CRYPTOGAMIC BOTANY

VOLUME I

Algae and Fungi

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SECOND EDITION

McGRAW-HILL BOOK COMPANY, INC.

New York Toronto London

1955

CRYPTOGAMIC BOTANY, Vol. 1

Library of Congress Catalog Card Number 54-8808

II

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE

The general plan of the first edition has been followed in preparing this revised edition. The general discussions of the major taxa have been entirely rewritten and numerous changes have been made in descriptions of the various genera selected as "types." In certain cases, especially in the red and the brown algae, genera with a wider geographical distribution have been substituted for those described in the first edition.

As in the case of the first edition, this book is designed for students who have had an introductory course in botany and who wish to make a more intensive study of plants below the level of seed plants. It is written from the standpoint that a thorough knowledge of a representative series in each of the major groups is better than scraps of information about a large number of members of each group. This has been done with full knowledge of the danger of presenting the subject through a series of "types," and with a full realization that students are apt to substitute the type for the group and to consider all Fucales identical with *Fucus*, all Mucorales identical with *Rhizopus*, and all Marchantiales identical with *Marchantia*. However, it is hoped that introductory discussions to divisions, classes, and other taxa will help call attention to those characters of the selected representatives which are characteristic of the taxon as a whole and those which are special to the representative itself. In certain cases, as with the diatoms and the blue-green algae, it has been thought more advantageous to present the group as a whole instead of discussing selected representatives.

An attempt has been made to make the space devoted to each group proportional to its diversity and to check the natural tendency to overemphasize groups in which an author is especially interested. I realize that some botanists will disagree with the allocation of space, especially in the relative proportions devoted to the algae and to the fungi. There has also been the problem of selecting representatives for each of the groups. Wherever possible the genera selected are found in the United States and are of widespread distribution. In some cases this has meant the selection of a highly specialized rather than a generalized type, but it is felt that the availability of living material for study in the laboratory offsets this disadvantage.

Any general discussion of a group involves inclusion of subjects that are a matter of controversy. An attempt has been made to present both sides of controversial subjects, but I have not hesitated to express an opinion upon the relative merits of the arguments. Any attempt to group plants in a natural system of classification necessitates a consideration of phylogeny, a subject upon which no two botanists are in entire accord. Phyletic diagrams are included in this book because it is thought that a graphic presentation is the best method by which the student may visualize the suggested interrelationships between the various taxa. However, they are presented with a full realization that every botanist will disagree in minor or in major points.

The bibliographies at the ends of the chapters are to be looked upon as indicating the sources where a student may find fuller discussions of the subjects, rather than as a documentation justifying the various statements. References to the entire literature on the various subjects would have involved an expansion of bibliographies to an extent inappropriate to a book of this size. Wherever possible, the references selected are to journals with a wide circulation in this country.

A large proportion of the figures have been especially drawn for this book. Figures designated as *semidiagrammatic* are those in which it has been impossible to draw all details of a preparation cell for cell. Figures designated as *diagrammatic* are more or less conventionalized drawings based upon one or more preparations. Theoretical drawings not based upon any particular preparation or preparations are designated as *diagrams*. Illustrations taken from other authors are designated as *from* when copied in facsimile, and as *after* when redrawn for this book. A large majority of the original drawings have been made by the author. Most of the habit sketches of red and of brown algae were drawn by Mrs. Carl F. Janish and Mrs. Fred Addicott; the habit sketches of fungi were drawn by Mrs. Janish.

The completeness of the series of original figures is due to the courtesy of other botanists in furnishing material and preparations. Professor E. M. Gilbert and the late Professor J. I. W. McMurphy furnished preparations of many fungi. Dr. D. A. Johansen granted me free access to his extensive collection of preparations. Many of the figures are based upon preparations made especially for me by Dr. Johansen, whose skill in sectioning and staining refractory material has made possible illustrative material that would otherwise have been unavailable. Certain of the new illustrations in this edition were drawn from special preparations made by W. K. Bowen, microtechnician of the Department of Biology of Stanford University. Professor G. J. Hollenberg has supplied preparations of *Polysiphonia;* Dr. H. C. Gilbert preparations of *Ceratiomyxa;* and Professor J. G. Dickson preparations of *Puccinia* and *Ustilago.*

Professor G. F. Papenfuss and H. L. Blomquist have furnished preserved material of *Dictyota;* Professor W. R. Taylor and Dr. Jean Feldmann have furnished preserved material of *Dudresnaya;* and Dr. Laura Garnjobst has furnished cultures of *Neurospora.*

Thanks are due Professor Alexander H. Smith, the Kelco Company, and the Johns-Manville Company for supplying photographs.

I am under deep obligation to my colleague Professor Robert M. Page for supplying cultures of various fungi, for answering various questions about fungi, and especially for his critical reading of the chapters on the fungi.

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CONTENTS

CHAPTER 1

THE CLASSIFICATION OF SPORE-PRODUCING PLANTS

The classification of plants has undergone many changes since Aristotle (384–322 B.C.) and his pupil Theophrastus (372–287 B.C.) first grouped them into *trees*, *shrubs*, and *herbs*. Beginning with the herbalists of the sixteenth century, there came a gradual realization that the most obvious characters are not necessarily the most important. Their gradual recognition that the structure of the flower is of more fundamental importance in classification than are vegetative characters paved the way for the "sexual system" of Linnaeus in which he grouped plants according to the number of stamens and carpels, their union, and their presence or absence in the flower. This system, although wholly artificial, had the great advantage that an unknown plant, when discovered, could be easily interpolated among those already known. Linnaeus divided the plant kingdom into 25 classes, one of which, the *Cryptogamia*, included all plants with "concealed" reproductive organs. He[1] characterized the class as follows: "*CRYPTOGAMIA continet Vegetabilia, quorum Fructificationes oculis nostris se subtrahunt, & structura ab aliis diversa gaudent.*" He divided the Cryptogamia into the following four orders: *Filices* which included all known pteridophytes; *Musci* which included all known mosses and leafy liverworts; *Algae* which included algae, lichens, and thallose liverworts; and the *Fungi*.

Natural systems of classification, that is, those in which plants were grouped according to what were thought to be their natural affinities, were established long before Darwin proposed the evolutionary theory. The first natural system, that of De Jussieu,[2] divided plants into three major groups, *Acotyledones*, *Monocotyledones*, and *Dicotyledones*. His Acotyledones are the approximate equivalent of Linnaeus' Cryptogamia, and the various orders he recognized among the Acotyledones are equally heterogeneous. Many other natural systems for the classification of plants were proposed during the first half of the nineteenth century, but all of them[3] are very inadequate as far as spore-producing (cryptogamic) plants

[1] Linnaeus, 1754. [2] De Jussieu, 1789.

[3] See Lindley (1847) for a summary of the various systems.

are concerned. The decade following Darwin's announcement of the theory of evolution in 1859 is marked by the appearance of true natural systems in which the fundamental basis for the classification of plants is phylogeny and in which they are arranged in an ascending series from the most primitive to the most complex.

The system[1] which places the cryptogamic portion of the plant kingdom in three divisions (*Thallophyta, Bryophyta, Pteridophyta*) was introduced about 1880. It soon became widely adopted and is still followed in a more or less modified form in many present-day textbooks. A decade or two after the turn of the century botanists began raising the question of whether or not the Thallophyta and the Pteridophyta are natural divisions. To date, botanists are universally agreed that the Bryophyta are a natural division.

Validity of the Thallophyta. The Thallophyta, with its two subdivisions the *Algae* and the *Fungi*, may be distinguished from other plants on the basis of structure of their gamete- and spore-producing organs. Sex organs of Thallophyta are one-celled, or when multicellular (as in certain brown algae) they do not have the gamete-containing cells surrounded by a layer of sterile cells. Bryophytes and pteridophytes have multicellular sex organs in which there is an outer layer of sterile cells. Sporangia of Thallophyta are always one-celled; those of more advanced plants are many-celled. Another distinction between Thallophyta and other plants is the fact that zygotes of Thallophyta never develop into multicellular embryos while still within the female sex organ.

Granting the common distinctive morphological features distinguishing algae and fungi from other plants there then arises the question: is this due to an evolution of the fungi from the algae, or have these common features been evolved independently in the two? If the fungi have been evolved from the algae there is some justification for maintaining the division Thallophyta. But, as will be shown in chapters dealing with the various classes of fungi, the evidence favors the view that none of the fungi has been evolved from algae. From this it follows that the Thallophyta are not a valid division, and that the subdivisions Algae and Fungi should each be placed in one or more divisions.

Organisms to Be Placed among the Algae. Before discussing whether the algae should be placed in one or more than one division it is necessary

[1] This is frequently stated to have first appeared in the third edition of Eichler's "Syllabus" (1883). Credit for establishment of these divisions should go elsewhere since they are not recognized in the second edition of Eichler's "Syllabus" (1880) and they are to be found in the synopsis of the plant kingdom published by Schimper in 1879. The division name *Thallophyta* was first introduced by Endlicher (1836), who called it a kingdom. The names *Bryophyta* and *Pteridophyta* were first (?) introduced by Haeckel (1866) but he was not the first to give these groups the rank of a division.

to take up the question of what organisms belong in this assemblage. Until the beginning of the twentieth century it was customary to recognize the following four classes of algae: *Chlorophyceae*, *Phaeophyceae*, *Rhodophyceae*, and *Myxophyceae* (*Cyanophyceae*). Diatoms were universally included among the algae and placed either in the Phaeophyceae or in a class distinct from other classes. During this time botanists rarely questioned the practice of protozoologists who placed all motile unicellular and colonial flagellated organisms with chlorophyll in the class Mastigophora of the phylum Protozoa. An exception must be made in the case of the volvocine series culminating in *Volvox*. Here, beginning a century ago,[1] botanists began calling certain members of this series algae but made no attempt to assign them a definite place among the algae. This was first done by Rabenhorst (1863), who placed the *Chlamydomonas-Volvox* series in the group of grass-green algae to which he gave the name Chlorophyllaceae.

When, at the beginning of this century, the *Xanthophyceae* (*Heterokontae*) were segregated[2] from the grass-green algae (*Chlorophyceae*) certain pigmented flagellates were included in the class.

Later, the chrysomonads and the dinoflagellates each were shown[3] to be related to organisms of an unquestionable algal nature. The euglenoids and the cryptomonads are also related to organisms of an algal type, but types not so highly advanced as in the algal types related to the chrysomonad and to the dinoflagellate series. Thus, with the possible exception of the chloromonads, all the various groups (orders) which protozoologists place in the subclass Phytomastigina of the class Mastigophora are phylogenetically related to organisms of a truly algal nature.

Classification of the Algae. It has become increasingly clear during recent decades that physiological characteristics of vegetative cells and the morphology of motile reproductive cells are the fundamental bases upon which algae should be classified. One important characteristic of vegetative cells is the nature of the pigments in their plastids, and throughout each of the classes of algae the plastids contain certain distinctive pigments not found in other classes of algae (Table 1). Correlated with this is the fact that the type of food reserve accumulated by the cell runs consistently throughout each class of algae and the type differs from class to class. Throughout each class there is a striking constancy in position of flagella of motile cells. In some classes all flagella are alike in structure. In other classes one flagellum is of the "whiplash" type and the other of the "tinsel" type (Fig. 91, page 168).

The Chlorophyceae and the Phaeophyceae may be cited to illustrate these differences. The Chlorophyceae have a predominance of chlorophylls in their plastids, contain certain unique xanthophylls, and almost always

[1] Braun, 1851; Cohn, 1853. [2] Luther, 1899. [3] Pascher, 1914, 1925, 1927.

TABLE 1. PRINCIPAL PIGMENTS OF THE DIFFERENT CLASSES OF ALGAE
(BASED ON STRAIN, 1951)

	Myxophyceae	Rhodophyceae	Xanthophyceae	Chrysophyceae	Bacillariophyceae	Phaeophyceae	Dinophyceae	Chlorophyceae	Euglenophyceae
Chlorophylls:									
Chlorophyll *a*	+++	+++	+++	+++	+++	+++	+++	+++	+++
Chlorophyll *b*	0	0	0	0	0	0	0	++	+
Chlorophyll *c*	0	0	0	...	+	+	+	0	0
Chlorophyll *d*	0	+	0	...	0	0	0	0	0
Chlorophyll *e*	0	0	+	...	0	0	0	0	0
Carotenes:									
α-Carotene	...	+	...	...	0	0	0	+	
β-Carotene	+++	+++	+++	+++	+++	+++	+++	+++	+++
ε-Carotene	...	...	...	...	+	0	...	0	
Flavicin	+	...	...	...	0	0	...	0	
Xanthophylls:									
Lutein	?	++	0	+	0	0	0	+++	?
Zeaxanthin	?	...	0	...	0	0	0	+	
Violaxanthin	...	...	...	...	0	+	0	+	
Flavoxanthin	...	...	...	...	0	+	...	?	
Neoxanthin	...	...	0	...	0	+	0	+	
Fucoxanthin	...	?	0	+	++	++	0	0	0
Neofucoxanthin A	...	...	0	...	+	+	0	0	0
Neofucoxanthin B	...	...	0	...	+	+	0	0	0
Diatoxanthin	...	...	0	...	+	?	0	0	0
Diadinoxanthin	...	...	0	...	+	?	+	0	0
Dinoxanthin	...	...	0	...	0	?	+	0	0
Neodinoxanthin	...	...	0	...	0	0	+	0	0
Peridinin	...	...	0	...	0	0	++	0	0
Myxoxanthin	++	...	0	...	0	0	0	0	0
Myxoxanthophyll	++	...	0	...	0	0	0	0	0
Unnamed	?	?	++	?		+			+
Phycobilins:									
r-Phycoerythrin	0	+++	0	?	0	0	0	0	0
r-Phycocyanin	0	+	0	?	0	0	0	0	0
c-Phycoerythrin	+	0	0	?	0	0	0	0	0
c-Phycocyanin	+++	0	0	?	0	0	0	0	0

+++ indicates the principal pigment in each of the four groups of pigments.
++ indicates a pigment comprising less than half of the total pigments of the group.
+ indicates a pigment comprising a small fraction of the total pigments of the group.
? indicates small quantities of a pigment whose source or identification is uncertain.
0 indicates known absence of a pigment.
... indicates lack of knowledge concerning the presence of certain pigments in some classes of algae.

store photosynthetic reserves as starch. Motile vegetative and reproductive cells have terminally inserted flagella that are all of the "whiplash" type and equal in length. The Phaeophyceae have a predominance of carotenoids in their plastids, contain certain unique xanthophylls, and store photosynthetic reserves as laminarin. Motile reproductive cells have laterally inserted flagella, one of the "whiplash" type, the other of the "tinsel" type.

According to the foregoing bases the algae are generally[1] divided into the following classes: *Chlorophyceae* (with or without segregation of the charas as a separate class, the *Charophyceae*), *Euglenophyceae*, *Xanthophyceae*, *Chrysophyceae*, *Bacillariophyceae*, *Phaeophyceae*, *Dinophyceae*, *Myxophyceae*, *Rhodophyceae*, *Cryptophyceae*.

Pascher[2] was the first to point out that certain of the classes mentioned above are sufficiently distinct to be recognized as divisions of the plant kingdom, whereas other classes have so many features in common that they are evidently related to one another. Thus, the number of divisions necessary for a complete classification of the algae is less than the number of classes. The first recognition of an affinity between certain classes was that which showed[3] a relationship between the Xanthophyceae, Chrysophyceae, and Bacillariophyceae. Features in common to these three classes include cell walls composed of two overlapping halves, silicified cell walls, motile cells with similarities in flagellation, a distinctive type of resting cell (cyst), and similarities in the nature of food reserves. Despite differences in chlorophylls and xanthophylls (see Table 1), there seems to be good ground for placing the three in a single division, the *Chrysophyta*. The golden brown chromatophores of Phaeophyceae have much the same color as chromatophores of many Chrysophyta but there are differences in the pigments causing the brown color (Table 1). Since there are striking differences in the food reserves and in insertion of the flagella of reproductive cells, the Phaeophyceae should be placed in a separate division, the *Phaeophyta*. The Myxophyceae and the Rhodophyceae are the only algae in which there are phycobilin pigments, but the phycobilins are not identical in the two.[4] The differences in nuclear organization, localization or nonlocalization of pigments in chromatophores, and presence or absence of sexual reproduction are so striking that there does not seem to be a phylogenetic connection between the two classes. Thus the Rhodophyceae are to be placed in one division, the *Rhodophyta;* and the Myxophyceae in another, the *Cyanophyta*. The chlorophycean series, including the charas, is also so distinctive that it should be placed in a separate division, the *Chlorophyta*. Similarities in pigmentation of Euglenophyceae and Chlorophyceae tempt one to place the Euglenophyceae in the

[1] Fritsch, 1935, 1944, 1945; Pascher, 1914, 1921, 1931; Smith, 1933, 1950.
[2] Pascher, 1914, 1921, 1931. [3] Pascher, 1914. [4] Strain, 1951.

Chlorophyta, but for the present it seems better to place them in a separate division, the *Euglenophyta*. The Dinophyceae have sufficient distinctiveness to be placed in another division, the *Pyrrophyta*. Opinion is divided as to whether the Cryptophyceae should be included in the Pyrrophyta,* or should not be included.[1] For the present it seems better to consider the Cryptophyceae a class of uncertain systematic position and not to place it in any of the divisions mentioned above. The question of the proper disposition of the chloromonads is even more difficult, and in their case, also, it seems best to group them among algae of uncertain systematic position.

Classification of the Fungi. The true fungi are universally divided into the following four classes: *Phycomycetae*, *Ascomycetae*, *Basidiomycetae*, and *Deuteromycetae* (Fungi Imperfecti). At one time some botanists placed the slime molds (*Myxomycetae* or *Mycetozoa*) in the animal kingdom, but today practically all botanists consider them related to the fungi. The Myxomycetae differ so markedly from other fungi that they should be placed in a separate division, the *Myxomycophyta*.

Whether the true fungi should be placed in a single division or in more than one division depends upon their mode of origin. One group of botanists holds that the Phycomycetes arose from algae that were either Chlorophyceae or Xanthophyceae; and that algae referable to the Rhodophyceae gave rise to the Ascomycetes which, in turn, gave rise to the Basidiomycetes. If this is correct the true fungi should be placed in two divisions; one containing the Phycomycetes; the other containing the Ascomycetes, Basidiomycetes, and Deuteromycetes. According to another group of botanists, the Phycomycetes arose from protozoa and in turn gave rise to the Ascomycetes and Basidiomycetes. Since, as will be shown in Chaps. 12 and 13, this seems the more probable, these three classes, together with the Deuteromycetes, may be grouped in a single division, the *Eumycophyta*.

Validity of the Pteridophyta. For a long time ferns, lycopods, and horsetails were thought to be sufficiently related to be placed in a single division, the *Pteridophyta*. Question as to the validity of the Pteridophyta arose when Jeffrey[2] showed that there are two fundamentally different types of vascular plants. He called these types "stocks." Ferns, gymnosperms, and angiosperms, a "stock" which he called the *Pteridopsida*, have macrophyllous leaves and leaf gaps when the vascular cylinder is siphonostelic (see Vol. 2, Chap. 6). Lycopods and horsetails, a "stock" which he called the *Lycopsida*, have microphyllous leaves and no leaf gaps when the vascular cylinder is siphonostelic. Jeffrey does not indicate

* Pascher, 1914, 1927. [An asterisk will be used hereafter to indicate a *discussion* source.]

[1] Graham, 1951. [2] Jeffrey, 1902.

whether these two "stocks" should be considered divisions or subdivisions of the plant kingdom. Scott[1] was the first to give them formal rank as divisions and to segregate the horsetails as a separate division, the *Sphenopsida*. Later, Scott[2] gave the Psilophytales the rank of a division but retained the ordinal name as a division name.

Ferns, lycopods, and horsetails are three series diverging from psilophytes; and seed plants are a series or group of series derived from ferns. The problem is that of what rank should be accorded diverging members of the collective series. Some botanists[3] place the collective series in a single division, the *Tracheophyta*, and divide it into four subdivisions: *Psilopsida*, *Lycopsida*, *Sphenopsida*, and *Pteropsida*. This reduction of the four to the rank of subdivisions minimizes their marked divergence one from another. In the opinion of the writer the differences between the psilopsidan, lycopsidan, and sphenopsidan series are of the magnitude of a division. There still remains the question of the degree of divergence among members of the pteropsidan series. Although ancestral to seed plants, the ferns seem to be sufficiently distinct from them to be placed in a separate division. Distinctive differences include gametic union by means of free-swimming antherozoids, gametophytes that are free-living from the beginning or eventually become so, uninterrupted growth of sporophyte from zygote to maturity, and absence of seed habit.

Finally, if psilophytes, lycopods, horsetails, and ferns are each to be given the rank of a division what names should be applied to these divisions? The International Code of Botanical Nomenclature as amended in 1950 recommends that all names of divisions end in the suffix -phyta and that subdivisions of vascular plants end in the suffix -opsida. Therefore although Lycopsida and Sphenopsida have been used as division names[1] they are inappropriate. The earliest system[4] in which the various classes of the Pteridophyta were each given the rank of a division used the name *Lepidophyta* for the lycopodian series and *Calamophyta* for the equisetaceous series. The division name Pteridophyta was restricted to include only the ferns. Because of the widespread use of the name Pteridophyta when all vascular cryptogams are grouped in a single division, the name *Pterophyta* is proposed for the division composed solely of ferns. The psilophytes should be grouped in a separate division, the *Psilophyta*.

Interrelationships. The various algal divisions mentioned on preceding pages seem to be phyletic series entirely independent from one another. The answer to the question as to whether they arose independently or from some common ancestral stock is obscure and purely a matter of speculation. However, numerous physiological and morphological features

[1] Scott, 1909. [2] Scott, 1923. [3] Eames, 1935; Tippo, 1942.
[4] Bessey, 1907.

in common suggest that they may have had a common origin in some primitively organized ancestral stock. The common physiological features include ability to elaborate food photosynthetically, ability to form enzymes, common features in permeability, and similarities in responses to external stimuli. Most of them also have such common cellular morphological features as a differentiation of the protoplasm into cytoplasm and nucleus, a localization of photosynthetic pigments in plastids, and a qualitative division of the nuclear material.

It is impossible to decide which of the algal divisions was the first to be evolved. The Cyanophyta are simpler in cell structure and in organization of their colonies, but this does not necessarily mean that they were the first to appear. In the Chrysophyta, Pyrrophyta, Euglenophyta, and Cyanophyta there has been but little advancement in evolution of the plant body, and in all of them the reproductive organs are simple. The Phaeophyta and Rhodophyta have attained a high algal level insofar as certain of each have a relatively large plant body of complex external form and with some internal differentiation of tissues. However, in neither the red nor the brown algae does there seem to have been an evolution of a true land plant.

If, as appears to be the case, the divisions of a fungal nature have evolved from protozoa they have no phylogenetic connection with other divisions of the plant kingdom. The two fungal divisions (Myxomycophyta and Eumycophyta) may have had a common origin but it is more probable that they were evolved independently.

Nowhere in the Chlorophyta are there algae as complex as are found in Rhodophyta and Phaeophyta. In spite of this, the presence of identical pigments in Chlorophyta and in true land plants, and the fact that the end product of photosynthesis in both is starch, suggests very strongly that all green plants at a higher evolutionary level than an algal organization have arisen from the Chlorophyta. The most primitive of these higher green plants are the Bryophyta. The Psilophyta are widely considered to be the most primitive of pteridophytes; but there is disagreement as to whether they were evolved directly from the Chlorophyta, evolved from the ancestral line leading to the Bryophyta, or evolved from one of the lines (classes) within the Bryophyta. As will be shown in Vol. 2, Chap. 6, the evidence seems to favor their origin from an anthocerotan type of bryophyte. Evolution from the Psilophyta proceeded in three distinct pteridophytic lines. Two of these lines, the Calamophyta and the Lepidophyta, did not evolve beyond the pteridophytic level. Seed plants were evolved from the third line, the Pterophyta, but it is beyond the province of this book to discuss the origin and classification of seed plants.

The relationships of plants are usually shown by a diagram having the form of a much-branched tree. A more accurate diagrammatic representa-

tion of evolutionary relationships among plants would be that of a tree adjoined by eight shrubs (Fig. 1). The tree would represent the Chlorophyta and the land plants derived from them. The shrubs would represent the other algae and the fungi. Four of the algal shrubs would be very low. The other two, representing the Phaeophyta and the Rhodophyta, would be somewhat taller.

Divisions and Classes of Cryptogams. The divisions and classes into which cryptogamic plants are here divided may be tabulated as follows,

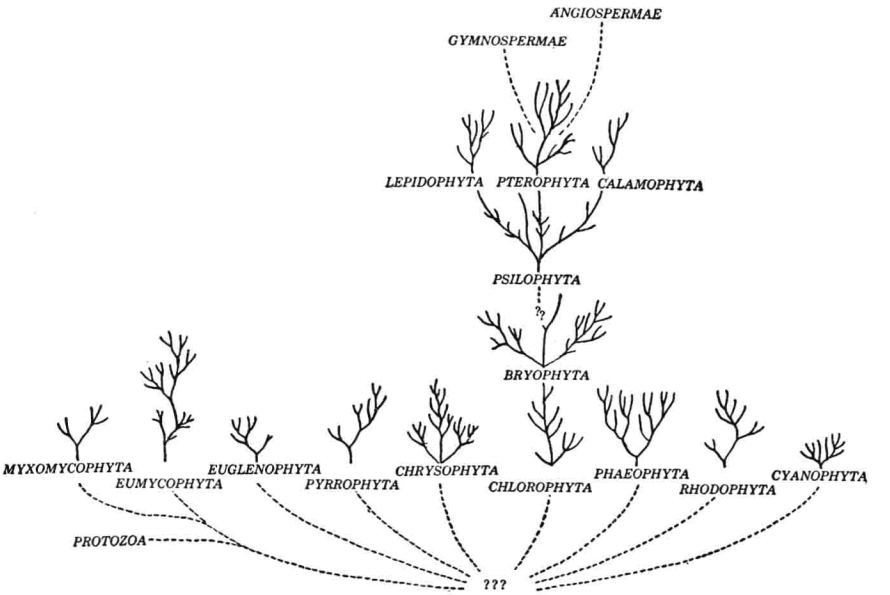

FIG. 1. Diagram showing the suggested interrelationships of the divisions of the plant kingdom.

but it should be noted that the sequence in which the algal divisions are arranged does not necessarily imply that the first on the list are the more primitive.

Division 1. Chlorophyta
- Class 1. Chlorophyceae (grass-green algae)
- Class 2. Charophyceae (stoneworts)

Division 2. Euglenophyta
- Class 1. Euglenophyceae (euglenoids)

Division 3. Pyrrophyta
- Class 1. Desmophyceae (dinophysids)
- Class 2. Dinophyceae (dinoflagelloids)

Division 4. Chrysophyta
- Class 1. Chrysophyceae (golden brown algae)
- Class 2. Xanthophyceae (yellow-green algae)
- Class 3. Bacillariophyceae (diatoms)

Division 5. Phaeophyta (brown algae)
  Class 1. Isogenerateae
  Class 2. Heterogenerateae
  Class 3. Cyclosporeae
Division 6. Cyanophyta (blue-green algae)
  Class 1. Myxophyceae
Division 7. Rhodophyta (red algae)
  Class 1. Rhodophyceae
Algae of Uncertain Systematic Position
  Chloromonadales
  Cryptophyceae
Division 8. Myxomycophyta (slime molds)
  Class 1. Myxomycetae
  Class 2. Plasmodiophorinae
  Class 3. Acrasieae
Division 9. Eumycophyta (true fungi)
  Class 1. Phycomycetae ("algal" fungi)
  Class 2. Ascomycetae (sac fungi)
  Class 3. Basidiomycetae (club fungi)
  Class 4. Deuteromycetae (imperfect fungi)
Division 10. Bryophyta
  Class 1. Hepaticae (liverworts)
  Class 2. Anthocerotae (hornworts)
  Class 3. Musci (mosses)
Division 11. Psilophyta
  Class 1. Psilophytinae (psilophytes)
Division 12. Lepidophyta
  Class 1. Lycopodinae (lycopods)
Division 13. Calamophyta
  Class 1. Equisetinae (horsetails)
Division 14. Pterophyta
  Class 1. Filicinae (ferns)

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