TAXONOMY AND ECOLOGY OF ALGAE IN PONDS AND LAKES OF THE FLATHEAD BASIN, MONTANA

(Exclusive of the Diatoms)

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

John F. Schindler

1954

This is to certify that the

thesis entitled

Taxonomy and Ecology of Algae in Ponds and Lakes of the Flathead Basin, Montana

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G W Prescott
Major professor

Date Dec. 3, 1954

TAXONOMY AND ECOLOGY OF ALGAE IN PONDS AND LAKES OF THE FLATHEAD BASIN, MONTANA

(Exclusive of the Diatoms)

By

John F. Schindler

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Botany and Plant Pathology

1954

APPROVED: G. W. Prescott

PURPOSE

The purpose of the investigation is to add to the records of Montana algae and to investigate their ecology in a natural area of the state, the Flathead Valley. Collections were taken from two lakes and four ponds during the summers of 1953 and 1954. The identified algae are listed with notes as to habitat; their ecology is discussed; and the environmental data are presented. New forms are included and briefly described, and illustrations are given. Other noteworthy species are also illustrated.

METHODS

Samples were collected once and often twice a week during the months of July and August. Collections were made with a plankton net and by hand collection of algal masses. The algae were then preserved for later study and identification. Camera lucida drawings were made as a record of each of the species, together with measurements for their determination.

DISCUSSION

The physical, chemical, and biological aspects of each habitat are discussed in relation to the algal populations. The total list of plants includes 243 species of which one species and one variety are thought to be new to science.

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ACKNOWLEDGMENTS

To Dr. G. W. Prescott under whose guidance this investigation was undertaken, I wish to express my sincere thanks and appreciation for his inspiration, supervision, and aid. I also wish to thank Dr. Prescott for so generously making his very extensive personal library available to me. Grateful acknowledgment is also due Drs. G. E. Baker and L. F. Potter for their valuable aid in the chemical, bacteriological, and mycological parts of the investigation. I am especially grateful to Wm. C. Vinyard for his suggestions, assistance, and encouragement.

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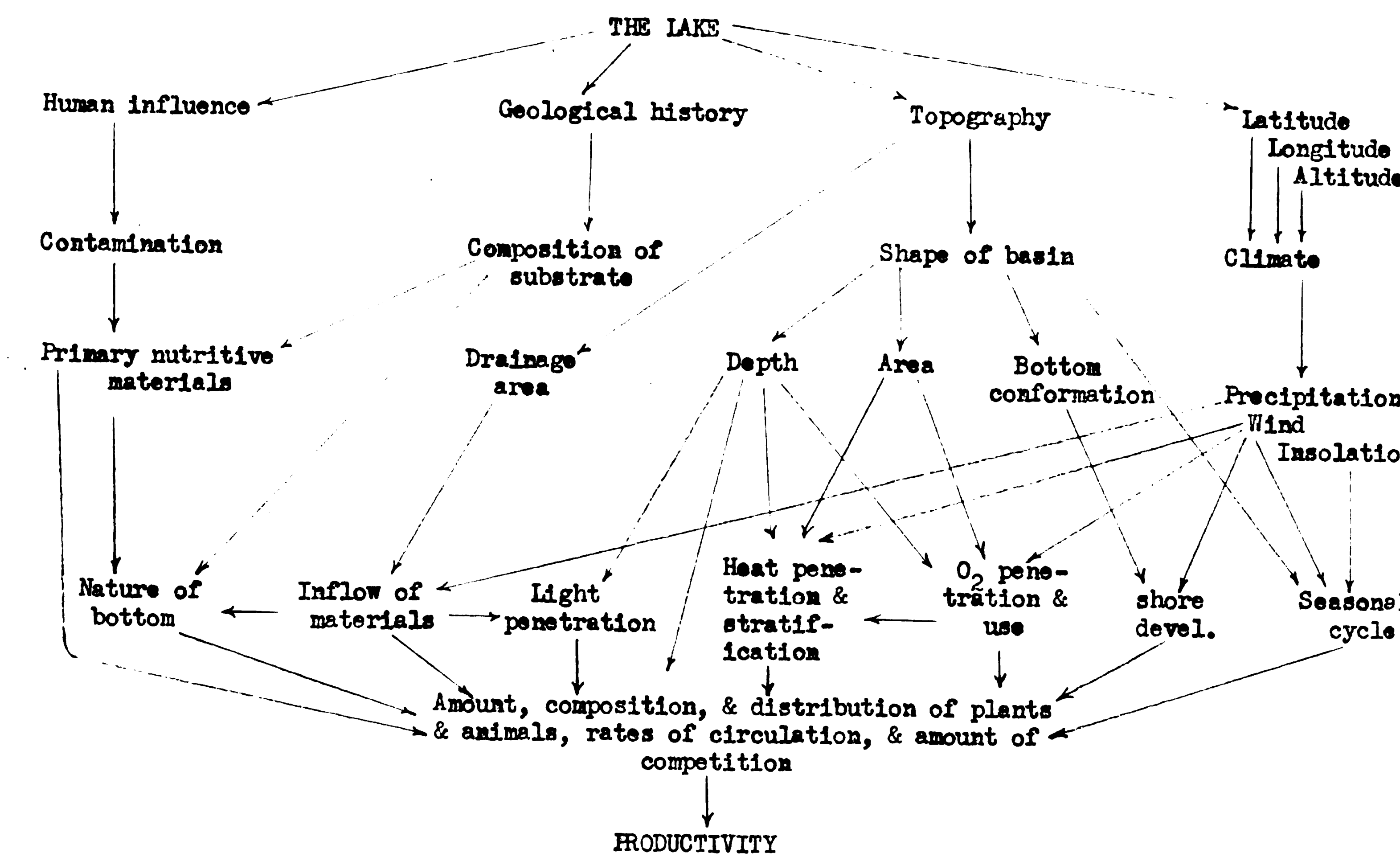
INTRODUCTION

The first published record of Montana algae was that of F.W. Anderson and F.D.Kelsey in 1891 (2). There are a few references of collections from the state since then and there has been only one publication directly concerned with the algae of the Flathead Basin (Lauff, 47). Many workers have done research on the flora of aquatic habitats but few have published ecological notes. One of the earliest publications on algal ecology in the United States was that of Eddy(23) in 1925. It was followed by those of Brown (12), Chambers (14), Hutchinson (37 to 41), Smith (68)(69), and Welch (85). In 1939 the American Association for the Advancement of Science sponsored the publication of a symposium of papers on lake biology which presents a solid foundation for future work in the field (61). Recently, Tiffany (76), Dineen (20), and Prescott (60) have published on the ecology of algae.

The purpose of this investigation is to add to the records of Montana algae and to investigate their ecology, in a natural area of the state, the Flathead Valley. This paper is based upon investigations of two lakes and four ponds in the lower Flathead Valley during the summers of 1953 and 1954. In addition to a study of the algae the project includes analyses of water and of bacterial and fungal populations in relation to the algae. A taxonomic list of algal species from each respective habitat is included. An attempt was made to synthesize the taxonomic and ecological aspects of this investigation in accordance with the views expressed by L. H. Tiffany. He postulates (76), "The large number of forms, varieties, and even species among certain genera of algae may someday be considerably reduced when we are able to evaluate accurately the environment of each algal species."

Figure 1

TROPHIC NATURE OF A LAKE



Modified after Rawson (61).

In the light of this idea, the science of Taxonomy cannot be an isolated study.

A lake is a dynamic cosmos, constantly changing both in content and form as a result of a myriad of interacting external and internal factors. It is a product of the influences of all contributing forces whether great or small. These agents may be divided for purposes of discussion into three realms; the physical, the chemical, and the biological. Nature, however, recognizes no such realms and the interplay between all three is as great as that between the constituents of each realm. An exhaustive study of algal ecology in a lake would include analyses of all factors influencing plant physiology and reproduction, because all agents in a lake determine the algal population both qualitatively and quantitatively. Rawson (61) presented a chart (Figure 1) which suggests the interrelation of the factors which affect the "metabolism" of a lake. He suggests that while the scheme is elaborate it is in no way complete. The plan of the diagram suggests a one-direction influence whereas this is not the case, and perhaps in almost all places arrows could be added reversing the direction of each influence. Also he has made no attempt to show the relative importance of each factor. The chart is presented here to aid the reader in visualizing the maze of relations in a lake before reading the discussions of ecology in subsequent sections.

METHODS AND EQUIPMENT

Qualitative algal samples were collected from the aforementioned six separate bodies of water during the months of July and August in 1953 and 1954. The 1953 collections were made once and often twice a week, all samples being preserved regardless of duplication. The samples collected during the summer of 1954 were preserved only when species new to the investigation occurred. In the ponds and along the lake shores attention was directed primarily to floating and attached forms intermingled with higher vegetation. Wherever possible, tows were taken using a plankton net of No. 20 bolting silk. Where tows were not possible the vegetation was squeezed and the drippings collected in a vial. All samples were preserved for later study in a 6-3-1 solution consisting of six parts water, three parts 95 % alcohol, and one part formalin. At least three microscope mounts were made from each vial, or until no additional species were found. Measurements were recorded for each algal species and a camera lucida drawing was made. A total of 237 species was found, including one species and one variety thought to be new to science.

The samples for water analyses were collected twice during the summer of 1953 and once in 1954. An attempt was made at each time to take the sample from the deepest part of the water, at least one-half meter below the surface. A Kemmerer water sampler was used and four 250 cc bottles were filled, using care not to introduce any gases from the atmosphere during the transfer of the sample. The Winkler method was used for the determination of dissolved oxygen; free carbon dioxide was determined with phenol-phthalein indicator and a sodium hydroxide titration. Both methods are those described by Welch (87). The remainder of the chemical determinations were made with a Hellige Aqua Tester.*

During the summer of 1953 bottom samples were taken with the aid of an Eckman dredge and then investigated for bacteria and fungi. At such times bottom temperatures were taken. Surface water temperatures

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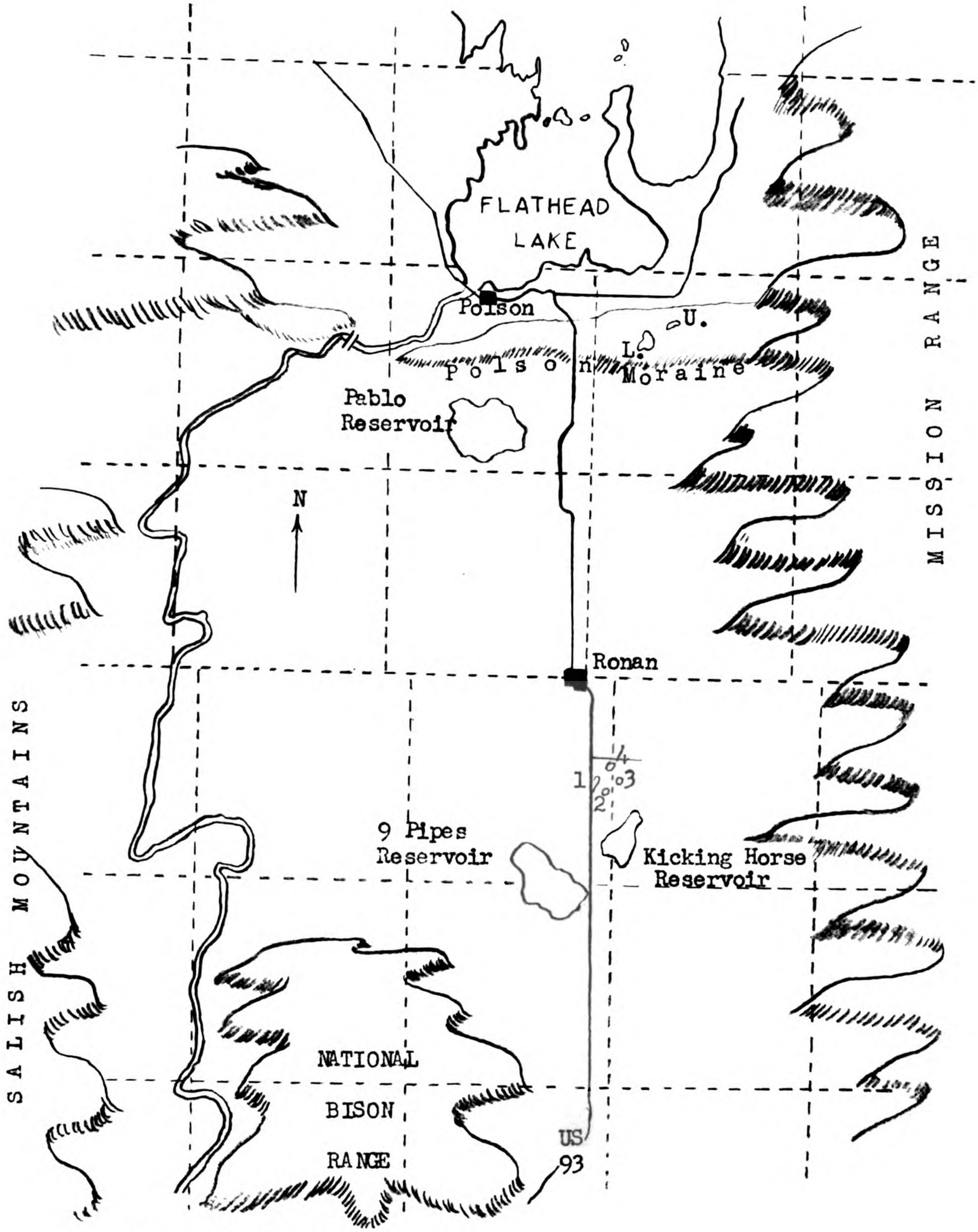
* Hellige Inc., Long Island City, New York.

were also taken with each water sample and at various times throughout the summer. All bacterial and fungal samples were plated on sodium caseinate agar in replicates of five. The water dilutions were: 1:10; 1:100; and 1:1,000. Because of the higher concentrations of individuals in the bottom samples, further dilutions were necessary. The mud dilutions were: 1:1,000; 1:10,000; 1:100,000 and 1:1,000,000. The mud dilution of 1:1,000 was also plated on rose bengal agar. The counts being taken from these plates. Hemp and cellophane cultures also were made from the 1:1,000 mud dilutions.

DESCRIPTION OF THE AREA

The lakes and ponds upon which this study was made are located in the Flathead Valley region of northwestern Montana, directly south of Flathead Lake, along the western slopes of the Mission Mountains (Figure 2). (Lake County, T. 22 N., R. 19 W., sections 17, 18; and T. 20 N., R. 20 W., section 24.) The valley is bounded on the west and south by the Salish Mountains and the hills of the Bison Range. These mountains were formed during the period of the general Rocky Mountain uplift at the close of the Mesozoic period about 60,000,000 years ago. They are composed of sedimentary rocks laid down under marine conditions in the Proterozoic era. Generally the rocks are limestones, shales, and argillites with a few layers of lava (22). They are important in this study because the glacial drift over which these lakes lie was mainly derived from them.

During the Pleistocene epoch this area was extensively glaciated with few peaks above the ice level. The last recession of the ice, 12,000 to 14,000 years ago, is the most important in the present valley



U - Upper Twin Lake
L - Lower Twin Lake
1,2,3,& 4 - Ponds

2½ miles

Figure 2.

Orientation map of the Lower Flathead Valley formation. As the valley glacier receded from an area just north of the Bison Range it deposited a very gently sloping ground moraine. This ground moraine is filled with many shallow depressions formed by melting blocks of ice. Four of these water filled depressions were considered in this study. The northern limits of the ground moraine are found in the Polson Terminal moraine. This moraine was formed while the ice front neither advanced or receded but remained relatively stationary accumulating a considerable drift deposit. It is in two of the swales, characteristic of this topographic feature, that the two lakes in this study were formed.

Though both lakes are found in the same topographic feature, within a short distance of each other, their basins are of slightly different soil types. Upper Twin Lake lies in the steep phase of Lonepine Sandy Loam. This is a rough broken and eroded soil, little suited for agriculture. In this area it has a nitrogen-content of .100 % and a phosphorus-content of .0686 % (20). Lower Twin Lake occupies a basin composed of Milville Loam. This is a hilly soil of chocolate brown gravelly clay overlying a fine sandy loam. At a depth of thirty to thirty-six inches a loose calcareous material occurs. This soil has a nitrogen-content of .150 % and a phosphorus-content of .0563 %. All the ponds are located in what is called Post Clay Loam. It is generally a light-textured soil of open structure and here has a nitrogen-content of .148 % and a phosphorus content of .0922 %.

The climate of the area is considered a cool highland type with moist winters according to Köppen's classification in Trewartha (81). The average annual maximum temperature is 104° F. and the average annual minimum temperature is -27°F. The area receives an average of 14.56 inches of precipitation a year and has a growing season of 138 days. The precipitation averages for the months of the study during 1953 are as follows: June - 2.06 inches; July - .90 inches; August - .91 inches. Although the summer season is short, growth is stimulated by the long hours of daylight peculiar to high latitudes and the greater intensity of sunlight incident to high altitudes. Excessively warm days are usually relieved by cool nights. The length of daylight ranges from a minimum of eight and one-quarter hours in December to sixteen and one-quarter hours in June. The area receives 76 % of the possible amount of sunshine (16). These figures were recorded at the weather station at Polson, Montana, within five miles of the site of this study.

DISCUSSION OF LAKES AND PONDS

As early as 1915 the need for a classification of lakes was realized and Thienemann (74) proposed the two terms, oligotrophic and eutrophic. In the original context they meant respectively, poor in nutrients and rich in nutrients. This original method of classification was generally adopted with the addition of the dystrophic category to include those lakes, in general acid, which were rapidly filling in. With additional work,other criteria of classification were added including amounts of dissolved oxygen and fixed carbon dioxide, depth, stratification, sedimentation, etc. Prescott (60) felt the need for one more classification of lakes and so created a separate category which he entitled bog lakes. In this he included those bodies of water with marginal mats of vegetation and which because of their phytoplankton and chemical composition are not included in the European classification. Welch (86) agrees with this added class and feels that the term dystrophic is rapidly losing it's usefulness. He completed a study in which he proposed the dissolved oxygen ratio between the epilimnion and the hypolimnion as an important criterion. According to Welch, oligotrophic lakes have a greater amount of dissolved oxygen in the hypolimnion than in the epilimnion. The reverse is true in a eutrophic lake. He continues by stressing the belief that one criterion is not sufficient for a classification system, and that many more studies of lake characteristics are necessary. A system of classification based on lake age rather than lake type may be useful. The recognition of a life history of a lake seems necessary at the present, with reference to such stages as very young (extreme oligotrophy), mature (eutrophy), and very old (extreme eutrophy or dystrophy). Just as a person can be in their "teens" chronologically and can be an adult physically so can a lake be a relatively recent formation and yet be "old" morphologically (extreme eutrophy). In this paper, each time a reference is made to a lake classification an attempt will be made to qualify the terminology.

At the beginning of the study a choice of ponds had to be made so that successive visits to the area would always include the same habitats. There is not a great deal of similarity in the general appearance of the ponds and the choice was difficult. A preliminary pH determination on a variety of ponds was made in the field in hopes of finding indications of different chemical conditions. It was on this basis in addition to the differences in the related higher vegetation and upon accesibility that the ponds were chosen.

POND 1

Pond 1 is a small depression partly filled by the roadbed of U.S. highway 93 (Plate XIX). The pond is generally oriented along a north-south axis. It has an approximate length of 135 feet and a width of 65 feet, with a surface area of .18 acres. There is a variation in depth during the year, the deepest point found on July 4, 1953 was 36 inches and on August 15 of the same year the greatest measured depth was 22 inches. Because the main source of water for all these ponds is precipitation and seepage there is an expected annual variation in depth depending mostly on the amount, intensity, and monthly distribution of precipitation. Near the middle of the second summer the greatest measured depth was 15 inches. The pond is generally protected from the action of the wind and is fenced off from cattle so disturbances such as gusts of wind and the introduction of debris come from vehicles on the nearby highway.

Before describing the "chemistry" of the pond it should be stated that the limited character and number of chemical analyses are realized. Generally all water samples were taken at a point thought to be the deepest part of the pond, during the late morning or early afternoon. This correlated with the time of greatest intensity of insolation. The analyses were made for dissolved oxygen and carbon dioxide, hydrogen ion concentration, carbonates, bicarbonates, ammonia, nitrites, nitrates, phosphates, and iron.

In Pond 1 oxygen was found at saturation except in the analysis made on July 18, 1954. On this date the water level was at it's lowest with the oxygen-content at .10 ppm. This condition was undoubtedly a result of the high rate of decomposition at that time. Paradoxically, carbon dioxide was never detected. The incredible nature of this caused the analyses to be suspected and tests were immediately repeated with new samples. The subsequent tests, however, gave exactly the same results. The carbonates as a group were at their lowest in the spring, reaching high concentrations as the summer progressed. On July 18, 1954 the bicarbonate measurement was 234 ppm. The pH showed a very unusual reciprocal correlation with the carbonates during 1953. As the carbonates increased the pH decreased, ranging from 9.0 to 8.0. No confirmed explanation was found for this decrease in pH which was detected in all ponds (See "Discussion" section).In Pond 1 nitrogen was present in small amounts in the form of ammonia, not present in the form of nitrite, and present in the form of nitrate in fairly high proportions (Table I). The phosphates, which are usually more abundant in eutrophic lakes, generally show high concentrations. Dineen (20) reports total phosphorus concentrations of .72 ppm in his study on a Minnesota pond. Since some algae have the capacity to store as much as ten times the amount of phosphorus which investigators report as normal it conceivably cannot be considered critical here unless blocked by some buffering action. The very high iron-concentration readings for this pond also seemed unreasonable and analyses were repeated. The second determination, however, was only slightly lower so the iron therefore must be considered present in great quantities. During 1953 the iron content ranged from 2.2 ppm to 3.0 ppm. The iron here probably occurs in organic compounds and as a colloid. These organic iron sols are very stable and waters may sometimes contain very high amounts even in the presence of dissolved oxygen (66).

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There was a variety of algae in this pond with a total of 100 species. An unusual number of desmid individuals were found, considering the relatively high pH of the pond. They usually occurred , however, away from the shore area which is the zone where blue-green algal concentration was the greatest. It is possible that the number of desmid species is related to the organic acids produced as a result of decomposition. *Scenedesmus incrassatulus* Bohlin *var. mononae* G.M.Smith which has been reported only once (from Wisconsin) was found in this pond. The percentages of the number of species identified in Pond 1 are as follows: *Cyanophyta* - 31 %; *Chlorophyta* - 37 %; *Desmidiaceae* - 19 %; other - 13 %. (Desmids are not included in the Chlorophyta but considered here as a special group because of the selectivity ascribed to them as an index of a type of habitat.)

POND 2

Although Pond 2 is located a short distance from Pond 1 and has the same soil type for it's basin it presents an entirely different aspect. The outline of this pond is almost circular with an average diameter of sixty feet; it has a surface area of .08 acres. The orientation of the pond in relation to the surrounding swales is such that wind disturbance is greater than on Pond 1. Although this pond was not fenced off from cattle the animals were seldom seen here. The greatest disturbance was from a family of muskrats which were constantly swimming and thus kept a large amount of matter suspended in the water, giving it a sallow tan color. This color factor may possibly invalidate the following chemical readings although compensations were attempted during the analyses.

Oxygen was present in amounts sufficient for saturation except on July 18, 1954 during low water-level conditions. Carbon dioxide was never detected in the pond possibly because the vegetation of the pond was consuming all that was available for photosynthesis. The pH again showed an unusual decrease from 9.6 on July 7, 1953 to 8.4 on August 10, 1953. Carbonates in this pond were unusually high and bicarbonates showed a range from 26 to 300 ppm, the low amount occurring on August 10, 1953. Nitrogens as a group were low, the highest concentration being found in the nitrite form. No determinations could be made on July 18, 1954 because of the color of the water. Phosphate-content was even higher than that determined in Pond 1 but iron, although relatively high, was lower than in Pond 1.

The main and almost exclusive constituent of the higher vegetation found in Pond 2 was Ceratophyllum demersum. Furthermore this plant was almost completely free of any epiphytes except members of the Bacillariophyceae. Decomposition in this pond did not seem as active and this was borne out by the fact that the numbers of bacteria and cellulose-digesting fungi were low in comparison to those in Pond 1.

Mention again must be made of the high turbidity of the water, due perhaps to the aforementioned disturbances. Above and about a small colony of Oscillatoria subbrevis Schmidle found growing on the bottom at a depth of three to four inches, the water was surprisingly clear. The clear water actually formed a halo around the patch which conformed to the outline of the colony. It is known that plants are capable of secreting cations and anions (51) and this offers a possible explanation. If Oscillatoria subbrevis is capable of secreting ions then these ions might cause the precipitation of the particles in colloidal suspension, thus clearing the water within the range of effectiveness.

On July 24, 1953 a bloom of Hydrodictyon reticulatum (L.) Lagerheim was discovered. When the next visit was made to the pond, three days later, there were very few traces of the mass growth of this species and only after painstaking search were any plants found. This situation is indicative of the fact that many organisms might be missed in a study such as this if repetitious and almost daily collections are not made.

A total of 43 species were identified from this pond. The number of species gives no indication of the few individuals found and the general poor quality of the algal flora. Of the species identified 13.7 % were members of the Cyanophyta; 48.8 % - Chlorophyta; 30.6 % Desmidiaceae; and 6.9 % were members of other groups.

POND 3

The third pond under consideration in this study was more removed from the highway, about 33 yards north and east of Pond 2. Pond 3 had a maximum length of 125 feet and a width of 100 feet. The total surface area measured .28 acres and the greatest measured depth was 24 inches. The long axis of the pond runs along a north-south line but the waters are generally subject to disturbance by winds from any direction.

This pond lies in a basin composed of the same soil type as for the previously described habitats. The chemistry of the water is similar to that of the other ponds and yet has a few characteristics which distinguish it. Oxygen was always present in large quantities but carbon dioxide was never detected. As in Pond 1 and 2 the carbonates throughout the summer showed a great range of variation, from 433 ppm to 51 ppm.

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Bicarbonates showed a similar decline from July 7, 1953 to August 10, 1953 as evidenced in Pond 2, but the decline here is from 111 ppm to zero. Bicarbonates seem to show the greatest variation in the chemistry of waters of the ponds. Determinations might have been very different if samples had been taken at a different site or even an hour earlier or later from the same site. The pH showed a decline similar to that found in Ponds 1 and 2 as the summer progressed, dropping from 9.6 to 9.2.

Ammonia, nitrites, and nitrates were present in only very small amounts but the population did not seem to suffer from any deficiency. The low nitrogen readings seem plausible because as fast as the Nitrosomonas and Nitrosococcus change ammonia to nitrite the Nitrobacter changed the nitrite to nitrate. In turn the nitrogen was fixed by the Azotobacter present and readily consumed by the autotrophic organisms. Little mention need be made of the phosphate- or iron-content of the waters as they were obviously present in growth-promoting amounts so far as the plant life is concerned.

The higher vegetation of Pond 3 was composed mainly of two species of Potamogeton which grew profusely. This pond, however, had a considerable area of open water near the center which was not the case in the previously discussed ponds.

The bacteria found in this pond had concentrations as high as 232,000 per liter. They cannot be overlooked as they possibly were very important competitors of the algae.

On June 27, 1953 a bloom of Tetraspora lubrica (Roth) C.A.Ag. was found in this pond. It was also short-lived and by June 29 was rapidly disappearing. The short duration of such algal blooms presents many problems in for

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problems in formulating reasons for their occurrence. The large number of individuals of a single species may deplete the waters of the nutrients necessary for it's continued growth. If such becomes the case, the alga, because of it's high numbers, creates a critical condition that causes it's own sudden depletion. If this should be the explanation, however, it would seem probable that a few individuals would survive and occur after the actual blooms or even endure throughout the summer. If the disappearance is a result of chemical change arising from another source this change might be attributable to the normal effects of seasonal and/or climatological factors. Chemical change may result from the algal blooms or the blooms may be induced by chemical change. Also the possibility of light as a factor must be considered. It is known that the activities of higher plants are subject to regulation by the intensity, quality, and duration of light (51). It is probable that algal activities also are subject to the same controls and that blooms are a result of favorable photoperiodic conditions. Pearsall (55) proposes that certain algae produce antibiotics which under "non-blooming" conditions are not able to react on other organisms because the secreted substances are diluted in the surrounding medium. Whereas under bloom conditions an antibiotic may be produced in sufficient concentrations as to be quite effective in limiting the growth of itself and other species. This explanation deserves considerable investigation since the antibiotic Chlorellin has been isolated from Chlorella vulgaris Beyerinck,proving that some algae can produce such growth inhibitors. Thus it is obvious that more than one factor must be studied in attempting to explain the behavior of blooms.

The number of species identified from this pond is almost equal to the number from Pond 2. The number of individuals in Pond 3 was much higher, however, than in Pond 2. Of the species identified from Pond 3, 22.7 % were members of the Cyanophyta; 36.4 % - Chlorophyta; 25.0 % - Desmidiaceae; and 15.9 % were members of other groups.

POND 4

The site of Pond 4 is about one half mile directly north of the other three ponds, and is situated in a basin of the same soil type. The pond is 80 feet long and 60 feet wide with the long axis extending east-west. It has a surface area of approximately .09 acres and a maximum depth of 24 inches (measurement on July 7, 1953). The pond is subject to disturbance by cattle which also frequent Ponds 2 and 3, and like Pond 3 is relatively open to wind action.

The oxygen- and carbon dioxide-contents of this pond are similar to those of the other three. However an analysis on July 18, 1954 showed 2 ppm of carbon dioxide. Also on this date the water level was at it's lowest. The carbonates were low at the beginning of the summer but did not show an increase as in the other ponds. On July 18, 1954 the carbonate determination could not be made because of the water color. The bicarbonates on this date reached a total of 354 ppm. This is similar to the high carbonates found in Pond 3 on the same day. The hydrogen ion concentration was at pH 9.4 at the beginning of the summer and did not show the expected increase as the summer progressed. A value of pH 8.4 was recorded on August 19, 1953 and July 18, 1954. In the nitrogen group ammonia was present in small amounts. Although nitrites were not detected, the concentration of nitrates seemed to remain constant. The activities of the Nitrobacter present may afford an explanation for this condition. Phosphate and iron-compounds were in relatively low concentrations. (See Appendix Table I)

The higher vegetation of this pond was similar to that of Pond 3 in that it was composed mainly of two species of Potamogeton which were restricted to the peripheral zone. The amount of open water in the center of this pond, however, was much smaller. On the northwest edge there was a clump of Scirpus validus and interspersed among the Potamogeton near this colony were a few aquatic individuals of Polygonum natans. The bacteria and fungi of this pond were found in much fewer numbers and not considered to be serious competitors.

No actual bloom was discovered until the water level became extremely low in 1954. On July 24, a haematochrome-producing form, Euglena elongata Schewiakoff became very conspicuous and formed a dusty brick-red film on the surface of the water. Also at this time a curious association was found between Gloeotrichia pisum (C.A.Ag.) Thuret and Gongrosira Debaryana Rabenhorst. The Gloeotrichia was found growing on a few submerged stems and in almost every instance a Gongrosira was found entangled among the blue-green filaments in an intimate association. The pond, as a whole, showed a much higher per cent of blue-green algae, which is more in keeping with the studies that report high Cyanophyta population numbers in ponds with high salt concentrations. The percentage composition of the total number of species identified was as follows: 45 % - Cyanophyta; 38.8 % - Chlorophyta; 12.4 % - Desmidiaceae; and 3.8 % were members of other groups.

UPPER TWIN LAKE

Upper Twin Lake is a small private lake located in the Polson Terminal moraine. It is seldom used for any type of recreation. In a conversation with the owners it was discovered that the lake had been stocked with bass in 1929 and since 1935 had been used rarely. During the study, cattle were found in a field adjacent to the lake on July 19, 1953. Three days later on July 22, Volvox globator Linnaeus was discovered in the plankton samples. This organism is considered an indicator of high nitrogen concentrations. The lake has a length of 735 feet and a width of 335 feet, presenting a surface area of 2.8 acres. It's long axis is along a north-east south-west line and there is enough open water for wind action to influence the lake. However, the surrounding relief is very high and generally only the strong orographic winds, characteristic of mountain regions, affect the lake. Morphologically the lake has the appearance of an oligotrophic-type lake, with steep gravelly banks and a measured depth of 21 feet. The chemical analyses of the waters of this lake also indicate oligotrophic conditions. The waters had a very high oxygen-content, well over saturation (Table 1). This was due perhaps to a bed of Chara sp. which covered the bottom near the shoreline. Carbon dioxide was not detected but the amounts of carbonates and bicarbonates were surprisingly high. The maximum concentration found for carbonates was 67 ppm on July 18, 1954. The pH ranged from 8.4 to 8.9. The higher reading was correlated with the high bicarbonate measurement. The nitrogens as a group were poorly represented with the highest concentration appearing in the nitrate form. On the same date as the above readings were taken, nitrates were measured at .03 ppm. Phosphorus and iron were not detected. The 1954 analysis showed a trace of iron, indicating that it's absence probably was due to the insensitivity of the methods used to detect minute quantities of the nutrients. Such trace elements should not be considered critical because of the small amounts required by plants.

The algal, fungal, and bacterial populations were lowest in number of individuals and diversity of species of all lakes investigated. The most prominent member of the aquatic vegetation (excluding Chara sp.) was Rhizoclonium crassipellitum W. and W. and even this form was found only intermittently throughout the time of observation. The paucity of individuals and of species, and the chemistry of the water indicate that a lake can be chronologically young and still have a high amount of carbonates present. Of the species identified, which totaled only 18, 22.2 % were members of the Cyanophyta; 61.6 % Chlorophyta; 5.1 % Desmidiaceae; and 11.1 % - Dinophyceae.

LOWER TWIN LAKE

Lower Twin Lake is located about one quarter-mile south-west of Upper Twin Lake and although evidently of similar origin, it is a completely different habitat. It is primarily used as a reservoir for irrigation waters and secondarily for recreational purposes. The lake was never found deserted of vacationers on any visit during the investigation. It's use as a reservoir subjects the lake to great variations in water level. During the summer of 1953 the level dropped eight feet within a two day period, and exposed a considerable amount of bottom, thus changing the outline of the lake. The water is generally exposed to wind action from all directions. The prevailing wind action is parallel to the length of the lake. The lake measures 1,970 feet by 1,820 feet and has a surface of 24.2 acres during high water periods. Surface area is reduced to 13.2 acres during extreme low water periods. The deepest measured depth was 15.4 feet on July 14, 1953. The lake is fed by two inlets, one an irrigation ditch entering on the north bank and the other a natural stream entering on the extreme east. Both inlets derive their waters from springs and streams of the Mission Mountains just to the east. These waters may have different chemical constituents from those of the waters which feed Upper Twin Lake because of their origin, and thus explain the attributes of this lake which are more eutrophic than those of Upper Twin Lake.

Before presenting the water analyses of this lake it should be pointed out that when the analyses were made on July 14, 1953 and July 18, 1954 the lake had a high water level. The second analysis of 1953 on August 12 was made when the lake had a low water level.Oxygen was always present in high amounts when the analyses were made but was as low as 6.0 ppm during periods of low water. Carbon dioxide was present in higher quantities when the oxygen-concentration was low. Decomposition was rapid at these times among those plants stranded in shallow water along the lake's margin. The pH ranged from 7.9 to 8.8. In both high water periods the pH was 7.9. The nitrogen group was poorly represented for so productive a lake. Nitrogen was present once in the form of ammonia (.05 ppm on July 18, 1954), and was detected in the nitrate form in all three analyses. Phosphorus and iron were not found. Extreme variations in the analytical results were expected because of the rapid water level fluctuations.

The higher vegetation of the lake included many terrestrial species because of the flooding of the shore during high water. Eleocharis sp. was commonly found along the lake margin. Blue-green algae were normally present, attached to, or entangled among the littoral vegetation. No plankton bloom was encountered on the lake as a whole. A local bloom of Botrydiopsis arhiza Borzi was discovered on July 23, 1953 in a small sheltered embayment. It was not found on the succeeding visits. Members of the Conjugales became more evident after the rapid decrease in water level. The filamentous genera such as Spirogyra sp. and Mougeotia sp. formed great floating masses near the shore line.

In general, the most consistently present species were those of the Cyanophyta with a wide variety of other forms appearing and disappearing. Of the algal species identified 35.2 % were members of the Cyanophyta; 39.6 % - Chlorophyta; 23.3 % - Desmidiaceae; and 2.9 % were members of other groups.

GENERAL DISCUSSION

A discussion of aquatic ecology cannot easily be directed toward any one aspect. An aquatic community is an expression of the physical, chemical, and biological components of the environment. These three groups of factors are intimately interdependent and any variation in one affects the others. (Figure 3) For example: The geological location of a pond determines the angle and amount of sunlight reaching the waters. The angle of incidence determines the amount of insolation absorbed and reflected. The absorbed insolation affects the rate of biological activities such as photosynthesis. These processes make

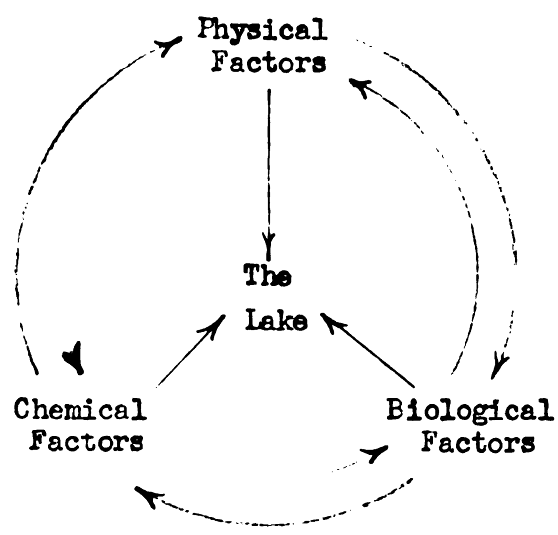

Figure 3.

corresponding changes in the chemical nature of the water. Thus geographic position may affect the chemical composition of the water, directly or indirectly. This chain of relationships has not taken into consideration such modifying factors as wind, water turbidity, available nutrients, and numerous others. Any one of these is equally important in determining the changes reflecting the variation of a single influence. "Factors vary in intensity, but they always vary in the presence of all other determiners of the environment. No one factor ever operates alone." (25) The agents influencing the relations between a plant and it's environment are many and they lead to ramifications which are all the more complex when the diversities of flora and fauna are considered.

Each lake is an individual entity (58). The characteristics of a lake are largely based upon or related to the surrounding physiographic features. The evolved state of the lake is a reflection of the duration and rate of operation of various factors on the physiography. The distribution of lake types or habitat types accounts in part for the distribution of aquatic plants. Algal species may possess wide geographical distribution but do not necessarily occur wherever a suitable environment occurs. An ecological study must first recognize the possibility that the algal form is not present because it's disseminules have not reached the habitat. Any correlations which might be made involving algal habitat preference, should be made with the presence of the alga and not it's absence.

Silva and Papenfuss (67), in their study on sewage oxidation ponds in California report, "There is no variation in the composition of the algal flora of these ponds that can be correlated to geographical distibution." The report emphasizes that their study includes a restricted area, the state of California, and infers that algal distribution per se does exist. Conversely Ström (73) states that all species have one characteristic in common; "...that they do not possess any sharp distinct geographical distribution. They occur where their claims upon the habitats are fulfilled." This view seems to imply that evolution has ceased and does not allow for the dynamic change which is characteristic of all life.

The physical form of a lake is important in determining it's bios. It seems evident from the accumulated data that Upper and Lower Twin Lakes are definitely different types. Both lakes were formed at the end of the Pleistocene epoch, so they are the same age chronologically. They are fed by waters from the same watershed and receive their nutrients from the same type of basin. Yet Lower Twin is a "good productive lake" and Upper Twin is a "poorly productive lake". The bottom of Lower Twin Lake is characteristic of a productive lake, being moderately silted, with relatively gentle slopes that form a shallow basin (65). These lakes developed at different rates because of the original configuration of their basins. The small area of shallow water in Upper Twin Lake encourages only a moderate amount of plant growth. The presence of a suitable substratum is very important in determining the flora. The chemical nature of the water may be suitable for a species but if the proper substratum is not present, growth of attached and benthic forms will not appear. Godward (31) investigated the flora of Lake Windemere by setting glass slides near the bottom to determine what forms grew at various depths. These glass slides were colonized by algae which had not been reported from the lake. Investigations of bottom samples did not show the presence of these colonials. Godward inferred that the appearance of these colonies depended on the presence of a suitable substratum. Along the shores, in or out of the waters of Lower Twin Lake Nostoc verrucosum Vaucher was often found and although the waters of Upper Twin Lake were similar in chemical composition and provided the aquatic habitat reported to be suitable for this species it did not occur. In this case it seems that the form preferred the recently inundated shores of the lower lake as a substrate, perhaps as a source of nutrients. The absence of the species in the upper lake however, is not definite proof that the environment would be unfavorable were the plant introduced.

Although secondary in importance to geographical and geological influences, heat and light are critical in as much as they have direct influences on both the daily and seasonal metabolic activities of the phytopopulation. Temperature undoubtably is closely correlated with light so that the response of algal growth to these factors is a complex function (62). The rapid increase of algal individuals in the spring is often correlated with an increase in light (4)(5)(12). The general rate of biological processes such as photosynthesis, however, doubles with an increase of 10 degrees C. temperature (within limits)(67). This study does not cover a sufficient period of time to permit correlation of light with the quantitative development of algal forms. The decrease in amount of insolation after the summer solstice (June 21) was believed compensated by the change in amount of temperature or some other factor.

A definite zonation of algal forms was observed. The very shallow waters which were subject to intense amounts of insolation were usually inhabited solely by members of the Cyanophyta. Other algal forms were found in water deeper than four inches, away from the immediate shore area. In the case of floating masses of certain Conjugales it was noticed that only the submerged members, which were growing in the shadow of those on the surface, had a healthy green appearance. Smith (69) reports that although light is essential for the growth of algae, intense light may not be favorable. He made attempts to grow algae under cultural conditions and frequently found it necessary to place them in diffused light because they were killed by the direct rays of the sun. Fritsch(26) suggests that the great predominance of Cyanophyta in the tropics may be due to a protection of the green pigment from intense light by the blue pigment.

Perhaps one of the most controversial subjects in aquatic ecology is the importance of the concentration of hydrogen ions. Changes in pH can be correlated with seasonal changes in phytoplankton (58) and many other algal activities. It is not known whether these changes are a true function of pH. Hydrogen ion concentration is merely an expression of other chemical conditions and interactions and *per se* has little effect on the composition of algal forms. G.E.Hutchinson strongly expresses similar views.

> "Owing to the supposed ease with which the concentration of hydrogen ions can be determined by dropping solutions of dyes into water samples, pH became a fashionable symbol. It is however, exceedingly doubtful if more than a single case has been brought forward demonstrating unequivocally that the natural variation in numbers of any species of plant or animal is due to a variation in pH." (39).

Wehrle (84) however, reports that the algae of the ponds in Germany were restricted within limits to three general ranges of pH. It seems therefore that whereas pH may not have a direct effect on the composition of the flora, it is somewhat indicative of the conditions which do determine distribution and occurrence.

In the lakes of this study an increase in pH was noticed as the summer progressed and the amount of vegetation in relation to the volume of water increased. Prescott (58) reports similar pH conditions with increased growth in his study on the phytoplankton of lakes. He found conductivity less with the consumption of electrolytic salts and a rise in pH with the precipitation of carbonates. This is supported in part by the experimental work of Ludwig, Oswald, and Gotaas (47)(48)(67). In bacterial and other heterotrophic metabolism, carbon dioxide and ammonia are evolved and various organic acids are formed. Some of the carbon dioxide unites chemically with the water and depresses the pH;

(1) $$CO_2 + H_2O \longrightarrow H^+ + HCO_3^-$$

the ammonia on the other hand increases the pH as follows:

(2) $$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

The occurrence of the first reaction is much more frequent than that of the second reaction and the organic acids decrease the pH. The algae during photosynthesis, remove carbon dioxide from the water, reversing equation one, and increasing the pH. In protein synthesis the algae directly or indirectly remove ammonia from the water reversing equation two and thus decreasing the pH. The occurrence of the first equation is again more common than that of the second and the net effect is to increase the pH. The relative magnitude of the net effect depends on the initial pH and the total alkalinity (67). In the ponds of this study a pH decrease was noted during the summer, and this was believed to be the effect of the bacterial decomposition (equation one) and the slower rate of algal photosynthesis.

Silva and Papenfuss (67) state: "The dissolved oxygen-content of the water probably has little or no effect on the composition of the algal flora except when the oxygen is totally depleted." The determinations made during 1953 and 1954 for the ponds and lakes of this study (Table I) show the dissolved oxygen-concentration ranging from .1 ppm to 12 ppm. These determinations were made around 11:00 A.M. when photosynthesis is at it's peak and the dissolved oxygen is often far above the saturation value (30)(72). No tests were made at night but it is probable the oxygen was depleted just before dawn in all ponds. The lack of dissolved oxygen therefore may have been critical. Fritsch (26) suggests that low dissolved oxygen-content over a long period appears to encourage filament formation. None of the ponds of this study were sufficiently low in dissolved oxygen to merit calculating the percentage of the forms identified which were filamentous.

In shallow waters, which are characteristic of the ponds of this study, carbon dioxide is perhaps the most important critical factor during the day (13). In the analyses of the waters, carbon dioxide was detected only rarely, however there was an abundance of dissolved carbonates. Dissolved carbonates increase the supply of carbon dioxide for plant use either directly or indirectly. Directly it is supplied by the half-bound carbon dioxide in the bicarbonates and indirectly from the monocarbonates which take up more carbon dioxide from the air than would be absorbed by the water without their aid (11)(14). Also the monocarbonates take up the carbon dioxide which is liberated by respiration which proceeds day and night and which otherwise would escape into the atmosphere. Because the concentrations of monocarbonates and bicarbonates in all these ponds seem sufficient to support enormous growths, the lack of free carbon dioxide was discarded as a critical factor. It's absence however, may have exercised some influence over the variety of species present. Those species generally present in habitats where there were waters with high concentrations of dissolved monocarbonates and bicarbonates were:

Pandorina morum (Muell.) Bory
Eudorina elegans Ehrenberg
Gloeocystis ampla (Kuetz.)Lagerh.
G. gigas (Kuetz.)Lagerh.
Apiocystis Braunii Naegeli
Scenedesmus bijuga (Turp)Lagerh.
Closterium moniliferum (Bory)Ehrenberg
Cosmarium Botrytis Menegh.
C. Botrytis var. mesoleium Nordst.
Ceratium hirundinella (Muell.)Dujardin
Oscillatoria limnetica Lemmermann
Nostoc paludosum Kuetz.

Chambers (14) found by cultural studies that the amount of photosynthesis was proportional to the concentration of bicarbonates present in the water. In distilled water, free from carbonates but saturated with carbon dioxide, photosynthesis was very slight. Bicarbonate concentrations were high in all determinations made in this study and the carbonates therefore were considered to be present in excess of a critical amount.

Often when making the collections it was noticed that many algal forms, especially some members of the Cyanophyta, were encrusted with layers of calcium carbonate. The explanations offered for this are twofold. The algae are capable of converting bicarbonates to monocarbonates by the following process and thus utilize the freed carbon dioxide (14).

$$Ca\ (HCO_3)_2 + O_2 \rightarrow H_2O + CaCO_3 + CO_2 + O_2$$

As the carbon dioxide is absorbed by the plants, carbonates are precipitated on those parts of the stems and leaves extracting the gas. If the proportion of calcium bicarbonate in the solution is so small that it would not be deposited by the photosynthesis activity of the plant then the precipitation is explained by the oxygen set free during photosynthesis.

In discussing the importance of the concentration of nitrogenous salts, Pennington (56) states:

> "Living systems, algae and bacteria in ponds, are capable of producing nitrate from ammonia and ammonia from nitrate. It appears to be immaterial to the flora in which form nitrogen is present in the water."

According to this theory the nitrogen supply is not critical if it is present in optimum concentrations regardless of the form in which it occurs. It is probable however, in waters where the ratio of ammonia to nitrate is low, variations in the ability of plants to use nitrate effectively may be of importance in regulating competition(35)(39)(92). Apparantly but little research has been concerned with the preference of the individual species for the form in which nitrogen is obtained. In all the ponds and lakes of this study, nitrogen is available in one form or another (Table I). Pearsall (53) has indicated that the Cyanophyta appear to favor the types of water rich in organic substances, the presence of nitrogen possibly being conducive to their growth. In the ponds of this study a correlation can be drawn between the presence of blue-green algae (Quantity and number of species) and the concentration of a form of nitrogen. In view of the studies which report nitrogen fixation by Cyanophyta members (1)(56)(58) this is not a cause-effect correlation. The algal form may be growing in the water because of the favorable nitrogen concentration or the nitrogen concentration may be a result of algal fixation in the presence of favorable carbohydrate concentrations.

The dissolved phosphates and iron compounds of all the ponds were found in relatively high concentrations. The algal populations in these ponds, except for Pond 2, were large both in numbers of species and individuals. Atkins and Harris (5) in their pond study state that they found the supply of phosphates depleted by vernal blooms which set a limit on further growth. This possibly might be the situation in Upper Twin Lake. Phosphates, however, were not detected in the waters of Lower Twin Lake which supported a relatively profuse algal flora. It is not impossible that the phosphorus readings of this study were due to a lack of sensitivity of the chemical methods used.

The necessity of iron for plant growth is well known (61), but it's actual physiological role is still uncertain (65). It probably acts as a catalyst in the formation of chlorophyll and possibly may be involved in respiratory activities. The form in which iron is present in the water is uncertain. In the ponds of this study it was present in concentrations as high as 3 ppm with no apparent detrimental effects on the algal flora. In simple ionic form iron is practically insoluble at the pH normally encountered in fresh water (66). Suspended and colloidal ferric hydroxide and organic colloidal compounds are probably always available. The iron in these ponds may well be present as ferric hydroxide in the form of bacterial sheaths.

Because of the limited amount of chemical data obtained from studies such as this, it is possible only in a few instances to draw conclusions concerning the ecology of the species. The danger of making generalities from such limited cases is admittedly great, for they might be misleading if not meaningless. The importance of the following quotation is realized.

> "It cannot be overemphasized that to discuss the effects of environmental factors in this or that group of organisms, or this or that genus, leads only to meaningless generalities. It is necessary to recognize that ecological and limnological studies of phytoplankton should be based on species adaptation only. Much of our literature is not as helpful as it might be on account of the failure to reduce phytoplankton ecology to a study of the species."
>
> Prescott (58).

When discussing the limiting factors, especially those discerned by cultural studies, it must be remembered that the actual range within which a critical factor operates is not fixed under natural conditions. It's level is primarily dependent on the individual requirements of the organism in question but it is also affected by the environment. Rodhe (62) states, "For each limiting factor there exists a potential (absolute) optimum and an actual (relative) optimum." This actual optimum is the limit controlled by the availability of the nutrient and by biological competition.

In Ball's (7) experiments on a fertilized lake he reports that the massive application of a fertilizer in shallow water during a period of hot weather and slight wind disturbance resulted in an increase in filamentous forms. Once established these forms did not show the intense fluctuations observed in plankton populations. These experiments indicate filamentous forms,once established, hold a biological advantage over the plankton forms in cases of restricted nutrients.

It is evident when studying water blooms, that only under intense growth conditions is spatial crowding probable. During the time of normal amounts of illumination the addition of nutrients to the water in the form of fertilizer will increase the algal crop (39), indicating that biological competition for nutrients is of prime importance. Often the source of nutrients is believed to be the basin itself. The production of nutrients is also a function of the bacteria and fungi in the waters and mud of the pond or lake. Bacteria are the most prominent organisms of the periphyton (i.e. aquatic organisms which grow attached to submerged surfaces.)(36). Henrici states that there is much evidence that the bacteria in waters for the most part are not free-floating, but are attached to algae and other plankton organisms. The great abundance of bacteria in bottom deposits is due in part to the fact that they are carried there by the sedimentation of these larger organisms. The heterotrophic bacteria then decompose the proteins of the larger organisms and eventually the nitrogen is liberated in the form of ammonia (36)(67). This physiological function of bacteria is their most important role in the economy of lakes. In this manner the bacteria link the ends of the nutrient chain and convert it into a cycle.

The bacteria have assistance from the fungi in the decomposition of organic matters. Because of their ubiquity, their rapid multiplication, and their versaitility as biochemical agents (8), the fungi are also very important in lake biology. Fungi are common, extensive, and often destructive parasites on the plant life of fresh waters. Occasional serious epidemics have been reported, chiefly on algae such as diatoms, desmids, and other plankton forms significant in aquatic ecology(91). In the ponds investigated four of the genera identified have been reported as parasitic on algae and other aquatic plants (8)(71). These are: Coniothyrum sp., Cephalosprorum sp., Fusarium sp., and Phoma sp."Many fungi are capable of the breakdown of silicon"(91). It is not unreasonable to suppose that a large population of fungi such as that found in Ponds 1 and 3 would have an inhibiting effect on algal growth.

SUMMARY

1. The algal ecology of four ponds and two lakes in the Flathead Valley, Montana was studied from June 23 to August 10 during 1953 and 1954.

2. Only qualitative methods were used in the study except those used in the investigation of bacterial and fungal populations. Collections were made with a plankton net, by squeezing higher vegetation, and by hand collection of algal masses. The algae were then preserved for later identification.

3. Chemical analyses of each body of water were made at least 3 times.

4. The physical, chemical, and biological aspects of each habitat have been discussed in relation to the algal population.

5. A total of 243 species are listed including one species and one variety believed to be new to science.

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APPENDIX

TABLE I

CHEMICAL ANALYSES OF WATER

	Ronan Pond 1 July 4, 1953	Ronan Pond 1 Aug. 10, 1953	Ronan Pond 1 July 18, 1954	Ronan Pond 2 July 7, 1953	Ronan Pond 2 Aug. 10, 1953	Ronan Pond 2 July 18, 1954
Depth (in.)	36	22	15	24	19	17
Temp. (°C.)						
Surface	18	15	15	22	17	21
Bottom	-	13	-	-	16	-
O_2 ppm	5.50	2.40	0.10	7.50	12.0	0.10
CO_2 ppm	0.00	0.00	0.00	0.00	0.00	0.00
CO_3 ppm	29.2	8.0	46.0	201.4	402.8	249.0
HCO_3 ppm	37.3	160.0	234.0	299.5	26.0	117.6
pH	9.0	8.0	9.1	9.6	8.4	9.5
NH_3	0.10	0.05	0.07	0.10	0.30	0.0?
NO_2 ppm	0.00	0.00	0.00	0.14	0.00	n.d.
NO_3 ppm	0.06	5.00	n.d.	0.80	0.80	n.d.
PO_4 ppm	1.00	4.00	1.00	0.60	1.80	12.0
Fe ppm	2.20	3.00	2.20	0.60	1.80	n.d.

n.d. - indicates no determination

TABLE I (Continued)

	Ronan Pond 3 July 7, 1953	Ronan Pond 3 Aug. 10, 1953	Ronan Pond 3 July 18, 1954	Ronan Pond 4 July 7, 1953	Ronan Pond 4 Aug. 10, 1953	Ronan Pond 4 July 13, 1954
Depth (in.)	24	24	19	24	17	15
Temp. (°C.)						
Surface	20	18	21	20	15	19
Bottom	-	17	-	-	14	-
O_2 ppm	5.0	1.0	5.0	3.0	2.0	1.0
CO_2 ppm	0.0	0.0	0.0	0.0	0.0	0.0
CO_3 ppm	270.6	473.0	51.0	96.0	18.4	n.d.
HCO_3 ppm	111.4	0.00	300	69.0	79.6	354
pH	9.6	9.2	9.0	9.4	8.4	8.0
NH_3 ppm	.05	.05	0?	0	.12	.12
NO_2 ppm	.001	0	0	0	0	0
NO_3 ppm	0.4	0.4	n.d.	0.24	0.24	n.d.
PO_4 ppm	6.0	5.0	10.0	1.0	0	2.0
Fe ppm	.60	.50	n.d.	.40	.80	n.d.

n.d. - indicates no determination

TABLE I (Continued)

	Upper Twin L. July 14, 1953	Upper Twin L. Aug. 12, 1953	Upper Twin L. July 15, 1954	Lower Twin L. July 14, 1953	Lower Twin L. Aug. 12, 1953	Lower Twin L. July 18, 1954
Depth (in.)	258	206	224	185	96	96
Temp. (°C.)						
Surface	23	22	23	23	20	22
Bottom	-	19	-	-	16	-
O_2 ppm	11.0	11.0	12.5	9.0	6.0	9.5
CO_2 ppm	0	0	0	0.2	0	1.0
CO_3 ppm	11.6	10.0	8.0	0.0	8.4	0.0
HCO_3 ppm	39.7	36.0	67.0	11.8	40.8	24.0
pH	8.4*	8.5	8.9	7.9	8.2	7.9
NH_3 ppm	0	0	.01	0	0	.05
NO_2 ppm	0	0	0	0	0	0
NO_3 ppm	.02	.02	.03	.03	.02	.02
PO_4 ppm	0	0	0	0	0	0
Fe ppm	0	0	trace	0	0	0

n.d. - indicates no determination
* - calculated pH 8.3

TABLE II.

BACTERIA ISOLATED FROM MUD AND WATER SAMPLES

	BACTERIA	ACTINOMYCETES	% of CHROMOGENS	NITROSOMONAS & NITROSOCOCCUS	NITRO-BACTER	AZOTO-BACTER
	(per cc H_2O) (per gm mud)					
Ronan Pond 1 (water)	18,000	0	44	*		*
Ronan Pond 1 (mud)	98.0 M	.02 M	35	*	*	*
Ronan Pond 2 (water)	10,600	0	30	*	*	*
Ronan Pond 2 (mud)	7.9 M	.82 M	33	*	*	*
Ronan Pond 3 (water)	232,000	0	71	*		*
Ronan Pond 3 (mud)	7.7 M	.16 M	37	*	*	*
Ronan Pond 4 (water)	6,700	0	53	*		*
Ronan Pond 4 (mud)	0.99 M	.27 M	36		*	*

M - million

* indicates presence

TABLE II (Continued)

	BACTERIA (per cc H_2O) (per gm mud)	ACTINOMYCETES	% of CHROMOGENS	NITROSOMONAS & NITROSOCOCCUS	NITRO-BACTER	AZOTO-BACTER
Lower Twin L. (water)	960	0	43	*		*
Lower Twin L. (mud)	.086 M	.003 M	26	*		*
Upper Twin L. (water)	530	0	19		*	*
Upper Twin L. (mud)	.05 M	0	32			*

M - million

* indicates presence

NOTE: All plating done in replicates of five.
Water dilutions: 1:10; 1:100; & 1:1,000.
Mud dilutions: 1:1,000; 1:10,000; 1:100,000; & 1:million.
Agar: sodium caseinate.

TABLE III

FUNGI ISOLATED FROM MUD AND WATER SAMPLES
(POPULATION COUNTS)

	Sodium caseinate agar cultures		Hemp & Cellophane cultures		
Station	Number/ml H_2O	Number/gm mud	H_2O Molds	Chytrids	Cellophane Digestion
Ronan Pond 1	0	17,000	-	*	*
Ronan Pond 2	0	15,000	-	-	-
Ronan Pond 3	0	27,000	-	*	-
Ronan Pond 4	0	11,000	-	-	-
Lower Twin L.	14	1,600	-	-	-
Upper Twin L.	0	0	-	-	-

* indicates presence

NOTE: All plating done in replicates of five.
Water dilutions: 1:10; 1:100; & 1:1000.
Mud dilutions: 1:1000; 1:10000; 1:100000; 1:million.
Agar: Sodium caseinate; mud dilutions of 1:1000 also done with rose bengal agar. Mud counts made from rose bengal agar plates. Hemp and cellophane cultures made with 1:100 mud dilutions.

TABLE IV

GENERA & SPECIES of FUNGI IN BOTH MUD AND WATER

	Ronan Pond 1.	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Lower Twin L.	Upper Twin L.
Alternaria	*		*	*		
Cephalosporium 1.	*			*	*	*
Cephalosporium 2.	*	*	*	*		
Chaetomium 1.		*				
Chaetomium 2.			*	*		
Coniothyrium	*	*	*	*		
Fusarium				*		
Gliocladium	*					
Penicillium 1. (green)	*		*	*	*	
Penicillium 2.	*	*	*		*	
Penicillium 3.				*		
Penicillium 4.			*			
Phoma					*	
Spicaria	*	*		*		*
Sporotrichum		*				
Stilbella		*	*	*		
Thielavia	*					
Trichoderma		*				
Trichosporium						*
Cleistothecial sp.			*		*	
Myc. Sterila					*	
Unidentified			2			
Total / Station	10	7	10	10	7	2

TABLE V

LIST OF ALGAL SPECIES FOUND IN THIS STUDY WITH COLUMNS INDICATING IN WHICH PONDS AND LAKES THEY WERE PRESENT

	Roman Pond 1	Roman Pond 2	Roman Pond 3	Roman Pond 4	Upper Twin Lake	Lower Twin Lake
CHLOROPHYTA						
Volvocaceae						
Pandorina morum (Muell.) Bory Pl. I.	x	x	x	x		x
Volvox globator Linnaeus				x	x	x
Eudorina elegans Ehren.		x	x	x		
Palmellaceae						
Sphaerocystis Schroeteri Chodat. Pl. I.	x	x				
Gloeocystis ampla (Kuetz.)Lagerh.	x	x	x			x
G. gigas (Kuetz.)Lagerh. Pl. I.	x			x	x	x
G. vesiculosa Naegeli	x		x			
G. major Gerneck ex. Lemmermann		x				
Palmodictyon viride Kuetz.						x
Tetrasporaceae						
Apiocystis Braunii Naeg. Pl. I.	x	x	x	x		
Tetraspora lubrica (Roth) C.A.Ag. Pl. I.			x	x		
Schizochlamys gelatinosa A.Braun in Kuetz. Pl. I.					x	
Elakotothrix viridis (Snow) Printz.						x

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Ulotrichaceae						
Ulothrix zonata (Weber & Mohr) Kuetz. Pl. II.				x		
U. variabilis Kuetz. Pl. II.				x		
Geminella crenulatocollis Prescott Pl. II.	x					
G. interupta (Turp.)Lagerh.						x
G. mutabilis (deBréb.) Wille	x				x	x
Microsporaceae						
Microspora pachyderma (Wille) Lagerh.						x
M. stagnorum (Kuetz.) Lagerh. Pl. II.	x					
M. tumidula Hazen Pl. II.		x				
Sphaeropleaceae						
Sphaeroplea annulina (Roth) C.A.Ag. Pl. II.						x
Chaetophoraceae						
Aphanochaete repens A.Braun. Pl. III.				x	x	
Chaetophora incrassata (Huds.) Hazen Pl. III.						x
Stigeoclonium polymorphum (Franke)Heering Pl. II.		x	x			

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Stigeoclonium stagnatile (Hazen) Collins		x				
S. tenue (C.A.Ag.) Kuetz. Pl. II.		x	x			
Draparnaldia plumosa (Vauch.) C.A.Ag. Pl. III.						x
Coleochaetaceae						
Coleochaete orbicularis Prings. Pl. III.				x		
Gongrosira Debaryanum Rabenh. Pl. IV.				x		
Chaetosphaeridium globosum (Nordst.)Klebahn Pl.III.						x
Cladophoraceae						
Cladophora insignis (C.A.Ag.) Kuetz.	x					
Rhizoclonium crassipellitum W. & W. Pl. IV.				x	x	
R. hieroglyphicum Kuetz. Pl. IV.					x	
Oedogoniaceae						
Bulbochaete insignis Pringsheim Pl. IV.						x
Oedogonium angustum (Hirn) Tiffany	x			x		
Oe. sociale Wittr. Pl. IV.				x		x
Oe._______new species Pl. V.						x

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Oedogonium Magnusii Wittr. Pl.IV.				x		
Oe. Borisianum (LeCl.) Wittr.				x		
Oe. aerolatum Lagerh.						x
Oe. crispum (Hass.) Wittr.Pl.IV.	x					
Oe. gracilius (Wittr.) Tiffany Pl. IV.				x		
Oe. multisporum Wood.						x
Oe. verrucosum Hallas	x					
Oe. paludosum (Hass.) Wittr. var.parvisporum Hirn.						x
Characiaceae						
Characium ambiguum Herman	x					
C. gracilipes Lambert	x			x		
C. Hookeri (Reinsch.) Hansg.	x			x		
C. obtusum A.Braun.				x		x
C. Rabenhorstii DeToni	x		x	x		
C. rostratum Reinhard ex Prinz				x		
C. stipitatum (Bachm.) Wille	x		x			x
Hydrodictyaceae						
Hydrodictyon reticulatum (L.) Lagerh. Pl. V.		x				
Sorastrum spinulosum Naeg. Pl. V.	x					x

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Pediastrum biradiatum Meyen	x					
P. Boryanum (Turp.)Menegh.		x				x
P. duplex Meyen Pl. V.	x			x		
P. Kawraiskyi Schmidle						x
P. tetras (Ehrenb.)Ralfs. Pl.V.	x					
P. tetras var.tetraodon (Corda) Rabenh. Pl. V.	x					x
Botryococcaceae						
Botryococcus sudeticus Lemmermann Pl. V.	x					
Oocystaceae						
Chlorella vulgaris Beyerin.		x				
Dictyosphaerium pulchellum Wood Pl. V.		x			x	x
Oocystis elliptica W.West.			x			
O. pusilla Hansg. Pl. V.			x			x
O. solitaria Wittr.						x
O. submarina Lagerh. Pl. VI.						x
Ankistrodesmus convolutus Corda Pl. V.					x	x
A. falcatus (Corda) Ralfs. Pl.V.	x			x		x
A. falcatus var.stipitatus Chod.	x	x				
A. fractus W. & W.				x		x

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Tetraedron minimum (A.Braun) Hansg. Pl. V.	x			x		
T. tumidulum (Reins.)Hansg.Pl.V.	x					
Protococcaceae						
Protococcus viridis C.A.Ag.		x	x	x		x
Scenedesmaceae						
Crucigenia quadrangulare						x
C. rectangularis (A.Braun)Gay Pl. VI.	x					
Scenedesmus acutiformis Schroeder Pl. VI.	x					x
S. arcuatus Lemmermann		x				
S. bijuga (Turp)Lagerheim	x	x		x		x
S. bijuga var.alternans (Reinsch) Hansg. Pl.VI.	x					
S. incrassatulus Bohlin	x	x				
S. incrassatulus var.mononae G.M.Smith Pl. VI.	x					
S. dimorphus (Turp) Kuetz.	x					
S. denticulatus Lagerh. var. linearis Hansg. Pl. VI.	x					
S. longus Meyen Pl. VI.			x	x		
S. longus var. brevispina G.M. Smith Pl. VI.		x				

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
S. longus var. minutus G. M. Smith Pl. VI.				x		
S. obliquus (Turp)Kuetz. Pl.VI.	x	x				x
S. opoliensis P.Richter Pl.VI.			x			
S. quadricauda (Turp) deBréb. Pl. VI.				x	x	
Zygnemataceae						
Spirogyra crassa Kuetz. Pl.VII.						x
S. subsala Kuetz. Pl. VII.	x					
S. Weberi Kuetz. Pl. VII.	x					
S. jugalis (Fl.Dan.)Kuetz. Pl. VII.				x		x
S. Spreeiana Rebenh. Pl. VII.			x			
Mougeotia laetevirens (A.Braun) Wittr. Pl. VII.					x	
Desmidiaceae						
Arthrodesmus phimus Turner Pl. VIII.	x					
Closterium acerosum (Schrank) Ehrenb. Pl. VIII.		X				
Cl. Ehrenbergii Menegh.	x			x		
Cl. littorale Gay Pl. VIII.	x			x		
Cl. Leibleinii Kuetz. Pl. VIII.	x	x		x		
Cl. lunula (Müller) Ralfs.		x	x			

TABLE V (Continued)

	Roman Pond 1	Roman Pond 2	Roman Pond 3	Roman Pond 4	Upper Twin Lake	Lower Twin Lake
Closterium lunula f. minor W. & W. Pl. VIII.			x			
Cl. moniliferum (Bory) Ehrenb.	x	x	x	x		
Cl. Ralfsii Bréb. Pl. VIII.		x				
Cl. venus (Kütz.) Bréb.	x					x
Cosmarium dentatum Wolle new variety Pl. X.						x
C. abbreviatum Racib.		x	x			
C. abbreviatum var. planctonicum W. & G.S.W.		x	x			
C. angulare Johnson	x					
C. angulosum Bréb.	x			x		x
C. Botrytis Menegh. Pl. IX.	x		x	x		x
C. Botrytis var. mesoleium Nordst. Pl. IX.	x	x	x	x		x
C. contractum Kirchner	x					
C. impressulum Elfv.				x		
C. intermedium Delponte		x				
C. obtussatum Schmidle		x	x			
C. quasillus Lund. Pl. IX.			x			
C. subtumidum Nordst.	x					
C. cyclicum Lund.	x	x				

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Cosmarium crenulatum Naeg. (approaching var. tumidulum Insam et Krieger.) Pl. IX			x	x		
C. margaritatum (Lund) Roy et Biss. Pl. IX.					x	x
C. subcrenatum Hantzsch. Pl. IX.		x				
C. polonicum Racib.			x			
C. pachydermum Lund. Pl. VIII.						x
C. Hammeri Kirch. var. protuberans W.& W. Pl. IX.				x		
Desmidium Swartzii C.A.Ag.						x
D. Aptogonum Bréb. Pl. XI.	x					
Euastrum verrucosum Ehrenb.var. alatum Wolle Pl. X.						x
Hyalotheca dissiliens (Smith) Bréb. Pl. XI.						x
Micrasterias rotata (Grev.) Ralfs. Pl. XI.						x
M. rotata f. nuda Wolle Pl. XI.						x
M. truncata (Corda) Bréb.						x
Pleurotaenium Ehrenbergii (Bréb.) DeBary Pl. XII.	x					x
P. coronatum (Bréb.) Rab. var. nodulosum Bréb. Pl.XII.						x

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Sphaerozosma vertebratum Ralfs. Pl. XI.						x
S. Aubertianum West. var. Archeri West. Pl. XI.						x
Staurastrum cyrtocerum Bréb.	x					
St. polymorphum Bréb.	x					
St. longiridiatum West Pl.XIII.	x					
St. granulosum (Ehrenb.) Ralfs. Pl. XIII.						x
St. dilatatum Ehrenb.						x
St. vestitum Ralfs. Pl. XIII.				x		
St. gracile Ralfs.						x
St. mucronatum Ralfs. Pl. XIII.						x
CHRYSOPHYTA						
Synuraceae						
Synura ulvella Shrenberg Pl. XV.	x					
Pleurochloridaceae						
Botrydiopsis arhiza Borzi.						x
Characiopsidaceae						
Characiopsis cylindrica (Lembert) Lemm.		x				
EUGLENOPHYTA						
Euglenaceae						
Euglena convoluta Korshik. ?			x			

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Euglena elongata Schwei. ? Pl. XV.	x	x		x		
Eu. minuta Prescott (non Agersborg)	x		x			
Eu. sanguinea Ehrenb.? Pl. XV.	x	x				
Trachelomonas granulosa Playf. Pl. XIV.	x					
T. hispida (Perty)Stein var. coronata Lemm. Pl.XIV.	x					
T. hispida var. duplex Defl. Pl. XIV.	x					
Phacus Birgei Prescott Pl. XIV.	x					
P. anacoelus Stokes Pl. XIV.	x		x	x		
P. Lemmermannii (Swir.) Skortz. Pl. XIV.			x			
P. asymmetrica Prescott	x					
P. orbicularis Huebner Pl. XIV.	x					
P. orbicularis var. caudatus Skortz.	x					
PYRRHOPHYTA						
Peridiniaceae						
Peridinium cinctum (Muell.) Ehrenb. Pl. XV.	x				x	x
Ceratiaceae						
Ceratium hirundinella (of Muell.) Dujardin Pl. XV.	x	x		x	x	x

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
CYANOPHYTA						
Chroococcaceae						
Chroococcus pallidus Naegeli				x		
C. minutus (Kuetz.) Naegeli				x		
C. dispersus (Keissl.) Lemm. var. minor G.M.Smith			x			
C. minor (Kuetz.)Naegeli	x		x	x		
C. varius A.Braun				x		
C. dispersus (Keissl.) Lemm.	x					
Gloeocapsa punctata Naegeli						x
Aphanocapsa rivularis (Carm.) Rabenh.						x
Microcystis aeruginosa Kuetz. Pl. XVI.	x			x		x
M. flos-aquae (Wittr.)Kirchner	x	x				
M. incerta Lemm.	x					x
Merismopedia glauca (Ehrenb.) Naegeli Pl. XVI.	x			x		
M. tenuissima Lemm.	x			x		x
Synechococcus aeruginosa Naegeli Pl. XVI.				x		x
Gloeothece rupestris (Lyngb.) Bornet	x					x
G. linearis Naegeli				x		

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Aphanothece microspora (Menegh.) Rabenhorst				x		
A. **gelatinosa** (Henn.) Lemm.						x
A. **nidulans** P.Richter				x		
A. **prasina** A.Braun						x
A. **stagnina** (Spreng.) A.Braun	x					
Coelosphaerium dubium Grunow Pl. XVI.						x
C. **Kuetzingianum** Naegeli	x	x				x
C. **pallidum** Lemm.	x					
Gomphosphaeria aponina Kuetz. Pl. XVI.				x		x
G. **aponina var. delicatula** Virieux				x		
G. **lacustris** Chodat	x					
G. **lacustris var.** compacta Lemm.						x
Glaucocystis oocystiformis Prescott						x
Gloeochaete Wittrickiana Lag. Pl. XVIII.						x
Oscillatoriaceae						
Spirulina major Kuetz.			x	x		x
S. **princeps** (W.& W.) G.S.West Pl. XVII.	x					

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Arthrospira Jenneri (Kuetz.) Stizenberg Pl. XVII.	x		x			
Oscillatoria amphibia C.A.Ag.		x	x	x		
O. anguina (Bory) Gomont Pl. XVII.				x		
O. Bornetii Zukal Pl. XVII.	x			x	x	
O. curviceps C.A.Ag. Pl.XVII.	x			x		
O. limnetica Lemm.	x	x	x	x	x	x
O. limosa (Roth) C.A.Ag. Pl.XVII				x		x
O. minima Gicklhorn	x					x
O. nigra Vaucher	x			x		
O. subbrevis Schmidle	x	x	x			
O. tenuis C.A.Ag. Pl.XVII.	x		x	x		x
O. terebriformis C.A.Ag.				x		
Phormidium tenue (Menegh.) Gomont	x					
Lyngbya Birgei G.M.Smith						x
L. aerugineo-caerulea (Kuetz.) Gomont			x			
L. limnetica Lemm.					x	x
L. major Menegh. Pl. XVII.	x					x
L. Hieronymusii Lemm.	x					

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Nostocaceae						
Anabaena aequalis Borge Pl.XVIII.	x					
A. circinalis Raben.				x		
A. flos-aquae (Lyngb.) DeBréb. Pl. XVIII.	x					x
A. planctonica Brunthaler Pl. XVIII.	x			x		x
A. sphaerica Born.& Flah. Pl. XVIII.				x		
A. unispora Gardner				x		
A.variabilis Kuetz. Pl. XVIII.				x		
A. wisconsinense Prescott ?				x		
A. inaequalis (Kuetz.) Born. & Flah. Pl. XVIII.	x					x
Nostoc carneum C.A.Ag. ?				x		
N. pruniforme C.A.Ag.						x
N. verrucosum Vaucher Pl.XVIII.						x
N. Linckia (Roth) Bornet & Thuret Pl. XVI.				x		
N. paludosum Kuetz.	?	?	x	x		x
Nodularia spumigena Mertens	x					
Cylindrospermum Marchicum Lemm. Pl. XVIII.						x

TABLE V (Continued)

	Ronan Pond 1	Ronan Pond 2	Ronan Pond 3	Ronan Pond 4	Upper Twin Lake	Lower Twin Lake
Aulosira laxa Kirchner Pl.XVIII.				x		
Trichodesmium lacustre Klebahn ? Pl. XVII.				x		
Scytonemataceae						
Tolypothrix distorta Kuetz.						x
T. lanata Wartman in Rabenhorst Pl. XVII.	x					x
T. tenuis Kuetz.	x					
Rivulariaceae						
Rivularia haematities C.A.Ag.	?					?
Gloeotrichia natans (Hedwig) Raben. Pl. XVI.				x		
G. longiarticulata G.S.West				?		
G. pisum (C.A.Ag.) Thuret Pl. XVI.				x	x	

PLATE I

1. Pandorina morum (Muell.) Bory., x440.

2. Gloeocystis gigas (Kuetz.) Lagerheim, x 880.

3. Tetraspora lubrica (Roth) C.A.Ag., x 440.

4. Schizochlamys gelatinosa A.Braun in Kuetz., x 880.

5. Apiocystis Brauniana Naeg., (young colony) x 440.

6. Sphaerocystis Schroeteri Chodat., x 660.

PLATE I

x 880,

x 440.

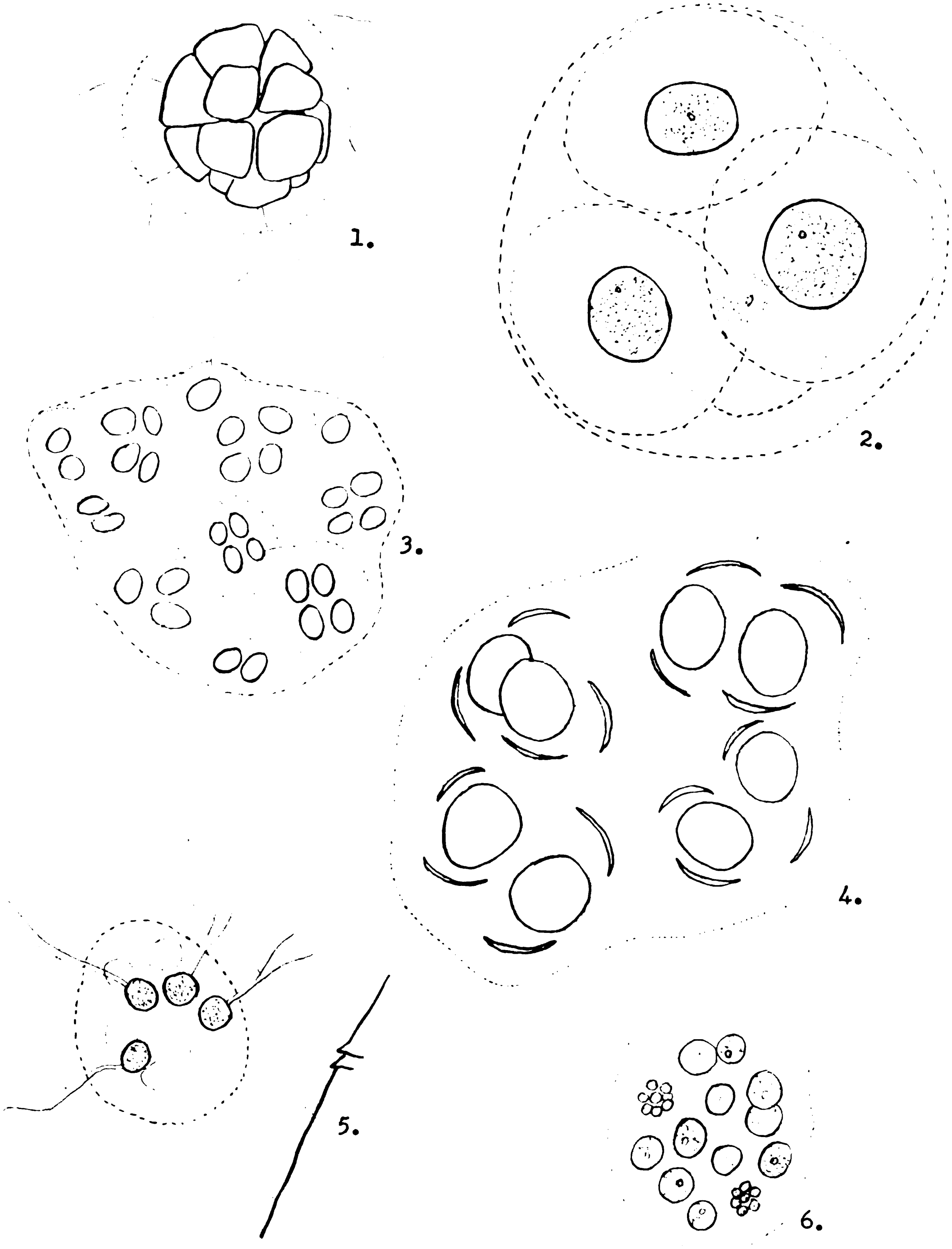


PLATE II

1. *Geminella crenulatocollis* Prescott, x 440.

2. *Palmodictyon viride* Kuetz., x 660.

3. *Ulothrix zonata* (Weber & Mohr.) Kuetz., x 200.

4. *U. variabilis* Kuetz., x 880.

5. *Microspora stagnorum* (Kuetz.) Lagerh., x 440.

6. *M. tumidula* Hazen, x 660.

7. *Stigeoclonium polymorphum* (Franke) Heering, x 880.

8. *S. tenue* (C.A.Ag.) Kuetz., x 440.

9. Sphaeroplea annulina (Roth) C.A.Ag.,
   a. x 110.
   b. non-motile, sphaerical zygote, x 880.

PLATE 11

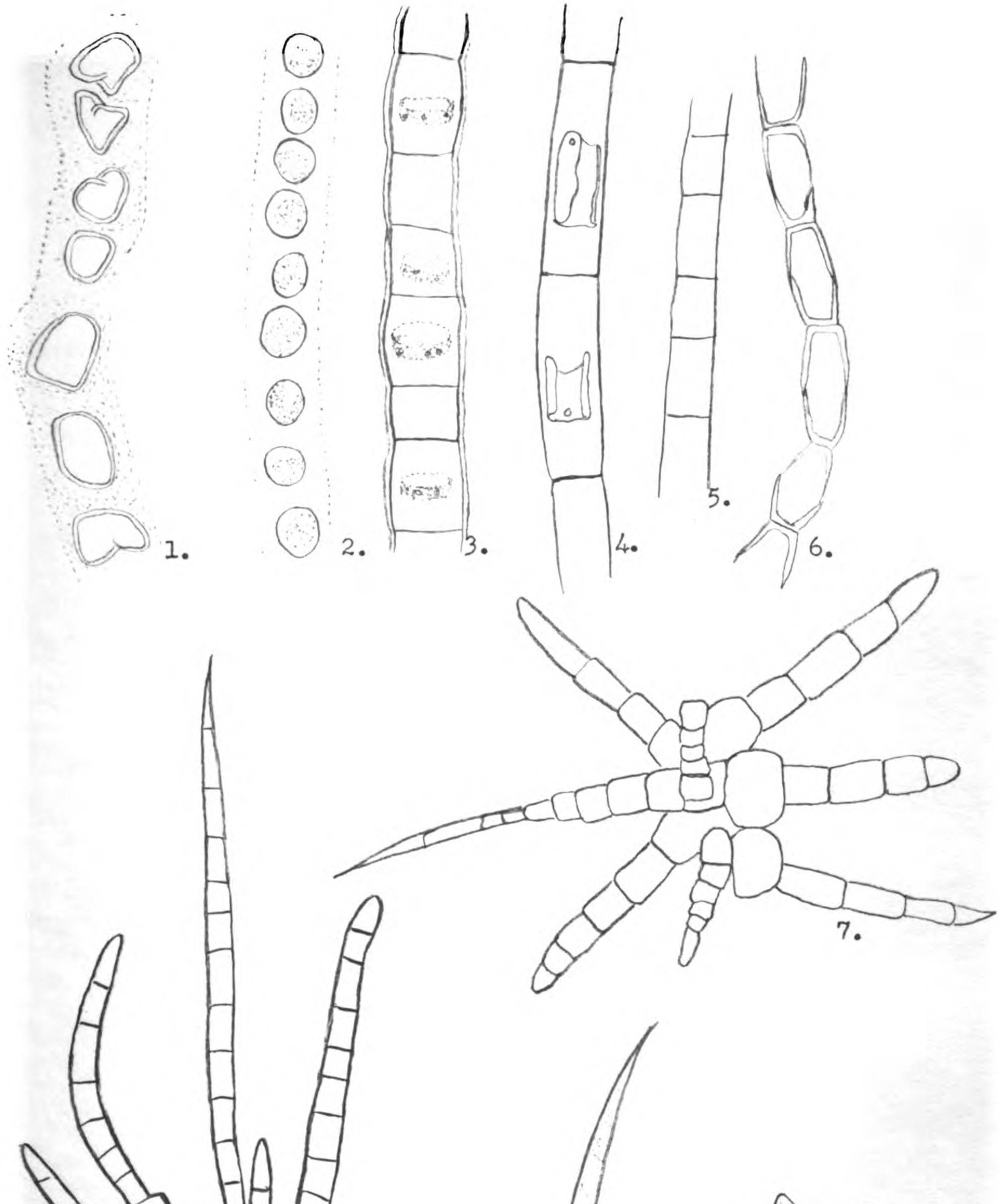


PLATE III

1. Aphanochaete repens A.Braun, x 880.

2. Chaetosphaeridium globosum (Nordst.) Klebahn, x 440.

3. Chaetophora incrassata (Huds.) Hazen, x 220. a. x $\frac{1}{2}$.

4. Draparnaldia plumosa (Vaucher) C.A.Ag., x 220.

5. Coleochaete orbicularis Pringsheim, x 440. a. x 10.

PLATE III

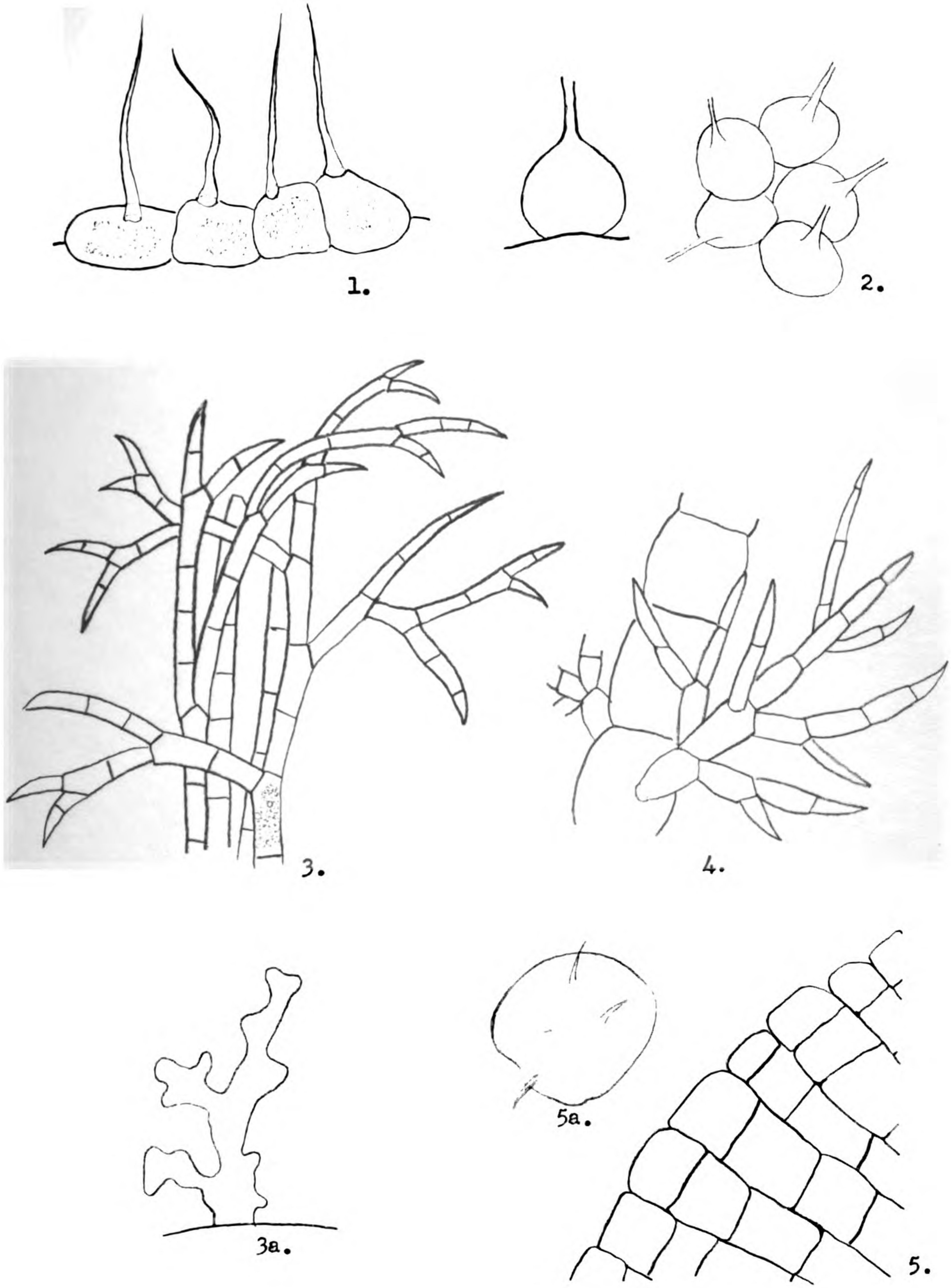


PLATE IV

1. Gongrosira Debaryanum Rabenh., x 145.
   Encysting and producing zoospores.

2. Rhizoclonium hieroglyphicum Kuetz., x 100.

3. R. crassipellitum W. & W., x 100.

4. Oedogonium Magnusii Wittr., x 880.

5. Oe. sociale Wittr., x 440.

6. Oe. gracilius (Wittr.) Tiffany, x 440.

7. Oe. crispum (Hass.) Wittr., x 440.

8. Bulbochaete insignis Pringsheim, x 880.

PLATE V

1. Oedogonium sp. nov., x 220.

Nannandrous - Idioandrosporus (?)
Operculate
Vegetative cells cylindric, 25 u in diam., 110 u long. Oogonium operculate, supra-median, 69 u diam., 88 u long. Oospore globose, wall smooth, median wall faintly scrobiculate, 65 u diam., 80 u long, nearly filling the oogonium. Suffultory cell enlarged, 53 u diam., 120 u long. Dwarf male - 4 celled, antheridium exterior, 4.5 u diam., 6 u long.

2. Ankistrodesmus falcatus (Corda) Ralfs., x 880.

3. A. convolutus Corda, x 880.

4. Hydrodictyon reticulatum (L.) Lagerh., young net, x 440.

5. Pediastrum duplex Meyen var. clathratum (A.Braun) Lagerh., x 600.

6. P. tetras (Ehrenb.) Ralfs., x 440.

7. P. tetras var tetraodon (Corda) Rabenh., x 660.

8. Sorastrum spinulosum Naegeli, x 880.

9. Dictyosphaerium pulchellum Wood, x 660.

10. Oocystis pusilla Hansg., x 660.

11. Tetraedron minimum (A.Braun) Hansg., x 880.

12. Botryococcus sudeticus Lemm., x 100.

13. Tetraedron tumidulum (Reins.) Hansg., x 440.

PLATE VI

1. *Scenedesmus incrassatulus* Bohlin *var. mononae* Smith, x 440.

2. *S. bijuga* (Turp) Lagerheim *var. alterans* (Reinsch.) Hansg., x 880.

3. *S. opoliensis* P.Richter, x 660.

4. *S. obliquus* (Turp) Kuetz., x 880.

5. *S. acutiformis* Schroeder, x 880.

6. *S. obliquus* (Turp) Kuetz., x 880.

7. *S. quadricauda* (Turp) de Bréb., x 880.

8. *S. longus* Meyen, x 660.

9. *S. longus var. brevispina* G.M.Smith, x 880.

10. *S. longus var. minutus* G.M.Smith, x 880.

11. *S. acutiformis* Schroeder, x 440.

12. *S. dimorphus* (Turp) Kuetz., x 660.

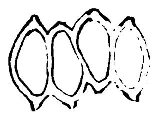
13. *S. denticulatus* Lagerh. *var. linearis* Hansg., x 880.

14. *Crucigenia rectangularis* (A.Braun) Gay, x 440.

15. *Oocystis gigas* Archer, x 880.

16. *O. submarina* Lagerh., x 880.

PLATE VI



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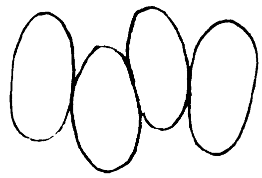

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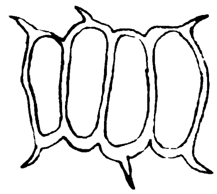

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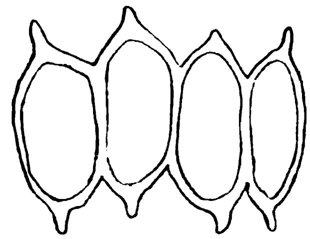

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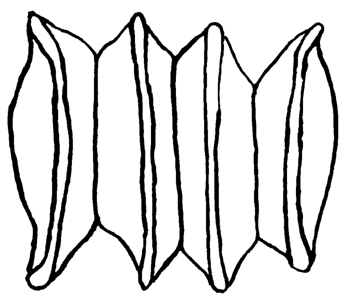

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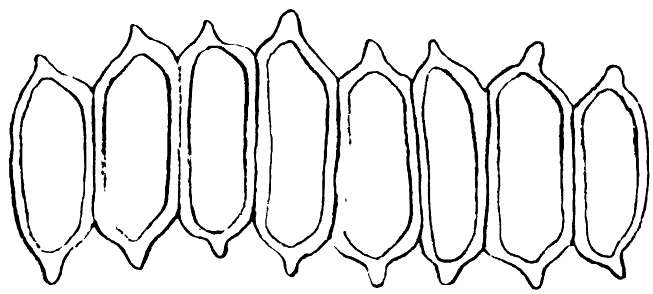

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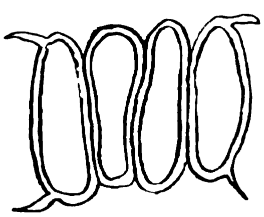

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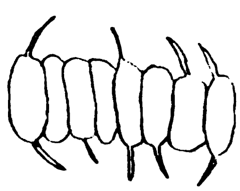

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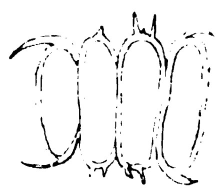

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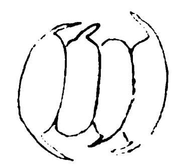

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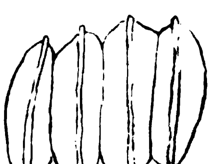

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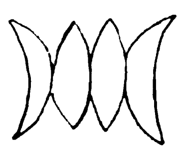

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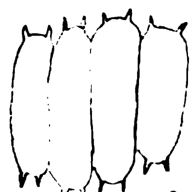

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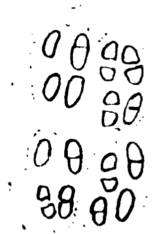

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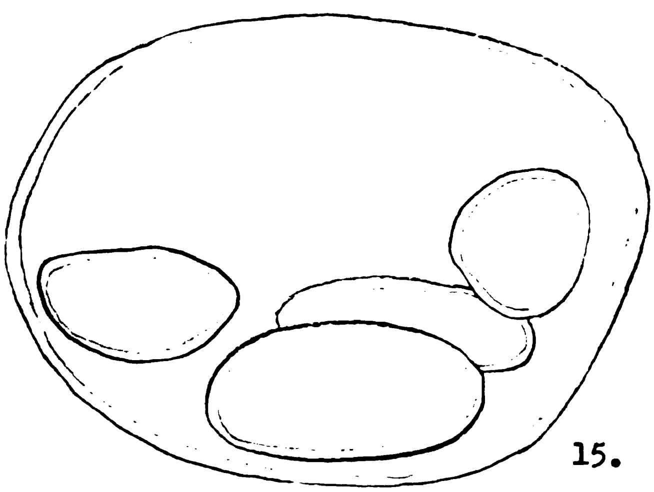

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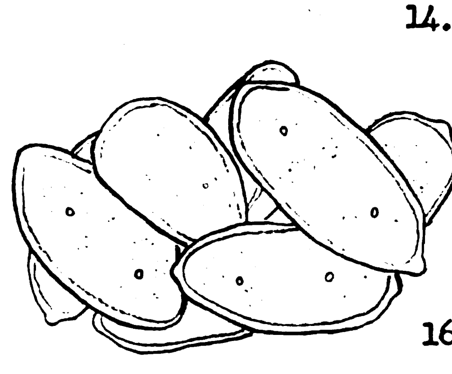


16.

PLATE VII

1. Spirogyra subsala Kuetz., x 440.
2. S. Weberi Kuetz., x 440.
3. S. crassa Kuetz., x 100.
4. S. Spreeiana Rabenh., x 440
5. S. jugalis (Fl. Dan.) Kuetz., x 100.
6. Mougeotia laetivirens (A. Braun) Wittr., x 220.

PLATE VII

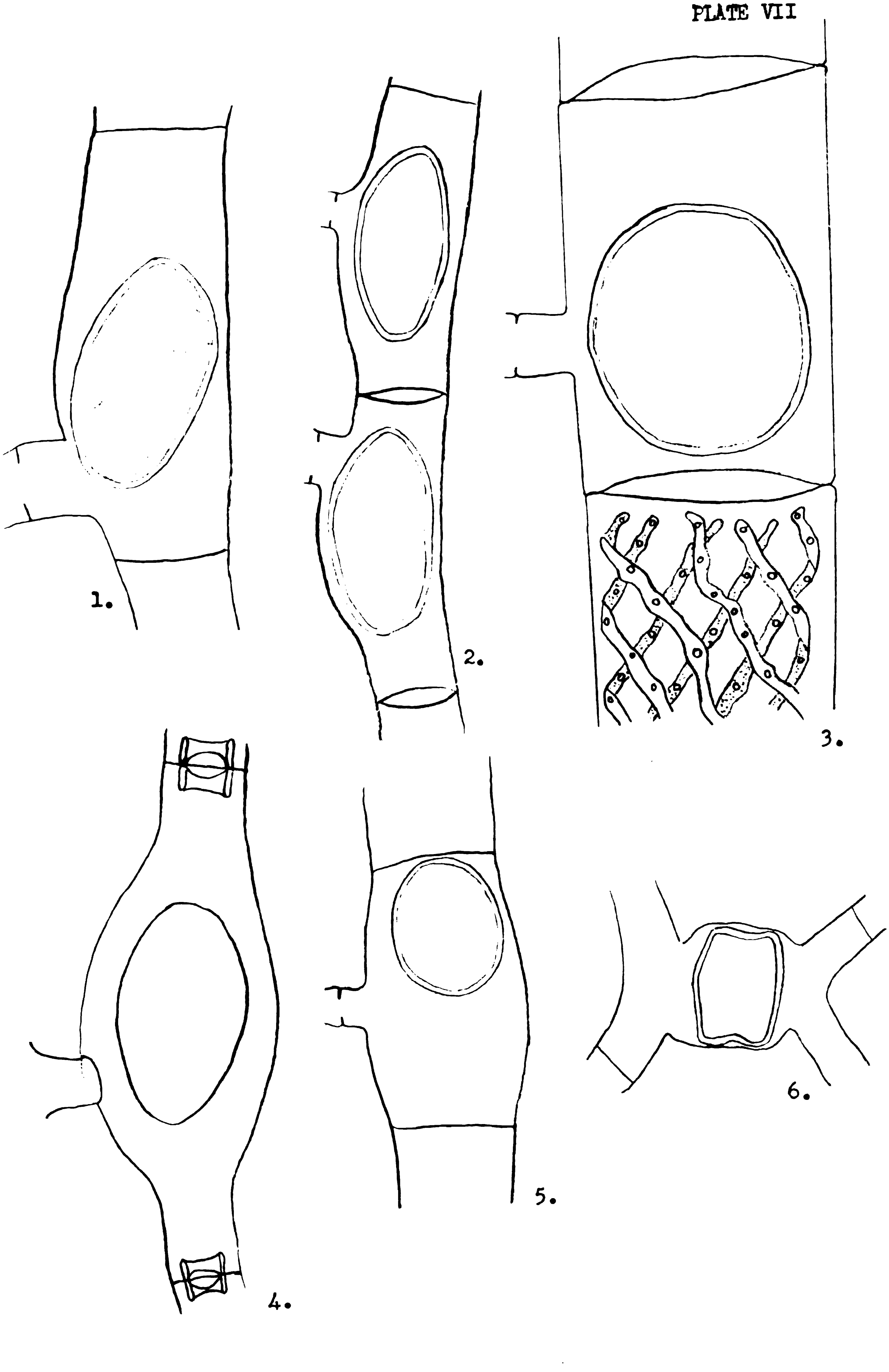


PLATE VIII

1. *Arthrodesmus phimus* Turner, x 440.

2. *Closterium Leibleinii* Kuetz., x 200.

3. *Cl. littorale* Gay, x 100.

4. *Cl. acerosum* (Schrank) Ehrenb., x 440.

5. *Cl. Ralfsii* Bréb., x 440.

6. *Cl. lunula* (Müller) Ralfs. *f. minor* (?), x 440.

7. *Cosmarium pachydermum* Lund., x 660.

PLATE VIII

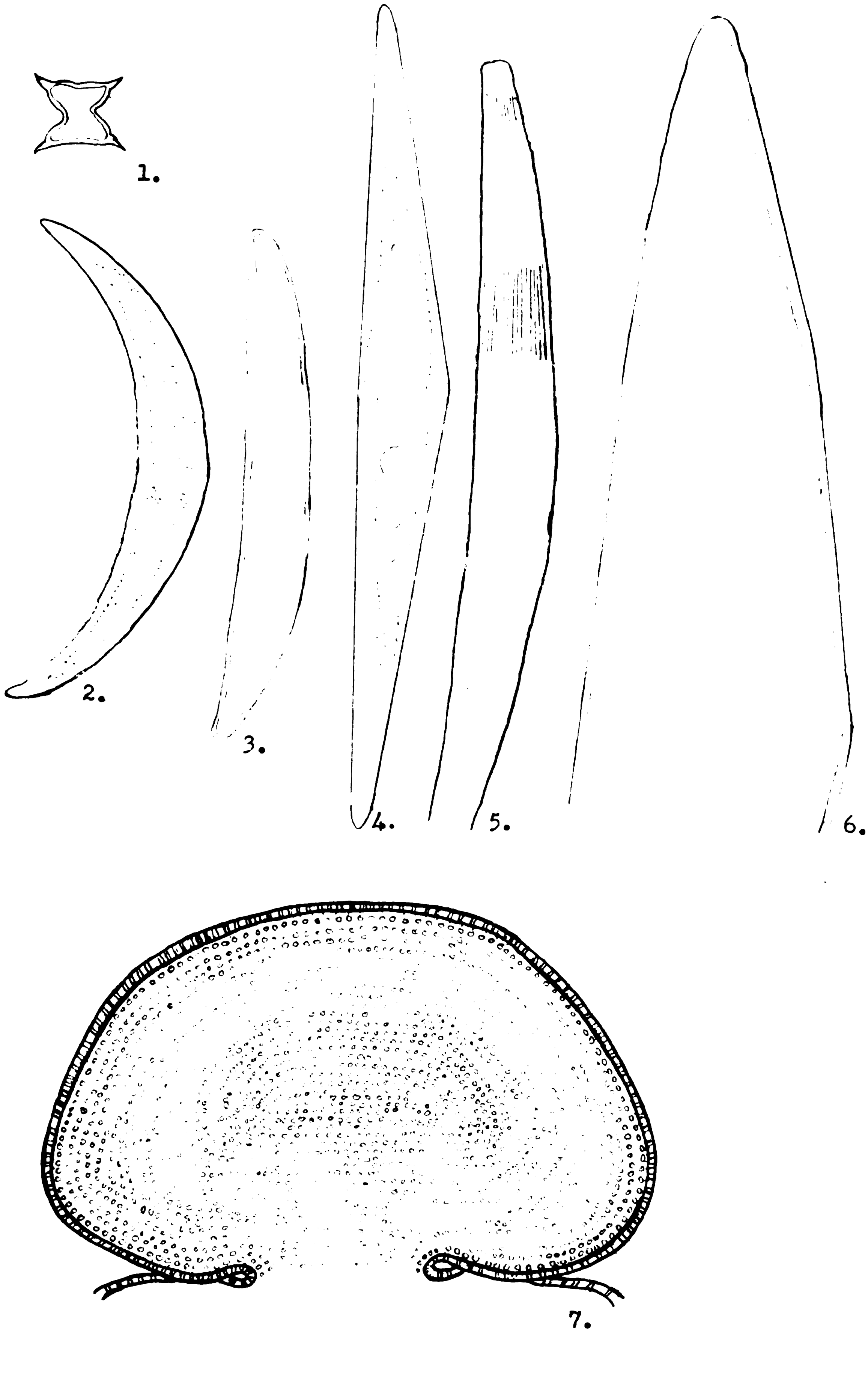


PLATE IX

1. *Cosmarium margaritatum* (Lund) Roy et Biss., x 880.

2. *C. quasillus* Lund., x 660.

3. *C. Hammeri* Kirch. *var. protuberans* W. & W., x 660.

4. *C. Botrytis* Menegh., x 880.

5. *C. subcrenatum* Hantzsch., x 440.

6. *C. polonicum* Racib., x 660 (?)

7. *C. crenulatum* Naeg., x 660. (appr. *var. tumidulum* Insam et Krieger.)

8. *C. Botrytis* Menegh. *var. mesoleium* Nordst., x440.

PLATE IX

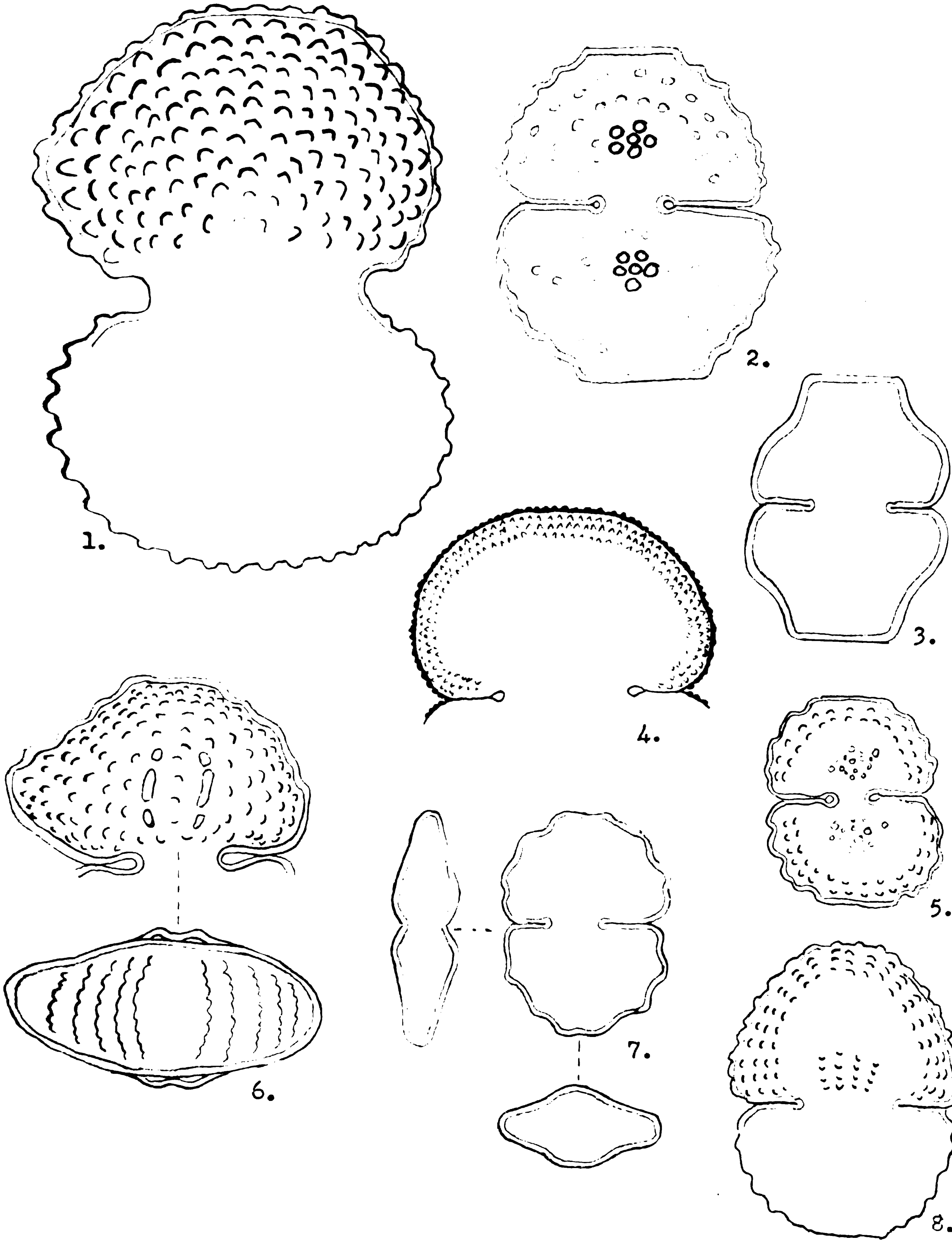


PLATE X

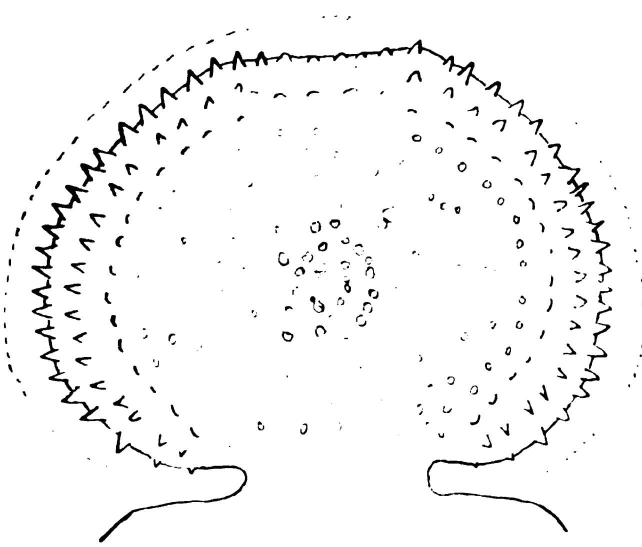
1. Cosmarium dentatum Wolle var. nov., x 440

Length: 138 u.
Width: 106 u.
Isthmus: 31 u.

Differs from type in number of teeth along lateral margin in face view. (Type - 10 teeth; var. nov. - 19 teeth.) ; also there are four rows of teeth in side view, not scattered as in type form.

2. Euastrum verrucosum Ehrenb. var. alatum Wolle, x 880.

PLATE X



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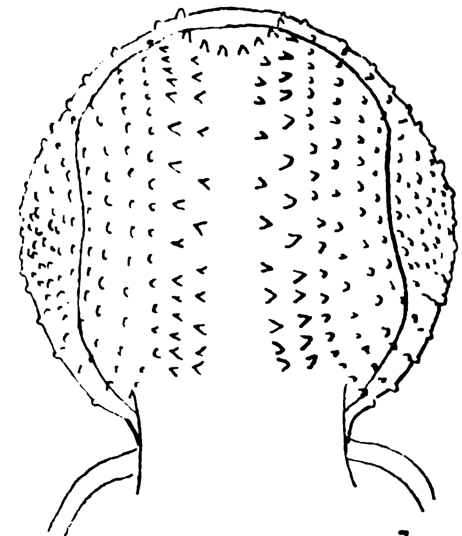

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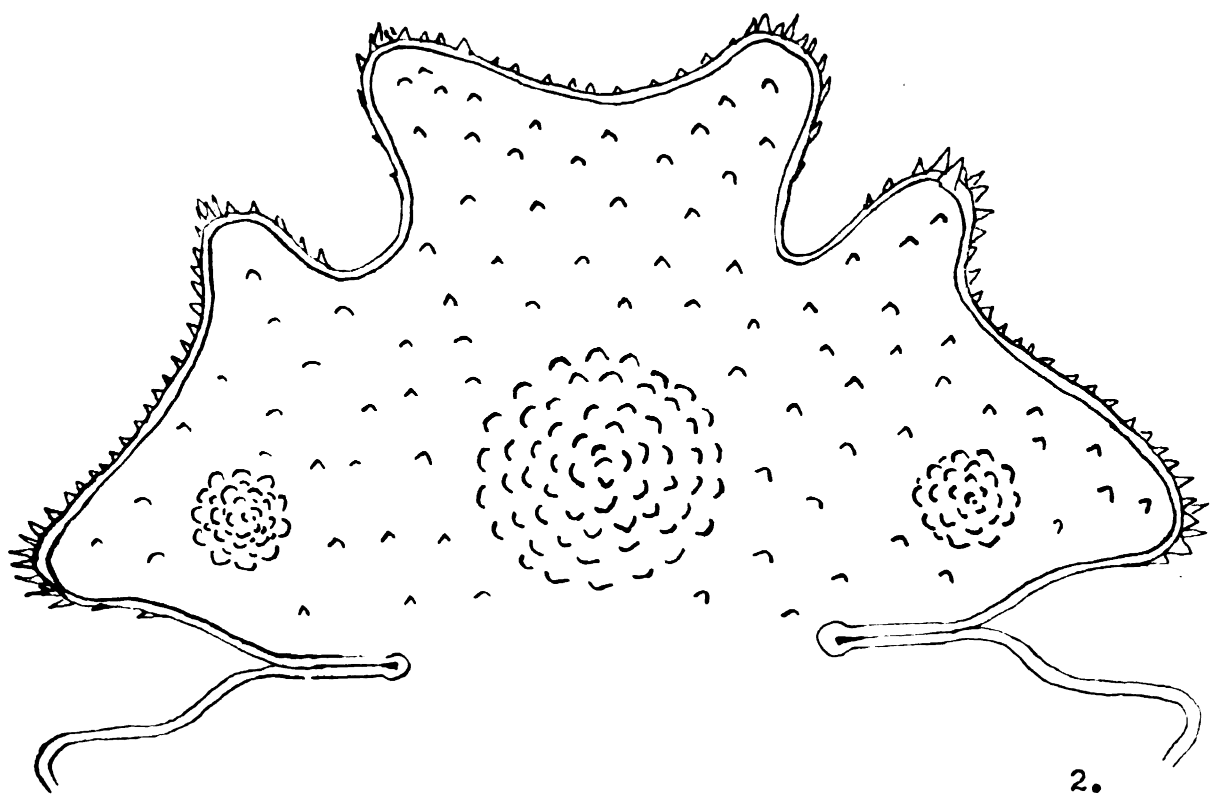


2.

PLATE XI

1. Micrasterias rotata (Grev.) Ralfs., x 200.

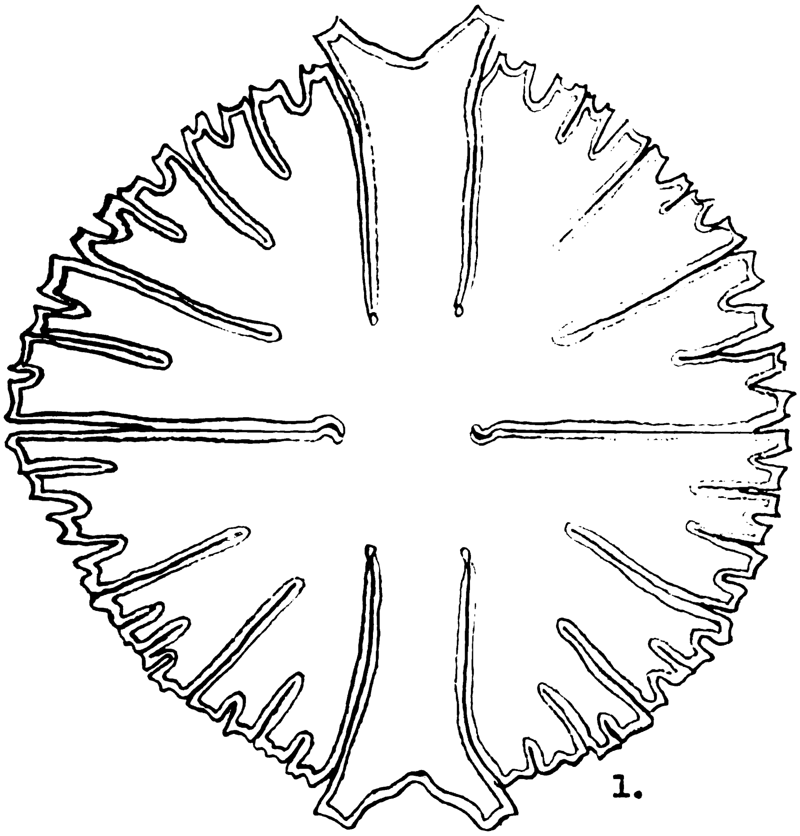
2. M. rotata forma nuda Wolle, x 200.

3. Hyalotheca dissiliens (Smith) Bréb., x 880.

4. Sphaerozosma Aubertianum West var. Archeri West, x 880.

5. S. vertebratum Ralfs., x 880.

6. Desmidium Aptogonum Bréb., x 440.



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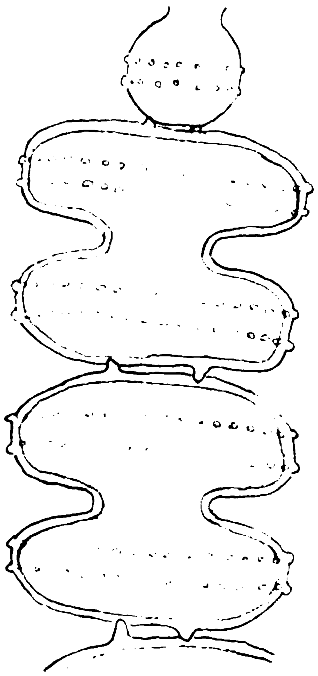

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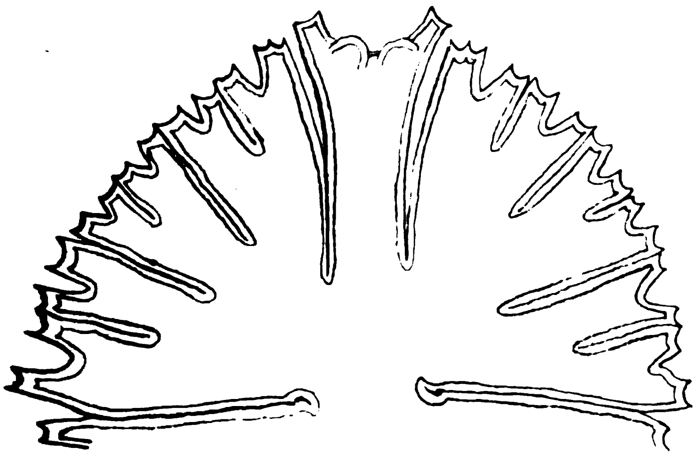

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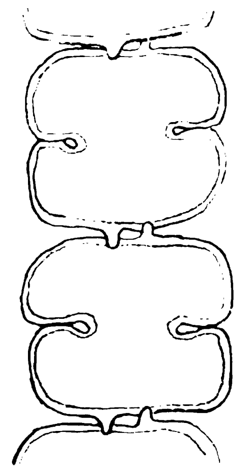

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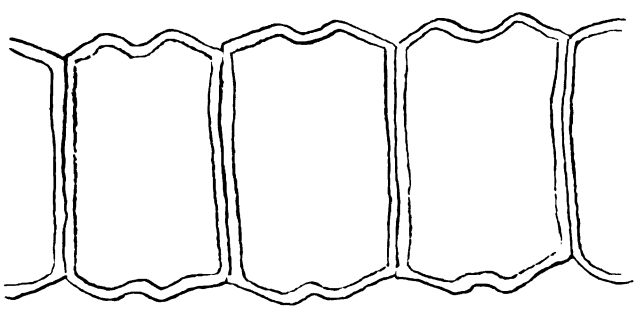

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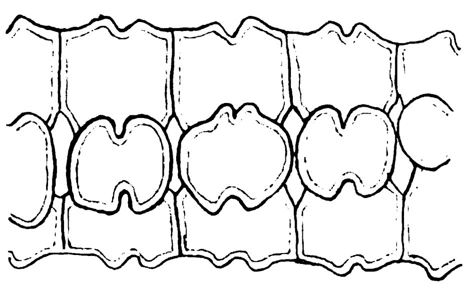
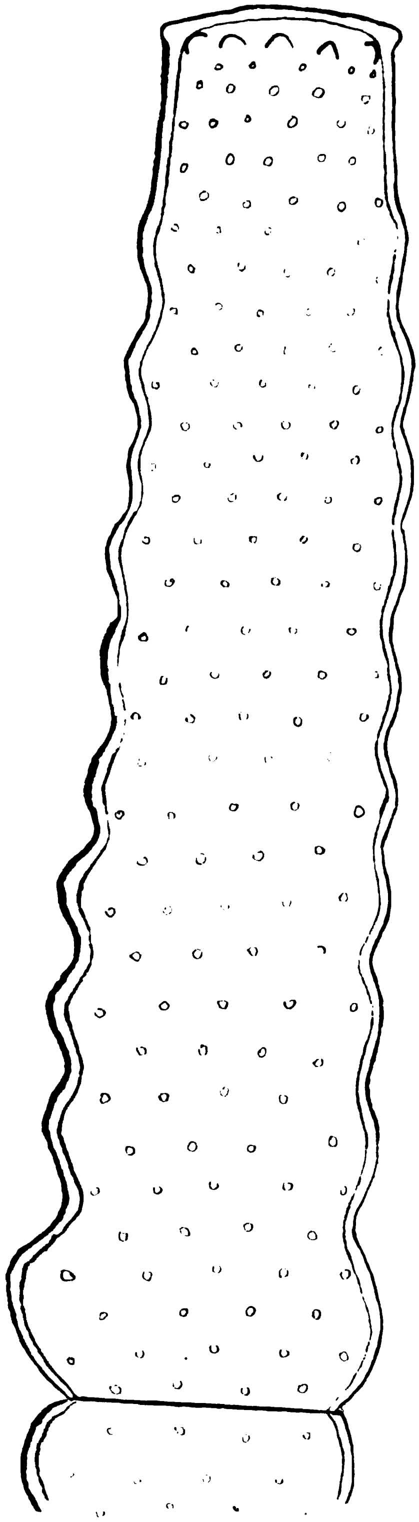


6.

PLATE XII

1. Pleurotaenium coronatum (Bréb.) Rab. var. nodulosum Bréb., x 440.

2,3,& 4. P. Ehrenbergii
2. x 660.
3. x 880.
4. x 880.



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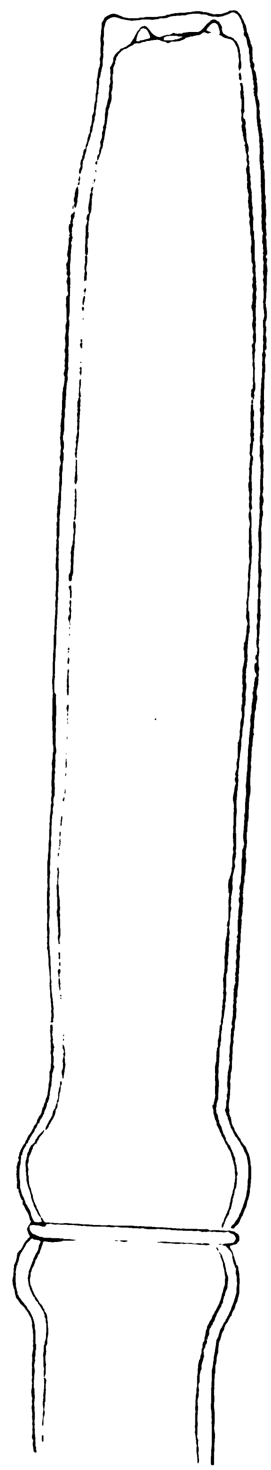

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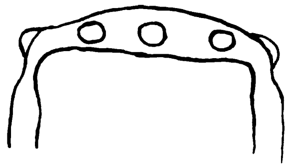

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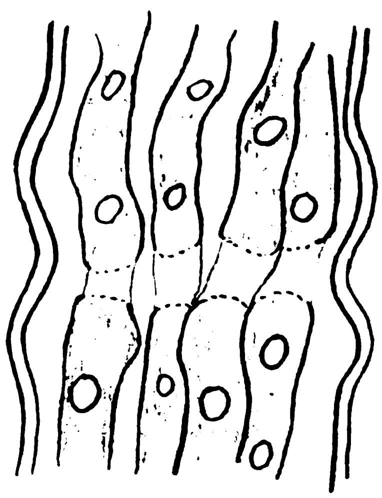


3.

PLATE XIII

1. *Staurastrum vestitum* Ralfs., x 880.

2. *St. mucronatum* Ralfs., x 880.

3. *St. granulosum* (Ehrenb.) Ralfs., x 660.

4. *St. longiradiatum* West, x 440.

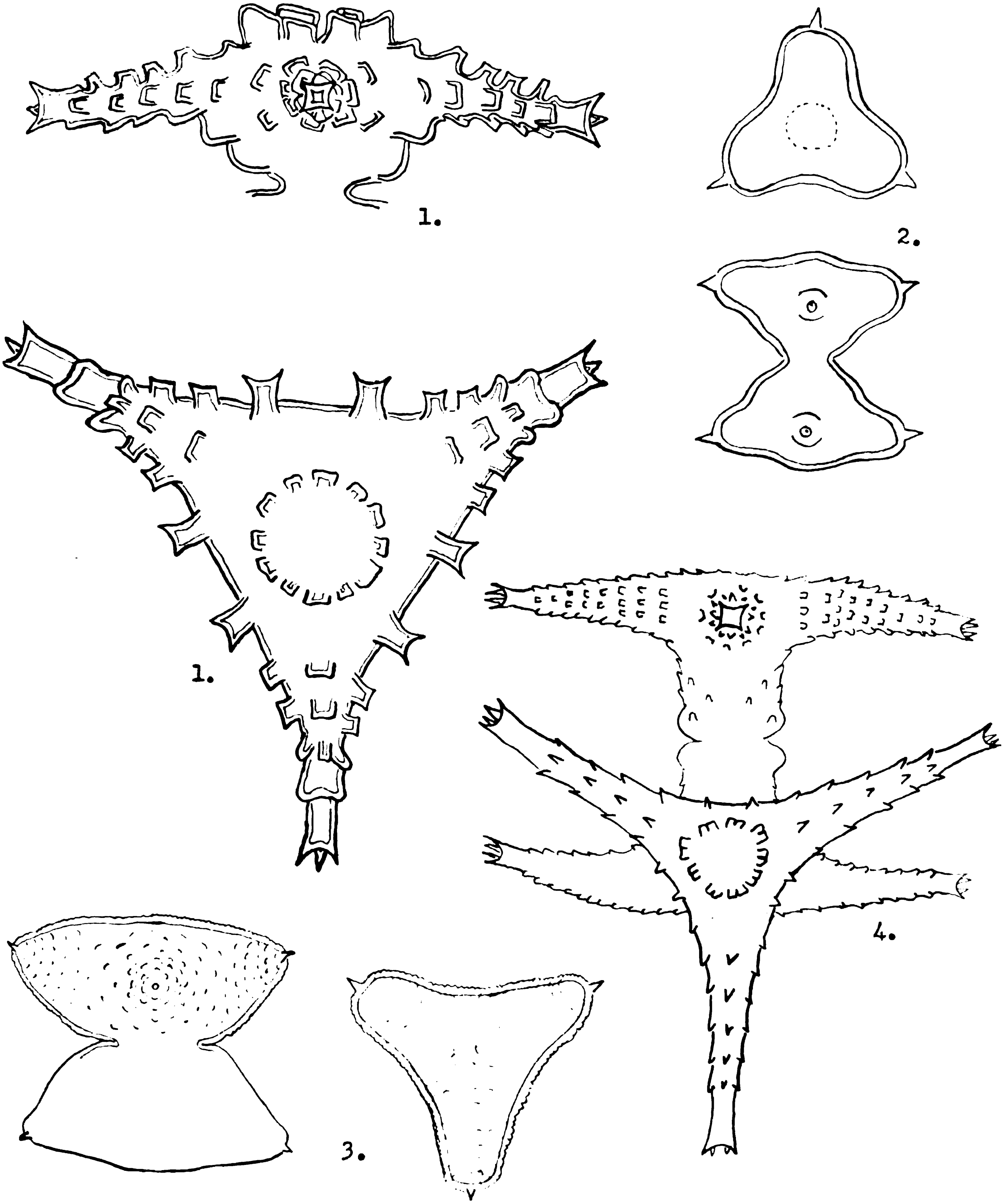

1.
2.
1.
4.
3.

PLATE XIV

1. *Phacus orbicularis* Huebner, x 880.

2. *P. asymmetrica* Prescott, x 880. (?)

3. *P. Birgei* Prescott, x 880.

4. *P. orbicularis* Huebner *var. caudatus* Skortz., x 880.

5. *Trachelomonas granulosa* Playf., x 880.

6. *T. hispida* (Perty) Stein *var. coronata* Lemm., x 880.

7. *Phacus anacoelus* Stokes, x 440.

8. *P. Lemmermannii* (Swir.) Skortz., x 440.

9. *Trachelomonas hispida* (Perty) Stein *var. duplex* Defl., x 880.

PLATE XIV

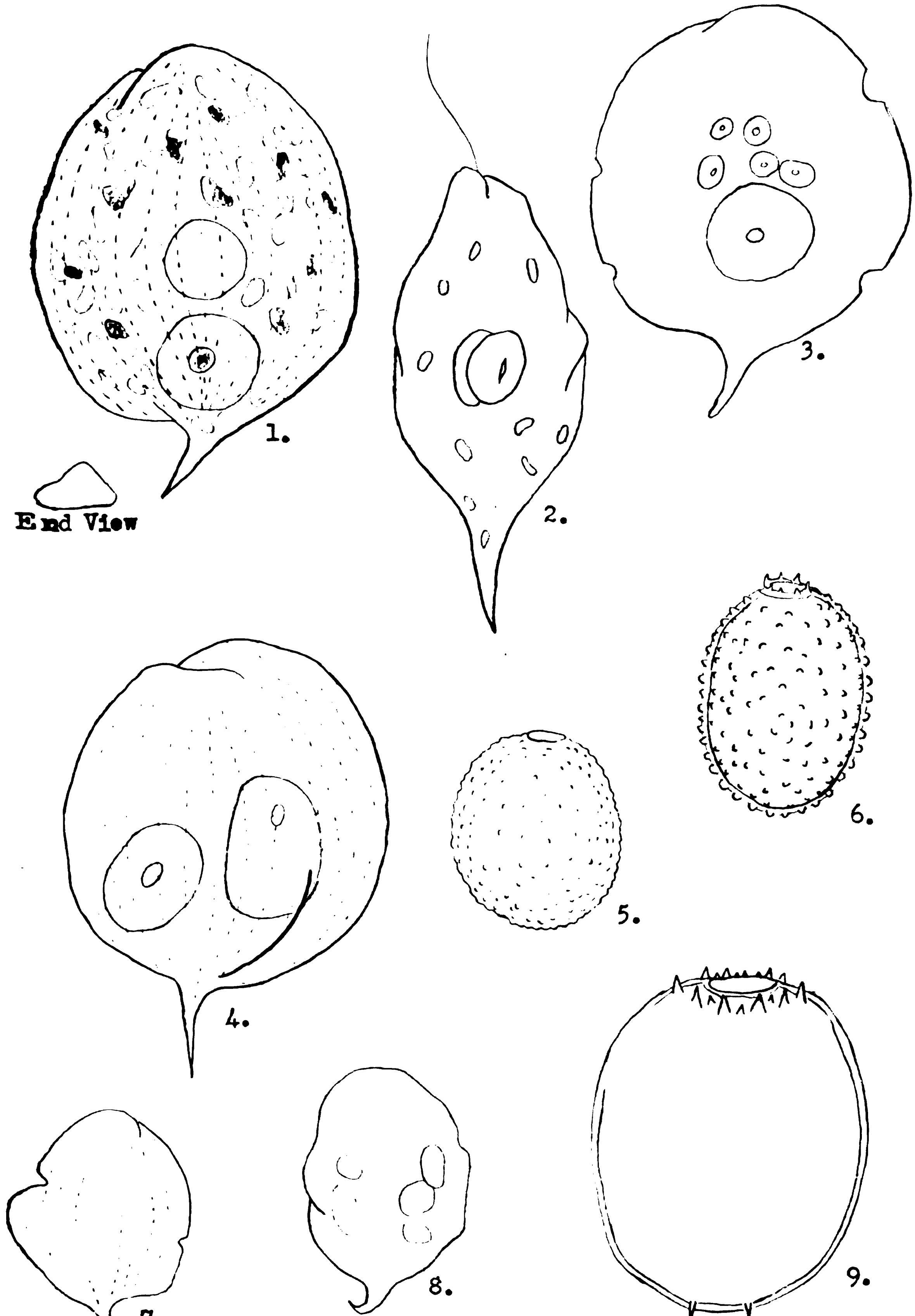


PLATE XV

1. <u>Euglena elongata</u> Schwei., x 440.

2. <u>Euglena sp.</u>
   a. x 440.
   b. x 440.
   c. x 440.

3. <u>Ceratium hirundinella</u> (of Muell.) Dujardin, x 440.

4. <u>Peridinium cinctum</u> (Muell.) Ehrenb., x 880.

5. <u>Synura ulvella</u> Ehrenberg, x 440.

PLATE XVI

1. *Microcystis incerta* Lemmermann, x 440.

2. *Synechococcus aeruginosa* Naegeli, x 880.

3. *Coelosphaerium pallidum* Lemmermann, x 440.

4. *Merismopedia glauca* (Ehrenb.) Naegeli, x 880.

5. *Gomphosphaeria aponina* Kuetz. *var*. *delicatula* Virieux, x 880.

6. *Microcystis aeruginosa* Kuetz. emend. Elekin., x 440.

7. *Nostoc linckia* Roth,
   a. x 880
   b. colony, x 1.

8. *Gloeotrichia pisum* (C. A. Ag.) Thuret, x 440.

9. *G. natans* (Hedwig) Rabenhorst, x 440.

PLATE XVI

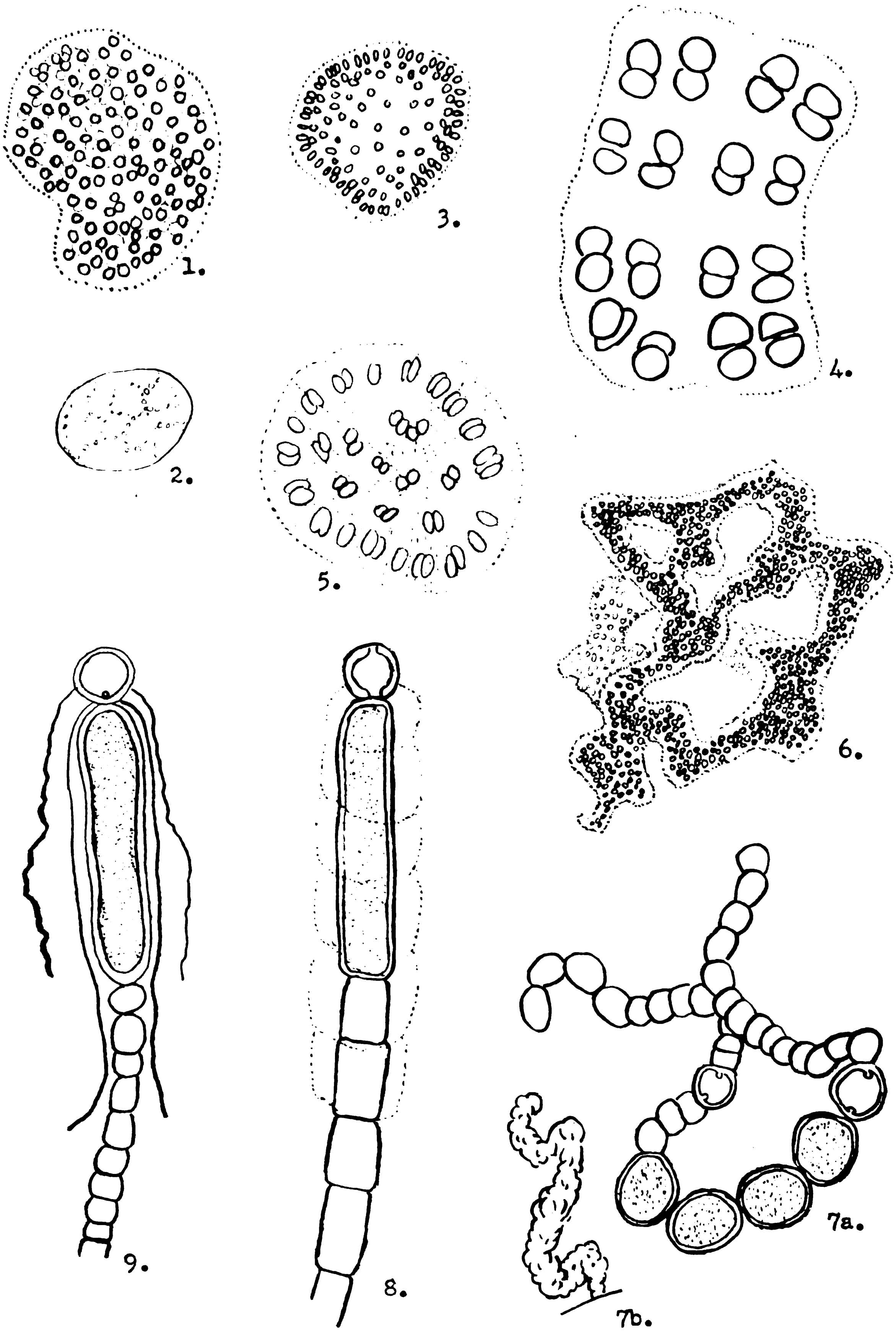


PLATE XVII

1. Oscillatoria limosa (Roth) C. A. Ag., x 880.

2. O. Bornetii Zukal, x 880.

3. O. anguina (Bory) Gomont, x 880.

4. O. curviceps C. A. Ag., x 880.

5. O. tenuis C. A. Ag., x 440.

6. Arthrospira Jenneri (Kuetz.) Stizenberg, x 440.

7. Trichodesmium lacustre Klebahn (?), x 880.

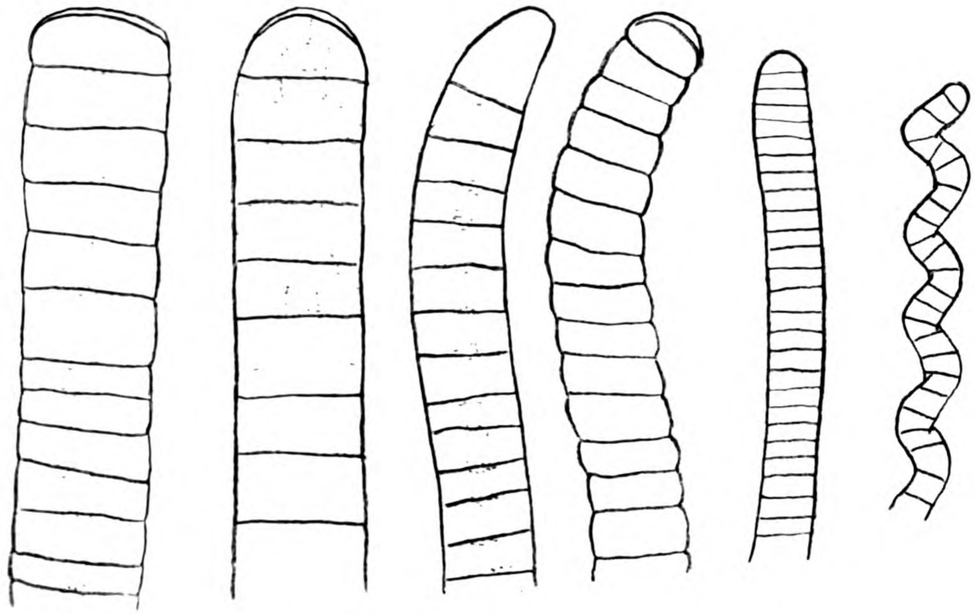
8. Lyngbya major Menegh., x 440

9. Tolypothrix tenuis Kuetz., x 440.

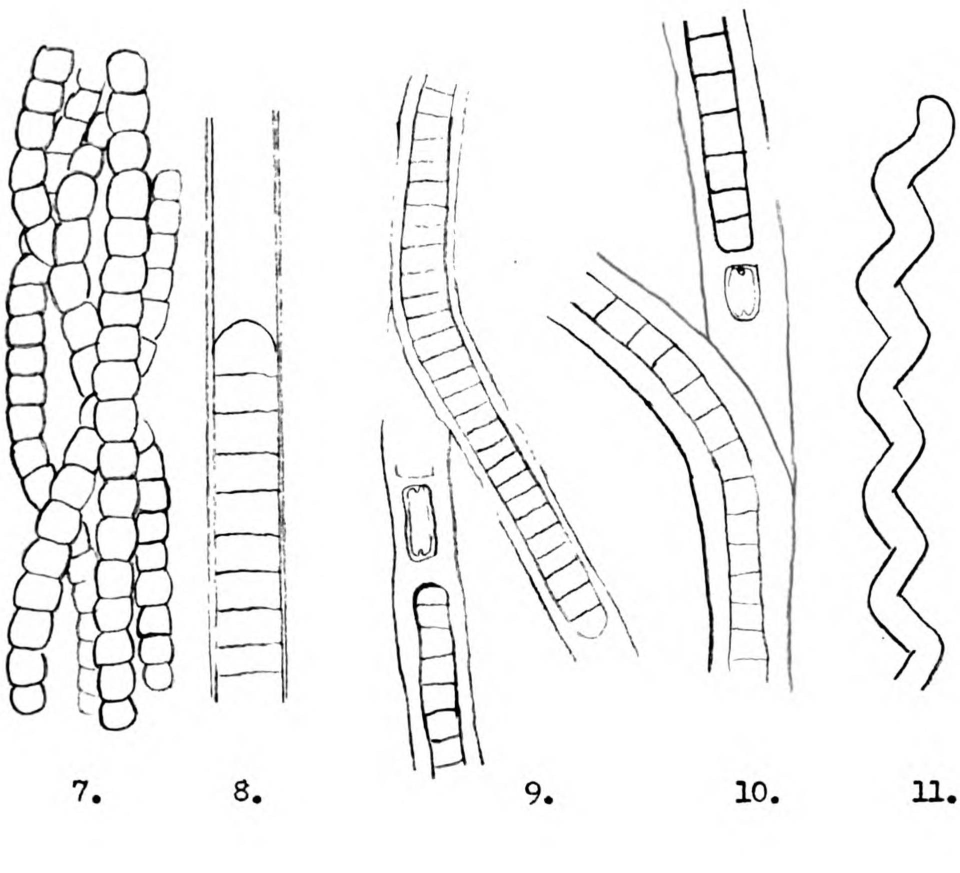
10. T. lanata Wartman in Raben., x 440.

11. Spirulina princeps (W. & W.) G. S. West, x 440.

PLATE XVII.



1. 2. 3. 4. 5. 6.



7. 8. 9. 10. 11.

PLATE XVIII

1. Nostoc verrucosum Vaucher
   a. x 440.
   b. colony, x 1 .

2. Aulosira laxa Kirchner, x 440.

3. Nodularia spumigena Mertens, x 880.

4. Anabaena aequalis Borge, x 880.

5. A. inaequalis (Kuetz.) Bornet & Flahault, x 880.

6. Gloeochaete Wittrockiana Lag., x 440.

7. Cylindrospermum Marchicum Lemm., x 440.

8. Anabaena Sphaerica, x 880

9. A. flos-aquae (Lyngb.) DeBréb., x 880.

10. A. planctonica Brunnthaler, x 440.

11. A. variabilis Kuetz., x 440.

PLATE XIX

Figure a. Photograph, Ronan Pond 1.

Figure b. Ronan Pond 1.

L (Length) : 135 feet.
W (Width) : 65 feet.
A (Area) : .18 acres.

Figure a.

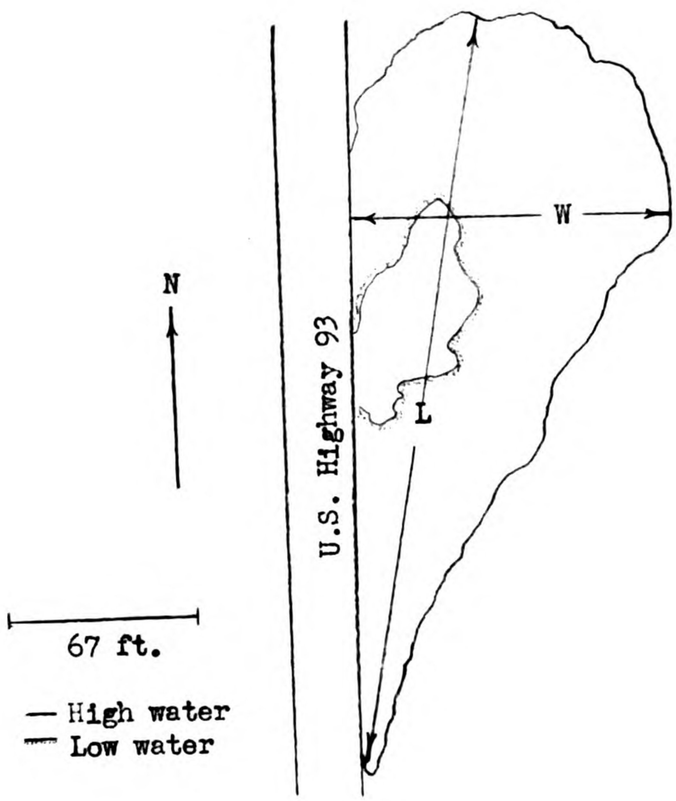


Figure b.

PLATE XX

Figure a. Ronan Pond 2; photograph illustrating the turbidity of the water.

Figure b. Ronan Pond 2.

L (Length) : 60 feet.
W (Width) : 60 feet.
A (Area) : .08 acres.

Figure a.

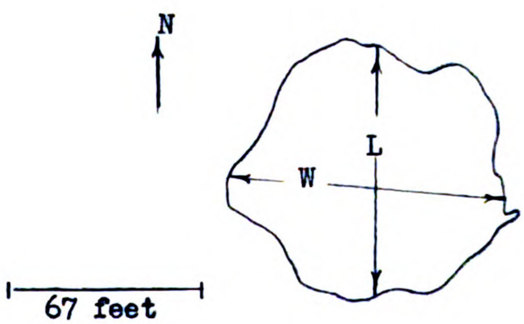


Figure b.

PLATE XXI

Figure a. Photograph, Ronan Pond 3.

Figure b. Ronan Pond 3.

L (Length)	:	125 feet.
W (Width)	:	100 feet.
A (Area)	:	.28 acres.

Figure a.

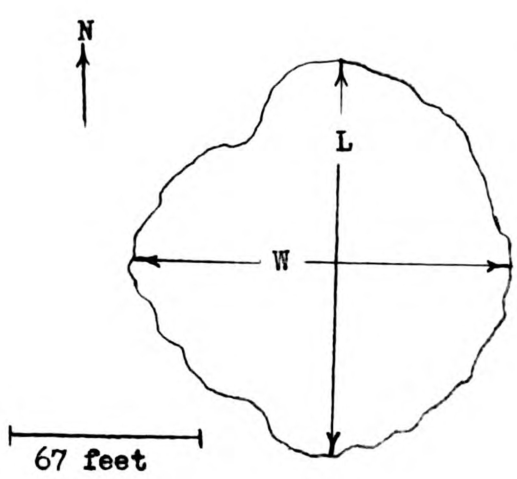


Figure b.

PLATE XXII

Figure a. Ronan Pond 4; photograph illustrating a bloom of Euglena elongata Schewiakoff encountered on July 24, 1954.

Figure b. Ronan Pond 4.

L (Length) : 80 feet.
W (Width) : 60 feet.
A (Area) : .09 acres.

Figure a.

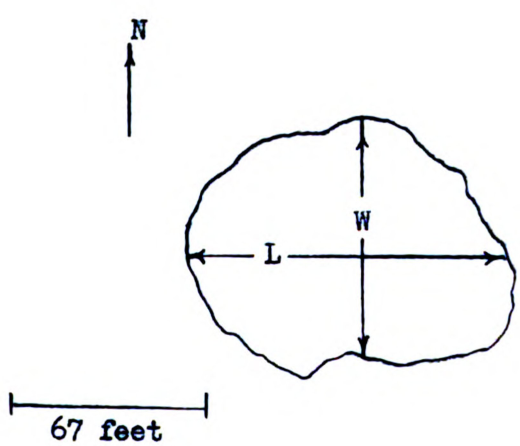


Figure b.

PLATE XXIII

Figure a. Photograph, Upper Twin Lake.

Figure b. Upper Twin Lake.

L (Length) : 735 feet.
W (Width) : 335 feet.
A (Area) : 2.8 acres.

Figure a.

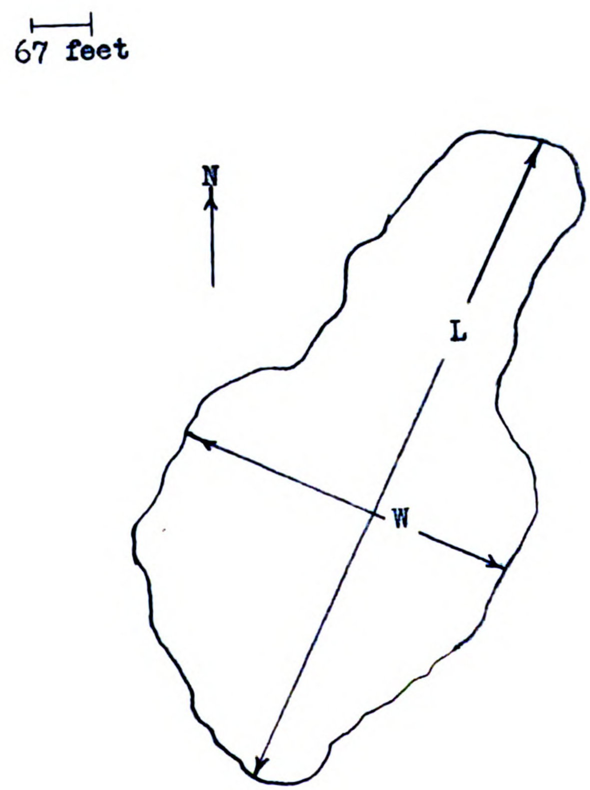


Figure b.

PLATE XXIV

Figure a. Lower Twin Lake; photograph illustrating eight foot drop in water level. Photo taken on July 28, 1953.

Figure b. Lower Twin Lake

L (Length) : 1,976 feet.
W (Width) : 1,824 feet.
A (Area)
High water : 24.2 acres.
Low water : 13.2 acres.

Explanation of symbols:
I - inlet
O - outlet
Is - island

Figure a.

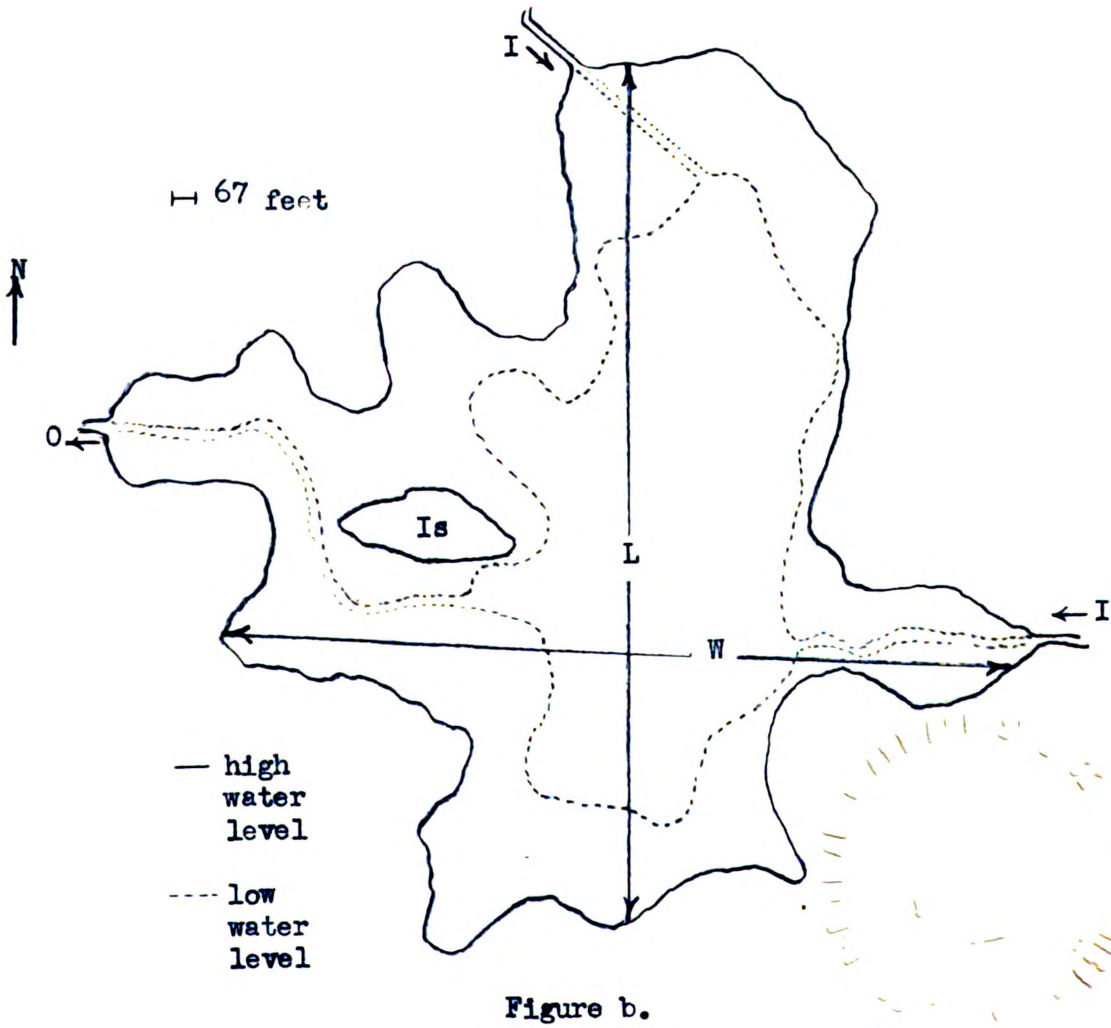


Figure b.