Dinophysiales, Dictyochales, Phytodiniales, Pyrocystales and Zooxanthellales.

Class *Desmophyceae* (includes orders Desmocapsales, Prorocentrales and Protospidales).

Division 8. **Rhodophycophyta** (Red algae) : Photosynthetic pigments are chlorophyll-*a*, (*d* in some Florideophycidae; *r*- and c-phycocyanin, allophycocyanin; *r*-and *b*-phycoerythrin; α-+β-carotene and several xanthophylls. Stored food is floridean starch (glycogen-like). Mostly brackish and salt water in habitat, some are fresh water.

It contains a single class *Rhodophyceae*, which in turn includes two sub-classes viz. Bangiophycidae and Florideophycidae.

Sub-class Bangiophycidae contains 4 orders such as Porphyridiales, Goniotrichales, Compsopogonales and Bangiales.

Sub-class Florideophycidae contains 5 orders such as Nemalionales, Cryptonemiales, Gigartinales, Rhodymeniales and Ceramiales.

Division 9. **Cryptophycophyta** (Cryptomonads) : Photosynthetic pigments are chlorophll-a, -c, α-, β- and Σ-carotene; distinctive xanthophylls (alloxanthin, crocoxanthin and monadoxanthin); phycobilins. Stored food is starch. Fresh water, brackish water and salt water in habitat.

This division does not include any class and order.

Classification of Algae by Robert E Lee 1989

Robert Edward Lee in the year 1989 proposed a classification following Christensen, (first edition of the book was published in 1980), in which he divided the algae into 6 groups, like— Cyanophyta, Glaucophyta, Chromophyta, Rhodophyta, Chlorophyta and Charophyta. The largest division is Chromophyta which includes 10 Classes, like– Euglenophyceae, Bacillariophyceae, Xanthophyceae and Phaeophyceae and others.

In the years 1989 he modified his classification as was proposed in the year 1980. The main characteristics of this classification are —

(i) Maintaining co-ordination with their evolution, the different divisions of the algae are included under four different groups.

(ii) By creating new division Prochlorophyta, Chlorophyll b containing algae are included under it.

(iii) Instead of keeping Charophyta in separate division, he included both the Classes Chlorophyceae and Charophyceae under the Division Charophyta.

(iii) Elimination of the division Chromophyta and keeping the different Classes under different divisions e.g. Phaeophyceae — Phaeophyta.

The standard Botanical Classification system is used in the systematics of the algae.

Phylum - phyta
Class - phyceae
Order - ales
Family - aceae
Genus -
Species -

Group 1. Prokaryotic algae

Division Cyanophyta (Cyanobacteria) – Chlorophyll a, phycobiliproteins, only one Class. Cyanophyceae e.g. *Nostoc, Oscillatoria.*

Division Prochlorophyta – Chlorophyll a, b present; phycobiliprotein absent e.g. *Prochloron.*

Group 2. Eukaryotic algae with a chloroplast surrounded only by two membranes of the chloroplast envelopes.

Division Glaucophyta – Algae that represent an intermediate position in the evolution of chloroplast; photosynthesis is carried out by modified endosymbiotic Cyanobacteria e.g. *Glaucocystis, Cyanophora.*

Division Rhodophyta (Red algae) – Chlorophylls a and d, phycobiliprotein present, no flagellated cells, storage product is floridean starch ; only one class Rhodophyceae e.g. *Polysiphonia.* .

Division Chlorophyta (Green algae) – Chlorophylls a and b, storage product starch is found inside the chloroplast. Divided into four Classes, like – Class I Micromonodophyceae e.g. *Montoniella,* class II. Charophyceae, e.g. *Chara,* Class III Ulvophyceae, e.g. *Ulva.* Class IV. Chlorophyceae, e.g. *Chlorella.*

Class I. Micromonadophyceae e.g. *Montoniella.*

Class II. Charophyceae – Motilic cells asymmetrical, two flagella attached in a lateral position in cell, flagellar root consisting of a broad band of microtubule and a second smaller microtubular root, multilayered structure may be present, no rhizoplast, scales outside, motile cells common, predominantly fresh water, occurrence of sexual reproduction involving formation of a dormant zygote, meiosis occurs when the zygote germinates e.g. *Chara.*

Group 3. Eukaryotic algae with chloroplasts surrounded by one membrane of chloroplast endoplasmic reticulum.

Division Euglenophyta (Euglenoids) – Chlorophylls a and b, one flagella with a spiral row of fibrillar hairs, proteinaceous pellicle in strips under the plasma membrane, storage product is paramylon, characteristic type of cell division. Only one Class Euglenophyceae e.g. *Euglena.*

Division Dinophyta (Dinoflagellate) – Monokaryotic nucleus, chlorophylls a and c present; cell commonly divided into an epicone and a hypocone by a girdle, helical transverse flagellum, thecal plates in vesicles under the plasma membrane. Only one Class. Dinophyceae e.g. *Peridinium.*

Group 4. Eukaryotic algae – With chloroplasts surrounded by two membrane of chloroplast endoplasmic reticulum.

Division Cryptophyta (Cryptophytes) – Nucleomorph present between inner and outer membrane of chloroplast endoplasmic reticulum, starch is formed in grains between inner membrane of chloroplast endoplasmic reticulum and chloroplast envelope, chlorophylls a and c, phycobiliprotein present, periplast is inside plasma membrane. Only one Class Cryptophyceae e.g. *Cryptomonas.*

Division. Chrysophyta — Chlorophyll a, C_1, sometimes C_2 and Fucoxanthin present; flagellated – whiplash (front side) and tinsel (backside), stored food matter is chrysolaminarin — stored within the vesicle of the cytoplasm.

Class I Chrysophyceae (Golden brown algae) e.g. *Ochromonas*

Class II Synurophyceae e.g. *Synura*

Division Prymnesiophyta (Haptophytes) – Two whiplash flagella, haptonema present, chlorophylls a and c, fucoxanthin, scales common outside cell, storage product usually chrysolaminarin occurring in vesicles in cytoplasm. Only one Class. Prymnesiophyceae e.g. *Prymnesium.*

Division Bacillariophyta, Class–Bacillariophyceae (Diatoms) – Unicellular, sometimes colonial, free living photosynthetic autotrophs, colourless heterotrophs or photosynthetic symbionts, cells surrounded by rigid two parts; box like cell wall composed of silicates called the frustule, chlorophylls contain chlorophyll a, c_1, c_2 with the major carotenoid being the golden brown fucoxanthin, which gives the cells their characteristic odour. Only one Class Bacillariophyceae e.g. *Navicula.*

Division Xanthophyta (Yellow-green algae) — Eye spot present, with Chloroplast, presence of Chlorophyll a and c, front portion of the flagella tinsel type and back portion whiplash type, only one Class

Division *Eumastigmatophyta* — Eye spot large, Chloroplast present outside, presence of chlorophyll a, front portion of the flagella tinsel type and back portion is whiplash type (generally reduced). Only one Class Eumastigmatophyceae e.g. *Chlorobotrys.*

Division *Raphidophyta (Chloromonads)* — Presence of Chlorophyll a and c, front portion of the flagella tinsel type and back portion whiplash type. Only one Class Rhaphidophyceae e.g. *Vaucheria.*

Division *Phaeophyta* (Brown algae) — Presence of chlorophyll a, c, and c_2 and fucoxanthin stored food chrysolaminarin, sporangia are of two types – unicellular and multicellular, front portion of the flagella tinsel type and back side whiplash type, only one Class Phaeophyceae e.g. *Ectocarpus.*

The term stramenopile (straw hair) has been used to include all Protists with tubular flagellar hairs.

● 1.2 Range of vegetative i.e. Thallus-structure in algae :

The algae exhibit an enormous diversity of thallus organisation, which ranges from the microscopic unicellular habit at one extreme to the giant macroscopic structures attaining a length of 100 metres— such diversity of thallus organisation (Figs. 1.5—1.7) may be grouped as follows :

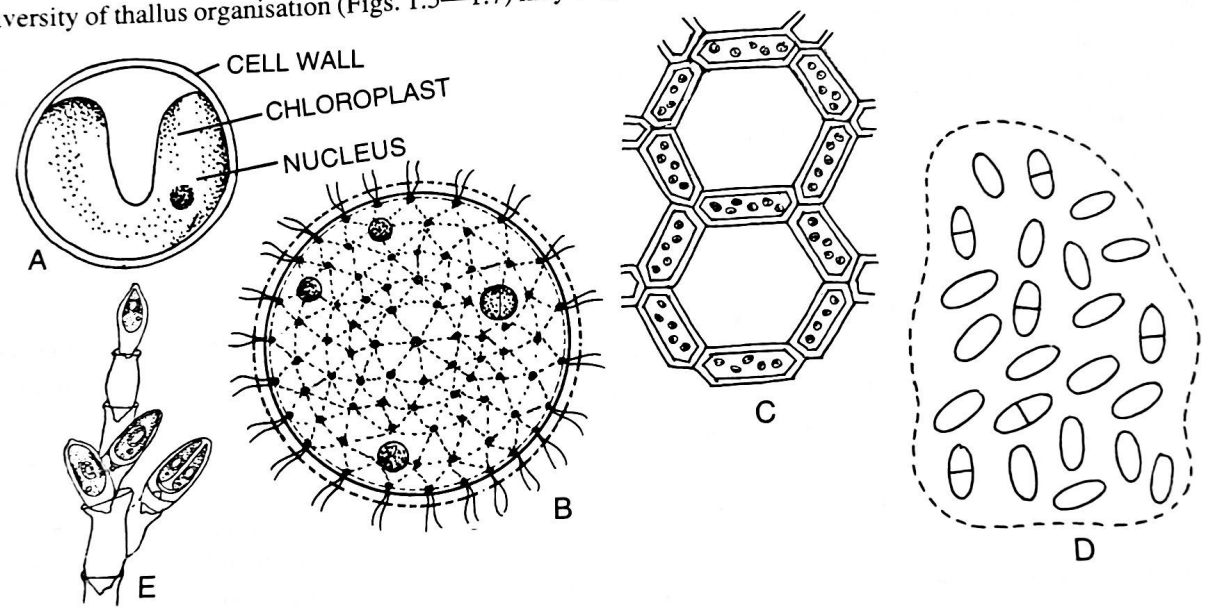

Fig. 1.5 Plant body types in algae. A—Non-motile coccoid unicellular form in *Chlorella* sp. (Chlorophyta). B— Motile coenobial type in *Volvox* sp. C—Non-motile coenobial type in *Hydrodictyon* D— Palmelloid colony in *Aphanothece* sp. E—Dendroid type of thallus in *Prasinocladus (after Fritsch).*

1. *Unicellular motile type* — This type includes the simplest form i.e. unicellular plant body having rounded, pear-shaped or oblong-shaped form bearing two flagella at their anterior region; they are motile. All vital activities are performed by the individual cells. Example : *Chlamydomonas, Chalorogonium* sp. (Chlorophyta); *Euglena, Phacus* of Euglenophyta; *Crytomonas* and *Chroomonas* of Cryptophyta, etc.

2. *Unicellular non-motile or Coccoid type*— To this type belong unicellular, small, more or less spherical, non-flagellate and non-motile members, e.g. species of *Chlorella, Chlorococcum,* etc. Some members are solitary, others are embedded in groups within a mucilagenous sheath. Examples : species of *Gloeocapsa, Chamaesiphon,* etc. of Cyanophyta; and *Porphyridium* of Rhodophyta.

3. *Motile multicellular or Coenobial i.e. Colonial type* — In this type, a number of individual unicellular cells with their flagella protruded out is embedded together in a gelatinous sheath to form a more or less rounded motile colony or coenobium (plural : coenobia). Example : *Volvox* sp. *Eudorina, Pandorina,* etc. of Chlorophyta, *Certatium, Gonyaulax* of Dinophyta.

4. *Non-motile coenobial type*— Here the colony or coenobium is composed of non-motile cells arranged in a single layer along the long axis, e.g. *Scenedesmus* sp. (Chlorophyta) or cells are attached end to end

forming a pentagonal or hexagonal mesh of net, e.g. *Hydrodictyon* (Chlorophyta). Sometimes the coenobium also forms star-shaped structure, e.g. *Pediastrum* sp. *Scenedesmus* sp. (Chlorophyta).

5. *Palmelloid type*— It is a temporary stage formed in the alga *Chlamydomonas* and *Chromulina* (Chlorophyta) under unfavourable conditions. During vegetative phase, the non-motile parent cell produces several non-motile daughter cells which are embedded within a common gelatinous envelope formed by gelatinization of the parent cell wall. The daughter cells further divide forming numerous cells within the matrix which later on become motile by the formation of flagella. Palmelloid habit is also noted in *Aphanothece* (Cyanophyta).

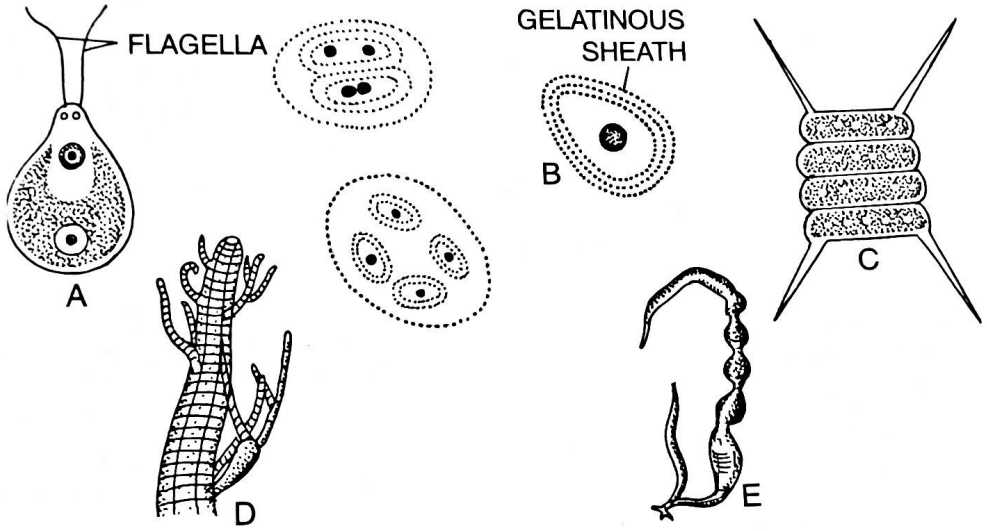

Fig. 1.6 Plant body types in algae. A—Unicellular motile (biflagellate) form in *Chlamydomonas* sp. B— Unicellular non-motile form in *Gloeocapsa* sp. C— Non-motile coenobial type in *Scenedesmus* sp.with cells arranged in a single layer. D—Filamentous polysiphonous thallus of *Polysiphonia* sp. E—Complex thallus of *Laminaria* sp.

6. *Dendroid type*— Dendroid means tree-like. In *Prasinocladus* (Fig. 1.5E), *Ecballocystis*, etc. the plant body looks like a microscopic tree. The mucilage is restricted in such cases usually at the base of the cells. Here the cells of the thallus are attached with each other like branching by mucilage.

7. *Filamentous type*— In these types, the cells are arranged one upon the other either in a row or in several rows to make the plant body filamentous or thread-like in appearance. Sometimes filamentous thallus may be definite in length. The filaments may or may not be differentiated into base and apex. The filamentous types may be branched, e.g. species of *Cladophora*, *Pithophora* (Chlorophyta) or unbranched, e.g. species of *Spirogyra, Ulothrix, Zygnema, Oedogonium,* etc. of Chlorophyta and species of *Anabaena, Oscillatoria, Calothrix* of Cyanophyta. Sometimes the thallus may have false branching e.g. *Scytonema* sp. (Cyanophyta).

8. *Siphonaceous type*— In siphonaceous type, the thallus is made up of long, hollow tube-like structure called *coenocyte*. The coenocytic filament (without partition walls) contains many nuclei and is branched. Examples : species of *Vaucheria* (Chlorophyta), *Botrydium* (Chrysophyta, Xanthophyceae).

9. *Heterotrichous type*— 'Hetero' means different and 'trichous' means trichome or filament. In this type, the plant body is differentiated into a prostrate system of branched filaments growing along the substratum (i.e. creeping) and an erect system consisting of one or more branched filaments developing away from the substratum. This type represents the most highly advanced type of thallus. This type is one of the characteristic features of the order Chaetophorales of Chlorophyta, such as *Stigeoclonium, Draparnaldia, Coleochaete,* etc. This type is also found is some species of Phaeophyta (*Ectocarpus* sp.), Rhodophyta (*Erythrotrichia*) and Cyanophyta (*Chaemosiphon*), etc.

10. *Parenchymatous type*— Repeated septation of filaments and cells division in two or more planes results in the formation of parenchymatous thallus like body in some algae. Such thallus may be ultimately foliose and flat (*Ulva* sp.) or tubular (*Enteromorpha*). Some other complex thallus structure is seen in *Chara*, *Fucus*, *Laminaria*, *Sargassum*, etc.

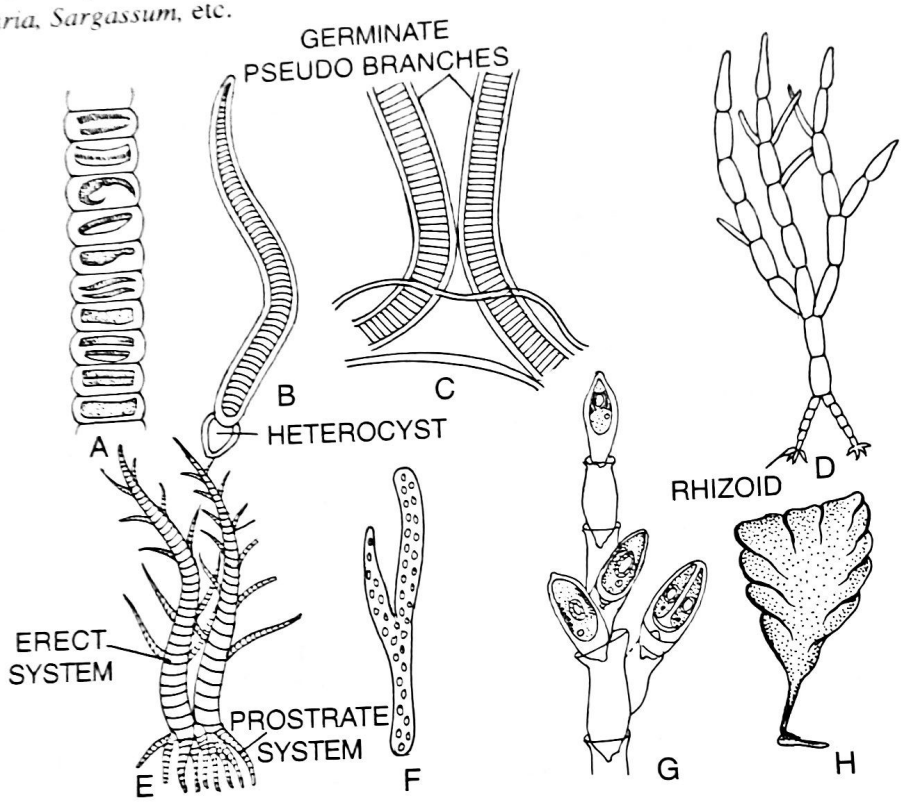

Fig.1.7 Plant body types in algae. A—Portion of a simple unbranched filament of *Ulothrix* sp. B— Unbranched polar filamentous form in *Calothrix* sp. C— Filamentous form in *Scytonema* sp. showing pseudo branching. D— Filamentous branched (true) form in *Cladophora* sp. E— Heterotrichous branched filamentous form in *Stigeoclonium* sp. F— Filamentous branched coenocytic habit in *Vaucheria* sp. G. Dendroid habit of *Prasinocladus* sp. (after Fritsch). H—Parenchymatous thalloid form in *Ulva* sp.

The plant body in some cases is very complex being differentiated into a perennial and an annual portion; in between two such portions, a meristematic region is often present. The thallus is also internally differentiated into pseudoparenchymatous and parenchymatous structures.

11. *Uniaxial type*— Here the plant body is composed of parenchymatous thalli in which there is one main axis and all others are side branches e.g. *Batrachospermum or Dumontia* of Rhodophyta.

Uniaxial type of thallus structure has been originated from the filamantous type in course of evolution.

12. *Multiaxial type*— In this type more than one axis are present in the thallus body. In *Polysiphonia*, *Chondrus*, *Scinaia*, etc. the thallus construction is such that there are present a number of threads in close juxtaposition, giving the appearance of more than one filaments i.e. axes. Those different filaments of central and lateral axes form a compact cortex.

● **1.3 Origin of Algae :** Whatever may have been the origin of the viruses and the bacteria, all the divisions of algae must have arisen from bacterial ancestors, probably from among the autotrophic bacteria (Dodson, 1960). It is not yet clearly understood due to lack of available evidence whether the different divisions of algae arose independently or from a common ancestor. However the division Cyanophyta or