CONTRIBUTIONS TO THE BIOLOGY OF THE GREAT LAKES.

THE PLANKTON ALGÆ OF LAKE ERIE, WITH SPECIAL REFERENCE TO THE CHLOROPHYCEÆ.

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INTRODUCTION.

The unicellular algæ, which in themselves show most interesting characteristics in their structure and life history, come to have a double significance when considered in connection with their environment. Investigation shows the presence of an intimate connection and interdependence between them and their surroundings. While they depend upon substances in the water for nutrition, they in turn probably perform a valuable function, the same that has been proved by Bokorny '94 and Strohmeyer '97, in the case of some higher algæ, that of purifying the water, reducing the amount of bacterial growth accompanying decay, and rendering the medium fit for higher life. Their value also as a food supply to the aquatic fauna is well known. In any biological study of a body of water the algæ must therefore receive attention, and should be considered with reference to their environment rather than as independent unrelated entities.

A study of this kind should be continued for a number of years, for aside from the desirability of repeated observations, it is necessary on account of variations in the flora from year to year. Certain species may be abundant each year, but others are periodic in their appearance, being found only at intervals of three or four years; and forms, more or less polymorphic, have been known to appear almost exclusively in one condition one year and in another condition the next, so that their identity has not been known until their life history has been traced. Such variations must be due to variations in environment, so that before these phenomena can be understood the environment must be known and its influence determined.

In the natural state, the elements in environment are so numerous and so connected that to know definitely which of these produce a certain effect on an organism is impossible. This must be ascertained under artificial conditions and experimentation must be resorted to for this purpose. Under these circumstances the environment may be altered, certain of its elements may be eliminated and the effect of others studied, so that after repeated trials we may arrive at more definite knowledge of the life principles of these organisms than would be possible in the native state. When the relation to environment is definitely known, then we may go still further and, by changing this environment, exert a certain control over these

organisms, causing them at will to reproduce, or to assume any stage in their development which we may desire.

At present great confusion exists in the nomenclature of these lower vegetable organisms. Many, in certain stages of their development, can not be distinguished from one another, and even some polymorphic filamentous algæ have often been confused with unicellular forms, as they may assume a unicellular condition in which even a skilled observer is unable to distinguish them with certainty from true unicellular plants. The entire life history should therefore be traced, and although there may be stages in the development of different ones which can not be readily distinguished, a broader knowledge must aid in recognition.

To determine accurately the life history of a species, observation should be made from pure cultures. The need of this has been pointed out by Klebs '96, Artari '92 and Senn '99, and has often been suggested by the inaccurate work of a number of investigators, in which many species have been confused. If one start with a single cell or a small cluster of cells, all of which are known to be the same, and from these procure an unlimited supply of absolutely pure material, then one can assert with certitude that whatever developments occur they are characteristic of that species, whereas if the material be not pure one is easily misled as to the connection of different forms. But even a pure culture under one set of conditions is not sufficient. Material should be subjected to all possible conditions which might ever occur in nature, and the effect of these conditions studied in all phases of development. When this is done we may venture to classify the organism, and then many phenomena not now understood will probably be explained.

In the present study, which was continued during the summer of 1898, 1899, and 1900 at Put-in Bay, Lake Erie, and at Ann Arbor, Mich., in 1900, the work has been largely preparatory, and has been confined to comparatively few of the numerous forms present. The first summer was devoted principally to becoming acquainted with the forms found in Lake Erie, and in experimenting with culture media, that pure cultures of the different forms might be obtained and the conditions governing development be determined. It was soon found that although algæ existed side by side in the water of the lake, the conditions which determined their growth were not the same—that the favorable conditions for development must be determined for each genus, and often for each species individually. Comparatively few would live at all in the media which are so generally used for more hardy forms found in stagnant pools. After determining the favorable media for some of the most common forms in the plankton, the following summers were devoted to tracing their life history and studying such biological facts as could be determined.

As the amount of work to be done was so great, it was thought best to limit investigation to some special group, and as the *Chlorophyceæ* are more easily maintained in culture and are more varied in their development, requiring more constant observation, they were taken first. All species to which special attention is given in this paper, unless a statement to the contrary is made, were taken from the plankton, and an abundance of pure material was obtained by cultivation. Cultures were made in the ordinary Stender dishes, and parallel with these were also continued hanging drop cultures, where the development of the same individuals could be observed from day to day and no step be overlooked.

Aside from tracing the development of a number of the members of this group,

a partial list is added of the algæ occurring in the plankton, though this is by no means complete, as comparatively little time was given to the determination of the Diatoms. The material was merely preserved for future examination. The determination of the Desmids was mainly left to Mr. A. J. Pieters, who has given a list of this family. (Pieters '01.) A number of the *Cyanophyceæ* also, which are common in the plankton, have not been determined. These are minute gelatinous forms occurring as flocculent masses in the water, and though the structure of the cells is constant, the form of the colony is more or less variable, depending apparently on the age of the colony and the kind and amount of nutritive substances in the water. To make an accurate list of these would require careful comparison and a more perfect knowledge of their life conditions than we now have. Undoubtedly many of them are undescribed species. Though the list of *Chlorophyceæ* here given is fuller than that of other classes, it is by no means complete. Some unrecognized forms were met with where attempts at cultivation failed, due to inappropriate culture conditions, and as a result classification could not be made.

In the examination of fresh plankton material, the more conspicuous forms were easily detected, but there were always a number of minute forms, such as *Chlorella*, *Chlorosphæra*, and *Chlamydomonas*, which easily escaped notice, or, if observed, they appeared as single green cells which could not be identified. That these might be taken account of, and not be altogether overlooked, large cultures were started from the fresh plankton, and in these cultures developed many such forms which had escaped observation in the examination of the fresh material. Some of these were isolated from all other forms of algæ and their development studied. It is believed, however, that farther study in this line will give many additional species and many interesting biological facts, for as yet but few of these larger cultures have been thoroughly examined and the species determined.

For the names of species, where a detailed study is not given, the determination is based on the simple descriptions of other authors. The list is given, however, only as a temporary guide to the forms present, for it is believed that new methods of investigation, when applied to the development of even some of the best recognized genera, will change the nomenclature considerably. Some forms which have been classed together may prove to be distinct species, and possibly others which show variation should be combined to form one species.

In the physiological work done on these forms, by far the greatest amount of attention has been given to the subject of nutrition and culture media. Temperature is of less importance, for relatively great variations do not seem to affect them. The water in the natural condition never reaches a temperature so high as to kill them, and low temperature—even freezing, at least in some cases—does not end their existence, but seems to affect them mainly in reducing their rate of increase. The degree of light, too, in which they can live would seem to vary largely, as they are often found at considerable depth, as well as at the surface. The belief of many recent investigators that algæ with chromatophores may make use of both organic and inorganic substances in their nutrition, is supported by the experiments of Artari '01 and Knörrich '01, both of whom found that the algæ used in experimentation thrived much better when organic substances were present in addition to the inorganic. Artari even found that at least certain forms could live and remain green in total darkness.

It has been the experience of the writer that great variation exists among

different algæ on this point and that the kind of substance and the amount best suited to development must be determined for every alga selected for culture. While some grow more luxuriantly in a purely inorganic solution, others, among which are the unicellular blue-green algæ, seem to prefer a solution where at most but a trace of mineral matter is present. The culture medium most favorable in a large number of cases was a decoction made from the organic matter of the plankton. This seemed especially favorable if large quantities of *Anabæna flos-aquæ* were present. This observation that the organic matter of the water could be used by the algæ has suggested a possible explanation of the great increase of algæ at certain seasons, causing the "water bloom." This phenomenon has been observed by the writer but three times, but at each time it was known that an unusual amount of dead organic matter was in the water of that vicinity. At one time the matter was in the form of numerous small dead fish floating on the water; at another time a quantity of refuse had been emptied into the bay where the water bloom was noticed; and a third time large areas of the surface of the water were covered with the skins of Ephemera which are shed before the insect reaches the imago state. Such phenomena as these can be explained only experimentally, and it is along these lines of increase and source of nutrition that further investigation should be carried.

THE STRUCTURE AND LIFE HISTORY OF CERTAIN PLANKTON ALGÆ.

Chlamydomonas gracilis Snow, new species.

This species of *Chlamydomonas* (fig. 1) in its most vigorous and normal motile condition is cylindrical, ovoid or ellipsoidal in shape, rounded at the posterior end and bluntly pointed at the anterior end. Length 10.5 to 13 μ; breadth 5 to 6.5 μ. In the nonmotile condition the cells are ovoid or spherical, and often motile individuals of the same shape are noticed, with a diameter of 9 to 10.5 μ. The chloroplast and entire contents are sometimes withdrawn from the membrane either at the anterior or posterior end. When at the anterior end the two protoplasmic flagella can be seen to be continuous with the protoplasm within. The flagella are somewhat longer than the cell.

The single hollow chloroplast lines the membrane throughout, except for a very small area just at the anterior end, at which point two pulsating vacuoles can be seen. The color is a dull bluish-green, rather than a vivid green. Oil is always present. The pyrenoid is in the extreme posterior end of the cell. The pigment spot is a conspicuous dull-red disk, and is often situated as far back as midway between the two ends or even farther. The nucleus occupies a position between the center and the anterior end of the cell. After division the cells are liberated by the enveloping membrane becoming dissolved at one point, through which the new individuals escape, leaving the empty membrane behind.

This species, like most species of *Chlamydomonas*, grew and reproduced readily in a 0.2 to 0.4 per cent Knop's solution, and this culture medium was used to trace the life history of the species.

On transferring material from Knop's solution to water, individuals were formed which were taken to be the gametes, though only in one instance was indication of copulation noticed (fig. 1, 4). These were in all respects like the ordinary motile form, except that they were smaller, ovoid in shape, and had no membrane (fig. 1, 3). Though the species resembled *Chlamydomonas debaryana* Goros., it is much smaller and more cylindrical in shape than that species.

This species was found 2½ miles north of Kelley Island, in Lake Erie. It is by no means widely distributed in the water of the lake.

Chlamydomonas communis Snow, new species.

This species in the motile stage resembles closely the preceding species, but after cultivating the two forms in pure cultures side by side for over two years, and finding characteristics which are distinguishing and constant, they have been separated into two species. The size and shape of the two are almost identical, the shape being oval or ellipsoidal and pointed at the anterior end (fig. 11).

The dimensions are 10.5 to 13 μ long and 6.5 to 8 μ broad. The color is a brighter and yellower green than that of the preceding species; the pyrenoid, instead of being at the extreme posterior end of the cell is near the center, and the pigment spot is an inconspicuous elongated strip of dull red which can rarely be distinguished, except when viewed at the side. In all other respects the structure of this species resembles that of the preceding. The division is longitudinal. *Chlamydomonas communis*, though in general appearance greatly resembling *Chlamydomonas media* Klebs, is smaller, the largest cells being only about half as large as the largest of that species. The mode of division also in the two species is so different that the two could not be classified together.

This species was found in many collections taken at the western end of Lake Erie.

Chlamydomonas globosa Snow, new species.

In the natural condition in the plankton of Lake Erie this species exists abundantly, but in a form not easily recognized as a *Chlamydomonas*. In appearance it resembles *Pleurococcus regularis* Artari, consisting of one or more clusters of spherical cells, more or less separated from each other, and all imbedded and held in place by a thick, gelatinous covering. When first placed in culture the gelatinous envelope disappears, the cells become isolated and the normal appearance of a *Chlamydomonas* is assumed; but when division occurs the alga takes again the cluster form as found in the plankton.

In the motile form the cells are spherical or slightly ellipsoidal, with a diameter of 5 to 7.8 μ. No anterior beak is present. There are two flagella, as long or slightly longer than the cell, and a small inconspicuous pigment spot at the side, about half way between equator and cilia (fig. III).

The chloroplast extends to the extreme anterior end of the protoplast, and is much thickened at the posterior end, in which portion the pyrenoid lies. The pyrenoid is enveloped by a thick layer of starch. Only a single pulsating vacuole can be distinguished at the anterior end, but this is unusually large in size. Several globules of oil are present in the anterior portion of the cell. Often the cell contents are withdrawn from the membrane, either at the anterior end, the posterior end, or at all points. Gametes were not found.

After division the cells are liberated by the cell wall becoming gelatinous. In 0.2 per cent Knop's solution, where division took place normally and rapidly, the cells existed in clusters of four, which resembled in every respect some of the cell compounds found in the plankton. This species of *Chlamydomonas* was cultivated for a period of two years, and during this time no variation was noticed.

Scenedesmus bijugatus var. **flexuosus** Lemm.

The form under consideration is identical with *Scenedesmus bijugatus* var. *flexuosus* described by Lemmerman '99, except that in a cœnobium 32 cells seem to occur more frequently than 16 (fig. IV, 1). Both numbers frequently appear in the plankton of Lake Erie, however, and the two forms are undoubtedly the same. This variety was cultivated by the author for about a year under a large number of conditions, and as some points were observed, not noted in Lemmerman's description, they are given here.

It was first thought from its general resemblance to *S. bijugatus* that it might be this species which had assumed a greater development due to unobstructed light and the inexhaustible supply of oxygen, carbon dioxide, and nutritive substances which are constantly supplied by the ever-moving water of the lake, but cultivation of the species for some months, during which many generations were traced, proved that the great number of cells was characteristic for the organism, and that when placed under the artificial conditions, where the supply of air and nutrition were not so constantly renewed as in the lake, it did not necessarily revert to the usual form of *S. bijugatus* with 8 cells. It is true that, under special conditions, where the vitality was low, it sometimes produced an 8-celled cœnobium, but in the same culture where 8 cells were found cœnobia of 16 or 32 cells were also found. The cœnobia of 8 or 16 cells produced again cœnobia of 32 cells, so that it would seem that the larger number of cells was normal, rather than abnormal.

The greatest diameter of the cells of a mature cœnobium is 20.8 μ, while the shortest is 8.9 μ. A young cœnobium of 32 cells measured 160 μ in length, while an older one measured 364 μ. The great length of one of these individuals strongly suggests a filamentous alga. The shape of the cells in young cœnobia is cylindrical, with slightly rounded ends. In older individuals which are

passing into a resting condition the ends become more rounded and the shape more ellipsoidal. In the mature resting stage the cells are spherical (fig. IV, 2).

The membrane is perfectly smooth without processes or markings of any kind. The composition of the membrane is cellulose, turning blue when treated with iodine and sulphuric acid. In the younger individuals the membrane is comparatively thin, but when the cell passes into a resting condition the membrane becomes very much thickened, is 2.5 to 3.25 μ in diameter, and two, three, or sometimes four layers are distinguishable. The thick inner layers are also of cellulose, while the outermost layer becomes to a greater or less degree cutinized. As the cells pass into a resting stage and become spherical in shape, the surface of contact between two adjoining cells becomes less and less, and finally they break away from each other and exist singly.

The chloroplast, under natural conditions, is a thin, homogeneous layer, irregularly interrupted at the center, and forming a lining to the membrane. At one side near this point a large pyrenoid is present. Under cultivation, in most media, the chloroplast assumes a granular appearance on the surface and the perforations are obscured. Later a large amount of oil is developed which is readily dissolved in absolute alcohol. As the cell passes into a resting condition this oil gradually assumes an orange color. On account of the ease with which the cells pass into a resting condition the normal condition of the chloroplast can with difficulty be maintained under cultivation.

The nucleus is small and lies near the pyrenoid, sometimes on one side, sometimes on the other. Staining with hæmatoxylin brings out the presence of several large vacuoles in the cell cavity.

In its relations to external conditions this variety seems in many ways to deviate from most other algæ. In a number of solutions, found generally to be favorable for algal culture, this variety simply passed into a resting condition. The only solution tried which really proved to be favorable was a solution of decaying *Anabœna flos-aquæ*, which occurred at times in great quantities on the surface of the lake. In this the development seemed normal. In an organic solution (decaying peas) and in 0.2 per cent Knop's solution the color became green and healthy, but no reproduction occurred, at least for many weeks. A solution from the organic material of the plankton proved favorable to reproduction, but old and young cœnobia alike soon became filled with orange-colored oil, passing into a resting condition, and remained in this condition until the nutrition of the medium was finally exhausted, or until they were transferred to a fresh and favorable solution.

Of the inorganic solutions, Sachs's, Knop's, Oelmann's and Knop's solution without calcium, Sachs's solution was the only one that was at all favorable. Here reproduction occurred readily, and the cells assumed a normal appearance, but even in this solution, after a time, the cœnobia gradually passed into a resting condition.

Staurogenia apiculata Lemm.

This species, which is very generally, though not universally, found in the plankton of Lake Erie, is undoubtedly that described by Lemmerman '98 as *Staurogenia apiculata*. His figure and measurements agree quite closely with those of the Lake Erie species, though his description leaves us in some doubt in regard to details.

In Lake Erie this alga may occur either as individual cœnobia, composed of 4 cells lying in one plane (fig. V, 4, 5), or these cœnobia may be united into large, more or less irregular rectangular plates of cells, measuring 50 to 150 μ on a side (fig. V, 1).

The 4 cells of the cœnobium are either lemon-shaped or oval, and are arranged to form a rectangle with a diamond-shaped space at the center. Of all the species of the *Cœnobiœ*, this is apparently the most constant in regard to the number of cells. In other members of this tribe the number of cells of any daughter individual depends very largely upon external conditions and the vitality of the parent cœnobium, but of the many thousand cœnobia of this species examined under widely varying conditions, only one individual showed any deviation as to number of cells. In this case division was incomplete and but 3 cells were formed instead of 4, though four pyrenoids were present.

The large plate-like structures which are found in the tow, and which also occur in cultures, arise from the daughter cœnobia remaining after liberation in the position in which they are formed (fig. V, 1), being held in place by a colorless, gelatinous substance which surrounds each individual. As each of the 4 cells gives rise to a daughter cœnobium of 4 cells, all of which lie in the same plane, a plate of 16 cells is formed, and as each of these again produces a cœnobium, a compound cœnobium of 64 cells is produced. This process continues, but the plate-like struc-

ture soon becomes more or less broken and distorted, as is seen in the material from the plankton, and the irregularity increases as reproduction continues. As the gelatinous substance which holds these together is invisible without reagents, one receives the impression that each plate-like mass is a cœnobium or individual, whereas in reality it is made up of many.

Under normal conditions of growth the cells of this species are ovoid or lemon-shaped, with the membrane projecting into a very short and almost obscure wart at one or both ends of the cell (fig. v, 4, 5). The typical shape is evidently that of a lemon which is more or less unsymmetrical with reference to its long axis. But in the cœnobia where two cells are in contact their opposed ends often become more or less flattened. The projecting portions of the membrane are then often not formed, and the cells are quite distinctly ovoid, the broader portions of the adjoining cells turned toward each other. The mature cells measure 5.2 to 8 μ long and 3.25 to 5.2 μ broad, while in young cœnobia they are 5 to 5.8 μ long and 3.25 to 4 μ broad.

The membrane is very thin and consists of cellulose as shown when treated with iodine and sulphuric acid. Surrounding the membrane and enveloping the whole cœnobium or compound cœnobium is the homogeneous gelatinous substance which unites the separate cœnobia. This is apparently excreted from the cells and is not a dissolved portion of the membrane, as the membranes of one or more preceding generations are sharply defined and lie embedded in this substance (fig. v, 1). The ways in which this responds to different stains are various. Fuchsin-iodine green neither stains the gelatinous substance nor is capable of penetrating it. It therefore leaves the cell contents uncolored. *Hæmatoxylin*, fuchsin, and safranin stain the cell contents, but not the gelatinous envelope; the latter, however, takes a deep color with gentian violet. The structure is best brought out by tannate vesuvine which stains it brown. With this stain single cœnobia show but a single layer of this substance, often thicker than the diameter of the cells themselves, though varying somewhat in amount. In the large compound cœnobia several layers are made visible, each successive outer layer being less dense than the adjoining inner layer. These different layers are the gelatinous envelopes developed during the different generations and retained from one generation to the next. The inner denser layer is sharply outlined from the others and is 3 to 3.5 μ thick. With the tannate vesuvine fine radiating lines are brought to view at right angles to the surface of the cell, and undoubtedly indicate a prismatic structure (fig. v, 2) such as described by Klebs '86 for *Zygnema*. The second or next outer layer shows no such striations, but is quite definitely outlined, while the third and outermost visible layer is more or less indistinct and gradually vanishes into the surrounding medium.

The chloroplast is thin, parietal, and forms a close lining to the membrane. In some young cœnobia, on the side of the cell next to the central space, there was seen to be an opening through the chromataphore, but in mature specimens no trace of an opening could be detected. Lying imbedded in the chloroplast is a single, relatively large pyrenoid surrounded by a thick layer of starch. The position of the pyrenoid in the cell is in no wise constant, as sometimes it lies nearer one end of the cell and sometimes nearer the other. Its position also in reference to the nucleus is not constant; the latter, however, occupies different positions in the cell according to the age.

In young cœnobia the nucleus invariably occupies a position near the wall adjoining the central space (fig. v, 6*a*), while in older individuals it moves toward the center or near to one end of the cell. The minuteness of the nucleus renders a detailed study difficult, but material stained with hæmatoxylin showed strands of protoplasm radiating from it, and in one case a nucleolus was plainly visible (fig. v, 8). In the same material also a stained network appeared throughout the cell and was undoubtedly due to the arrangement of the protoplasm and vacuoles. Small globules of oil were always present, and occasionally larger globules. This oil became darkened by osmic acid and was dissolved in 10 per cent potassium hydrate. It was not dissolved in absolute alcohol, which would show the oil to be of a fatty rather than an ethereal nature.

The new individual arises from the successive bipartition of the contents of any cell of the cœnobium. The first division is a transverse one (fig. v, 4). The second division, which occurs in each of the products of the first division, is at right angles to the first and in the same plane in the two products, so that the elements are arranged in the form of a rectangle while still within the mother membrane. The division of the different contents of the cell is not simultaneous, as the chromataphore is divided before the pyrenoid, and judging from their relative position in the cell at this time, both of these divide before the nucleus. The four daughter nuclei occupy a position near the point of contact of the four chromataphores (fig. v, 4*a*), while the pyrenoids lie

toward the opposite end of the daughter cell (fig. v, 4). The nuclei retain this position in the cell for some time after the cells are liberated (fig. v, 6). Before liberation each cell becomes invested with a membrane.

The daughter cœnobium is set free by the membrane of the mother cell becoming ruptured from the middle of the base to the apex, so that one longitudinal half is loosened and thrown back like a lid, thus setting free the daughter individuals (fig. v, 7). Under conditions where but little gelatinous substance is present and only single cœnobia are produced, many such empty membranes are found in the surrounding medium. Where the gelatinous substance is in great abundance, and large plates of cells are formed, these remnants of membranes for two or more generations may be found clinging to the sides of the cells.

Physiology.—This species of *Staurogenia* is greatly affected by the kind of substances available for nutrition. Cultures were made in a large number of different solutions—Knop's solution, sugar solution, decoctions of mixed vegetable and animal matter found in the plankton, decoctions of pure vegetable matter, and decoctions of earth. Other solutions were also used which will be referred to later. In most cases cultures were made in a number of different concentrations of the same solution, so that amount of substance, as well as kind, was taken into consideration. For rapidity of increase the organic solutions seemed to be of far more importance to the species than the inorganic, and the solutions found most favorable to this were the decoctions of organic matter from the plankton, though a solution from decaying peas was also favorable. In fresh cultures in these solutions the plates usually consisted of sixty-four cells (fig. v, 1), one-half usually being folded back upon the other, but in the older cultures, where the material had increased greatly, the plates were small, consisting in a large number of cases of sixteen cells (fig. v, 2).

Knop's solution, which is a favorable medium for a large number of algæ, did not prove favorable to either reproduction or development in this species. In cultures of 0.4 per cent, 0.1 per cent, and 0.05 per cent of this solution, very little increase took place, the color was pale and the regularity of the cœnobia was lost, while, owing to the absence of gelatinous substance, the large masses were never formed. In 0.1 per cent and 0.05 per cent growth was more abundant than in the 0.4 per cent. The cells showed no regularity of arrangement, however, and no trace of gelatinous substance could be detected even when treated with tannate vesuvine (fig. v, 3). In the decoctions of earth development was normal, increase was rapid, and the general condition was vigorous. In a 2 per cent sugar solution the species lived but a short time. In cultures where nutrition had become exhausted the cells assumed a dull rust color, due to the presence of oil. This probably was a resting stage, though all attempts to resuscitate it after it had been dried in this condition failed; when not dry, however, the green color soon returned if fresh nutrient solution was added.

As this species did not flourish in Knop's solution the question arose as to what element in the compound was detrimental to the alga and prevented development. It was thought that it might be the large amount of calcium in Knop's solution which produced this effect, and to determine this point Knop's solution was then made without calcium, and a solution without calcium used by Oelmann in the cultivation of sphagnum was tried. Cultures were made in various concentrations of both these solutions with the following results: In a 0.4 per cent Oelmann's solution development was far more natural than under any other artifical conditions, the group of cells being much larger than in other cultures. The same appearance, though to a less extent, was found in other concentrations—0.1 per cent and 0.05 per cent of the same solution and also in 0.5 per cent and 0.25 per cent of Knop's solution without calcium. Apparently, then, calcium interferes with development, and in nature the organism probably would not find a habitat in water containing much of this element, but would seek a soft water rather than a hard. The number of clusters which were formed in these cultures without calcium was few in comparison to the number in organic solutions and the cells were a trifle smaller. The direct cause of the development being higher where the individuals are fewest was not determined in this case, but it seems to be true of the other algæ as well as of this.

Fusola viridis Snow, new genus and new species.

In the natural condition, as found in a stagnant pond in Middle Bass Island, in Lake Erie, the cells of this species were single, fusiform in shape, and sometimes slightly sigmoid (fig. vi, 3). They vary from 27 to 39 μ in length and 8.5 to 21 μ in width. A medium size is 28.5 μ long and 8 μ broad.

A distinguishing character is the gelatinous covering, usually about 6.5 to 8 μ thick, surrounding each cell. This is excreted from the cell and is of such a consistence as to be plainly visible under the microscope, but shows no laminated structure. In mature cells no further structure is visible in the gelatinous substance; but in rather young individuals, if cells be stained with tannate vesuvine, and sometimes without staining, two portions of the ruptured mother membrane are seen lying imbedded in this gelatinous substance (fig. VI, 4).

The membrane of the cell is composed of cellulose, which shows the blue color with iodine and sulphuric acid. The gelatinous envelope remains unaltered in appearance with these reagents. The chloroplast occupies the larger portion of the cell, leaving near the center only a relatively small space, which in direct view appears as a lighter circle. In this lies the nucleus. A large pyrenoid is prominent, lying also near the center of the cell. Small globules of oil occur and become darkened by osmic acid. In old cultures the cell assumes something of a brownish color, which may represent a resting stage, but when such a brownish cell was allowed to dry it could not be induced to grow again.

The reproduction takes place by a single transverse division of the contents of the mother cell (fig. VI, 1, 2). The two parts thus formed gradually elongate in opposite directions from the point where division took place, one slipping by the other in the process (fig. VI, 3, 4) and both becoming invested with a membrane. As the gelatinous material is excreted from the cells they become gradually separated from each other, the surrounding membrane is diagonally ruptured, and the cells are set free. The division is rapidly repeated so that the appearance is as if 4, 8, or 16 cells originated at once from a single cell, but in the present study in no case were more than two cells seen to originate at one time from a parent individual.

The shape of the cells and the formation of colonies is largely controlled by the nutrient medium in which the alga grows. A large number of cultures were made in different solutions, and it was found that 0.05 per cent Knop's solution most nearly reproduced the species in the form in which it was first found. In a weak decoction of earth and in an infusion of *Anabæna flos-aquæ* the cells assumed a much longer and more slender form, while on agar mixed with 0.4 per cent Knop's solution all resemblance to the original form was lost, the cells becoming perfectly spherical, with dark contents, and a wide, gelatinous envelope. In a solution containing organic matter from the plankton, also in the decoction of earth, gelatinous masses were formed as large as a pea, while in 0.05 per cent Knop's solution the cells usually existed either singly or in smaller clusters of 4 to 16 cells. After some months these cultures appeared as a vivid green jelly, due to the great increase in the number of cells.

In some of the general characteristics this species resembles those species of *Oocystis*, where the cells lie imbedded in a gelatinous matrix, but the fusiform shape, the greater density of the gelatinous envelope, and the structure of the chloroplast would all indicate that it can not be classified with *Oocystis*.

Oocystis borgei Snow, new species.

In frequency of appearance and the form in which it occurred this species showed great variation during the three summers when observations were made. In 1898 it was not noted at all in the plankton, while in 1899 it was the most abundant of all of the *Chlorophyceæ* and appeared in large complexes of many cells grouped into twos, fours, or eights, and all imbedded in a homogeneous, transparent, gelatinous substance. In a very few cases colonies of two cells were noted. In 1900 these large gelatinous masses were never observed, but the small colonies of two or four cells, such as described by Borge ('00) occurred frequently. From the large gelatinous masses pure cultures were easily obtained. The cells measure 13 μ long and 9 μ broad, and the shape is ellipsoidal or slightly fusiform (fig. VII, 1, 2, 3).

The membrane is a thin layer enveloping the contents. Outside of this is a thick, gelatinous, covering which unites the cells into colonies, and varies in thickness from one-half to twice the diameter of the cell (fig. VII, 4, 5). The membrane consists of cellulose, taking a blue color with iodine and sulphuric acid. Cells in the natural condition and young cells in culture showed the membrane to be of the same thickness at all points, but some older cells in culture, though not all, showed the membrane to be somewhat thickened at the ends. This thickening, however, did not take the nature of a wart or projection, such as has been noted in other species. The outer

gelatinous envelope becomes stained with hæmatoxylin and also with tannate vesuvine. With the latter it is homogeneous and shows no prismatic structure characteristic for such coverings in many similar forms of algæ. Two layers can often be detected, however, the inner one the more dense. The outer one probably belongs to the preceding generation (fig. VII, 4).

There is but a single, vivid green, homogeneous, parietal chloroplast, through which there is an opening at one side or near one end. From this opening the chloroplast gradually increases in thickness toward the opposite side, where it incloses a large pyrenoid (fig. VII, 1, 2). The central portion of the pyrenoid shows a crystalline character, and is surrounded by a thick starch envelope. The single spherical or elongated nucleus lies near the center (fig. VII, 1*a*). With hæmatoxylin a network throughout the cell is brought to view, and is probably due to the arrangement of protoplasm and vacuoles. Oil is found in greater or less quantity in all cells. This oil is turned brown by osmic acid and becomes dissolved in absolute alcohol.

Reproduction occurs by means of bipartition or repeated bipartition of the cell contents, so that two, four, or eight cells are formed from one individual. The first division is a transverse one (fig. VII, 3*a*); then, if the process continues, the next divisions, dividing the products of the first, take place at right angles to the first division and at right angles to each other (fig. VII, 3*b*). Each part then becomes invested with a membrane and the outer gelatinous substance begins to be excreted by the cells before they are set free from the mother cell. The enveloping mother membrane becomes much distended, probably by means of the gelatinous substance (fig. VII, 4), until finally it becomes ruptured at one point and the two, four, or eight cells are set free, leaving the remnant of the old cell wall clinging to the outer surface of the gelatinous covering (fig. VII, 3, 5). Though in young individuals there is but a single chromatophore, this very soon becomes divided into two or four, long before the division of the cells occurs, so that in a culture the great majority of cells contain four chromatophores, and it was first thought that four was the normal number. Preceding the division of the chlorophyl body occurs the division of the pyrenoid. The division of the nucleus does not occur until just before the formation of the daughter cells and long after the division of the chloroplast.

Physiology.—Though in the natural conditions the cells are usually found united into larger or smaller complexes, the aggregated form of growth is by no means necessary to existence and is characteristic only under certain conditions, for under the various environments to which the alga was submitted in artificial culture, it was found that either the isolated or aggregated condition of the cells could be produced at will. Cultures were made in various media, such as different concentrations of Knop's solution, decoctions of earth, and solutions containing animal and vegetable matter taken in the tow from the lake and stagnant ponds. Of the various solutions used the organic solutions seemed best to reproduce the aggregated form as it is found in the plankton, but even here the masses were not quite as large as those in the natural condition, although the appearance of the individual cell was perfect (fig. VII, 4). The concentration of the organic solution had a marked effect in producing the isolated or aggregated condition in the development. The exact amount of substance in solution was not determined, but it was found that in the solution which was taken as a standard the cells were all grouped in colonies, and several of these were united into compound colonies. In the same solution, but of one-half the standard concentration, and even in the above solution after the concentration had become reduced by the growth and increase of the algae, only isolated cells were formed, which were distributed throughout the liquid instead of resting on the bottom of the culture glass, as occurred in most cultures. Each individual cell was surrounded by a gelatinous covering one-half to twice the diameter of the cell in thickness, but these were not held together by a common envelope (fig. VII, 5). The vigor of the culture, however, seemed just as great as where the families were formed. It is probable that the greater amount of water present in proportion to the organic matter reduced the consistency of the gelatinous substance, and the connection between the cells was broken.

Knop's solution of different concentrations did not seem to be favorable to development, for in no case was the appearance normal. Cells were usually isolated and a great amount of oil was developed in the contents. In 1 per cent and 0.4 per cent increase was slight, while in 0.1 per cent and in 0.05 per cent, notwithstanding a very large amount of oil being present (fig. VII, 5), increase was rapid. In the decoction of earth growth was abundant and normal, except for the presence of a large amount of oil.

This species certainly resembles closely the *Oocystis lacustris* described by Chodat '97, but after cultivating the two forms, both of which occur in Lake Erie, and obtaining an abundance of pure material of both, each was found to show certain characteristic differences which separate them into different species. The most striking of these was the protruding point at the ends of the cell of *Oocystis lacustris*, while in the other species, if any thickening was noticeable at the poles, it did not project in the form of a wart, but was a gradual thickening of the membrane. Another difference, which was constant, was the longer and more slender shape of *Oocystis lacustris*.

From the figure given by Borge, 1900, of a form occurring in Sweden, it would seem that the species in question must be the same, though the dimensions are slightly smaller than those given by Borge. In recognition of Borge having first figured the species it has been called *Oocystis borgei*.

Chodatella citriformis Snow, new species.

This new species is distinguished from other species of this genus by the shape of the cell, there being a short, obtuse elongation at either end, and at the base of these are arranged the whorls of spines which characterize the genus (fig. VIII, 1, 2, 3).

The length of the cells varies from 8 to 10 μ. The spines are very delicate, often 33 to 36 μ long and but 0.5 μ broad at the base. In different individuals six, seven, eight, and nine spines were found. It was not thought by the author, however, that these represented different species, although some authors seem to distinguish different species by the number of spines. Unfortunately, large cultures of this species were not obtained; and although cells were observed through several generations in hanging drop cultures, it could not be determined whether or not the number of spines was constant in the descendants of a single individual, for as soon as an individual was confined in a hanging drop, the spines became gradually indistinct, finally disappearing, and the daughter individuals possessed either no spines or very rudimentary ones. Apparently the spines were of a gelatinous nature. In the test for cellulose with iodine and sulphuric acid they quickly disappeared when the acid was added. The reaction for cellulose was obtained in the membrane.

The chlorophyl is contained in a single parietal chloroplast, leaving the opposite side colorless. A pyrenoid lies embedded in the chloroplast.

The reproduction occurs by the cell contents becoming divided into two, four, and sometimes eight parts. Each becomes invested with a membrane, and forms a daughter individual (fig. VIII, 3). Though the actual process of liberation of the cells was not witnessed by the author, due to insufficient material, it was inferred that they were set free by the rupturing of the membrane, as membranes were found which were undoubtedly the empty mother membranes of this species.

Chodatella citriformis was found in surface tow and at a depth of about 10 meters, near North Bass Island, in Lake Erie.

Pleurococcus regularis Artari.

One of the most conspicuous and common of all the plankton algæ is a form determined by the writer as *Pleurococcus regularis* Artari (fig. IX, 1). It consists of cell complexes composed usually of 4, 8, 16, or 32 clusters of cells, more or less separated from each other and embedded in a transparent, gelatinous substance (*a*). Each cluster in turn is composed of 4, 8, 16, or 32 cells, which may be in contact with each other or may be separated from each other and held in place by the same gelatinous material. Without doubt it is these complexes which Senn '99 regards as stages in the development of *Cœlastrum microporum* Naeg., and Chodat as stages of *Cœlastrum sphærium* Naeg. The striking resemblances of these complexes to *Cœlastrum* was noted by the writer when the alga was first seen in the plankton. The view held by Chodat as to the identity of the two forms was then accepted and the difference in appearance was regarded simply as different phases of the same form, due to different conditions. It was noted, however, that side by side in the large plankton cultures, as well as in the fresh collections, both forms were found. The one corresponding to *Cœlastrum* consisted of single, isolated cœnobia composed of many closely arranged cells with very little surrounding gelatinous substance. The other form consisted of many clusters, widely separated from each other and embedded in a common gelatinous matrix. The individual cells also, as well as the cœnobia, were more or less separated from each other according to age. With a view to determining definitely whether these were the same species in different stages or distinct forms, each was isolated and placed in culture under the same condi-

tions. The difficulty attending the cultivation of the *Pleurococcus*-like form was very great, and it was not until after a very large number of attempts had been made that vigorous cultures were obtained from which conclusions could be drawn with any degree of certainty. All ordinary solutions, so commonly used in the cultivation of algæ, failed as culture media. In 0.2 to 0.4 per cent Knop's solution the form simply assumed a yellowish color and passed into a resting condition. In Knop's solution without calcium it remained green for at least six weeks, but showed no indication of reproduction. Organic solutions of various compositions and concentrations proved more favorable to its existence, but even in these not more than three generations could usually be obtained in any culture. The only solution tried that seemed really favorable was from a quantity of decaying *Anabæna flos-aquæ*. The chemical composition of this solution and the degree of concentration were not determined, but in it reproduction took place rapidly, and, as far as could be determined, normally. This solution proved equally favorable for *Cœlastrum*. Pure cultures were then made of each of the forms and placed in conditions as nearly alike as possible.

In the course of four weeks an abundance of material of both forms was obtained. These cultures were then repeated several times, and the results agreed each time. Even externally a difference in the cultures could be detected. The *Cœlastrum* form showed as a very thin green covering on the bottom of the culture glass, while in the other culture a thick cloudy layer, 3 to 4 mm. deep, covered the bottom. A minute examination showed a still more marked difference, and one which was identical with the two forms from which the cultures were made. The thick layer on the bottom of the *Pleurococcus* culture was composed of the floating loose compound clusters embedded in jelly exactly as in the plankton, except perhaps that the arrangement of the cells was less regular (fig. IX, 2–4). Unless reproduction had just occurred all the cells were more or less separated from one another, sometimes widely so, but all were held in place by the surrounding jelly. In a fresh *Cœlastrum* culture, where there were many hundreds of cœnobia, but one instance was noticed where any separation of a cell from a cœnobium occurred. Each of the other cœnobia was complete and distinct, without any connection with the other cœnobia in the culture (fig. IX, 5). In old cultures the disintegration of the cœnobia was more frequent, but in no case after disintegration had occurred were the individual cells connected by a surrounding gelatinous substance. There is, as Senn (1898) has stated, a relatively thin gelatinous envelope to the cells, but after the cells have become appreciably separated from one another this envelope no longer connects them. In no case did *Cœlastrum microporum* form compound clusters. As a result of these experiments, it seems evident to the writer that the two forms are distinct species and can not be united.

Artari ('92), in his description of *Pleurococcus regularis*, says nothing about the presence of a gelatinous envelope, but from his figures it is evidently present, as the cells, though loosely arranged, are held in place by some substance not shown. The gelatinous envelope of a cluster, when taken from the plankton, as well as of those in the artificial culture, is homogeneous, but somewhat denser near the cells. When treated with tannate vesuvin the jelly is colored brown, but no prismatic radiations from the cell are shown, as in *Staurogenia apiculata* Lemm. The thickness of the envelope seems to vary somewhat with age, being in young individuals less in diameter and denser in consistency than in older compounds (fig. IX, 2, 3). When distilled water is added the substance becomes at least partially dissolved.

The membrane is thin and consists of cellulose, turning blue when iodine and sulphuric acid are added. The chloroplast is, as Artari states, a hollow sphere closely lining the membrane, but with a circular opening at one side. In each chloroplast is a single pyrenoid. When stained with hæmatoxylin the single nucleus may be seen.

The new complexes arise by the division of the cell contents into 2, 4, 8, 16, and possibly 32 parts (fig. IX, 1). Each of these becomes invested with a cell membrane, and the enveloping mother membrane becomes more or less irregularly ruptured and the cell complex is set free. In this process of division the first visible step is the division of the pyrenoid, then the division of the chloroplast. At just what time the nucleus divides in reference to the division of the other parts was not determined. After the chloroplast has undergone one or more divisions the appearance is that of a cell with several chloroplasts, each with its own pyrenoid. It is a question whether mistakes have not been made at times by investigators in different species of algæ in taking these portions of the divided chloroplast to be entire chloroplasts and characteristic for the species. The mother membrane, after it is cast off, remains for a time embedded in the gelatinous substance (fig. IX, 2, 3*a*), but in the older complexes it is no longer visible (fig. IX, 1, 4).

As the type species of *Pleurococcus*, *Pleurococcus vulgaris* Menegh., reproduces by means of simple vegetative division involving both contents and membrane, it would seem that this species could not rightly be called *Pleurococcus*. In respect to the mode of reproduction it agrees with *Chlorella*, but the presence of the thick, gelatinous envelope is not characteristic for that genus. The physiological characteristics also of this species vary widely from those of *Chlorella*. The correct systematic position seems to be near to *Kirchneriella*, as the chief point of distinction between the two forms is the shape of the cells, the cells of this species being spherical, while the cells of *Kirchneriella* are crescent-shaped. The formation of cell complexes is the same.

Pleurococcus aquaticus Snow, new species.

Pleurococcus aquaticus shows in its highest development the typical structure of *Pleurococcus*, consisting of clusters of cells 2, 4, 8, 16, 32, or even more in number, arranged in cubical form (fig. x, 1). These clusters arise from the repeated division of cells, alternating in three directions of space.

The diameter of the cells of a cluster varies from 4 to 7 μ. The membrane is thin and gives no reaction with iodine and sulphuric acid. The chloroplast is single, concave, thin, parietal, a vivid green in color, and has an opening on one side, which, however, is rarely distinguishable while the cells are arranged in the cluster. No pyrenoid is present. The small spherical or oblong nucleus lies near the center of the cell.

The large clusters of cells evidently do not increase indefinitely in size, for after a period, under ordinary conditions, the cells undergo a dissociation, the contact between them becomes destroyed, and the cells fall into formless masses (fig. x, 5). The individual cells may then divide and either produce again the large clusters (fig. x, 1, 4), or they may divide and remain in the isolated state in which they were (fig. x, 2). It has been noticed that if the cells are some distance apart they produce again the large clusters, but if they are closely crowded, instead of remaining united after division, they become separated and exist as many single cells, which, except for the absence of a pyrenoid, can with difficulty be distinguished from an ordinary *Chlorella vulgaris* Beyerinck. They are spherical or, before division, ellipsoidal, and the opening on one side of the chromatophore is conspicuous. At any time these cells, when separated from each other, again form large clusters. In large cultures both single cells and clusters were usually present, and in only one instance were the single cells wholly lacking. This was in a culture started for other purposes in a tube made from collodion, similar in shape to a test tube. This was filled with a 0.2 per cent Knop's solution, the algæ inserted and the tube sealed. The whole was then immersed in a 0.2 per cent Knop's solution. After a few weeks the increase had been great, but only the large masses were present. Why the alga did not undergo a dissociation in this mode of cultivation, as well as in others, was not determined. The cells were also somewhat larger than in ordinary cultures, all having a diameter of 6.5 to 7 μ (fig. x, 3).

This species was in no case found in fresh material, but was found in a large plankton culture and also in a culture taken from washings of *Chara* growing among *Scirpus americana* Pursh. and *Sagittaria rigida* Pursh., in Squaw Bay, South Bass Island. As it was found in but a single plankton culture, it is probable that it is one of the many littoral forms which at times are found in the plankton, and that it had been carried out into the plankton by the action of the water. As it was never seen except in culture, it is difficult to say in what condition it exists in the natural state, whether as isolated cells or in large cell complexes. It is probable that the dissociated form is more usual, as the large cell complexes would be less apt to be overlooked.

Chlorococcum natans Snow, new species.

The cells are spherical or slightly ellipsoidal, the greatest diameter noticed being 13 μ. In appearance they resemble somewhat *Chlorococcum infusionum* Menegh., but are smaller in size, are of a lighter, more transparent green, and the contents, instead of being granular, are mottled, due to thicker and thinner places in the chloroplast (fig. xi, 1).

The shape of the chloroplast is a hollow sphere through which is a circular opening. On the side opposite this lies a pyrenoid with a starch envelope. The membrane is of cellulose. In the young stages there is a single nucleus, but shortly before reproduction the nucleus divides so that, for a period, the cells are multinucleate.

If the material be cultivated in a 2 per cent Knop's solution, almost all individuals produce gonidia; that is, the contents become divided into two, four, or eight portions, as if to produce zoospores, and these divisions, instead of becoming liberated as zoospores, become invested with a membrane and germinate while still within the mother membrane. These in turn may produce gonidia before they become liberated, so that two, and possibly three, generations may be included within a single cell wall (fig. XI, 2). When cultivated in organic solutions and in 0.4 per cent Knop's solution, oblong gonidia are formed, but the enveloping membrane becomes gelatinous, and the alga passes into a palmella condition (fig. XI, 3).

If the material be transferred from a nutritive solution to water, zoospores are formed. If transferred from 0.2 per cent or 0.4 per cent Knop's solution, the shape of the zoospores is cylindrical (fig. XI, 4). They measure 6.5 to 8 μ long and 2.5 to 3.25 μ broad and they move with a rapid motion. If the same material be transferred from 0.4 per cent Knop's solution to organic solution, the zoospores are oval (fig. XI, 5), 7.8 to 10 μ long and 5.2 to 6.5 μ broad, somewhat amœboid in nature, and they move with a slow, lethargic motion. Apparently they are the cells which, if they had not been transferred, would have produced gonidia. The structure in both cases is the same, there being a concave chloroplast in which is embedded a pyrenoid about equally distant between the two ends. At the anterior margin of the chloroplast is a red pigment spot. There are two cilia slightly longer than the cell, and at the base of these, two pulsating vacuoles. The zoospores become liberated by the mother membrane becoming gelatinous. In the case of the smaller cylindrical ones, as they expand, the enveloping membrane suddenly gives way at one point and the spores are liberated either in mass or singly. With the larger oval ones the process takes place more slowly. They arise by successive division of the contents of a cell (fig. XI, 7).

Although there is a difference in the size of these two kinds of zoospores, there is no indication that these represented distinct macrozoospores and microzoospores. Apparently the larger size is more of an abnormal condition of the zoospores, as in all respects the cylindrical form seemed the more natural.

The cells in the palmella condition and also the large zoospores resemble greatly *Chlamydomonas*, but the absence of a membrane in the motile form, the short period of motion, and the mode of growth of the alga in the inorganic solutions all showed a resemblance to *Chlorococcum*.

Botrydiopsis eriensis Snow, new species.

The younger stages of this species resemble that of *Botrydiopsis arhiza*, described by Borzi '95, but the later stages differ from that species. The cells are spherical, and when mature have a diameter of 18 to 21 μ. In the younger stages the chromatophores are more or less hexagonal disks, and are closely applied to the membrane, with spaces between them (fig. XII, 2, 3). In the older stages the chloroplasts are relatively smaller, more elongated, and more crowded (fig. XII, 1).

The membrane, which is thin, gives the characteristic reaction for cellulose with iodine and sulphuric acid. Within the cell no starch, pyrenoid, or oil is present, and the single small nucleus lies near the center.

The reproduction coincides in the main with that of *Botrydiopsis arhiza* Borzi, usually 16 or 32 zoospores being formed within a cell (fig. XII, 7). The successive stages of their formation were not observed, but it is probable that they arise from the repeated bipartition of the contents of the cell, as in other species of *Botrydiopsis*. In the mode of liberation of the zoospores this species deviates from *Botrydiopsis arhiza* and from other known forms of *Botrydiopsis*, where the zoospore mass, together with the inner layer of the enveloping membrane, escapes gradually through a small opening in the outer layer of the membrane. In this species the whole mass remains within the outer layer until both layers become gelatinous, and after a short period of motion within the membrane the zoospores one by one break through the membrane and escape.

The zoospores (fig. XII, 5) are 5.2 μ long, 2.5 to 3.25 μ broad, and they possess all of the characteristics of *Botrydiopsis* zoospores. They are very amœboid, changing their shape constantly as they move. Two elongated chromatophores are present, lying on opposite sides of the cells. One projects farther toward the anterior end than the other, and at the anterior extremity of this lies the pigment spot. A single flagellum is present. During the amœboid movements, when the protoplasm happens to project at the anterior end beyond the chloroplast, two contractile vacuoles may be seen, but they are discernible only under these conditions. The motion of the zoospores

is of short duration, and immediately upon coming to rest they become spherical in shape, but often retain the flagellum and the pigment spot after the spherical form is assumed. The germination takes place immediately (fig. XII, 6), the cells increasing in size, and the two chloroplasts becoming divided into 4, 8, and more as the size increases. Very often in old cultures and in vigorous cultures along the sides of the culture glass at the surface of the liquid the zoospores, instead of being liberated, germinate within the mother membrane and remain united in a mass long after the surrounding membrane disappears (fig. XII, 4). Before they are mature, however, they separate and have the same appearance as cells which come from the motile spores.

Botrydiopsis oleacea Snow, new species.

This species was first found in a culture from plankton material, but many cells taken to be the same were also found in fresh collections, the distinguishing characteristic being a large brownish-red globule near the center of each cell, which as yet has not been found in other plankton algæ. The cells in the mature stage are either spherical, ovoid, or lemon-shaped, but usually become more rounded in later stages of existence (fig. XIII, 1, 2). The ovoid or lemon-shaped cells were most often noted when the cells had attained about two-thirds their natural size, the latter shape being conspicuous on account of the wart-like projection on one or both ends of the cell (fig. XIII, 3, 4). The cause of these excrescences was not determined. They occurred on some but not on all cells of the same culture. The largest cells were broadly ellipsoidal, or almost spherical, and 13.5 μ in diameter.

For some months after this form was placed in culture it was regarded as a *Chlorococcum*, so nearly did the general appearance agree with the characteristics of that genus, the only striking differences being the shape, the absence of the pyrenoid, and the presence of the large red globule near the center. On account of the very granular appearance of the cell, due to small globules of oil, the chlorophyll was thought to be in a single chloroplast, as in *Chlorococcum*, and the presence of numerous small chloroplasts characteristic for *Botrydiopsis* was not suspected until the entire development was traced. Different phases of reproduction, however, showed such a resemblance to *Botrydiopsis* that the chloroplasts were again examined. In some young cells it was evident that there were several instead of one in each, though these were not distinguishable in mature cells further than that certain areas seemed slightly darker than others. Many mature cells appeared almost black, so filled were they with the minute globules of oil. This oil became dissolved in absolute alcohol. Iodine with sulphuric acid showed the membrane to be of cellulose, and hæmatoxylin brought to view the single small nucleus a little to one side of the center.

The red globule which was always present was at first taken to be a particle of red-colored oil, but, on account of the color, the ordinary tests could not be used satisfactorily. When absolute alcohol was added the globule disappeared. Its position is apparently underneath the layer of chloroplasts. It was noticed that in the formation of the zoospores the globule did not become divided, but remained in the center throughout the whole process, though it apparently grew somewhat smaller as the process continued. When the zoospores were liberated it was cast out with them and had no further connection with the organism. This suggested the appearance described by Klebs ('96), in his work on *Protosiphon* and *Hydrodictyon*, where the cell sap did not enter into the process of zoospore formation and was cast out in the same way when these were liberated. The same phenomenon has also been noted by the author in an undescribed species of *Botrydiopsis*.

The zoospores, of which 2, 4, 8, 16, or more are formed in a cell, arise through the repeated division of the entire cell contents, except the red globule, until the final number of zoospores is reached (fig. XIII, 5, 6, 7). The zoospores are characteristic for *Botrydiopsis*, having but a single cilium and being very amœboid in their motion (fig. XIII, 8). Though their shape is constantly changing, the general form is pear-shaped, broadly rounded at their posterior end, and tapering toward the cilium. In length they vary from 5 to 7.8 μ and in breadth from 3 to 5 μ at their broadest extremity. As in the mature cells so in the zoospores the chloroplasts are obscured by oil. In the anterior end, just at the base of the flagellum, is a very refractive dull red spot, but it could not be determined whether this was the ordinary pigment spot of the zoospore or the beginning of the red globule found in the older cells. The zoospores are active and seek the light. On coming to rest they become rounded and the chloroplasts become more distinct than at any other stage of their

existence. In some cases two chloroplasts are distinguishable in very young cells (fig. XIII, 9). In the liberation of the zoospores the membrane becomes to a certain extent dissolved, then the zoospores by their motion gradually expand the cell until finally the wall gives way and the spores escape. The time required for this process varies from 1 to 30 minutes.

When the nourishment of the medium in which the organism grows becomes exhausted, the cells pass into a resting stage (fig. XIII, 10, 11), the contents assume a yellow color, and the membrane becomes thick. The red globule still remains prominent. In this condition the alga can withstand being dried, but it quickly changes to the vegetative form when fresh nutritive solution is added. It was cultivated under many different conditions, but it was constant in all.

Chlorosphæra lacustris Snow, new species.

Chlorosphæra lacustris resembles somewhat the *Chlorosphæra angulosa* Klebs, but is distinguished from it in a number of details, the principal one being the size, the largest cells of this species measuring 9 to 10.5 μ, while those of *Chlorosphæra angulosa* measure from 15 to 30 μ.

The shape of the single cell of *Chlorosphæra lacustris* is either spherical, oval, or ellipsoidal (fig. XIV, 1). As in other species of *Chlorosphæra*, a vegetative division of the cells occurs in three directions of space, involving both contents and membrane, after which the cells usually remain connected, forming complexes of two, four, eight, or more cells (fig. XIV, 2, 3). In time these complexes may fall apart and the cells become spherical, as before division.

The membrane is thin and is composed of cellulose, as the test with iodine and sulphuric acid shows. The chloroplast lies close to the membrane and is of the same shape as the membrane, though relatively much thicker. No opening through the chloroplast could with certainty be detected, though a lighter area at one side was prominent. Surrounded by the chloroplast is a pyrenoid with a starch envelope.

The zoospores are 6.5 to 9 μ long and 2.6 to 4 μ broad; they are slightly broader at the posterior end than at the anterior (fig. XIV, 4). Two cilia about as long as the cell are present; also a pigment spot. The chloroplast is concave and extends nearly to the anterior end. Two pulsating vacuoles are found just back of the cilia, and a pyrenoid is embedded in the chloroplast. Four, eight, or more zoospores are formed from a cell (fig. XIV, 7). They are liberated by the membrane becoming gelatinous at one point, through which first one or two gradually force their way. The others follow in quick succession, leaving the empty membrane behind. On coming to rest the zoospore assumes at once a spherical form (fig. XIV, 5) and develops into a mature cell. In this respect it differs from *Chlorosphæra angulosa* Klebs, as in that species the zoospores retain for some time the elongated form. They originate by the successive bipartition of the cell contents (fig. XIV, 6).

Though both forms of reproduction, the vegetative division and the production of zoospores, were found in all cultures, it seemed to reproduce mainly by means of zoospores. Knop's solution of 0.2 per cent concentration seemed to be the most favorable medium for development and was used in tracing the life history. In this solution the zoospores were formed very rapidly, and when transferred to distilled water they were produced in a much shorter time than is usually required for the production of zoospores in unicellular algæ.

Chlorosphæra parvula Snow, new species.

The present species resembles somewhat the preceding species, though, aside from being smaller, it is easily distinguished from it by the gelatinous nature of the membrane after division, causing the cells to separate slightly, though held in complexes of 2, 4, or 8 cells (fig. XV, 1, 2). The two species might also be distinguished by their zoospores, those of the preceding species being more oval or ellipsoidal than those of this species. The minute points of structure of the mature cell, however, the chloroplast, the composition of the membrane, and the contents of the cell, are the same in this species as in *Chlorosphæra lacustris*. The diameter of the full-grown cell is 7.8 to 9 μ. The zoospores (fig. XV, 3), of which four are usually formed in a cell, are oval or spherical; when oval they measure 6.5 μ long and 4.5 to 5 μ broad and the spherical ones 5 to 6 μ in diameter. They have an obliquely placed concave chloroplast, a pigment spot, two cilia about 1½ times the length of the cell, and two contractile vacuoles. The zoospores are formed in the usual manner, by successive divisions of the cell contents, and are liberated by the gradual softening of the membrane.

Mesocarpus sp.

This small species of *Mesocarpus* was found so often in the plankton that it might almost be called a plankton species. At first it could not be recognized as *Mesocarpus*, for usually the chlorophyl was greatly reduced and was collected in a very small space at the center of each cell (fig. XVI, 2), and it was only after the form was placed in culture that it was recognized as belonging to that genus (fig. XVI, 1). As the zygospores were never found, the species could not be determined with certainty. By means of cultures [a] in a large number of media it was determined that the chlorophyl collects under any circumstances that are not favorable, such as in too weak or or too strong culture media (1 per cent or 0.05 per cent Knop's solution), or in media that are not adapted to the plant, as well as in old cultures when the nutrition has become exhausted. It would appear, then, that when this form occurred in the open lake, the nutrition was not qualitatively or quantitatively favorable to its most vigorous condition, though adequate to maintain its existence and even growth.

Cœlosphærium roseum Snow, new species.

Several forms of *Cœlosphærium* are almost universally found in the plankton during the summer months. Some of them are easily recognized, while others are of doubtful name, and the difficulty of cultivation makes the classification more difficult. One of those most commonly found is the form shown in fig. XVII, 1. The colonies are 34 to 52 μ in diameter; the cells measure 3.25 to 4 μ in diameter, are spherical, pinkish or brownish in color, and are closely arranged or somewhat scattered over the surface of the gelatinous sphere. Indigo solution shows the presence of a gelatinous covering to the colony, varying in thickness according to conditions. On agar cultures this covering assumed a diameter almost equal to that of the colony.

If the cells are closely arranged, and if the focus of the microscope is on the surface of the sphere, the colony appears as a typical *Cœlosphærium* where the gelatinous sphere is homogeneous (fig. XVII, 1 *a*), but if the cells are less closely arranged and the focus is at center the gelatinous portion may be seen not to be homogeneous, but to consist of a system of dichotomous gelatinous branches radiating from a common center, bearing the cells on their terminal divisions (fig. XVII, 1 *b*), as in *Dictyosphærium*. Between these branches lies gelatinous substance continuous with that surrounding the colony. The line of demarkation between this substance and the branches is more or less distinct, according to conditions. In some cases it is hardly distinguishable, while in others it is sharply defined.

As a solution from a quantity of *Anabœna flos-aquæ* was the only one in which vigorous cultures could be obtained, the alga could not be subjected to a very great variety of conditions, and yet simply transferring from the lake water to this solution produced some change. Always in cultures the cells became more closely arranged, the branches became indistinct, and in many cases, apparently when the conditions were less favorable than in the lake, the color changed from a pink to a brown, though if the concentration of the solution were right the pink color was maintained. Apparently the distinctness of the branches is controlled somewhat by the density of the surrounding medium—the denser the medium the denser the surrounding substance, and, consequently, the less conspicuous the branches. Distilled water seems to be a solvent of this substance and the cells become detached entirely from the colony. The reproduction of this species is typical in all respects for *Cœlosphærium* as described by Naegeli. If the cells become detached from the stalks, then division occurs once in three directions of space, and afterwards only in two directions, both at right angles to the surface of the sphere. As no very small colonies were found in the plankton, however, it is probable that in nature reproduction usually occurs by the division of the entire colony into two, rather than that new colonies originate from the separated cells.

Both forms mentioned—the pink, with the visible gelatinous branches, and the brown, where the gelatinous branches are not visible—were at times found in the plankton, but their identity is evident. A number of others differing slightly from either of these were found which possibly may have been connected with these, but as neither could be made to assume the characteristics of the other artificially, their identity as yet can not be assumed. In one case all traces of the enveloping gelatinous substance were wanting, and the cells, borne on what seemed to be perfectly free gelatinous stalks, were moved about freely by the action of the water (fig. XVII, 2). Other

[a] These cultures were continued for some weeks by Miss Anna L. Rhodes, as well as by the writer.

forms were found with conical or oval cells, which undoubtedly were the *Gomphosphæria lacustris* of Chodat, '98, and possibly the *Cœlosphærium naegelianum* as figured by Borge, '00.

The resemblance of the form described, as well as of these other forms, to certain species of *Gomphosphæria*, such as *Gomphosphæria lacustris* Chodat, is fully recognized by the author, but a study of the well-known *Gomphosphæria aponina* Kütz, and of the well-recognized species of *Cœlosphærium* has caused the writer to place it under the genus *Cœlosphærium* rather than *Gomphosphæria*. From a study of the true *Gomphosphæria* each cell, instead of simply resting at the extremity of the stalk, seems to lie in a capsule of the same substance as the stalk and continuous with it, as has been figured by Schmidle ('01). The outer boundary of this capsule is sharply outlined about each individual cell, an appearance which has not been noted in any of these other forms. Further, it would seem that all *Cœlosphærium* species, although the central gelatinous sphere appears homogeneous, really have at the center the dichotomously branched framework of denser gelatinous material. If a colony of *Cœlosphærium kutzingianum* Naeg. be crushed under a cover glass, it will first divide into two, then into four, and then into eight equal parts, each becoming spherical immediately, just as would occur if left to take its normal course, whereas if it were perfectly homogeneous the mass would crush without any system. In all cases of multiplication where the colony becomes divided into two, evidently the two branches of the first dichotomous division at the center become detached from each other, and the two halves, unable to hold together by the less dense gelatinous substance, are set free.

Chroococcus purpureus Snow, new species.

The cells are spherical, or, just before division, somewhat elongated, usually arranged two by two in colonies of four or eight, all cells of which are more or less separated from each other according to age, and held in place by an enveloping gelatinous substance. The diameter of the cells is 13 μ; the membrane is thin. The color in the natural condition is grayish purple (fig. XVIII).

This species is distinguished from the *Chroococcus multicoloratus* Wood in being larger, the cells more loosely associated into colonies, and in possessing a more decided purple color. When it was first noted in the plankton it was thought it might be a *Chroococcus limneticus* Lemm., which is so abundant in the plankton and which differs from it only in color, that being a blue-green, while this is a purple. Though the two species could not be maintained in artificial culture for observation during any extended period of time, still, in an organic solution *C. purpureus* was kept in a healthy condition for a number of weeks, during which another culture of *Chroococcus limneticus*, under identical conditions, was kept for comparison. This was long enough to convince one that the two forms were not the same and that the purple did not change into the blue-green. Both this and *Chroococcus limneticus*, however, did vary their hue somewhat, according to conditions, both taking on a much darker shade of their respective colors as the concentration of the organic substances in the culture medium was increased. In old solutions both became paler, the purple form assuming something of a brown tinge and the blue-green a yellowish gray. Under no conditions, while in a healthy state, did the two algæ assume the same appearance. In both species, however, when cells lost their vitality, the contents contracted, the outline of the enveloping gelatinous substance became sharply outlined, and the color became a deep blue-green (fig. XVIII, *a*). In this condition they could not perhaps be distinguished. Whole clusters of them were found in the plankton, and until this phase of these two forms was noted they were supposed to be a species of *Glœocapsa*, but were probably only pathological stages of one of these species.

DESCRIPTIONS OF NEW SPECIES.

Chlamydomonas gracilis Snow, new species (fig. I).

Cells cylindrical, rarely oval or spherical, 10.5 to 13 μ long, 5 to 6.5 μ broad, color a dull bluish green; cilia 2, about 1½ times as long as the cell; pigment spot a dull red disk, often equally distant from the two ends; pyrenoid at the extreme posterior end. Gametes (?) oval in shape and somewhat smaller than the vegetative individual. Locality, plankton of Lake Erie.

Chlamydomonas communis Snow, new species (fig. II).

Shape, ovoid, cylindrical or ellipsoidal, 10.5 to 13 μ long, 6.5 to 8 μ broad; color a light yellowish green, the pyrenoid near the center; pigment spot an inconspicuous red rod; cilia 2, slightly longer than the cell; division longitudinal. Locality, plankton of Lake Erie.

Chlamydomonas globosa Snow, new species (fig. III).

Cells spherical or slightly ellipsoidal, 5.2 to 7.8 μ in diameter; membrane smooth at anterior end; two flagella as long or slightly longer than the cell; pigment spot small and inconspicuous; chloroplast much thickened at the posterior end; pyrenoid present; a pulsating vacuole at anterior end. Gametes not found. Locality, plankton of Lake Erie.

Fusola viridis Snow, new genus and new species (fig. VI).

Cells fusiform or slightly sigmoid, 27 to 29 μ long and 6.5 to 21 μ broad, each cell surrounded by a thick, homogeneous, gelatinous envelope, the outer line of demarcation being prominent; color a bright green. The chloroplast occupies most of the cell except for a small spherical cavity near the center, in which lies the nucleus; a pyrenoid is present. Reproduction by means of division of the contents into two, the halves gradually assuming the shape of the mother cell, during which process the enveloping membrane becomes obliquely ruptured. Membrane of cellulose. Large masses of cells may be formed in the presence of a great amount of nutritive substance. Locality, a pond on Middle Bass Island, Lake Erie.

Chodatella citriformis Snow, new species (fig. VIII).

Cells ellipsoidal with an obtuse projection at either end; length 13 to 23 μ, breadth 8 to 20 μ; spines slender, forming whorls at the bases of the projections. Chloroplast single, parietal, lying lengthwise of the cell. Reproduction by division of the contents of the parent cell into 4 or 8, each part becoming invested with a membrane and thus forming a complete individual. Found in surface and deep tow of Lake Erie.

Pleurococcus aquaticus Snow, new species (fig. X).

Cells 4 to 7 μ in diameter, existing either as spherical or ellipsoidal individual cells, or as somewhat angled cells combined into large cubical or irregular masses. Membrane thin, chloroplast concave, with an opening at one side; no pyrenoid. Reproduction by division of membrane and contents alternating in three directions of space. Locality, the plankton of Lake Erie.

Chlorococcum natans Snow, new species (fig. XI).

Cells spherical or slightly elongated, not exceeding 13 μ in diameter. Membrane of cellulose; chloroplast concave, of the shape of the cell, with a circular opening at one side; nucleus single in young individuals, but just before reproduction of the same number as the zoospores. In 2 per cent Knop's solution the organism often forms gonidia, while in weak organic solution it passes into a palmella condition in which the cells are oblong. Zoospores 6.5 to 8 μ long, 2.5 to 3.25 μ broad, with two flagella, a concave chloroplast, a pyrenoid, a pigment spot, and two pulsating vacuoles. Locality, plankton of Lake Erie.

Botrydiopsis eriensis Snow, new species (fig. XII).

Cells spherical, 18 to 21 μ in diameter; the chloroplasts in mature cells elongated and irregularly arranged, in young cells appearing as hexagonal disks closely applied to the membrane. Zoospores 2.5 μ long, 2.5 to 3.25 μ broad, with two chloroplasts, a single flagellum, a pigment spot, and two contracting vacuoles. Usually 16 zoospores formed in a cell; when liberated the inner layer of the mother membrane emerges with the zoospores from the outer layer. Locality, plankton of Lake Erie.

Botrydiopsis oleacea Snow, new species (fig. XIII).

Cells spherical, ellipsoidal or lemon-shaped, not exceeding 16 μ in diameter, containing numerous minute particles of oil which obscure the outline of the chloroplasts; near the center a large, prominent, dull-red globule; membrane of cellulose. Zoospores pear-shaped, 2, 4, 8, or 16 in number, formed from repeated bipartition of the cell contents, excepting the red globule; size of zoospores 5 to 7, 8 μ by 3 to 5 μ; character amœboid; flagellum single at smaller end; pigment spot present; chloroplasts obscured by oil, two of them discernible in germinating cells. Zoospores liberated by the softening of the entire enveloping membrane. Under unfavorable conditions a resting stage is assumed, the membrane becomes thick, and the contents assume a yellow color. Locality, the plankton of Lake Erie.

Chlorosphæra lacustris Snow, new species (fig. XIV).

Individual cells 9 to 10.5 μ in diameter, spherical or ellipsoidal, usually in complexes of 2, 4, 8, or more, formed by vegetative division, including membrane and contents; chloroplast concave; pyrenoid present; membrane thin, of cellulose. Zoospores 6.5 to 9 μ long, and 2.6 to 4 μ broad, oval, larger at the posterior end; two cilia present, a pyrenoid, a pigment spot, and 2 contractile vacuoles; 4 to 8 zoospores formed in a cell, liberated by the softening of the membrane at one point. Locality, the plankton of Lake Erie.

Chlorosphæra parvula Snow, new species (fig. XV).

Cells usually in complexes of 4 or 8, more or less separated from each other by the partial dissolution of the membrane. Diameter of cells 7.8 to 9 μ; chromatophore concave, with a circular opening near the newest portion of the membrane. Pyrenoid present; membrane of cellulose; zoospores oval or round, 5 to 6 μ in diameter, 4 formed in each cell, liberated by the softening of the entire membrane. Locality, the plankton of Lake Erie.

Cœlosphærium roseum Snow, new species (fig. XVII).

Colony 35 to 52 μ in diameter; cells spherical, pinkish or brown, 3.25 to 4 μ in diameter, arranged more or less closely over the surface of the gelatinous center; the gelatinous center not homogeneous, but containing a system of dichotomously branched gelatinous stalks, on the ends of which are borne the cells; in the spaces between the gelatinous branches and surrounding the whole is a less dense gelatinous substance. Common in the plankton of Lake Erie.

Chroococcus purpureus Snow, new species (fig. XVIII).

Cells spherical, or just before division elongated, usually arranged 2 by 2 in colonies of 4 or 8, separated from each other and held in place by an enveloping gelatinous substance; color a grayish purple, changing to brown under unfavorable conditions. Cells when dying assume a dark blue-green, and the gelatinous envelope is sharply outlined. Common in the plankton of Lake Erie.

LIST OF PLANTS DETERMINED IN LAKE ERIE.

In the following list no account is taken of the number of individuals found, or of the relative number found during the different years, as no accurate quantitative work was done by the writer; but, had such a study been made, it is probable that interesting results would have been obtained. For instance, during the summer of 1898 *Kirchneriella obesa* (West) Schmidle was one of the most common of all the *Chlorophyceæ* found in the plankton, while in 1899 it was found but a very few times, and in 1900 only occasionally. During its absence in 1899 its place seemed to be taken by *Oocystis borgei*, which the preceding year had not been noted at all, and the next season was found only in very small quantities. An equal variation was noted in the occurrence of different forms from week to week during each year. Certain forms, such as *Anabæna flos-aquæ*, appeared in quantities for a few days and then disappeared almost altogether. The number of diatoms also varied very largely at different times. An explanation of such variations would undoubtedly involve a more accurate knowledge than we now have of the composition of the water, as well perhaps as of other elements in the environment.

In the collections of the plankton numerous fragments of filamentous algæ—*Spirogyra*, *Zygnema*, *Mesocarpus*, *Œdogonium*, and *Bolbochæte*—were often found, but as no stages of reproduction were present they could not be determined, and so, except in a few cases, no mention is made of them.

The species that are not starred were taken from the plankton. Those marked with one star were found in washings of stones and of plants growing in the lake. Those marked with two stars were found in Lemna Pond, South Bass Island, and those marked with three stars were found in a stagnant pond on Middle Bass Island.

List of plants determined in Lake Erie.

CONFERVOIDEÆ.

Coleochæte scutata Bréb.*
Œdogonium cryptoporum Wittr.*
Prasiola sp.
Stigeoclonium tenue Kg.
Chætophora endiviæfolia Ag.*
Aphanochæte repens A. Br.
Cladophora glomerata Kg.
var. *subsimplex* Rabh.
Hormidium nitens Menegh.
flaccidum (Kg.) Braun.
Bumilleria sp.

SIPHOPHYCEÆ.

Protosiphon botryoides (Kg.) Klebs.

PROTOCOCCOIDEÆ.

Volvox globator Ehrb.
Eudorina elegans Ehrb.
Pandorina morum Bory.
Synura volvox Ehrb.*
Gonium tetras A. Br.*
pectorale Müller.*
Chlamydomonas communis Snow.
gracilis Snow.
globosa Snow.
Hydrodictyon utriculatum Roth.
Scenedesmus acutiformis Schröder.
acutus Meyen.
alternans Reinsch.
bijugatus Kütz.
var. *flexuosus* Lemn.
brasiliensis Bohlin.
caudatus Corda.
var. *abundans* Kirch.
var. *setosus* Kirch.
dimorphus Kg.
obliquus (Turpin) Ktz.
opoliensis Richter.
var. *carinatus* Lemn.
quadricaudatus (Turp.) Bréb.
var. *ecornis* Ehrb.
Cœlastrum microporum Näg.
proboscideum Bohlin.
reticulatum (Dang.) Senn.
sphæricum Näg.

NOTE.—A specimen was found agreeing in every respect with *Cœlastrum cubicum* Näg., which produced typical cœnobia of *Cœlastrum proboscideum*, so that the species of *Cœlastrum cubicum* is to be questioned.

Sorastrum spinulosum Kg.*
Pediastrum boryanum Menegh.
var. *longicorne* Reinsch.
constrictum Hass.**
ehrenbergii A. Br.*
pertusum Kütz.
var. *brachylobum* A. Br.
var. *clathratum* A. Br.
var. *microporum* A. Br.
rotula Ehrb.*
sturmii Reinsch.
Staurogenia apiculata Lemn.
quadrata (Morren) Kütz.
rectangularis Näg.
Kirchneriella lunaris (Kirch.) Möb.
var. *dianæ* Bohlin.

PROTOCOCCOIDÆ.

Kirchneriella obesa (West) Schmidle.
var. *contorta* Schmidle.
Golenkinia fenestrata Schröd.
Ophiocytium parvulum A. Br.*
capitatum Wolle.
Characium ambiguum Herm.
angustum A. Br.*
Polyedrium cruentum Näg.
enorme D. By.*
gigas Wittr.**
lobulatum Näg.
minimum A. Br.*
muticum A. Br.*
pinacidium Reinsch.
trigonum Näg.*
var. *tetragonum* Rabh.
Dictyosphærium ehrenbergianum Näg.
pulchellum Wood.
Hormospora sp.
Tetraspora natans Kütz.
Schizochlamys gelatinosus A. Br.
Fusola viridis n. sp.***
Dimorphococcus lunatus A. Br.***
Porphyridium cruentum Näg.*
Botryococcus braunii Kg.
Glœcystis ampla Rabh.
Nephrocytium agardhianum Näg.
Oocystis borgei Snow.
lacustris Chodat.
solitaria Wittr.
Chodatella citriformis Snow.
Rhaphidium biplex Reinsch.
braunii Näg.
convolutum Rabh.*
falcula A. Br.
minutum Näg.
polymorphum Fres.
Rhaphidium (?) *spirale* Turner.
Selenastrum acuminatum Lagerh.
bibraianum Reinsch.
gracile Reinsch.
Dactylococcus infusionum Näg.
Stichococcus bacillaris Näg.
Pleurococcus aquaticus Snow.
regularis Artari.
Chlorella infusionum Beyerinck.
vulgaris Beyerinck.
Chlorococcum infusionum Rabh.
natans Snow.
Botrydiopsis eriensis Snow.
Chlorosphæra lacustris Snow.
parvula Snow.
Scotinosphæra paradoxa Klebs.

CONJUGATÆ.

Mesocarpus sp.
Hyalotheca dissiliens Bréb.
Onychonema lœve Nordst.
var. *minus*.
Sphærozosma filiforme Rabh.
Closterium acerosum Ehrb.
dianæ Ehrb.
ehrenbergii Meneg.
leibleinii Kg.
lineatum Ehr.**

List of plants determined in Lake Erie—Continued.

CONJUGATÆ.

Closterium pronum Bréb.
var. *acutum* Klebs.
var *linea* Klebs.
Pleurotœnium trabecula Näg.
Cosmarium crenatum Ralfs.
cuastroides N.
granatum Bréb.
kjellmanii Wille.
meneghinii Bréb.
var. *concinum* Rabh.
punctulatum Bréb.
pygmæum Archer.
ralfsii Bréb.
var. *typicum* Ralfs.
reniforme Ralfs.
tetraopthalmum Kütz.
tinctum Ralfs.
Euastrum binale Ralfs.
verrucosum Ehrb.
Staurastrum crenulatum Näg.**
gracile Ralfs.
oblongum N.
polymorphum Bréb.
var. *chætoceras* Schröd.
striolatum (Näg.).
teliferum Ralfs.

BACELLARIACEÆ.

Navicula cryptocephala Kg.*
limosa Ag.
longa Ralfs.*
Pinnularia major Sm.**
radiosa Sm.*
Stauroptera parva (Ehrb.) Kirch.**
Stauroneis fenestra Sm.**
phœnicenteron Ehrb.*
Amphiprora ornata Bail.
Pleurosigma attenuatum Sm.*
Amphora ovalis Kg.*
Cymbella maculata Kg.
rotundata H. H. C.
Encyonema prostratum Ralfs.
Cocconeis placentula Ehrb.*
Cocconema cistula Hempr.
lanceolatum Ehrb.
Gomphonema acuminatum Ehrb.
capitatum Ehrb.
constrictum Ehrb.
intricatum Kg.*
Achnanthes exilis Kg.*
Nitzschia linearis Sm.**
sigmoidea Sm.
Campylodiscus cribrosus Sm.
Cymatopleura solea Bréb.
elliptica Bréb.*
Surirella ovalis Menegh.
saxonica Auersw.
splendida Kg.
Synedra oxyrhynchos Kg.
ulna Ehrb.
var. *longissima* Wm. Sm.

BACELLARIACEÆ.

Fragilaria crotonensis (A. M. Edwards) Kitton.
virescens Ralfs.
Asterionella formosa Hassal.
Tabellaria fenestrata (Lyng) Kg.
flocculosa Kg.
Epithemeia ocellata Kg.**
turgida Kg.**
ventricosa Kg.**
zebra Kg.
Melosira arenaria Moore.
granulata (Ehrb.) Ralfs.
varians Ag.
Orthosira orichalcea Sm.
Cyclotella comta (Ehrb.) Kutz.
dubia Hilse.
meneghiniana Rabh.*
striata (Kutz.) Grun.
Stephanodiscus niagara Ehr.

SCHIZOPHYCEÆ.

Rivularia radians Thur.
var. *dura* Kirch.
var. *minutula* Kirch.
Mastigonema œrugineum Kirch.
Alphanizomenon flos-aquæ Allman.
Anabæna flos-aquæ Kg.
var. *circinalis* (Rabh.) Kirch.
Plectonema mirabile Thur.
Oscillatoria œrugineo-cærulea Kg.
chalabea Martens.
frœhlichii Kg.*
imperator Wood.*
natans Kg.
subtilissima Kg.
tenerrima Kg.
tenuis Ag.
Lyngbya wollei Farlow.
Microcoleus anguiformis Harv.
Merismopedia elegans A. Br.
glauca Näg.
kützingii Näg.
tenuissimum Lemm.
violacea Kg.**
Cœlosphærium kützingianum Näg.*
roseum Snow.
Clathrocystis œruginosa Henfr.
roseo-persicina Cohn.
Gomphosphæria aponina Kg.
var. *aurantiaca* Bleisch.
Polycystis icthioblabe Kg.
Glœocapsa fenestralis Kg.
punctata Näg.
Chroococcus pallidus Näg.
limneticus Lemm.
purpureus Snow.

PHYCOMYCETES.

Beggiatoa leptomitiformis Trevis.
arachnoidea Rabenh.
Spirochæte plicatilis Ehrb.

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EXPLANATION OF FIGURES.

PLATE I.

I. *Chlamydomonas gracilis* Snow.
1,2. Motile cells.
3. Gamete (?).
4. Copulation of gametes?.

I. *Chlamydomonas communis* Snow.
1-3. Motile cells.

III. *Chlamydomonas globosa* Snow.
1-5. Motile cells.

IV. *Scenedesmus bijugatus* var. *flexuosus* Lemm.
1. Cœnobium of 32 cells.
2. Resting stage.

V. *Staurogenia apiculata* Lemn.
1. Compound cœnobium of 64 cells.
2. Compound cœnobium of 16 cells, showing gelatinous envelope as brought out by tannate vesuvine.
3. Mass of cells from .05 per cent Knop's solution.
4. Single cœnobium in early stages of reproduction, taken from an organic solution. (*a*) Nucleus. (*b*) Pyrenoid.
5. Single cœnobium.
6. Diagram showing relative position of nuclei and pyrenoids in young cœnobia. (*a*) Nucleus. (*b*) Pyrenoid.
7. Membrane of a cœnobium after daughter cœnobia have been liberated.
8. Cell showing nucleus and pyrenoid. (*a*) Nucleus. (*b*) Pyrenoid.

PLATE II.

VI. *Fusola viridis* Snow.
1-4. Different stages in process of division. (*a*) Ruptured membrane of mother cell.
3. Typical cells.

VII. *Oocystis borgei* Snow.
1. Single cell showing nucleus, *a*.
2. Young cells from a culture in organic solution.
3. Cells after division of chromatophore. Taken from organic solution.
4. Small colony taken from organic solution.
5. Single cell from 0.05 per cent Knop's solution, showing remnant of mother membrane, *b*.

VIII. *Chodatella citriformis* Snow.
1. Mature cell seen from side.
2. Cell seen from end.
3. Cell showing reproduction.

IX. 1-4. *Pleurococcus regularis* Artari.
1. Complex from the plankton.
2-4. Clusters from a culture.
5. *Cœlastrum microporum* Näg.

PLATE III.

X. *Pleurococcus aquaticus* Snow.
1. Cell complex.
2. Individual cells before formation of clusters.
3. Complexes grown in collodion tubes.
4. First stages in formation of complexes.
5. Disintegration of the larger complexes.

XI. *Chlorococcum natans* Snow.
1. Mature cell.
2. Gonidia formed in 0.2 per cent Knop's solution.
3. Gonidia formed in 0.4 per cent Knop's solution.
4. Typical zoospores.
5. Zoospores formed when material is transferred from Knop's solution to organic solution.
6. Germinating zoospores.
7. First stage in formation of zoospores.

XII. *Botrydiopsis eriensis* Snow.
1. Mature cell.
2,3. Young cells.
4. Gonidia formed from nonliberation of zoospores.
5. Zoospores. (Free hand.)
6. Germinating zoospores.
7. Zoospores before liberation.

XIII. *Botrydiopsis oleacea* Snow.
1,2. Mature cells.
3,4. Younger cells of different shapes.
5-7. Different stages in the formation of the zoospores.
8. Zoospores.
9. Germinating zoospores.
10-11. Resting condition.

PLATE IV.

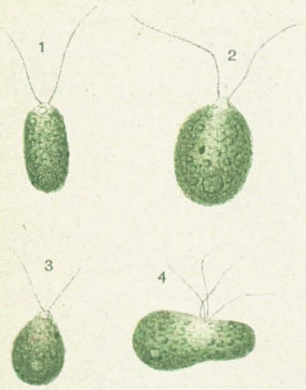
XIV. *Chlorosphæra lacustris* Snow.
1. Single cells.
2,3. Complexes arising from division.
4. Zoospores.
5. Germinating zoospores.
6,7. Stages in the formation of the zoospores.

XV. *Chlorosphæra parvula* Snow.
1,2. Complexes formed by division.
3. Zoospores.

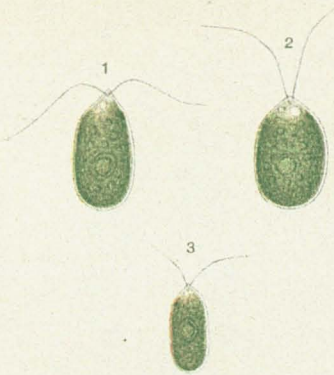
XVI. *Mesocarpus* spec.
1. Normal filament.
2. Filament under unfavorable conditions.

XVII. *Cœlosphærium roseum* Snow.
1. Typical individual. *a*. Surface view. *b*. Interior view.
2. *Cœlosphærium* (?) showing free dichotomous gelatinous branches.

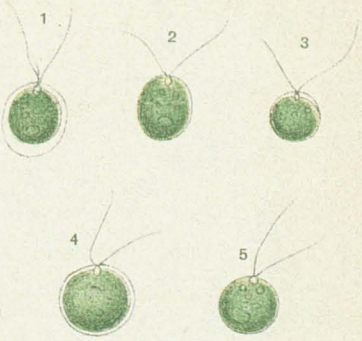
XVIII. *Chroococcus purpureus* Snow.
Showing mode of growth in small clusters embedded in gelatinous substance.



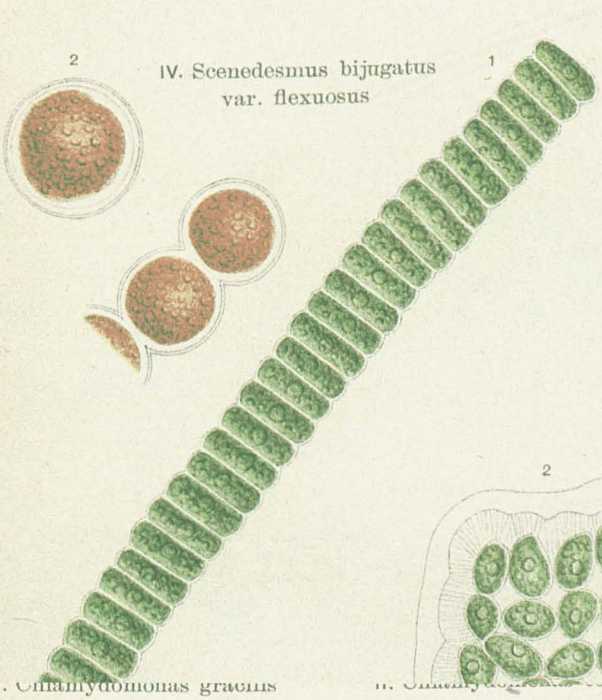
I. Chlamydomonas gracilis

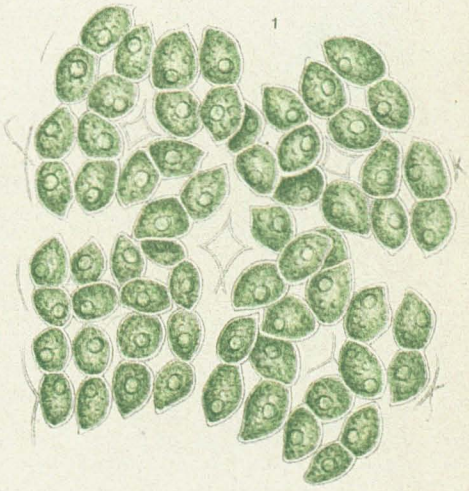


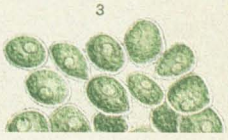
II. Chlamydomonas communis



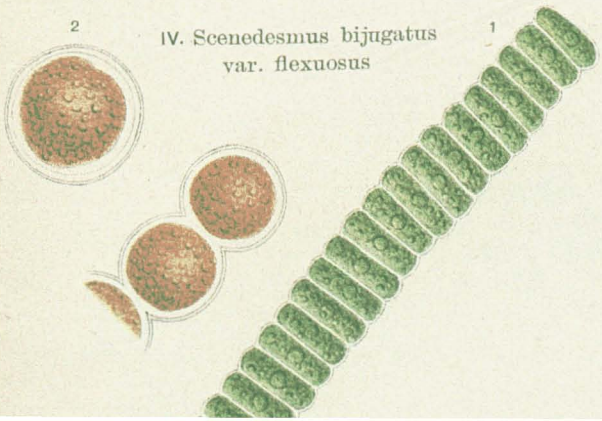
III. Chlamydomonas globosa

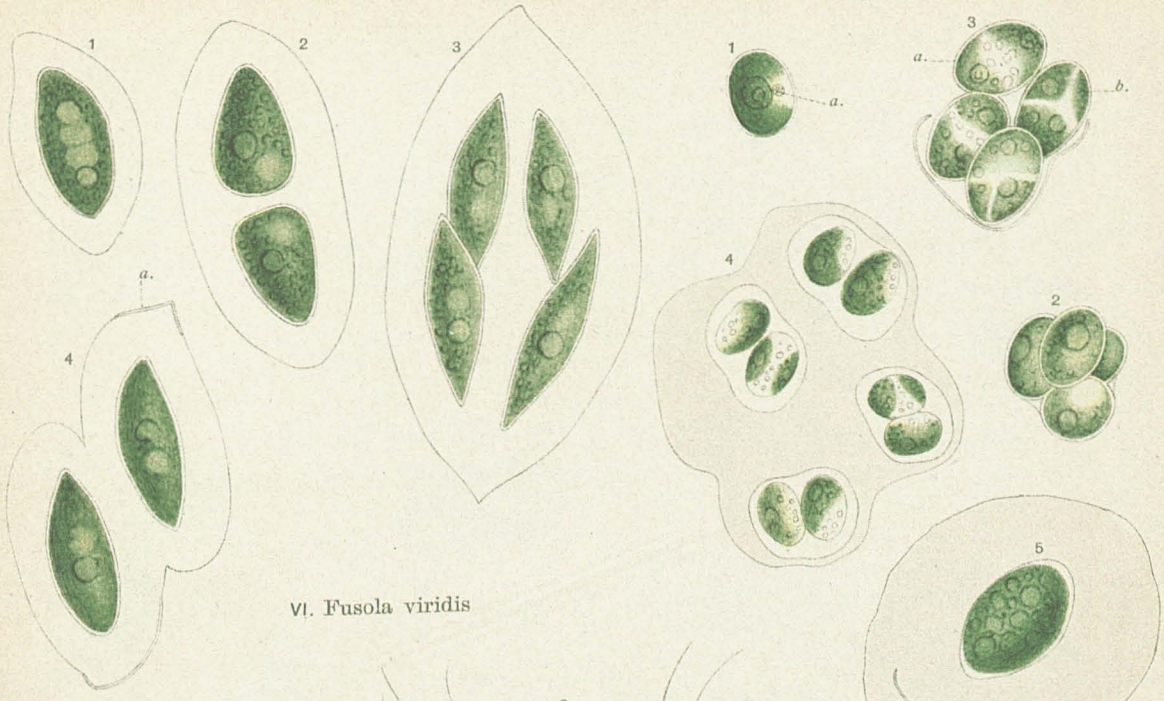






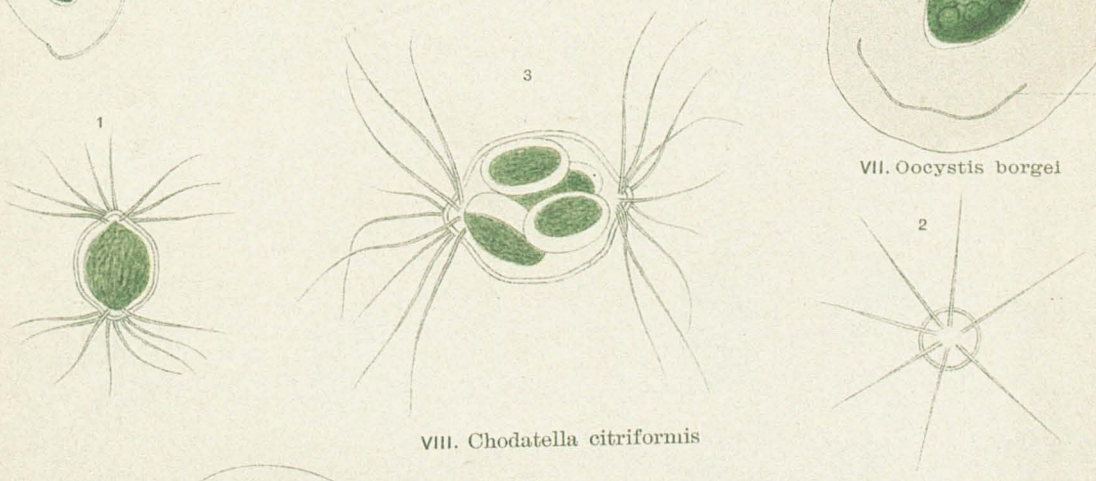
I. Chlamydomonas gracilis



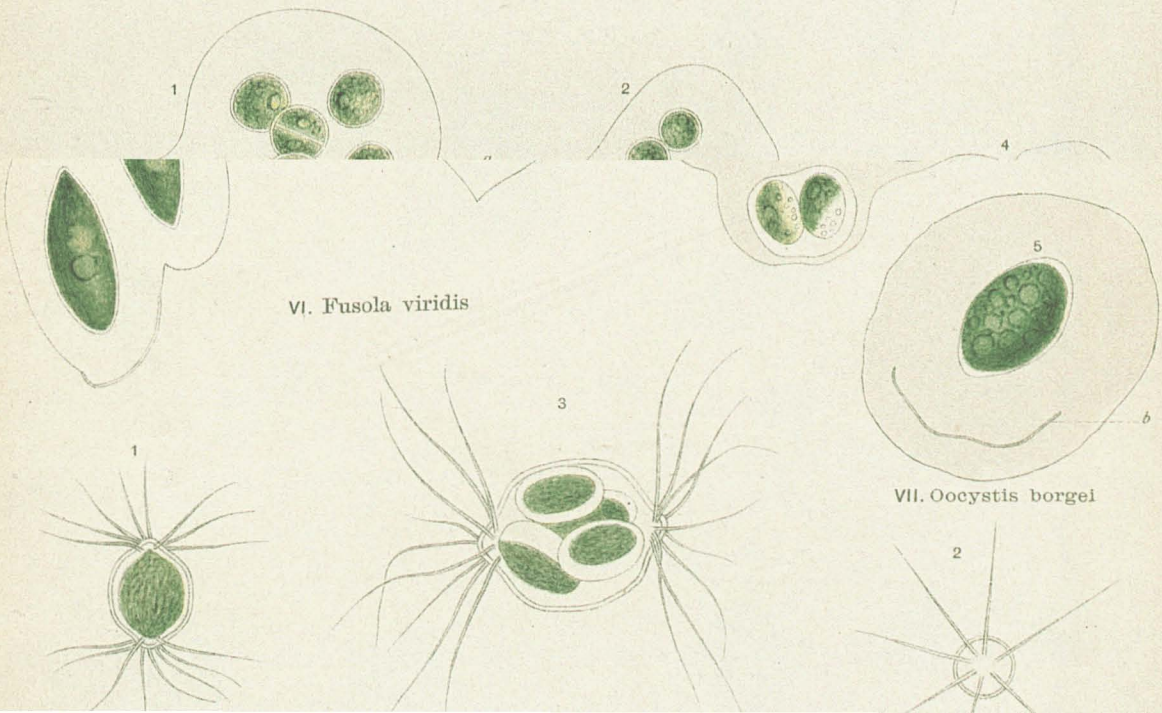


VI. Fusola viridis

VII. Oocystis borgei

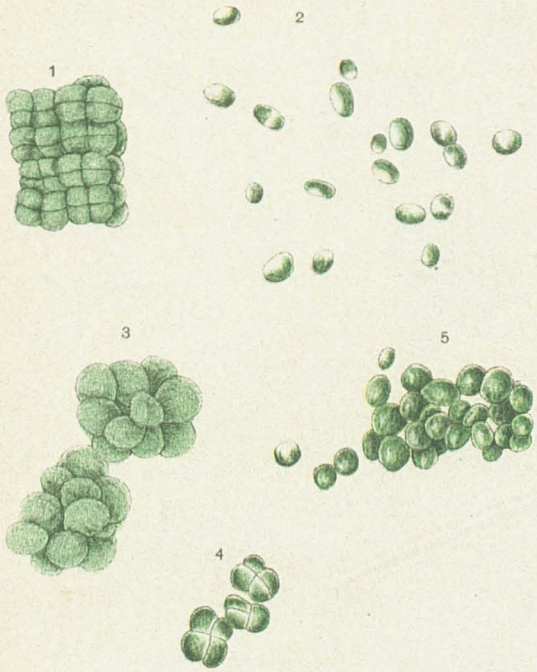


VIII. Chodatella citriformis



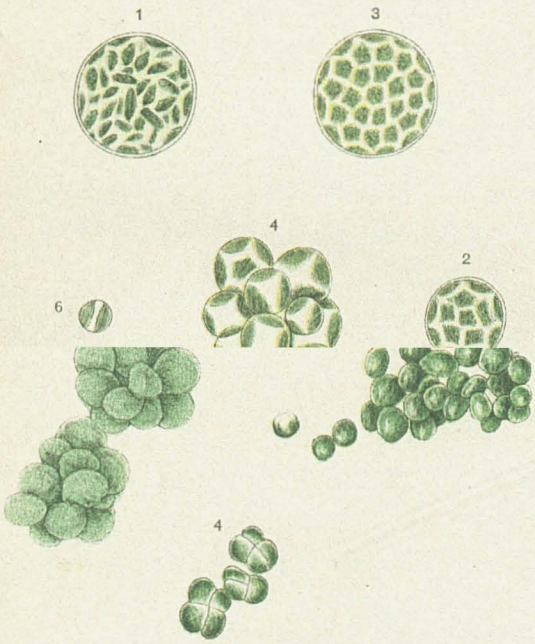
VI. Fusola viridis

VII. Oocystis borgei

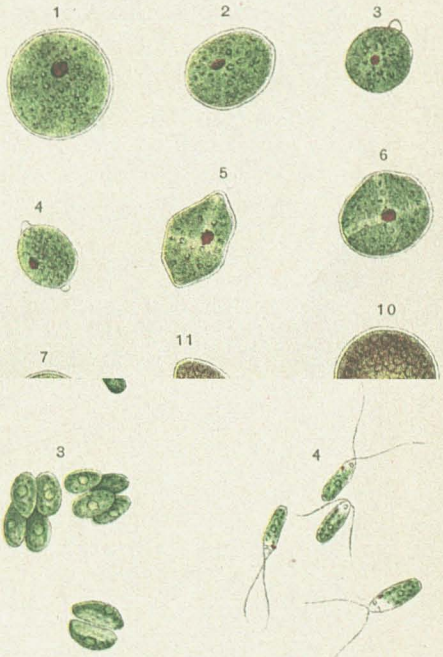


X. Pleurococcus aquaticus

XI. Chlorococcum natans



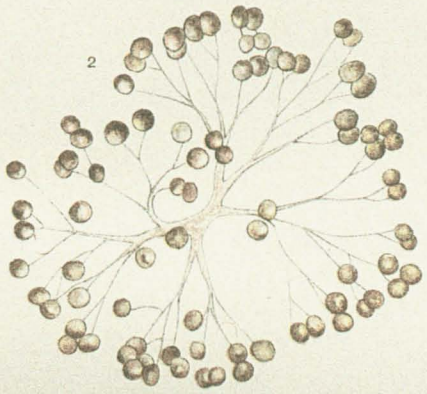
X. Pleurococcus aquaticus



XI. Chlorococcum natans

XIV. Chlorosphaera lacustris

XVI. Mesocarpus spec.

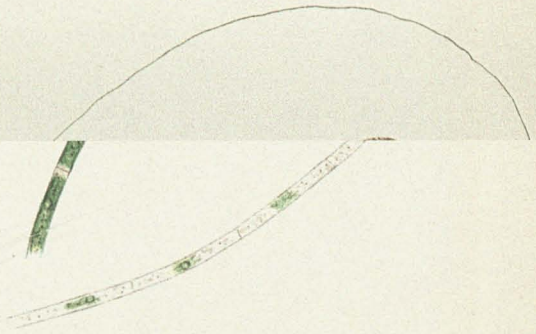


Coelosphaerium ?

XVII

Coelosphaerium roseum

XIV. Chlorosphaera lacustris



XVI. Mesocarpus spec.