Classification

2.1 WHAT IS A CLASSIFICATION?

Classification may be defined: "Scientific categorization of the organisms in a hierarchical series of groups." Though there are now existing "varieties" and "forms" but "species" is generally considered the smallest group. More similar species are grouped together in a "genus", similar genera are grouped into "families", families into "orders", orders into "classes", classes into "divisions", and divisions into "kingdoms". A kingdom (whether of plants or animals) is the highest taxonomic rank.

2.2 NOMENCLATURE

The Greek word for algae is phykos[1], and according to International Rules of Botanical nomenclature a group of algae should necessarily be incorporated by the word 'phykos'. Because of such incorporation the words such as Chlorophyceae, Phaeophyceae and Rhodophyceae indicate an idea of their relation with algae.

The *International Code of Botanical Nomenclature* (Lanjouw, 1956) has recommended the following suffixes for the different categories of algae:

Division: phyta
Sub-division: phytina
Class: phyceae
Sub-class: phycidae
Order: ales
Sub-order: inales
Family: aceae
Sub-family: oideae
Tribe: eae
Genus: generally a Latin name
Species: generally a Latin name
Variety: A Latin word
Form: A Latin word

Therefore, because the words like Chlorophyta, Phaeophyta and Rhodophyta end with "phyta", these are equivalent to the status of a division; words like Chlorophyceae, Phaeophyceae and Rhodophyceae end with "phyceae" and therefore are equivalent to the status of a class; and words like Volvocales, Oedogoniales and Charales end with "ales" and hence are orders in the algal classification.

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[1]According to Prescott (1969), Latins borrowed the word 'phykos' and spelled it *Fucus*.

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2.3 BASIS OF CLASSIFICATION

Rarely one, and generally a combination of a few or more of the following characters, are considered by the algal taxonomists while classifying algae:

1. Pigments: Their complement, relative amount, kinds, chemical composition, etc.
2. External form: Size, shape, appendages and other structures
3. Chromatophore shape: Whether cup shaped, stellate, reticulate, discoid, spiral, girdle shaped, etc.
4. Reserve food products: Starch, oil, etc., and their chemical composition
5. Flagella: Structure, type, number, position, anatomy and insertion on the body
6. Cell wall: Submicroscopic wall, its chemical composition, etc.
7. Nucleus: Presence or absence of a definite nucleus
8. Chromosome: Number, arrangement, shape, etc.
9. Life-history and reproduction: Type of life-history, method of reproduction, shape of reproductive bodies, presence or absence of sexual reproduction, etc.
10. Algal physiology: Different details
11. Ecological data: Freshwater, marine, etc.

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2.5.6 Classification Proposed by F.E. Fritsch[6]

Fritsch (1935, 1945) believed that algae, as a group, is equivalent to a division and therefore it should not be divided into any more "phyta" (=divisions) but it should be divided only into classes (=phyceae). Hence there are no Chlorophyta, Phaeophyta or Rhodophyta in classification proposed by him. Instead, there are only classes like Chlorophyceae, Phaeophyceae or Rhodophyceae. Some other important suggestions of his classification are:

1. Class Conjugatae of Pascher's classification should be treated only as an order (=Conjugales)[7] of class Chlorophyceae.
2. Division Charophyta of Pascher's (1914, 1931) classification or class Charophyceae of Smith's (1933, 1955) classification should be treated only as an order (Charales) in class Chlorophyceae. They show similarity in pigmentation and product of assimilation.
3. Fritsch does not recognize Desmokontae.
4. Fritsch criticized the inclusion of Xanthophyceae, Bacillariophyceae and Chrysophyceae under one single division, i.e. Chrysophyta.[8] According to him, there is hardly any clear similarity between Bacillariophyceae and other two classes (Xanthophyceae and Chrysophyceae) because:
   (a) Bacillariophyceae are all diploid whereas Xanthophyceae and Chrysophyceae are haploid
   (b) Cell-wall constituents of diatoms differ from that of Xanthophyceae and Chrysophyceae
   (c) Mode of reproduction is different in diatoms and other two classes
   (d) Pigments as well as the product of assimilation in Bacillariophyceae are different from those of Xanthophyceae and Chrysophyceae.
5. Members of Euglenophyta were placed by Fritsch in two separate classes, i.e. Euglenineae and Chloromonadineae.

If all these five modifications are applied in Pascher's classification, the classification proposed by Fritsch becomes apparent. In this system, algae are divided into following 11 classes:

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[6]The classification proposed by Fritsch (1935, 1945) has been followed in this book.
[7]Smith (1933) used the word Zygnematales instead of Conjugales.
[8]See Pascher's and Smith's classifications.

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1. Chlorophyceae[9]
2. Xanthophyceae
3. Chrysophyceae
4. Bacillariophyceae
5. Cryptophyceae
6. Dinophyceae
7. Chloromonadineae
8. Euglenineae
9. Phaeophyceae
10. Rhodophyceae
11. Myxophyceae.

An outline of his classification is given in Table 2.1.

Table 2.1 Classification of Algae by F.E. Fritsch (1935, 1945)

Cl. I. CHLOROPHYCEAE

Ord. I. VOLVOCALES
- Sub-Ord. (a) Chlamydomonadineae (motile)
  1. Chlamydomonadaceae *Chlamydomonas*
  2. Sphaerellaceae *Volvox, Sphaerella*
  3. Polyblepharidaceae *Polyblepharides*
  4. Phacotaceae *Phacotus*
- Sub-Ord. (b) Tetrasporineae (palmelloid)
  5. Tetrasporaceae *Tetraspora*
  6. Palmellaceae *Palmella*
- Sub-Ord. (c) Chlorodendrineae (dendroid)
  7. Chlorodendraceae *Ecballocystis, Prasinocladus*

Ord. II. CHLOROCOCCALES
1. Chlorococcaceae *Chlorococcum*
2. Eremosphaeraceae *Eremosphaera*
3. Chlorellaceae *Chlorella*
4. Oocystaceae *Oocystis*
5. Selenastraceae *Selenastrum*
6. Dictyosphaeriaceae *Westella*
7. Hydrodictyaceae *Pediastrum, Hydrodictyon*
8. Coelastraceae *Scenedesmus*

Ord. III. ULOTRICHALES
- Sub-Ord. (a) Ulotrichineae
  1. Ulotrichaceae *Ulothrix*
  2. Microsporaceae *Microspora*
  3. Cylindrocapsaceae *Cylindrocapsa*
  4. Ulvaceae *Ulva, Enteromorpha*
- Sub-Ord. (b) Prasiolineae
  5. Prasiolaceae *Prasiola*
- Sub-Ord. (c). Sphaeropleineae
  6. Sphaeropleaceae *Sphaeroplea*

Ord. IV. CLADOPHORALES
1. Cladophoraceae *Cladophora, Pithophora*

Ord. V. CHAETOPHORALES
1. Chaetophoraceae *Stigeoclonium, Fritschiella, Draparnaldiopsis, Draparnaldia*

[9]Blackman and Tansley (1903) used the word Isokontae for Chlorophyceae.

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2. Trentepohliaceae *Cephaleuros, Trentepohlia*
3. Coleochaetaceae *Coleochaete*
4. Chaetospharidiaceae *Chaetosphaeridium*
5. Pleurococcaceae *Pleurococcus*

Ord. VI. OEDOGONIALES
1. Oedogoniaceae *Oedogonium, Oedocladium, Bulbochaete*

Ord. VII. CONJUGALES
Sub-Ord. (i) Euconjugatae
(a) Mesotaenioideae
1. Mesotaeniaceae *Cylindrocystis*
(b) Zygnemoideae
2. Zygnemaceae *Spirogyra, Zygnema*
3. Mougeotiaceae *Mougeotia, Sirogonium*
4. Gonatozygaceae *Gonatozygon*
Sub-Ord. (ii) Desmidioideae
5. Desmidiaceae Desmids (*Closterium, Cosmarium, Desmidium*)

Ord. VIII. SIPHONALES
1. Protosiphonaceae *Protosiphon*
2. Caulerpaceae *Caulerpa, Bryopsis*
3. Derbesiaceae *Derbesia*
4. Dasycladaceae *Acetabularia, Dasicladus*
5. Codiaceae *Codium*
6. Valoniaceae *Valonia*
7. Chaetosiphonaceae *Chaetosiphon*
8. Phyllosiphonaceae *Phyllosiphon*
9. Vaucheriaceae *Vaucheria*

Ord. IX. CHARALES
1. Characeae *Chara, Nitella*

Cl. II. XANTHOPHYCEAE

Ord. I. HETEROCHLORIDALES
Sub-Ord. (a) Heterochlorineae
1. Heterochloridaceae *Heterochloris*
Sub-Ord. (b) Heterocapsineae
2. Heterocapsaceae *Chlorogloea*
Sub-ord. (c) Heterodendrineae
3. Mischococcaceae *Mischococcus*
Sub-Ord. (d) Heterorhizidineae
4. Heterorhizidaceae *Rhizolekane*

Ord. II. HETEROCOCCALES
1. Halosphaeraceae *Halosphaera*
2. Myxochloridaceae *Myxochloris*
3. Chlorobotrydaceae *Chlorobotrys*
4. Chlorotheciaceae *Chlorothecium*
5. Ophiocytiaceae *Ophiocytium*

Ord. III HETEROTRICHALES
1. Tribonemaceae *Tribonema*
2. Heterocloniaceae *Heterodendron*

Ord. IV. HETEROSIPHONALES
1. Botrydiaceae *Botrydium*

Cl. III. CHRYSOPHYCEAE

Ord. I. CHRYSOMONADALES
(a) Chrysomonadineae

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(i) Chromulineae
1. Chromulinaceae *Chromulina*
2. Oicomonadaceae *Oicomonas*
3. Mallomonadaceae *Mallomonas*
4. Cyrtophoraceae *Cyrtophora*

(ii) Isochrysideae
5. Isochrysidaceae *Syncrypta*
6. Coccolithophoridaceae *Coccolithus*
7. Synuraceae *Synura*

(iii) Ochromonadeae
8. Ochromonadaceae *Ochromonas*
9. Monadaceae *Monas*
10. Lepochromonadaceae *Dinobryon*

(iv) Prymnesieae
11. Prymnesiaceae *Prymnesium*

(b) Rhizochrysidineae
12. Rhizochrysidaceae *Rhizochrysis*
13. Lagyniaceae *Lagynion*

(c) Chrysocapsineae
14. Chrysocapsaceae *Chrysocapsa*
15. Naegeliellaceae *Naegeliella*
16. Hydruraceae *Hydrurus*

Ord. II. CHRYSOSPHAERALES
1. Chrysophaeraceae *Chrysosphaera*
2. Chrysostomataceae *Chrysostrella*
3. Pterospermaceae?

Ord. III. CHRYSOTRICHALES
1. Nematochrysidaceae *Nematochrysis*
2. Phaeothamnionaceae *Phaeothamnion*
3. Thallochrysidaceae *Thallochrysis*

Cl. IV. BACILLARIOPHYCEAE[10]

Ord. I. CENTRALES
1. Discoideae *Cyclotella*
2. Solenoideae *Corethron*
3. Biddulphioideae *Isthmia*
4. Rutilarioideae *Rutilaria*

Ord. II. PENNALES

(i) Araphideae
5. Fragilarioideae *Fragilaria*

(ii) Raphidioideae
6. Eunotioideae *Eunotia*

(iii) Monoraphideae
7. Achnanthoideae *Achnanthes*

(iv) Biraphideae
8. Naviculoideae *Navicula*
9. Epithemioideae *Epithemia*
10. Nitzschioideae *Nitzschia*
11. Surirelloideae *Surirella*

[10]The classification of diatoms adopted by Karsten (1928) and Hustedt (1930) has been followed by Fritsch (1935).

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Cl. V. CRYPTOPHYCEAE

Ord. I. CRYPTOMONADALES
- (a) Cryptomonadineae
  - 1. Cryptomonadaceae *Hillea*
  - 2. Nephroselmidaceae *Sennia*
- (b) Phaeocapsineae
  - 3. Phaeocapsaceae *Phaeoplax*

Ord. II. CRYPTOCOCCALES
- 4. Cryptococcaceae *Tetragonidium*

Cl. VI. DINOPHYCEAE (Peridinieae)[11]

(A) DESMOKONTAE
- Ord. I. DESMOMONADALES
  - 1. Desmomonadaceae *Desmocapsa*
- Ord. II. THECATALES
  - 2. Prorocentraceae *Prorocentrum*
- Ord. III. DINOPHYSIALES
  - 3. Dinophysiaceae *Dinophysis*
  - 4. Amphisoleniaceae *Amphisolenia*

(B) DINOKONTAE
- I. DINOFLAGELLATA
  - (i) Peridinieae
    - (a) Gymnodinioideae
      - 5. Pronoctilucaceae *Pronoctiluca*
      - 6. Gymnodiniaceae *Gymnodinium*
      - 7. Polykrikaceae *Polykrikos*
      - 8. Noctilucaceae *Noctiluca*
      - 9. Warnowiaceae *Warnowia*
      - 10. Blastodiniaceae *Blastodinium*
    - (b) Amphilothaloideae *Amphilothus*
    - (c) Kolkwitzielloideae *Kolkwitziella*
    - (d) Peridinioideae
      - 11. Glenodiniaceae *Glenodinium*
      - 12. Protoceratiaceae *Protoceratium*
      - 13. Gonyaulaceae *Gonyaulax*
      - 14. Peridiniaceae *Peridinium*
      - 15. Ceratiaceae *Ceratium*
      - 16. Goniodomaceae *Goniodoma*
      - 17. Ceratocoryaceae *Ceratocorys*
      - 18. Podolampaceae *Podolampas*
  - (ii) Dinocapsineae
    - 19. Dinocapsaceae *Gloeodinium*
  - (iii) Rhizodinineae *Dinamoebidium*
- II. DINOCOCCALES
  - 20. Dinococcaceae *Tetradinium*
- III. DINOTRICHALES
  - 21. Dinotrichaceae *Dinothrix*
  - 22. Dinocloniaceae *Dinoclonium*

Cl. VII. CHLOROMONADINEAE

A very small class comprising a

[11]The classification of Dinophyceae given by Lindemann (1928) and Schiller (1931) has been followed by Fritsch (1935).

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few highly specialized, unicellular flagellates (Fritsch, 1935, p. 721), e.g. *Trentonia, Vacuolaria*

Cl. VIII. EUGLENINEAE

1. Euglenaceae *Euglena*
2. Astasiaceae *Astasia*
3. Peranemaceae *Peranema*

Cl. IX. PHAEOPHYCEAE

Ord I. ECTOCARPALES
1. Ectocarpaceae *Ectocarpus*
2. Myrionemataceae *Myrionema*
3. Elachistaceae *Halothrix*
4. Leathesiaceae *Leathesia*
5. Mesogloeaceae *Mesogloea*
6. Acrotrichaceae *Acrothrix*
7. Spermatochnaceae *Halorhiza*
8. Splachnidiaceae *Splachnidium*
9. Punctariaceae *Punctaria*
10. Asperococcaceae *Asperococcus*
11. Encoeliaceae *Iyengaria*
12. Dictyosiphonaceae *Dictyosiphon*

Ord. II. TILOPTERIDALES *Tilopteris*
Ord. III. CUTLERIALES *Cutleria*
Ord. IV. SPOROCHNALES *Sporochnus*
Ord. V. DESMARESTIALES *Desmarestia*
Ord. VI. LAMINARIALES
1. Chordaceae *Chorda*
2. Laminariaceae *Laminaria*
3. Lessoniaceae *Macrocystis*
4. Alariaceae *Alaria*

Ord. VII. SPHACELARIALES
1. Sphacelariaceae *Sphacelaria*
2. Stypocaulaceae *Halopteris*
3. Cladostephaceae *Cladostephus*
4. Choristocarpaceae *Choristocarpus*

Ord. VIII. DICTYOTALES *Dictyota*
Ord. IX. FUCALES
1. Fucaceae *Fucus*
2. Himanthaliaceae *Himanthelia*
3. Cystoseiraceae *Cystophora*
4. Sargassaceae *Sargassum*
5. Hormosiraceae *Hormosira*
6. Durvilleaceae *Durvillea*
7. Ascoseiraceae *Ascoseira*

CL. X. RHODOPHYCEAE

Sub-Class I. BANGIOIDEAE
Ord. I. BANGIALES
1. Bangiaceae *Bangia*
2. Porphyridiaceae *Neevea, Porphyra*

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Sub-Class II. FLORIDEAE[13]

Ord. I. NEMALIONALES

1. Acrochaetiaceae *Kylinia*
2. Batrachospermaceae *Batrachospermum*
3. Lemaneaceae *Lemanea*
4. Naccariaceae *Naccaria*
5. Bonnemaisoniaceae *Bonnemaisonia*
6. Thoreaceae *Thorea*
7. Helminthocladiaceae *Helminthora*
8. Chaetangiaceae *Chaetangium*

Ord. II. GELIDIALES

1. Gelidiaceae *Gelidium*

Ord. III. CRYPTONEMIALES

1. Gloeosiphoniaceae *Gloeosiphonia*
2. Endocladiaceae *Gloeopeltis*
3. Callymeniaceae *Callymenia*
4. Grateloupiaceae *Aeodes*
5. Dumontiaceae *Pikea, Dumontia*
6. Cruoriaceae *Cruoria*
7. Rhizophyllidaceae *Rhizophyllis*
8. Squamariaceae *Ethelia*
9. Corallinaceae *Corallina*
10. Choreocolaceae *Choreocolax*

Ord. IV. GIGARTINALES

1. Calosiphoniaceae *Calosiphonia*
2. Nemastomaceae *Platoma*
3. Sebdeniaceae *Sebdenia*
4. Furcellariaceae *Furcellaria*
5. Solieriaceae *Anatheca*
6. Rissoellaceae *Rissoella*
7. Rhabdoniaceae *Rhabdonia*
8. Rhodophyllidaceae *Rhodophyllis*
9. Hypneaceae *Hypnea*
10. Plocamiaceae *Plocamium*
11. Sphaerococcaceae *Heringia*
12. Gracilariaceae *Gracilaria*
13. Mychodeaceae *Mychodea*
14. Acrotylaceae *Acrotylus*
15. Phyllophoraceae *Phyllophora*
16. Gigartinaceae *Gigartina*

Ord. V. RHODYMENIALES

1. Champiaceae *Champia*
2. Rhodymeniaceae *Rhodymenia*

Ord. VI. CERAMIALES

1. Ceramiaceae *Ceramium*
2. Delesseriaceae
   (a) Delesserieae *Delesseria*
   (b) Nitophylleae *Nitophyllum*
   (c) Sarcomenieae *Sarcomenia*
3. Rhodomelaceae
   (a) Polysiphonieae *Polysiphonia*
   (b) Lophothalieae *Lophothalia*

[13]The classification of Florideae, proposed by Kylin, has been followed by Fritsch (1945).

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(c) Bostrychieae *Colacopsis*
(d) Rhodomeleae *Rhodomela*
(e) Chondrieae *Chondria*
(f) Laurencieae *Ricardia*
(g) Pterosiphonieae *Pterosiphonia*
(h) Herposiphonieae *Herposiphonia*
(i) Lophosiphonieae *Lophosiphonia*
(j) Polyzonieae *Polyzonia*
(k) Amansieae *Vidalia, Amansia*

4. Dasyaceae *Dasya*

CI. XI. MYXOPHYCEAE (CYANOPHYCEAE)

Ord. I. CHROOCOCCALES
1. Chroococcaceae *Chroococcus, Gloeocapsa*
2. Entophysalidaceae *Placoma*

Ord. II. CHAMAESIPHONALES
1. Dermocarpaceae *Dermocarpa*
2. Chamaesiphonaceae *Chamaesiphon*
3. Endonemataceae *Endonema*
4. Siphononemataceae *Siphononema*

Ord. III. PLEUROCAPSALES
1. Pleurocapsaceae *Pleurocapsa*
2. Hyellaceae *Hyella*

Ord. IV. NOSTOCALES
1. Oscillatoriaceae *Oscillatoria, Lyngbya, Phormidium*
2. Nostocaceae *Anabaena, Nostoc*
3. Microchaetaceae *Richelia*
4. Rivulariaceae *Gloeotrichia, Rivularia*
5. Scytonemataceae *Scytonema, Tolypothrix*

Ord. V. STIGONEMATALES
1. Pulvinulariaceae *Loriella*
2. Capsosiraceae *Capsosira*
3. Nostochopsidaceae *Nostochopsis*
4. Loefgreniaceae *Loefgrenia*
5. Stigonemataceae *Stigonema*

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Classification

There are four distinct groups within the algae. The remainder of the text is divided into four parts based on these four groups.

1. Prokaryotes. The cyanobacteria are the only prokaryotic algae.
2. Eukaryotic algae with chloroplasts surrounded by the two membranes of the chloroplast envelope.

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3 Eukaryotic algae with the chloroplast surrounded by one membrane of chloroplast endoplasmic reticulum.
4 Eukaryotic algae with the chloroplast surrounded by two membranes of chloroplast endoplasmic reticulum.

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
Cyanophyta (cyanobacteria) (Chapter 2): chlorophyll *a*; phycobiliproteins.

Group 2 Eukaryotic algae with chloroplasts surrounded only by the two membranes of the chloroplast envelope.
Glaucophyta (Chapter 3): algae that represent an intermediate position in the evolution of chloroplasts; photosynthesis is carried out by modified endosymbiotic cyanobacteria.
Rhodophyta (red algae) (Chapter 4): chlorophyll *a*; phycobiliproteins; no flagellated cells; storage product is floridean starch.
Chlorophyta (green algae) (Chapter 5): chlorophylls *a* and *b*; storage product, starch, is found inside the chloroplast.

Group 3 Eukaryotic algae with chloroplasts surrounded by one membrane of chloroplast endoplasmic reticulum.
Euglenophyta (euglenoids) (Chapter 6): chlorophylls *a* and *b*; one flagellum with a spiraled row of fibrillar hairs; proteinaceous pellicle in strips under the plasma membrane; storage product is paramylon; characteristic type of cell division.
Dinophyta (dinoflagellates) (Chapter 7): mesokaryotic nucleus; chlorophylls *a* and c_1; cell commonly divided into an epicone and a hypocone by a girdle; helical transverse flagellum; thecal plates in vesicles under the plasma membrane.
Apicompexa (Chapter 8): heterotrophic flagellates with colorless plastids.

Group 4 Eukaryotic algae with chloroplasts surrounded by two membranes of chloroplast endoplasmic reticulum.
Cryptophyta (cryptophytes) (Chapter 9): nucleomorph present between inner and outer membrane of chloroplast endoplasmic reticulum; starch formed as grains between inner membrane of chloroplast endoplasmic reticulum and chloroplast envelope; chlorophyll *a* and *c*; phycobiliproteins; periplast inside plasma membrane.
Heterokontophyta (heterokonts) (Chapters 10–21): anterior tinsel and posterior whiplash flagellum; chlorophyll *a* and *c*; fucoxanthin; storage product usually chrysolaminarin occurring in vesicles.
Chrysophyceae (golden-brown algae) (Chapter10)
Synurophyceae (Chapter 11)
Eustigmatophyceae (Chapter 12)
Pinguiophyceae (Chapter 13)
Dictyochophyceae (silicoflagellates) (Chapter 14)
Pelagophyceae (Chapter 15)
Bolidophyceae (Chapter 16)
Bacillariophyceae (diatoms) (Chapter 17)
Raphidophyceae (chloromonads) (Chapter 18)
Xanthophyceae (yellow-green algae) (Chapter 19)
Phaeothamniophyceae (Chapter 20)
Phaeophyceae (brown algae) (Chapter 21)
Prymnesiophyta (haptophytes) (Chapter 22): two whiplash flagella; haptonema present; chlorophyll *a* and *c*; fucoxanthin; scales common outside cell; storage product chrysolaminarin occurring in vesicles.

Data from molecular studies indicate that the red algae diverged about 1400 million years ago from the common line leading to higher plants (Saunders and Hommersand, 2004). This was followed by divergence of the green algae and, then, multiple independent secondary endosymbioses evolving to those algae with chloroplast endoplasmic reticulum. The host phagocytic organisms leading to the euglenoids was probably a kinetoplastid, that leading to the dinoflagellates was probably an apicomplexan, and that leading to the photosynthetic cryptophytes and haptophytes was a colorless cryptophyte and haptophyte,

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