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GENERAL CHARACTERISTICS AND CLASSIFICATION OF ALGAE AND PROTOZOA

Volume 1- GENERAL CHARACTERS OF ALGAE

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Introduction to Algae:

The term algae (Latin — seaweeds) was first introduced by Linnaeus in 1753.

It is an important group of Thallophyta (Gr. Thallos — a sprout; phyton — a plant), the primitive and simplest division of the plant kingdom.

The algae are chlorophyll-containing primitive plants, both prokaryotic and eukaryotic, starting from unicellular to multicellular organizations.

Characteristics of Algae:

1. Algae are chlorophyll-bearing autotrophic thalloid plant body.

2. Almost all the algae are aquatic.

3. The plant body may be unicellular to large multicellular structure.

4. The multicellular complex thalli lack vascular tissue and also show little differentiation of tissues.

5. The sex organs are generally unicellular but, when multicellular, all cells are fertile and in most cases the entire structure does not have any protection jacket.

6. The zygote undergoes further development either by mitosis or meiosis, but not through embryo formation.

7. Plants having distinct alternation of generations. Both gametophyte and sporophyte generations — when present in the life cycle are independent.

ALGAE - CELL STRUCTURE

Mostly Prokaryotic (Cyanopheceae, Myxophyceae and Blue Green Algae) and Eukaryotic (In Remaining Algal Groups) cell structures can be observed in Algal members Mesokaryotic cell structure (Nucleus is present, but chromosomes are without basic histone proteins) is present in Dinophyceae.

Cell Wall: The cell wall is made up of two layers. Outer amorphous pectic substances and the inner fibrillar cellulose layer. But cell wall composition is different in different Algal members.
Xanthophyceae – Solely Pectic Substances
Phaeophyceae – Hemi Cellulose, Alginic Acid , Fucoisan
Diatoms – Silica and Pectin
BGA – Mucopolymers.
Flegella : Motile vegetative or reproductive cells are found in all groups of algae except Rhodophyceae and Cyanophyceae . Their motility is due to Protoplasmic appendages called flagella .
Flagella are of following types :
(i) Whiplash or Acronematic flagella : Smooth surface and abruptly terminates in a fibril.
(ii) Tinsel or Pleuronematic flagella: Flagella covered with fine filamentous appendages called Mastigonemes or Flimmers .
They are further divided into three categories on the basis of arrangement of Mastigonemes:
(a) Pantonematic: Mastigonemes are arranged on either side of the flagellum .
(b) Stichonematic: Mastigonemes develop only on one side of flagellum .
(c) Pantacronematic: Pantonematic flagellum is with a terminal fibril

Plastids and Chromatophores:

Plastids with Chlorophyll a and b are called Chloroplast , while those lacking chlorophyll b are called Chromatophores .

The chloroplast may be cup-shaped (***Ulothrix, Chlamydomonas***) or discoid (***Vaucheria , Chara***) or Reticulate (***Oedogonium***) or Spiral (***Spirogyra***) or Stellate (***Zygnema***).

Pigements : The various pigments associated with algal members are listed below

(a) Chlorophylls:

Chlorophyll – a (all groups)
Chlorophyll - b (Chlorophyceae);
Chlorophyll – c (Phaeophyceae , Cryptophyceae , Bacillariophyceae & Chrysophyceae),
Chlorophyll – d (Rhodophyceae)
Chlorophyll - e (Xanthophyceae).

(b) Cartenoids : Carotenoid include Carotenes and Xanthophylls.

Xanthophylls: More than 20 types of Xanthophylls are present.

Fucoxanthin - Phaeophyceae, Diatoms.

Pyrenoids: Proteinaceous bodies found either within or the surface of plastids. Concerned with storage of starch in green algae or to store similar food in other algae. Number may vary from one to many.

Storage Products: Chlophyceae(starch) Rhodophyceae (Floridean starch) BGA (Cyanophycean starch) Phaeophyceae (Laminarin & Mannitol) Chrysophyceae ,Diatoms (chrysolaminarian,oils) , Xanthophyceae (Lencosin).

Golgi-bodies : They may be at base or at the nucleus.

Mitochondria: Present in all algal members concerned with respiration.
Vacuoles: Osmotic functions or absorption of solutes and water.

Eye- spot or Stigma: The motile vegetative and reproductive cells of algae have a pigmented spot known as eye-spot or Stigma. It is a photo receptor organ.
Nucleus: Most of the algal members are uninucleate , but coenocytic siphonales , cladophorates , charales , heterosiphonales .

Occurrence of Algae:

The algae are ubiquitous in distribution, i.e., they are found in fresh water as well as marine water, on soil, on rock, as epiphytes or parasites on plants and animals, in hot springs, in desert, on permanent snow-fields etc. But they mainly dwell in aquatic environments.

Based on habitat the algae may be categorized as:

1. Aquatic algae.
2. Terrestrial algae, and
3. Algae of remarkable habitats.

1. Aquatic Algae:

Aquatic algae may be fresh water (when salinity is as low-as 10 ppm) or marine (when salinity is 33-40%). Again, certain algae grow in brackish water which is unpalatable for drinking, but less salty than sea water. The fresh water algae usually grow in ponds, lakes, tanks, ditches etc.

The very common fresh water algae are Chlamydomonas, Volvox, Ulothrix, Chara, Oedogonium, Spirogyra, Nostoc, Oscillatoria etc. Some of the very common marine algae are Sargassum, Laminaria, Ectocarpus, Polysiphonia, Caulerpa, Bangia, Padina etc.

Fresh water algae may be termed as planktonic when they grow and remain suspended on the upper part of water (e.g., Volvox, diatom), while the benthic algae are bottom-dwellers. The algae that grow at air-water interface are called neustonic. The benthic algae may be epilithic, that grow on stones; epipelic attached to sand or mud; epiphytic — growing on plants; and epizoic — growing on animal body surface.

The marine algae may be supralittoral or sub- aerial, as they grow above the water level and in the spray zone.

Other marine algae are sublittoral, meaning that they are constantly submerged at depths as great as 30-60 metres (100-200 ft).

Again, the supralittoral algae may be edaphic— that grow in and on the soil, epilithic— growing on stones, epiphytic — growing on plants, epizoic— growing on animal body surface, and corticolous — growing on tree barks and parasitic on plants and animals. Some algae (e.g., Chlorella) live endozoically in various protozoa, coelenterates, molasses etc.

2. Terrestrial Algae:

Some algae are found to grow in terrestrial habitats like soils,' rocks, logs etc. The algae that grow on the surface of the soil are known as saprophytes. Many blue-greens grow under the surface of the soil, and are called cryptophytes.

The algae growing in the desert soil may be typified as endedaphic (living in soil), epidaphic (living on the soil surface), hypolithic (growing on the lower surface of the stones on soil), chasmolithic (living in rock fissures) and endolithic algae (which are rock penetrating).

The common terrestrial members are Oscillatoria sancta, Vaucheria geminata, Chlorella lichina, Euglena sp., Fritschiella sp. and Phormidium sp.

Some algae occur in uncommon habitats such as-

1. **Halophytic Algae**

They grow in the highly concentrated salt lakes, and include Chlamydomonas ehrenbergli, Dunaliella and Stephanoptera sp.

2. Symbiotic Algae:

They grow in association with fungi, bryophytes, gymnosperms or angiosperms. The best examples of symbiotic algae found in association with fungi are Nostoc, Gloeocapsa, Rivularia; the members of Cyanophyceae and Chlorella, Cytococcus, Pleurococcus; the members of Chlorophyceae.

This symbiotic association consisting of algae and fungi is called lichen. Nostoc may also associate with Anthoceros and Anabaena associates with the roots of Cycas to form coralloid roots.

3. Cryophytic Algae:

This group of algae growing on ice or snow provides attractive colours to snow-covered mountains. The alpine and arctic mountains become red due to the growth of the Haemotococcous nivalis; green snow in Europe is due to the growth of Chlamydomonas yellowstonensis.

Scotiella nivalis and Raphidonema brevirostri cause black colouration of snow, whereas Ancyclonema nordenskioldii is responsible for brownish purple colouration.

4. Thermophytes or Thermal Algae:

This group of algae occurs in hot water springs (50- 70°C) where normal life is not possible. Many blue-greens (e.g., Oscillatoria brevis, Synechococcus elongates, Heterohormogonium sp.) are grown in such hot springs.

5. Lithophytes:

They grow on the moist surface of stones and rocks, e.g., Nostoc,. Gloeocapsa,, Batrachospermum etc.

6. Epiphytic Algae:

They grow on other plants including other algal members.

These are:

a. Algae on Algae:

i). Ptilota plumosa and Rhodymenia pseudopalmatta on Laminaria hyperborean, ii). Diatoms on Oedogonium, Spirogyra etc.

b. Algae on Bryophytes:

Blue-green algae like Nostoc, Oscillatoria, diatoms like Achnanthes etc. grow on different bryophytes.

c. Algae on Angiosperms:

Algae like Cocconis, Achnanthes etc. grow epiphytically on Lemna, an aquatic angiosperm. Alga like Trentepohlia grows on the barks of different angiospermic plants, and is very common in Darjeeling (India).

7. Epizoic Algae:

The algae growing on animals like fish, snail etc. are called as epizoic, e.g., Stigeoclonium are found in the gills of fishes.

8. Endozoic Algae:

They grow in the tissues of animals, e.g., Zoochlorella sp. is found in Hydra viridis.

9. Parasitic Algae:

Some algae grow parasitically on different plants and animals.

eg. Cephaleuros (Chlorophyceae) is parasitic and grows on the leaves of various angiosperms, such as tea (Camellia sinensis), coffee (Coffea arabica), Rhododendron, Magnolia and pepper (Piper nigrum). The most important one is Cephaleuros virescens, which causes Red rust of tea.

10. Psammon:

The algae which grow in sandy beaches are called psammon, e.g., Vaucheria, Phormidium etc.

Thallus Organisation in Algae:

Thalli of algae show a range of organization starting from unicellular form to highly organized multicellular habit where the plant body is differentiated into root-like, stem-like, and leaf like structures giving a higher plant-like appearance. Their size ranges from a few micron to several meters.

The algal thalli are grouped into the following, based on their organization:

A. Unicellular Algae:

Unicellular forms of algae are also called acellular algae as they function as complete living organisms. Unicellular forms are common in all the groups of algae except Rhodophyceae, Phaeophyceae and Charophyceae. The unicells may be motile or non-motile.

a. The motile unicells are either rhizopodial or flagellated.

The rhizopodial forms lack rigid cell wall and have cytoplasmic projections that help them in amoeboid movement, e.g., Chrysamoeba (Chrysophyceae,), Rhizochloris (Xantho- phyceae).

The flagellated unicells resemble the motile gametes and zoospores. The flagella function as the organ of locomotion varying in number and type in different groups. The flagellated unicells are found in many groups of algae, e.g., Phacotus and Chlamydomonas of Chlorophyceae. Euglena of Eugleno- phyceae etc.

B. Multicellular Algae:

1. Colonial:

The colonial habit is achieved by loose aggregation of cells within a common mucilaginous investment. The cells of these usually remain connected with each other by cytoplasmic threads.

a. Coenobium:

When a colony has a definite number of cells with a definite shape and arrangement, it is called coenobium.

Coenobium may be:

i. Motile, or

ii. Non- motile.

i. In motile form, cells are flagellated and whole coenobium can move by the organized beating action of flagella, e.g., Volvox), Pandorina ,Eudorina etc. In Volvox the coenobium is a hollow sphere.

ii. In non-motile form, the cells are without flagella, thereby the coenobium is non- motile, e.g., Scenedesmus ,Hydro- dictyon

b. Aggregated Form:

Unlike coenobium the cells are aggregated irregularly showing a colonial mass of various size and shape.

It is of three types:

i. Palmelloid,
ii. Dendroid, and
iii. Rhizopodial.

i. Palmelloid:

In this type the non- motile cells remain embedded in an amorphous gelatinous or mucilaginous matrix.

Each and every cell of the organization is independent and can perform all the functions as an individual.
Chlamydomonas and Chromulina represent palmelloid as a temporary feature in their life cycle.

But in Tetraspora and Palmodictyon (Chlorophyceae), Gleochloris and Chlorosaccus (Xanthophyceae), Phaeocystis (Chrysophyceae) and Microcystis (Cyanophyceae), the palmelloid habit is a permanent feature.

ii. Dendroid:
In this type the number, shape and size of the cell is variable. They look like microscopic trees (e.g., Prasinocladus, Ecballocystis, Chrysodendron. A mucilaginous thread is present at the base of each cell, thus showing a sort of polarity.

iii. Rhizopodial:
In this type the cells are united through rhizopodia. e.g., Chrysidiastrum .
The filamentous plant body is formed through repeated cell divisions in a single plane and in a single direction, where the cells remain firmly attached to each other — end to end forming a chain or a thread. The filaments may be unbranched or branched.

a. Unbranched Filament:

It may be free-floating e.g., Spirogyra, or attached to the substratum (e.g., Ulothrix , Oedogonium , etc.). The free-floating unbranched filaments are not differentiated into basal and apical ends. All the cells in the filament are alike.

But the Unbranched filaments that remain attached to the substratum are differentiated into base and apex.
All the cells of the filament are similar except the basal attachment cell that is specially modified for the purpose called holdfast or rhizoidal cell.

The cell is devoid of chloroplast and only performs the function of anchorage. So certain degree of division of labour among the cells of the filament is established as rest of the cells performs photosynthetic and reproductive functions.

b. Branched Filament:

It is formed when a filament occasionally starts division in a second plane.

It is of two types:

i. Falsely branched, and

ii. Truly branched.

i. Falsely Branched:

The trichomes of blue greens may break either due to death or decay of the intercalary cells. The broken ends emerge out of the mucilaginous sheath in the form of a branch. They do not arise as lateral outgrowths, e.g., Scytonema

ii. Truly Branched:

When a cell in the filament occasionally starts division in a second plane, true branch is formed. Thus true branches arise as lateral outgrowths of the main filament. True branches are of the following three types: Simple filament, Heterotrichous habit, and Pseudoparenchymatous habit.

Simple Filament:

In this branching system the whole thallus remain attached to the substratum by a basal cell and the branches may arise from any cell of the filament except the basal cell, e.g., Cladophora

Heterotrichous Habit:

In this branching system the whole thallus is differentiated into prostrate and erect system. Both the prostrate and erect systems may be well-developed (e.g., Fritschiella, Ectocarpus.)
Progressive elimination of the prostrate system is observed in Draparnaldiopsis, Stigoclonium, oi of the erect system as in Coleochaete

Pseudoparenchymatous Habit:

If one or more central or axial filaments together with their branches fuse to form a parenchymatous structure, it is called pseudoparenchymatous. thallus. Again, if it is formed by the branches of a single filament it is known as uniaxial (e.g., Batrachospermum, or it may be multi-axial where more than one filament are involved (e.g., Polysiphonia)

3. Siphonaceous Forms:

In this form the thallus is aseptate and multinucleate i.e., a coenocyte. It may be simple branched (e.g., Vaucheria,) or may be very elaborate with clear division of labour, differentiated into aerial and subterranean portions (e.g., Botrydium

4. Parenchymatous Forms:

When the cells of a filament divide in multidirectional planes, it results the formation of a parenchymatous thallus and ultimately becoming foliose and flat (e.g., Ulva,), tubular (e.g., Enteromorpha, Scytosiphon) or complex (e.g., Sargassum,) structure.

Growth of the parenchymatous thalli may be diffused (when all the cells can divide), intercalary (when the dividing region remain in the intercalary position) e.g., Laminaria), trichothallic (growth by a specialised intercalary meristem at the base of a terminal hair) e.g., Porphyra or apical (when one or more well-defined apical cells divide to produce the remainder of the thallus), e.g., Fucus.

Origin and Evolution of Sex in Algae:

Algae-like most of the other plants — reproduce by all the three means: vegetative, asexual, and sexual. The sexual reproduction is absent in the class Myxophyceae but they can reproduce by both vegetative and asexual means.

In other groups the reproduction takes place by all the above three means, out of which asexual and sexual methods are very common.

Many plants multiply vegetatively, but they do not involve rejuvenation of the protoplasm.

The asexual reproduction takes place by means of specialized motile or non-motile sex cells, the spores, which do not undergo fusion and, on germination, they give rise to new individuals.

Lastly, sexual reproduction involves the union of sex cells, the gametes, and the result of union of gametes is the zygote (2n), which on germination gives rise to new plant.

The gametes are incapable of developing a new plant on germination.

Origin of Sex in Algae:

The zoospores and gametes are developed during asexual and sexual reproduction, respectively. Both zoospores and gametes are morphologically alike except their size. The gametes are smaller in size than the zoospores. The origin of gamete is the starting point of the origin of sex.

Chlamydomonas debaryanum is the ideal member under the class Chlorophyceae. In this member the gametes and zoospores are alike in structure, shape and mode of development, but the difference lies in their size.

The gametes are smaller in size than the zoospores. The above difference is visible due to the difference in the number of divisions in their maternal protoplasm.
During their formation, if the number of division is less, the unit protoplasts develop into zoospores. These zoospores have the sufficient amount of protoplasm to develop new plants on germination.

On the other hand, if the number of division is more, then the mother protoplast divides into more units and each unit develops into a structure like zoospore, but smaller in size and is incapable of germination into a new individual.
e.g.-Ulothrix zonata, another member of the class Chlorophyceae. U. zonata can produce three types of zoospores during asexual reproduction.

These are:

1. Quadriflagellate macrozoospores,
2. Quadriflagellate micro- zoospores, and
3. Biflagellate microzoospores.

1. Quadriflagellate Macrozoospores:
If there is no division of protoplast or the number of division is very less, single or a few zoospores are developed. This zoospore on germination develops into healthy plant.

2. Quadriflagellate Microzoospores:
If the number of division of protoplast is more, more number of zoospores are formed and, on germination, they develop new plants, weaker than the plants developed by macrozoospores.

3. Biflagellate Microzoospores:
If the number of division of protoplast is still more, the sporangium forms large number of unit of protoplasts, those form biflagellate microzoospores. These microzoospores, on germination, develop into plants, those are still weaker than the above two cases.

The microzoospores are alike in structure and show similar mode of development like gametes. During unfavourable condition, the microzoospores fail to liberate from the sporangium and undergo more divisions and thus form more number of smaller units.
These smaller units behave as gametes. These gametes undergo fusion to form zygote. The zygote takes rest and during favourable condition germinates into a new plant, which bears asexual spores again.

According to the "starvation theory" of Cholnoky, the sexuality is originated in algae due to attraction between two nutritionally deficient cells.

Evolution of Sex in Algae:

The evolution of sex takes place by a different process from simple isogamy to complex heterothallic oogamy through physiological and morphological anisogamy.

1. Isogamy:

In the primitive and simplest form like Chlamydomonas debaryanum, Cladophora etc., both the fusing gametes are morphologically and physiologically identical, thus they cannot be differentiated into male and female gametes. The gametes are called isogametes and the process is called isogamy.

2. Physiological Anisogamy:

In some algae, the gametes are morphologically alike, but differ in their physiological behaviour.

a. In **Ulothrix,** the gametes thus produced are morphologically identical, but the fusion takes place between gametes originating from the different filaments indicate the difference in their physiological characteristics and can be designated as + and – gametes.

b. In **Spirogyra**, the gametes are non- motile and identical in shape and size; those develop singly within the cell. At the time of conjugation the two filaments come very close to each other and some of the cells are connected by conjugation tube.

Out of the two fusing gametes one becomes passive and remain within the cell and behave as female gamete. On the other hand, other gamete though non-motile becomes active and passes to the female through conjugation tube and behave as male gamete .Thus, though the gametes are morphologically identical, they show difference in their behaviour i.e., the physiological anisogamy.

3. Anisogamy:

In Ectocarpus, Pandorina, Clodium and Chlamydomonas braunii, the anisogamy is directly visible, here both the gametes are ciliated i.e., motile, but unequal in size. The gametes are called aniso- gametes. The smaller one is called micro-gamete which behaves as male and the larger one is called macrogamete which behaves as female.
The micro- and macro- gamete are produced within the micro- and macro-gametangium, respectively .

4. Oogamy:

This type of sexual union is visible in Chlamydomonas oogamum, C. coccifera etc. Here male and female gametes are pro-duced within antheridia and oogonia, respectively. The smaller one is active and called male gamete or antherozoid but the relatively larger one is inactive and called female gamete or egg.

Usually single egg is formed within oogonium except in Fucus and Sphaeroplea. Many male gametes are formed within the antheridium.
In Phaeophyceae, both male and female gametes are discharged from the antheridium and oogonium, respectively, and their union occurs in water. This type is called primitive oogamy.

In Oedogonium, the male gametes i.e., antherozoids, are smaller, flagellated and develop in pair within unicellular antheridium, but the female gamete i.e., egg, develops singly within oogonium. The fertilization takes place within oogonium.

In Chara, the sex organs are further specialised. The round male sex organ is the globule containing huge number of antherozoids and the more or less oval, much protected structure is called nucule containing only one egg. The protection of egg and zygote is much more, indicating an advanced characteristic.

In Fucus, separate male, female and mixed conceptacles are formed on receptacles. Out of eight (8) eggs developed in oogonium, seven (7) degenerate. Till now all the species are homothallic.

The evolution of sex reaches its climax in the heterothallic species of Rhodophyceae. Spermatia, the male gametes, are non-motile and developed singly in spermatangium, those are carried by water current to the trichogyne, the receptive region of the female sex organ — the carpogonium.

In Polysiphonia and Oedogonium, out of four tetraspores or zoospores developed (by meiosis) from tetrasporangia or directly from zygote, two produce female plants and others two male plants.

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