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A PRIMER IN ALGAE[1]

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Introduction

This is a scientific paper, written in non-technical language as far as possible. It is based on experiences, both personal and derived, during the first ten professional years of a beginning and advanced student of algae. The writing is intended as an introduction for students and biology teachers to an interesting and important group of plants, although specialists in other fields may find it a handy reference too. Such an introduction and handy reference is needed since the primary steps in the study of the algae are most difficult, as this student recalls. Instead of sifting through a stack of rarely available references and fruitlessly wasting time and effort in blind alleys, the student, teacher, or specialist may use this primer to attain a higher and more interested level of understanding with a little less difficulty. If a simple presentation of the most useful lessons of experience can improve the appreciation and understanding of the algae, it is felt that a genuine scientific objective will have been gained.

What Algae Are

"Algae" is a general term in biological classification which includes a variety of widely different organisms. These algal plants are separated from other plants, except the fungi, because their sporangia (spore bearing organs) are not surrounded by a tissue layer of sterile cells. In addition, most algae are quite small or simple in structure, although there are some (seaweeds) which grow six hundred feet long. Algae are distinguished from fungi primarily because they are pigmented with chlorophyll and capable of synthesizing their food from inorganic materials, while fungi are not. However, some algae are not pigmented. They are considered algae, nevertheless, because their structure resembles that of some pigmented algae more than that of any fungi. Even animal-like forms of algae, which move, eat, and lack pigment, are structurally similar to more plant-like algae.

The Field of Algal Studies

The beginning student of algae should have a broad view of the field which he is surveying. It includes the studies of organisms differing more widely among themselves than do many plants placed in entirely different groups in the remainder of the plant kingdom. There is a greater range of difference, for instance, in the pigments, food making processes, and form among the several groups of algae than among mosses, ferns, and flowering plants. It is not surprising,

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then, that such a heterogeneous group as the algae should interest us in various ways. Some fossil diatoms serve as an index to petroleum bearing rock strata, while others make up beds of Fuller's earth, which is used in making filters and hot refractory surfaces. The living algae of our inland waters furnish pasturage for a myriad of small animals which eventually become food for game fish. Since algae play such an important role in the food economy of aquatic habitats, crops of fish can be raised successfully by fertilizing ponds so that a greater amount of algae is produced in them. Under certain conditions, however, algae may cause water supplies to have an unpleasant taste, or even to poison livestock. Soil algae are useful in retarding erosion on bare surfaces, and they contribute to the organic content of the soil.

These effects on our lives are overshadowed by the untapped possibilities of algae. The algae may soon contribute substantially to the nutrition of the human race. Food has already been obtained in quantity from vats of algae by British scientists, and engineers are operating pilot plants in California for the production of protein by algae. Biologists in different commercial laboratories are investigating the antibiotics and other valuable products which algae contain. More important still, the great problem of photosynthesis is being attacked through the use of cultures of algae, and it may eventually be possible to produce food from carbon dioxide and water without the agency of green plants.

In addition to its possibilities for the welfare of mankind, algae will always provide an aesthetic satisfaction to their observers, who will be intrigued by the variety, the beauty of color and design of the plants, as well as the thrill of discovering unknown facts about them.

Habitat

Fortunately for the interested naturalist, algae occur almost everywhere. They are not only in streams, lakes, and ponds, but also on and in soil, on moist rocks and tree trunks, and in lichens. Where there is a little moisture and some light, algal pioneers will establish a colony.

Equipment Needed for Study

The study of fresh water algae is chiefly microscopic. While considerable skill in observation can be developed with the naked eye or a hand lens, it is only with the microscope that careful study can be carried out effectively. An ordinary student microscope, magnifying up to about four hundred times, is quite adequate for accurate work in most groups. Essential tools are glass slides and cover glasses, one or two dissecting needles, a pair of finely pointed forceps (tweezers), and a scalpel (the small spear-pointed kind is quite handy). A pipette (eye-dropper) may be desirable for handling liquids, but the finger tip holds a drop nicely if no pipette is at hand. For more advanced studies and the identification of species, an eyepiece micrometer is a necessity. This measuring device must be calibrated from a special slide which has an accurate scale fixed to it, called the stage micrometer.

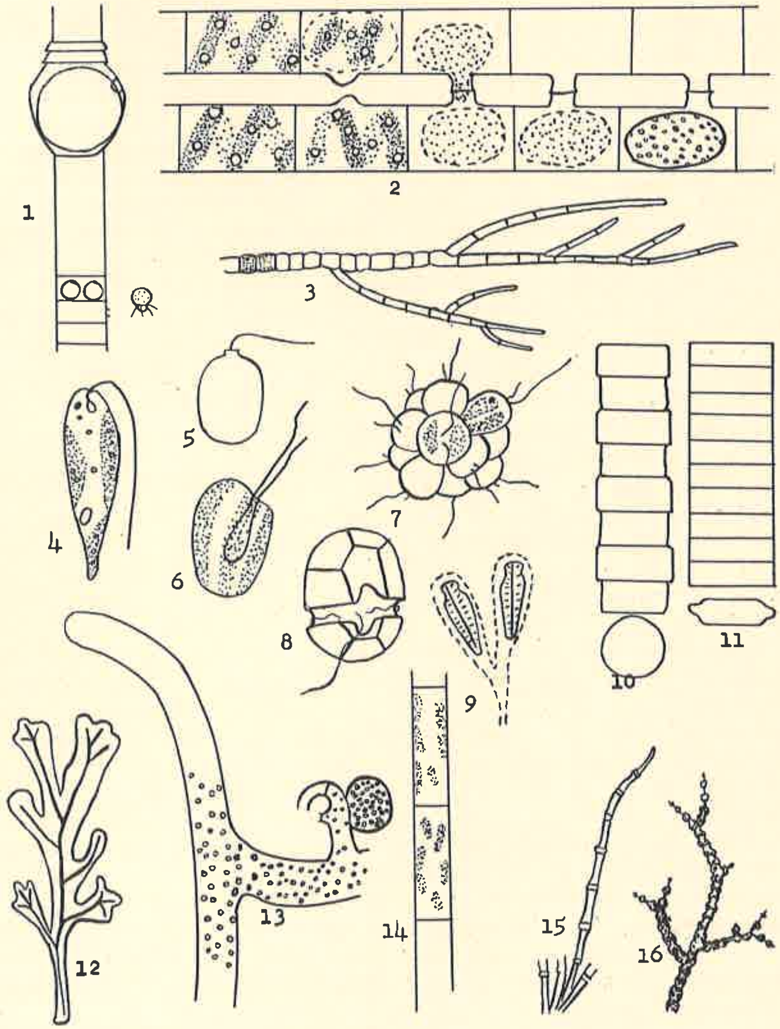
CULTURING

Information about identity, life history, and variation is best obtained from living algae, and they are far more interesting to study than preserved ones. *Oedogonium*, a filamentous green alga, grows well in clear glass jars or bottles of water, and later frequently produces the particular rounded, swollen fruiting structures which distinguish them. *Spirogyra*, readily recognizable because of its spiral green chloroplasts, sometimes undergoes sexual reproduction and produces the spores necessary for careful identification. *Stigeoclonium* may be studied through its life cycle in cultures. Branching green filaments produce swimming spores and then disintegrate. Later, spores germinate into small patches of cells, then tufts of cells, and these grow again into elongated, branched plants.

Algae which are sparse in numbers and inactive, such as those encountered in soil, may multiply and become active if water is added to the material containing them. They can be allowed to incubate in an illuminated place, and should be covered to prevent contamination. In effect, this is a simple culturing practice. The soil-water culture method is a good one for many collections. Some sterile soil is placed in a Petri dish, or any convenient covered glass vessel, and water added. Tap water is harmful to some algae, so sterilized natural water should be used whenever possible. The soil-water medium is inoculated with bits of material selected out of field collections and transferred by forceps, pipette, or an inoculating needle such as the bacteriologist uses. Soil and water may be filtered and the extract placed in test tubes for use as a liquid culture solution. If a solid medium is desired, one percent of agar can be added to the soil-water extract. After addition of agar and sterilization, the medium can be allowed to solidify in test tube slants or Petri dishes.

Culturing is time-consuming, but a knowledge of these rudimentary procedures may be helpful to the beginner. Culturing is a fascinating study, particularly for those who possess the sort of "green thumb" it requires. Unfortunately, its most interesting aspects are beyond the scope of this publication.

Plate I. (Opposite page.) Fig. 1. *Oedogonium*, showing female and male structures, male swimming cell; greatly enlarged. Fig. 2. *Spirogyra*, showing conjugation of cell contents and spore formation; greatly enlarged. Fig. 3. *Stigeoclonium*, in adult condition; greatly enlarged. Fig. 4. *Euglena;* greatly enlarged. Fig. 5. *Trachelomonas;* greatly enlarged. Fig. 6. *Cryptomonas;* greatly enlarged. Fig. 7. *Synura*, showing colony of pear-shaped, yellowish cells; greatly enlarged. Fig. 8. *Peridinium;* greatly enlarged. Fig. 9. *Gomphonema*, a diatom growing within a gelatinous sheath; greatly enlarged. Fig. 10. *Melosira*, a filamentous diatom; greatly enlarged. Fig. 11. *Odontidium*, a filamentous diatom; greatly enlarged. Fig. 12. *Fucus*, a seaweed, about 1/8 natural size. Fig. 13. *Vaucheria*, showing sexual structures; greatly enlarged. Fig. 14. *Tribonema;* greatly enlarged. Fig. 15. *Lemanea;* about natural size. Fig. 16. *Batrachospermum;* about natural size.



Retaining and Recording Collections

Since algae are best studied when alive, a few comments on methods of retaining and recording specimens may be useful. Some small bottles are needed. It is well to select a uniform size with cork tops, which can be written upon with a ball-point pen. Bottles about as big as the little finger may be placed directly into an envelope for permanent storage. Many algae will not remain healthy in these small containers, so a few larger bottles, about half-pint size, should be available.

Plain bond paper envelopes are rather good containers for algae which may be dried immediately or require only dampness to be kept in good condition. Good paper takes ball-point pen markings (clear, even under water) better than newspaper. Newspaper, however, is readily available for wrapping specimens. If squares of newsprint are used for wrapping the specimens, several layers should be used to make a firm package.

Each specimen should be numbered and the number immediately recorded in a field note book, along with the date, habitat, and location, including county and state. The writer has never found memory a reliable means of determining where a specimen came from, even after only a short lapse of time. It will be most worth while, although time consuming, to transcribe field notes into a "smooth log" or permanent note book, along with notes as to the disposition of the specimen, such as "lost," "discarded," "preserved," etc.

Preservation and Filing

If examination cannot be carried out while material is fresh, algae may be preserved shortly after being collected. Drying requires no special equipment, but preservation in bottles of liquid solution requires the preparation of and transportation of the preservative. The most popular preservative is "6-3-1," composed of water, 95 percent ethyl alcohol, and formalin (40 percent formaldehyde) in that order. Only the last two ingredients may be mixed, and water is added from field sources before preserving algae in the solution.

Bottles are difficult to label properly and store in an orderly fashion. Furthermore, they must be refilled periodically with preservative. Therefore, after examination, liquid-preserved specimens may be dried for convenient permanent storage. Unfortunately, specimens treated in this way are usually somewhat damaged. Dried specimens (or even small bottles of liquid) may be placed into an envelope packet (the size which folds to about three by five inches is adequate for most algae), and all pertinent data may be written on the packet or on a card inside it. All packets should contain a card on which identifications from subsequent examinations may be noted. The bit of sample which is examined should be placed on the card, circled, and then dated and initialed by the examiner. This way there is no doubt as to what was examined, and it may be rechecked.

Classification

To get an idea of the extreme diversity of the plants included under the term "algae," their classification should be examined. It might be recalled that the word-ending "-phyta" designates the broadest division within the plant kingdom, indicating equivalence to the phylum rank in the classification of animals. All seed bearing plants —pine trees, buttercups, grasses, and daisies—have been assigned to a single division, Spermatophyta, while there are seven divisions assigned to the algae alone. The "-phyceae" ending indicates a botanical class. For example, all flowering plants are in one class of seed plants while all cone-bearing seed plants are in the other.

The Algae

CHLOROPHYTA—The grass-green algae.

Chlorophyceae—Most green algae, including *Spirogyra*.

Charophyceae—The *Charas* or stoneworts.

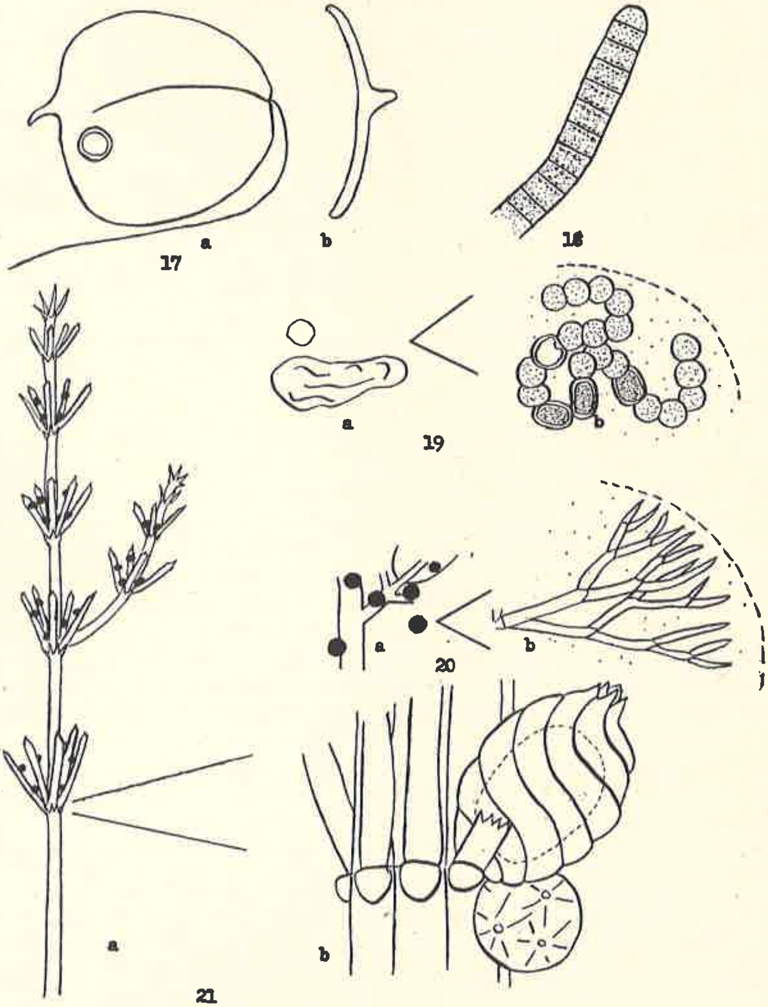


Plate II. Fig. 17. *Phacus*, a euglenoid. a. Top view. b. End view. Fig. 18. *Oscillatoria*, a blue green alga, showing end of filament. Fig. 19. *Nostoc*, a blue green forming gelatinous colonies. a. Colonies natural size. b. Greatly enlarged portion of colony. Fig. 20. *Chaetophora*, a green alga forming gelatinous colonies. a. Colonies on a water plant, natural size. b. Greatly enlarged portion of colony. Fig. 21. *Chara*, a stonewort. a. Plant about natural size. b. Portion of plant at node enlarged about 25 times, showing male and female reproductive structures.

EUGLENOPHYTA—The euglenoids, including *Euglena* and *Trachelomonas* which are rather common.

CHRYSOPHYTA—The yellow-greens and yellow-browns.

XANTHOPHYCEAE (HETEROKONTAE)—The yellow-greens, including *Tribonema*.

BACILLARIOPHYCEAE—The diatoms, including *Melosira* and *Odontidium* (*Diatoma*).

CHRYSOPHYCEAE—The yellow-browns, including *Synura* and *Vaucheria*.

PYRRHOPHYTA—

CRYPTOPHYCEAE—The golden-browns, including *Cryptomonas*.

DINOPHYCEAE—The Dinoflagellates, including *Peridinium* and related forms.

CRYPTOPHYTA—A rare and distinct group, represented by *Gonyostemum*.

PHAEOPHYTA—The brown algae, an almost exclusively marine group. *Fucus* is a common seaweed.

RHODOPHYTA—The red algae, mostly marine, but including *Lamanea*, *Batrachospermum*, and a few others in fresh water.

CYANOPHYTA—The blue-greens, without a highly organized nucleus, as in the bacteria: example, *Oscillatoria*.

COLLECTING AND HANDLING

Green and Blue-Green Algae. The most casual observer is likely to have seen conspicuous displays of at least two groups of algae, the greens and the blue-greens. The green algae are the strands of grass-green color observed in bunchy masses in ponds or lakes, or trailing in the current of streams. The blue-greens frequently occur as dark coatings on stream rocks or in mud puddles or mud flats. This simple color difference between green and blue-green is a rather good one for field use, and it enables the collector to handle each group differently. The greens are kept uncovered in small bottles with an ample supply of water and air. The blue-greens may merely be wrapped in newspaper or envelopes and kept moist or permitted to dry. For the examination of dried material no special soaking is generally required, but a drop of one of the commercial detergents (Dreft, etc.) in solution will cause the plants to swell to a more natural appearance than will plain water. Blue-green algae are often encrusted with mud and sand so that cover glasses may be broken, making microscopic examination difficult. To clean this material, small bits of it may be washed on the slide itself with successive drops of water or detergent; the specimen is further freed by careful shaking and picking with the finely pointed forceps. Two precautions should be noted: use small portions of the material, carefully untangled; examine bits from different parts of the collection to see if the plant varies in appearance from portion to portion.

Euglena and Its Kin. Another group of algae is likely to be familiar to anyone who is acquainted with stock ponds. The oily green or red coating which sometimes covers them is often composed of numerous euglenoids (the genus *Euglena* and its kin). These algae either swim about, propelled by flagella (thread-like whips protruding from their front ends), or they remain quietly rolled into anomalous looking balls. In spite of the frequency and abundance of this group, they have been so neglected that only a single comprehensive treatment of them has been completed in the United States. The neglect is regrettable, since they are possibly the most beautiful and exciting group of algae. It is understandable, though, since almost all euglenoids must be examined while alive and moving. They can be retained in this condition only temporarily unless troublesome cultural methods are used.

Since euglenoids are best observed while slowly moving or temporarily at rest, a little corn syrup or commercial cellulose preparation (Methocel and others) may slow them down to a desirable pace. The structures which distinguish euglenoids are not always readily apparent; it took several months and many attempts before the writer could actually see flagella, and many more months before the chloroplasts (characteristically shaped, pigmented bodies) appeared as anything but blobs of green.

A few euglenoids, such as certain *Phacus* species, are well preserved when dried on paper, mica, or plastics. Limited success might be obtained with liquid preservative too, but, in general, euglenoids simply cannot be preserved satisfactorily. Preserved euglenoids should best be regarded as a challenge for a future investigator to attempt identification.

Xanthophyceae, Dinoflagellates, and Cryptomonads. Other swimming algae, whether greens or the more infrequent yellow-greens, dinoflagellates, and cryptomonads, present the same difficulties in observation and preservation as the euglenoids, and they must be handled similarly. The dinoflagellates, however, possess a firm cellulose shell which preserves well after the death of the protoplasm inside. These shells can be used to identify them. Shell-forming algae may be preserved in liquid or by drying, but it is easy to overlook specimens in small dried collections.

Diatoms. One particular group of algae can be classified entirely by the characteristics of its shells, which are silicified (silica being the material of sand or glass). The shells are etched with an infinite variety of patterns which differ from group to group but are similar within groups. The diatoms, although quite common, are usually inconspicuous. They occur as scattered individuals in soil, and are suspended in still or running water, or are seen as a light yellow-brown coating on rocks. The diatoms *Melosira* and *Odontidium* are exceptional, growing as extensive masses of filaments. These masses appear to have a metallic sheen, especially when dried. Living diatoms are most interesting. Some move without any apparent organs of locomotion (!), while other diatoms are found within branched or unbranched gelatinous sheaths.

Diatoms may be preserved readily by drying, but accurate identification can be achieved only from specially prepared samples. Two traditional methods of preparation to remove organic matter from the shells are: (a) heating in a crucible at full heat for half an hour; (b) boiling gently for twenty minutes in concentrated sulfuric acid, then adding some crystals of potassium dichromate and continuing to heat for a few minutes, allowing the mixture to settle, decanting off most of the liquid, and replacing it with distilled water. This procedure is carried out twice a day for about a week until the solution is no longer acid. A recent alternative method devised by E. H. Ahlstrom produces rather good results with less effort than the boiling process. Fairly clean material, free of sand grains, is placed on a cover glass and heated on an electric hot plate at highest heat for about 48 hours. After cooling, the diatoms are ready for mounting.

Cleaned diatoms may be retained in small bottles or envelopes, or they may be mounted immediately. Mounting consists of: (a) allowing a drop of water containing diatom shells to dry on a cover glass; (b) spreading the shells to get various positions in the mount; (c) placing a drop of mounting fluid (balsam, Hyrax, Styrax, etc.) on the cover glass; (d) inverting the cover glass (specimen and mounting fluid down) on a glass slide and pressing slightly; (e) warming the mount gently to remove bubbles in the mounting fluid.

Red Algae, Charas, and Algae Forming Large Colonies. Relatively few fresh water algae are large enough for their form to be distinguished by the unaided eye. Some grow into fairly large jelly-like masses: *Nostoc*, a blue-green, and *Chaetophora*, a green alga, are examples. Others have a definite form of growth which can be preserved by mounting them on paper in much the same way that flowering plants are handled for preservation.

Two red algae mount beautifully. *Batrachospermum*, which is present in many rocky springs before mid-summer, is sticky enough to glue itself to paper. It can be floated out into beautiful patterns in a pan of water. Then, a piece of paper is slipped under it and the plant lifted out with the pattern preserved. *Lemanea*, found clinging to rocks in the foam of dashing streams, is firm and cartilaginous. Its spiney tufts may be taped to a sheet of paper or a card.

Chara and its relatives, the stoneworts, may be handled like *Lemanea*. Stoneworts are peculiar off-shoots of the green algae and are so different from other plants that their relationship is a considerable puzzle. They are pond and lake dwellers, and their "stem," branched at intervals with whorls of "leaves," attain considerable length. The writer has found them over four feet long in Reelfoot Lake, Tennessee.

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This list is intended to be minimal. It includes those publications to which the student may turn when his interest has been aroused and he first resolves to collect and study algae.

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