; (E), C.S. Eukaryotic Flagellum.

a) Kinds of flagella

They are of two main types, whiplash (A) and tinsel (B). The whiplash flagellum has a smooth surface. The tinsel flagellum bears longitudinal rows of fine, minute flimmer hairs arranged along the axis almost to the tip of the flagellum. There may be a single row of hairs as in the Euglenophyta and Pyrrophyta or two as in Chrysophyceae and Phaeophyceae. The hairs arise from the margins of the peripheral fibrils. The whiplash or smooth flagella are also known by other names such as acronematic or peitchgeisel. The other names for the tinsel flagella are pantonematic**,** flimmer or flimmergeisel. The use of electron microscope has revealed a third kind of flagellum in which the surface of the flagellum is covered by scales (*Chara*) and minute, short, stiff hairs. The hairs differ from those on the tinsel type. They can be easily detached.

b) Flagellation

The position, number and kinds of flagella on the motile cells are strikingly constant in each division of algae but differ from division to division. Thus it forms an important taxonomic feature for primary classification of algae. The blue – green and red algae lack flagella. The motile cells in green algae and stoneworts usually have two, rarely four equal flagella of whiplash type inserted at the anterior end (A and B) the only exception is the Oedogoniales in which the motile cells have a crown of flagella (C) . The yellow green algae (Xanthophyceae) have two unequal anterior flagella. One of these is of whiplash type and the other tinsel (D). The diatoms (Bacillariophyceae) are characterized by a single tinsel flagellum on the male cell at the anterior end (E). In brown algae only the reproductive cells are motile. They are furnished with two unequal flagella. One of these is of tinsel type and other whiplash (F).

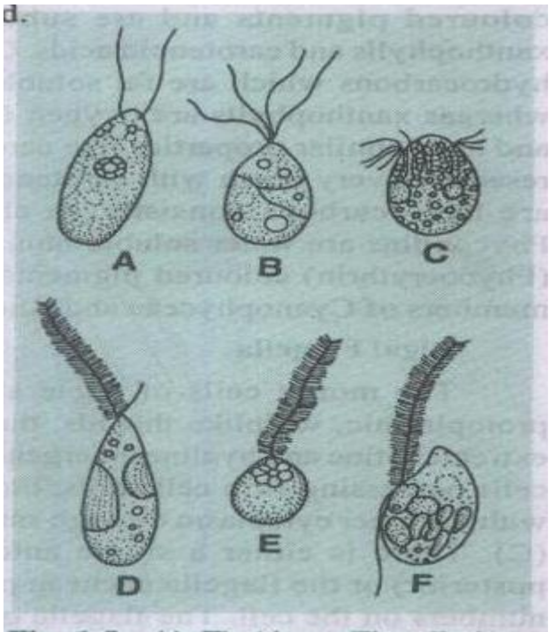


Fig. 1.5. (A-F) *Algae*. Flagellation., Chlorophyceae (A-C); Xanthophyceae (D); Bacillariophyceae (E) and Phaeophyceae (F).

Nutrition

With respect to their nutrition the algae are eutrophic. All or most of the cells of the thallus normally contain chlorophyll. The green cell can manufacture their carbohydrate food from carbon dioxide and water through the agency of sunlight. The aquatic forms obtain water and carbon dioxide by osmosis and diffusion respectively from the medium in which they grow. The aerial forms obtain water from the damp substratum and carbon dioxide from the air. The algae are also to synthesize oil and proteins from the carbohydrates which they manufacture and soluble forms of nitrogen and other minerals available in solution in the water in which they grow.

Food reserves

The food materials which accumulate as food reserves in the form of polysaccharides, however, vary from group to group and thus provide useful data for preliminary classification of algae. True starch is typical of only two algal divisions namely, Chlorophyta and Charophyta. The two other kinds of characteristic starches are the cyanophycean starch (Cyanophyta) and floridean starch (Rhodophyta). The three other important polysaccharides which accumulate as reserve food are laminarin found in the brown algae, paramylon characteristic of Euglenoids and leucosin peculiar to the Xanthophyta, Bacillariophyta and Chrysophyta. Besides, a proteinaceous compound cyanophycin is found only in the cells of blue-green algae. Mannitol which was formerly considered to be unique to the brown algae has recently been reported to occur in a few red algae. Fats occur as reserve food in the cells of Xanthophyta, Bacillariophyta and Chrysophyta.

Factors affecting algal growth

1. Light

The light of the important factors affecting the growth of algae in the waters of rivers and lakes and in rivers, but the light may be less often because of turbidity, which accompany the rivers, which lead to block the light from the sun except a thin layer of surface water.

2. Macronutrient

Nutrients, major inorganic Macronutrient such as: phosphate and Nitrate. Are the major nutrients of the key factors that determine the number and types of algae, especially nitrates and phosphates and the element is added to the silica for the diatoms.

3. Temperature

Various factions of algae for micro-, super- and optimal temperature in which to grow, for example, the optimum temperature for the growth of Diatoms ranging from 18-30 °C, while green algae thrive at temperatures ranging from 30-35 °C, and blue-green algae thrive at temperatures ranging between 35 -40°C.

4. Micronutrient

Most algae grow best when the concentration of iron in the water ranges between 0.2 to 2 mg/l, while the observed toxicity of iron when the increased focus on the 5 mg/l.

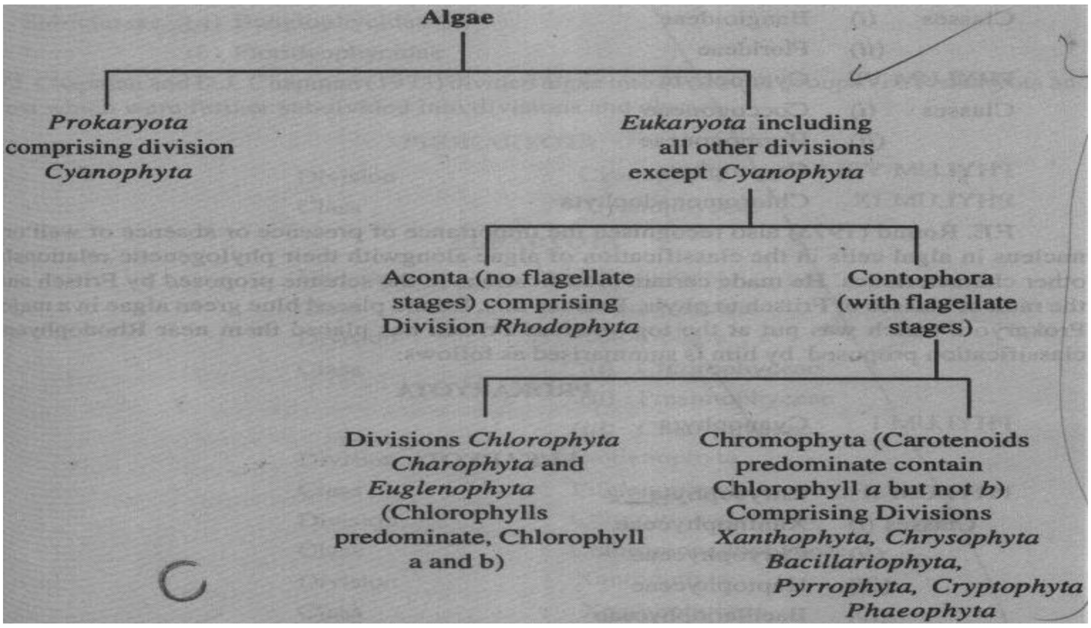
5. Biological factors: such as

a) Competition between aquatic organisms on nutrients.

b) The rate of other organisms feeding on algae.

Classification

Christensen (1964) proposed a new scheme of primary classification of algae into Procaryota and Eucaryota on the basis of difference between the Procaryotic and Eucaryotic cells. It is briefly given below:



Economic important of algae

Benefical role of algae

1. Algae as human food: From ancient times large numbers of algae have been used as human food. They are often mixed with rice and fish and consumed as salad, soups etc. *Spirulina* is a blue-green microalga with a long history as a food source in East Africa. As it is high in protein and other nutrients it is currently used as a food supplement and as a treatment for malnutrition. *Chlorella elliposidea* is used successfully with tea in Japan.

2. Algae as fodder: Seaweeds are classified as Rhodophyta (red algae), Phaeophyta (brown algae) or Chlorophyta (green algae) depending on their nutrition and chemical composition. The Chlorophyta (green algae) is an important group of marine algae, which is important both ecologically and scientifically. Seaweeds mainly the members of brown algae are used as feed for domestic animals in different parts of the world. *Sargassum, Fucus* and *Laminaria* are consumed by cattles in Scotland. The use of dried seaweeds as cattle food has enhanced ten percent milk yield. The milk does not any taste of algae after the Seaweed diet. *Rodymenia* is a common cattle-feed in France. Macrocystis is used for cattle-feed because it is rich in vitamins A and E. in Japan *pelvetia* is used as a cow- feed. Hens which feed on *Ascophyllum* –meal and *Fucus*- meal produce eggs with increased iodine content.

3. Algal role in fisheries: Various algae have utilized in fish culture. The members of planktonic and periphytic algae serve as primary food for fishes and other aquatic animals. Species of *oedogonium, Microspora, Ulothrix, Spirogyra, Cladophora,* diatoms, etc. sever as fish food in freshwater systems. It has been estimated that about a hundred Kg of algae produce approximately one Kg of fish. As oxygen is vital for the fish life and the higher concentration of Carbone dioxide is lethal, the role of photosynthetic algae is very important in aquaculture, the removal of carbon dioxide and the release of oxygen during photosynthetic process. A fish named *Tilapia* uses only the members of Cyanophycea and Chlorophyceae as its food. Many fishes depend on their food only on diatoms.

4. Algae as nitrogen fixation: conversion of atmospheric nitrogen into nitrogenous compound i.e., nitrogen fixation is one important attribute of blue-green algae. A large number of members belonging to order Chroococcales and Nostocales have been found to perform this function.

5. Algae in soil fertility and land reclamation: The species of *Nostoc*, *Scytonema*, *Lyngbya, Anabaena,* and *cylindrospermum* grow extensively on moist soil surfaces. Many of these are fix atmospheric nitrogen and increase the soil fertility due to their mucilaginous sheath they are able to prevent soil erosion by binding the soil particles firmly. They also reduce the evaporation of water because of thick covering on the soil. Due to the presence of these algae, water holding capacity is increased by 40 % and pH is reduced from 9.7 to 7.6.

6. Algae as fertilizer: These algae increase the water holding capacity besides the addition of their chemical constituent in the soil. Seaweeds, particularly brown algae improve the fertility of soil in cultured fields as their algin content helps in conditioning the soil, facilitating aeration, moisture retention and adsorption of nutrient elements. Seaweed liquid fertilizers will be useful for achieving higher agricultural production, because the extract contains growth promoting hormones (IAA and IBA), gibberellins, cytokinins, trace elements and vitamins and increased resistance to diseases upon treatment in various crops have been reported, among them, Fucus spp., Padina spp., Laminaria spp., Sargassum spp., and Turbinaria spp. are used as biofertilizers in agriculture**.**. They are either mixed with some other organic materials or are allowed to rot in the field as such.
Fucus is used as common manure by Irish people. Genera like *Lithophyllum*, *Lithothamnion* and *Chara* are used in the deficiency of calcium in the field.

A 30% increase in the total production of rice grains was reported by algologists at Central Rice Research Institute, Cuttack, when the rice fields were inoculated by some nitrogen –fixing blue- green algae.

7. Algae as oxygen donors and link of food Chain: Algae oxygenate the environment by photosynthesis. They are primary link of many diverse food chains. Aquatic animals depend ultimately for food on algae.

8. Algae in sewage treatment: In sewage oxidation tanks, presences of algae oxygenate the sewage to a great extent. The released oxygen is utilized by bacteria in rapid decomposition of the sewage. Algae used in sewage ponds mainly belong to Chlorococcales, Volvocales (Chlorophyceae) and Euglenophyceae. The common members are *Chlorella, Scenedesmus, Pediastrum Euglena; Phacus* etc. algae of sewage disposal ponds utilize nutrients to breakdown sewage.

9. Algae as research material: *Chlorella* culturing tanks are used in space vehicles because the alga restores the oxygen by it photosynthesis. Algae like *Chlamydomonas, Chlorella* etc. are very much useful in physiological, cytological and genetical studies. Species of *Nitella* are used in the studies of cytoplasmic movement, ion accumulation etc. *Valonia* and *Halicystis* help in understanding the phenomenon of permeability.

10. Algae and medicinal use: Brown algae are used in various goiter medicines due to their high iodine content. *Sargassum* which is used against goiter and other glandular troubles. Insect diseases to humans are treated with extract from *Corallina, Digenia, Codium, Alsidium* and *Durvillea*. Fucoidin and compounds of laminarin are used as anticoagulant while carrageenin acts as blood coagulant. Algae are used in the treatment of kidney, bladder and lung disease in China and Japana. *Gelidium* is used in stomach disorders and in heat induced illness.

Antibiotic chlorellin is extracted from *Chlorella vulgaris* which inhibits the growth of certain bacteria and a few algae. The growth of Escherichia coli (E. coli) is found to be reduced by *Nitzschia palea* (diatom). Microcystis reveals inhibitory action to *Staphylococcus, Closteridium* and zooplanktons like *Cyclops* and *Daphnia*.

11. Algae as source of growth promoting substances: Algae have been to increase the yield even when the soils are well manured. Seed treatments with *Phormidium* results in profuse tillering, increased height and multiple rice yields. There is also an increase in protein contents of grains of treated plants. *Phormidium* is not a nitrogen-fixing alga.

12. Algae in uptake of heavy metals and radioactive wastes: There are important role of algae in absorbing radioactive wastes and heavy metals. Species of *Chlorella, Euglena, Spirogyra, Cladophora, Scenedesmus* and *porphyra* have been found to absorb the radioactive elements and heavy metals.

13. Lens paper: For cleaning optical articles, lens paper is produced from *Spirogyra*.

14. Algae in the origin of petroleum and gas: The plankton of the seas is probably of great importance as a source of organic matter. Organic compounds produced from photosynthesis get accumulated in bottom deposits and in an oxygen-free environment gradually converted into oil and gas. Natural gas (largely methane) can be produced by certain kinds of anaerobic bacteria and oil formation is also associated with this.

15. Algae and limestone formation: Some members of green algae, blue green, red algae and flagellates deposit calcium carbonate on their cell wall or gelatinous sheath both in fresh and salt water. Algae also play an important role in formation of beds of limestone rocks.

16. Algae as indicator to the source of water : Can identify the source of the water potential of a sample of surface water, by selecting the numbers and types of algae and associated in this sample, this is possible because the numbers and types of micro-organisms that may be established linked to the quality of water sources where they live. For example, green algae are more prevalent in the open lakes of fresh water while hosting the blue-green algae in lakes closed.

17. The role of Algae in industries: Many commercial products are extracted from algae and their cell walls. Here only brief accounts of these are given.

a) Alginates (Alginic acid): derived from cellulose free middle lamella and primary wall of the members of phaeophyceae like *Macrocystic, Laminaria, Ascophyllum* ,*Lessonia* etc. Alginic acid content varies with the location, seasones, temperature and parts of the plants. Its content approximately 30-40% in brown algae on dry weight. It is similar to cellulose and pectic acids in composition consisting of a long unbranched chain of β-d-mannuronic acid joined by 1:4 glycosidic linkages. The soluble calcium salt of alganic acid is algin.

As algin has remarkable water absorbing capacity it is used in many industries where there is the requirement of thickening, suspending, emulsifying, gel-forming, and stabilizing. Sodium salt of algainic acid is used in textile industry as they form excellent polishing and dressing material. Alginates are used also in food industry for filing creams, thickening soup, sauces, in cosmetics industry as dispensing agents in ointments, creams tooth pastes, shampoos, in paint industry for suspension of pigments, stabilization of emulsion; in pharmaceutical industry as emulsifyers and as filters in the manufacture of tablets, pills. Aginats are also used as gel in the freezing of fish, antibiotics and in the treatment of shocks.

b) Agar (Agar-agar): This is dried gel-like non-nitrogenous, gelatinous extract obtained from many red algae. This is one the best known algal products and used as a solidifying agent in the preparation of microbiological culture media. Dried agar is insoluble in cold water but soluble in hot water. The important algae used for the extraction of agar are *Gelidium, Gracilaria, Pterocladia, Gigartina, Chondrus*. Gelling property varies with the species but it will set at from 35to 52 ^{0}c. The major component of agar is agarose. Uroinc acid, pyruvic acid, polysaccharides like agarose and agaropectin are also present in agar-agar.

Besides most important use of agar in the preparation of culture media. It has also been used in food industry, cosmetics, leather, textile industry, pharmaceuticals, dental impression mold and meat packing, for clotting of blood and as emulsifyers, laxatives.

c) Carrageenan (Carrageenin): it is carbohydrate mucilage named after Irish village Carrageenin which is extracted from red alga *Chondrus crispus* and to a lesser extent from *Gigartina*. The compound is a cell wall polysaccharide complex of D-galactose-3, 6-anhydro-D-galactose and monoesterified sulphuric acid. These compounds are used like alginates in food, textile, leather, and industry, pharmaceutical and brewing industries. This gelatinous carbohydrate is variously used with pudding, consumed with milk, fruit and ice-cream. It is used as clearing agent in beer preparation.

d) Iodine and other compounds: Members of brown algae such as *Laminaria digitata* and *Fucus* spp.are known for the extraction of iodine. The maximum percentage of iodine (1.23%) has been obtained in Laminarias of Britsh Coasts. Seaweed are also known for the presence of macronutrients useful for human consumption like iron, manganese, zinc, copper etc. bromine , formic acid , acetone, acetic acid are also extracted from seaweeds. Seaweed ash is also used as source of salt and soda.

Harmful roles of algae

Besides many uses, algae are also known to create problems for human beings.

1. **Death of aquatic animals and fishes:** Many of blue green algae produce toxins which cause death to domestic animals and fishes. Important among these algae are *Microcystis, Anabeana* and *Aphanizomenon*. Besides death many harmful effects like loss of weight, weakness, abortion etc. have been reported in cattles. Phycocyanin pigment found in blue- greens is sensitive to light and when they enter in the blood capillaries of cattle cause an internal and peeling of the skin.

2. **Disease and death to human beings:** The direct consumption of dinoflagellates through fishes has resulted in human death. Dinoflagellates like *Gonyaulax*, when consumed with shell fish, produce several diseases. Reports about the occurrence of paralysis, respiratory failure and death within 2 to 12 hours after consumption of dinoflagellates are available.

3. **Algae and water supply:** algae interfere and create problems in water supply and storage reservoirs in many ways like in a) profuse growth and interference with filtration process, b) production of bad odour by their decomposition, c) imparting objectionable tastes, d) formation of slimes in water, colouration to the water, f) corrosion of pipes, g) interference in disinfection process by imparting turbidity, h) formation of sediments in service reservoirs.

The increase in the rate of excessive growth of algae to changes in physical properties, chemical and biological agents in water bodies. Where that rise to the phenomenon of the eutrophication is characterized by a high concentration of phosphates and nitrates, which lead to a significant increase in the rate of growth of some species of algae over some of the other races and species usually prevail in the unwanted presence of water bodies because of their detrimental effect on the rest of the organisms that coexist with them and the quality of the water.

The water quality is divided into a water body according to the abundance of nutrients, depending on the rate of growth of algae as follows:

a) Oligotrophic Water

It is characterized by the water that the concentration of major nutrients is rare, so do not lead to an increase in the numbers and types of algae. Featuring the region that the water is pure and transparent and the bottom of the river is relatively free from sediment, and inorganic materials such as calcium, magnesium, iron, sulfur, and dissolved half carbonate are found in small quantities.

b) Mesotrophic Water

Water containing medium concentrations of major nutrient which allows an increase of algae growth rate slightly

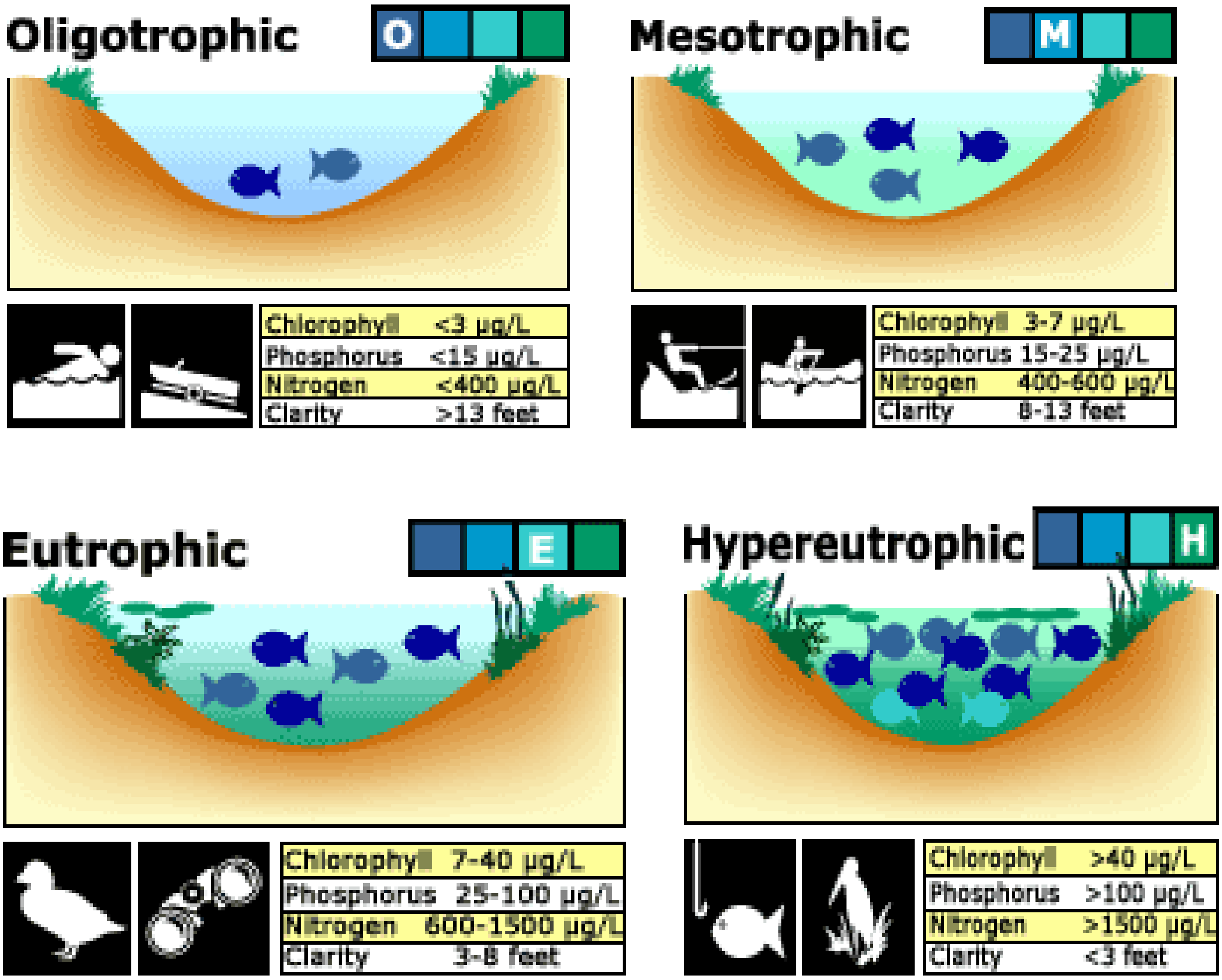
c) Eutrophic Water

A water with a high concentration of major nutrients leading to increased algae growth rate substantially, which in turn leads to a phenomenon of the Euotrophication, which is usually accompanied by a phenomenon of algal bloom and which is characterized by a predominance of certain species of harmful algae, especially those excreted phycotoxins or algal toxins that produce certain chemicals that occur a change in the taste and smell of water.

d) Hypereutrophic Water

It is water that is characterized by high abundance of nutrients in the major, which in turn leads to a dramatic growth and the significant increase in the numbers and types of algae

Algae causing these problems belong to cyanophyceae (*Oscillatoria, Microcystis, Scytonema, Cylindrospermum, Chroococcus* and *Anabaena*), Chlorophyceae (*Ankistrodesmus, Chlorella, Pediastrum*), Euglenophyceae (*Euglena and Phacus*).



4. Damage to building: During rainy season, on moist wall surface many blue-green algae grow. Gradually these spoil the walls of the buildings. *Scytonema, Tolypothrix* and *Chlorococcum* are some common algae causing such damage in tropical countries.

5. Accidents due to blue-green algae: Due to intensive growth of blue-greens, ground surface becomes slippery by which cattles and human beings get slipped.

6. Parasitic algae: Many algal forms are true parasites which cause severe damage to economically important parts of the plants.

Algal bloom

An algal bloom (water bloom) occurs when the numbers of algal cells increase rapidly to reach concentrations usually high enough to be visible to the naked eye. Algal bloom concentrations may reach millions of cells per milliliter. Many types of algae form blooms. Algal blooms are often green, but they can also be yellow-brown or red, depending on the species of algae. Not all algal blooms are toxic. Some, such as the blooms of diatoms in the early spring, are very important to the health of the ecosystem.

Bright green blooms are a result of blue-green algae, which are actually bacteria (cyanobacteria). Blooms may also consist of macroalgal, not phytoplankton, species. These blooms are recognizable by large blades of algae that may wash up onto the shoreline. "Black water" is a dark discoloration of sea water, first described in the Florida Bay in January 2002.

Algae causing water blooms

*Microcystis aeruginosa, M.viridis, M.flos-aquae, Anabaena circinalis, A.microspora, A.spiroides, Lyngbya limnetica, Oscillatoria planktonica, Spirulina gomontiana, Nostoc linckia, Noduaria spumigena (*cyanophyta*), Chlamydomonas, Pandorina, Volvox, Scenedesmus, Botryococcus, Cosmarium, Zygnema, Mougeotia, Odogonium (*Chlorophyta*) and Tabellaria* are the common bloom-forming algae.

Factors of bloom formation

There is no single factor which causes an algal bloom. A large number of factors have been found to be associated with the formation of water blooms such as water temperature, water movements, light and inorganic nutrients (mainly phosphorus and nitrogen). When phosphates are introduced into water systems, higher concentrations cause increased growth of algae and plants. Algae tend to grow very quickly under high nutrient availability, but each alga is short-lived, and the result is a high concentration of dead organic matter which starts to decay. The decay process consumes dissolved oxygen in the water, resulting in hypoxic conditions. Without sufficient dissolved oxygen in the water, animals and plants may die off in large numbers. Excess carbon and nitrogen have also been suspected as causes, although a study suggested that this is not the case. Major elements and heavy metals like zinc play an important role in the bloom formation. Blooms of dinoflagellates are related to cobalamine begin washed out in the sea from the soils which posses sufficient amount of this vitamin. As the planktonic blue-green algae have floating device (gas vacuoles), blooms of the members of this class are mostly of permanent nature. Within a few days, a bloom can cause clear water to become cloudy. The blooms usually float to the surface and can be many inches thick, especially near the shoreline. Cyanobacterial blooms can form in warm, slow-moving waters that are rich in nutrients such as fertilizer runoff or septic tank overflows. Blooms can occur at any time, but most often occur in late summer. They can occur in marine and fresh waters, but the blooms of greatest concern are the ones that occur in fresh water, such as drinking water reservoirs or recreational waters.

Measurement

Algal blooms are monitored using biomass measurements coupled with the examination of species present. A widely-used measure of algal and cyanobacterial biomass is the chlorophyll concentration. Peak values of chlorophyll a for an oligotrophic lake are about 1-10 µg/l, while in a eutrophic lake they can reach 300 µg/l. In cases of hypereutrophy, such as Hartbeespoort Dam in South Africa, maxima of chlorophyll a can be as high as 3,000 µg/l.

Harmful effects

HAB stands for harmful algal bloom. There are many species of single-celled organisms living in the oceans, including algae and dinoflagellates. When certain conditions are present, such as high nutrient or light levels, these organisms can reproduce rapidly. This dense population of algae is called a bloom. Some of these blooms are harmless, but when the blooming organisms contain toxins, other noxious chemicals, or pathogens it is known as a harmful algal bloom (HAB). Of particular note are harmful algal blooms (HABs), which are marine algal bloom events involving toxic phytoplankton such as dinoflagellates of genus Alexandrium and Karenia. Such blooms often take on a red or brown hue and are known colloquially as red tides.

Examples of common harmful effects of HABs include:

1. The production of neurotoxins which cause mass mortalities in fish, seabirds and marine mammals .
2. Human illness or death via consumption of seafood contaminated by toxic algae.
3. Mechanical damage to other organisms, such as disruption of epithelial gill tissues in fish, resulting in asphyxiation.
4. Oxygen depletion of the water column (hypoxia or anoxia) from cellular respiration and bacterial degradation.

Mechanism of algal bloom causing fish mortalities

These algae like *Microcystis* and *Anabaena* usually have gas vacuoles which expand in warm water and rise to the surface. The dense plankton in surface layers absorbs and reflects the sunlight causing an inadequate penetration of light for photosynthesis. Due to fall in light intensity, oxygen concentration decrease to 1ppm at depth. After few weeks when there is no oxygen or insufficient oxygen in the greater depth, fish moves into the upper water where oxygen is sufficient. But when the oxygen deficient water up wells to the surface, fish of all types are trapped and killed.

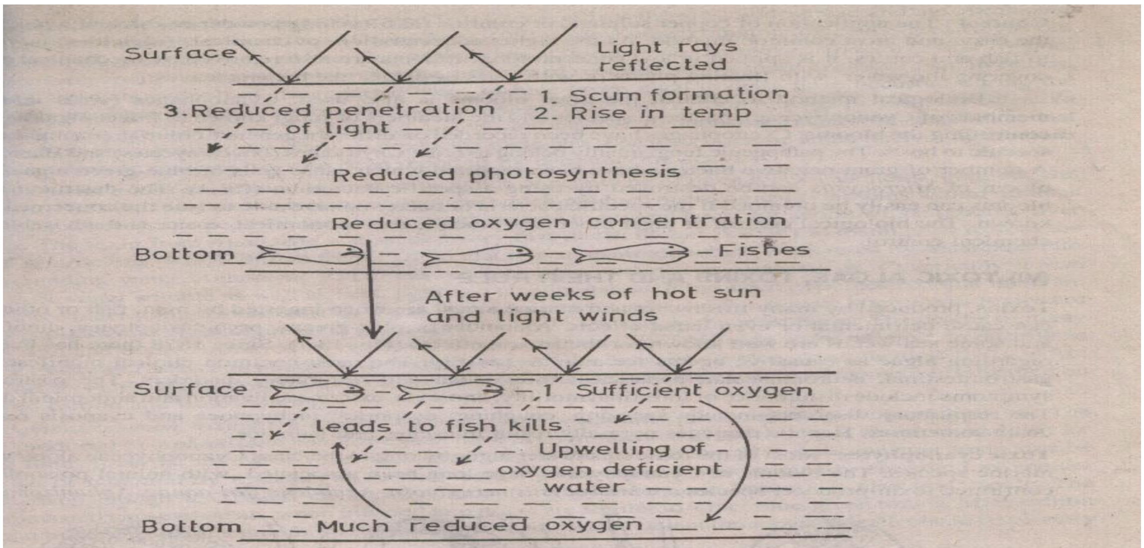


Fig.13.6. Mechanism of fish kill by algal bloom. (After Swingle, 1966).

If the HAB event results in a high enough concentration of algae the water may become discoloured or murky, varying in colour from purple to almost pink, normally being red or green. Not all algal blooms are dense enough to cause water discolouration.

Red tides

"Red tide" is a term often used to describe HABs in marine coastal areas, as the dinoflagellate species involved in HABs are often red or brown, and tint the sea water to a reddish colour. The more correct and preferred term in use is harmful algal bloom, because:

1. these blooms are not associated with tides
2. not all algal blooms cause reddish discoloration of water
3. not all algal blooms are harmful, even those involving red discoloration

Control of blooms

1. The chemical method: the application of copper sulphate or chlorine (as bleaching powder or calcium hypochlorite) is the easy and most common method. As the higher concentration of chemicals (algicides) may be lethal to fish and cattles, it is applied in low concentration.

2. Mechanical methods: by covering the water with floating plants or with parts of plants like banana leaves.

3. Biological methods: by used Cyanophages (virus infecting the members of Cyanophyceae), bacterial species and the members of fungi known to infect algae are used for controlling the blooms. The pathogenic fungi (Phycomycetes) and a number of gram negative bacteria have been reported which cause lysis of blue-green algae. The algal blooms of *Microcystis* can be destroyed by using a specific bacterium (CP-1). The biological control of algal blooms is much more economical, easier and advisable than the chemical control.

Water treatment

Algal blooms sometimes occur in drinking water supplies. In such cases, toxins from the bloom can survive standard water purifying treatments. Researchers at Florida International University in Miami are experimenting with using 640-

kilohertz ultrasound waves that create micropressure zones as hot as 3,700 °C. This breaks some water molecules into reactive fragments that can kill algae.

Toxic Algae

Death and sickness to pets, livestock, wildlife and even man have been attributed to the presence of certain algae, mostly blue-green forming species, in water supplies. Lethal substances produced by these algae are retained within the cells and released after death or are secreted from living cells. Many unattended farm ponds and other waters contain some of these toxic forms, posing a threat to human health and the environment. Medical case histories, biologist reports and laboratory tests show some of the Possible effects of toxic algae.

Humans: Exposure to and ingestion of algae caused a variety of "discomforts" including: skin rashes, headaches, nausea, vomiting, diarrhea, fever, muscular pains and eye, nose and throat irritation.

Livestock: There have been reports of rapid deaths of a great variety of animals after drinking water containing high concentrations of blue-green algae such as *Microcystis*, *Aphanizomenon*, *Nostoc*, *Rivularia, Nodularia*, and *Anabaena*. Fatal poisonings have occurred among cattle, pigs, sheep, dogs, horses, turkeys, ducks, geese and chickens. It is believed that such algae may be toxic to all warm-blooded animals.

Cyanotoxins

Cyanotoxins: Cyanotoxins are toxins produced by cyanobacteria.

Cyanobacterial Toxins and Symptoms:

Some cyanobacteria produce toxins that can affect animals and humans. These toxins have the potential to affect the liver, the nervous system, or exposed skin. In order to be affected, people, pets or wildlife have to be exposed to the toxin by drinking or playing in water with a toxic bloom.

Risks to humans and animals:

The toxins can damage the liver and neurological system of both humans and animals and in severe cases can cause death. Can cause gastrointestinal, skin, eye and respiratory irritations to humans and animals.

Chemical structure:

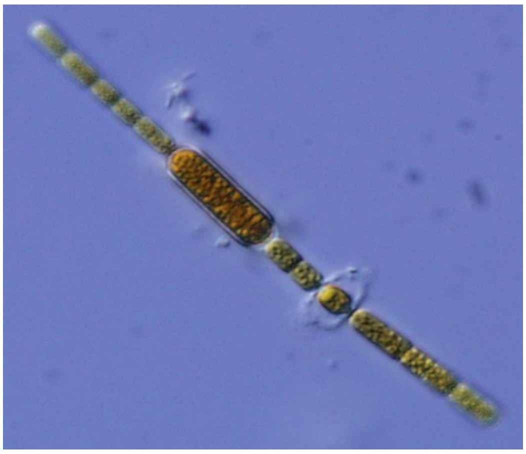
The chemical structure of cyanotoxins falls into three broad groups:

1. **Cyclic peptides**
2. **Alkaloids**
3. **Lipopolysaccharides**

Chemical structure of cyanotoxins			
Structure	**Cyanotoxin**	**Primary target organ in mammals**	**Cyanobacteria genera**
Cyclic peptides	**Microcystins**	**(Hepatotoxins)** **Liver**	***Microcystis, Anabaena, Oscillatoria (Planktothrix), Nostoc, Hapalosiphon, Anabaenopsis***
	Nodularins	**Liver**	***Nodularia***
Alkaloids	**Anatoxin-a**	**(Neurotoxins)** **Nerve synapse**	***Anabaena,*** ***Oscillatoria (Planktothrix), Aphanizomenon***
	Anatoxin-a(S)	**Nerve synapse**	***Anabaena***
	Saxitoxins	**Nerve axons**	***Anabaena, Aphanizomenon, Lyngbya, Cylindrospermopsis***

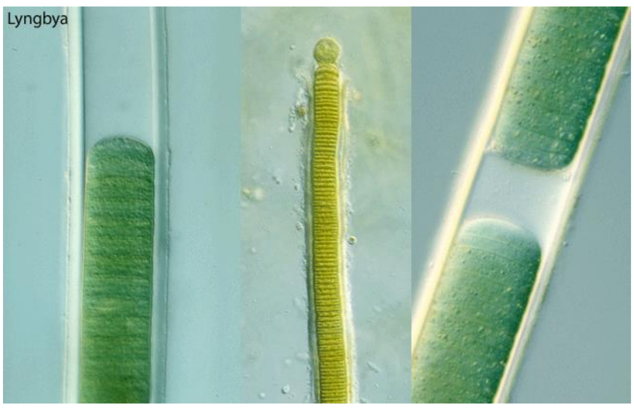
	Aplysiatoxins	**Skin**	***Lyngbya, Schizothrix, Oscillatoria (Planktothrix)***
	Cylindrospermopsins	**Liver**	***Cylindrospermopsis, Aphanizomenon, Umezakia***
	Lyngbyatoxin-a	**Skin, gastro-intestinal tract**	***Lyngbya***
Lipopolysaccharides		**Potential irritant; affects any exposed tissue**	**All**

***Anabaena* spp.**

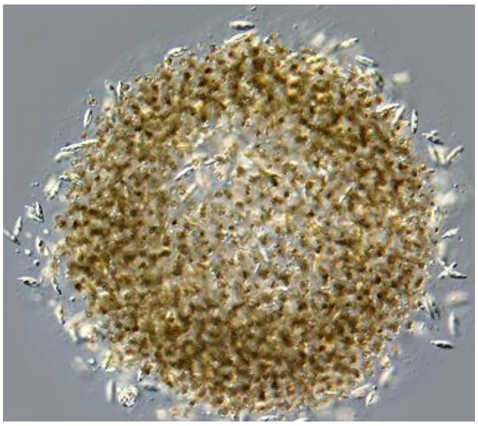


***Aphanizomenon* spp.**

Cylindrospermopsis



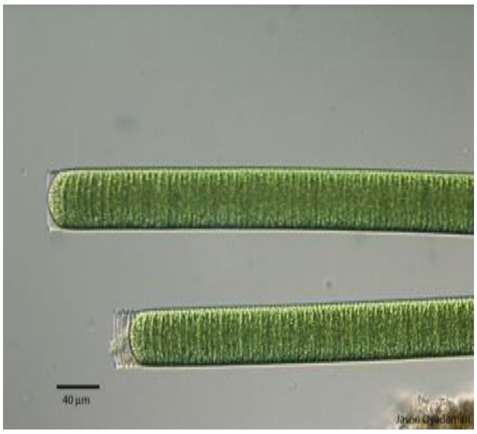
***Lyngbya* spp.**



***Microcystis* spp.**

Nodularia

Nostoc



Oscillatoria/Planktothrix

1. **Cyclic peptides**: A peptide is a short polymer of amino acids linked by peptide bonds. They have the same chemical structure as proteins, except they are shorter. In a cyclic peptide the links link back to the start to form a stable circular chain. In mammals this stability makes them resistant to the process of digestion and they can bioaccumulate in the liver. Of all the cyanotoxins, the cyclic peptides are of most concern to human health. The microcystins and nodularins poison the liver, and exposure to high doses can cause death.

A) **Microcystins**: Microcystins were named after the first organism discovered to produce them, *Microcystis aeruginosa*. Blooms containing microcystin are a problem worldwide in freshwater ecosystems. Microcystins are cyclic peptides and can be very toxic for plants, animals and humans. They bioaccumulate in the liver of fish, in the hepatopancreas of molluscs, and in zooplankton. They are hepatotoxic and can cause serious damage to the liver in humans.

Microcystin toxicosis may include:

- jaundice
- abdominal pain/distention
- weakness
- nausea
- vomiting
- severe thirst
- rapid/weak pulse
- death.

B) **Nodularins**: The first nodularin variant to be identified was nodularin-R, produced by the cyanobacterium *Nodularia spumigena*. Most common toxins present in cyanobacterial blooms in fresh and brackish waters are the cyclic peptide toxins of the nodularin family. Nodularins are potent hepatotoxins and can cause serious damage to the liver. They present health risks for wild and domestic animals as well as humans.

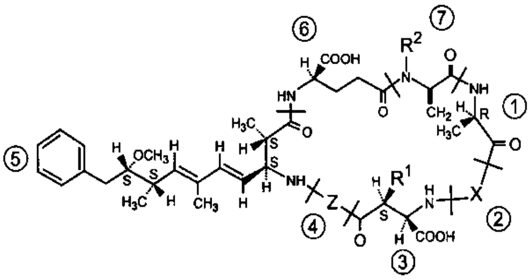
2. **Alkaloids:** Alkaloids are a group of naturally occurring chemical compounds which mostly contain basic nitrogen atoms. They are produced by a large variety of organisms, including cyanobacteria. Alkaloids act on diverse metabolic systems in humans and other animals, often with toxic effects. Almost uniformly, they are bitter tasting.

A) **Anatoxin-*a*:** also known as "Very Fast Death Factor" When it was first discovered, the toxin was called the Very Fast Death Factor (VFDF) because when it was injected into the body cavity of mice it induced tremors, paralysis and death within a few minutes.
Toxic effects from anatoxin-a progress very rapidly because it acts directly on the nerve cells (neurons) as a neurotoxin. The progressive symptoms of anatoxin-a exposure are loss of coordination, twitching, convulsions and rapid death by respiratory paralysis.

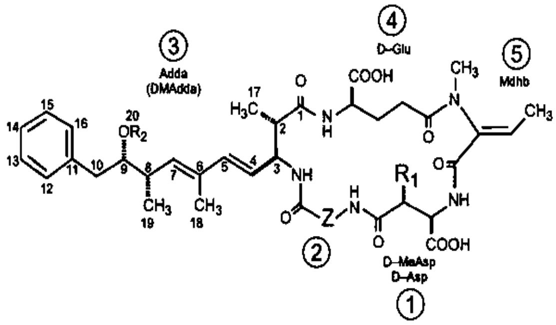
B) **Cylindrospermopsins:** (abbreviated to CYN or CYL).
Cylindrospermopsin was isolated from the cyanobacterium *Cylindrospermopsis raciborskii.* Cylindrospermopsin is toxic to liver, kidney, heart and other organs and is thought to inhibit protein synthesis and to covalently modify DNA and/or RNA. Symptoms of liver toxicosis include nausea, vomiting, and acute liver failure.

C) **Saxitoxins:** Saxitoxin (STX) is one of the most potent natural neurotoxins known. The term saxitoxin originates from the species name Saxidomus giganteus, whereby it was first recognized. Saxitoxin is produced by the cyanobacteria *Anabaena* sp., some *Aphanizomenon* sp., *Cylindrospermopsis* sp., *Lyngbya* sp. and *Planktothrix* sp. Saxitoxins bioaccumulate in shellfish and certain finfish. Ingestion of saxitoxin, usually through shellfish contaminated by toxic algal blooms, can result in paralytic shellfish poisoning. Death often occurs from respiratory failure.

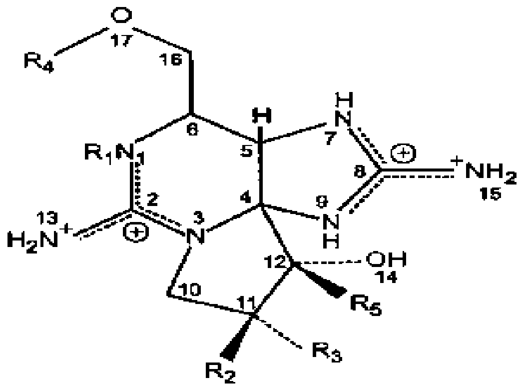
3. **Lipopolysaccharides**: Lipopolysaccharides are present in all cyanobacteria. Lipopolysachharides are less toxic than hepatotoxins or neurotoxins but are significant in terms of water supply for drinking, showering and recreation. Lipopolysacharides have been associated with outbreaks of gastroenteritis, skin and eye irritations and fever, in humans that have come into contact with algal blooms. Humans that contact Lipopolysachharides in the aerosol form (fine spray) may suffer asthma, eczema, and blisters in the lining of the nose and mouth.



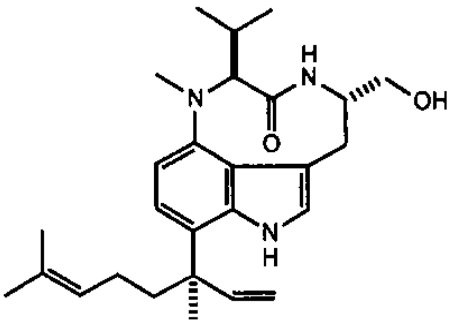
Microcystin



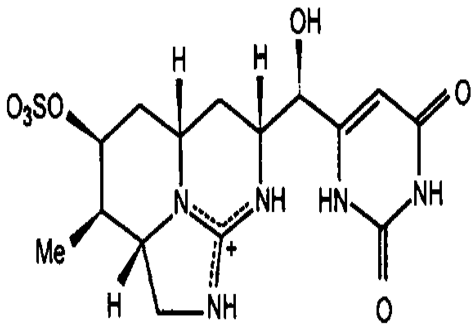
Nodularin

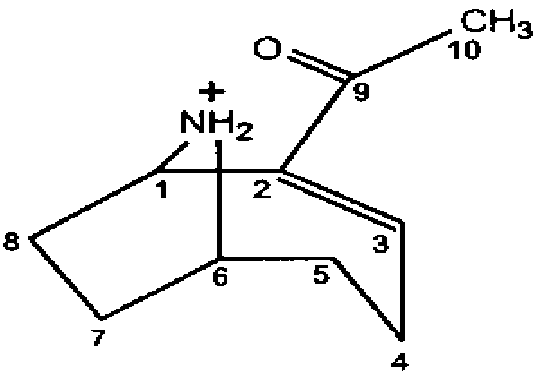


Saxitoxin



Lyngbiatoxin*-a*





Cylindrospermopsins **Anatoxins**

Chemical structure of cyanotoxins

Marine algal blooms: Ocean warming has combined with nutrient enrichment to create larger, more frequent algal blooms around the world. Other environmental stresses that encourage blooms include over-harvesting of fish that feed on plankton. Marine algal blooms affect Commercial and recreational shellfish and fish harvesting, recreational swimming and diving, fish and wildlife food chain.

Toxic effects on humans:

Common human health problems caused by harmful marine algae consist of the following syndromes:

- ➢ Amnesic Shellfish Poisoning (ASP)
- ➢ Diarrhetic Shellfish Poisoning (DSP)
- ➢ Neurotoxic Shellfish Poisoning (NSP)
- ➢ Paralytic Shellfish Poisoning (PSP)
- ➢ Ciguatera Fish Poisoning (CFP)
- ✓ Each of these syndromes are caused by different species of toxic algae

Amnesic Shellfish Poisoning (ASP):

Causative organisms: *Pseudo-nitzschia*

Toxin produced: Domoic Acid

ASP is characterized by gastrointestinal and neurological disorders including short-term memory loss (Amnesia).

Gastrointestinal symptoms: Gastroenteritis usually develops within 24 hours of the consumption of toxic shellfish and symptoms include: nausea, vomiting, abdominal cramps, diarrhea.

Neurological symptoms: Neurological symptoms appear usually within 48 hours of toxic shellfish consumption. These symptoms include: dizziness, headache, seizures, disorientation, short-term memory loss, respiratory difficulty, in severe cases coma may occur followed by death.

Diarrhetic Shellfish Poisoning (DSP):

Causative organisms: *Dinophysis sp., Prorocentrum sp.*

Toxin produced: Okadaic Acid

Symptoms: DSP is characterized by gastrointestinal symptoms (nausea, diarrhea, vomiting, abdominal pain). The patients usually recover within a few days (2-3 days). Chronic exposure to DSP is suspected to promote tumor formation in the digestive system.

Neurotoxic Shellfish Poisoning (NSP):

Causative organism: *Gymnodinium breve*

Toxins produced: Brevetoxins

It is characterized by gastrointestinal and neurological disturbances usually with recovery within few days.

Symptoms:

Typical symptoms include:

Numbness, tingling, dizziness, fever, chills, muscle pains, nausea, diarrhea, vomiting, headache, reduced heart rate and pupil dilation, but is never fatal. In addition, formation of toxic aerosols by wave action can produce respiratory asthma-like symptoms.

Paralytic Shellfish Poisoning (PSP):

Causative organisms: *Alexandrium sp., Gymnodinium sp., Pyrodinium sp.*

Toxins produced: Saxitoxins

Symptoms: Symptoms include tingling and numbness of the mouth, tongue and extremities, nausea and vomiting. In severe cases the patient will exhibit more severe neurological symptoms such as ataxia, weakness, dizziness, followed by complete paralysis. The most severe cases result in respiratory arrest within 24 hours of consumption of the toxic shellfish. Death occurs due to respiratory paralysis.

Ciguatera Fish Poisoning (CFP):

Causative organisms: *Gambierdiscus toxicus* (benthic dinoflagellates).

Toxins produced: Ciguatoxin

Symptoms: Ciguatera produces gastrointestinal, neurological and cardiovascular disturbances, and recovery often takes months or even years.

Gastrointestinal symptoms include: Typical symptoms are diarrhea, abdominal pain, nausea, vomiting and followed by lots of neurological signs.

Neurological symptoms include: reversal of temperature sensation (cold objects feel hot), numbness and tingling of hands and feet, dizziness, anxiety, chills, sweating, balance difficulties, rashes.

Cardiovascular symptoms: low heart rate and blood pressure, it can very rarely cause death in humans. Extreme cases can cause death from respiratory failure.