TRANSACTIONS

OF THE

American Microscopical Society

Organized 1878 Incorporated 1891

EDITED BY THE SECRETARY

Twenty-Third Annual Meeting

HELD IN

NEW YORK CITY, JUNE 28, 29, AND 30, 1900

VOLUME XXII

LINCOLN, NEB.:
STATE JOURNAL COMPANY, PRINTERS
1901

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ERRATUM

Page 205, second paragraph, first line, for "Limnological Committee" read "Limnological Commission."

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TWENTY-THIRD ANNUAL MEETING, HELD AT NEW YORK CITY, NEW YORK, JUNE 28, 29, AND 30, 1900

THE ANNUAL ADDRESS OF THE PRESIDENT

THE DETECTION AND RECOGNITION OF BLOOD

By A. M. BLEILE

Following in the path marked out by the steps of some of my predecessors, I have chosen for the subject of this address a theme which is not rigidly microscopical in all of its aspects; nor do I present it as based entirely or even for the largest part on own work or on original observation. Again, the treatment is not rigidly technical, since in a membership made up of persons engaged in very different lines of work, as is the case in this Society, such treatment could at best be of interest to only a very limited number. An attempt has been made to give a resume of a given question with here and there a statement based on own experience, and thus it is hoped that a somewhat wider interest, sufficient to hold during its presentation, may be evoked in the subject chosen, which is "The Detection and Recognition of Blood." By the detection of blood I mean the finding of blood in a given object, a fluid or a stain; by recognition of blood is meant, in addition to the foregoing, the identification of the find as having come from a particular species of animal and from no other.

In the detection and recognition of blood are presented two questions of supreme importance and interest in many cases to the physiologist, the physician, and the jurist. Often, too, the layman has in these questions,—even when not personally involved or where his own body or welfare are not directly concerned, as in medico-legal cases,—at least a curiosity, if not an actual concern, born of that value we all set on affairs affecting the general public weal or woe. While the physiologist is often enough called upon to determine the presence or absence of blood, still in his cases the amount available is in most instances large enough and the specimen fresh enough so that no unusual difficulties present themselves to him in the application and the interpretation of the recognized tests. The physician who wishes to determine the presence or absence of blood in the various exudates and secretions of the body, and on which he will form his diagnosis and even the treatment of a case,—two factors on which the whole future progress of the individual may depend,—is apt to meet with difficulties more or less great. Sometimes the amount obtainable for examination is quite small; nearly always the blood is mixed with organic fluids of greater or lesser complexity whose own composition may offer obstacles to the use of the otherwise ready and sure tests, only to be overcome by ingenuity displayed in meeting the different complications as they arise in individual cases. From a juridic point, however, these questions present a most important aspect and often great complications. In such cases is there many times the most communal interest. Matters of the most vital concern may be at stake in a single case, with a single small fragment at hand for examination, and here the observer meets with his greatest difficulties, not only in carrying on his work so that the results may be certain and satisfactory to himself, but also in carrying it on so that its outcome may be convincing to judge or jury. The problems presented for solution in such cases are two-fold. In many instances it may be sufficient to determine only whether or not blood be present in a given fluid or on a given object in the form of stains or spots, while sometimes there is added to this the desirability or need to recognize the blood as having come from man or a lower animal, and this is by far the more difficult and uncertain—under circumstances impossible—part of the riddle given. The way to its solution is beset with snares and pitfalls to be avoided only by most conservative and circumspect consideration of all difficulties and sources of error.

As to the means at our command for the answer of the questions propounded, you know that we have only two elements peculiar to the blood as contrasted with the contents of the other fluids found in the animal body. These are, on the one hand, the red blood-corpuscles, and on the other their unique constituent, the hemoglobin or oxyhemoglobin; and only the first of these, with present knowledge—the corpuscles, can come into play when it is attempted to recognize the blood as having come from a particular kind of animal. A question of such vital import in its answer has of course received much attention, and among the workers applying themselves to its solution we count several members of this Society. As aids here we have the well-known fact that the red corpuscles in man and all animals (except the Camelidae) are biconcave, nonnucleated, circular disks, and that in birds, reptiles, or fishes, they are biconcave, nucleated, oval (except in cylostoma). This, however, gives a distinction too broad to be of use in many cases, since the question is not often one involving such general differentiation, but narrows itself to the recognition, in nearly every instance, of mammalian bloods, where we have the same general form and where alone differences in size might be invoked to help to the identity of a given specimen. Accordingly the fact being fixed that different kinds of mammals do present differences in the sizes of the respective red corpuscles, much effort was given to their measurement in the hope that here might be found the much-desired means of recognition, and work along this line had not a little influence on the perfecting of the optical parts of the microscope and the measuring apparatus employed, since it was felt that only the use of the most exact and accurate appliances could lead to successful or trustworthy conclusions. In the prosecution of this work two ideas, fundamental for its import, seem to have been generally and tacitly accepted by some investigators. The first one was that for every species of mammal there is a fixed size of the corpuscle presenting at most extremely minute variations in different individuals of that species or in the same individual; the second was that in restoring corpuscles from old or dried states the means used were such as guaranteed the re-establishment of the former normal, fresh dimensions. While, then, measurements were being established, and on these men were found enthusiastic enough to declare even under oath that the results were positive and trustworthy, thus taking upon themselves the greatest responsibility in vouching for the correctness of the statement that the blood in hand was or was not human blood, newer and better knowledge soon led to a more conservative position. For we know now that differences in size do exist in the corpuscles of one individual and in individuals of the same species, differences so great that they may easily overlap the average measurements given for another species, as for example in dog and man. As to the second premise, that restoration of corpuscles to original volume would be completed by the means employed, few histologists familiar with the delicate nature of these bodies, and having in mind the readiness with which they respond in structure to even slight variations in their surrounding fluid, would be willing to subscribe to this proposition. This method of recognition, then, as between mammalian bloods has been generally given up as untrustworthy; and while it is easy to distinguish between the oval and nucleated corpuscles of the ovipara and the circular non-nucleated of mammals, it is to the highest degree unsafe according to more conservative view to attempt more. Success can only be looked for in exceptional cases and under favorable circumstances, with fresh specimens, where the question is not a general one, but where it is narrowed down to the distinction between two bloods with widely different corpuscles, i. e., man, or mouse, or squirrel. The finding of the red corpuscles will therefore in nearly every instance mean the detection of blood, with only a broad statement as to its source; and even in going so far corroborative tests are highly desirable, since the form alone of these bodies is not quite sufficient to establish their identity. In support of this statement it may be recalled that certain fungus spores present an appearance almost identical with that of the human red corpuscle, and showing the same dimensions, which have led to error in their interpretation. True, in many cases where such an error was made these bodies were globular and not biconcave, and an inspection by a trained observer would at once have set at rest doubts that might have arisen as to their nature; but in a few instances discoid bodies with an apparent central concavity have been found, thus giving a much closer resemblance to the red corpuscle, demanding a more rigid scrutiny for their recognition. That the danger of fallacious finding is a real and not infrequent one is apparent from a perusal of the literature on the subject, in which are given many instances of such mistakes; and one having even a limited experience in this line will be sure to have encountered such bodies in one or two instances. In fact, Richardson, referring to the various fluids recommended for the extraction of corpuscles from old stains, and speaking of one of them—Na_2SO_4—says, "It must, I think, owe its popularity chiefly to the fact that it contains large quantities of fungus, the spores of which resemble blood corpuscles both in size and appearance and have, I have no doubt, frequently been mistaken for blood-cells." A very careful study of the chemical composition of blood-cells shows that there are slight differences in the amounts of alkalies, phosphates, hemoglobin in different animals, but the amount of blood necessary for such determinations is so large as to preclude use of the facts for the purposes before us. Since, then, the answer to be obtained from a study of the corpuscles as such is limited, their available constituent, the hemoglobin, a crystallizable body, has been called upon with the hope of getting from it something definite or trustworthy. This interesting body, also known as the blood-pigment or blood-coloring matter, may therefore be considered in some of its properties, even at the risk of repeating what is everyday knowledge.

Hemoglobin occurs in the red cells and belongs chemically to the proteid group, and can be obtained more or less readily in crystals. It is a very unstable body, readily undergoing change and decomposition by agencies inert to other physiological constituents; in fact, it owes its physiological value in the organism to the ease with which it may be changed. Heat, weak acids or alkalies will split it up into an albumen—globulin—and an iron containing colored organic body, the hematin, and this change will even take place in dried blood when long exposed to the air. It is well known that the form of the crystals and the ease with which they may be obtained will differ with the species of the animal from which the blood has come. Accordingly Guelfi made this a basis for some work bearing on the question of the recognition. A 2% NaFl. solution is used with an equal quantity of blood and held at a temperature of 40°, when crystallization will soon take place. Thus there are procured from guinea pig blood tetra-hedra; from the dog's, prisms; while some other bloods will give needles. Fresh arterial or venous human blood will give no crystals. Furthermore, pigs' and dogs' blood dried for periods of up to eight months will give crystals which, of course, after the statement made, could not be obtained from dried human blood after any lapse of time, though the remarkable fact is given that partially dried human blood will give needles. The conclusions drawn are that crystals obtained from older stains show that it is not human blood, as does also the finding of tetra-hedra or prisms in fresh fluids; though the finding of needles does not bindingly indicate that the blood is human. Such a test under circumstances may be useful, but it will require further observations to make the conclusions as given convincing, for the question of the crystallography of the hemoglobin is one on which there is yet no accord, some writers holding that different systems of crystallization do occur in different bloods, others maintaining that there is only a variation of form in one system—that all shapes are sphenoids belonging to the rhombic system. Certainly the same blood can by different methods be made to yield crystals of different shapes; the squirrel's blood giving, according to methods used, either hexagons, or prisms, or tetra-hedra. Proof therefore is still to be given that this particular method will always under all variations give the same shape of crystal for the same blood. Another proposition for the recognition of blood has been brought forward by Magnamini, who makes use of the statement that oxyhemoglobin from different bloods is decomposed at a varying rate by the action of acids or alkalies, a time which may be readily determined by noting the disappearance of the absorption bands from the spectrum given by such solutions. He finds, working with certain concentrations of solution, that the bands will disappear from human blood in thirty-eight minutes, from dogs' blood in 110 minutes, and in other bloods after three hours or more. The results were the same with stains up to sixty days old, but after that age oxyhemoglobin became progressively less resistant. The poetic statement that drops of different bloods in drying on a glass plate would give different figures, each one characteristic for a certain blood, thus leading to its identification, needs only to be mentioned to show that science is not always divorced from fancy.

The second part of our question, the mere detection of blood, will have to do exclusively with the hemoglobin, though it follows of course that the positive find of red corpuscle would at once include and settle this. The detection of this body or its derivatives depends largely on its or their spectroscopic behavior, though some other tests may be mentioned.

1. The Guaiac test, characterized by the fine blue color which a blood solution will assume, if it is treated first with a fresh alcoholic solution of gum guaiac and then with H_2O_2 or, better, with old oil of turpentine. There can be no question about the delicacy of this reaction if properly carried out though there has been much controversy over the reliability as a test for blood. Wormley has obtained this reaction in solutions containing 1 part of blood in 50,000 and with sufficient fluid it will show with one part blood in 100,000. It is stated that stains twelve years old gave the test, though Babcock had unsatisfactory results with stains over three years old. Unfortunately for the convincibility of this test, a number of substances give the same reaction. Among these, as having particular bearing here, are pus, bile, nasal mucus, sweat stains, and, as was found during this work, formaldehyde, now so largely used in the arts and laboratories. The value of this test is very slight, and its failure even does not conclusively show absence of blood, since alkalies and possibly other reagents interfere with the reaction.

Ganntner treats suspected stains with a drop of weakly alkaline water, then with a drop of H_2O_2 solution. If blood is present there will be an evolution of gas bubbles settling into a white persistent foam. Failure indicates absence of blood but—again a restriction—pus among other substances will give the same result. The hemin or Teichmann's test comes down to us hallowed by the lapse of time. In this test are obtained the microscopic hemin or rather haematin hydrochloride crystals, distinguished by their black or deep brown color and their form, triclinic plates, prisms frequently crossed or in clusters. The procedure is a simple one. A fragment is placed on a slide with a minute crystal of salt, covered with glacial acetic acid and heated, the crystals appearing on subsequent cooling. With fluids—Struve's method—treating first with an alkali, then tannin, precipitating with acetic acid, then treating this dried precipitate as above, seems after many trials with other methods to give the best results. The delicacy of this test must be conceded—Wormley figures crystals obtained from 1-500 grain blood and says it is possible to get them from 1-1000 grain or a fluid of 1 blood in 50,000, yet—again restrictions—iron interferes with the test so that blood spots on rusted steel could not be detected, and often too it will fail with very old stains. Further, the conditions essential to its success, though not in all cases fully understood, must be so closely adhered to that in experienced hands even the test may fail from undetermined causes. To quote from Babcock: "In brief, crystals of hemin, if found, furnish conclusive evidence of the presence of blood; failure to obtain them is not conclusive as to its absence." Various substitutes—and this is indicative of uncertainty in any procedure—have been proposed, as the substitution of NaI or NaBr for NaCl and formic for acetic acid, but personal experience has not established their superiority over the older reagents.

Coming next to the spectroscopic tests for blood or its coloring matter, it may be said that the apparatus necessary for the prosecution of this work need be neither complex nor costly. A large spectroscope provided with a scale may be convenient and even essential for the determination of the exact location of the absorption bands, but the ones involved in this kind of research are characterized in other ways and behaviors, so that a spectrometer may safely be dispensed with. Virtually a large spectrum, that is, one resulting from great dispersion, will in dilute solution show less, on account of the spreading or thinning out of the bands, than a short one where the lines are crowded together and in which consequently the bands would show narrower but more intense and better defined. And, while a spectroscopic eye-piece in the miscroscope is a great convenience, practically everything can be accomplished with the small, direct vision, so-called pocket spectroscope. This may be inserted in the miscroscope instead of the ordinary eye-piece, and with a $\frac{2}{3}$ or $\frac{1}{2}$ inch objective will give excellent results. Hemoglobin, dark red in solution, is, as already stated, the mother substance from which the other bodies here concerned are derived. It is recognized by a broad, rather dim band beginning near the yellow or D line and extending upward to near the E line, mean λ 550. On exposure to the air the solution assumes a brighter red color, due to the formation of oxyhemoglobin, which now gives two bands, one just above D λ 579, the other just below E λ 553.8, the lower ones alone persisting in very dilute solutions. On adding a weak reducing agent the two bands disappear to make way for the one band of the again formed hemoglobin; or since the hemoglobin band is not so perceptible in extremely dilute solution it may be that the oxyhemoglobin bands only may be made to disappear and reappear. At any rate there is here a very definite deportment, diagnostic of the presence of blood pigment, and not to be confounded with other coloring matters grossly resembling it. The test is certain and quite delicate. The intensity of the bands will of course depend, (1) upon the strength of the solution; (2) upon the thickness of the latter, or, what amounts to the same thing, the width of the slit in the spectroscope. With the appliances mentioned blood may be detected in a layer 15 mm. deep diluted 1:4000 or in a 40 mm. layer 1:5000, the actual quantity of fluid used being in the latter case equivalent to .0003 c.c. of blood, in the former .0001 c.c. However, as said repeatedly, hemoglobin is a fugaceous substance, and in fluids not neutral, or in old stains or heated or washed ones, this body has been decomposed, leaving commonly the hematin previously mentioned. This substance, soluble in acids and alkalies by means of whose action on hemoglobin it is obtained in the laboratory, also has a definite spectrum, its lower absorption band lying close to the D line. Spectroscopically hematin is less sensitive than oxyhemoglobin, not showing in dilutions greater than 1:1000 (15 mm. layer), yet it possesses properties which make it admirably adapted as a witness in this question, and on which properties is based the proposition of the method for blood examination to be suggested. Unlike hemoglobin, hematin is a stable body not readily affected by agencies to which blood-containing fluids or spots are usually subjected. From it Hoppe, Seyler and Stokes first obtained by reduction a body known as reduced hematin—or better, hemochromogen—with its own spectrum and other properties which make its identification certain beyond any doubt. For the production of hemochromogen the following method is well fitted: The solution or substance is treated with KHO solution 5%, using heat with old and dried material. To the solution is added pyridin (1-10 its volume) and $(NH_4)_2S$, when the previously greenish solution will turn cherry red and remain so if kept from the air. In the spectrum can now be seen two well-marked extraordinarily intense absorption bands, the lower one of which is the more persistent and which alone need be considered here. It lies midway between the D and E lines, mean λ 557. On shaking with air the bands disappear to come again on resting the fluid. In this way can blood be detected, with a 15 mm. layer, in dilution of 1 blood to about 20,000 of water, or, with a 40 mm. layer, 1 in 40,000 involving of actual blood about 5-100,000 c.c. The certainty and characteristic of this test is equal to that of oxyhemoglobin and it is from three to four times more delicate.

Inquiry as to the availability of this test where the material to be examined had been so treated as to lead to a greater or lesser decomposition of the blood, was suggested by a case necessitating such an investigation under peculiar circumstances. A triple murder had been committed, the instrument used being an ax shown to be the property of defendant in the trial. After the murder the house, a wooden one, containing the bodies, was set on fire, burning to the ground. The ax had been thrown down outside about eight feet from the house, thus being subjected to a high heat, as further shown by the charred remains of the ax handle, which was burnt up into the ax. On the ax were found charred and brittle hairs and some brownish black spots which, if blood, were too much altered to yield hemoglobin and on account of the iron rust would presumably fail to give the hemin crystals. To test the resistibility of the coloring matters, though not bearing directly on this case, blood was first treated with various chemicals known to affect the hemoglobin, such as 10% solutions of KHO, NH_4O, HCl, HNO_3, H_2SO_4, $HgCl_2$, strong alcohol and formalin. After six months' maceration in these fluids it was easy to obtain, by the method given, the hemochromogen reaction with all its essential points. To test the influence of heat, dried blood was heated for ten minutes at temperatures from 100° up to 280° centigrade, and in all cases the reaction was obtained, though the color of the pyrogenous bodies formed at the highest temperatures employed interfered with the spectroscopic examination and forced great dilution of the fluid. Age of material does not apparently interfere with this test. At least the bands were obtained from a stain on cloth sixteen years old and not over one mm. in diameter. Having in mind then the ease of application, delicacy, certainty, and freedom from influences by many disturbing agencies, of this test, an outline of a convenient method for the detection of blood would be as follows: After an attempt to find red corpuscles, and with or against success in this direction, without wasting further time or material which may be at disposal in small quantities only in a search after the less delicate or less persistent hemoglobin or the hemin crystals so liable to fail, the substance is to be at once treated with KHO solution, heating if difficult of solution or not already dissolved, and then adding pyridin and $(NH_4)_2S$, as previously outlined, and observing the spectrum. Where a small stain on a thin fabric is the object of study it can be placed on a cover glass, moistened with a drop of KHO solution and pyridin. After some minutes a drop of $(NH_4)_2S$ is to be added, the preparation inverted over a hollow ground slide, sealed with oil, and placed under the microscope, when the spectrum will show the hemochromogen band, disappearing on exposing the preparation to the air, if blood is present.

SOME ADVANTAGES OF FIELD-WORK ON SURFACE WATER SUPPLIES

By HORATIO N. PARKER,
Biological Laboratory of the Metropolitan Water Works of Massachusetts

There are several ways of procuring a water-supply. The simplest is by catching the rain as it runs from the roofs of houses and storing it in cisterns. Where provision has been made for passing the first portion of the rain, saving only that which falls later, and when the cistern has been carefully built, this is a satisfactory method. But the amount that can be obtained in this manner is small, and serves, at the most, to supply only two or three houses. Another source of supply is the underground water which is derived from springs, wells, and filter-galleries. Carefully operated works of this class usually afford a water of excellent quality and one which is very satisfactory to the consumers. Unfortunately, however, it, too, is limited in quantity, and besides, as larger demands are made on it, tends to deteriorate, becoming constantly harder and at the last carrying bacteria in high numbers. By far the greater part of our cities are supplied with surface water which is taken from rivers,—with or without filtration,—from natural lakes, or from artificially constructed storage reservoirs. It is the purpose of this paper to point out the necessity of carefully conducted field-work in those places whose supplies are obtained from the two last sources.

As the rain falls to earth, it washes the dust, the spores of microscopic organisms and the bacteria from the air, and absorbs from it various gases. But these impurities are trifling as compared to those it acquires after it reaches the ground. The character of a water is determined by the watershed from which it is collected.

To make what follows perfectly clear, let us imagine a watershed which comprises all the features commonly found in the localities on which water-supplies are built. It has an area of about one hundred square miles and a somewhat diversified topography. There are a few high hills, one of which is crowned by a large town, which is sewered, and whose sewage disposal works are outside the watershed. Through the town runs a brook which flows onto English filters at the shore of a lake which forms part of the system of water supply. The effluent from these filters runs directly into the lake. All of the hills slope abruptly to the flat land at their base. A river with its numerous tributaries courses through the middle of the watershed. On one of these streams whose drainage area is wild, wooded, gravelly land, and which has its rise in dense cedar swamps, a storage reservoir is built. A second and larger tributary flows through a cultivated district whose soil is a loam mixed with considerable clay. Here and there are farm houses with the accompanying live stock, and some distance away is a hospital with its own water supply and English filters for sewage disposal. This stream has been dammed at three points, and each of the storage reservoirs thus formed has its own tributaries which for the most part are fed by springs. All of the brooks enter the reservoirs at the head, and on some of them dams have been built to form mill-ponds. These are now abandoned. The soil has been stripped from the bottoms of all the storage reservoirs, which vary from fifteen to fifty feet in depth, and have a capacity of two billion gallons. They are constructed so that water can be drawn from the surface, mid-depth and bottom. The lake is somewhat isolated from the storage basins; it has a capacity of three billion gallons, and the bottom has never been cleaned. The mains are built so that water can be drawn from all the supplies at once, or any source may be used independently of the others. No houses are allowed on the shores of these ponds, and the whole district is under rigid sanitary supervision.

Let us first consider the chain of reservoirs which are built on the stream flowing through the inhabited area. The first rain that falls after a long dry spell will be soaked up by the earth, but as the storm continues the capacity of the ground to do this becomes exhausted, and the excess of water must flow away over the surface. Not in clear rivulets, however, but in very dirty ones, for the continual beating and pelting of the rain loosens the clayey soil so that it is easily dislodged and carried away by the water toward the reservoirs. Moreover, we have said that the valley of the stream is cultivated; this necessitates manuring, and if there are market gardens, heavy manuring, which means that some and possibly much night-soil is used. Thus a chance is afforded for disease germs to be washed into the reservoirs, and in any case many bacteria and nitrogen in the form of nitrates will be gathered from this source.

So these little rivulets flow on with their ever increasing burden of mud and putrescible matter and deposit it in the feeders of the reservoirs. Of course the gross polluting centers, such as barnyards, privies, etc., have been kept from draining directly into the supply. It is only the small waste incident to life, to which man and beast alike contribute, that is carried into the storage basins. The swollen feeders are now adding bacteria to the reservoir and mud to make them turbid. This is an objectionable state of affairs, for from the head of the reservoirs the roily water, high in bacteria, moves onward till it is delivered to the consumers or passes out of circulation. Its progress through the reservoirs must be carefully watched. It is not enough to wait till samples collected at the intake announce its appearance there. The superintendent not only ought to know the character of a water he is using at a particular time, but he should be kept informed as to whether it is likely to improve or deteriorate in quality.

Turbidity is a deterioration, and is justly complained of by the consumers; not that it is injurious to the health, but for aesthetic reasons. It makes the water unsightly, and imparts an earthy flavor to it. The degree of turbidity depends upon the amount of clay in suspension. The sand particles soon settle out, but the clay, which is very finely comminuted, does so very, very slowly. If a little clay is brought to the supplies by a short rain, it may sink to the bottom before it reaches the mains, unless the reservoirs are kept stirred up by the wind. On the other hand, a severe storm will bring much clay, which will gradually pass through the reservoirs to the intake.

It is evident, that careful records of the clearness of the water should be kept. There are several ways of estimating turbidity. The oldest is by determining the weight of suspended matter in a given weight of water. This method is being abandoned because of its inaccuracy. A small amount of sand would raise the weight of suspended matter very considerably without a corresponding gain of turbidity, while a large addition of clay would cause a marked increase of turbidity without materially increasing the weight of matter in suspension.

Nowadays, the commonest ways of measuring turbidity are by means of the Silica Standards,* Diaphanometer,† and the Platinum Wire.‡ Each has its advantages, and that must be selected for use which is best adapted for the work in hand. Still another method was formerly employed on the Metropolitan Water Works; a disc,§ five inches in diameter and painted like a surveyor's target, is lowered into the water, and the greatest depth at which the divisions can be distinguished is recorded.

In reservoirs several factors work toward reducing the bacteria. They tend to sink to the bottom, and, besides, the water is not as favorable a medium for them to grow in as is the land from which they have been washed; further, the sunlight is inimical to them. So altogether they fare badly after they reach the supplies, and the chance of their reaching the intake are somewhat less than that of the clay.

It is well after a severe storm to make a thorough examination of the supplies. So we go in a boat from the foot to the head of the reservoirs, taking turbidity readings and bacteria samples at frequent intervals. The bacterial examinations are mainly quantitative, supplemented by tests for coli reactions. It must be so, as a search for disease germs among the host of other bacteria would be as futile as the search for the needle in the haymow. This work serves to let us know the condition of the reservoirs soon after the rain. A few days later the trip should be repeated and, by comparing the results obtained then with the former ones, we can tell whether the chances favor increased bacteria and turbidity at the intake or whether they will disappear without occasioning disturbance. If one of the reservoirs is in an unsettled condition from these causes we shut it off for the time being, and draw from one which appears to be normal. In this way complaints from consumers can be avoided, and a feeling of security established in the community which would have been impossible without the field-work.

We have taken up the two main factors which menace the

* Technology Quarterly, Vol. XII, No. 4, p. 283.
† Technology Quarterly, Vol. XII, No. 2, p. 145.
‡ Hazen, Filtration of Public Water Supplies, 3d edition, p. 118.
Whipple, The Microscopy of Drinking Water, p. 75.

supply in the inhabited district, but there remains to be considered the abandoned mill-ponds and the hospital. The mill-ponds will be spoken of later. Let us turn our attention to the hospital. It is situated on high ground at some distance from the chain of reservoirs, but the effluent from its disposal works must finally find its way into the supply. For this reason it is imperative that the English filters at all times do their work perfectly. It will not do to trust entirely to the hospital authorities in this matter. They will undoubtedly be honest in their intention to run the filter beds properly, but the best of employes grow lax at times, and accidents will happen so that he who is responsible for the purity of the water supply should be able to say that at such and such a time the beds were doing thus, and so. Much tact is necessary, in a case of this kind, where a third person must concern himself with another's business, but if all approach the matter in the right spirit there need be no friction.

The field-work on the storage reservoir in the wild land takes on a different nature. As the soil is gravelly there will be little additional turbidity after rains, and as it is uninhabited no great increase of bacteria that may be objectionable. But this reservoir, in a small way, but in a serious one, is liable to contamination. We have indicated that it is wooded; its chief feeder rises in a cedar swamp, and its shores are covered with deciduous trees. This being so, it will be a resort for picnic parties, and for any one who wishes a day's outing. They should not cause trouble, but unclean people will be among them, and they will not fail to arrange matters so that some foecal matter will find its way into the supply. The sick, and not the well, will offend oftenest. The danger is a real one, and the only relief is to have the shores so thoroughly policed that sinning will be difficult. It will not do to rely for protection on bacterial examinations. As has been said before, it is next to impossible to distinguish the disease germs among the shoal of other bacteria. We must keep them out of the supply, and not rely on hunting them down after they are once in.

It may not be amiss to speak here of the danger of allowing skating, fishing, and camping on bodies of water which are used for drinking by man. The evil is the same as in the case of the picnickers, and so these sports should be prohibited. A public water-supply is not a plaything, nor a play-ground; it is an extremely sensitive and expensive plant, built to administer to certain definite needs of the entire people, and should not be sacrificed to the pleasures of a few. Of the same kind of nuisance is the inexcusable and unnecessary custom of manuring the sides of reservoirs to get thick grassy slopes. The practice is a filthy one and dangerous besides, for in the majority of cases the origin of the manure is unknown, and it is not at all impossible that it contains disease germs. If it does the wind and rain will surely not leave them on the shores. When enrichment is desired it would seem perfectly feasible to use some of the cheap chemical fertilizers.

But to return to the reservoir once more. Color is the other point to be considered in regard to this source. We have said that the feeders rise in swamps; in flowing through them they will acquire a deep red color. This will be more noticeable some times than at others. When the water flows rapidly through the swamps, it will be much lighter colored than when the flow is sluggish, and time enough has elapsed for it to leach out the coloring matter from the roots and peat. In the late spring it will be particularly dark, for the water which comes out then has remained backed up in the swamps all winter, and besides the leaves which were shed by other trees than the evergreens the autumn before have disintegrated and their coloring matter is added to that from other sources.

When the influents reach the head of the reservoir, their course depends on their temperature and that of the reservoir itself. If the temperature of the feeders is such as to make their density less than that of the reservoir, the dark influent, unless disturbed by winds, will flow over the surface of the reservoir to the intake, arriving there almost as dark as when it entered at the head. If the density of the influent is greater than the reservoir water, it will flow along the bottom; if they are of the same density or high winds prevail, their waters will commingle. Sunlight bleaches the water somewhat so that the reservoir is likely to be lightest colored at its foot. At best, the water is too dark to be used by itself without disquietude on the part of the consumers; so when distributed it must be mixed, in such quantities as not to cause comment, with the light colored water of the supply. This is very nice work, and it makes it necessary for the color of the water to be accurately determined.

Not only must color samples be taken, but careful record of the temperature of the reservoir throughout its greatest depth must be kept, together with that of the influent streams. At the outlet color readings must be made on samples from the surface, mid-depth and bottom, in order that water may be drawn at that point where the color is the lightest. Also the color of the influents must be determined besides that of samples taken at various points intermediate between the foot and head of the reservoir. This is done to trace the progress of the water through the basin. All this work occasions frequent visits to the supply, but the time is profitably spent, for no change in a water is so quickly noted by the citizens as that in color, and superintendents value highly the information which enables them to anticipate criticism from this cause.

Turning our attention next to the lake, we find as its most striking feature the proximity of the town on the high hill. The town is a constant threat to the purity of the lake. To be sure, the sewage is carried outside of the watershed, and the brook, which takes almost all of the surface drainage which escapes the sewers, is filtered. But the town with its busy life is there, and if an accident should happen to the sewerage which should let the sewage unobserved into the lake or some similar misfortune should occur, trouble would surely ensue. The best the water works managers can do is to watch the filters carefully, and to be constantly on the alert for escaping sewage from the sewerage system. Those places where it passes near brooks which empty into the lake should be especially guarded. Bacteria samples should often be taken from the brooks, and frequent trips for inspection should be made along their banks.

To watch the filters is a comparatively easy matter. In the first place the plant should be in the hands of a competent person. Then bacteria samples should be taken from the effluents at regular intervals, and at any time the operator of the station may see fit to suggest. Whenever bacteria samples are taken from the effluents a bacteria sample and a sample for microscopical examination should be taken from the applied water. As the lake is fed by springs, and as the only important influent is filtered there will be little trouble from turbidity and color.

We have now taken up the salient features of each source of supply which necessitates peculiar field-work on their watersheds. One characteristic which is common to all remains to be discussed. I refer to the growth of microscopic organisms and the tastes and odors caused thereby. When we first began to strip our storage reservoirs, we found that we had removed the organic matter so thoroughly that large growths did not exist, and we hoped this condition would be permanent. Experience has proved otherwise. The organisms have gradually established themselves in reservoirs which were built in the most painstaking manner. Many causes contribute to this result. Perhaps the three most prominent ones are the increase of population on the watershed, the slow accumulation in the reservoirs or organic matter from the feeders, and the bringing in of microscopic forms by these same brooks. So we must acknowledge the growths to be common to all reservoirs. Not in equal degree, however, for we ordinarily expect them to be smaller, and to occur less frequently in the basins where the cleansing has been most perfect.

It is the duty of the water works biologist to know the organisms that cause trouble, to study the conditions under which they occur, and to so draw from the supplies at his command that the water served to the community shall be palatable and wholesome. He can never do these things satisfactorily unless he has an intimate personal knowledge of the system, and this can only be gained by much field-work.

It will not do to rely entirely on the analyses made in the laboratory of samples collected by another. They give no idea of the distribution of a growth, and at times are very misleading as to its size. The collector may be attracted by little specks in the water and, knowing that they are of interest to the analyst, try to get as many as possible into the bottle. Or he may have been warned against doing this, and so, almost unconsciously, try to keep the sample clear. Again, he may be very much hurried, and take the sample without noticing the condition of the water at all, it being merely a matter of luck whether it is a representative one or not. Indeed, analyses of samples taken in this manner simply show what the collector dipped up. A carefully trained collector would ordinarily do effective work, but the results obtained on his samples must be checked by work in the field if a comprehensive idea of the growths and the conditions which make for and against their development is to be obtained. The field-work must not be conducted in a haphazard way, but the general principles which influence plankton growths must be kept in mind.

As the name implies, the plankton is made up of floating growths, and many of them float near the surface of the water, while others live at some depth beneath it. But all are influenced by currents and winds. There is a steady current from the influent to the foot of the reservoir, so that there will be a tendency for all forms to be swept toward it. Then the wind will blow the growths hither and thither over the pond, now toward one shore, now toward another. Not only does the wind waft them from place to place, but distributes them also in the vertical through which it acts. So those forms which usually grow in the upper five feet and those which float conspicuously on the surface will be mixed with those which develop at a depth.

When the wind subsides they again take their normal position in this vertical. It is easy to see how all this may influence the samples. In the first place, organisms may be blown towards or entirely away from the usual collecting points. So easy is it to be deceived by this occurrence that it is not a bad plan to have the direction of the wind noted on the sample tag. If the samples are taken soon after a high wind they will give an entirely false idea of the vertical distribution of the organisms. Moreover, a small growth may be carried from its place, and collect about the intake. A bottle received from the collector at this time will create uneasiness which will be dispelled by a visit to the works where the true size of the growth is revealed, together with the fact that it will be dissipated again by the wind, leaving the water as good as ever.

Matters do not always work out as satisfactorily as this. These microscopic organisms commonly develop in bays and nooks where there is a shallow flowage, and in places where the cleansing of the reservoir has not been thorough. It happens at times that they are blown from these places out into the reservoir, and there increase enormously, causing the water to become very offensive to taste and smell. If the biologist finds a growth of this kind on his hands his procedure will be determined by the results of his field-work. If they show that the growth is confined to the surface, water may still be drawn from the mid-depth and bottom. This state of affairs many times exists in the case of growths of cyanophyceae and of some infusoria. But if it has been learned that the whole reservoir, from surface to bottom, from foot to head, is infested there is nothing to do but shut off the supply, and wait until the vigor of the growth is abated before using it again. Now this is a vital point. By putting the works in the care of a competent biologist, and constructing them so that water may be drawn from the surface, mid-depth and bottom, as occasion may require, it is perfectly feasible to deliver at all times good tasting water to the users. Even in the cases where there is only one source of supply much may be done in this direction, and where there are many sources to supplement each other the water should always be good. Our municipalities have not yet learned this lesson, but they must be made to as a matter of decency and economy. The microscopic organisms, besides developing in the shallows and bays of a reservoir, may be brought into it by the influent streams. Ordinarily they do not carry many organisms, and those that they do carry are quite harmless forms, such as Anthophysa, a few chlorophytes, and diatoms. But if the streams expand to broad quiet pools in some places, or if they rise in swamps which contain ponds, they may bring from thence many organisms which will work harm in the reservoirs below. These little swamp ponds and pools in the streams are ideal places for certain infusoria and cyanophyceae to breed, and they may reach a large development there, being retained in these localities as long as the weather is dry, and the streams are low. A heavy rain, however, washes them into the reservoirs where they are likely to grow, and do much injury. I believe many storage reservoirs which have been stripped at great expense have been spoiled by neglecting to eliminate the ponds from swamps and the pockets from the streams.

It is in this connection that we should consider the effect of the abandoned mill-ponds on some of the feeders of the chain of reservoirs. In summer time the microscopic organisms are bound to develop abundantly in them, and a long rain will make them overflow, and deliver their noxious growths into the stream; once there, the journey to the reservoirs is a short one. These ponds are always a great cause of worriment to the biologist. Samples should be taken from them often enough to determine their predominant organisms, and the grade of their water surface should be read from time to time, that they may not overflow unexpectedly, and so start a considerable growth, which may remain for a time at the head of the reservoir, unobserved by the biologist.

The seasons of overturns of the ponds are periods of great activity in the field. As this phenomenon is dependent on the temperature of the water many temperature readings ought to be made before and after it occurs. The overturn is succeeded by a rapid multiplication of diatoms and other forms, so that many samples have to be taken for microscopical examination. It is not till the material brought up from the bottom has been oxidized, and has settled out, and the microscopic organisms have in consequence somewhat decreased that there can be any let up in this work.

Some water works are built so that one reservoir can be filled from another, and not infrequently it is necessary to do this. Here is another chance for field-work, for the empty basin should never be filled with water of questionable quality. When such a work is to be undertaken, the biologist should invariably visit the works in person and assure himself that there is no marked turbidity, that the color is low, and that there are few organisms. It would be the height of folly, for instance, to fill an empty reservoir in mid-summer when so many organisms of all classes are present in the water. With the advent of cold weather many forms die so that the actual number of organisms is less, but of vastly more importance is the fact that many of the spores, which in warm weather are somewhat generally distributed in the water, sink to the bottom, and there remain till the spring overturn brings them to the surface and sunlight again. The significance of this is that we have a choice; we may fill our reservoirs with water which is comparatively free from organisms, and is likely to remain so, or we may fill them with water holding a multitude of forms which in time will die, leaving seed-like bodies, which will inevitably germinate as soon as conditions favorable to their development recur. In the light of these facts, it seems as though we ought always to act cautiously and wisely in the matter of running the water from one place to another in the system. But at times an apparent necessity tempts us to take chances which prudence would forbid our accepting. If we yield to these promptings, it should be with a full realization of the fact that it is easy to give the microscopic organisms a foothold in our reservoirs, but that it is not so certain that we are ever entirely rid of them again.

Elsewhere, I have spoken of nitrates in a manner which indicates that they are deleterious to a supply. It is only right to qualify this, for they are not injurious to health, but they are a detriment in that they serve as a food for the algae. Now the nitrates of a watershed increase with population; consequently, when it becomes very dense we may expect much trouble from these alone. In ground water supplies we ordinarily find high nitrates, but they are not harmful so long as the sunlight is excluded. Under its influence, however, the chlorophyllous plants produce extremely abundantly. Indeed so marked is this tendency that reservoirs for waters of this class are usually covered.

Many examples of the efficiency of field-work might be quoted to emphasize its value. But as we have treated the subject in a general way it does not seem fitting to do this. It will be sufficient to cite one case where its results were much appreciated by those for whom it was undertaken.

The town of A bought water from the Metropolitan Water Board; at the same time it used some of its own water, and this mixed supply was delivered to the consumers. The A supply was filtered water taken from filter-galleries near the shore of a lake, and this was mixed with the surface water supplied by the Board. The mixing did not take place in an open reservoir but in the mains. For a time all went well, but suddenly the town of A complained that the Metropolitan water was unfit to drink. I at once investigated the matter. Samples were taken from the reservoir which the Metropolitan Water Board used to supply A, from the A taps, from the A filter-galleries, and from the lake near which the filter-galleries were built. The analyses showed that the water from the Metropolitan reservoir was good, and that from the A taps was bad. It followed that the trouble must be with the water supplied by A itself. There were two organisms, Crenothrix and Coelosphaerium, in the A taps water which were not in the Metropolitan water. The water from the filter-galleries contained Crenothrix but not Coelosphaerium. The water from the lake contained great quantities of the latter, and as it was this which was causing the trouble it was important to discover how it got into the supply. The superintendent bethought himself of a pipe which was formerly used to let water direct from the lake to the town mains. A visit to this solved the mystery; the valve which closed the pipe was leaking badly. When it was replaced the trouble stopped.

THE WORK OF MT. PROSPECT LABORATORY OF THE BROOKLYN WATER WORKS

By GEORGE C. WHIPPLE, C. E., Biologist and Director

WITH FOUR PLATES

The practical value of the sciences in our modern civilization is strikingly attested by the increase in the number of laboratories connected with various departments of nation, state and municipality. This is emphatically true in the domain of sanitary science, where the advances in chemistry, microscopy and bacteriology have wrought revolutionary changes. With the knowledge that many diseases are caused by living organisms, and that some of them are transmitted by water, came the need of more careful supervision of public water supplies, which resulted in the establishment of laboratories devoted to water analysis. The pioneer work of the Massachusetts State Board of Health has been followed by the installation of laboratories in most of our large American cities. In many instances these are operated in connection with the departments of health, but in Boston, Lynn, Louisville, Cincinnati, Pittsburg, Albany, Washington, and elsewhere laboratories have been organized in connection with the departments of water supply, either for the purpose of experimental work or because the character of the water supply was such that proper management depended upon analytical as well as engineering data. Departments of water supply should be justly held responsible for the quality as well as the quantity of water supplied to the public. This involves a constant knowledge of the sanitary condition of the water, which can be obtained only by frequent analysis and inspection.

The complicated character of the water supply of Brooklyn made the need of a laboratory apparent to the Department of Water Supply several years ago, but it was not until 1897 that an appropriation for the purpose was obtained. In May of that year the writer was appointed biologist and director of the laboratory, and instructed by Mr. I. M. De Varona, Engineer of Water Supply, to prepare plans for the installation and equipment of a complete chemical and biological laboratory. Mt. Prospect reservoir, near the entrance to Prospect Park, was selected as the most available site, and the gate house of the reservoir was found to have ample accommodations. Contracts were let during the summer, and the laboratory was in complete operation on the 1st of October, though regular microscopical examinations of the water were begun early in July.

Mt. Prospect laboratory has a fortunate location. It is conveniently near the Long Island depot, where the samples from the watershed are received, Ridgewood reservoir, the main distribution reservoir, and the office of the department at the municipal building. Its isolation and elevation make it comparatively free from noise and dust, while the building is well lighted by large windows, heated by hot water, provided with gas, electricity and telephone. The upper portion of the building contains three rooms, besides the keeper's office, and a corridor from which visitors may ascend to an observatory on the roof. The three rooms are known as the general laboratory, or preparation room, the biological laboratory, and the chemical laboratory. In the basement are the physical laboratory, the general store room and the furnace room. There is also a sub-basement, suitable for bacteriological work during hot weather.

The general laboratory is devoted to the shipment of bottles and reception of samples, the washing of glassware, the sterilization of apparatus, the preparation of culture media and to such chemical operations as might charge the air with ammonia and the fumes of strong acids. The room contains a well-ventilated hood; a work table, under which are closets and drawers; a shipping desk; a large sink, with draining boards on the sides; a drying oven; a hot-air sterilizer; a steam sterilizer; an autoclav; an automatic still, and a distilled water tank, lined with block tin and having delivery tubes that extend to the other rooms.

The biological laboratory is devoted to the bacteriological and microscopical examinations of water and to the study of the various organisms found. It also forms the office of the director. It contains a work table; a long wórk shelf, with three windows in front; three incubators; an ice chest for the storage of culture media; a case for sterilized apparatus;

a bookcase, with a good working library; a desk; a typewriter, and cabinets for report blanks, biological specimens, etc. Electric bells connect with the different laboratories and with the telephone in the office of the keeper of the reservoir.

The chemical laboratory is the largest of the three rooms. Its atmosphere is kept free from ammonia and from the fumes of strong acids, in order not to vitiate the results of the water analyses there carried on. It contains a table for holding the samples of water that are being analyzed; three work tables; two work shelves, with windows in front; a weighing room, with balance in front of window and with a wide desiccator shelf and a drying closet; a hood, under which are two steam baths; a battery of twelve stills for ammonia distillations; a still for obtaining redistilled water; an apparatus for gas analysis; a battery of twelve Sedwick-Rafter filters, used in the microscopical examination of water; an apparatus case; a case for chemicals; a Richards pump, and various pieces of specially designed apparatus that facilitate the work of analysis. The room also contains a combustion furnace and a Mahler bomb calorimeter for the analysis of coal and the determination of its heating power. A storage room opens from the chemical laboratory, and there is a small dark room under the stairs. The three laboratories have marble-tiled floors, and the work tables and shelves are covered with white tiles throughout. The partitions between the rooms are largely of glass.

The physical laboratory in the basement is not fully completed. At present it contains a crusher, a coal sampler, sieves for sand analysis, and a complete equipment for testing cement. Much of the room is devoted to storage and to shop work.

The laboratory force consists of one biologist and director, one chemist, one assistant chemist and three assistants.

WATER ANALYSES

The routine work consists of the regular examination of samples of water received from all parts of the water-shed and distribution system, i. e., from the driven wells, streams, ponds, aqueducts, reservoirs and service taps. The complicated and varied character of the water supply requires the examination of an unusually large number of samples, and it is safe to say that no water supply in this country is examined more thoroughly and minutely than that of Brooklyn. The regular routine includes the bacteriological examination of three samples of water from the Ridgewood pumping stations and from a tap in the city collected daily; the complete physical, chemical and biological examination of nine samples from the distribution system collected weekly; the physical, biological and partial chemical examination of 24 samples from the supply ponds collected weekly, with complete chemical analyses monthly, the complete examination of 19 samples from driven wells collected monthly; and the complete examination of 21 samples from the private water supply companies of Brooklyn and from the water supplies of the Borough of Queens, collected quarterly. In addition to these regular samples many extra samples are taken at various times and places, as occasion requires. During the 2½ years that the laboratory has been in operation this schedule has resulted in the analysis of more than 6,000 samples, as follows:

Samples received from July 12, 1897, to April 1, 1900	6,471
Physical examinations	5,025
Complete chemical analyses	2,562
Partial chemical analyses	1,049
Microscopical examinations	4,688
Bacteriological examinations	5,230
Tests for bacillus coli communis	2,630

The samples of water from the watershed are collected in the forenoon during the early part of each week and sent to the laboratory by express. The average time that elapses between the collection of a sample and the beginning of its analysis is about four hours, but this time varies from ten minutes to eight hours. Samples are collected in large bottles for chemical and microscopical analysis and in small sterilized bottles for bacteriological examination. The large bottles have a capacity of one gallon, are made of heavy, clear, white glass, and have glass "hood" stoppers. They are not sterilized, but are carefully cleaned with chromic acid before leaving the laboratory. Brown paper is tied over the stoppers to prevent contamination from dust, and the bottles are packed in boxes that have separate compartments lined with indented fiber paper and that are provided with tight-fitting covers. The breakage of bottles packed in this way is very small.

The bottles for the bacteria samples hold 2 ozs., and are made of clear, white glass, and have wide mouths with glass stoppers. They are known to the trade as "chemical salt mouths." These bottles are sterilized each time before use. The stoppers of the bottles are covered with pieces of tin foil, and each bottle is then placed in a screw-capped tin box, just large enough to receive it. The tin boxes are painted to keep them from rusting. The bacteria samples are shipped in portable ice-boxes. There is an outer box with asbestos packing and a copper lining and an inner copper tray, divided into compartments to hold the tin boxes just mentioned, and between the outer box and the tray is a large space for ice. The box holds sufficient ice to last eight hours in hot weather, and the samples almost invariably are received in good condition.

The samples from the supply ponds are collected at a depth of 1 ft. below the surface. The shallowness of the ponds makes it unnecessary to collect samples at greater depths. The samples from the distribution reservoirs are collected just outside the gate houses, where the flowing water gives a representative mixture of the water entering or leaving the reservoirs. Special precautions are taken to avoid contamination in the collection of samples, and to this end special forms of collecting apparatus have been devised.

In the apparatus for collecting the bacteria samples the sterilized bottle is placed in a metal frame attached to the lower end of a small brass tube, and is held in position by spring clips. A small rod extends through the brass tube, and at the lower end is provided with a clutch for grasping the stopper of the bottle. By means of this rod the bottle may be opened and closed under water.

The apparatus used for collecting samples from beneath the surface, when necessary, is as follows: The frame consists of a brass wire attached to a weight with clips for holding the bottle. The frame is supported by a spring joined to a sinking rope. A flexible cord extends from the top of the spring to the stopper of the bottle. The length of this cord and the length and stiffness of the spring are so adjusted that when the apparatus is suspended in the water by the sinking rope the cord will be just a little slack. In this condition it is lowered to the desired depth. A sudden jerk given to the rope stretches the spring and produces sufficient tension on the cord to pull out the stopper.

The apparatus for collecting bacteria samples from beneath the surface is similar in principle. The bottle is replaced by a sterilized vacuum tube, with end turned outwards and backwards and drawn to a point. The pull of the cord breaks off the tip of the tube and the pressure of the water causes the tube to fill. The end may be then sealed with an alcohol lamp or closed with a bit of sterilized wax. The frame for holding the tube consists of a short piece of lead pipe, which also serves as a weight.

The temperature of each sample is taken at the time of collection and recorded on a certificate, together with the locality of the sample, the date of collection, the name of the collector, etc. Temperature reading below the surface are obtained with the thermophone.*

When the samples reach the laboratory each is given a serial number and entered in an index book, and throughout all the examinations each sample is known by its number rather than by the name of the locality from which it was collected.

It would be out of place in this paper to describe in detail all the methods used in the analysis of the samples, but inasmuch as methods differ considerably in different laboratories, it seems desirable to give at least an outline of the methods used and to describe such as differ materially from those practiced elsewhere.

PHYSICAL EXAMINATION

The physical examination includes the observation of the temperature of the water, its general appearance, its turbidity, its color and its odor.

Temperature.—The temperature of the sample is observed at the time of the collection, as mentioned above.

Appearance.—The amount of sediment and the turbidity, after standing twelve hours, are estimated by inspection and recorded numerically according to the following scale: 0, none; 1, very slight; 2, slight; 3, distinct; 4, decided.

Turbidity.—The actual turbidity is determined by comparison of the sample with silica standards of turbidity, as described by Whipple and Jackson in the Technology Quarterly for December, 1899, and September, 1900. According to this standard, a turbidity of 100 is equal to that produced by adding 100 mg. of finely divided diatomaceous earth to one liter of water. Comparisons are made in gallon bottles or in

*Henry E. Warren and Geo. C. Whipple, "The Thermophone," Technology Quarterly, July, 1895.

Nessler jars, held toward the light or placed over a series of black lines.

Color.—The color is determined by comparison with the platinum-cobalt standard, described by Hazen in the American Chemical Journal, Vol. XIV, p. 300. The comparisons are made in 100 cu. cm. Nessler jars, 1 in. in diameter and 12 ins. long.

Odor.—The "cold odor" is observed after vigorously shaking the bottle in which the sample is contained. The "hot odor" is observed by heating about 200 cu. cm. of the sample in a beaker, covered with a watch-glass, to a point just short of boiling and applying the nose as soon as the water has sufficiently cooled. The results are expressed according to the following scale of intensity and with the following abbreviations:

Scale of intensity.—0, none; 1, very faint; 2. faint; 3, distinct; 4, decided.

Abbreviations.—v, vegetable; e, earthy; a, aromatic; g, grassy; f, fishy; m, moldy, etc.

CHEMICAL ANALYSIS

The sanitary chemical analysis ordinarily includes the determination of the nitrogen as albuminoid ammonia, free ammonia, nitrites and nitrates; total residue on evaporation, loss on ignition, chlorine, iron and hardness. In addition to these the following determinations are sometimes made: oxygen consumed, alkalinity, incrusting constituents, dissolved oxygen, carbonic acid, etc.

Form of Expression.—The results of the chemical analysis are expressed in parts per million.

Nitrogen as Albuminoid Ammonia.—The method of Wanklyn is used, according to the practice of the Massachusetts State Board of Health, described in the two special reports on water supply and sewerage published in 1890. The total albuminoid ammonia is determined on the unfiltered water. The dissolved albuminoid ammonia is determined after filtering the sample through filter paper. The suspended albuminoid ammonia is found by subtracting the dissolved albuminoid ammonia from the total albuminoid ammonia. In the case of ground waters only the total albuminoid ammonia is determined. The form of distilling apparatus is practically the same as that designed by Mr. H. W. Clark and used at the laboratory of the Massachusetts State Board of Health. Permanent standards are used as described by Jackson in the Technology Quarterly for December, 1900.

Nitrogen as Free Ammonia.—The free ammonia is determined by Wanklyn's method, referred to under albuminoid ammonia. Five hundred cu. cm. of the sample serves for the determination of both the free and albuminoid ammonia.

Nitrogen as Nitrites.—Warrington's modification of the Griess method is used. Permanent standards are used.

Nitrogen as Nitrates.—The phenolsulphonic acid method of Grandval and Lajoux is used, but with certain modifications tending to refinement. The quantities of water operated upon vary from 2 to 50 cu. cm., according to the amount of nitrogen present as nitrates. Permanent standards are used instead of preparing fresh standards for every set of comparisons. Comparisons are made in 100 cu. cm. Nessler jars.

Residue on Evaporation.—For the determination of the residue on evaporation 200 cu. cm. of the sample are evaporated to dryness on a water bath in a platinum dish of known weight, dried for half an hour in a steam oven, cooled in a desiccator and weighed. Where it is necessary to determine the amount of suspended matter the residue is determined both before and after filtering the sample through filter paper or through a Pasteur filter, and the difference obtained.

Loss on Ignition.—After the determination of the total residue on evaporation the platinum dish is placed in a larger platinum dish that serves as a radiator, ignited for seven minutes at a low red heat, treated with a small amount of distilled water to restore any loss of water of crystallization that may have been driven off by the ignition, evaporated to dryness on the water bath and dried, cooled and weighed as before. The difference of weight before and after ignition gives the loss on ignition. The loss on ignition is not determined for the ground waters or for the water of the distribution system, which is a mixture of the surface and ground waters.

Chlorine.—The chlorine is determined by titration with silver nitrate, using potassium chromate as an indicator, according to Hazen's modification of Mohr's method, described in the American Chemical Journal, Vol. XI, p. 409.

Hardness.—The hardness is determined by Clark's soap method, substantially as described in Sutton's "Volumetric

Analysis," but with certain modifications in the preparation of the soap solution. No attempt is made to separate the "temporary hardness" from the "permanent hardness" by the method of boiling. The information covered by these terms is obtained when required by the determination of the alkalinity and the incrusting constituents.

Alkalinity.—The alkalinity of a water is a measure of the carbonates and bicarbonates present. It is ordinarily determined by titrating 100 cu. cm. of the sample with N-50 H_2SO_4, using methyl orange as an indicator; but it is sometimes desirable to substitute lacmoid for methyl orange as an indicator, making the titration after heating the sample to the boiling point. Phenacetolin is also used. It has been found that when the true end-points are known and the proper corrections are applied the various indicators give practically the same results. These indicators differ in their power of showing the presence of sulphate of alumina, and methyl orange should not be used in determining the alkalinity of a water that has been treated with that coagulant.

Incrusting Constituents.—The incrusting constituents are the salts that give to water its "permanent hardness." The determination is made according to Hehner's method, as described by Leffman in his "Examination of Water." The sum of the alkalinity and incrusting constituents is approximately equal to the hardness as determined by the soap method.

Iron.—The iron is determined from the residue in the platinum dish according to Thompson's method, as described in Sutton's "Volumetric Analysis," but with certain changes in technique that tend to greater accuracy.

Oyxgen Consumed.—The Kubel method is used substantially as described in the special reports of the Massachusetts State Board of Health, above referred to. The period of boiling is five minutes. This determination is seldom made on the regular samples.

Dissolved Oxygen.—Winkler's method is used according to the modifications of Drown and Hazen, described in the special reports of the Massachusetts State Board of Health, above referred to.

Carbonic Acid.—Pettenkofer's method is used according to the modifications of Trillich, described in Ohmuller's "Untersuchung des Wassers," edition of 1896, when it is desired to determine the free and half-bound carbonic acid. The free carbonic acid is determined by titrating with N_{22}NaOH, using phenolphthalein as an indicator.

MICROSCOPICAL EXAMINATION

The microscopical examination of water determines the number and kind of microscopic organisms present, together with the amount of amorphous matter. The Sedgwick-Rafter method is used, with the modifications described in the author's "Microscopy of Drinking Water." The results are expressed in number of standard units of organisms per cubic centimeter.

BACTERIOLOGICAL EXAMINATION

The bacteriological examination consists of the determination of the number of bacteria present in a sample of water and a qualitative test for the presence of bacillus coli communis. No general qualitative work is undertaken in connection with the regular routine.

Quantitative Examination.—One cubic centimeter of the sample (diluted 1-10, or 1-100, if necessary) is mixed with 5 cu. cm. of sterilized nutrient gelatine in a ventilated petri dish and allowed to cool on a level surface. When hard the culture is placed in an incubator and kept at a temperature of 20° C. in an atmosphere saturated with moisture for 48 hours, after which the number of developed colonies is counted. It is then returned to the incubator and kept 24 hours longer, after which a second count is made. The 72-hour count is the one reported. All determinations are made in duplicate. The gelatine used as the culture medium is prepared substantially as recommended in the report of the Bacteriological Committee of the American Public Health Association, published in 1898. It is given an acidity of 1.5%.

Test for Bacillus Coli Communis.—Smith's fermentation method is used as the basis of the test, isolation of the colon bacillus according to ordinary qualitative methods being attempted only when a positive test is obtained in the fermentation tube. If the amount of gas in the fermentation tube after 48 hours' incubation at 37° C. is above 30% and below 70% of the closed arm, a portion of the sediment is plated on lactose-litmus-agar. If red colonies develop after 12 hours' incubation transfers are made from them to glucose-gelatine, milk, nitrate solution, sugar-free broth (for indol), and glucose broth in a fermentation tube. If these tests give positive results, the presence of the colon bacillus is considered as proven.

The members of this Society will be naturally most interested in the results of the microscopical examinations. These cannot be described in detail within the compass of this paper, but the following account of some of the more important microscopic organisms will indicate the nature of the problems that are being investigated.

MICROSCOPIC ORGANISMS IN THE BROOKLYN WATER SUPPLY

The troubles of the Brooklyn water supply during the past few years have been occasioned by the growth of odor-producing organisms in the distribution reservoirs. The growth of Asterionella in Ridgewood and Mt. Prospect reservoirs and its effect upon the quality of the water have been so fully described (report of Dr. Albert R. Leeds to the Department of City Works, Division of Water Supply, Brooklyn, 1897) that it is not necessary to again relate the details of its occurrence. That the growths of Asterionella continue to occur periodically is shown by the diagram.

Asterionella is not the only odor-producing organism that develops in the distribution reservoirs. Anabaena, Synedra, Cyclotella and other forms are sometimes present in great abundance. The character of the water collected from the watershed of the Brooklyn supply is such as to furnish abundant nourishment for microscopic plant life, and organisms that in many water supplies appear in small numbers without having any noticeable effect on the character of the water develop in Brooklyn to an enormous extent.

This is emphatically true in the case of Synedra pulchella, a diatom that until recently has not been classed as an odor-producing organism. Like Asterionella, this diatom contains oil-globules, but the oily substance has not the same strong odor as the oil of Asterionella. Nevertheless, Synedra is capable of imparting an odor to water if present in sufficient numbers. The odor is not a characteristic one like that of Asterionella, Uroglena, Dinobryon, etc., and can be described by no more exact term than "vegetable." The taste imparted to water by Synedra is perhaps more noticeable than the odor, being somewhat "earthy," as well as "vegetable."

In few water supplies in this country is Synedra pulchella ever present in numbers greater than 5,000 per cu. cm. and, although a smaller number than this will make a water turbid, it requires about this number to produce a noticeable odor. In Brooklyn, however, the growths of Synedra have been much heavier, as may be seen from the diagram. On several occasions the numbers have reached 15,000 per cu. cm., and once as many as 20,000 per cu. cm. were observed. The water at such times has been very turbid, and has had the vegetable and earthy taste and odor just referred to.

The seasonable distribution of Synedra in the Brooklyn reservoirs is worth noting. In Mt. Prospect reservoir it has appeared regularly in the spring and fall, according to the usual mode of occurrence of the diatoms, but it has always appeared after the Asterionella growths in the spring and before the Asterionella growths in the fall. In Ridgewood its occurrence has been more variable. In 1899 there were heavy growths in basins 1 and 3 during the month of August.

Cyclotella is another diatom that, because of its limited occurrence, has been seldom known to cause trouble in water supplies. Yet in Ridgewood reservoir it is sometimes present in large numbers. Its growth has been usually of short duration, but when present in numbers equal to 5,000 standard units per cu. cm. its aromatic odor could be distinctly recognized.

Two species of Melosira occur in the Brooklyn supply. Melosira granulata, the common free-floating form, is seldom present in sufficient numbers to cause trouble, though 2.000 or 3,000 per cu. cm. are sometimes found. Melosira varians grows luxuriantly on the shores of Ridgewood reservoir, and constant scraping is required during the summer to keep the banks clean. During severe storms the filaments of Melosira become detached from the shores and are scattered through the water, and on one occasion the amount of vegetable matter so detached was sufficient to impart a distinct taste to the water. Like Synedra pulchella, Melosira produces simply a vegetable, earthy and somewhat oily taste and odor, very different from the aromatic-fishy odor of Asterionella and Cyclotella.

Next to Asterionella, Anabaena has probably caused more trouble in the Brooklyn water supply than any other organism. During the past two years it has appeared but once, but there are good reasons to believe that in the summer of

1896, prior to the investigations of Dr. Leeds, the disagreeable odor of the tap water was due not so much to Asterionella as to Anabaena.

In July, 1898, Anabaena appeared in all the Ridgewood basins. In Basin 3 it did not develop to any extent. In Basin 1 it attained a maximum growth of 1.720 standard units per cu. cm. on August 19, and gave to the water its characteristic odor of moldy grass. In Basin 2, however, it developed to an enormous extent. On August 3 there were 24,000 standard units per cu. cm. From the last of July until early in September the water in the basin was intensely turbid and had a green color. On quiet days a scum collected on the surface and drifted about with the wind. The water was entirely unfit for use, and the gates of the reservoir were kept closed. As soon as the organisms disappeared in the fall and the water had again assumed its normal condition, Basin 2 was emptied and cleaned, with the hope of preventing recurrence of such growths in the future. An examination of the deposit at the bottom of the reservoir showed that it was well seeded with the spores of Anabaena. Since that time there has been no further development of this organism.

In September, 1898, a phenomenally large growth of Scenedesmus occurred in Mt. Prospect reservoir, the water at one time containing 25,800 standard units per cu. cm. This organism, in the numbers ordinarily found, causes no odor, but on this occasion the water had a distinct vegetable and aromatic odor and taste. The growth continued for several weeks.

There are several other organisms that deserve mention, because they occur in larger numbers in the Brooklyn water than in most water supplies. Dictyosphaerium, Eudorina, Pandorina and Volvox are often present in numbers of 500 standard units per cu. cm. Clathrocystis is not often found in Ridgewood reservoir, but in Mt. Prospect reservoir it has been as high as 1,440 standard units per cu. cm. As a rule the Brooklyn water contains comparatively few protozoa, but Mallomonas has been observed as high as 660 per cu. cm. in Ridgewood reservoir, and Cryptomonas has been as high as 2,000 per cu. cm. in Mt. Prospect reservoir. Chlamydomonas has been found occasionally.

To the water consumers of Brooklyn, however, the important fact is not the number of organisms in the distribution reservoirs, but the number present in the tap water in the city. Prior to the construction of the by-pass at Ridgewood the organisms that developed in the reservoir found their way as a matter of course to the service taps of the consumers. But by using the by-pass it has been found possible to so regulate the distribution of the water that very few organisms reach the consumer. Guided by the frequent and regular microscopical examinations made at Mt. Prospect laboratory, the engineer has directed one or more basins to be isolated whenever it was found that odor-producing organisms were developing in them, the water meanwhile being delivered through the by-pass direct from the force mains to the distribution pipes. It has been found possible also to isolate Mt. Prospect reservoir and pump directly into the pipes when growths of organisms made it seem advisable. The beneficial effect of this management can be illustrated by the following comparison.

At the time when Dr. Leeds made his report on the condition of the water, i. e., from November, 1896, to February, 1897, Asterionella was present in the distribution system as follows:

	No. per cu. cm.
Ridgewood reservoir, Basin 1	3 to 48
" " " 2	2 " 10
" " " 3	2,608 " 4,648
Mt. Prospect reservoir	4,808 " 8,640
Tap supplied from Ridgewood, Basins 1 and 2	3 " 81
" " " " Basin 3	1,240 " 8,800
" " " Mt. Prospect reservoir	2,400 " 7,460

During November and December, 1899, the corresponding figures were as follows:

	No. per cu. cm.
Ridgewood reservoir, Basin 1	5,600 to 27,280
" " " 2	0 " 8
" " " 3	0 " 16
Mt. Prospect reservoir	6,512 " 24,960
Tap ordinarily supplied from Ridgewood, Basin 1 and 2	0
Taps supplied from Ridgewood, Basin 3	0 " 16
Tap ordinarly supplied from Mt. Prospect reservoir	8 " 56

During November, 1896, and February, 1897, the water supplied to the city from Basin 3 and from Mt. Prospect reservoir had a very disagreeable taste and odor, due to the presence of Asterionella, but during November-December, 1899, the water in the city had no odor due to Asterionella, even though that organism was far more abundant in Ridgewood and Mt. Prospect reservoirs than it had been during the winter of 1896-97. This freedom of the tap water from Asterionella was due to the use of the by-pass, the sections of the city that are ordinarily supplied from Ridgewood Basins 1 and 2 and from Mt. Prospect reservoir being supplied with water direct from the Ridgewood force mains.

EXPLANATION OF PLATES

Plate I

Exterior view of Mount Prospect Laboratory, Brooklyn Water Works.

Plate II

Plan of main floor, Mount Prospect Laboratory.

Plate III

View of a portion of the Chemical Laboratory.

Plate IV

Variations in numbers of microscopic organisms in the Brooklyn Reservoirs, November, 1897, to February, 1900.

PLATE I

PLATE II

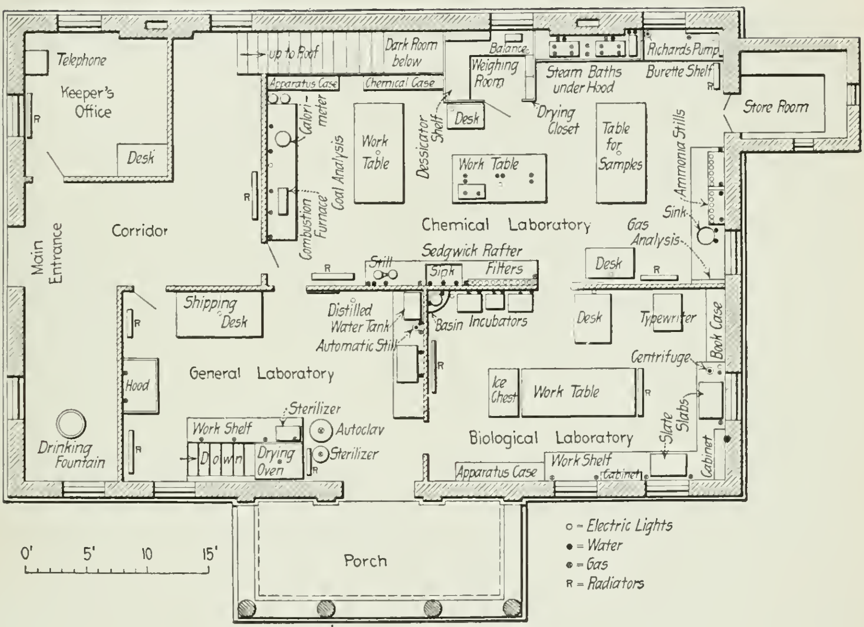
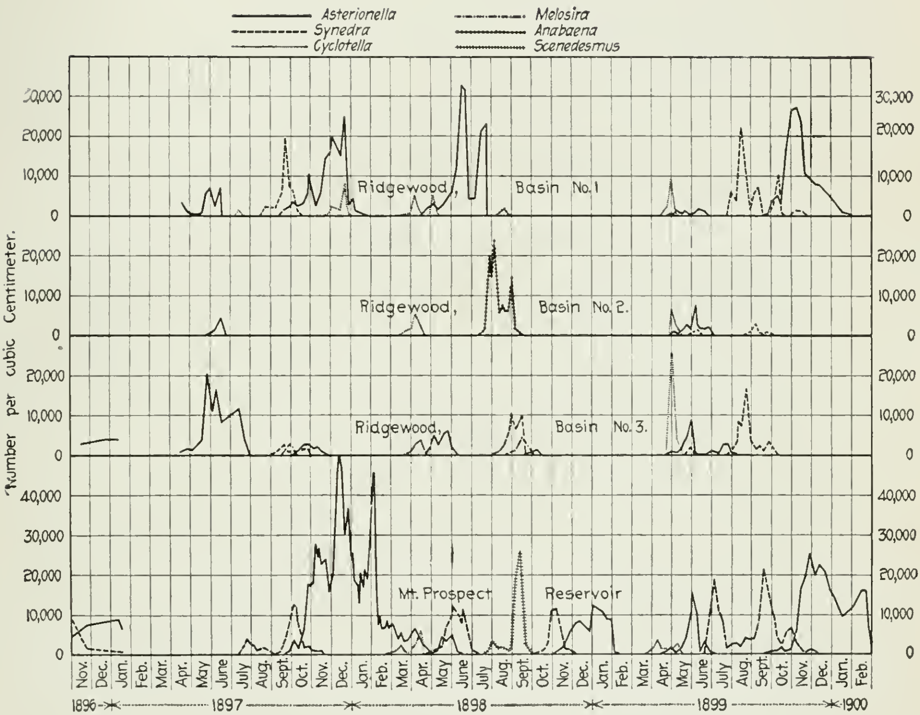

Telephone
Keeper's Office
Desk
R
Corridor
Main Entrance
up to Roof
Dark Room below
Apparatus Case
Chemical Case
Calori-meter
Coal Analysis
Combustion Furnace
Work Table
Dessicator Shelf
Balance
Weighing Room
Desk
Drying Closet
Steam Baths under Hood
Richards Pump
Burette Shelf
Store Room
Work Table
Table for Samples
Ammonia Stills
Sink
Chemical Laboratory
Gas Analysis
Sedgwick Rafter
Still
Sink
Filters
Desk
Shipping Desk
Distilled Water Tank
Automatic Still
Basin
Incubators
Desk
Typewriter
Book Case
Centrifuge
General Laboratory
Hood
Ice Chest
Work Table
Slate Slabs
Sterilizer
Autoclav
Sterilizer
Work Shelf
Down
Drying Oven
Drinking Fountain
Biological Laboratory
Work Shelf
Apparatus Case
Cabinet
Cabinet
Porch
0'
5'
10
15'
o = Electric Lights
• = Water
⊛ = Gas
R = Radiators

PLATE III

PLATE IV



Asterionella
Synedra
Cyclotella
Melosira
Anabaena
Scenedesmus
Ridgewood, Basin No. 1
Ridgewood, Basin No. 2.
Ridgewood, Basin No. 3.
Mt. Prospect Reservoir
Number per cubic Centimeter.
Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb.
1896 1897 1898 1899 1900

METHODS OF PRODUCING ENLARGEMENTS AND LANTERN SLIDES OF MICROSCOPIC OBJECTS FOR CLASS DEMONSTRATIONS

By JOHN ASPINWALL

For convenience we will divide the subject of this paper into three parts:

1. Making the Photomicrograph.
2. Making the Lantern Slide.
3. Making the Enlargement.

MAKING THE PHOTOMICROGRAPH

The method used by the writer is the result of an attempt to produce photomicrographs of considerable magnification, and yet of great depth of focus, while using lenses of high resolving power.

In the ordinary process of photomicrography, the amplification is obtained in one of three ways:

1. A low power objective, and fairly high power ocular.
2. A high power objective and low power ocular, or none.
3. A great extension of the bellows of the camera, combined with the use of a projection eyepiece, or none.

In all of these cases, amplification is obtained at the expense of the focal depth; and, although there is often definition over an extended area at right angles to the axis of the beam of light, the relation of the parts is only shown over a very thin area in the line of the axis of the instrument.

The method of the writer is to use an objective of medium power, where fairly high amplification is desired, say a one-quarter Spencer, making the negative of a diameter of 1½ to 2 inches.

In a lantern slide camera, enlarge from one-half to three-quarters of the central area of its negative to twice its diameter upon a Paget lantern slide plate. By another enlargement from this positive, a negative of any diameter can be secured.

This appears a roundabout method, but the object is obtained, viz., to get the maximum depth of focus and any desired amplification.

It is important to make the positive upon a plate rich in chloride, such as the Paget, in order to obtain a deposit without grain, and capable of registering the minutest detail with no suggestion of film structure.

It is also important that the enlarging lens be of the very best type, such as a Ross, a Guerz, or a Zeiss, and well stopped down.

In making a negative for an enlargement on bromide paper, the same methods may be pursued.

The writer prefers, in making the original negative, to use an objective without the ocular, and instead of the usual substage condenser of high angle, to employ an ordinary objective of, say, one inch focus.

For the best results, the beam of light approaching this objective condenser should be of a very low angle. This can be obtained in the ordinary photomicrographic outfit by the interposition between the lantern condenser and substage of a biconcave lens of suitable curvature.

MAKING THE LANTERN SLIDE

First of all, no American plate known to the writer is capable of producing the best grade of lantern slide. We prefer the Paget plate, which is made in England.

It is important to depart from the beaten path, and leave, in most cases, the black and white effect, and reach into the warmer tones of brown, purple and red.

This may sound esthetic, but the fact remains that the subject is given a look of life and substance by adopting a warmer tone. Nothing but a suggestion of death lurks in the chalky white and black tone of the ordinary commercial lantern slide.

It is certain that two slides of a hand suffering from skin disease—one in black and white, and the other in a tone near to flesh tint—bear no comparison; one is the hand of the dead, the other that of some living being.

In the matting, too, there is much to do with the ultimate results. This point cannot be too strongly enforced. Any subject surrounded by a mass of glaring white light will fail to show the most delicate lines and gradations of tone, owing to the eye being dazzled by the surrounding whiteness.

The proper mat is one capable of being cut to suit the subject; such an one, for instance, as that known in the photographic world as the Boston mat. The lines given on this mat enable one to shape the opening to suit the subject. The use of the mat of ordinary size, such as usually employed by the commercial lantern slide maker, would seem to indicate that the value of the slide was in proportion to the area of the opening; while the reverse is really the case in most instances.

The Paget slow plate is capable of giving tones from black, through the browns and reds, into the purple.

The developer used by the writer is made up as follows:

Hydrochinon	100 grains
Sodium sulphite (crystals).......	400 grains
Sodium carbonate (crystals).....	400 grains
Water	20 ounces

The exposure will run from 20 seconds to 15 minutes, according to the light or the tone desired. A long exposure and a weak developer, with bromide added, producing the warmer tones, and a short exposure, with strong developer, the blacks and whites. The dilution of developer is made as follows:

1. For black tone—

Developer	1 ounce
Water	2 ounces
10% solution of bromide........	1 to 2 drops

2. For brown tone—

Developer	1 ounce
Water	4 ounces
Bromide	5 to 8 drops

3. For red tone—

Developer	1 ounce
Water	8 ounces
Bromide	15 to 25 drops

4. For purple tone—

   Over exposure and the use of the No. 2 dilution.

As Hydrochinon is inert at low temperatures, for uniform results the developer should be slightly warm in winter, so that it will be between 70 and 80 degrees F.

The exposure is made, say 20 seconds for black tones, $1\frac{1}{2}$ to 2 minutes for brown tones, and from 5 to 15 minutes for red ones. The quality of the negative counts, of course, and no rule can be given—the foregoing exposures being merely suggestive.

The reader will have to work out the problem from the hints herein given. The time of development increases as the tones get warmer.

The writer has obtained the best results in making slides by using a reducing and enlarging camera in preference to making slides by contact with the negative.

It must be apparent to anyone that a slide from a photomicrographic negative $2\frac{1}{4}$ inches in diameter will be superior in depth of focus and detail to one made by reducing a negative six inches in diameter made of the same subject and area of subject where this increased size of negative is obtained by drawing out the bellows, or using a higher power objective. Quite a remarkable effect can be obtained in some cases where tissues are differentiated by highly stained nuclei, in the following manner:

A lantern slide is made with the reddest tone obtainable. After fixing and washing, but before the slide is dry, it is toned for a short time in a gold bath made as follows:

1. Sulphocyanide of ammonium....200 grains
   Water .... 32 ounces
   Carbonate of soda (granuls)..... 2 grains
2. Chloride of gold (brown)........ 15 grains
   Water .... 1 ounce

For use take two ounces of No. 1 and four drops of No. 2, always remembering to add No. 2 to No. 1, and never reversing the operation. This amount of solution will tone one slide to a perfect blue throughout; but in our process, we only immerse the red slide, before spoken of, long enough to permit the gold to attack the lighter deposit of silver in the film. The result of this will be to give the lantern slide an appearance of a microscopic slide, which has a nuclear stain of carmine, and the deepest stain of methyl blue.

The gold bath should be kept at a temperature of from 72 to 76 degrees—a lower temperature would result in failure.

It would seem that the effect we obtain is not altogether permanent, as, after a couple of years or so, the blue appears to gradually creep into the red nuclei and spoil the differential effect.

You must not fail to remember that in all these colored effects, any shadow in the negative caused by refraction will assume solid proportions when interpreted in the color of the subject. This, however, holds true somewhat of a black deposit. I would advise using the more brilliant tones only upon subjects made with a low power objective, unless it be of a very thin section, and an image which it is clear cut and free from exterior refraction lines.

A finely hand colored slide is probably the most perfect for the purpose of class demonstration, but such slides are very expensive, and require some time to prepare; while chemically colored slides are quickly produced, and cost practically no more than the ordinary kind.

There is one point which is important in producing the very best grade of lantern slide with the Paget plate. This is the clearing operation which must follow the fixing. The development should be carried a trifle further than normal, and after the slide is fixed, but before washing, swab it over with a tuft of cotton immersed in a weak solution of ferricyanide of potassium (red prussiate of potash) of the color of very pale sherry. This will remove all chemical fog and clear up the whole image while reducing the entire deposit a trifle.

Areas too prominent and calculated to divert attention from the greatest points of interest, may be either reduced or entirely wiped out. For instance, in the cross section of the skin, and the tissues below, it frequently happens that the portion outside of the tissue proper shows refraction areas, or specks of dirt, and bits of the tissue. These can be entirely removed by rubbing gently with the cotton dipped in a strong solution of ferricyanide, being careful to hold the slide so that the solution will not run down onto the image of the section.

It is frequently the case in sections through the skin and below, that the epidermis is brought out with too much prominence; while the tissues below are the subject of discussion, and therefore, it is wise to reduce this superficial layer to a density which will not attract the eye away from the main subject.

MAKING THE ENLARGEMENT

A convenient form of enlargement for demonstration in a small class is a circle of about 18 inches in diameter, mounted upon a very heavy square card with a white margin of about an inch on each side. These can be either set up before the class, or handed around. The method of producing these does not differ materially from that usually employed.

I use a rather weak negative, such an one as would give an Aristo print of fine gradations, with no portion very dense.

Parallel light is obtained by means of an arc lamp and a condenser so arranged that the arc is at its focus. Only the central portion of the condenser is used; i. e., we would use an 8-inch condenser to project a negative image of not more than 4 inches in diameter. The finest medium focus, double series, view lens, is used for projection, and it is well stopped down, say to F.-16. A paper made by Eastman, of quick speed for the class of negative employed, is tacked to a board absolutely at right angles to the axis of the beam of projection, and enough time is given to insure the obtaining of every detail of the image.

Where there has been over-staining in certain areas of the sections, portions may be shaded to prevent false effects.

Developing is done in adurol: one portion of developer to about 30 of water, and bromide added according to the character of the image required. After development, wash and place in a weak solution of hypo, with a saturated solution of chrome alum added, say in the proportion of 1 to 20, in order to prevent blistering.

The quantity of chrome alum to be added depends somewhat upon the temperature. A solution of formaldehyde, made very weak, may be used after the print has been partially washed upon removal of the hypo solution. Wash thoroughly and hang up to dry.

Adurol, if properly handled, gives a brownish tone just off a black, and adds life to the enlarged image.

In making the enlargements from a negative with clear glass surrounding the round microscopic image, a piece of dense paper, preferably the yellow post office paper, is cut to whatever size we desire, and placed back of the negative so as to cut off the light of the arc lamp from the surrounding area.

It is well to reduce somewhat the size of the image upon the negative by allowing the paper to lap down upon the image. This gives a clear cut edge to the circle when enlarged upon the bromide paper. The writer believes that if this system is followed out, with such modification as may occur to the manipulator, the result for class demonstrations with lantern slides and enlargements will be superior to that now generally obtained.

ON THE DISTRIBUTION OF GROWTHS IN SURFACE WATER-SUPPLIES AND ON THE METHOD OF COLLECTING SAMPLES FOR EXAMINATION

By FREDERICK S. HOLLIS

WITH FOUR PLATES

The purpose of the study of the micro-organisms floating in a body of water may be two-fold. It may be conducted for purely scientific information or for practical purposes, as a means of determining the total amount of material which is available as food for higher forms of life, or the results of the study may be used as a guide in properly conducting a system of water works. In the case of the study of the micro-organisms in connection with water-supplies, they are to be regarded as deleterious, and the determination of the exact position and recurrence of growths becomes of the utmost importance as a means of avoiding them.

For such practical ends in this connection, the determination of the micro-organisms is only a part of the necessary study, and such determinations should be supplemented by chemical and bacteriological examinations of the water. The micro-organisms are, indeed, to be considered only as a phase or form of the organic contents of the water, which, in this form, is objectionable as a source of odor and taste caused either by the characteristic odor of growth of the particular form or resulting from its decay, and as a source of food which will during its decay give rise to an abnormally large bacterial growth. The relation between the micro-organisms and the other forms of impurities of a water is best seen in a study of the nitrogen contents of the water. Starting, say with an organic growth, the nitrogen is in combination with the other constituents of the organic bodies and appears in the chemical analysis as albuminoid ammonia. After the death of the organism it becomes disengaged as a result of decomposition and exists, first as free ammonia and, as the result of various states of oxidation, as nitrites and nitrates, in which last stage it is available as plant food to be built up again into organic bodies.

Individual samples must be taken for the chemical and bacteriological examinations and, in order that the comparison may be made between the organic life and the impurities in the other forms, the samples for microscopical examination must be identical with those taken for the other examinations.

Microscopical examinations have been made for the past ten years of the water of the reservoirs of the Massachusetts Metropolitan Water Works, which passed from the control of the City of Boston on January 1st, 1898. Samples are taken regularly once a week from the surface, mid-depth and bottom at the deepest point of the reservoirs, which is commonly near the gate-house or outlet. These results have been supplemented, when necessary, by samples taken every few feet and, during periods of growth, by regular inspection of the sources and the collection of samples at various parts of the reservoir, as a means of determining the rate of extension of growths through the reservoir.

Chemical samples are taken less frequently and also occasional bacterial samples at the surface, mid-depth and bottom for comparison.

The results obtained from the samples collected in this way and their usefulness as a means of avoiding growths which would be objectionable if taken into the distributing reservoirs have convinced us that the information which is most to be desired is best obtained from such samples.

The samples for the microscopical and chemical examination are taken by lowering a collecting bottle to the desired depth in a weighted cage and, by means of a separate cord, withdrawing a cork stopper which has been substituted for the ground glass stopper. The neat form of collecting cage in which a spring releases the stopper, thus making unnecessary a separate cord, was devised by Mr. G. C. Whipple.

The eight reservoirs of the Metropolitan Water Works offer uncommon advantages for the study of the surface water of that section of New England. Each receives surface water colored more or less according to the season of the year by the peaty matter of the valley through which the influent flows, but almost entirely free from the turbidity caused by the presence of clay, which is noticed in other sections of the country. Such slight turbidity as is caused by the spring rains is due largely to the presence of fine sand or rock flour and subsides so quickly that it rarely reaches the outlet end of the reservoir.

Lake Cochituate is formed of a chain of three lakes which were deepened considerably by building a dam across the outlet of the lowest one fifty years ago, when water was first taken from this section for the supply of the City of Boston.

Whitehall Reservoir was also formed by enlarging a natural pond, but it is deepened to such an extent that it is practically an impounding reservoir. Framingham Reservoirs Nos. 1 and 2 were formed by constructing dams across the main stream of the Sudbury River.

Sudbury Reservoir, Framingham Reservoir No. 3 and the Ashland and Hopkinton Reservoirs were formed by building dams across the various feeders of the Sudbury River.

Water from the south branch of the Nashua River, which will eventually be impounded in the largest reservoir of the series, has been collected for more than two years by means of a temporary dam and deflected to the Sudbury Reservoir, the largest present member of the series, of which it has become the principal feeder.

	Contents in billion gallons.	Depth, when filled, at deepest point.
Lake Cochituate	2.9	60 ft.
Framingham Reservoir No. 1	0.3	15 ft.
Framingham Reservoir No. 2	0.5	17 ft.
Framingham Reservoir No. 3	1.2	21 ft.
Sudbury Reservoir	7.6	about 55 ft.
Hopkinton Reservoir	1.5	about 52 ft.
Ashland Reservoir	1.4	49 ft.
Whitehall Reservoir	1.6	25 ft.

The water from the Nashua River, together with that collected from the water shed of the Sudbury Reservoir passes, after storage for a considerable period, through Framingham Reservoir No. 3, the next lower reservoir of the series, to the entrance of the pipe line and aqueduct leading to Chestnut Hill Reservoir. Water from the other reservoirs passes through Framingham Reservoir No. 1 and to the same aqueduct. A separate aqueduct leads from Lake Cochituate to Chestnut Hill Reservoir. From Chestnut Hill Reservoir it runs directly to Boston in pipes or is pumped to the various distributing reservoirs of the Metropolitan district.

All save Lake Cochituate and Whitehall Reservoirs have gates for drawing the water from both the surface and bottom, and the deeper and more important ones have also a gate at the mid-depth.

The surface soil has been completely removed from the entire area of the more important reservoirs, and in some cases the influent streams have been diverted from the swampy areas, which caused an increase of color, by ditching. The water of a few of the brooks, more likely to be contaminated than the others, is filtered before it is received into the reservoirs.

All of the examinations have been made by the Sedgwick-Rafter method which commends itself because of its accuracy and the comparatively small factors used in converting the recorded results of the observations into standard units per cc. The Jackson funnel is used and the degree of concentration most commonly employed is 500 to 10. All results are expressed in terms of the standard unit per cc. (1 standard unit=400 sq. microns) as proposed by Mr. G. C. Whipple.

Results expressed in standard units per cc. are an approximation to a quantitative estimation in which the same number of standard units of the different forms express as nearly as possible equal amounts. Results so expressed agree more closely with the results of chemical analysis than those expressed in numbers per cc., and are to be preferred greatly for accuracy and usefulness.

From a study of the growths of the principal reservoirs it is seen that they may be divided into groups which show a different development and distribution of growths. In those in which water is collected and held until used, the water is quiescent except for the action of the wind and the overturn at spring and autumn due to temperature changes. In such reservoirs the development of the growths is a normal one and, in general, a marked difference is noticed between the abundance of the organisms at different depths.

In those in which the water passes through the reservoir at a considerable rate, growths are brought in and mingled with those of the reservoir and a normal development is prevented by the circulation of the water.

On the accompanying plates this is shown by the average of weekly analyses from 1895-9 inclusive for six of the reservoirs. (Plates V and VI.)

Calling the average number of organisms for the year of each source at the surface as 100, the following table shows the average yearly number of organisms of the mid-depth and bottom of each source expressed in percentages of the surface growth:

	Surface		Mid-depth		Bottom	
	Organisms	Per cent. of surface	Organisms	Per cent. of surface	Organisms	Per cent. of surface
Sudbury Res.	339	100	226	67.5	169	49.2
Hopkinton Res. ..	550	100	276	50.2	214	38.9
Ashland Res.	178	100	123	69.1	95	53.5
Lake Cochituate...	672	100	576	84.9	608	88.0
Fram. Res. No. 2..	158	100	143	90.5	107	67.9
Fram. Res. No. 3..	581	100	510	87.7	487	83.8

The Sudbury, Hopkinton and Ashland Reservoirs belong to the first group in which normal growths are possible and do occur. Framingham Reservoirs No. 2 and 3 are as ordinarily conducted members of the second group. The organisms of Framingham Reservoir No. 3 have been much lower since water has been supplied from the Sudbury Reservoir and the Nashua River than when filled with water from its own water shed.

Lake Cochituate, while it would seem to fall under the second group, does, in reality, belong as far as most of the growths are concerned to the group in which there is a normal development of growths. Several causes act to make the average number of organisms irrespective of species similar at the surface, mid-depth and bottom. The lake at its deepest point where samples are collected is sixty feet deep and the bottom at this point is such that marked stagnation effects follow the quiescent state of the water during the summer and to a lesser extent during the winter when the surface is covered with ice. When the water at the surface reaches the temperature of greatest density which commonly happens in November and again in the spring soon after the ice leaves the reservoir, there is a complete mixing of the water of all depths.

Crenothrix, which has become abundant at the bottom, is brought up and distributed quite evenly throughout the water at all depths.

The food material which has accumulated at the bottom during the period of stagnation is also distributed throughout the water by the overturn, thus supplying abundant food for the support of a large diatom growth, which has commonly commenced before the time of the overturn. As the water remains in circulation until the surface water becomes enough colder to make it less dense than that of the lower layers, the diatom and other growths become generally quite evenly distributed.

One of the characteristics of the stagnant layer of water is a marked increase of color.

The temperature and color at the surface, mid-depth and bottom of Lake Cochituate for a year, indicating the quiescent state and the spring and autumn overturns are given on the accompanying plates. (Plates VII and VIII.)

The distribution of the micro-organisms before and at the time of the autumn overturn of the water for the same year is shown by the following analyses:

LAKE COCHITUATE—1896

DATE	SURFACE					MID-DEPTH					BOTTOM				
	Total Organisms	Diatomaceae	Cyanophyceae	Infusoria	Crenothrix	Total Organisms	Diatomaceae	Cyanophyceae	Infusoria	Crenothrix	Total Organisms	Diatomaceae	Cyanophyceae	Infusoria	Crenothrix
Oct. 20......	476	333	72	27	00	397	293	26	33	4	56	54	0	0	0
Oct. 27......	446	235	258	7	70	574	289	180	29	58	483	258	42	3	174
Nov. 3......	762	645	34	43	0	638	568	18	27	20	849	357	0	16	428
Nov. 9......	742	677	26	26	8	880	783	36	17	10	655	422	0	28	152
Nov. 16.....	1279	805	334	25	114	1344	1004	250	40	50	1319	1223	28	0	88
Nov. 23	2016	1725	188	17	78	1924	1576	256	17	50	1701	1425	228	18	36
Nov. 30.....	1479	1218	200	47	10	1319	1039	258	7	12	1304	1156	84	36	28
Dec. 7......	1980	1633	258	63	26	1762	1502	200	13	10	1761	1506	228	5	14
Dec. 14.....	1876	1570	182	104	4	1454	1288	76	68	0	1739	1524	861	26	20

That the amount of water at the bottom of the lake in which these stagnation effects are marked is insignificant compared with the whole volume of the water is evident from the very slight increase of color imparted by the water of the stagnant layer to the water of the other depths at the time of the overturn.

As has been stated, the surface soil has been removed from the entire area of most of the reservoirs and in these the stagnation effects and the collection of food material at the bottom is very slight, although the same dissemination of organisms throughout the different depths at the time of the overturn is noted as in the case of Lake Cochituate.

DIATOMACEAE

In Lake Cochituate, as a result of this mixing of the diatoms at all depths by the spring and autumn overturn of the water during the time of development of the diatom growths, together with a considerable local growth of Melosira at the bottom, the average diatom growth for 1898 and the first month of 1899, during which time the autumn growth continued, was as follows: Surface, 326; mid-depth, 358; bottom, 372.

The same tendency is shown in the Sudbury Reservoir toward a more uniform number of diatoms at all depths due to the mixing at the time of the overturn, although all the conditions are favorable for a normal development. The average for the year 1897 was 84 at the surface, 81 at the mid-depth and 61 at the bottom. For the period between the first of May and the first of December, 1899, the average for this source was 329 at the surface, 283 at the mid-depth and 199 at the bottom.

Aside from Lake Cochituate but few of the reservoirs of the Metropolitan supply support diatom growths which are ever large enough to be seriously detrimental to the character of the water. Furthermore, while the average for the year may be so influenced by the large numbers which follow the period of overturn and extend to all depths, there are many diatom growths during the year where there is, for part of the period of growth at least, a marked tendency to local development at a particular depth, in which case the forms can frequently be avoided, along with the other growths, by drawing the water from a depth at which the diatom growth does not exist.

Such a growth is Asterionella, which commonly develops in largest numbers at or near the surface. I recall one instance of a surface growth of Asterionella amounting to about 250 stand. units per cc. in a comparatively small reservoir 30 ft. deep in a hilly or almost mountainous district in Pennsylvania, which was entirely washed from the reservoir over the spill-way by a single heavy rain, during a period when I was studying the supply.

Most of the diatoms impart an oily or aromatic odor and taste to the water which is characteristic of the form, but generally not particularly well marked. This odor is generally increased somewhat by heating.

Asterionella is an exception and is characterized by a well-marked distinctive aromatic odor resembling rose-geranium leaves, which is frequently lost by heating.

The forms of most importance in determining the purity of a water-supply are found among the Cyanophyceae, and Infusoria and to a lesser extent among the Chlorophyceae and Rotifera. These undoubtedly all tend to a local development during the period of maximum growth in a reservoir in which the conditions are such that a normal growth is possible.

CYANOPHYCEAE

Of the Cyanophyceae, Anabaena is perhaps the most common and the most objectionable form, as it develops in large numbers and imparts its characteristic choky odor and unpleasant taste to the water and the odor is much intensified by heating. It tends under normal conditions to a maximum development during the period of growth at the surface, where it collects in large numbers in areas which are moved about the surface of the reservoirs by the action of the wind. It is frequently mixed through the water by heavy winds or by the flow of a large volume of water through a reservoir, but, if in a vigorous growing condition, it tends to rise again to the surface.

In the Sudbury Reservoir during a period of growth from the middle of August to the middle of September, 1897, the average was 346 at the surface, 81 at the mid-depth and 18 at the bottom, with a maximum growth of 684 at the surface.

For the same source for the period of growth between the middle of May until the first of November, 1899, the average for the surface was 121, for the mid-depth 69 and for the bottom 48, with a maximum growth of 648 at the surface in August.

The same is true for Framingham Reservoir No. 3, Lake Cochituate and the other sources in which it develops. The largest growth of Anabaena that has ever come to my attention was one in the same Pennsylvania reservoir in which the growth of Asterionella was noted, where it showed the same tendency to a maximum development at the surface. The samples were taken July 27, 1897, and showed 5,100 at the surface, 670 at the mid-depth and 123 at the bottom.

Clathrocystis is another form of Cyanophyte which is quite generally distributed and causes difficulty in a supply by imparting a sweetish odor and taste suggestive of the husks of green corn to the water. Its distribution is best studied in the Hopkinton Reservoir in which it has reached large numbers in recent years. The most abundant growth occurs betwween June and November. Like Anabaena it tends to grow at the surface and to form patches.

The averages for the periods of growth for the last three years and the maximum growth at the surface are as follows:

	Surface	Mid-Depth	Bottom	Maximum Growth at Surface	
1897	1644	645	693	3460	August 10
1898	824	246	46	2900	June 28
1899	386	75	48	2000	June 20-27

Coelosphaerium, while quite as widely distributed as Clathrocystis, is not, however, as objectionable. It is present with the growth of Clathrocystis in the Hopkinton Reservoir and between May and November of last year showed an average of 144 at the surface, 98 at the mid-depth and 102 at the bottom.

A growth in Framingham Reservoir No. 3, between May and October, 1895, showed an average of 489 at the surface, 469 at the mid-depth and 412 at the bottom.

It tends to grow at the surface and to collect in masses as do the other members of this group but, on account of its more compact structure, it seems more apt to remain at a depth when carried there by the action of the wind.

Aphanizomenon, which occurs as large growths only in Lake Cochituate, imparts a characteristic sweetish taste to the water which is not, however, as objectionable as that of the other Cyanophyceae already described. The growth commences at a depth and is first noted at the mid-depth and bottom during July. The maximum growth is at the surface, where it is very abundant in the form of flocks, and generally occurs late in November or during December. As the growth is well developed at the time of the autumn overturn it is generally quite well distributed at all depths.

The growth in 1898, which was rather larger than usual, appeared at the mid-depth and bottom on June 27, reached a maximum of 1385 per cc. at the surface on December 12, and continued until February 6 of the following year. The average for the period of growth was 318 at the surface, 220 at the mid-depth and 144 at the bottom.

Microcystis is frequently abundant and attains a large growth at the bottom as well as at other depths. It is, however, not objectionable in the quantity in which it is found in our reservoirs.

Oscillaria is observed floating in flakes attached to thin plates of mud after it has risen to the surface. Its presence has never given rise here to any objectionable condition of the water.

CHLOROPHYCEAE

Among the Chlorophyceae, the floating forms that are met develop maximum growths at the surface. Their presence has never caused any objectionable qualities in the water of our reservoirs.

Protococcus is of very common occurrence at certain seasons of the year, but is rarely abundant.

A growth in the Sudbury Reservoir between July 7 and October 27, 1897, amounted to an average of 53 at the surface, 24 at the mid-depth and 7 at the bottom.

Gonium has at times been quite abundant at the surface of part of the Sudbury Reservoir.

Spirogyra, Conferva and Draparnaldia are common as growths along the lower course of the influent streams, but they are rarely met in samples of water taken at the lower end of the reservoir.

DESMIDEAE

Among the Desmideae, Staurostrum is the only form that is ever found in any abundance in the main body of water of the reservoirs. Its presence has never caused trouble. Other members are common in the influent streams and detached shallow portions of water.

The presence of Crenothrix is characteristic of the stagnation effects at the bottom of a reservoir and, unless washed in in large numbers from adjoining swamps, is present in the main body of water only after an overturn of the water.

INFUSORIA

The Infusoria are perhaps the most objectionable forms encountered in water-supplies, both on account of the objection able odor and taste imparted to the water by many of them and on account of their universal distribution and very rapid development. The more objectionable ones tend to develop in large numbers at or near the surface, but are frequently distributed through the water and, during the decline of a growth, they frequently collect near the bottom of a reservoir.

Uroglena is frequently present in large numbers between early autumn and the following summer, and imparts a strong and unpleasant oily odor and taste strongly suggestive of whale oil soap to the water. This odor is much intensified by heating. Normally, it tends to develop in greatest abundance at the surface. Such a normal growth is just disappearing from Lake Cochituate. The average number of Uroglena between May 17 and June 18 was 973 at the surface, 157 at the mid-depth and 86 at the bottom, with a maximum growth of 3800 at the surface on May 31.

The largest growth at Uroglena noted in our reservoirs was in Framingham Reservoir No. 3 in 1897, at a time when the water of the reservoir was uniformly turbid as the result of work in progress on a reservoir above it on the same water shed.

The growth extended to all depths from the time of its appearance and lasted from May 12 to June 23, 1897. The average at the surface was 2178, at the mid-depth 2288 and at the bottom 2696, with maximum growth of 4700 at the surface and mid-depth.

It is not uncommon for Uroglena, when seeded into a storage reservoir, to develop to such an extent as to be higher in the water thus contaminated than in the original source.

Synura is another form which may be expected at almost any time of the year except during the most extreme heat of summer, although it is most common in cold weather. It imparts a characteristic and unpleasant taste and odor to the water and this is intensified by heating.

Like Uroglena, it is capable of increasing rapidly if seeded into a reservoir from a contaminated source. Normally it tends to develop in largest numbers near the surface, but a vigorous growth generally extends to a considerable depth.

A growth in the Sudbury Reservoir between the first of April and the middle of May showed an average of 31 at the surface, 27 at the mid-depth and 1 at the bottom, with a maximum growth of 134 at the surface on May 5.

A considerable Synura growth in Lake Cochituate in 1897 was distributed as follows:

		Stand. units per cc. of Synura	Taste of Water	Taste of Concentrate
Feb. 7	Surface	286	Synura taste	Strong Synura taste
Feb. 8	Surface	116	Synura taste	Strong Synura taste
	5 ft.	144	Synura taste	Strong Synura taste
	10 ft.	74	Synura taste	Strong Synura taste
	15 ft.	64	Synura taste	Strong Synura taste
	20 ft.	48	Synura taste	Synura taste
	25 ft.	32	Slight Synura taste	Slight Synura taste
	35 ft.	0	No Synura taste	No Synura taste
	45 ft.	10	No Synura taste	No Synura taste
	55 ft.	42	Slight Synura taste	Synura taste

Dinobryon, Glenodinium, Peridinium, Chlamydomonas and Mallomonas have been noted in considerable numbers and all impart an odor and taste to the water.

The first three give it an oily odor which is increased by heating. Chlamydomonas causes an oily odor when present in moderate numbers and a disagreeable odor when very abundant. Mallomonas when very abundant imparts an odor suggestive of violets.

Dinobryon and Glenodinium reach the highest numbers at the surface, but are frequently present in large numbers at lower depths, especially during the decline of the growth.

Peridinium, while common at the surface, is frequently found in abundance at the lower depths.

Chlamydomonas has been observed in large numbers but once in any of our reservoirs. From August, 1898, to late in the spring of the following year it was present in considerable numbers and, while mainly a surface growth, it was present to the extent of about 150 at the surface, mid-depth and bottom when it reached its maximum growth in March, 1899.

Mallomonas is of frequent occurrence, but has never been the cause of trouble. It is a form which develops at a considerable depth and is brought to the surface by the circulation of the water. It tends to settle back to its original position. Lake Cochituate and Whitehall Reservoir have shown the most marked growth. It was brought to the surface of one portion of Whitehall Reservoir to the extent of 2168 standard units per cc. by a wind storm in August, 1897. Four days afterwards the maximum growth of 1936 standard units per cc. was found at a depth of 10 feet. On the middle of September it was all near the bottom.

ROTIFERA

Rotifera are frequently quite abundant, but not often to an extent sufficient to influence the character of the water. While the largest growths are generally at the surface, it is not uncommon for them to appear first at the bottom of a reservoir. Their appearance seems often to follow a growth of Infusoria. Polyarthra, Synchaeta and Anuraea are the forms most commonly observed.

It has been impossible for me, in the short space of time that I have been able to allow myself for the preparation of this paper, to make a sufficient number of averages from the occurrences of the different growths to give the results the definiteness at which I had aimed. Such as I have made are, however, selected carefully from the great mass of accumulated results as types, and have been worked out for periods of a considerable length of time. Many averages not here given have been prepared from the results of the other sources and have served merely to confirm the ones selected, which better represent the typical growths.

They are, therefore, only types of the many hundred that might be produced in the case of any of the forms more commonly met, and will, I think, justify the following conclusion:

With reservoirs properly constructed, from which the surface soil has been removed, so that marked stagnation effects are avoided, with outlets at the surface, mid-depth, and bottom, and so arranged that an individual reservoir can be cut out of the chain in case of contamination from a growth, it is possible by watching the water through the regular examination of samples from the surface, mid-depth and bottom and well directed field work, as a means of tracing the development of a growth through a reservoir, to avoid almost entirely the results of such growths. Such information enables one to fill one reservoir from another when the water thus stored for future use is in its best condition and to supply water for consumption as free from growths as the nature of the supply permits.

Even with reservoirs less carefully constructed and less fortunately situated than those of the present Metropolitan supply, much can be accomplished by such study of the sources.

Laboratory of the Metropolitan Water Works,
Boston, Mass., June 26, 1900.

EXPLANATION OF PLATES

Plate V

Graphic representation of the average of weekly analysis from 1895 to 1899, inclusive, to show the abundance of organisms at surface, mid-depth and bottom for Sudbury, Hopkinton and Ashland reservoirs.

Plate VI

The same for Framingham reservoirs Nos. 2 and 3 and for Lake Cochituate.

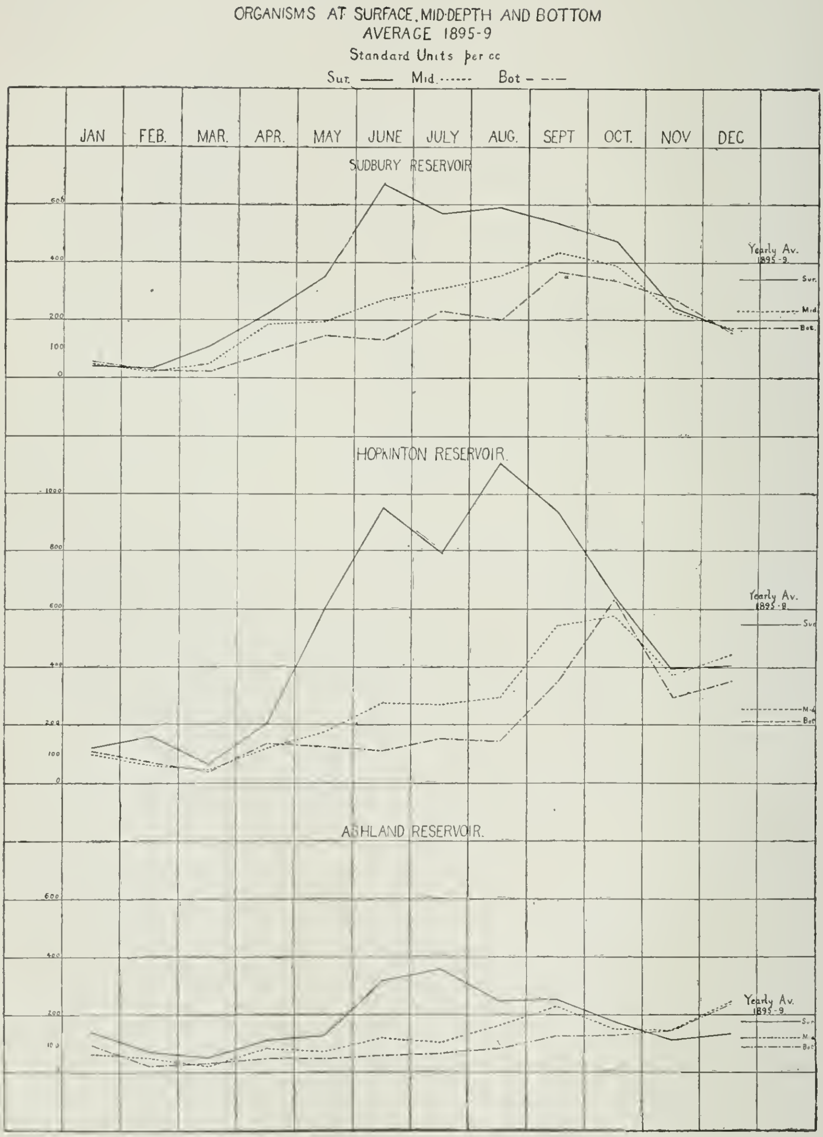
Plate VII

Graphic representation of yearly record of temperatures in Lake Cochituate for 1896, showing the quiescent state and the spring and autumn overturns.

Plate VIII

The same for color in Lake Cochituate during 1896.

PLATE V



ORGANISMS AT SURFACE, MID-DEPTH AND BOTTOM
AVERAGE 1895-9
Standard Units per cc
Sur. —— Mid. ------ Bot – –·–
JAN
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT
OCT.
NOV
DEC
SUDBURY RESERVOIR
HOPKINTON RESERVOIR.
ASHLAND RESERVOIR.
Yearly Av. 1895-9

PLATE VI

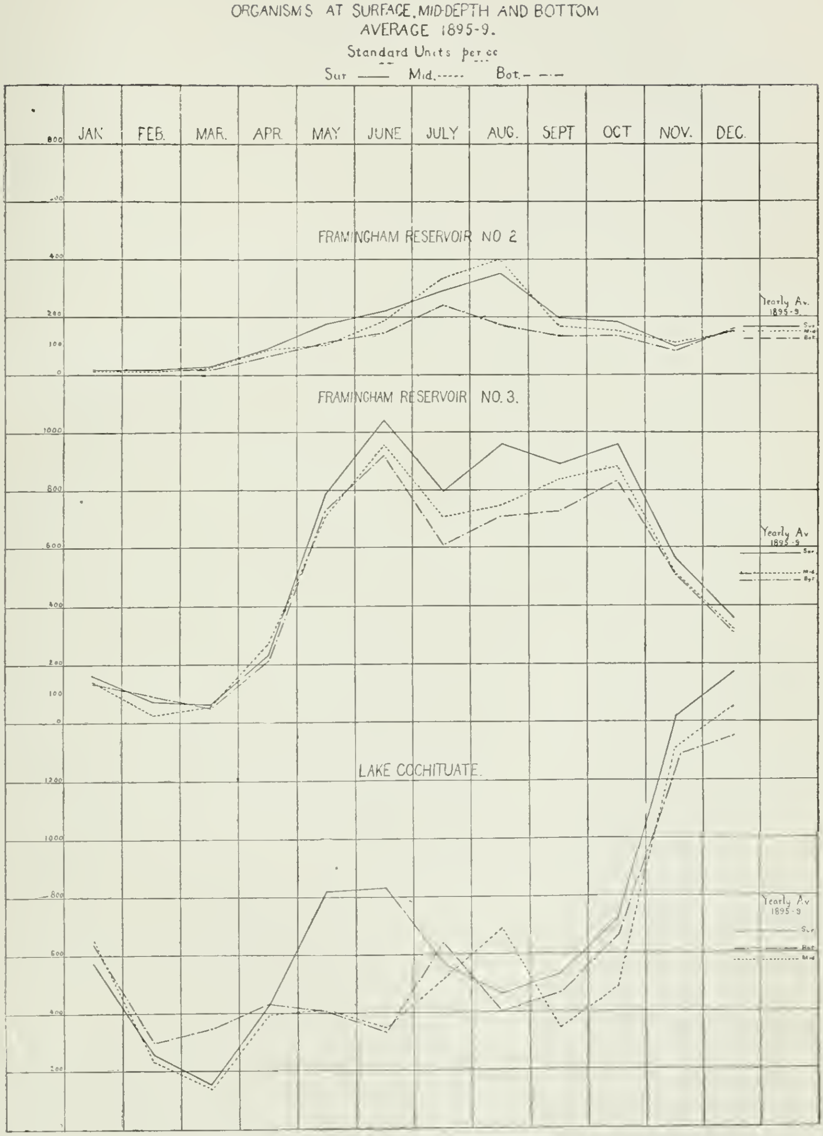
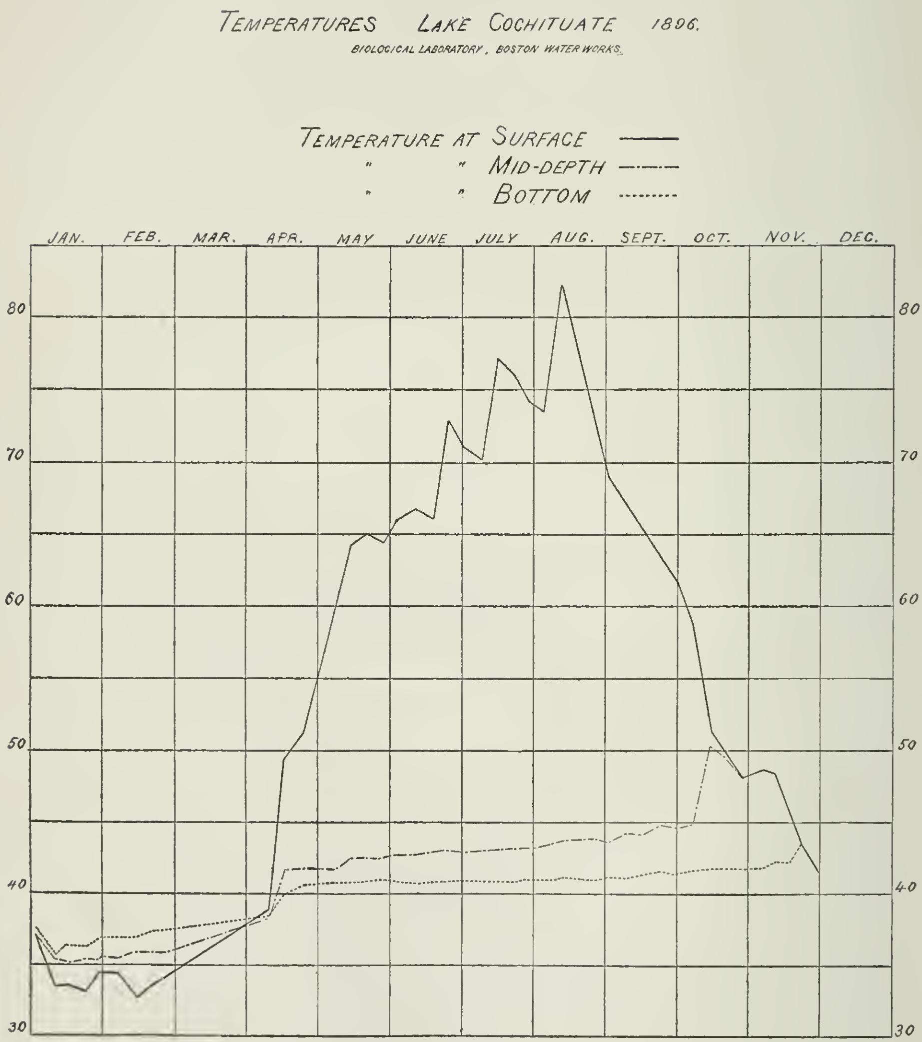
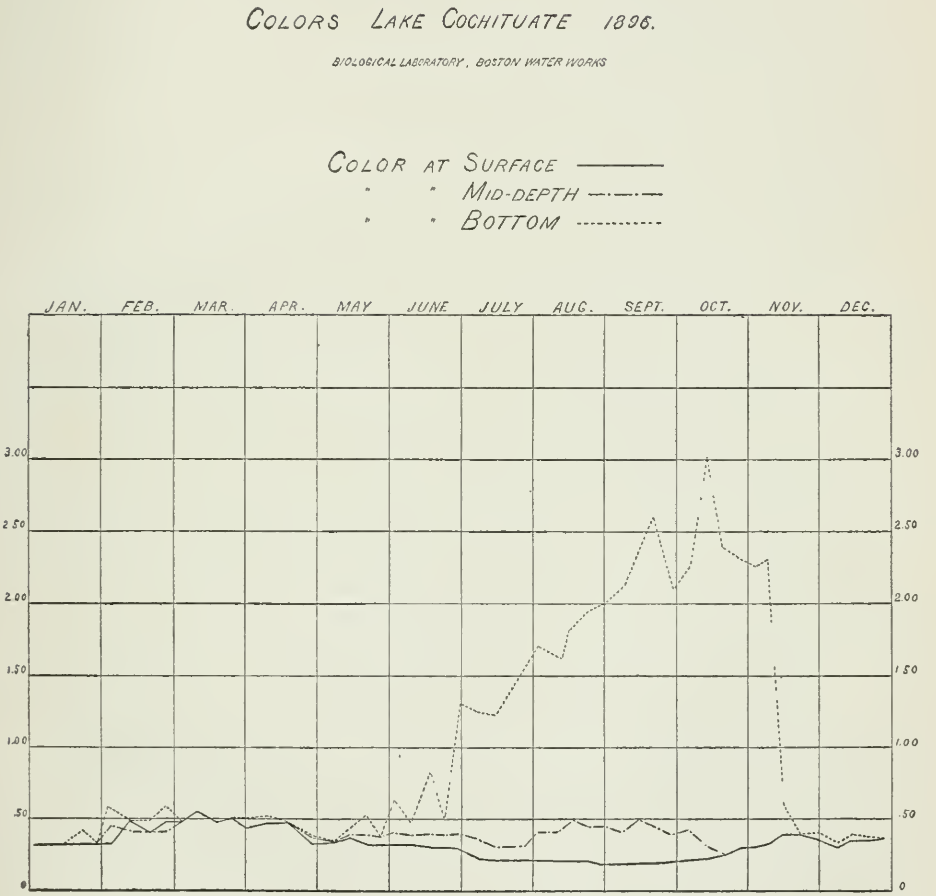

ORGANISMS AT SURFACE, MID-DEPTH AND BOTTOM
AVERAGE 1895-9.
Standard Units per cc
Sur —— Mid.----- Bot.– –·–
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT OCT NOV. DEC.
FRAMINGHAM RESERVOIR NO 2
FRAMINGHAM RESERVOIR NO. 3.
LAKE COCHITUATE.
Yearly Av. 1895-9.
Yearly Av 1895-9
Yearly Av 1895-9
800
400
200
100
0
1000
800
600
400
200
100
0
1200
1000
800
600
400
200

PLATE VII



TEMPERATURES LAKE COCHITUATE 1896.
BIOLOGICAL LABORATORY, BOSTON WATER WORKS.
TEMPERATURE AT SURFACE
" " MID-DEPTH
" " BOTTOM
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
80
70
60
50
40
30

PLATE VIII


COLORS LAKE COCHITUATE 1896.
BIOLOGICAL LABORATORY, BOSTON WATER WORKS
COLOR AT SURFACE
" " MID-DEPTH
" " BOTTOM
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
3.00
2.50
2.00
1.50
1.00
.50
0

LIMNOLOGICAL INVESTIGATIONS AT FLATHEAD LAKE, MONTANA, AND VICINITY, JULY, 1899

By MORTON J. ELROD, University of Montana

WITH NINE PLATES

The University of Montana Biological Station was organized in the summer of 1899, and consequently but one season's work has been done. The organization of the work was made possible through contributions from friends in the state, contributions being made from individuals in Missoula, Kalispel, Butte, and other places.

The object of the station is twofold: (1) to offer a place where biological investigations may be pursued during the summer months, where the collecting season is short and concentrated, and to encourage students in their work, to offer them facilities, and to bring biological study to a higher plane in the schools; (2) to pursue systematic work along definite lines with a view of working out some scientific problems, to make collections for the University work and for the museum, and to work up the natural history resources of the state.

The plan for the work was presented to the State Board of Education, which heartily approved of it. The station was placed on the same basis as a department of the University, and so far as possible appropriation was made for its maintenance. The work of the first year was preliminary, most of the time being spent in laborious detail work, in fixing up a laboratory, looking after boats, seeking collecting sites, and in similar duties. Nevertheless, a dozen workers were gathered together, much good material was collected, and a good beginning made.

The station facilities are not large, but present ample opportunity for work as a beginning. A small field laboratory has been erected, with tables for twelve students, a dark room for photography, and a store room. The boats consist of a gasoline launch capable of carrying eight people, a row boat, and a canvass boat for use in mountain lakes and in remote regions where a boat must be transported. Microscopes, glassware, chemicals, books, and all necessary materials are taken to the field laboratory from the University. Nets after Kofoid's plans, and also a pump for plankton, after plans by Ward, have been made. Apparatus for taking fish and insects, cameras, firearms, etc., are provided. The boats and equipment referred to can be seen in Plates XVI and XVII.

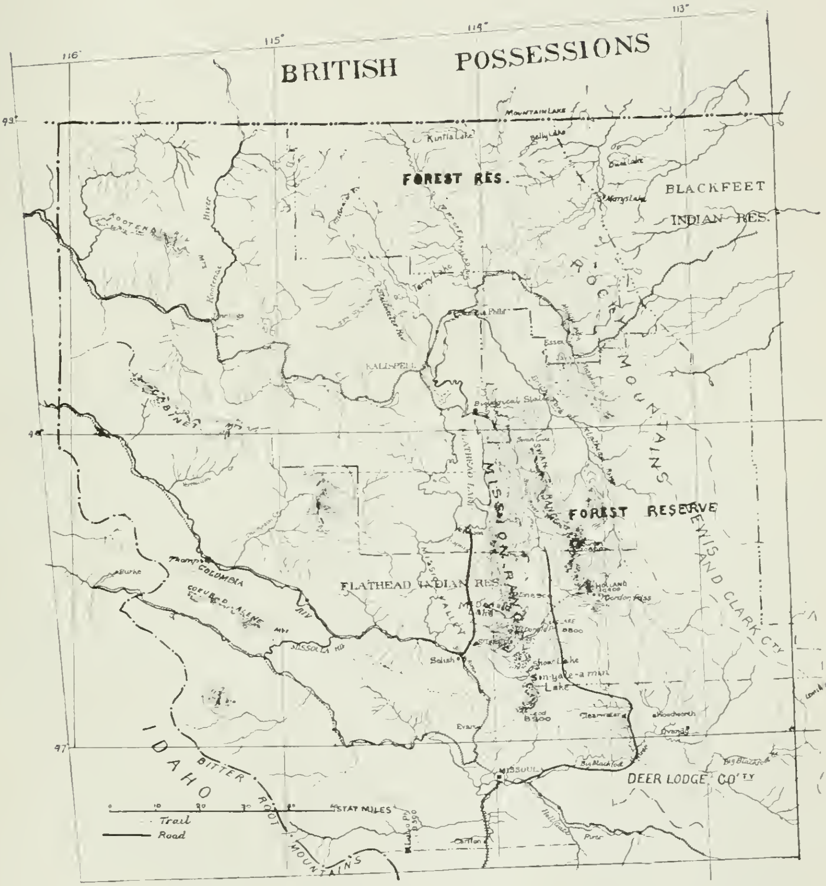
During the first season very little work could be done on Flathead Lake. A number of soundings were made, and at each sounding the net was let to the bottom and hauled to the surface. Although this method was unsatisfactory, yet the results are very interesting. Surface hauls were made on several occasions. In addition to this work on Flathead Lake considerable time was given to Daphnia Pond, near the laboratory, and described later. A day was spent at McDonald Lake in the Mission Mountains.

Very little work has been done in the region, or in Alpine lakes in general in this section. Ichthyological work was carried on by Dr. David S. Jordan in the Yellowstone National Park, in 1889, and by Prof. W. B. Evermann, in Montana and Wyoming, in 1891. In 1890, Prof. Edwin Linton, of Washington and Jefferson College, Pennsylvania, and Dr. S. A. Forbes, of the University of Illinois, together made extensive study of the life of the waters of the Yellowstone National Park, the former having in hand the study of fish parasites, the latter of fresh water invertebrates. In 1891, Dr. Forbes and Prof. Everman spent some time in the region around and adjacent to Flathead Lake; the former again looking after fresh water invertebrates, the latter collecting fishes and seeking a suitable place for a trout hatchery. The results of Dr. Forbes' work are given in a paper of 52 pages, with six plates, in the Bulletin of the United States Fish Commission, Vol. XI, pp. 207-258. The work of these men is all that has been done on the life of these lakes, so far as is known to the writer.

The map (Plate IX)* will give an idea of the general

*Map showing the section of the state north of Missoula to the boundary line, and from the main chain of the Rocky Mountains west to the Idaho boundary line. Only a few of the smaller lakes are included. The rivers and streams are not accurately drawn, but are to the best of our present knowledge. Few of the mountain ranges are indicated. Each water course is a canyon, usually narrow, between two ranges of hills or mountains. Few wagon roads have been made through the canyons, but of those existing only two or three are located. Most of the streams, many of the lakes, and all of the peaks are inaccessible except on foot or by pack train.

PLATE IX


116°
115°
114°
113°
49°
48°
47°
BRITISH POSSESSIONS
FOREST RES.
BLACKFEET
INDIAN RES.
ROCKY MOUNTAINS
FOREST RESERVE
LEWIS AND CLARK CO'TY
KALISPELL
FLATHEAD INDIAN RES.
MISSION RANGE
MISSION VALLEY
COLUMBIA RIV
MISSOULA
DEER LODGE CO'TY
IDAHO
BITTER ROOT MOUNTAINS
STAT MILES
Trail
Road

outline and shape of Flathead Lake, the streams flowing into the lake, the outlet, routes of travel, and other points of information. A brief description of the lake, with its geological history, will be of importance in taking up the study of the life found. The geological description here given is furnished by Prof. Fred D. Smith, of the University of Montana. (Cf. Plates X, XI, XII.)

"The lake occupies the lowest portion of an immense valley that reaches from the Jocko Mountains, a low range between the Jocko River and Mission Valley, northward across the British Columbia line into the latter country, a distance of over one hundred miles. It is but the remnant of a lake that in Tertiary times occupied this valley throughout its whole extent. The great level plains on either end of the lake are the beds of sediment deposited in the former lake, and show by the character of their soils that the lake was a large and quiet body of water. The plain on the southern end of the present lake is about thirty-five miles long. On the northern end of the lake the plain extends a distance of sixty miles to the border of the United States and into the British possessions.

"The valley, as well as the lake throughout much of its length, is bordered on the eastern side by the Mission Mountains, a range which rises abruptly from the plain to a height of 10,000 ft. These mountains, with a very steep western slope, have their summits within relatively short distances from the valley, and consequently the streams therefrom are not large nor of great volume in discharge. The peaks of the range rise bare and steep. The range appears to terminate as such at a point near the upper end of the lake where the Swan or Big Fork River changes its course from northward to west and southwestward, to flow into Flathead Lake.

"Mission Valley, Flathead Lake, and Flathead Valley extend about a hundred miles from north to south; Flathead Lake separating Mission Valley on the south and Flathead Valley on the north. Perhaps the most interesting feature of the region represented is its drainage. The drainage from Flathead Valley is through the Flathead River. This has three great tributaries, the South, Middle, and North Forks. The latter, only, is a real factor in the drainage of the valley. The Flathead River flows into Flathead Lake from the north, as does also the Swan River. These together materially increase the size of the lake in the spring time. The outlet of the lake is the Pend d'Oreille River, also called Flathead, which flows out of the lake at the southern extremity. Following a circuitous route in a south-westerly direction, it receives the streams that cross the southern portion of the valley transversely, and eventually unites with the Missoula River to form Clarke's Fork of the Columbia. Considered thus, Flathead Lake appears as an enlargement of Flathead River, and as one element in the drainage system.

"The Mission Mountains were made by an immense fault, having the general direction of north by south. The mountains were raised, while the corresponding strata on the western edge of the fault were depressed, thus producing the usual basin for the immense lake which afterwards filled it. Possibly the lake was not a part of a drainage system, as the present lake is, but acted as a large reservoir. When the lake was drained, probably through a passage to the north,* there was no large amount of run-off from any extensive drainage system to be carried away. The small streams that came from the lower part of the Mission Mountains cut small water courses directly across the beds to the west in parallel directions. Flathead Lake receded to the lowest parts of the depression in the great valley, which were approximately the central portions. The lake may have occupied different levels in its present position, though it has probably never been high enough to receive any of the drainage of the lower Mission Mountains, owing to a larger embankment along its southern end. This ridge may be of morainal origin, and probably was, since it is higher than the surrounding plains on either side, and no evidence has been observed of higher levels of the sedimentary lakes.

"When in its new position the lake, receiving considerable inflow from the north, began to find an outlet across the beds in a southwesterly direction towards the Missoula River. Whether this was caused by a damming of the streams on the north by glaciers or by elevation of the country is not plain at present. The carving of what is now the Pend d'Oreille River canyon probably was rapid, and the lower plains on the north of the present lake were uncovered, thus making the fertile areas south of the city of Kalispel. The

*Later research indicates that the passage was out of the western bay, possibly near Dayton.

Flathead River in its present condition is but a remnant of the lake which extended over these areas.

"This Flathead River winds its way in a very circuitous path across the plains, and has a total length of about thirty-five miles, while the distance as measured by a straight line is but fifteen miles. In general its width is from three hundred to six hundred feet, and its depth is over twenty feet in all places, and often reaches seventy-five feet. For these reasons it may be considered but an arm of the lake, since its level is the level of the lake except for sufficient fall to cause the waters of the tributaries to flow to the lake. On account of the very sluggish nature of the current of this river the erosion of the banks is slight, while the deposition in the bottom and at the mouth of the river is rapid.

"The northern end of the lake around the mouth of the river is apparently composed of sediments deposited as a large delta in the manner mentioned. The course of the river is plainly traced into the lake for some distance by the delta thus formed, which for a distance of from one-fourth to one-half a mile from the shore is sufficiently high to be covered by vegetation, and in some places by shrubbery. Beneath the surface of the water the formation is discernible for a long distance farther into the lake.

"At the end of the Swan River Valley near the location of the Biological Station are to be seen many rounded hills which are probably morainal in origin. On the slopes of the Mission Mountains that form the termination of this range are found many evidences of glacial action in form of smoothed rocks, post-glacial gorges and stream courses, glacial scratches, etc., while the glacial origin of the ridge at the foot of the lake has already been suggested. There is no doubt but that glacial agencies have materially affected the history of the lake both in its present and in its older form. To what extent moraines may affect the contour of the lake bottom can only be surmised, but as they are apparent on the beds of the older lake it is to be expected that they may be found on the bed of the present lake."

The outlet is called by some Pend d'Oreille River, by others Flathead River. Some consider Flathead River to extend from its source to the lake, then from the lake to the Missoula River. Others give the name Pend d'Oreille to the stream from Flathead Lake to the Missoula River. The river formed by the junction of the Missoula and Pend d'Oreille is called Clarke's Fork of the Columbia.

The present outlet of Flathead Lake is of recent origin. The river for several miles near the lake is swift and rocky, a series of rapids alternating with more quiet water. About a mile from the lake there is a large bank of clay through which the river has cut. The clay is continuous with, and apparently a part of, the moraine mentioned. At the river bank it has been cut and eroded by the wind and rain. The bank is abrupt and steep, the clay clinging together so as to form cliffs, some ending in sharp pinnacles. Below the clay is the bed rock, similar to that found at different places around the lake. The river has done some cutting through the solid rock bed, but not much. At one place the channel is partially dammed by a large rock in the center of the river. Above and below this place the river is a beautiful sheet of foam, with several small falls. It is as beautiful a rapid as one usually sees. In my estimation it is superior to the rapid above the first falls in the Yellowstone. While not so large, it impressed me more deeply than did the rapids below Niagara. Several cases have been reported of people who were overcome by the sight close to the water's edge and had to be carried away. Plate XIII shows the rapids as seen from the hillside a couple of hundred feet above the water. This is a great fishing resort for the Indians on the reservation, and one seldom visits the place without seeing several tepees on the bank some place near. The osprey is as industrious as the Indian, and is seldom absent from the scene when one visits the rapids.

The banks of the lake do not afford as much shelter for invertebrate life as would at first seem apparent. The southern third, cut off by the islands, is shallow, nowhere of greater depth than twenty feet. The eastern slope of this bay, formed by the peninsula projecting from the Mission Mountains, is very marshy, with muddy bottom. Rushes and weeds grow abundantly, offering an excellent harbor for smaller life. This is the largest marshy region around the lake. Between the mouth of Flathead River and the mouth of Swan River, along the northern shore, is another marsh in the spring, of peculiar nature. At the water's edge is an embankment of a more or less rocky nature. North of this embankment is a shallow marsh, a couple of miles long and a quarter to a half mile wide. When the lake rises, as it does in the spring, from ten to twelve feet, the water flows over the embankment, and into the low land. As the lake recedes the imprisoned waters cannot escape, and offer a fine breeding place for mosquitoes for some time, until the waters evaporate or filter through the soil to the lake again. Most of the remaining banks are rocky, precipitous at the water's edge, with or without a gravelly beach. The bottom generally is reported to be rocky, with little mud. This report comes from the captain of the boat Klondyke, who has anchored all over the lake; his experience on the lake extends over a period of many years. Compared with the size of the lake the swampy country is small. From this it would appear that the breeding grounds for most of the fish must be in regions distant from the lake, causing long migration periods. This is made more apparent from the fact that fish are rarely caught any place in the lake except at or near the streams entering the lake, or at the outlet.

Flathead Lake is popularly supposed to be very deep. I was told it was 1,500 ft. deep in places. During the summer of 1899 some twenty soundings were made in the lake and rivers. The greatest depth obtained was 280 ft. The location of this may be found by referring to the map. Eugene Hodge, captain of the Klondyke, states that nowhere is the water deeper than this sounding. During the season of 1900 other and more numerous soundings will be made.

McGovern Bay, on the northern end of the lake, is about seventy feet at the deepest. Flathead River has filled in a large amount of sediment. East of the mouth of Flathead River the drop in depth is sudden from the river bar. The deepest portion of the lake is off shore on the east side, next the Mission Mountains. In high water a great deal of land at both ends of the lake is covered. If the depth of the lake should be lessened by ten feet, thousands of acres at the lower end would be uncovered. The annual rise and fall of the lake is from ten to fourteen feet, but it has risen as much as nineteen feet in a season. The lake acts as a huge reservoir for water storage, but overflows much land almost every year when it is at the highest. The amount of water flowing into the lake and out of the lake annually has not as yet been determined.

Life in Flathead is scarce. Although some species are taken in great abundance, the cold clear waters, with rocky bottom and banks and with few marshes, make life scarce as compared with similar bodies of water located in warmer climates at lower altitudes.

The first collecting done with the net was on July 22, the last August 11. The method employed was to let the net to the bottom and slowly bring it to the surface. This was not satisfactory, but was the best that could be done at the time. The material from each haul was placed in a vial and numbered, the data being recorded. Twenty-one numbers were taken at Flathead Lake, an additionel number at McDonald Lake. As will be seen from the data subjoined these collections were made at different parts of the lake, and represent the life of the lake at this season fairly well. It is to be regretted that material could not be taken both earlier and later in the season, but this will have to await further developments.

The record of collections and material, with data, is as follows:

No. 1. July 25, 11:00 A. M., bright sunshine. Swan River, opposite Sliter's house, near the Station. Contents, sand.

No. 2. July 25, 11:20 A. M. Mouth of Swan River opposite club house. Contents, sand.

No. 3. Bottle lost, not examined.

No. 4. July 26, A. M. Bay in front of club house, in the waters from the Swan River. Contents, nothing that could be determined.

No. 5. July 26, 10:00 A. M. Opposite first bluff below club house, where the waters from the river have become quiet; depth, 60 ft. Contents, a few *Epischura nevadensis* Lilljeborg, *Diaptomus ashlandi* Marsh quite numerous, about as many *Cyclops pulchellus* Koch, and a few *Cladocera*.

No. 6. July 26, 10:30 A. M. Between club house and mouth of Flathead River, nearly a mile from shore and perhaps a mile and a half from the river; depth, 96 feet. Contents, *Cyclops pulchellus* Koch made up the bulk of the material taken, *Diaptomus ashlandi* Marsh was rather abundant, and a few *Daphnids*.

No. 7. July 27, A. M. Flathead River, opposite Holt, which is about three miles from the mouth; depth, 56 feet. Contents, a few *Diaptomi*.

No. 8. July 27. Half mile below No. 7. A few each of *Daphnia* and *Diaptomus*.

No. 9. Mouth of Flathead River, same date; depth, 18 feet. Contents, nothing but sand.

No. 10. July 26. Lake, east of the mouth of the Flathead River; depth, 10 feet. This was in the northern shallow end of the lake, but not on the sandbar which receives the waters from the river. Contents, *Cyclops pulchellus* Koch, *Diaptomus minutus* Lilljeborg, in about equal quantities.

No. 11. Bottle lost.

No. 12. July 26. Lake, one-half mile east of club house; depth, 10 feet. Conditions similar to those in No. 10. Contents, a few *Diaptomi*, with an occasional *Daphnia thorata* Forbes.

No. 13. Lake near rocks by club house; depth, 15 feet. This is in the waters of the Swan River. Contents, a few *Cyclops pulchellus* Koch.

No. 14. Bar at the mouth of Flathead River. Contents, nothing.

No. 15. Lake between Flathead River and the club house; depth, 40 feet. Contents. *Diaptomus ashlandi* Marsh, *Cyclops pulchellus* Koch, with three or four specimens of a larger form of *Cyclops*, 2 mm. long.

No. 16. August 11. Lake about six miles below Chapman's, east side, about three miles from shore, not far from midway of the length; depth, 280 feet. *Diaptomus minutus* was found in large quantity, and *Cyclops pulchellus* Koch in somewhat smaller amount.

No. 17. August 11. Near the islands on the north, in the "channel" used by the steamboats; depth, 15 feet. Not examined for species, but no doubt similar to No. 16.

No. 18. August 11. In shallow water below or south of the islands; depth, 17 feet. Not examined for species.

No. 19. August 11. Lower end of the lake, about one mile north of the islands, opposite the point of land on the west, and the middle of the flat-topped mountain on the east; depth, 167 feet. Contents, *Cyclops pulchellus* Koch, *Diaptomus*, probably *ashlandi*, though slightly smaller, and one specimen of *Epischura nevadensis* Lilljeborg.

No. 20. August 11. Near No. 19, but at a depth of 75 feet. Contents, *Cyclops pulchellus* Koch in largest quantity, *Diaptomus* in smaller quantity.

No. 21. August 11. Several bottles of skimmings from the surface of Flathead Lake at different places. On this date a round trip was made to the foot of the lake. At different places skimmings were taken with the net. *Cyclops pulchellus* was taken in very large quantity, and was very noticeable. While at Chapman's, on the east side, for wood, a bottle was shown him, which rather startled him when he considered he was drinking from the lake. The only comment made was that there were a good many people drinking from the lake, and he was not alone. To dip up a tin cup full of water was to take numbers of them. As the day was bright, in the middle of August, this is rather surprising, as they generally stay down during sunshine. Moreover, Forbes reported *Cyclops* as very scarce in his collecting.

No. 22. August 18. Collection made at McDonald Lake, as recorded under description of that lake.

The list taken from Flathead Lake is not large, and is as follows:

Diaptomus ashlandi Marsh.

Cyclops pulchellus Koch.

Epischura nevadensis Lilljeborg.

Diaptomus minutus Lilljeborg.

Daphnia thorata Forbes.

A few *Cladocera.*

Some young that could not be determined definitely.

Of these *Cyclops pulchellus* was exceedingly abundant, taken at nearly every point on the lake where collections were made. *Daphnia thorata* was scarce, which is surprising from the fact that Forbes relates that in his haulings with the surface net in late September, 1891, this species made probably from four-fifths to nine-tenths of each haul. He also records that *Daphnia pulex* was not seen at all, though common in Yellowstone Lake. *Daphnia pulex* was taken by thousands in Daphnia Pond, near the Station, as recorded in description of work in this pond. He also records *Epischura nevadensis*, var. *columbiae* as very common, but with us it was scarce. It therefore seems that the Entomostracan life is undergoing great changes, which will offer good field for investigation. It seems peculiar that such complete changes should be made in the waters of a lake of this size as indicated by this comparison.

The absence of *Daphnia pulex* from Flathead Lake, and its abundance in Daphnia Pond, which is but a few rods from the lake, suggests either that this species does not like cold water, or else that it is preyed upon by fish. Since it is common in Yellowstone Lake, neither of these explanations would be satisfactory. The absence of *Daphnia pulex* and the great abundance of *Cyclops pulchellus*, as noted, need explanation.

McDonald Lake of the Mission Mountains lies at the foot of McDonald Peak on the northwest. It is about eleven miles from St. Ignatius Mission, and about fifteen miles due north of Sin-yale-a-min Lake. Sin-yale-a-min Lake is at the foot of Sin-yale-a-min Mountain, the last on the range south next the Jocko River, which river cuts the range in two. McDonald Lake, like Sin-yale-a-min Lake, is hemmed in on all sides except the west by mountains, but at McDonald the mountains are tall, rugged, and very picturesque. The lake was named back in the sixties, and, according to priority, the name McDonald should easily displace the same name given to Terry Lake, above Kalispel.

McDonald Lake is a beautiful spot. Seldom will one find such a combination of grand mountain peaks with the quiet serenity of the water. The sun sinking in the west at the close of the long days of summer gilds the peaks with tints of surpassing beauty. Campers on the banks of the lake have seen goats on the crags above, though at present they are comparatively scarce so close to the haunts becoming frequented by man. The banks of this lake have been a resort for the Indians and white men of the region for many years. There is but a small place at the western end where camping is possible, and the banks for the remainder are abrupt, steep, and rocky, but the small grassy spot, with the peaks in the immediate foreground, is a place frequented often. Of course the usual stories are told about the great depth of the lake, and up to the time of our visit no one had any idea of the real depth, but it was said to be "bottomless."

The valley enclosed by the peaks, in which the lake now is, has been carved out by a glacier, the remnant of which yet exists on the slopes of the peak in plain sight from almost any place on the lake. The rocks along the sides have been ground smooth, and show plainly the marks of the ice. At the outlet of the canon a large moraine has been made. The water in times past has evidently been much deeper than at present, and at the upper end what is now a wooded valley was covered with water and was a part of the lake.

The lake is about a mile and a quarter long, with an average width of less than a quarter of a mile. On either side the mountains come abruptly to the water, as may be seen by the illustration. At the upper end there is an unexplored small valley, abundantly wooded with large arbor vita trees and with fir, birch, and small trees of other species. The inlet divides above the lake, one branch receiving the water from the glacier visible, the other bringing the water from the amphitheatre toward the east, and has for drainage not only the peaks visible, but also the eastern slope of McDonald Peak. (Pl. XIV.)

The bottom of the lake slopes gently (Pl. XV), showing that the lake has apparently filled up a great deal. The depth from end to end is nearly uniform, the greatest being sixty-eight feet. The lower end is shallow, the outlet being crossed by a ford, hub deep at the time of the examination, late in July. There is considerable shallow water, and the bottom is of mud of a reddish color, apparently from the decomposition of the soft rock on the north. At a point near the middle a ledge of rocks projects from either side, making the lake at this point quite narrow. The rocks are precipitous, and the water a few feet from the rocks is deep. These rocks are worn smooth by glaciation, and show deep and numerous glacial scratches.

On the north, to the left in the illustration, the rocks are precipitous for about 2,000 feet. Four waterfalls, with small streams, tumble over the rocks, the water disappearing in the loose talus at the base long before it reaches the lake. The southern slope is not so abrupt, large masses of loose talus, with large boulders, lining the water's edge, making a loose and spongy surface for the retention of moisture.

Life in and around the lake is not abundant. Frogs and snakes are practically absent, but one of the former being seen, none of the latter. On the rocks at the water's edge, altitude 3,300 feet, several pika, *Lagomys princeps*, were killed. This is the lowest altitude known to the writer at which these peculiar mammals have been killed. The banks are so steep and rough that it is all but impossible to climb along, almost an entire afternoon being spent in getting from one end to the other, a few hundred feet from the water's edge. If explored it is very likely the upper end will show a possibility of greatly increasing the surface by increasing the depth.

On the northern side the timber is not so dense, owing to the nature of the rocks, which are steep and allow poor foothold for timber. On the mountain above the precipitous rocks the timber is quite heavy, largely of yellow pine and fir. The southern bank is well wooded, and the canyon at the head of the lake is densely wooded, through which there does not appear to be an entrance made by road or trail. At the outlet and along the moraine near the lake there is fine timber, some of which has been cut for rails and lumber. Everywhere there is much underbrush, making progress difficult.

The road to the lake is good, and there is considerable travel over it in the summer time, as the lake is a great resort for the Indians and others, who visit the reservation on account of the excellent fishing and beautiful scenery. There is no drift around the shores, most of the drift having lodged in the outlet where there is quite a jam.

An ascent of the mountain, and conversation with men from the United States Geological Survey has given a comprehensive idea of the drainage system. The upper slopes of the mountains are bare. Most of them have been partially covered on the higher surfaces with black pine, which has been killed off by fire.

McDonald Peak is double, the western peak being perhaps a thousand feet lower than the eastern. The two are connected by a ridge with a depression in its middle. To pass from the western peak to the eastern is to descend over rock for a thousand feet, then up about two thousand. The western peak is easy of ascent, the last fifteen hundred feet requiring about four and a half hours, however. But to ascend the high summit from this peak appears difficult, though by taking the snow it is no doubt possible. So far the main peak has not been ascended from the west.*

The main peak has three or four spurs projecting in different directions, behind which the snow lies in deep drifts, making ice, and remaining the year through. There is little snow on the western peak, and its importance as a snow holder lies in the fact that it permits the snow blowing from the valley in the west to pile up between it and the main peak, thus making the glacier visible from almost every part of the valley. These spurs make such protection that in

*Since writing the above I am told ascent has been made this way, along the edge of the snow. Three Indians are said to have gone up and returned in safety.

three different places on the heights of this mountain the snow piles in drifts, which never melt, making three large glaciers. One of these, the one seen from the lake, is shown in the illustration, the others lying behind the spurs. The waters from these three snow masses all flow into McDonald Lake. The supply is therefore abundant and never failing. Moreover, the peaks to the north of McDonald Peak, and to the north of the lake, give much of their waters to the lake.

Post Creek, the outlet of the lake, at a point some twelve miles from the lake, lower in altitude by a thousand feet, with considerable loss through irrigation, carried 473 second feet of water on the 30th of June, 1900.

The microscopical life of the lake will no doubt prove interesting when it is worked up, as will be the case of most of these mountain lakes. The collecting net revealed an abundance of *Diaptomus ashlandi*, and the female of another form a little smaller. These were taken August 18, the net being let down to the bottom, 67 feet. *D. ashlandi* was abundant, being quite conspicuous on account of its red color.

The steep and rocky talus along the lake produces a new species of land shell, named by Pilsbry, *Pyramidula elrodi*. Description of this shell is to be found in Nautilus, Vol. XIV., p. 40. About forty were secured, all dead. The dead shells are a beautiful white, their color against the dark brown or lichen colored sandstone making them very conspicuous objects. The shells were scattered among the talus at the base of the cliffs of the mountain, and though they were conspicuous it required considerable effort to secure the few taken. Diligent search failed to reveal live specimens, but later search may serve to find them.*

In the waters of the lake *Limnaea emarginata* Say is quite abundant. It apears to be of a variety distinct from any described, and for it the varietal name *montana* has been suggested. The animals cling to the rocks along the sides and bottom of the lake, seldom found away from the rocks. A few *Physas* were found, but they were scarce. It was surprising not to find a single *Planorbis* in the lake. *Pyramidula strigosa* Gld., var. *cooperi* W. G. B., and *P. solitaria* Say were found abundantly in the damp woods along the lake and creek. It is interesting to note that a large series was secured which had evidently been killed by squirrels, as

*Several dozen have since been found.

each had a hole gnawed in the shell. These shells alive showed very strikingly the idea of protection, as it required the most careful search to find them, and repeatedly they were overlooked by the person in front and seen by the one behind. Their home is in the damp brushy woods, and to secure the series taken resulted in scratched hands and faces and torn clothes, not to speak of the discomfort of crawling among the brush on hands and knees, with the digging among the debris of old logs necessary to find them.

Altogether but five species of shells were found, rather a low number considering the size of the lake and the country.

During the summer of 1900 a stay of ten days is planned for McDonald Lake. It is hoped to find live species of the new shells. Further study of the Entomostraca will be made on the lake, with pumping apparatus. The adjacent country will be searched for birds, and alpine forms collected.

Daphnia Pond, so-called on account of the great numbers of *Daphnia pulex* found in it, is a small pond of some ten to fifteen acres. It is about a mile and a half from the Station, alongside the regular wagon road, and only about a half mile from the lake, but at a little higher altitude. This pond is no doubt of glacial origin, as the entire northern end of the Mission Range has been overrun by glaciers, leaving many evidences behind. In the center the water is about twenty feet deep, but for the most part the pond is shallow and overgrown with rank vegetation, offering an excellent harbor for smaller forms of life. No fish have as yet gotten into this pond, and consequently the invertebrate fauna is not affected by them, and has few enemies. It is a typical place to study some of the forms of life found therein, living as they do under very favorable conditions. The varied and abundant life in this small pond is in strange and striking contrast to the limited quantity and paucity of species in the large lake, so short a distance away.

The most abundant Entomostracan forms were *Diaptomus lintoni* Forbes, described from specimens taken in the lakes and pools of Yellowstone Park, and *Daphnia pulex*, so abundant that the water appeared of a dirty red color. Numbers of half-grown individuals were found with the adults. In the open water they were taken by the tablespoonful with an ordinary insect net. Nowhere have I ever seen anything so abundant as *Daphnia pulex* in Daphnia Pond. Swimming among the pond lilies, and keeping out of the open water might be seen a large species of *Gammarus*, an inch in length when expanded. A few *Cyclops pulchellus* were found among the more abundant species.

Shells are numerous in specimens though not in species *Planorbis trivolvis* Say is the most abundant. This widely distributed species was taken in all sizes from small to fully grown. *Sphaerium partumenium* Say was found among the dense vegetation, and was taken in considerable quantity. *Physa ampullacea* Gld. (possibly *heterostropha* Say) was not uncommon. Along the banks of the large lake the land form, *Pyramidula strigosa* Gld., var. *cooperi* W. G. B., was found. At the lower end of Flathead Lake, in the fine sand along the river bank, were found *Planorbis parva* Say, while in the sands of the lake were fragments of the bivalve, *Margaritana margaritifera* L.

In insects there is likewise great abundance in Daphnia Pond. Dragon-flies were noted most especially. The first week in August, 1899, *Aeschna constricta* Say was exceedingly abundant. Hundreds were flying in the air, and wherever Odonata were found flying mosquitoes were rare. The exuviae of this species were taken in quantity from the rushes, cattails, tall grass and weeds. The exuviae had the characteristic living attitude, the feet firmly clasping the stalk of the plant. They were usually found a foot or two above the water, but it was not uncommon to find them even three or four feet above water, the insect having crawled this distance before transforming into the adult. Only a few larvae could be found, showing that the transformation was practically completed at this date for the species.

The next largest was *Libellula pulchella* Drury. These were also on the wing in numbers the first week in August.

During the last two weeks in July *Lestes unguiculata* Hag. were emerging in great numbers. They are at first very feeble on the wing, lacking in color, with soft flabby bodies. While no birds were actually seen eating dragon-flies the presence of many king-birds, *Tyrannus tyrannus*, was a pretty good indication that these birds were seeking such insects for food.

Other dragon-flies taken are as follows: A few *Lestes disjuncta* were taken. *Enallagma calverti* Morse was on the wing in the middle of July in abundance. *Enallagma prae-*

varum Hag. was taken, thus extending the distribution of this species. It is now reported only from Louisiana, Kansas, and Montana. *Sympetrum scotica* Donov. was rather abundant, as also *Sympetrum rubicundula* Say, var. *assimilata* Uhler. Many larvae of different species were taken, but all have not as yet been determined.

Case-worms were found in considerable abundance. One species builds the cases out of leaves and the stalks of the green vegetation. Leeches, water-beetles, dipterous larvae, water-bugs, and worms add to the list collected and yet unworked.

Daphnia Pond is near the field laboratory, and presents good opportunity for work. Farther along the road is a second pond, which will present as good a field. Neither of these contains fish, and both teem with life in the summer time.

The region near Kalispel has many lakes awaiting study. Swan Lake, about eight miles from the Station, has been unworked save for a few hauls made by Forbes. Following up the river which enters Swan Lake to the divide and down the Clearwater and the Big Blackfoot to Missoula, a distance of a hundred and twenty-five miles, one passes a dozen to fifteen lakes of different sizes which have been as yet untouched. The northern end of the state has Terry or McDonald Lake and St. Mary's Lake, both of good size, and neither of which has been worked. The opportunities offered for work in Montana are great, but difficulties and distances are also great. As but a small portion of the time during the summer of 1889 could be devoted to this work, and during this time many pressing things engaged the attention, it is not surprising if there is much disappointment at the comparatively meager results. But the way is opened, the field partially disclosed, and a trail cut through the apparently impassable wilderness. Each succeeding pack train will make the trail plainer and meanwhile the facilities for taking the train in and getting material out will be better. Moreover, it is hoped the numbers composing the pack trains will increase. More than any other one thing the naturalist working in Montana needs kindred spirits to rub up against for mutual aid, to brush away the cobwebs that accumulate, and to ask stimulating and difficult questions, even though the answers may require years of work. More work, and more valuable work, will be done in succeeding years.

EXPLANATION OF PLATES

Plate X

Mouth of Swan River, and Flathead Lake. In the distance, to the right, about three miles off, may be seen the bar at the mouth of Flathead River. Cabinet Mountains in the distance. View is southwest.

Plate XI

A bit of beach at Flathead Lake, showing characteristic shore, vegetation, and drift.

Plate XII

A

Lower end of Flathead Lake, from summit of moraine, showing islands in the distance. In the foreground to the left is the outlet of the Pend d'Oreille River. The islands are about seven miles out from the shore. The view is north.—Photograph by Chas. Emsley.

B

Mission Mountains, from Crow Creek, after a storm. The high peak in the center is McDonald. The view is almost directly due east. The distance is about eighteen or twenty miles.

Plate XIII

Rapids in the Pend d'Oreille River, near the lake outlet, Flathead Indian Reservation. View is northwest.—From Photograph by M. J. Elrod.

Plate XIV

McDonald Lake, Mission Mountains, Montana, from the outlet. McDonald Peak is on the right. On the left bank in the picture was found the new shell *Pyramidula elrodi* Pils. View is east.

Plate XV

Outline map of Lake McDonald, showing contour, lines of depth, and geological features referred to in text.

Plate XVI

Canvas boat and plankton outfit of Montana Biological Station at Swan Lake, Montana, August, 1900. At the outlet of the lake looking into Swan River. Swan Mountains in the distance to the right.

Plate XVII

Launch Missoula and rowboat Culex of the University of Montana Biological Station in Swan River harbor, Flathead Lake. Plankton equipment, net, pump, hose, reel, etc., on the shore nearby.

PLATE X

PLATE XI

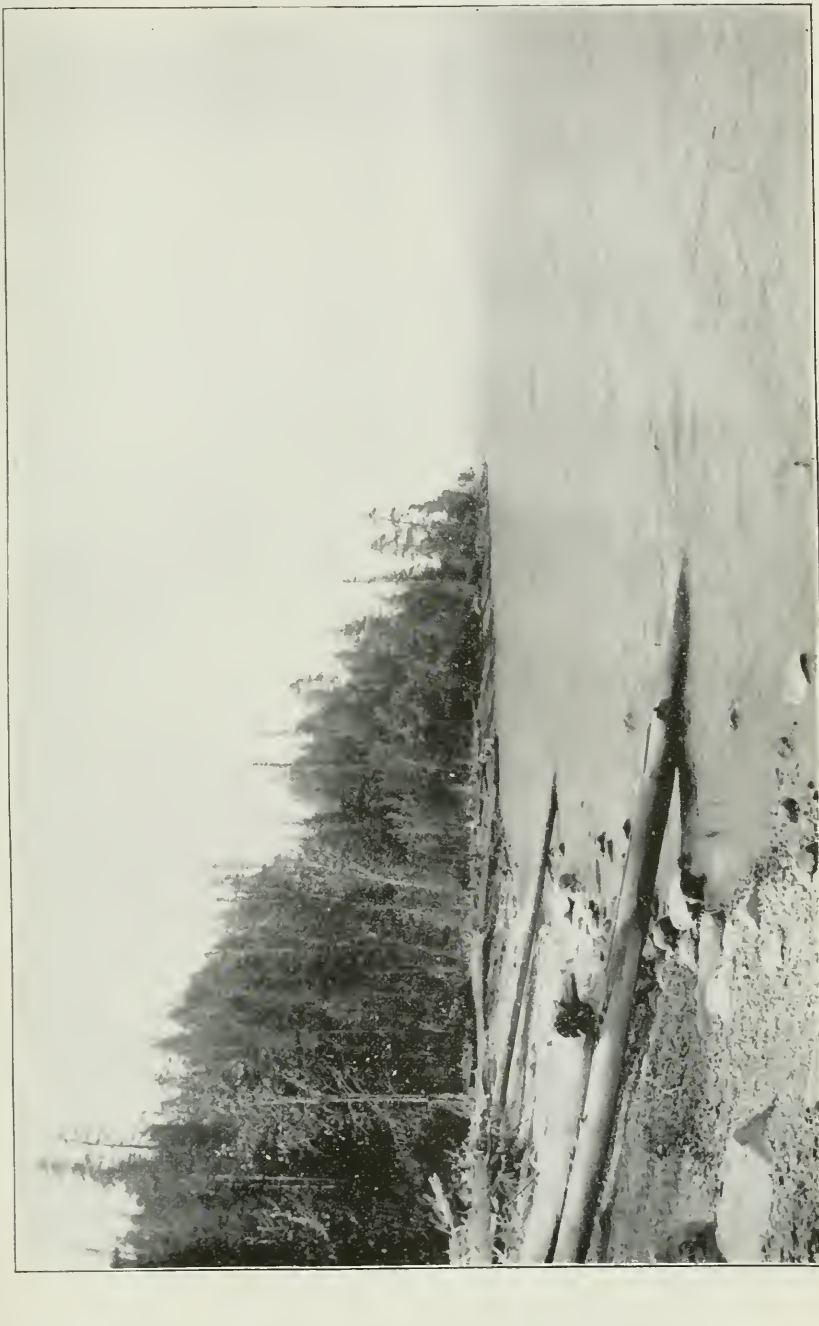


PLATE XII

A

B

PLATE XIII

PLATE XIV

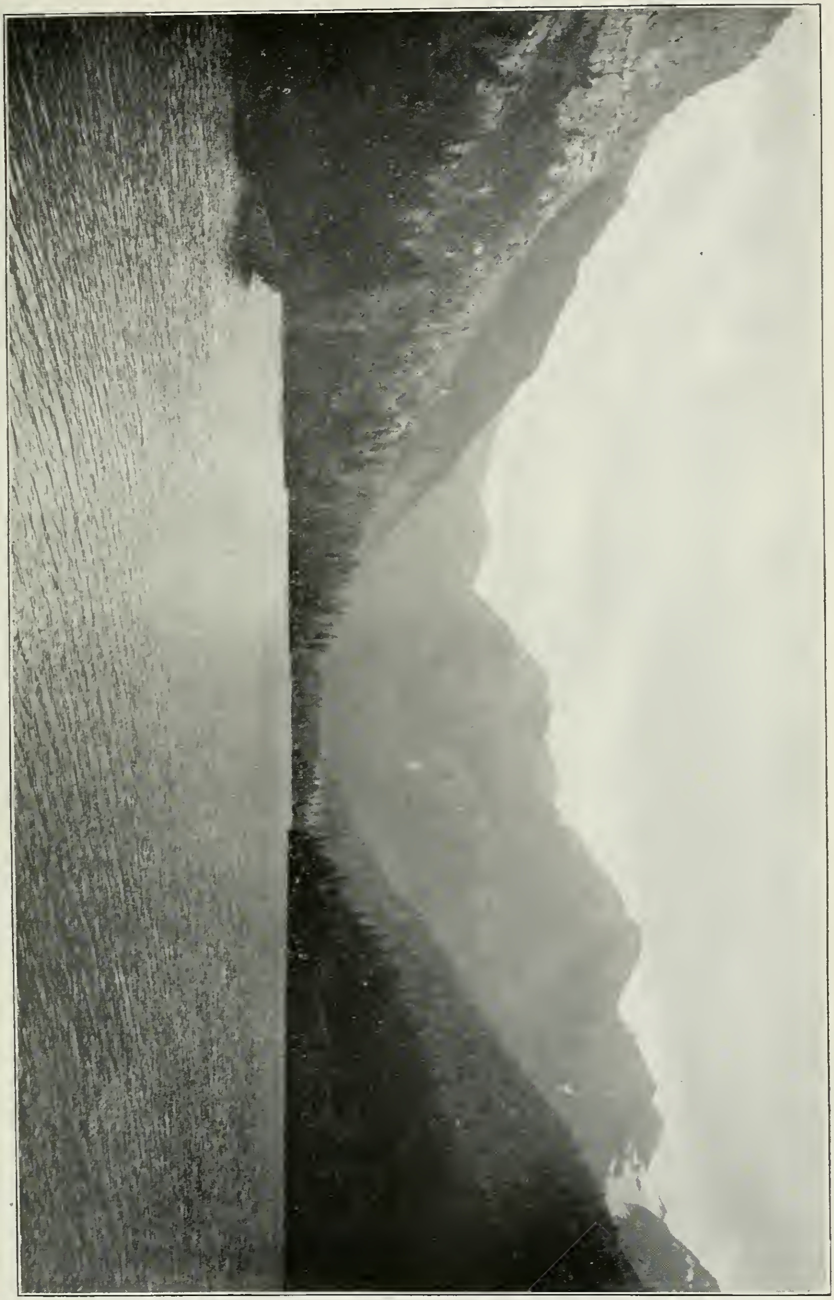


PLATE XV

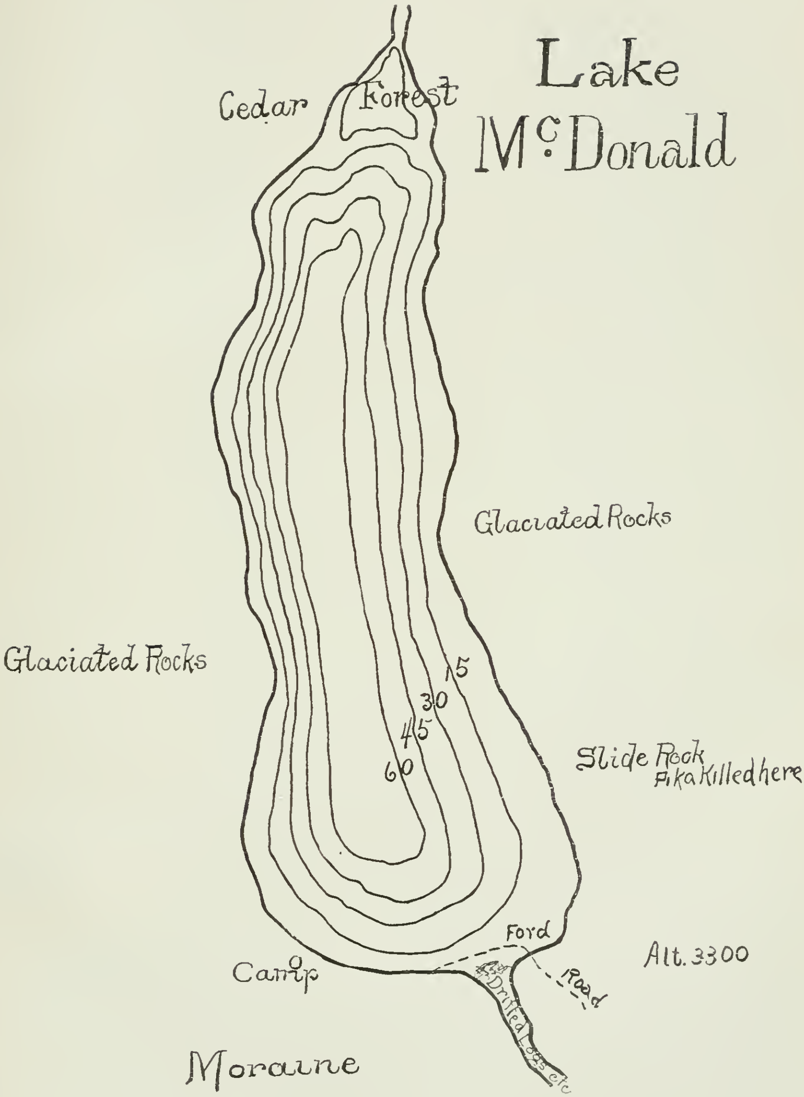
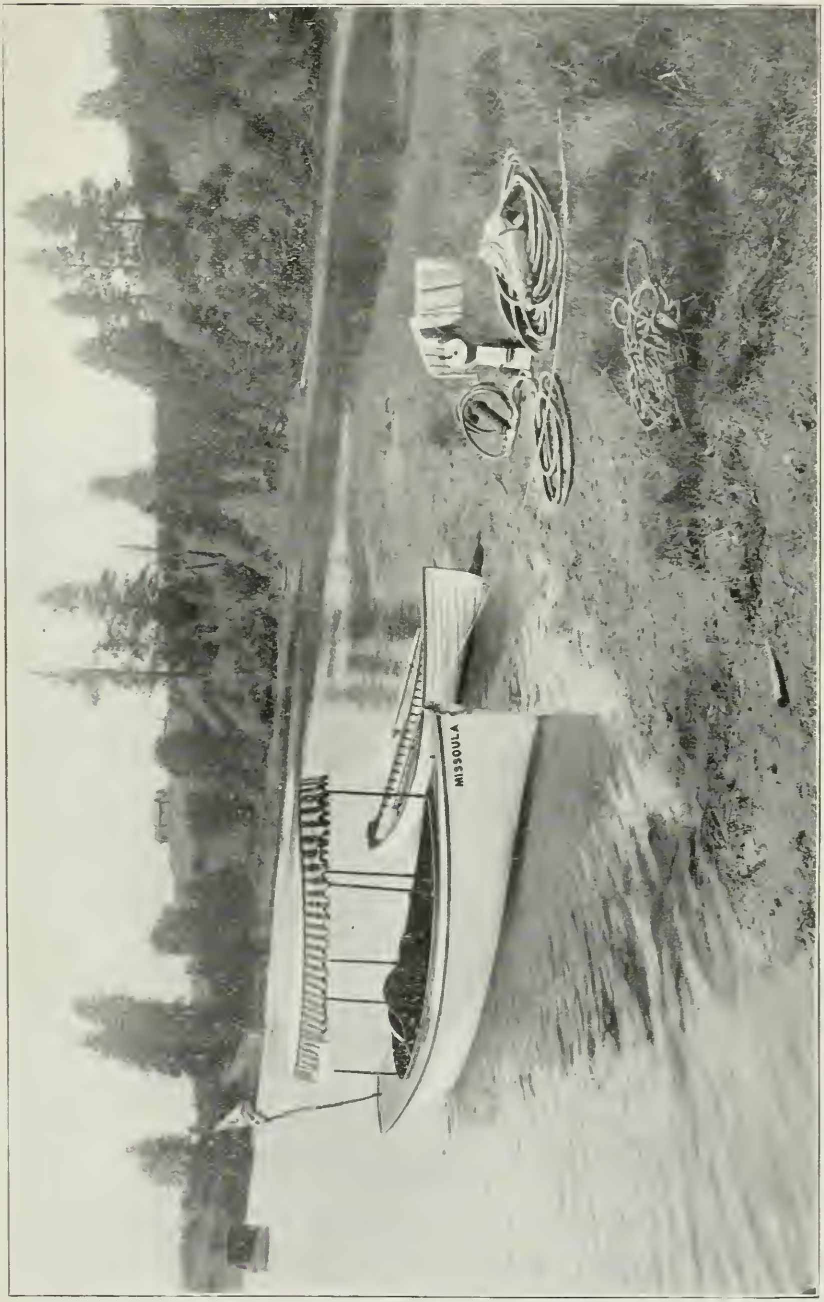

Lake
Mc Donald
Cedar Forest
Glaciated Rocks
Glaciated Rocks
15
30
45
60
Slide Rock
Pika Killed here
Ford
Alt. 3300
Camp
Road
Drifted Logs etc
Moraine

PLATE XVI

PLATE XVII



AN ADDITION TO THE PARASITES OF THE HUMAN EAR

By ROSCOE POUND

WITH ONE PLATE

The list of Fungi which have been reported as parasites in the human ear is somewhat large. The number of species which are well identified is much smaller. The confusion long prevalent in the groups to which the ear-parasites belong, recently abated in the Black Moulds by A. Fischer, but still in force in the Imperfect Fungi, and the fact that otologists have not been much concerned with mycology nor always able to command the assistance of expert mycologists, have united with the inherent difficulties due to the effect of situs on the forms themselves to produce errors in determination, uncertainty, and even controversy. The greater number of the species reported and the greater number of the well identified and authenticated species belong to the Aspergillaceae. Next come the Mucoraceae. The Protoascineae and Pezizineae contribute one each. In addition there are several Imperfect Fungi, some of which, however, seem to owe their place upon the list to ubiquity rather than to any special adaptation to the habitat. It seems probable that almost any of the commoner pantogenous Imperfect Fungi is liable to be added to this portion of the list at any time.

The following species appear to constitute the fungus flora of the human ear:

Mucoraceae.

Mucor mucedo L.

M. racemosus Fres.

M. corymbifer F. Cohn.

Ascophora mucedo Tode (*Rhizopus nigricans* Ehrb.).

Doubtful and less known species:

Thamnidium elegans Lk. (*Ascophora elegans*).

It has been suspected, with good reason, that the forms referred to *T. elegans* were merely *Mucor mucedo* with sporangiola.

Mucor septatus Bezold, according to A. Fischer, is probably to be referred to *M. racemosus*.

M. rhizoformis Lichth.

Endomycetaceae.

Bargellinia monospora Borzi.

This curious fungus, placed by Saccardo in the somewhat heterogeneous group of Gymnoascaceae, is doubtfully referred to the Endomycetaceae by Schroeter in the *Pflanzenfamilien*.

Aspergillaceae.

Aspergillus glaucus (L.) Lk. (*A. herbariorum* (L.) E. Fisch.).

A. repens (Corda) Sacc.

A. fumigatus (Fres.) De Bary.

A. malignus (Lindt.) E. Fisch. (*Eurotium malignum* Lindt.).

A. flavus Lk.

A. virens Lk.

A. nidulans (Eidam) Wint. (*Sterigmatocystis nidulans*).

A. niger Van Tiegh. (*Sterigmatocystis nigra*).

Penicillium crustaceum (L.) Fr.

P. minimum Siebenmann.

Doubtful or less known species:

Aspergillus flavescens Wred. Believed to belong to *A. flavus*.

A. hageni Hallier.

Otomyces hageni Hallier.

A. microsporus Boke.

A. nigrescens Robin.

A. nigricans Wred. (1868).

A. nigricans Cooke (1885).

Cooke says his *A. nigricans* appears to be distinct from *A. nigrescens*, but seems to consider it the same as *A. nigricans* of Wreden. Siebenmann refers *A. nigrescens* to *A. fumigatus* and *A. nigricans* Wred. to *A. niger*. Cooke's figure (Journ. Queckett Micr. Club, II, 2: t. 9 f. 3) precludes identification with *A. niger*. Cattaneo refers *A. nigricans*, to *A. nigrescens*, which would then mean, probably, *A. fumigatus*.

A. noelting Hallier.

A. ramosus Hallier.

A. rubens Green. Believed to be *A. nidulans.*

Sterigmatocystis antacustica Cram. Supposed to be *Aspergillus niger.*

Otomyces purpureus Woronin is thought to belong to *A. nidulans.*

Mollisiaceae.

Mollisia auriculae (Garov.) Sacc.

Peziza auriculae Garov.

Fungi Imperfecti.

Alysidium rufescens (Fres.)

Torula rufescens Fres.

Oospora rufescens Sacc.

Verticillium graphii Bezold.

Acrostalagmus parasiticus Hallier.

Stachylidium sp. Hallier.

These seem likely to prove the same.

Trichothecium roseum Lk.

Stemphylium polymorphum Bon.

Graphium penicillioides Corda.

Coremium bicolor (Web.) Pound & Clements.

Stysanus stemonites (Pers.) Corda.

Spores of one of the Ustilagineae (smuts) are also reported as found germinating in an infested ear, which is not to be wondered at in view of the ubiquity of these spores.

To the foregoing list we now have to add *Sterigmatocystis candida.*

The Mucoraceae enumerated include the three commonest of the Black Moulds. They are to be found on all manner of organic substances throughout the world, and their occurrence as ear-parasites is doubtless partially due to that fact. But some connection has been suggested between the growth of *Mucor racemosus* in the ear and cases of diabetes, which is rendered not improbable by the yeast-like mode of growth of this fungus and its power of acting as a ferment. *M. corymbifer* has been found to be pathogenic in other connections.

The nature and position of *Bargellinia monospora* are doubtful. It is placed provisionally in a small group of Ascomycetes or sac-fungi in which no spore-fruit is developed and the ascus is of a very primitive type. But it is not certain that *Bargellinia* is an Ascomycete at all. The so-called onespored ascus may prove to be some form of conidial fructification.

Of the Aspergillaceae named, the ten listed as doubtful or less known are reported as ear-parasites only. But they require further study, and some at least are believed by competent authority to be identical with other species of more general occurrence. The type of this group, *Aspergillus glaucus*, is the ordinary herbarium mould found everywhere on all manner of organic substances. It occurs in the ear in the conidial stage in which the ends of certain fertile hyphae swell up and produce chains of asexual spores. The stage in which small, yellow, sexual spore-fruits are produced, visible to the naked eye, was long considered a distinct species, called *Eurotium herbariorum*, and by some the plant is now known as *Aspergillus herbariorum*. The rules of nomenclature adopted by American botanists, however, seem to justify the retention of the well known name *A. glaucus*. It has been suggested that the forms described under the name *Otomyces* represent this second stage of the Aspergilli also. This has been controverted by good authority, but the belief seems to be general that the *Otomyces* forms are connected with *Aspergillus*.

Under the name *Aspergillus*, besides the forms whose life-histories are well worked out, which are known in both stages, mycologists include also a large number of forms known only in the first or asexual condition. Many of these may go on indefinitely in this stage and never develop further. Others possibly are but ill-understood variations of the better known forms. It is to this category of "Imperfect Fungi" that one or two of the more widely known species and all the species peculiar to the ear enumerated above are to be referred. The Aspergilli are among the commonest and most wide-spread of saprophytes, but in addition seem to find themselves at home in diseased animal tissues. Thus, in addition to the long list of Aspergilli which infest the human ear, *A. fumigatus* has been observed in the human lung, *A. niger* in the lungs of birds, *A. malignus* and *A. nidulans* are otherwise pathogenic, and *A. virens* has been found upon tissues imperfectly preserved in alcohol.

Penicillium crustaceum, the ordinary blue mould of cheese, fruit, jelly, etc., is the commonest of fungi. It is closely related to *Aspergillus*, producing a spore-fruit of the same sort, and is most readily distinguished in that the chains of conidia (asexual spores) proceed from verticillately branched hyphae instead of from a terminal swelling. This species also has a weakness for diseased tissues, having been found parasitic in other parts of the human body. *P. minimum* is known only as an ear-fungus.

The Aspergilli proper, which furnish the bulk of the species infesting the ear and, according to report, are the fungi usually met with in cases of *otitis parasitica*, fall into three groups. In the first, the chains of conidia proceed from mere roughenings of the terminal vesicle of the fertile hypha. In the second, they proceed from well developed but simple sterigmata. In the third group these sterigmata are branched. The first two are included in the genus *Aspergillus*, the third has been made a distinct genus under the name of *Sterigmatocystis*. But systematists who take into account the further development of *S. nigra*, the type, and its spore-fruit condition, now concur in uniting the genus with *Aspergillus*, so that it is kept separate chiefly because of the imperfect forms that are described under the other name. *Sterigmatocystis nigra*, or *Aspergillus niger*, is a very common saprophyte, only less common than *A. glaucus* and *Penicillium crustaceum*, and like them thoroughly pantogenous. *S. antacustica*, an ear-parasite described by Cramer in 1859, was referred to *Aspergillus niger* by Wilhelm in his monograph of *Aspergillus*, and afterwards by Winter and Siebenmann. E. Fischer in the *Pflanzenfamilien* places it there doubtfully. There is good reason to suspect that *A. niger* is more common in the ear than the reports would show, as at least one figure labeled *A. nigricans* has branching sterigmata and the general appearance of *A. niger*.

Mollisia auriculae, a cup-fungus discovered in Italy in 1871 in a case of otitis, is known from a careful drawing made at the time by Dr. Frigerio. The name *Peziza auriculae*, under which it was published by Garovoglio in 1872, seems to have been a *nomen nudum*. The drawing shows a well developed spore fruit with asci and paraphyses as in typical Pezizineae.

The Imperfect Fungi reported give rise to many difficulties. *Trichothecium roseum* is one of the most common of saprophytes and is pantogenous. On the other hand, *Stemphylium polymorphum*, *Graphium penicillioides*, and *Coremium bicolor* are saprophytes of decaying wood and are by no means so common or widely distributed. Siebenmann believes the two first to be connected with the form described as *Verticillium graphii*, the forms referred to *G. penicillioides* being only compact growths of the conidiophores. It will not escape notice that *Verticillium*, *Acrostalagmus*, *Stachylidium*, *Trichothecium*, and *Graphium*, the genera of Imperfect Fungi under which ear-fungi are described, have the common characteristic of being conidial stages of Hypocreales. We may suspect, therefore, that some single nectrioid fungus may ultimately be found to account for most of these, though the pantogenous *Trichothecium roseum* scarcely needs to be accounted for. *Coremium bicolor* was not found in the ear but in cultures of mycelia taken from the ear, and its place on the list is doubtful. *Alysidium rufescens* was first noted as a growth on the lens in cataract.

Some time ago, Dr. S. E. Cook of Lincoln submitted to me material of an ear-parasite, plainly one of the Aspergillaceae, which had much of the outward appearance of the common *A. candidus*. Examination revealed branching sterigmata, and I referred the form provisionally to *Sterigmatocystis candida* Sacc. The latter species was discovered by Saccardo in Italy in 1876 growing upon decaying insect larvae, and has since been found in France growing upon the surface of citric acid. It is probably pantogenous, like the rest of the group. While the form found by Dr. Cook differs from *S. candida* in being somewhat smaller at all points, the shape of the sterigmata is so characteristic, and agrees so thoroughly with Saccardo's figure (Fungi Italici, t. 80) that in the absence of authentic material for comparison, notwithstanding Professor Underwood's caution that American fungi identified by European names are a source of confusion and must be renamed, it seems best to refer this form to *S. candida*, noting the slight divergence in measurements.

A brief description, figures and bibliography are added.

Sterigmatocystis candida Sacc.

In a human ear affected with otitis, Lincoln, Neb. (Dr. S. E. Cook).

Fertile hyphea hyaline or whitish, rather strict, 150 to 200x10 μ; vesicle globose, 30 to 35 μ; basidia clavate, $30 \times 7\frac{1}{2}\,\mu$, noticeably obtuse and flattened at the top, bearing three filiform sterigmata 10 to 15 μ long; conidia gobose, not exceeding 2 μ.

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EXPLANATION OF PLATE

Plate XVIII

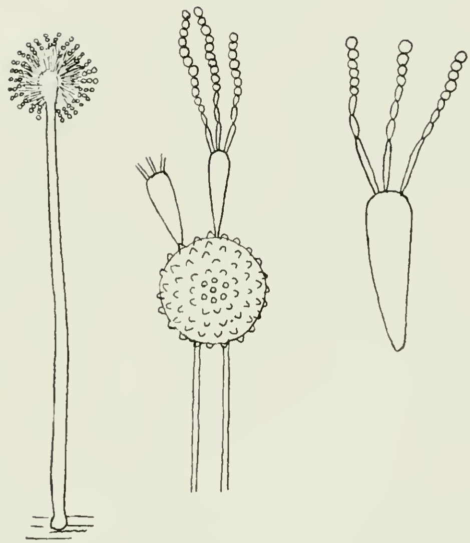
Sterigmatocystis candida Sacc.

(*a.*) Fertile hypha.

(*b.*) Terminal vesicle with "basidia" attached.

(*c.*) A single "basidium."

PLATE XVIII



THE MODERN CONCEPTION OF THE STRUCTURE AND CLASSIFICATION OF DESMIDS,

WITH A REVISION OF THE TRIBES, AND A REARRANGEMENT OF THE NORTH AMERICAN GENERA

By CHARLES E. BESSEY, Ph. D.

WITH ONE PLATE

The recent revision of the Green algae in Engler and Prantl's "Pflanzenfamilien" by Professor Wille, the eminent Swedish algologist, brings together in compact form the results of the work of many investigators. Taking this admirable monograph as a basis and bringing to my aid the monograph of the Bacillariales by Professor Schuett in the same publication, I have ventured to attempt to carry out Wille's work somewhat nearer to what appears to me must be its logical conclusion. I should associate in one group (Conjugatae) the families Zygnemaceae (including Mesocarpaceae of some authors), Desmidiaceae, and Bacillariaceae (all of holophytic species), and to this group I assign ordinal rank. Until quite recently I have associated with these the families Mucoraceae and Entomophthoraceae, composed of hysterophytic plants, in accordance with the theory that they are colorless, degenerate relatives of the holophytic families just named. However, further study of the problem has led to the conclusion that Mucoraceae and Entomophthoraceae have little affinity with the families of the Conjugatae, and that they are to be removed to that remarkable group of hysterophytic families (Saprolegniaceae, Cladochytriaceae, Ancylistaceae and Peronosporaceae) in the Siphoneae, which appears to have sprung from or near the Vaucheriaceae. With these relationships this paper is not directly concerned, and they may be passed without further discussion.

The families of the Conjugatae (Zygnemaceae, Desmidiaceae, and Bacillariaceae) are here regarded as consisting of typically filamentous plants, as is well illustrated in the common Conjugata (Spirogyra) of the pools. As shown in another paper* many diatoms are filamentous plants, and in those species in which the cells occur singly we may regard this condition as the result of the early *solution* of the filament. In the present paper it is assumed that the Desmids, also, are typically filamentous, or in other words, that they have been derived from filamentous forms, a structure which is still maintained in a considerable number of genera, and that the unicellular condition is derived from this structure by the early separation of the cells, or as expressed above, by the *solution* of the filament.

This conception necessitates an arrangement of the genera somewhat different from that adopted by Wille, without, however, seriously disturbing their inter-relationships. It is not difficult to see that the family is easily separable into three quite well-marked groups of genera, which we may, perhaps, regard as tribes. Thus the filamentous forms may be brought together (as indeed was done by Hansgirg and De Toni a dozen years ago), and in like manner the unicellular forms may be easily separated into two tribes, (*a*) those with elongated cells, little if at all constricted, and (*b*) those with broad, deeply constricted cells. To the first of these three tribes I have given the name DESMIDIEAE, preferring this to EUDESMIDIEAE, used by Hansgirg for the name of his equivalent sub-family. The second tribe I name ARTHRODIEAE (from the genus *Arthrodia*, heretofore known as *Closterium*, but clearly antedated by Rafinesque's name) while for the third the name COSMARIEAE.

In accordance with the foregoing conclusions I have drawn up the technical diagnosis of the family in the following terms:

FAMILY DESMIDIACEAE

Cells bright green, in unbranched filaments, cylindrical, angled or flattened in cross section, and quadrangular, rounded, or lobed and often constricted in side view; or more commonly separating early into isolated individuals which are similarly shaped, or symmetrically lobed or branched in side view; cell wall composed of cellulose, commonly finely

* The Modern Conception of the Structure and Classification of Diatoms, with a revision of the tribes and a rearrangement of the North American genera; in Transactions of the American Microscopical Society, Vol. XXI, p. 61.

porous, and often covered with a gelatinous layer, and composed in most genera of two halves which adhere to each other at the middle of the cell, which is usually constricted; propagation by the transverse fission of each cell into two equal, but unsymmetrical daughter cells, which soon grow to be symmetrical; generation by the rupture of the outer walls of two contiguous cells, and the protrusion of a thin-walled tube from each, these fusing and uniting their contents into a resting spore (zygote) from which on germination one, two, four, or eight new cells are formed.—Minute freshwater plants, floating free in the water of quiet pools, or entangled with Sphagna, mosses and other aquatic plants.

Key to the Tribes.

A. Cells in unbranched filaments, Tribe 1. *Desmidieae.*
B. Cells solitary,
I. Cells elongated; not at all, or but moderately constricted, Tribe 2. *Arthrodieae.*
II. Cells broad, deeply constricted, Tribe 3. *Cosmarieae.*

Tribe 1. Desmidieae

Cells in unbranched filaments, from much elongated to shorter than broad, cylindrical to angular or flattened, and from not at all to deeply constricted; filaments naked or enclosed in a hyaline sheath.

Key to the Genera.

I. Filaments naked (without a sheath),
a. Cells cylindrical,
1. Chromatophore single, axial, 1. *Gonatozygon.*
2. Chromatophores three, parietal, spiral, 2. *Genicularia.*
b. Cells barrel-shaped, 3. *Gymnozyga.*
c. Cells quadrangular, deeply constricted, 4. *Phymatodocis.*
II. Filaments surrounded by a hyaline sheath,
a. Cells not constricted, or very little,
1. Filaments cylindrical, 5. *Hyalotheca.*
2. Filaments 3- to 4-angular, 6. *Desmidium.*
b. Cells deeply constricted, filaments flattened,
1. Cells unarmed, 7. *Sphaerozosma.*
2. Cells armed with several divergent horns, 8. *Onychonema.*

1. *Gonatozygon* De Bary. Cells elongated-cylindrical, or truncate-fusiform, attached to one another in an unbranched filament, which has no sheath, not at all constricted in the middle; chromatophore one, axial, undulated.—Small desmids of few species, rarely seen.

2. *Genicularia* De Bary. Cells elongated-cylindrical, attached to one another in an unbranched filament, which has no sheath, not at all constricted in the middle; chromatophores three, parietal, spiral, sometimes confluent or irregular.—Small desmids of few species, rarely seen.

3. *Gymnozga* Ehrenberg. Cells oblong, barrel-shaped, each with two median hoop-like ridges, attached to one another in an unbranched filament, which has no sheath, not constricted in the middle; chromatophores of several axial plates with divergent wings.—Small desmids of few species, several of which are common in quiet waters.

4. *Phymatodocis* Nordstedt. Cells oblong, truncate, quadrangular in transection, attached to one another in an unbranched filament, which has no sheath, deeply constricted in the middle; chromatophores not known.—Small desmids, rarely seen.

5. *Hyalotheca* Ehrenberg. Cells short-cylindrical, attached to one another in an unbranched filament, which is surrounded by an ample, colorless sheath, very slightly (obtusely) constricted in the middle; chromatophores of several axial plates with divergent wings.—Small desmids of few species, several of which are frequent in some portions of this country.

6. *Desmidium* Agardh. Cells oblong, truncate, triangular or quadrangular in cross-section, little or not at all constricted in the middle, attached to one another in an unbranched filament, which is surrounded by a hyaline sheath; chromatophores of three or four longitudinal plates lying in the angles of the filament.—Small desmids, common throughout the country.

7. *Sphaerozosma* Corda. Cells compressed, deeply constricted in the middle, unarmed, ends rounded or truncate, slightly attached to one another in a lobed, unbranched filament, which is surrounded by a hyaline sheath; chromatophores quadriradiate.—Small desmids, some species of which are common in ponds and ditches.

8. *Onychonema* Wallich. Cells compressed, deeply constricted, armed with divergent horns, ends rounded or truncate, slightly attached to one another in a lobed, unbranched filament, which is surrounded by a hyaline sheath; chromatophores quadriradiate.—Small desmids, rarely seen.

Tribe 2. Arthrodieae

Cells solitary, elongated, cylindrical to fusiform; transection circular, not at all to moderately constricted; cells sheathless.

Key to the Genera.

I. Cells not constricted, transection circular,
  a. Cells straight,
    1. Chromatophores of one or more spiral bands, 9. *Entospira.*
    2. Chromatophore a single axial plate, 10. *Mesotaenium.*
    3. Chromatophores of several axial plates, with divergent wings, 11. *Penium.*
  b. Cells more or less falcate, or semi-lunate, 12. *Arthrodia.*
II. Cells straight, moderately constricted, transection circular.
  a. Chromatophores axial,
    1. Cells short-cylindrical or fusiform, ends rounded, emarginately incised, 13. *Tetmemorus.*
    2. Cells long-cylindrical, much elongated, ends truncate or rounded or 3-lobed, 14. *Docidium.*
  b. Chromatophores axial, 15. *Pleurotaenium.*

9. *Entospira* Brebisson (*Spirotaenia* Brebisson).* Cells solitary, sometimes aggregated in a gelatinous matrix, straight, oblong-cylindrical or fusiform, not constricted in the middle; transection circular, ends rounded or acuminate; chromatophores of one or more spiral parietal bands.—In pools, ponds, and in wet mosses.

10. *Mesotaenium* Naegeli. Cells solitary, sometimes aggregated in a gelatinous matrix, short-cylindrical, elliptical or ovate, not constricted in the middle; transection circular,

*Of these two names by the same author, *Entospira* has the priority, having been proposed by him in 1847 in Kuetzing's Tabulae Phycologicae, while *Spirotaenia* did not appear until 1848, in Ralf's British Desmidieae.

ends rounded; chromatophore a single axial plate or ribbon, sometimes divided in the middle.—In pools, on wet rocks, walls or damp ground.

11. *Penium* Brebisson. Cells solitary, sometimes aggregated in a gelatinous matrix, straight, cylindrical, or fusiform, not constricted in the middle; transection circular, ends rounded or somewhat truncate; chromatophores of several axial plates, with divergent wings.—Large desmids, 11 to 80 μ in diameter, and 6 to 10 times as long, common in pools and springs.

12. *Arthrodia* Rafinesque, (*Closterium* Nitzsch).* Cells solitary, more or less falcate or lunate, incurved (rarely nearly straight), fusiform or cylindraceous, not constricted in the middle; transection circular, ends acuminate; chromatophores of several axial plates, with divergent wings.—Medium to large sized desmids, 3 to 110 μ in diameter, and from 5 to 20 times as long, common in pools and springs.

13. *Tetmemorus* Ralfs. Cells solitary, straight, cylindrical, or fusiform, moderately constricted in the middle; transection circular, ends rounded, narrowly emarginately incised; chromatophores axial.—Rather large desmids, common in ponds.

14. *Docidium* Brebisson. Cells solitary, straight, oblong—cylindrical, moderately constricted in the middle, usually long (6 to 30 times their diameter); transection circular, ends truncate, rounded, three-lobed and three-spined; chromatophores axial, of two to four radiating bands.—Large or medium sized desmids, frequent in ponds.

15. *Pleurotaenium* Naegeli. Cells solitary, straight, cylindrical, more or less constricted in the middle; transection circular, ends truncate; chromatophores parietal.—Large desmids, some species of which are common in ponds.

Tribe 3. Cosmarieae

Cells solitary, broad, more or less flattened; transection rounded to angular, oblong and elliptical, deeply constricted, the half-cells from entire to many-lobed; cells sheathless.

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* Nitzsch's name, *Closterium*, was first proposed in 1817, while Rafinesque's name, *Arthrodia*, was used four years earlier, i. e. 1813; hence the latter having clear priority. must be used for these beautiful organisms.

KEY TO THE GENERA.

I. Cells short-cylindrical or orbicular, transection rounded or oblong, half-cells not lobed,
  a. Unarmed,
    1. Solitary,
      a. Chromatophores axial, radiating, 16. *Cosmarium.*
      b. Chromatophores parietal, longitudinally laminiform, 17. *Pleurotaeniopsis.*
    2. Joined in gelatinous, branching threads, 18. *Cosmocladium.*
  b. Each half-cell armed with a spine on each side, 19. *Arthrodesmus.*

II. Cells orbicular, oblong or elliptical, transection flattened or elliptical, half-cells lobed,
  a. Half-cells with few, usually rounded lobes, and broad sinuses, 20. *Euastrum.*
  b. Half-cells with many pointed lobes and narrow sinuses, 21. *Micrasterias.*

III. Cells oblong or orbicular, transection rounded or oblong or angular,
  a. Armed with spines, chromatophores parietal, laminiform, 22. *Xanthidium.*
  b. Smooth, verrucose or hairy, chromatophores axial, 23. *Staurastrum.*

16. *Cosmarium* Corda. Cells solitary, short-cylindrical or orbicular, smooth, verrucose, or rarely spiny, deeply constricted in the middle; transection sub-oval or oblong, ends rounded or truncate, entire; chromatophores one or two in each half cell, axial, radiating.—Mostly small desmids of many species, widely distributed and common in mossy ponds.

17. *Pleurotaeniopsis* Lundell. Cells solitary, short-cylindrical or rounded, unarmed, deeply constricted in the middle; transection sub-oval or circular, ends rounded or truncate; chromatophores parietal, longitudinally laminiform.—Medium to large sized desmids, a few of which may be found in our quiet waters.

18. *Cosmocladium* Brebisson. Cells joined in gelatinous, dichotomously branching threads, elliptic-reniform, constricted in the middle; chromatophore one in each half-cell, central.—Small desmids of few species, but one of which has been found (in spring water) in this country.

19. *Arthrodesmus* Ehrenberg. Cells solitary, short-cylindrical or orbicular, smooth, with a single spine on each side of each half-cell, deeply constricted in the middle; transection oblong or fusiform-elliptical, ends rounded or truncate, entire; chromatophores axial, laminated.—Small to very small desmids, not common.

20. *Euastrum* Ehrenberg. Cells solitary, oblong or elliptical, with few rounded lobes and broad sinuses, smooth or verrucose, deeply constricted in the middle; transection oblong or elliptical, ends rounded or truncate, usually emarginate or deeply incised; chromatophore one in each half-cell, axial, of longitudinally radiating threads.—Small desmids of many species, widely distributed and quite common.

21. *Micrasterias* Agardh. Cells solitary, orbicular, or oblong-elliptical, deeply constricted in the middle, each half-cell with three to five radiating, pointed lobes, separated by (usually) narrow sinuses, the lobes sometimes again divided; transection fusiform, ends entire, sinuate or incised; chromatophores axial, laminated.—Large desmids, common in mossy ponds and lakes.

22. *Xanthidium* Ehrenberg. Cells solitary or geminately connected, orbicular, inflated, armed with spines, deeply constricted in the middle; transection rounded, oblong or angular, ends neither emarginate nor incised; chromatophores parietal, laminiform.—Medium to small sized desmids, apparently not common.

23. *Staurastrum* Meyen. Cells solitary, oblong or orbicular, smooth, verrucose or hairy, deeply constricted in the middle, each half-cell in transection 3-to-6 or more angular, the angles often prolonged into obtuse or acute horn-like processes, ends mostly rounded or truncate; chromatophores axial.—Small desmids of many species, widely distributed but not abundant.

EXPLANATION OF PLATE

(All cells are drawn with their corresponding axes parallel, and are magnified about two hundred diameters.)

Plate XIX

TRIBE DESMIDIEAE.

1. Two cells of a *Gonatozygon* filament.
2. Portion of a filament of *Genicularia*.
3. Filament of *Gymonzyga*, with eight cells.
4. Three cells of a filament of *Phymatodocis*.
5. Portion of a filament (eleven cells) of *Hyalotheca*, enclosed in a thick sheath.
6. Ten cells of a filament of *Desmidium*, enclosed in a sheath.
7. Portion of a filament of *Sphaerozosma*, enclosed in a sheath; two cells at the right just divided.
8. Filament of eleven cells of *Onychonema*, enclosed in a sheath.

TRIBE ARTHRODIEAE.

9. A cell of *Entospira*, with spiral chromatophore.
10. Cell of *Mesotaenium*.
11. Cell of *Penium*.
12. Cell of *Arthrodia*.
13. Cell of *Tetmemorus*.
14. Cell of *Docidium*.
15. A little more than one-half of a cell of *Pleurotaenium*.

TRIBE COSMARIEAE.

16. Cell of *Cosmarium*.
19. Cell of *Arthrodesmus*.
20. Cell of *Euastrum*.
21. Cell of *Micrasterias*.
22. Cell of *Xanthidium*.
23. Cell of *Staurastrum*.

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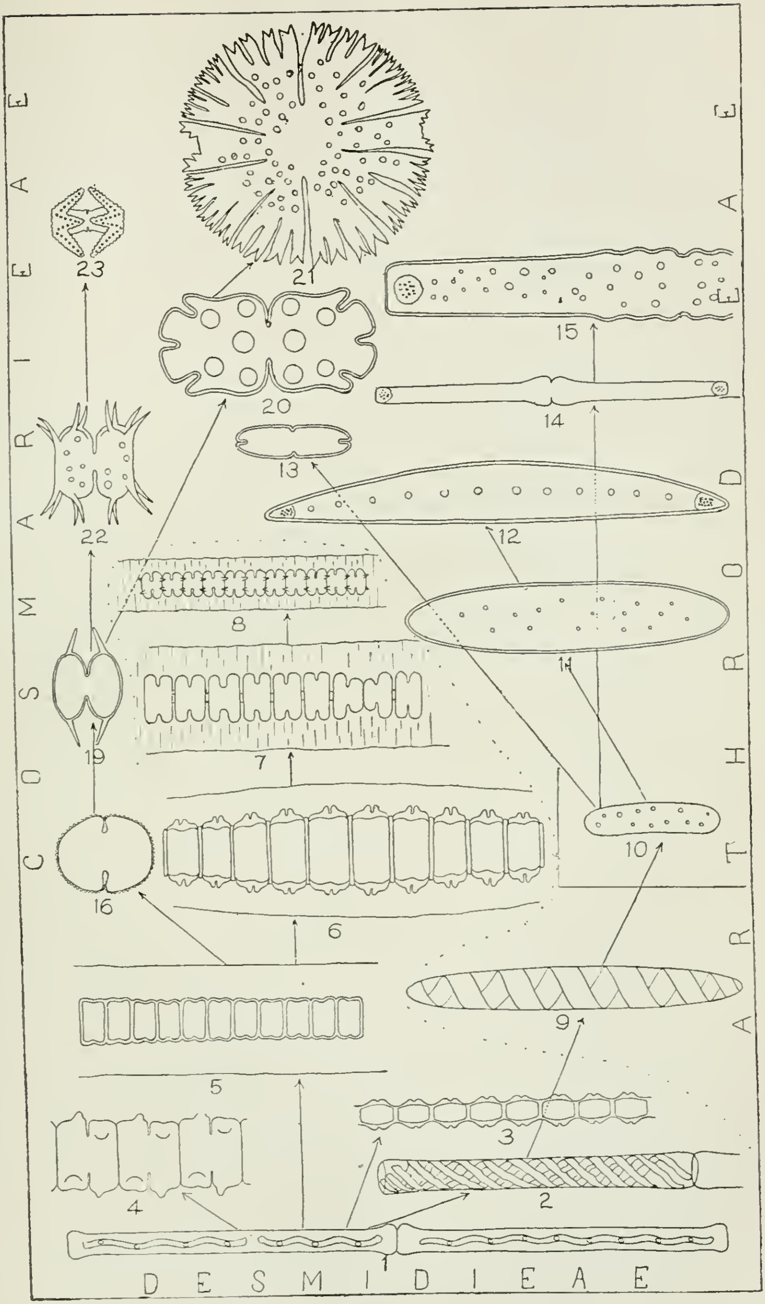
COSMARIEAE
ARTHRODEAE
DESMIDIEAE
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PHOTO-SPECTOGRAPHY OF COLORED FLUIDS

By MOSES C. WHITE, M. D., New Haven, Conn.

WITH ONE PLATE

Every person with a moderate knowledge of mathematical optics is more or less familiar with what are known as the Fraunhofer lines in the solar spectrum, and they know too that incandescent vapors of different metals give characteristic bright lines in the spectra of flames in which the various metallic and non-metallic substances are volatilized. It is not so generally known that many fluids, both colored and colorless, give characteristic dark lines when light passed through them is transmitted through the spectroscope. It is thus that the purity of olive oil may be determined by the spectroscope, which shows dark bands quite different from those produced by any other oil, intercepting the light admitted to the spectroscope. The examination of blood stains in medico-legal cases calls for some color test to distinguish blood from other colored fluids. It is well known that carmine, madder, alkanet, cineraria, permanganate of potash, wine, and many other fluids often look so much like blood as to give much trouble to distinguish them.

The peculiarity of the spectrum as modified by the presence of blood has been ably described by many writers, and yet our books give only diagrams.

Chemists give attention to the spectra of gases and astronomers are spending hundreds of thousands of dollars photographing the light of the stars, and still more, photographing the corona of the sun in total eclipse of that orbit, hoping to learn more of the quality and condition of the matter composing that wonderful luminary. But the character of the lines shown in the spectra of fluids is so different from the lines shown by incandescent gases, that I have thought it might be both interesting and useful to show by photography the absorption bands of blood and other colored fluids.

In entering upon this work we are met at once by the great difficulty of photographing red light. The portrait photographer knows too well the red photographs, as blood and blue and violet appear in the photograph as almost pure white. Most colored fluids give their characteristic absorption bands in or near the red end of the spectrum, and it is well known that the so-called orthochromatic plates used by the modern photographer, while highly sensitive to blue and yellow, are almost wholly insensitive to ruby red, as it is ruby light and that only which is allowed in the dark room while developing modern dry plates.

Plates then that are sensitive to red must be developed mostly in total darkness, and that is what astronomers do in preparing photographs of the sun and stars.

Pure olive oil (Gallipole) in a tube $\frac{5}{8}$ to $\frac{3}{4}$ inch in diameter presents a dark shadow, or cutting out of the blue and violet ray with a fine almost indistinct line in the green and a strong dark band in the red.

Refined cotton-seed oil presents the same appearance as regards the blue and violet only, but the blue and the red are continuous. If cotton-seed oil is mixed with the olive oil, there is no change in the blue and violet rays, but an almost entire fading out of the delicate line in the green and considerable diminution of the dark band in the red.

With 50 per cent of cotton-seed oil the loss in intensity is considerable. With 25 per cent the variation is discernible.*

To photograph the spectrum of colored fluids, specially prepared plates are required. To sensitize the plates for the red end of the spectrum cyanine is used according to the following formula which comes to us from Germany. These plates will not retain their sensitiveness to red more than four or five days. The cyanine plates require long exposure, five or ten times as long as the same plates if not bathed in cyanine; hence fast plates are selected for this work.

Take a solution of cyanine (1 to 1000) in absolute alcohol, 6 ccm.

Codeia solution in absolute alcohol (1 to 1000), 34 ccm.

Aniline oil, chemically pure, 5 drops.

Distilled water, 960 ccm.

In this mixture bathe the plates two minutes.

Then rinse the plates one minute in alcohol, 34 ccm.;

*Chemical News, quoted in Scientific American, August 28, 1880, No. 243, p. 3874; also Olive Oil, Scientific American Supplement, June 28, 1884.

distilled water, 966 ccm. Wipe the back of the plates with filter paper and dry rapidly in the dark; using chloride of calcium to hasten the drying. If successfully prepared, these plates are sensitive to all the colors of the spectrum, from the ultra violet to the extreme red.

Figure S (Pl. XX) shows the entire length of the spectrum photographed as white of nearly uniform intensity. The solar spectrum is shown with the Fraunhofer lines sharply defined. In contrast with the Fraunhofer lines we see the absorption bands of blood (Fig. B, Pl. XX) wider, less sharply defined, and increasing in breadth as the solution is more dense. The line nearest the red, close to the line D of the solar spectrum, is more dense and more sharply defined than the second line (in the orange) which is broader and paler. Then we see the whole of the space belonging to the blue and violet is cut off by one broad absorption band produced by the blood.

Didymium sulphate (the nitrate gives the same bands), a solution in water with a slightly pinkish hue, gives two absorption bands—the first placed close to the D line in the solar spectrum, which is seen in the photograph (Fig. D, Pl. XX) as a brown shadow close to the left or red side of the first didymium line. The second didymium line, narrower and sharper than the first, lies about two-thirds of the distance from D toward E of the solar spectrum. In the blue and violet portions of the spectra of blood and didymium are seen lines produced by the carbons of the electric arc light used in producing the photographs.

Figure P (Pl. XX) shows a series of beautiful lines of varying size and intensity in the spectrum of a solution of permanganate of potash. This colored fluid produces three heavy dark absorption bands in the green and a medium band in the orange and a *very fine* line in the yellow.

It will be seen at once that many colored fluids are thus readily distinguished by the spectroscope.

L. MOLOSSEZE ON SPECTRUM OF PICROCARMINATE OF AMMONIA.*

We have long known the double absorption bands which are given by suitable solutions of alkaline carminates. I learned also from Ranvier that the picrocarminate of ammonia shows these two bands. But I did not believe that the spectra of

* Archives de Physiologie Normale et Pathologique, Paris, 1877; 23, IV, pp 40-43. Translated by M. C. White, February 29, 1884.

picrocarminate at different degrees of concentration had been sufficiently studied, or that the resemblances and differences between blood and picrocarminate in solutions had been sufficiently described.

When one examines with the spectroscope solutions of picrocarminate sufficiently concentrated, the *red* and the *orange* rays are alone transmitted. All that part of the spectrum beyond the sodium line, D, is obscured. The violet end of the spectrum is especially dark. In more dilute solutions the part previously dark is cleared up for a little distance from the line D and permits the green rays to pass. As we add still more water to the solution the dark part is cleared up still further, permitting the bluish-green (greenish-blue) to pass. There thus results to the right of D two absorption bands, the first, or the one nearest to D, narrower, while the second is the wider of the two.

Continuing to dilute the picrocarminate the two absorption bands diminish a little in extent and become paler, the first more than the second; at the same time the right or violet end of the spectrum clears up more and more. At last the absorption bands entirely disappear, the second band being the last to disappear. If we compare this series of spectra with those given by haemoglobin in similar conditions, one is struck by the great similarity in concentrated solutions either of haemoglobin or picrocarminate, the red rays only being transmitted. In dilute solutions we find to the right of the sodium line two absorption bands, the first narrow, the second wider, while the right or violet end of the spectrum remains more or less obscure. There are, however, a certain number of differences between haemoglobin and picrocarminate. In the spectrum of picrocarminate the part which first clears up when the solution is diluted little by little corresponds to the clear space which separates the two absorption bands the one from the other; the clear space which we find to the right of the two bands only appears later. In other words, the first absorption band is first separated from the dark part; the second band is separated later. In the spectra of haemoglobin, on the contrary, the part which first clears up is that which is to the right of both bands of absorption, while the bands themselves are only separated when the solution becomes more dilute. The absorption bands of picrocarminate are a little more distant from the sodium line and a little more distant from each other than that of haemoglobin. The clear space which separates the bands of picrocarminate corresponds to the second band of haemoglobin. When we continue to dilute, the solutions of picrocarminate grow pale more rapidly and it is the first band (the one nearest to the sodium line) which disappears first. The bands of haemoglobin remain longer, clear and distinct and the second band is the first to disappear. If one does not fully understand the phenomena which solutions of picrocarminate present he might say that the spectra of haemoglobin and picrocarminate are but little different from each other. The spectrum of picrocarminate is explained by that of carmine and by that of picric acid. The two absorption bands of picrocarminate appear and disappear in the same way as those of carmine. Their positions and intensities are the same. But in the spectrum of carmine the extreme right becomes clear rapidly when the solution is diluted, while it remains dark much longer in the spectrum of picrocarminate.

This obscurity is due to the presence of picric acid. The spectrum of this coloring matter is dark at the right (at the violet end) and becomes clear very slowly. The spectrum of picrocarminate is thus a true combination between the spectrum of carmine and that of picric acid.

NOTE.—At the New York meeting, when Dr. White read this paper, he was, despite advancing years, one of the most active and interested members present, participating in all the discussions with keen enjoyment. He did not have an opportunity to correct the proofs of this article before his last illness had come upon him. Consequently the reader will find no doubt that there are minor errors which have escaped the editor's notice, but which would have been rectified by the author.

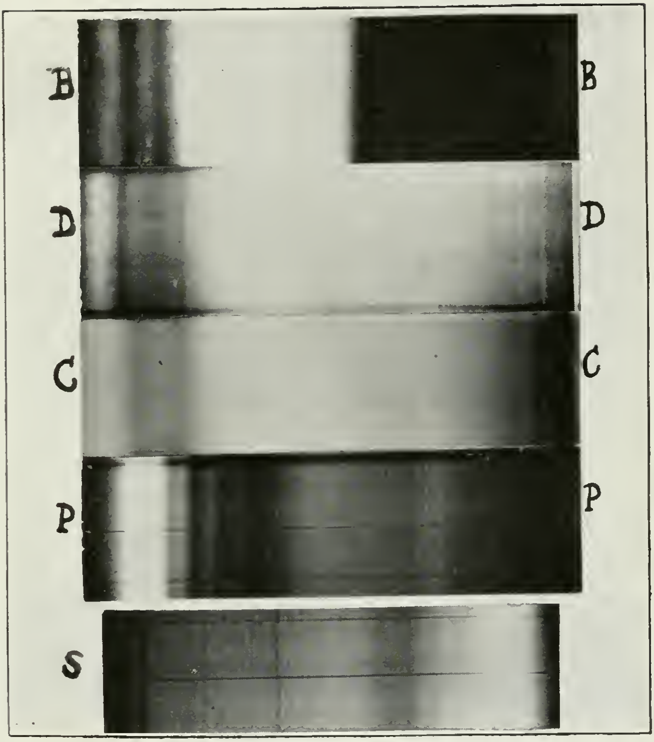
EXPLANATION OF PLATE

All figures after photographs by M. C. White.

Plate XX

B. Spectrum of Blood.
D. Spectrum of Didymium Sulphate.
C. Spectrum of Picrocarminate.
P. Spectrum of Permanganate of Potash.
S. Solar Spectrum with Fraunhofer Lines.

PLATE XX



DESCRIPTION OF A NEW GENUS OF NORTH AMERICAN WATER MITES, WITH OBSERVATIONS ON THE CLASSIFICATION OF THE GROUP

By ROBERT H. WOLCOTT

WITH ONE PLATE

I. Steganapsis nov. gen.

Diagnosis of the genus: An hydrachnid of the family Hygrobatidae, characterized by the possession of a very delicate exoskeleton in the form of a continuous open meshwork; with palpi of the character of those of *Arrenurus*, the four basal segments being stout, the fifth small and opposable to the distal end of the fourth; with epimera resembling in form and arrangement those of *Arrenurus;* with legs bearing swimming hairs; and with the genital opening guarded by valves and these in turn flanked by numerous acetabula imbedded in the wall of the body.

At first glance, and as seen from the ventral surface the species which is the type of this genus was taken for an *Arrenurus* on account of the form and relationships of the epimera, and the general character of the structures about the genital opening. This impression was strengthened by an examination of the palpi. But when turned over, the absence of the characteristic chitinous exoskeleton of *Arrenurus* with its prominent furrow, and the general appearance of the specimen as seen from the other side dispelled the illusion. A careful examination shows that it differs in many and important details from the species included in *Arrenurus*, and that it is evidently a type of a related genus, hitherto undescribed, and intermediate between the genus named and some soft-bodied form, from which perhaps that genus is descended.

The name is derived from the Greek *steganos,* covered, and *apsis*, a mesh, and is bestowed in allusion to the chitinous exoskeleton which gives to the mite, when mounted on a slide and viewed as a transparent object, a characteristic appearance.

Steganapsis arrenuroides nov. sp.

The body of the single specimen in the author's collection is of medium size and broadly elliptical in form, the width being almost precisely three-fourths of the length. It is evenly rounded at both ends, strongly convex above, moderately convex below, and flattened over the epimeral area. The hairs which it bears are long and very slender; on either side of the posterior end of the body is an extremely long and fine hair, and at its outer side a shorter one also very fine. The cuticula is marked by rather conspicuous irregular striae, and beneath it is an exoskeleton consisting of a continuous meshwork (Pl. —, Fig. 1), the openings in which are, over the body, large, practically uniform in size, and with irregular rounded outline. The epimera, the exoskeleton of the palpi and that of the legs are made up of a similar meshwork with finer meshes and with proportionately heavier trabeculae, and this diminution in size of mesh and increase in coarseness of trabeculae is, in any particular part, greater or less, apparently in direct proportion to the strength desirable. At the extreme ends of the epimera about the insertion of the legs the chitin is very thick, and without any trace of such meshes. This meshwork on surface view presents an appearance in a certain degree resembling that seen in *Arrenurus*, but the meshes contain no granular, gland-like cells such as those which occupy the goblet-shaped pores in the thick exoskeleton of that genus and of *Krendowskia*.

The eyes are large, widely separated, and close to the lateral margins of the body.

The maxillary shield is broad and relatively short, with parallel sides and evenly rounded posterior margin. The rostrum (Pl. XXI, Fig. 2, r.), rather similar to that of certain species of *Arrenurus*, is short and blunt.

The mandibles (Pl. XXI, Fig. 3) are more slender than in any species of *Arrenurus* examined, and the proximal segment tapers towards its distal end, becoming, at the articulation with the claw, of the same breadth as the claw which itself is slender and strongly curved.

The palpi (Pl. XXI, Fig. 2) are short and stout with a relatively short ventral margin, and long dorsal margin as seen in *Arrenurus*. Segment 1 is small and narrow; 2, 3, and 4 of about equal thickness, and 5 a mere claw. Segment 2 has a very convex dorsal margin and a shorter straight ventral margin. It possesses several spines, one in the middle of the dorsal margin, two short ones on the distal portion of the median surface toward the dorsal side, and three longer toward the ventral side. Segment 3 is nearly triangular with a very short ventral margin; it bears a long slender spine on the inner surface nearer the dorsal than the ventral margin. The dorsal margin of 4 is quite convex, the ventral moderately so, the distal end being a little over one-third the diameter of the proximal and bearing the claw-like distal segment. This segment 4 bears a flat keel-like expansion which begins on the ventral surface about one-third the way from the proximal end and passes around the distal end to the dorsal surface, its margin forming a rounded angle a little less than a right angle. This keel projects beyond the base of segment 5 at its outer side and bears a coarse spine on its inner surface.

The epimera (Pl. XXI, Fig. 4) form three masses, I and II on either side being approximated, and the first pair being fused along their median edges, the suture between them becoming quite obliterated posteriorly; the median posterior margin of this pair is also indistinct. The space between II and III is of moderate width and less than that separating III and IV of opposite sides. The anterior and median border of this mass forms an even curve, the posterior is straight and runs slightly backward forming a blunt angle towards the outer side. The external ends of the epimera are moderately produced and rounded.

The legs are of moderate length, only the last exceeding the length of the body and that by very little. Leg I is about two-thirds the length of IV and II and III intermediate, with III a trifle longer than II. The segments are, in II and III, in order of length 6, 4, 5, 3, 2, 1; in I, 5 is equal to 4 or even a little longer, and in IV, 4 is even longer than 6. The legs increase regularly in stoutness from I to IV, and the segments from the tip of each leg to the base. The distal segment of each leg bears a pair of small and extremely slender, sharply pointed, simple claws. Spines and hairs are numerous on the legs, and many of them extreme in their length and fineness. Legs I and II possess a clump of long slender spines at the tip of segment 2, and another at the base of 3, and two long and stouter ones at the tips of 3, 4, and 5, while other spines are few and stout. Leg III has similar spines on 2 and 3, and numerous long hairs toward the tips of 3, 4, and 5, fewer in number on 5. On IV are a great many spines at the tip of 2 and along the whole ventral surface of 3, 4, and 5, varying in length and coarseness, and a profusion of swimming hairs of extreme length and fineness. The distal ends of all segments but the basal of each leg are produced on the anterior and posterior sides, beyond the insertion of the next segment, into two processes; these on segments 2 and 3 of each leg are sharply pointed, while on 4 of each a spine is inserted into the extensor side of this process and on 5, this spine being at the tip, the process becomes bifid. This process varies on different segments but in general the anterior is more prominent than the posterior on any particular segment, and the processes on leg IV are less prominent than on the anterior legs. (See Pl. XXI, Fig. 5.)

The genital area (Pl. XXI, Fig. 4) of the specimen under observation, which is apparently a female, resembles very closely that of a female *Arrenurus*. The opening is flanked by two movable lunate valves, and beyond these numerous acetabula, occurring in an area which is in the form of a band somewhat less in width than the length of these valves, and which runs backward, upward and outward for a short distance on the sides of the body where its end is evenly rounded. These acetabula are set into the meshes in the chitinous exoskeleton. Between this tract and the posterior epimeron of either side is a gland, and posterior to the genital opening and midway between it and the end of the body is the anus.

Measurements:

Length of body, exclusive of claw....0.868 mm.
Total length of palpi (average of two).0.204 mm.
Length of leg I, exclusive of claw....0.617 mm.
Length of leg II, exclusive of claw...0.699 mm.
Length of leg III, exclusive of claw..0.729 mm.
Length of leg IV, exclusive of claw..0.908 mm.

For the single specimen in the collection of the author he is indebted to Mr. James B. Shearer, of Bay City, Michigan, who collected it at Les Chenaux Islands in northern Lake Huron, during August, 1895.

The name given is suggested by the very close superficial resemblance between this form and the females of *Arrenurus.*

II. Krendowskia ovata Wolcott

Wolcott, 1900: 181, Pl. IX, Figs. 1-7.

In material collected in Lamberton Lake near Grand Rapids, Michigan, July 22, 1898, were found six specimens of this species including four nymphs. Both the adults are males with three acetabula on either valve, and in neither is the proboscis protruded.

The nymphs (Pl. XXI, Fig. 6) are about 0.4 mm. in length, and present the broadly oval outline and the strongly convex dorsal surface of the body characteristic of the adult. The surface of the body is covered by an exoskeleton in the form of a delicate chitinous meshwork with fine meshes. There are numerous long hairs, especially long at the posterior end of the body, and a pair just within and anterior to each eye. The palpi are also similar in form to those of the adult. The epimera have much the same form and relationships except that the first two are fused in the median line and the space included between the ends of all seems to be filled in with a thin sheet of chitin. The last pair do not show the characteristic excavation toward the median end. The legs are sparingly furnished with relatively coarse spines and at the distal end of segments III, 5 and IV, 5 and IV, 6 are a few very long and very fine swimming hairs. The genital area is occupied by a chitinous plate which has in general the form of an equilateral triangle all the angles of which are truncated and rounded, and which lies with a more strongly truncated apex anteriorly and with an emarginate base posteriorly. It bears two acetabula on either side.

Thor, in a private communication, has expressed the view that this species is identical with his *Geayia venezuelae,* in which case the name should stand *Krendowskia venezuelae* (Thor).

III. Koenikea concava Wolcott

Wolcott, 1900: 190, Pl. XI, Figs. 15-22, and Pl. XII, Figs. 23, 24.

The result of recent examination of material previously unassorted, and re-examination of material collected several years ago, has been to extend the known range of this species over a wide area. Specimens are in the author's collection from the following localities:

Massachusetts: Cranberry Lake, Wood's Hole, July 28 and August 13, 1900.

Michigan: Lake St. Clair, August and September, 1893.

Susan, "26," and Twin Lakes, Charlevoix, August 6 and 21, 1894.

Reed's, Fisk's, Round, Soft-water, Lamberton, Muir's, Dean's and Power's Lakes, and Grand River, Grand Rapids, June 27, 1895, and at various dates during July and August, 1895, '96, '97, '98.

Illinois: Fox Lake, Lake County. September 17, 1894 (coll. by H. B. Ward).

Nebraska: Pond at State Fish Hatchery, South Bend, September 2, 1897.

Pond at Wayne, September 8 and 9, 1899 (coll. by Miss Caroline Stringer).

It is a pleasure to record the fact that this genus, dedicated to the author of the first paper of real value on North American hydrachnids, is not only a most attractive form but also by virtue of its wide distribution a characteristic member of our hydrachnid fauna.

IV. Tanoagnathus spinipes Wolcott

Wolcott, 1900: 194, Pl. XII, Figs. 25-28.

A second specimen of this species, collected in Lamberton Lake near Grand Rapids, Michigan, July 22, 1898, belongs to the same sex as the type specimen and agrees with it in every respect.

V. Observations on the Classification of Water Mites

Among the recent additions to the literature of the Water Mites, the papers of Thor are noteworthy. Since the work of Neuman, which culminated in his "Sveriges Hydrachnider," for many years the most pretentious work on the subject, no Scandinavian student of the group had appeared, until in 1897 Thor began a series of papers which has become both numerous and valuable, and has given us a very complete knowledge of the Norwegian hydrachnids. Among the most recent of these is a "Prodromus" (Thor, '00) in which he suggests a division of the group into fourteen families: Limnocharidae, Eylaidae, Hydryphantidae, Hydrachnidae, Lebertiidae, Sperchonidae, Limnesiidae, Hygrobatidae, Pionidae, Curvipedidae, Atacidae, Brachypodidae, Aturidae and Arrenuridae. Although these families are not characterized and the basis on which they rest is not fully apparent, the paper is interesting to a student of the group as being the first attempt to break up the Hygrobatidae—or Hygrobatinae, as one pleases —into smaller groups, an attempt induced by the rapid increase in the number of described genera. It seems to the writer, however, that in certain respects the proposed arrangement is decidedly a step backward since the families suggested do not represent groups of equivalent value, while its author seems to have passed over all that had been previously accomplished.

Even in the writings of very early writers is observable a tendency to partition the genera of Water Mites, then few in number, between groups of higher rank, and Leach (15) in 1815 recognized two families; the Eylaides with one genus, *Eylais*, and the Hydrachnides with two genera, *Hydrachna* and *Limnochares*. Koch (37), in 1842, included under the order Acari, Section 1 or Water Mites, containing forms with movable swimming hairs, two families, Hygrobatides and Hydrachnides. To the former, characterized by the possession of two eyes, he assigned the genera *Atax*, *Nesaea*, *Piona*, *Hygrobates*, *Hydrochoreutes*, *Arrenurus*, *Atractides*, *Acercus*, *Diplodontus* and *Marica*; to the latter, characterized by the presence of four eyes, *Limnesia*, *Hydrachna*, *Hydryphantes*, *Hydrodroma* and *Eylais*. Under Section 2, or Swamp Mites, containing forms with a prominent snout, he included *Limnochares*, *Thyas*, *Smaris* and *Alycus*, of which neither of the last two have been again grouped with the Water Mites until Nordenskiold's proposed arrangement, given hereafter. Kramer (77) divided the hydrachnids into four families: Hydrachnidae, with mandibles one-jointed, lancet-shaped (type *Hydrachna*); Eylaidae, with mandibles dwarfed and consisting of two hooklets (type *Eylais*); Hygrobatidae, with mandibles distinctly two-jointed, the distal claw-like (types *Nesaea* and *Arrenurus*); and Limnocharidae, with mandibles and labrum fused forming a firm capitulum (type *Limnochares*).

Haller (81a) gave to the "Hydrachnidae" the rank of a sub-order and recognized two families on the basis of the position of the eyes; Medioculatae, including *Limnochares* and *Eylais*, and Lateroculatae, including all the other genera. In 1891 Canestrini (91) raised the "Hydracarini" to the rank of an order, and included under it three families—Halacaridae, Limnocharidae and Hydrachnidae. The first, or Marine Mites, are by most authorities separated entirely from the Water Mites, while of the two other families the former is equivalent to Haller's Medioculatae, and the latter to his Lateroculatae.

Thus the matter of systematic arrangement stood, when in a later paper Kramer (93) by distinguishing clearly between three principal types of larvae, and making this the basis of his arrangement of the genera, proposed the following, which seems to the writer the first logical classification:

Order Prostigmata—

Fam. 1—Hydrachnidae (larval type I).
Fam. 2—Hygrobatidae (larval type II).
Fam. 3—Eylaidae (larval type III).
Fam. 4—Trombididae.

Piersig (97) in his great work on "Deutschlands Hydrachniden" reduced the Hydrachnidae to the rank of a family with five sub-families—Limnocharinae, Hydrachninae, Eylainae, Hydryphantinae, and Hygrobatinae. Nordenskiold (98) later canvassed very carefully the morphological and systematic relationships of the Hydrachnidae and came to the conclusion that the term Trombididae should include a number of sub-families, representing two lines of descent, to the forms included under one of which he applied the term Trombidiformes, and to the others Rhyncholophiformes. The former contains, according to him, the sub-families Trombidinae, Hydryphantinae, and Hygrobatinae on the one hand, and Eylainae and Limnocharinae on the other; the latter the Hydrachninae, Rhyncholophinae, including the genus *Rhyncholophus*, etc., and Smaridinae, including *Smaris*, *Smaridia*, etc.

From an examination of the literature accessible the opinion seems to be quite generally held among recent authors that the Water Mites as a whole form a group of higher rank than that of a family, and in the judgment of the writer this opinion is well founded. A careful consideration of the subject involving an earnest study of previously proposed arrangements and a careful weighing of the value of the characters offered by these forms has so far not led to results that the author is willing to publish as final, but the following tentative scheme is suggested to indicate the relationships of the group and its components:

Phylum—Arthropoda,

Class—Arachnoidea,

Order—Acarina,

Sub-order—Prostigmata,

- Tribe I—Trombidini,
- Tribe II—Hydracarini,
  - Fam. 1—Hydrachnidae,
  - Fam. 2—Limnocharidae,
    - Sub-fam. 1—Limnocharinae,
    - Sub-fam. 2—Eylainae,
    - Sub-fam. 3—Hydryphantinae,
  - Fam. 3—Hygrobatidae,
    - Sub-families?

It seems to the writer that no argument is necessary to explain the use of the terms above down to that of sub-order. He believes also that Kramer's position in regard to the natural character of the group Prostigmata is well taken, but it does not seem that the characters of this group are such as to be accorded more than sub-ordinal rank. The separation of this sub-order into the tribes Trombidini and Hydracarini is based on views suggested or expressed by several authors. The former is practically synonymous with Canestrini's Trombidina plus his Hoplopina, which do not seem to be co-ordinate groups, while the Halacaridae are thrown out of the Hydracarini, since as Trouessart (89) says, they seem to be intermediate between the Gamasidae and Sarcoptidae. As thus limited the Hydracarini form a well-defined and very homogeneous group, certain forms in which furnish an easy transition to the Trombidini.

The three families suggested are based on Kramer's arrangement, and are separated not only by characteristic larval types but also by structural characters of the adult, especially such as relate to the form and relationships of the mouthparts. The sub-families of the Limnocharidae are also based on both larval and adult characters. As to the possibility of further division of the Hygrobatidae on characters that are essential or natural the author at this time reserves his opinion. He would, however, present for consideration the following propositions:

1. The tribe Hydracarina as defined above is polyphyletic in origin as evidenced by the wide difference between the three larval types.

2. The uniformity of conditions under which the species exist has led to a great similarity of structure among adults.

3. The group becomes thus both sharply limited and very homogeneous.

4. The characters of the early stages reveal more of the phylogenetic relationship than do those of the adult.

5. On the other hand, owing to the same uniformity of conditions the forms are unusually conservative, and specimens from widely separated regions and very different localities show practically no variation.

6. The structural characters presented by the adult may in consequence be accepted as possessing a maximum value in classification.

8. In the division of the tribe into families and then into sub-families the natural grouping of the genera must depend on the characteristics of the larvae, to which should be added in the definition of the group the common structural characters of the adult.

Certain facts brought out in the study referred to earlier in this paper support these views. The genus *Koenikea* illustrates very well the constancy of the forms. Specimens collected in a small shallow pond (Cranberry Lake, Wood's Hole, Mass.) nowhere over two feet deep, and covering an area of but an acre or two, and lying out on a peninsula with a bluff on the one hand and on the other the Atlantic Ocean, from which it is separated by a narrow strip of sand; others from a lake (Lake St. Clair, Mich.) covering over 400 square miles and with a very uniform depth over the center of about 20 feet; others from lakes (near Grand Rapids, Mich.) of half a mile to a mile and a half in diameter, and 60 to 80 feet in depth; others from a small artificial pond (South Bend, Nebr.) separated by 1,500 miles from the first locality named; others from a narrow prairie slough (Wayne, Nebr.) the remnants of a former creek bed; and still others from among the reeds and rushes in a rapidly flowing river (Grand River, Mich.)—all are on careful examination quite indistinguishable, and altogether nearly 100 specimens have been examined without the detection of an appreciable variation.

The homogeneous character of the group must be evident to every student of these forms, at least if his experience be similar to that of the writer, who approached the study of them quite unprepared for the wonderful variety exhibited by the details of structure which have become apparent after careful examination, where at first on superficial examination all looked practically alike.

The temptation is strong to continue these observations on the classification of the forms with which we are dealing, but further discussion concerning the more comprehensive groups and a consideration of the basis upon which the genera in the group should rest is withheld, to be published in another paper.

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EXPLANATION OF PLATE

All figures drawn with the aid of a camera lucida—but in Figs. 1 and 3 only certain dimensions thus secured, the rest sketched by eye.

Plate XXI

All but Fig. 6, of *Steganapsis arrenuroides* nov. sp.

Fig. 1. A portion of the meshwork formed by the exoskeleton, from near the base of one of the palpi and showing the opening of a gland. × about 375.

Fig. 2. The palpi and rostrum (r.). × 250.

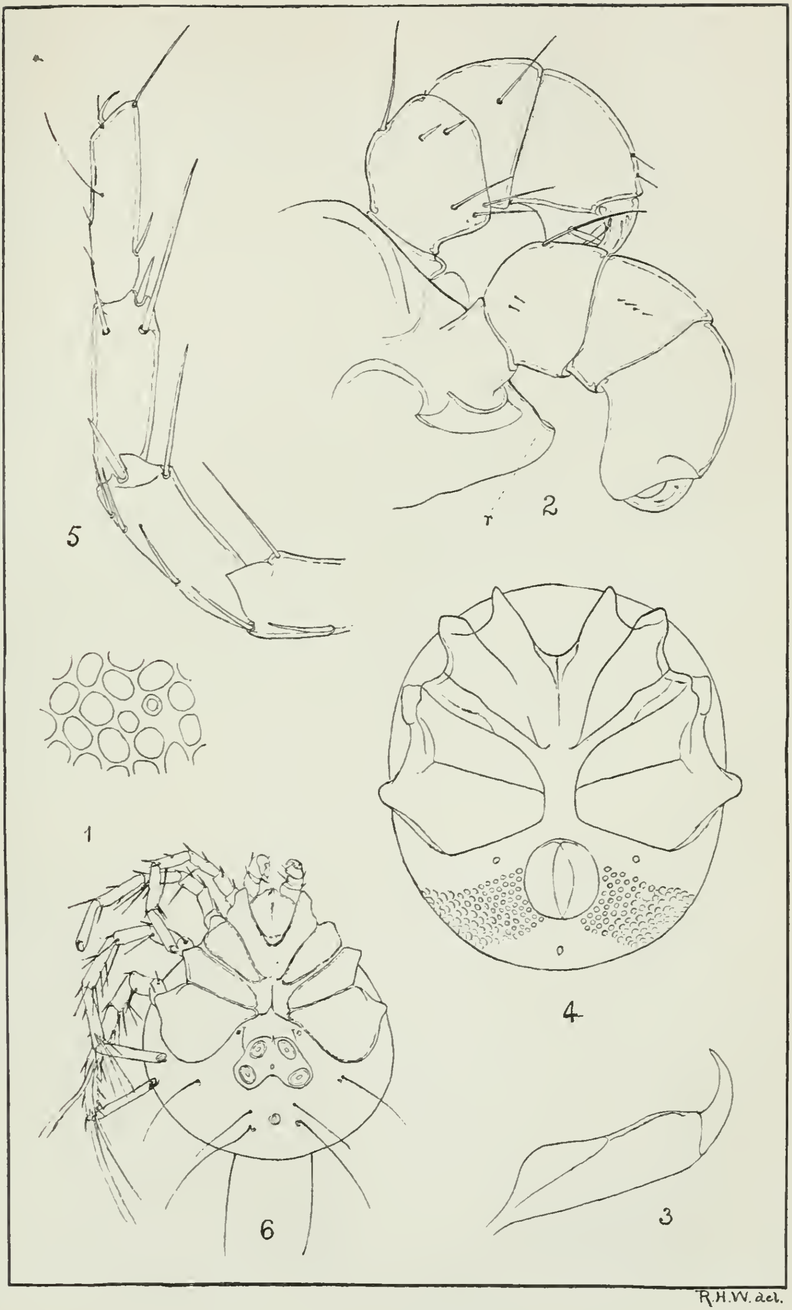
Fig. 3. The right mandible. × 250.

Fig. 4. The epimeral and genital areas, drawn from the preserved specimen before being dissected and the parts mounted on a slide. × 60.

Fig. 5. Anterior side of distal segments of the left fore leg. × 192.

Fig. 6. Ventral view of the nymph of *Krendowskia ovata* Wolc. × 75.

PLATE XXI



R.H.W. del.

THE CLADOCERA OF NEBRASKA*

By CHARLES FORDYCE, Nebraska Wesleyan University

WITH FOUR PLATES

INTRODUCTION

In the fall of 1895 the writer began a study of the Cladocera of Nebraska; the work on this group has continued with increasing interest for a period of five years, with such results as may be found in this paper, which has been prepared in connection with a course of graduate study in the Department of Zoology in the University of Nebraska and accepted by the Faculty, June, 1900, as a thesis for the degree of Doctor of Philosophy.

Gratitude is due Dr. R. H. Wolcott and Miss Caroline E. Stringer for several bottles of material received from them, and the writer would express his most grateful acknowledgments to his friend Dr. H. B. Ward, of the University of Nebraska; for it was through his influence and kind personal guidance that the task has been pursued and finally completed.

METHODS

The material was obtained partly with the Birge net and partly by the use of a small plankton pump which was devised by the writer during the early part of his work, Fordyce (98). It has proved to be a very valuable piece of collecting apparatus as it enables one to collect in many places inaccessible to the ordinary net, and by means of it both the qualitative and quantitative value of the collections may be ascertained as well as the vertical distribution of the fauna.

The material is preserved partly in formalin, partly in alcohol and partly in a solution consisting of:

Glycerine	2 parts by vol.
Distilled water....................	3 parts by vol.
Glacial acetic acid................	2 parts by vol.
Absolute alcohol	1 part by vol.

* Studies from the Zoological Laboratory, The University of Nebraska, under the direction of Henry B. Ward, No. 42.

This latter solution, recommended for water mites by Koenike (91), allows both form and color to deteriorate, but prevents hardening of the tissues, rendering them more favorable for dissection, especially for external work. It has proved also to be a valuable solution for specimens designed for permanent mounting on slides. For the preservation of form and color, the formalin proved decidedly preferable.

Many methods of fixing, staining and mounting have been tried, but the best results are found in transferring from Koenike's solution to picro-sulphuric acid, washing in 70% alcohol, staining in Mayer's alcoholic cochineal, dehydrating, clearing and mounting in balsam.

HISTORICAL

Until a quarter of a century ago the Cladocera were practically unknown in this country and not till near the close of the preceding century did fresh water investigations yield sufficient data for a systematic treatise on these entomostraca even in the old world.

Jules Richard (94 and 96) gives a bibliography that contains a very extensive list of the literature showing what has been done on this group not only in Europe but in most other countries. It will, therefore, be needless in this article to refer to any literature aside from that concerning itself with the work done in our own country. S. I. Smith (74) in his Sketch of the Invertebrate Fauna of Lake Superior opens American literature on this subject. In this article Smith reports five species:

Eurycercus lamellatus Mueller.
Leptodora hyalina Lilljeborg.
Daphnia pulex De Geer.
Daphnia galeata Sars.
Daphnia pellucida Mueller.

There were no further contributions for several years when Chambers (77) reported five species one of which was new; in the order given, the first two were from Colorado, and the remaining three from Kentucky:

Chydorus sphaericus Mueller.
Daphnia brevicauda n. sp.
Daphnia pulex De Geer.
Daphnia mucronata Mueller.
Moina branchiata Jurine.

E. A. Birge (78) contributes his first list of thirty-eight species, largely from Madison, Wisconsin. This contribution is remarkable for the number of forms new to science, there being twenty new species, one new genus and one new variety, as indicated in the subjoined list:

Sida crystallina O. F. Mueller.
Daphnella exspinosa sp. nov.
Moina brachiata Jurine.
Ceriodaphnia dentata sp. nov.
Ceriodaphnia consors sp. nov.
Ceriodaphnia cristata sp. nov.
Simocephalus americanus sp. nov.
Simocephalus vetulus O. F. Mueller.
Scapholeberis mucronata (?) O. F. Mueller.
Scapholeberis nasuta sp. nov.
Daphnia pulex De Geer, var. denticulata, var. nov.
Daphnia levis sp. nov.
Lathonura rectirostris O. F. Mueller.
Macrothrix rosea Jurine.
Bosmina longirostris O. F. Mueller
Bosmina cornuta Jurine.
Eurycercus lamellatus O. F. Mueller.
Pleuroxus procurvus sp. nov.
Pleuroxus straminius sp. nov.
Pleuroxus insculptus sp. nov.
Pleuroxus denticulatus sp. nov.
Pleuroxus unidens sp. nov.
Pleuroxus hamatus sp. nov.
Pleuroxus acutirostris sp. nov.
Chydorus sphaericus O. F. Mueller.
Chydorus globosus Baird.
Crepidocercus setiger sp. nov.
Graptoleberis inermis sp. nov.
Alona angulata sp. nov.
Alona porrecta sp. nov.
Alona glacialis sp. nov.
Alona spinifera Schoedler.
Alona oblonga P. E. Mueller.
Alona tuberculata Kurz.
Alonopsis media sp. nov.
Acroperus leucocephalus Koch.
Camptocercus macrurus O. F. Mueller.
Polyphemus pediculus De Geer.

S. A. Forbes (78) lists among fish foods of the Illinois River seven species:

Leptodora hyalina Lillj.
Eurycercus lamellatus Mueller.
Bosmina sp. (?)
Daphnia angulata Say.
Ceriodaphnia angulata Forbes.
Daphnia pulex De Geer.
Daphnia galeata Sars.

C. L. Herrick (79) gives without reference to geographic distribution a few interesting notes on the genera *Daphnia*, *Sida*, *Ceriodaphnia*, *Polyphemus*, *Bosmina* and *Eurycercus*. A year later Birge (81) adds in his notes on the Crustacea of the Chicago Water Supply a full description of *Latona setifera* mentioning the points in which his specimen differs from the European species.

Herrick (82) describes the development of *Daphnia magna* and *D. pulex* and speaks of the importance of Cladocera as agencies in purifying stagnant waters; in his second article (82a) he deals with a new genus, *Lyncodaphnia*, giving a figure and description of the species *L. macrothroides*, his representative of this new genus.

In still another article (82b) Herrick reports among the crustacea of the fresh waters of Minnesota twenty-four forms; three of these, as indicated below, are new species, one is a new variety and two are undetermined:

Daphnella brachyura Liev.
Sida crystallina Mueller.
Moina rectirostris Jurine.
Daphnia pulex De Geer.
Daphnia sp. (?)
Scapholeberis mucronata Mueller.
Scapholeberis armata, var. (?) n.
Bosmina longirostris Mueller.
Bosmina cornuta Jurine.
Bosmina striata n. sp.
Macrothrix tenuicornis Kurz.
Hyocryptus spinifer n. sp.
Lyncodaphnia macrothroides Herrick.
Eurycercus lamellatus Mueller.
Leydigia quadrangularis Leydig.
Camptocercus macrurus Baird.
Camptocercus rotundus n. sp.
Acroperus sp. (?)
Pleuroxus procurvus Birge.
Pleuroxus unidens Birge.
Graptoleberis inermis Birge.
Crepidocercus setiger Birge.
Alona oblonga P. E. Mueller.
Polyphemus pediculus De Geer.

Somewhat later (84) Herrick produced an extensive and valuable article in which he gives a complete synopsis of the species known at that time in North America. This article is enriched by twenty-three plates and the addition of the following new forms:

Ceriodaphnia scitula n. sp.
Simocephalus rostratus n. sp.
Daphnia pulex, var. nasutus, var. n.
Daphnia minnehaha n. sp.
Daphnia magniceps n. sp.
Alona modsta n. sp.
Alona glacialis, var. tuberculata, var. n.
Alona glacialis, var. laevis, var. n.
Alonella pulchella n. sp.
Pleuroxus affinis n. sp.
Polyphemus stagnalis n. sp.

C. M. Vorce (81) lists from Lake Erie *Bosmina longirostris* Mueller and *Daphnia pulex* De Geer, and later (82) he reports from the same lake *Chydorus sphaericus* Mueller and an undetermined species of *Daphnia*.

L. M. Underwood (86) gives one of the most serviceable contributions in our literature; it is a list indicating the distribution of the Cladocera then known in the United States, with references to American and foreign literature bearing upon these species; his list embraces 137 species, distributed as follows:

ALABAMA

Pseudosida bidentata Herrick.
Moina rectirostris Baird.
Ceriodaphnia alabamensis Herrick.
Scapholeberis angulata Herrick.
Scapholeberis armata Herrick.
Simocephalus daphnoides Herrick.
Daphnia pulex De Geer
Leydigia quadrangularis Kurz.
Pleuroxus affinis Herrick.
Pleuroxus denticulatus Birge.
Pleuroxus hamatus Birge.
Pleuroxus unidens Birge.

COLORADO

Daphnia brevicauda Chambers.
Chydorus sphaericus Baird.

ILLINOIS

Daphnia hyalina Leydig.
Daphnia retrocurva Forbes.

KENTUCKY

Daphnia brevicauda Chambers.
Daphnia hyalina Leydig.
Chydorus sphaericus Baird.

MASSACHUSETTS

Sida crystallina Mueller.
Daphnella brachyura Baird.
Latona setifera Strauss.
Ceriodaphnia cristata Birge.
Daphnia pulex De Geer.
Bosmina cornuta Baird.
Bosmina longirostris Baird.
Acroperus leucocephalus Schoedler.
Camptocercus macrurus Baird.
Graptoleberis testudinaria Kurz.
Alona angulata Birge.
Alona glacialis Birge.
Alona parvula Herrick.
Alona porrecta Birge.
Alona spinifera Schoedler.
Alonella excisa Kurz.
Pleuroxus acutirostris Birge.
Pleuroxus denticulatus Birge.
Pleuroxus hamatus Birge.
Pleuroxus procurvus Birge.
Pleuroxus stramineus Birge.
Chydorus sphaericus Baird.
Polyphemus pediculus Linn.

MINNESOTA

Sida crystallina Mueller.
Daphnella brachyura Baird.
Moina rectirostris Baird.
Ceriodaphnia cristata Birge.
Ceriodaphnia laticaudata Mueller.
Ceriodaphnia parvula Herrick.
Ceriodaphnia scitula Herrick.
Scapholeberis americanus Birge.
Simocephalus vetulus Schoedler.
Daphnia dubia Herrick.
Daphnia galeata Sars.
Daphnia hyalina Leydig.
Daphnia kalbergensis Schoedler.
Daphnia magniceps Herrick.
Daphnia minnehaha Herrick.
Daphnia pulex De Geer.
Daphnia rosea Sars.
Bosmina cornuta Baird.
Bosmina longirostris Baird.
Bosmina striata Herrick.
Macrothrix pauper Herrick.
Macrothrix tenuicornis Kurz.
Lathonura rectirostris Lillj.
Lyncodaphnia macrothroides Herrick.
Ilyocryptus spinifer Herrick.
Eurycercus lamellatus Baird.
Camptocercus macrurus Baird.
Camptocercus rotundus Herrick.
Alonopsis latissima Kurz.
Alonopsis media Birge.
Leydigia acanthocercoides Kurz.
Graptoleberis testudinaria Kurz.
Crepidocercus setiger Birge.
Alona affinis Schoedler.
Alonella pulchella Herrick.
Alonella pygmaea Kurz.
Pleuroxus denticulatus Birge.
Pleuroxus procurvus Birge.
Chydorus caelatus Schoedler.
Chydorus globosus Baird.
Chydorus sphaericus Baird.
Monospilus dispar Sars.
Polyphemus pediculus De Geer.

MISSISSIPPI

Scapholoberis angulata Herrick.
Simocephalus americanus Birge.
Simocephalus rostrata Herrick.

PENNSYLVANIA

Daphnia abrupta Haldeman.
Daphnia reticulata Haldeman.

WISCONSIN

Daphnia crystallina Mueller.
Moina rectirostris Baird.
Ceriodaphnia consors Birge.
Ceriodaphnia cristata Birge.
Scapholeberis aurata Birge.
Simocephalus americanus Birge.
Simocephalus vetulus Schoedler.
Daphnia kerusses Cox.

Daphnia pulex Claus.
Bosmina longirostris Baird.
Macrothrix rosea Baird.
Acroperus leucocephalus Schoedler.
Camptocercus macrurus Baird.
Graptoleberis testudinaria Kurz.
Crepidocercus setiger Birge.
Alona oblonga Mueller.
Alona porrecta Birge.
Alona spinifera Schoedler.
Alonella excisa Kurz.
Pleuroxus denticulatus Birge.
Pleuroxus procurvus Birge.
Pleuroxus unidens Birge.
Chydorus globosus Baird.
Chydorus sphaericus Baird.

LAKE SUPERIOR

Daphnia galeata Sars.
Daphnia hyalina Leydig.
Daphnia pulex Claus.
Eurycercus lamellatus Baird.
Leptodora hyalina Lillj.

LAKE MICHIGAN

Sida crystallina Mueller.
Holopendium gibberum Zaddach.
Daphnia hyalina Leydig.
Camptocercus macrurus Baird.
Pleuroxus denticulatus Birge.
Chydorus sphaericus Baird.
Leptodora hyalina Lillj.
Latona setifera Strauss.

EASTERN UNITED STATES

Scapholeberis mucronata Schoedler.

SOUTHERN UNITED STATES

Daphnia angulata Say.
Daphnia rotundata Say.

Forbes (86) gives a full description of *Leptodora hyalina* caught at Chautauqua Lake, New York, and in other articles (88, 88a) in the reports of the Illinois State Laboratory of Natural History adds valuable notes on Cladocera among the foods of fresh water fishes.

C. S. Fellows (88) reports from Lake Chautauqua, New York, the following six forms:

Leptodora hyalina Lillj.
Daphnella brachyura Liev.
Chydorus sphaericus Mueller.
Bosmina longirostris Mueller.
Ceriodaphnia sp. (?)
Daphina sp. (?)

Forbes (90) gives a complete diagnosis of the new species *Chydorus rugulosus* and reports from Lake Superior the following sixteen species:

Polyphemus pediculus L.
Leptodora hyalina Lillj.
Eurycercus lamellatus O. F. M.
Acroperus leucocephalus Koch.
Alona sp. (?)
Pleuroxus procurvus (?) Birge.
Chydorus sphericus Baird.
Chydorus rugulosus n. sp.
Chydorus globosus Baird.
Bosmina longirostris O. F. M.
Scapholeberis mucronata O. F. M.
Daphnia retrocurva Forbes, var. intexta.
Daphnia laevis Birge.
Daphnella brachyura Lievin.
Sida crystallina O. F. M.
Holopedium gibberum Zaddach.

E. A. Birge (91) reports sixty-four species, representing the collections made from Madison, Wisconsin, since 1878, three of these as indicated in the following list being new to science:

Holopedium gibberum Zad.
Sida crystallina O. F. M.
Daphnella brachyura Liev.
Daphnella brandtiana Fisch.
Latona setifera O. F. M.
Latonopsis occidentalis sp. nov.
Moina brachiata Jur.
Moina sp. nov.
Simocephalus vetulus O. F. M.
Simocephalus serrulatus Koch.
Ceriodaphnia megops Sars.
Ceriodaphnia reticulata Jur.
Ceriodaphnia pulchella Sars.
Ceriodaphnia consors Birge.
Scapholeberis aurita Fisch.
Scapholeberis obtusa Schdl.
Scapholeberis mucronata O. F. M.
Daphnia pulex De Geer.
Daphnia schoedleri Sars.
Daphnia minnehaha Herrick.
Daphnia hyalina Leydig.
Daphnia kalbergensis Schoedler.
Daphnia kalbergensis, var. retrocurva Schdl.
Daphnia kalbergensis, var. retrocurva Forbes.
Lathonura rectirostris O. F. M.
Macrothrix rosea Jur.
Macrothrix laticornis Jur.
Drepanothrix dentata Euren.
Ophryoxus gracilis Sars.
Ilyocryptus sordidus Lieven.
Ilyocryptus longiremis Sars.
Bosmina longirostris O. F. M.
Bosmina longicornis Schoedler.
Bosmina cornuta Jur.
Bosmina bohemica Hellich. (?)
Eurycercus lamellatus O. F. M.
Leydigia quadrangularis Leydig.
Alona quadrangularis O. F. M.
Alona affinis Leydig.
Alona lineata Fischer.
Alona guttata Sars.
Alona costata Sars.
Alona tenuicaudis Sars.
Alona lepida sp. nov.
Graptoleberis testudinaria Fischer.
Dunhevedia (Crepidocercus) setiger Birge.
Pleuroxus trigonellus O. F. M.
Pleuroxus denticulatus Birge.
Pleuroxus gracilis Hudendorff, var. unidens Birge.
Pleuroxus exiguus Lillj.
Pleuroxus excisus Fischer.
Pleuroxus procurvatus Birge.
Chydorus sphaericus O. F. M.
Chydorus sphaericus, var. caelatus Schdl.
Chydorus sphaericus, var. punctatus Hellich.
Chydorus globosus Baird.
Alonopsis latissima Kurz.
Alonopsis media Birge.
Acroperus leucocephalus Koch.
Camptocercus macrurus O. F. M.
Camptocercus rectirostris Schdl.
Camptocercus biserratus Schdl.
Polyphemus pediculus De Geer.
Leptodora hyalina Lillj.

During the same year Vorce (91) gives a complete description of his new species *Daphnella tuckermanni.*

C. Turner (92 and 93) reports from Cincinnati, Ohio, the following fifteen species with references to American literature descriptive of these forms:

Sida crystallina Mueller.
Moina paradoxa Weismann.
Scapholeberis mucronata Mueller.
Simocephalus vetulus Mueller.
Daphnia pulex De Geer.
Alona porrecta Birge.
Alona glacialis Birge.
Alona intermedia Sars.
Pleuroxus denticulatus Birge.
Pleuroxus hamatus Birge.
Chydorus sphaericus Mueller.
Bosmina cornuta Jurine.
Camptocercus macrurus Mueller.
Leydigia quadrangularis Leydig.
Dunhevedia setiger Birge.

Forbes (93) reports among the fish foods from the Yellowstone National Park, Wyoming, and from the Flathead Region of Montana twenty-one species, among these there are, as shown in the list appended, four new species and one new variety:

Alona sp. (?)
Bosmina longirostris Mueller.
Ceriodaphnia reticulata Jur.
Chydorus sphaericus O. F. M.
Daphnella brachyura Liev.
Daphnia angulifera (?)
Daphnia arcuata n. sp.
Daphnia clathrata n. sp.
Daphnia dentata Mantile.
Daphnia dentifera n. sp.
Daphnia pulex De Geer.
Daphnia pulex, var. pulicaria n. var.
Daphnia schoedleri Sars.
Daphnia thorata n. sp.
Eurycercus lamellatus O. F. M.
Holopedium gibberum Zad.
Leptodora hyalina Lillj.
Macrothrix sp. (?)
Polyphemus pediculus De Geer.
Scapholeberis mucronata O. F. M.
Sida crystallina O. F. M.
Simocephalus vetulus O. F. M.

Birge (93) enlarges his list from Wisconsin to eighty-four species; the following twenty are not found in the list from Madison, Wisconsin (Birge, 91); among these, four, as indicated, are new:

Simocephalus exspinosus Koch.
Ceriodaphnia quadrangula Sars
Ceriodaphnia lacustris sp. nov.
Bunops scutifrons sp. nov.
Streblocerus serricaudatus Fischer.
Acantholeberis curvirostris O. F. M.
Alona falcata Sars.
Alonella rostrata Koch.
Monospilus tenuirostris Fischer.
Pleuroxus nanus Baird.
Pleuroxus hastatus Sars.
Anchistropus minor sp. nov.
Chydorus rugulosus Forbes.
Chydorus faviformis sp. nov.
Acroperus angustatus Sars.
Moina affinis Birge.
Moina flagellata Hudendorff.
Daphnia microcephala Sars.
Daphnia longiremis Sars.
Camptocercus biserratus Schdl.

Birge (94) reports from Lake St. Clair, Michigan, the following thirty-four species and varieties, none being new:

Holopedium gibberum Zad.
Sida crystallina O F. M.
Daphnella brachyura Liev.
Latona setifera O. F. M.
Daphnia pulex De Geer, var. pulicaria Forbes.
Daphnia hyalina Leyd.
Daphnia kahlbergensis Schdlr., var. retrocurva Forbes.
Daphnia kahlbergensis, var. intexta Forbes.
Simocephalus serrulatus Koch.
Simocephalus vetulus O. F. M.
Ceriodaphnia lacustris Birge.
Scapholeberis mucronata O. F. M.
Ilyocryptus longiremis Sars.
Ophryoxus gracilis Sars.
Bosmina longirostris O. F. M.
Bosmina longispina Leyd.
Eurycercus lamellatus O. F. M.
Camptocercus rectirostris Schdlr.
Acroperus leucocephalus Koch.
Alona lineata Fisch.
Alona guttata Sars.
Alona affinis Leyd.
Alona sp. (?)
Alonella rostrata Koch.
Graptoleberis testudinaria Fisch.
Monospilus tenuirostris Fisch.
Pleuroxus denticulatus Birge.
Pleuroxus procurvatus Birge.
Pleuroxus nanus Baird.
Pleuroxus gracilis Hud., var. unidens Birge.
Chydorus sphaericus O. F. M.
Chydorus globosus Baird.
Polyphemus pediculus De Geer.
Leptodora hyalina Lillj.

Birge (95-97) gives an extensive and invaluable article on the vertical distribution of Cladocera. L. S. Ross (96) furnishes preliminary notes on the Entomostraca of Iowa and reports the following twenty-five species:

Sida crystallina O. F. M.
Daphnella brachyura Liev.
Simocephalus vetulus O. F. M.
Simocephalus serrulatus Koch.
Ceriodaphnia reticulata Jur.
Ceriodaphnia consors Birge.
Ceriodaphnia lacustris Birge.
Scapholeberis mucronata O. F. M.
Scapholeberis obtusa Schdl.
Daphnia hyalina Leydig.
Daphnia kahlbergensis Schoedler.
Daphnia kahlbergensis, var. retrocurva Forbes.
Daphnia sp. (?)
Macrothrix laticornis Jur.
Ilyocryptus sordidus Lieven.
Eurycercus lamellatus O. F. M.
Alona sp. (?)
Dunhevedia setiger Birge.
Pleuroxus denticulatus Birge.
Pleuroxus procurvatus Birge.
Chydorus sphaericus O. F. M.
Chydorus globosus Baird.
Leydigia quadrangularis Leyd.
Camptocercus rectirostris Schdl.
Leptodora hyalina Lillj.

Next Herrick and Turner (95) produced their monograph on the Entomostraca of Minnesota. This is the most extensive American contribution to Cladoceran literature, aiming to give diagnoses of all species previously reported from the United States. These diagnoses are accompanied by forty-one full paged plates. The volume contains descriptions and figures of the new species, *Daphnia exilis*, *Daphnia minnesotensis*, *Macrothrix nova-mexicana* and numerous European forms not yet found in this country.

Two years later Ross (97) describes a new species, *Ceriodaphnia acanthinus*, and reports the following twenty-nine other known species and varieties, all from the province of Manitoba, Canada:

Simocephalus vetulus O. F. Mueller.
Simocephalus serrulatus Koch.
Scapholeberis angulata Herrick.
Scapholeberis mucronata O. F. Mueller.
Eurycercus lamellatus O. F. Mueller.
Alona costata Sars.
Daphnia pulex, var. pulicaria, Forbes.
Lathonura rectirostris O. F. Mueller.
Macrothrix laticornis Jurine.
Bunops scutifrons Birge.
Sida crystallina O. F. Mueller.
Ceriodaphnia reticulata Jurine.
Pleuroxus procurvus Birge.
Pleuroxus excisus Fischer.
Pleuroxus sp. (?)
Acroperus leucocephalus Koch.
Polyphemus pediculus Linn.
Dunhevedia setiger Birge.
Pleuroxus denticulatus Birge.
Chydorus globosus Baird.
Alonopsis latissima, var. media, Birge.
Bosmina longirostris O. F. Mueller.
Alona quadrangularis O. F. Mueller.
Camptocercus rectirostris Schoedler.
Daphnia pulex De Geer.
Ilyocryptus sp. (?)
Chydorus sphaericus O. F. Mueller.
Graptoleberis testudinaria, var. inermis, Birge.
Leptodora hyalina Lilljeborg.

In the same year Ross (97a) adds to his previous list from Iowa (Ross, 96) six species, making a total of thirty-one species from that state; one of these as shown below is new to science:

Daphnia pulex De Geer.
Daphnia hybus n. sp.
Bosmina longirostris O. F. Mueller.
Pleuroxus exiguus Lilljeborg.
Alona guttata Sars.
Graptoleberis testudinaria, var. inermis, Birge.

Most of the literature mentioned in the preceding pages is in the form of brief articles found in pamphlets or government reports difficult of access. Not only are many of these contributions unavailable, but examination shows that some of them contain errors; in many instances the diagnoses are indefinite and unaccompanied by figures, and in some cases even the figures furnished do not harmonize with the descriptions. Incomplete as this literature is it has yet proved invaluable to the writer in his attempt to add a little to the work done in this country on the Cladocera.

The author acknowledges his indebtedness to Jules Richard, whose excellent synopsis of the entire suborder, with the clear-cut treatise and accurate figures on the families Sididae, Holopedidae and Daphnidae, has proved indispensable.

DISTRIBUTION IN NEBRASKA.

The literature cited shows but little work done on the Cladocera west of the Mississippi River, and so far as the author can learn from but two of the states bordering on Nebraska, viz., Iowa and Colorado, are Cladocera reported as found among their plankton organisms. Nebraska, located in the center of a great continent and remote from all large bodies of water, has been regarded as a field unfavorable to an extensive or varied aquatic fauna; investigation, however, shows its waters comparatively rich in faunal life. The state presents a great diversity in topography, soils, water supply and general surface conditions that tend to modify the life within its borders. The surface slopes to the southeast, giving the rivers a corresponding direction. An average altitude of 5,000 feet at the west end of the state and 1,000 at the east end gives these rivers a rapid current. Besides six important rivers, there are more than one hundred surveyed lakes which, were it not for the entrance of other factors, would, under our favorable climatic conditions, doubtless give us a plankton of fair volume and variety; but the waters are rapidly picked up and transported from our borders by dry winds that almost constantly prevail. As a result, many of our lakes are but temporary, thus limiting the conditions of aquatic life.

The soil of Nebraska is pre-eminently sandy, the sand varying all the way from a coarse quality in the eastern part of the state to silt in the southwest. In the central portion the loose sand shifts about, constituting the great Sand Hill region. The soil contains but little clay; in the eastern section of the state the boulder clays form a fair per cent, while in the western portion the clays are rich in lime and other minerals, forming the Marl region.

The character of the soil divides the surface into an Eastern or Drift region, a Central or Sand Hill region, a Southern or Loess region and a Western or Marl region (see map, Pl. XXIV). Each of these four regions, diversified by elevation, rainfall, evaporation, soil, etc., is characterized by a faunal life more or less peculiar to itself. The rivers, turbid with eroded soils which are held in suspension, flow rapidly along their valleys and deposit by overflows numerous lakes and bayous; from these bodies of standing water the collections have all been taken, for Cladocera are unable to withstand the strong, silt-laden currents of our rivers. The material has been collected from fifty-eight different stations indicated in the map (Pl. XXV). These stations, as indicated, are widely separated and many of them difficult of access, in consequence of which one visit only has been made to some of these points, a fact much to be regretted as frequent visits to other stations reveal not only interesting instances of seasonal polymorphism, but such seasonal changes in species and even in genera as to make it clear that the only means by which one can investigate the complete fauna of a station is to study the results of numerous collections that extend well through the various seasons of the year.

The collections were made mainly in the summer and autumn months, although many stations have been visited as well in the winter and spring. Of the fifty-eight stations from which the material was collected, thirty-six are located in the Eastern or Drift region, eleven in the Loess region, six in the Sand Hill region and five in the Marl region. The following families of Cladocera have been found at these stations: Sididae, Daphnidae, Lyncodaphnidae, Bosminidae and Lynceidae. It is a remarkable fact that there have been found no representatives of either Holopedidae or Leptodoridae and that Lyncodaphnidae are found only at one station, while their near relatives, Lynceidae and Daphnidae, are quite generally distributed. The following table shows the distribution of the families at the various stations in the four regions of our state:

1. Eastern or Drift Region with 36 stations—

Sididae found in	10 stations
Daphnidae found in	20 stations
Lyncodaphnidae found in	1 station
Bosminidae found in	10 stations
Lynceidae found in	19 stations

2. Southern or Loess Region with 11 stations—

Sididae found in	6 stations
Daphnidae found in	9 stations
Lyncodaphnidae	absent
Bosminidae found in	2 stations
Lynceidae found in	3 stations

3. Central or Sand Hill Region with 6 stations—

Sididae	absent
Daphnidae found in	3 stations
Lyncodaphnidae	absent
Bosminidae	absent
Lynceidae found in	4 stations

4. Western or Marl Region with 5 stations—

Sididae	absent
Daphnidae found in	3 stations
Lyncodaphnidae	absent
Bosminidae	absent
Lynceidae found in	3 stations

It will be observed that the family Sididae is represented in sixteen of the fifty-eight stations, Lynceidae in twenty-nine, Daphnidae in thirty-five, Bosminidae in twelve and Lyncodaphnidae in only one; the cosmopolities, Daphnidae and Lynceidae, are found in all four regions, and these are the only families yet found in the regions designated as the Sand Hills and the Marl region. A reference to the subjoined table shows that there are comprised in Nebraska under these families seventeen genera and twenty-six species; the distribution of which so far as thus ascertained is given in the table, pp. 132, 133.

The twenty-six species in the following table are distributed as follows:

Sididae, 2.
Daphnidae, 8.
Lyncodaphnidae, 1.
Bosminidae, 3.
Lynceidae, 12.
Total of 26.

Of this number all are new to Nebraska and the following are new to science:

Daphnia parvula
Bosmina ornamenta.
Leydigia fimbriata.

Pleuroxus truncatus is new to the United States and the following are rare in this country:

Macrothrix tenuicornis Mueller.
Dunhevedia setiger Birge.
Bosmina obtusirostris Sars.
Daphnia curvirostris Eyl.
Chydorus rugulosus Forbes.

Unfortunately there is little opportunity for comparing the Cladocera of Nebraska with those of adjoining states, as literature contains little reference to work done on this group in these states. Ross has furnished thirtytwo species from Iowa and Chambers reports two species from Colorado as shown in previous pages, but there seems to have been nothing done on the group in other states bordering on ours.

Of the twenty-six species found thus far in Nebraska the following named twelve only, as shown in preceding pages, have been reported from Iowa:

Sida crystallina Mueller.
Diaphanosoma brandtianum Sars.
Daphnia pulex De Geer.
Scapholeberis mucronata Mueller.
Simocephalus vetulus Mueller.
Bosmina longirostris Mueller.
Eurycercus lamellatus Mueller.
Graptoleberis testudinaria Fischer.
Dunhevedia setiger Birge.
Pleuroxus procurvus Birge.
Pleuroxus denticulatus Birge.
Chydorus sphaericus Mueller.

The last named species has been reported by Chambers from Colorado; the remaining fourteen Nebraska species have not, as far as the author can learn, been found in any of the states bounding ours.

The map (Pl. XXV) shows that the central and western regions are limited in the number of species found. These regions are further marked by a plankton meager in volume, parallel with which is a phytoplankton not only deficient in quantity but made up of such forms as do not afford desirable food for Cladocera. There are good reasons for believing that this scarcity of the phytoplankton limits the variety of the

	1. Arapahoe, fish pond	2. Beaver City, near depot	3. Beaver City, n. mill dam, 2 m. w. of 2	4. Beaver City, mid. mill dam, 2 m. w. of 2	5. Bellevue, springs n. town	6. Bethany, 2 m. e. Lincoln	7. Blair, DeSoto Lake, 4 m. s. town	8. Blair, DeSoto Canyon, 3½ m. s. 7	9. Broken Bow, pool ½ m. n. town	10. Curtis, lake e. side near town	11. Curtis, lake west side near town	12. Curtis, Medicine Creek, 1½ m. w. of 10	13. Crawford, lake 2 m. s. town	14. Decatur, Betsey's Lake, 1 m. n. town	15. Decatur, Clear Lake, mid., 1 m. n. 14	16. Decatur, Clear Lake, w. side, 1 m. n. 14	17. Decatur, Circle Lake, e. side, 1½ m. n. 14	18. Decatur, Circle Lake, w. side	19. Decatur, Mud Lake, 1 m. n. 14	20. DeWitt, Big Blue Bayou, 1 m. e.	21. DeWitt, mill pond, 1 m. e.	22. Elmwood, pool s. town	23. Fremont, pond west town
SIDIDAE																							
1. Sida crystallina Mueller	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..
2. Diaphanosoma brandtianum Sars	..	..	×	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	×
DAPHNIDAE																							
3. Daphnia pulex De Geer	..	..	..	..	..	..	..	..	..	×	×	×	×	..	×	..	..	..	..	..	×	..	..
4. Daphnia curvirostris Eyln.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..
5. Daphnia galeata Sars	×	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..
6. Daphnia parvula n. sp.	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7. Ceriodaphnia scitula Herrick	..	..	×	×	..	..	×	×	..	..	..	..	×	..	×	×	..	..	..	..	..	..	..
8. Scapholeberis mucronata Mueller	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	..
9. Simocephalus vetulus Mueller	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
10. Moina affinis Birge	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
BOSMINIDAE																							
11. Bosmina longirostris Mueller	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	×	×	×	..	×	..	..	..
12. Bosmina obtusirostris Sars.	..	..	..	..	..	..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	×	..	..
13. Bosmina ornamenta n. sp.	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
LYNCODAPHNIDAE																							
14. Macrothrix tenuicornis Kurz	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
LYNCEIDAE																							
15. Eurycercus lamellatus Mueller	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16. Camptocercus macrurus Mueller	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..
17. Leydigia fimbriata n. sp.	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18. Graptoleberis testudinaria Fisch.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19. Dunhevedia setiger Birge.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
20. Alona glacialis Birge	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×
21. Alonella rostrata Koch	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
22. Pleuroxus procurvus Birge	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
23. Pleuroxus truncata Mueller	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
24. Pleuroxus denticulatus Birge	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
25. Chydorus rugulosus Forbes	..	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	×	×	×	..	..	..	..
26. Chydorus sphaericus Mueller	..	..	..	..	..	..	..	×	×	..	..	..	×	..	×	×	..	..	..	..	..	..	×

Locality	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
24. Fort Robinson, 3 m. w. of 13							×		×																	
25. Havelock, Horseshoe Lake, 3 m. e.			×					×	×																	
26. Hastings, lake, 2 m. n.		×	×						×																	
27. Hastings, So. Br. Blue, $1\frac{1}{3}$ m. n. 26		×							×																	
28. Indianola, Coon Cr., $\frac{1}{3}$ m. s.		×	×																							
29. La Platte Lake, 10 m. s. 5		×																								
30. Lincoln, pool n. city			×					×																		
31. Marsland, Robb's Pond																										×
32. Marsland, Niobrara R.																									×	
33. Mindon, Rodger's Pond																	×									
34. Monroe Canyon								×								×									×	
35. Minnechaduza Bayou, 1 m. n. of Valentine																										×
36. Nehawka, pools n. town																								×		
37. Neligh, pools near town		×																								
38. Ord, Bayou Dane Cr. n.									×																	
39. Rifle Range, springs near 5																										×
40. Rifle Range, Fish Pond		×						×												×	×					
41. Sterling, pond s. town			×				×																			
42. Santa Lake, 3 m. n. 44		×																								×
43. Stella, Willson Lake, 3 m. n.											×															
44. South Bend, fisheries		×		×								×						×						×		
45. St. Michael, lakes near town									×																	
46. Swan Lake, 25 m. s. O'Neill									×					×	×	×	×	×	×	×	×	×	×		×	
47. Tecumseh, bayou w. town									×																	×
48. Tekamah, 3 m. n. of town																										×
49. Thedford, pools n. depot																								×		×
50. Thedford, peat bogs							×																	×	×	×
51. Tobias, cistern			×																							
52. Tobias, pool 1 m. s. w. 51		×																								
53. University Place, 3 m. e.								×	×																	
54. Waverly, pools near town								×																		
55. Wayne, pools near town																									×	×
56. Wayne, Stringer's Lake e. 55																					×				×	×
57. Weeping Water, pools s. e. town		×																								
58. Weeping Water, creek 3 m. e. 57		×							×															×		

species in the zooplankton, for there is little here upon which Cladocera can feed, aside from *Chroococcus*, Diatoms and *Ceratium;* both of the latter because of their size and silicious shells are poor food, especially for young broods (Richard, 94). That this food supply is an important factor in limiting and determining the zooplankton is evident from the fact that wherever in these regions the conditions favor a continuous phytoplankton of good volume and variety the Cladocera are correspondingly abundant. This is well illustrated in comparing the two stations at Crawford and Curtis, both in dry districts.

The lake at Curtis has an elevation of one thousand meters and is about one thousand meters long and five hundred meters wide, with a depth of seven meters. It is fed by springs, well lighted and provided with an alluvium bottom that gives a rich growth of higher plants about the shore. All of the conditions favor an abundant growth of Cladoceran food in the form of infusoria and algae of several varieties. As a result the water teems with Cladocera, representing all the Nebraska families except the Lyncodaphnidae, including even the pelagic form *Diaphanosoma.* Crawford Lake in the Bad Lands resembles this lake in depth, size and favorable location for light; it is likewise spring fed, but its marl bottom and other physical conditions are evidently unfavorable to the maintenance of vegetable plankton, a fact noted by Ward (96) in his investigations in Pine Lake whose bottom and physical conditions are similar to those in Crawford Lake. Aside from *Oscillaria* and an occasional diatom this lake seems almost sterile. Here only *Daphnia pulex*, *Ceriodaphnia scitula* and *Chydorus sphaericus* were found and these rarely.

One fact which doubtless exerts a modifying influence over the life as found in these lakes ought to be mentioned here, viz., that while both lakes are spring fed and therefore permanent bodies of water, yet each has been enlarged by artificial means. The collections were made at Curtis eleven years after the lake had been thus enlarged and those at Crawford but two years after the enlargement of the lake.

The lakes in the Sand Hill and Marl regions have a very scanty vegetable plankton; a glance at the table of distribution shows that the zooplankton is limited mainly to the cosmopolite *Chydorus* which is the only strictly perennial species found thus far in the state. Its favorite food is *Chroococcus* which grows almost anywhere it finds moisture. The hardy Daphnidae are the only other general representatives of these regions and they are limited in number. Diatoms are found generally distributed here and these again are the preferable food of Daphnids. The peat bogs near Thedford depart from the conditions prevalent in most of the Sand Hill and Marl districts. Here the environmental conditions favor the development of phytoplankton. Cladocera are correspondingly abundant (see table).

It is in the Eastern or Drift region, where nearly all factors favor the development and maintenance of a varied vegetable plankton, that the greatest number and variety of Cladocera are found. The one factor interfering here is the salinity of the waters in some places. Thus the brackish water in the lakes and bayous along Salt Creek is plankton poor. While the greatest volume of plankton is found in the smaller spring-fed ponds, invariably the larger lakes yield a greater variety, provided they are deep and spring-fed so as to resist the vicissitudes of temperature. In such lakes the Cladocera seem to go through the same cycle of life year after year, although the year 1899 showed a marked departure from the standard of the preceding four years. In this year the plankton was reduced in volume and quality, some species having disappeared from localities where they were previously prevalent.

This scarcity was observed by investigators of all groups of aquatic fauna within the state. The explanation may lie in the fact that the winter of 1898-99 was one of the longest and severest that the state has known for years; on February 12 the temperature was —47° F. at Camp Clark; varying from this extreme to —35° F. in most parts of the state. Farmers and ice-men found lakes and ponds that rarely freeze more than a foot frozen to the bottom. It would seem plausible that the plankton was unable to resist this extreme temperature and that this accounts for the reduction in its volume and the disappearance of some forms.

The hauls in Clear Lake near Decatur show some evidence of a division of the fauna into littoral and pelagic zones; in this lake the shore catches yield large volumes of the genera *Chydorus, Bosmina, Alona* and *Ceriodaphnia*, while the center of the lake yields but few of these littoral forms, but it is rich in *Daphnia* and *Camptocercus*. Collections from other parts of the state indicate no differentiation into littoral and pelagic areas.

VERTICAL MIGRATION

Observation reveals a considerable variation in vertical distribution which seems dependent on the disposition of the vegetable plankton; for in those lakes where the food consists mainly of algae that float on the surface, the Cladocera accumulate near the surface, particularly at night; but in lakes where the principal foods are diatoms and *Ceratium* that have a more uniform distribution the zooplankton is found correspondingly disposed. In several instances collections were made at night-time. In these collections it was observed that the volume of the plankton, especially in the superficial and bottom strata, differed so widely from collections made at other periods of the day that it was determined to make a few observations on the effect of light on vertical distribution.

Birge (95-97) in his plankton studies on Lake Mendota observed that Cladocera migrate to the surface stratum soon after sundown and descend shortly before sunup. Blanc (99) made a series of observations on the vertical movement of the Cladocera and other Entomostraca in Lake Geneva (Switzerland), concluding that the maximal number in the upper stratum occurred at 4 A. M. when its volume was 25 times as great as it was at 4 P. M. Two and one-half miles distant from his home a small pond was selected in which the writer made observations for a period of one week. The pond is excellently adapted for such investigations, being 25 meters long, 7 wide and 3 deep. It is spring-fed and contains only one species of Cladocera, viz., *Leydigia fimbriata* n. sp., which is large, brilliantly colored and easily counted with the unaided eye. The material was obtained with the Birge net and plankton pump with practically the same results. Collections were made at each visit from the upper stratum (one-third of a meter below the surface) and from the lower stratum (on the bed of the pond); to give uniform results with the net, it was thrown out for each haul a distance of 15 meters; with its depth regulated by a float, and drawn ashore at the rate of one meter per second. The observations were made at 12 o'clock M., 4 P. M., 8 P. M., 12 P. M., 4 A. M. and 8 A. M. in clear weather with the following results:

Time of observation	Terms in % of maximum
4 A. M.	100
8 A. M.	16
12 M.	0
4 P. M.	33
8 P. M.	66
12 P. M.	66

In the lower stratum the maximum occurred at 4 P. M. when it was much larger than was the maximum of the upper stratum. The minimum of the lower stratum came at 4 A. M., the time of the maximum of the upper stratum. The *Copepoda* showed a somewhat similar migration in the upper strata but did not yield corresponding results in the lower; at no time was their volume in the upper stratum comparatively so low as that of *Leydigia;* they seem to confine themselves more uniformly to the middle and upper strata. Most Cladocera are negatively affected by light; these observations on the new species *Leydigia fimbriata* in its reactions to different intensities of light indicates that it too belongs to the list of such organisms.

TAXONOMY

The Cladocera are minute, fresh water entomostraca with a laterally compressed body lying more or less concealed within a carapace that takes the form of a bivalved shell. The second pair of antennae are biramose and adapted for locomotion. There are four to six pairs of thoracic limbs, or feet, mostly foliaceous and lobate. The head is distinct and furnished with only one eye.

The suborder Cladocera is divided into two great groups, Calyptomera and Gymnomera; in the former, the body and thoracic appendages are encased in a bivalved shell; in the latter, the carapace is rudimentary, giving little or no protection to the body.

SYNOPSIS OF THE FAMILIES *

A. Calyptomera.

I. Six pairs of similar, nonprehensile, foliaceous feet whose margins are fringed with hairs arranged like the teeth of a comb. *Ctenopoda.*

* The synopsis of the families as here given departs but little from the one found in Richard, while that of the genera is in many cases a complete modification of that given by the French author.

1. Second pair of antennae biramose, with laterally compressed articulations furnished with numerous hairs. *Sididae.*

2. Second pair of antennae uniramose in the female (among the males the rudiment of a second ramus), subcylindrical, furnished with only three apical hairs; animal surrounded by a gelatinous envelope. *Holopedidae.*

II. Five or six pairs of feet, the anterior pair being prehensile with their laminae destitute of branchiae; the second pair of antennae with cylindrical articulations furnished with few hairs. *Anomopoda.*

1. Ventral ramus of the posterior antennae with three articulations, dorsal with four.

(a) Five pairs of feet, with a large interval between the last two pairs; intestine with two cephalic caeca. *Daphnidae.*

(b) Five or six pairs of equidistant feet.

1′. First pair of antennae in the female long, immobile, proboscis-like, with the sensorial hairs remote from apex; no cephalic caeca. *Bosminidae.*

2′. First pair of antennae in female long, mobile, with sensorial hairs apical; intestine simple or convolute. *Lyncodaphnidae.*

2. Second pair of antennae with three articulations in each ramus.

(a) Five or six pairs of equidistant feet; intestine circumvoluted. *Lynceidae.*

B. Gymnomera.

I. Feet bare, subcylindrical, all prehensile.

1. Four pairs of prehensile feet armed with strong claws provided with maxillary processes at the base. *Polyphemidae.*

2. Six pairs of simple feet without maxillary processes. *Leptodoridae.*

KEY TO THE GENERA OF SIDIDAE FOUND IN NEBRASKA

1. Second pair of antennae with three articulations in the dorsal ramus and two in the ventral. Rostrum distinct; numerous teeth on the post-abdomen. *Sida.*

2. Second pair of antennae with two articulations in the dorsal ramus and three in the ventral; no abdominal teeth. *Diaphanosoma.*

Sida crystallina O. F. Mueller

*Birge (78).

Herrick (79, 82, 84).

Herrick and Turner (95:147; Pl. 35, Figs. 13-15, and Pl. 37, Figs. 1, 2).

Among all the collections made in Nebraska during a period of five years but a single representative of this comparatively widely distributed species was found; this occurred among algae in the edge of Betsey's Lake, a large sheet of cold water near Decatur; the specimen is a large female measuring 2 mm. in length and 1 mm. in height. The body is elongato-quadrangular, separated from the large subquadrangular head by a distinct depression. The eye is located in the antero-ventral part of the head and is large, provided with numerous crystalline lenses well differentiated from the voluminous pigment. The first pair of antennae is cylindrical, with several coarse divergent sensorial hairs and with a tentacular hair much longer than the rest. The second pair of antennae is very strong, extending almost to the posterior margin of the shell; the basilar joint is robust, curving slightly ventrad, the biarticulate ventral ramus being furnished with fine apical plumose setae and a sharp spine on the ventro-apical part of the first articulation. The dorsal ramus is a third longer than the ventral, has three plumose setae on the second articulation and seven on the third. There are six pairs of feet well separated and armed with numerous long, stiff hairs arranged like the teeth of a comb. The ventral margin of the shell is ornamented with short, stiff hairs and terminates in a short caudo-ventral spine. The post-abdomen is conical, ending in slightly curved claws with four almost straight secondary teeth equal in length. On either side of the post-abdomen

*Since full references to the literature on Cladocera are to be found in such standard European works as those of Richard and others, reference is made in this paper to American contributions only.

is a series of twenty marginal teeth. There are two biarticulate abdominal setae destitute of spinules. The intestine is without caeca and gradually increases in diameter anteriad.

Diaphanosoma brandtianum Sars

Fig. 9, Pl. XXIII

Daphnella exspinosa Birge (78:3; Pl. II, Figs. 1-4).
Daphnella winchelli Herrick (79a).
Daphnella brachyura Herrick (84:21; Pl. Q 5, Figs. 11-16).
Daphnella brachyura Herrick and Turner (95:148; Pl. 26, Figs. 11-16).

Description of Female.—This is a comparatively small Cladoceron, the length being from 0.7 to 0.8 mm. The head is long, narrow, extending directly forward, measuring about one-third the total length of the animal; the dorsal margin is faintly convex. There is a distinct depression between the head and the thorax in distinction from *D. brandtianum* Sars in which the depression is very slight. The rounded anterior part of the head is somewhat truncate at the extremity and the lower margin presents a slight incurving just below and back of the eye; the portion from this point back to the body is slightly convex.

The carapace, as seen from the side, exhibits a rather homely outline: the dorsal margin is convex, the anterior three-fifths of the ventral margin is but slightly convex, while the posterior two-fifths is distinctly convex and armed by seven (and in some instances eight) sharp, faintly curved spines that point caudad. The interval between each two spines is filled by two to three irregular set smaller straight spines (Fig. 9). Herein our species departs from the description of *D. brandtianum* Sars which has six smaller spines in each interval. The lower portion of the posterior margin is ornamented by very fine, short hairs. The eye is large, approaching the anterior and lower margins of the head; the pigment matter is voluminous, the crystalline lenses large, few in number and, seen from the side, form seemingly only one circle. The antennae of the first pair are small, tapering gradually from the distal to the proximal end with the tentacular hair much longer than the others. The antennae of the second pair are robust and when flexed they extend almost to the posterior margin of the shell; the basilar joint is large, strong, curved slightly ventrad and nearly as long as the dorsal ramus; its length being 0.26 mm., and that of the dorsal ramus 0.28 mm.

The proximal joint of the dorsal ramus bears four biarticulate setae with a dorso-apical spine and the distal seven with a short apical spine on its dorsal side. The ventral ramus is about two-thirds as long as the dorsal; the proximal joint is very short, only about half as long as the distal, and in many specimens very indistinctly marked off. The middle joint is as long as the two extreme joints together and is furnished with a sharp spine on the ventral portion of the distal end. The terminal joint is furnished with four biarticulate setae, two of which are apical, the other two lateral, one attached near the middle of the dorsal margin and the other at the base of the ventral margin.

The post abdomen is small, armed with two gracefully curved terminal claws which have three slightly curved, nearly parallel secondary teeth near their base. The dorsal margin of the post abdomen is destitute of teeth; the abdominal setae are 0.3 mm. in length and emerge from a single nodular prominence. The feet are all furnished with suboval vesicular appendages.

In the first foot the branchial lamina is much narrower than in the rest.

Male.—The form agrees in general with that of the female. The average length of the male is about 0.2 mm. less than that of the female.

The antennae of the first pair are very much longer than those of the female; they are furnished with numerous coarse sensory hairs and a long curved, gradually attenuated flagellum with its margins densely ciliate. The second pair of antennae is comparatively longer than in the female; when flexed, they surpass the posterior margin of the carapace. The first foot is armed by a long, slender claw.

D. brandtianum is widely distributed over the state, being found in fifteen of the fifty-eight stations visited and in many of these stations it is abundant. It seems to preter well lighted, clear, cold water.

KEY TO THE GENERA OF DAPHNIDAE FOUND IN NEBRASKA

I. First pair of antennae in female small, inserted below the rostrum or on the posterior margin of the head.

A. Shell reticulated with small quadrate or polygonal areas.

1. Ventral margin regularly convex; the dorsal margin produced posteriad in an almost median line in the form of a spine or sharp point. The shell presents no posterior margin.

(a) Anterior antennae of female immobile. Head separated from the thorax by an obtuse depression or by none; anterior margin of the head with no sinus; rostrum distinct. Shell ornamented with quadrate or rhombic areas.

1. Pigment fleck present. *Daphnia.*

(b) Anterior antennae of female mobile; head separated from the thorax by a deep sinus; rostrum usually absent. Shell ornamented with pentagonal or hexagonal areas. *Ceriodaphnia.*

2. Ventral margin of shell almost straight, continued directly back, forming a spine or sharp point; a distinct posterior margin. *Scapholeberis.*

B. Shell ornamented with sub-parallel transverse lines. *Simocephalus.*

II. First pair of antennae in female long, mobile, inserted on both sides of the ventral margin of the head.

A. Pigment fleck absent, body bulky, fornix small. *Moina.*

Daphnia pulex De Geer

Daphnia minnehaha Herrick (84:57; Pl. K, Figs. 1, 2; Pl. D, Fig. 1, 2; Pl. U, Fig. 16).

Herrick and Turner (95:193).

Female.—The average length 1.4 mm.; height 1 mm. The body is laterally compressed, elongate with the ventral margin more convex than the dorsal. The spine is comparatively short in the specimen examined, the average length only 0.26 mm., and placed near the dorsal margin. The head is large, slightly depressed, anterior margin rounded, bulging slightly in front of the eye, with no sinus separating the head from the thorax. The antero-ventral side of the head is somewhat concave, the rostrum distinct and sinuate on the posterior side. The fornix is high: the margins of the posterior half of the body as well as the spine are formidably armed with stout, sharp spines that extend backward. The reticulation of the shell presents uniform quadrate areas. The eye is large, the pigment prominent, the crystalline lenses large, few in number, and considerably separated from one another. The pigment fleck is small.

The first pair of antennae is short with short rather stiff closely set sensorial hairs extending barely to the margin of the beak.

Second pair of antennae short and weak; the trunk slender; the dorsal ramus provided with four setae, three being apical and the fourth on the ventral side of the distal end of the third articulation. The ventral, or triarticulate ramus is longer than the dorsal and provided with five setae, three apical and one on the ventro-distal end of both the first and the second articulation. The setae are very sparingly plumose.

The post-abdomen is narrow, with its posterior margin armed with fourteen curved teeth gradually decreasing in length dorsad. The terminal claws are provided with four prominent secondary teeth and a lateral series of coarse cilia, increasing in size upward, ending finally in a comb of six slender teeth. The abdominal processes are more or less hairy, the first one very prominent, slightly falciform, curving anteriad; the second also falciform, curving posteriad; the third process is short, tooth-like. The caudal setae are short, measuring only 0.35 mm. in length. The males have an average length of 1 mm. The first pair of antennae is considerably longer than they are in the female, with the flagellum about as long as the antenna itself. The abdominal processes are short and blunt.

The species seems to resemble the variety *minnehaha* Herrick more closely than any other variety, although it differs from this in size, in the form of the rostrum, in the number of secondary teeth on the terminal claw and in the number of anal teeth. The material was collected from waters presenting widely differing environmental conditions; some specimens come from small shallow pools, others from large deep lakes and the finest specimens obtained were taken out of a cistern at Tobias where they are abundant in the fall of the year.

Daphnia parvula n. sp.

Figs. 2, 3, 4, Pl. XXII

This is a very small daphnid, the average length being 0.65 to 0.7 mm., height 0.4 mm. In general, the form agrees with *D. pulex* except in the marked concavity of the ventral side of the head and in the absence of secondary teeth on the terminal claw. In size and form of the post-abdomen, the animal bears a close resemblance to *D. longispina*. The valves present a broadly elliptical outline; the dorsal and ventral margins unite to form a very short caudal spine, which in many cases is little more than an obtuse angle, which is always located dorsad.

In most cases the spine and the margins of the valves are destitute of spinules; in some specimens a few scattering short ones were observed. The reticulation of the shell is so indistinct as to be invisible, except in a few specimens in which faint quadrate areas appear. There is no depression separating the head from the thorax. The head is large, representing about one-fourth the total length of the body and about one-half the depth of the valves; the anterior margin is convex and the ventral margin markedly concave. The rostrum is distinct, blunt and marked by a deep sinus on the postero-ventral side. (Fig. 2.) The eye is remote from the margin of the head, large, with crystalline lenses few and distinctly separated. (Fig. 3.) The first pair of antennae is short, with a brush of stiff sensorial hairs that extend a little below the extreme ventral point of the beak. The second pair of antennae when flexed extend but little beyond the middle of the valves. The apical end of the basilar joint as well as each articulation of the rami is furnished with short teeth. (Fig. 2.) The setae extend to the posterior edge of the carapace and are destitute of cilia.

The post-abdomen ends in slender gracefully curved claws provided with a lateral row of coarse cilia that gradually diminish in length as they approach the apex. There are ten anal teeth, of which the first is one-third the length of the terminal claw; the remaining nine gradually decrease in length and are recurved, the last tooth lying almost parallel with the margin of the post-abdomen. (Fig. 4.) The first abdominal prolongation is rather long and distinctly curved anteriad; the second is as long as the first and but slightly curved anteriad; the third process is about half as long as the second from which it is clearly separated. The gastric caeca are prominent and curved back. The male shows the ordinary modifications peculiar to the sex. The young male differs but little from the female; in the adults, the beak is more obtuse than that of the female; the flagellum is very short, being but little longer and thicker than the ordinary sensorial hairs. The abdominal prolongations are almost obsolete in the males. In other particulars the male resembles the female. These daphnids were found in abundance, with no other species except occasional Sididae, in a small fish pond on a cattle ranch two and a half miles southwest of Arapahoe; the pond is about 50 meters long by 25 meters wide with an average depth of 5 meters. The water is spring-fed, poorly lighted and filled with algae, Oscillaria being especially dominant.

Daphnia curvirostris Eylmann
Fig. 5, Pl. XXII.

Daphnia curvirostris Herrick and Turner (95:94).

Female.—Average length 1 mm., height 0.54 mm. The posterior half of the dorsal margin of the valves is nearly straight, while the anterior half continues the uniform curve of the head. The ventral margin is convex; the two margins reunite on the dorsal side in a short caudal spine whose length is about one-half that of the body. The ventral margin and the spine are armed with sharp thick spinules which gradually disappear anteriad on the dorsal margin. The valves exhibit well marked quadrate areas. In a very few specimens was there noticed a slight depression separating the head from the thorax; the head is large, representing about one-fourth the total length of the body and about three-fourths the depth of the valves. The anterior margin of the head is gradually rounded; the ventral margin is nearly straight; the beak is convex on its posterior side, well developed and often concealed by the valves. The eye is small, approaching closely the margin of the head; the crystalline lenses are comparatively small, numerous and thickly set.

The pigment fleck is small. The anterior antennae are prominent, extending a little beyond the extremity of the beak; the anterior sensorial hair is much coarser and longer than the rest, forming a sort of flagellum. The second pair of antennae extend back to the posterior third of the valves; they are slender and graceful, the setae being faintly plumose. The basal joint is slender and extends to the anterior margin of the head; a short spine appears on the dorso-apical portion of each articulation of the dorsal ramus.

The post-abdomen is rather short; the terminal claw provided with two ventral teeth and a comb of eight secondary teeth, of which the distal tooth is the longest, the others gradually decreasing upward. The recurved anal spines are eight or nine in number, beginning close to the base of the terminal claw; they decrease gradually in length. The abdominal processes are pretty well grown together, exhibiting in most cases an irregular outline; the first forms a nodular tooth-like process. In the male, the beak is more obtuse with the ventral edge slightly sinuous. The first pair of antennae is long, the basilar joint measuring 0.13 mm. and the flagellum 0.1 mm. There is a slight depression on the ventral side of the curved flagellum about one-fourth of the way up from the distal end giving the appearance of a partial break in the flagellum. (Fig. 5.) The sensorial hairs are short and few in number. Aside from these two features, the males are very similar to the females.

This form was found at South Bend and also in Circle Lake near Decatur; in both lakes the water is deep, cold and full of algae.

Daphnia galeata Sars

Daphnia galeata Smith (74:695).

Daphnia galeata Herrick (84 [*pro parte*]: 150; Pl. 61, Pl. U, Fig. 6).

This form was found in deep pools in the western part of Nebraska; one portion of the material was collected at Curtis, and the other at Arapahoe. The characters agree in the main with the description of Sars, yet the length of my specimens falls considerably below those described by Sars. None in my collection exceed a millimeter in length. The body is oval in outline, the ventral margin uniformly and markedly convex, the dorsal margin but slightly curved upward. The shell is but indistinctly reticulate. The two margins of the shell reunite dorso-caudad to form a spine whose length is equal to or exceeds two-thirds the total length of the body. The spine is armed by stout, sharp teeth which are continued forward on the posterior portion of the dorsal margin where they become much more slender. The posterior two-thirds of the ventral margin as well as the caudal portion are armed with short sharp teeth like those on the spine. The head is large without a sinus separating it from the thorax; the length of the head in my specimens scarcely exceeds one-fourth that of the body while its depth is equal to three-fourths the depth of the valves. The anterior margin is uniformly rounded, except at a point in front of and usually but slightly above the eye, where there appears a large angular tooth, terminating more or less sharply; the anterior part of the ventral margin is convex, while the posterior part is either straight or faintly concave. The beak is very obtuse. The fornix is high and prominent, the eye is medium in size, the crystalline lenses are well differentiated from the pigment and more numerous than indicated by Sars. The pigment fleck is small and placed a considerable distance directly back of the eye.

The first pair of antennae is short and difficult to see. The sensorial hairs are few and extend but little beyond the extreme margin of the beak. The second pair of antennae is medium in size, extending, when flexed, a little farther than the middle of the valves. The basilar joint is comparatively long and curved slightly ventrad. The post-abdomen is robust, terminating in long, sharp claws, ornamented with a series of densely set cilia. There are ten recurved anal teeth gradually diminishing in length dorsad. The first one is placed near the base of the terminal claw and is about one-third as long as the terminal claw. The anterior abdominal process is short and curved cephalad, the second is short and dentoid, the third is but a nodular protuberance. The abdominal setae are short and ciliated.

The males are about three-fourths as large as the females which they resemble very closely. The first pair of antennae differs but little from those of the female; they are but little longer and are not distinguished by the usually prominent flagellum, the flagellum here being little more than a thickened sensorial hair.

Ceriodaphnia scitula Herrick

Herrick (84:40).

Herrick and Turner (95:172; Pl. 42, Figs. 5 to 8; Pl. 44, Figs. 1, 2; Pl. 45, Fig. 1).

This species is found with *Simocephalus* in great abundance in the marshy plains of the peat bog region near Thedford, Nebraska. The water is clear, cold, and rarely exceeds a depth of one decimeter. The general outline is oval; the dorsal and ventral margins of the shell unite in a sharp caudo-dorsal point. The shell is ornamented with pentagonal areas. There is a marked depression separating the head from the thorax; the ventral margin is provided with a few short teeth, while the dorsal margin and the caudal point are smooth; the head is comparatively large, distinctly depressed, slightly concave above the eye, uniformly rounded on the ventral side and concave on the posterior side. The fornices are prominent; the eye medium in size; the pigment voluminous, and the crystalline lenses few and so poorly differentiated from the pigment as to be scarcely noticeable. The anterior pair of antennae are prominent, 0.2 mm. long, with a nodular prominence on the anterior side, about one-fourth the way up from the distal end from which there springs a stout spine whose length is equal to or greater than the stalk of the antennae. The sensorial hairs are coarse and granular in appearance. The second pair of antennae are rather strong; when flexed, they extend to the posterior third of the body; the trunk is long (0.15 mm.) and slightly curved ventrad, the ventral ramus is scarcely shorter than the stalk of the antenna; the basilar articulation extends to the middle of the third articulation of the dorsal ramus; the four biarticulate swimming setae are but feebly ciliated, and in many specimens the dorsal ramus has cilia on the dorsal margin of the second, third and fourth articulations.

The terminal claw is without secondary teeth, ornamented with a series of short cilia that extend along the inner face; the anal teeth are nine in number: the fifth, sixth, seventh, and eighth being longer and less curved than the others. The abdominal prolongations are merely swellings on the margin, except the anterior one, which is in the form of a short tooth-like process. The male resembles very much the female, the first pair of antennae being a little longer and marked by a much longer flagellum. Average measurements: length of female 0.8 mm., of the male 0.6 mm.; height of female 0.54 mm., of male 0.4 mm. First pair of antennae in female 0.2 mm., in the male 0.25 mm.; second pair of antennae 0.28 mm.

Scapholeberis mucronata Mueller

Daphnia mucronata Herrick and Turner (95:172; Pls. 43, Figs. 4 to 7; 45, Fig. 5).

This species agrees in the main with *D. mucronata* as described by Mueller; the average length of the female is 0.8 mm., height 0.55 mm. The shell shows distinct hexagonal areas. The posterior part of the dorsal margin is straight or slightly concave, uniting with the straight posterior margin in such a way as to form an obtuse angle. The ventral margin projects posteriad in the form of a sharp spine which is about one-sixth the total length of the body. The straight ventral margin is interrupted in front by a rounded prominence that projects ventrad; just back of this prominence the margin is slightly convex and armed with teeth, each perpendicular to the portion of the convexity from which it extends. From this convexity back to the spine are found short teeth extending posteriad. There is a small distinct sinus between the thorax and the head which is markedly prone; the anterior portion of the head is rounded and apparently nearly filled with the large eye. There is a marked concavity on the ventral side just back of the eye. The beak is long, ending obtusely, pointing obliquely downward and is usually more or less concealed by the valves. The crystalline lenses are few, large and seemingly buried in the voluminous pigment, only the outer margins of them are discernible. The fornices extend to the beak and are short but prominent.

The first pair of antennae are short and the sensorial hairs few and divergent. The second pair of antennae are weak; when flexed, they barely reach the middle of the shell. In form, they are of the usual daphnid type. The post-abdomen is short and truncate. The terminal claw is but slightly curved; its posterior face is provided with a series of very short teeth. The anal teeth are four in number and of nearly the same length, instead of rapidly decreasing in length as indicated in Mueller's description. They occupy the middle portion of the truncated margin of the post-abdomen. The broad pouch of many of the females contains from four to five eggs.

This species is found in several stations as indicated in the table of species and always in deep, clear water; no males are in the collections.

Simocephalus vetulus Mueller

Figs. 6, 7, Pl. XXII

Simocephalus vetulus Birge (78:84).

Simocephalus vetulus Herrick (84:46).

Simocephalus vetulus Herrick and Turner (95:178; Pls. 44, Fig. 7; 52, Figs. 6-9).

Simocephalus vetulus Harvey (94:395).

Female.—This species was found most abundantly with *Ceriodaphnia* in marshy low grounds in one of the peat bog regions of Nebraska near Thedford. The water spreads over the open prairie among the ferns which grow almost as abundantly as the grass. The water is clear, cold, and rarely ex ceeds a decimeter in depth. The species is found in small numbers in several other stations. The general form of the body is quadrate; the head is small and somewhat depressed. In most specimens there is a slight depression immediately above the eye. The ventral side of the head is variable in shape; in some cases there is a concavity under the eye back of which there is an angular projection. The eye, contrary to Harvey's description (94), does not approach very closely the margin of the head. It is rather large, the crystalline lenses numerous, closely set, yet distinct from the pigment. The first pair of antennae are short, fusiform and provided with a prominent bulb on the upper third of the anterior face, from which there emerges a spine whose length is about two-thirds that of the body of the antennae. I failed to find the circles of minute teeth described by Harvey as encircling the body of the antennae. On first examination, the sensorial hairs seemed to be arranged in two series, as is shown in Harvey's figures, but on closer examination under an immersion lens this effect is shown to be due to the fact that the basilar half of the hairs is granular while the distal half is hyaline. (Fig. 6.) The second pair of antennae are short, extending when flexed only to the middle of the valves. The apical end of the basilar joint as well as that of each of the articulations of the rami is ornamented with densely set cilia. The biarticulate swimming setae are plumose and about twice as long as the rami. The valves are marked by fine sub-parallel lines; the ventral margin is gradually curved to the ventro-posterior point, from which the margin continues upward in a nearly straight line till it unites with the dorsal margin to form an obtuse angle whose position is variable but lies usually on the dorsal side; the dorsal margin is slightly convex, there being a slight but distinct depression between the thorax and the head. The caudal prominence is armed by sharp teeth which are continued cephalad on the dorsal margin and ventrad on the caudal margin, gradually decreasing in size on the former but interspersed with smaller teeth on the latter. (Fig. 7.) The ventral margin of the shell is ornamented by long, slender, plumose setae which are inserted above the margin and extend to or below its free edge.

These setae are replaced at the postero-ventral portion of the shell by four or five thick slightly ciliated setae that take on the form of spines. (Fig. 7.) The post-abdomen is robust and terminates in a long, slender, curved claw destitute of secondary teeth, but adorned with a series of short cilia; the anal teeth are at the truncated end of the abdomen; the first three are long, stout and ciliated, the remaining seven or eight gradually diminish in length. There is a prominent hairy angle just back of these claws above which there is a concavity.

The caudal setae are sparsely plumose and emerge from a single nodule which is found in a depression of the posterior face. But one abdominal process is prominent; this is dentoid and projects anteriad. The average length of the female is 1.6 mm., height 1 mm.; of the male 1 mm., height 0.7 mm. In my collection I found but few males, which differ from the females only in their smaller size and the greater length of the first pair of antennae; they resemble the young females so closely as to make it difficult to distinguish them.

Moina affinis Birge

Fig. 8, Pl. XXIII

Moina affinis Birge (93:290; Pl. 10, Figs. 1, 3, 5, 7, 8, 12, 13, 14).

I have been in doubt as to whether this cladoceron is more closely allied to the European species *M. rectirostris* Jurine, to *M. propinqua* Sars of Australia or to *M. affinis* Birge of the United States. On the whole it agrees more generally with the latter, from which it differs, however, in several details. The general outline of the body is about the same as Birge's species, but the head is more prolonged and decidedly more depressed. I find the same characteristic depression above the eye and the absence of the angle on the postero-ventral side of the head. The eye is large, the crystalline lenses numerous, oval in form and clearly differentiated from the pigment. The eye is more remote from the margin of the head than is indicated by Birge. The first pair of antennae in the female corresponds exactly to Birge's description, but in the male my animal presents notable variations; in the first place, I find but one curve, while *M. affinis* Birge shows a double curve; my form is more slender and graceful and has but a single sensory hair on the anterior margin, which is farther from the proximal end than Birge indicates. (Fig. 8.)

The distal end shows no variation, there being four curved claws or hooks near the end, on the most apical portion of which appear a few coarse sensory hairs. The second pair of antennae are comparatively strong; the basilar joint is robust, gradually decreasing in size from the proximal to the distal end which bears between the rami a long spine. A sharp spine appears on the dorsal side of the apical end of the rami; similar spines are often found on the dorso-apical portion of most other articulations.

The post-abdomen is long and slender, gradually decreasing in size to the claw, with the exception of a swelling on the posterior side just below the middle. The abdominal prolongations are scarcely noticeable, except the anterior one, which is a short nodule. The abdominal setae emerge from a common protuberance. The anal teeth form a lateral series, beginning with a long, smooth bident near the base of the terminal claw and decrease gradually upward. These teeth, except the bident, are serrated and thick at the base; their number is nine.

The terminal claw is beautifully curved and ornamented by a series of coarse cilia that gradually increase in size toward the base where they approach the appearance of very fine secondary teeth. The base of the terminal claw is provided on its anterior face with a brush of coarse hairs. The valves are sculptured with lines crossing each other in an irregular way. The ventral margin is densely ciliate.

Measurements of average specimens

Female—Length 0.6 to 0.7 mm., height 0.33 to 0.45 mm.

Male—Length 0.5 mm., height 0.3 mm.

Length of first pair of antennae in the male 0.3 mm.

This species was found abundantly in a large mill pond two miles west of Beaver City. The water is clear, cold, well lighted and contains few algae. The average depth of the pond is about 1½ meters.

CHARACTERS OF THE GENUS BOSMINIDAE FOUND IN NEBRASKA

First pair of antennae immobile, continuing the rostrum into a proboscis-like prolongation with the sensorial hairs remote from the apex. Pigment fleck and caeca absent.

Bosmina.

Bosmina obtusirostris Sars

Bosmina obtusirostris Birge (93:300-1; Pl. 12, Figs. 10, 11).

Female.—Length 0.56 mm.; height, 0.4 mm.

The dorsal margin, head, and first pair of antennae, which seem to be an attenuated prolongation of the head, form an almost perfect semicircle. The protuberance in front of the eye is not so marked as indicated by Sars in his description. The shell is marked by lines parallel to the dorsal margin; the ventral margin is strongly convex anteriad and slightly concave posteriad, uniting with the posterior margin to form a short straight spine that is directed obliquely downward. There are three teeth on the dorsal side of this spine. The eye is small and remote from the margin of the head; the crystalline lenses are distinctly differentiated from the pigment. The first pair of antennae is but slightly curved and shows about ten segments and a sharp spine about one-fourth the way down from the base. The sensory hair is located on the antero-ventral side of the head just above the attachment of the first pair of antennae.

The basilar joint of the second pair of antennae extends when projected forward almost to the anterior part of the head. The dorsal and ventral rami are about equal in length and both composed of very short articulations. The swimming setae are arranged after the daphnid type. The post-abdomen is comparatively large, truncate at the apex and armed with six to ten small slender anal spines arranged in groups of two; the terminal claw is provided with seven secondary teeth of equal length. I find no males in my collection. This species seems to be rare in this country. Miss H. Merrill (Birge, 93:300) collected it near Woods Holl, Mass., Sars found it in Norway, Richard in Lapland, De Guerne and Richard report it from Siberia and Poppe and Richard report it as probably occurring in China. My specimens agree so generally with the descriptions and figures of these collectors that I do not hesitate to put it under the name of this rather rare species. The material was collected in spring-fed lakes at Curtis, Decatur, South Bend and Havelock.

Bosmina ornamenta n. sp.

Fig. 1, Pl. XXII, and Fig. 10, Pl. XXIII

This species was found in abundance and alone in a deep pool near Beaver City. The pool is located in a canyon, is cool and comparatively clear, containing Dinoflagellata (*Ceratium*) in great numbers, but no algae seem to be present. The general outline bears a close resemblance to *Bosmina cornuta* Jurine, but differs in having its greatest height in the anterior third of the body and in having the caudo-ventral spine shorter and directed obliquely downward. The shell is reticulated by small pentagonal and hexagonal areas on the lower side; on the upper these areas are elongate and extend lengthwise; in the middle of the shell the two forms of markings gradually shade into each other. (Fig. 1.) The head represents one-third of the total length of the body and two-thirds of its total depth; it is slightly protuberant in front of and a little above the eye. The first pair of antennae is long and so curved at their lower end as to point caudad. Its anterior margin shows slight elevations at the segments, of which there are eleven to thirteen. The sensory hairs are divergent and emerge from a tooth-like prominence situated on the anterior face about one-half of the way down from the base to the apex. The flagellum is fixed to a cylindrical prominence located just above the attachment of the beak-like antennae. The labrum is prominent; the eye is large and remote from the lower side of the head; the crystalline lenses are well separated from each other and from the voluminous pigment.

The second pair of antennae is short and thick; when projected forward, they surpass but little the anterior margin of the head. The basilar joint is robust and about twice as long as the rami; its dorsal margin is longer than the ventral, making an oblique articulation with the rami, which are composed of very short articulations, the diameter of each being considerably less than its predecessor; the dorsal or four-jointed ramus exceeds the triarticulate ramus by half the length of the apical joint; the number and arrangement of the sensorial hairs follow the usual type of the family. The ventral margin of the shell is convex in front and with the caudo-ventral spine forms a faint concavity in the region of the posterior third. The convex portion is furnished with several long, coarse hairs. The post-abdomen presents one of the most beautiful patterns found in the sub-order: in form it is rectangular; the terminal claw represents nearly one-third the total length; the secondary teeth begin at the extremity of the basal half of the claw and point downwards, the first two or three being long, slender and parallel with each other; the remaining members of the series gradually diminish in size dorsad till the comb ends above the base of the terminal claw. The apical half of the claw is serrate, the teeth are cylindrical, and project upward.

There are three small anal spines at the postero-apical point and numerous triad groups of hairs scattered along the posterior margin. The sides of the post-abdomen are ornamented with artistically arranged, short cilia, usually in groups of four. (Fig. 10.) The caudal setae are short, curved downward and fixed in a slight depression, above which several short spines appear on the posterior margin. The dorsal margin exhibits no abdominal prolongations.

Males are rare in my collection and show few distinguishing characteristics, except the presence of the copulatory hook on the first pair of feet. The average length of the animal is 0.36 mm., height 0.28 mm., length of post-abdomen 0.1 mm., terminal claw 0.033 mm., length of first pair of antennae 0.1 mm.

Bosmina longirostris Mueller

Bosmina longirostris Birge (78:91).

Bosmina longirostris Herrick (82:244).

Bosmina longirostris Herrick and Turner (95:207; Pl. 45, Fig. 2; Pl. 65, Fig. 2).

This form is identical with Mueller's species and is found abundantly in a small lake on Salt Creek near Havelock. The general form is oval; the posterior margin is slightly concave, the caudo-ventral spine is long and directed horizontally backwards. The greatest height is in a line passing through the middle of the body; the shell is reticulated by large hexagonal areas. The first pair of antennae is less curved than they are in *Bosmina ornamenta* and the second pair of antennae more slender. The post-abdomen is short, thick, with no anal teeth and the terminal claw is without secondary teeth, there being simply a series of cilia. The species is so familiar as to need no further description.

OUTLINE OF GENUS OF LYNCODAPHNIDAE FOUND IN NEBRASKA

Body oval, ending posteriad in an obtuse angle; head short and thick; ventral ramus with the swimming setae of the first and second joints large and armed with spines. *Macrothrix.*

Macrothrix tenuicornis Kurz

Macrothrix tenuicornis Herrick (82:245).

Macrothrix tenuicornis Herrick (84:70).

Macrothrix tenuicornis Herrick and Turner (95:214; Pls. 54, Figs. 5 to 8; 56, Figs. 1, 3, 12, 20).

Description of Female.—The outline of the shell resembles that of *Daphnia;* the dorsal and ventral margins, both of which are convex, unite to form an obtuse angle varying in position but always lying above the axis of the body. The ventral margin is provided with long, irregularly curved spines, between each two of which may be seen from two to three sharp teeth. This margin is further marked by a series of long, dense cilia which are attached above the margin extending to or beyond it. There is a slight sinus between the head and thorax; the head represents almost one-third the total length of the body and its depth equals about two-thirds the greatest depth of the shell. The lower anterior portion of the head is somewhat concave; immediately below this concavity is the blunt beak to which the first pair of antennae is attached; the head is produced ventro-posteriad into a prominent angle. The eye is medium in size with distinct lenses; the pigment fleck is prominent and located near the lower margin.

The first pair of antennae is long and shaped like the Italic letter *f*. There is a stout, sharp spine at the antero-distal end and a short one on the postero-distal end; other short spines are found scattered irregularly over the antennae. The sensorial hairs are few in number and coarse. The second pair of antennae is short and very spinulose. The basilar joint is robust, distinctly curved ventrad and armed here and there with spines. The rami are equal in length; there are numerous lateral spines on the upper side of the dorsal ramus and a few on the dorsal side of the ventral ramus. The distal end of each articulation is furnished with short teeth. The swimming setae are triarticulate, the middle articulation being very short. Each ramus is furnished with three apical hairs, the dorsal two in each case being furnished with a sharp spine at the first joint, pointing dorsad; the basal articulations of these setae are spinulose. Each ramus is furnished with a long dorso-apical spine. The seta extending from the distal end of the first point of the ventral ramus is very coarse, greatly enlarged at its base and armed with numerous prominent spines. The post-abdomen is short, terminating in short, thick, curved claws which have a nodular swelling at the base; there are no secondary teeth on the claws. The posterior margin has a prominent convexity just above the claws; the entire posterior margin is armed with sharp teeth; just inside of these teeth the surface is densely ciliate, particularly toward the distal end.

The caudal setae are short and almost destitute of cilia; the broad pouch contains three to four eggs. Average measurements among the females: length 0.66 mm., height 0.4 mm.; rami 0.16 mm., basilar joint 0.196 mm., elongated seta 0.45 mm., apical setae 0.32 mm., first pair of antennae 0.12 mm. The male differs but little in size and form from the female; the only marked difference lies in the first pair of antennae, which are longer by one-third and straighter than they are in the female and marked by apical teeth in connection with the long, coarse sensorial hairs. There are also two sharp spines on the posterior side a little above the end instead of the apical spines as in the female. This species has not, as far as I can learn, been before reported in this country except in Minnesota. It is abundant in Swan Lake, Holt County. The lake is about seven miles long and has an average depth of three meters. The water is filled with algae, is well lighted and cold.

KEY TO THE GENERA OF LYNCEIDAE FOUND IN NEBRASKA

General characters intermediate between Lyncodaphnidae and Lynceidae.

Intestine of the daphnid type. *Eurycercus.*

Post-abdomen large, with posterior margin swollen into a semicircle and armed with numerous long spines. Second pair of antennae with long sharp spines. *Leydigia.*

Shell elongate, provided with one to several minute teeth at the ventro-caudal angle. Head and back ridged. Post-abdomen very long and slender; terminal claw long and armed with a single secondary tooth. *Camptocercus.*

Head with a proboscis-like extension curved either forward or backward. Posterior margin of the shell armed with one to many teeth. Post-abdomen concave at distal end: terminal claw with two secondary teeth. *Pleuroxus.*

Shell rectangular, sculptured with longitudinal lines; head long and slender: post-abdomen subrectangular and armed on either side with two series of oval teeth. *Alona.*

Shell rectangular, head long, thick and directed horizontally forward; caudo-ventral angle armed with two teeth. Post-abdomen diminishing in size toward distal end and curved ventrad. *Graptoleberis.*

Characters intermediate between Pleuroxus and Alona. *Alonella.*

Shell globose, head slender, beak curved back close to valves; intestine circumbolute; prominent anal caecum. *Chydorus.*

Eurycercus lamellatus O. F. Mueller

Eurycercus lamellatus Smith (74:696).
Eurycercus lamellatus Birge (78:92).
Eurycercus lamellatus Herrick (82:248; 84:80).
Eurycercus lamellatus Herrick and Turner (95:226,Pls. 46, Figs. 7, 8; 51, Fig. 6; 60, Figs. 5, 6; 62, Fig. 19).

This is a very large Cladoceron, attaining an average length of 1.8 mm. It is evidently a conecting link between the *Lyncodaphnidae* and the *Lynceidae* as the intestine has no convolution and is provided with anterior caeca. The dorsal margin is nearly straight in its posterior half. The head is contained three times in the length of the valves and approximately three times in the depth; it is directed horizontally forward, terminating in a blunt beak which extends obliquely downward; the head conforms in general to the Lynceid type. The eye is large and resembles very much the daphnid eye. The lenses are few, prominent and separated from each other. The pigment fleck is small and located about one-third of the way down from the eye to the beak. The first pair of antennae is long (averaging 0.16 mm.), somewhat wedge shaped and curved anteriad at the basal end; the apical end is armed with long, sharp teeth, which are about one-third as long as the coarse, hyaline sensorial hairs. The second pair of antennae is built on the daphnid type and is short and weak with the basilar joint small and curved forward into an elbow. The basal joint of the dorsal ramus is short and the second joint is as long as the third and fourth combined; the dorsal ramus extends to the middle of the distal joint of the ventral ramus; in this latter ramus the basal joint is equal in length to the second and third together. The swimming setae are biarticulate, strong and plumose; the basal articulation is one-half as long as the distal; the conformity to the Lynceid type is broken in the dorsal ramus by the absence of the lateral seta. The dorso-apical end of the basilar joint of the antenna, of the second and fourth articulations of the dorsal ramus, and the distal articulation of the ventral ramus are each furnished with a long, stout, sharp spine. The apical end of each articulation is armed with short teeth; there are also several teeth on the ventral margin of the first articulation of the dorsal ramus.

The ventral margin of the shell is convex, being deepest in the anterior half; this margin is hairy. The posterior margin is rounding and ornamented with very fine teeth. The post-abdomen is very large and rectangular in form with both the anterior and posterior margins convex; the posterior margin is armed with very beautiful saw-like teeth which decrease in length dorsad. The tooth on the postero-apical end is about twice as long as the others; the distal end is concave, the terminal claw long (average length 0.18 mm.) and straight with its posterior face densely ciliate. The base is armed by a large, sharp secondary tooth, and beginning at the base of the claw there are two series of distal teeth which extend to the middle of the concavity. These teeth are long at the base of the claw and decrease gradually posteriad; this species is rare in Nebraska; a few specimens only are in my collections from Swan Lake. No males are found.

Camptocercus macrurus Mueller

Camptocercus macrurus Birge (91:395).

Camptocercus maerurus Herrick and Turner (95:229; Pl. 61, Figs. 10, 10a).

The body as seen from the side is elongate and elliptical with the anterior part of the shell emphasized; the dorsal margin is markedly convex, the curve continuing uniformly to the beak. The anterior fourth of the ventral margin is convex, just back of which there is a slight concavity; the posterior half of the margin curves upward to join the rounded caudal margin; at the caudo-ventral curve are found two or three teeth pointing dorsad. The shell is distinctly ornamented with parallel longitudinal striae. The anterior half of the ventral margin is provided with coarse cilia which grow gradually shorter posteriad. The head is large and directed obliquely downward at an angle of about 45° with the axis of the body; the beak is blunt, the postero-ventral margin of the head is slighted excavated in its lower half and concave in the upper half. The eye is small and placed back of the center of the head; the crystalline lenses are large, few and partly hidden by the pigment. The eye spot is smaller than the eye and located about half way down from the eye to the beak. The first pair of antennae is long, curved anteriad at the proximal end and slightly tapering to the apex, which has an expanded margin; the sensorial hairs are long, stiff and divergent. I have failed to find the elongate terminal seta described by Mueller. The flagellum emerges from the posterior side near the middle of the antenna. The second pair of antennae is very weak; when extended downward they reach but little beyond the ventral margin of the shell; they conform to the usual Lynceid type. The post-abdomen is very long and slender and tapers toward the apex; the terminal claw is likewise long and slender. It is nearly straight and armed at the base by a single large secondary tooth which is ciliate; it is further armed with a series of teeth that gradually increase in size from the base to the middle of the claw where they terminate.

There are sixteen to eighteen anal teeth which are thick at the base and serrate on their dorsal side; the post-abdomen is ornamented laterally by numerous groups of short, fine cilia. The intestine is circumvolute and provided with a small anal caecum. The average length of the female is 0.8 mm., height 0.46 mm., the post-abdomen is 0.28 mm. long, the terminal claw 0.12 mm. long and the basal secondary tooth 20 microns in length. I found but few males; their body is more slender and the beak more blunt. The post-abdomen is also more slender; the specimens are numerous in Swan Lake, Holt County, Nebraska.

Leydigia fimbriata n. sp.

Figs. 11, 12, 13, 14, Pl. XXIII

Female.—The outline of this species differs from the described forms of *Leydigia* in having the shell almost elliptical instead of ovate, with the larger end placed anteriad. The dorsal margin of the head is a continuation of the uniform curve of the upper part of the valves. The head is long and thick, the anterior half of the ventral margin is concave while the posterior half is distinctly convex. (Fig. 11.) The labrum is very prominent, extending ventrad almost as far as the beak. The eye is small with the lenses completely buried in the pigment. The pigment fleck is larger than the eye and is diamond shaped. (Fig. 12.) The first pair antennae is long and tapers toward the distal end, which is supplied with several fine sensory hairs. The second pair of antennae is short and presents a stunted appearance. When flexed they scarcely reach the middle of the shell. The basilar joint is stout and armed by numerous spines; its dorso-apical end, as well as those of the first and second articulations of the dorsal ramus, are armed by four strong, sharp divergent spines. The ventral ramus exceeds the dorsal ramus in length. Its basal joint is robust and presents a prominent swelling near the dorsal side of the basilar end. (Fig. 13.) A long spine appears on its distal end and a similar one marks the distal end of the first articulation of the dorsal ramus. There are three apical, biarticulate swimming setae and a dorso-apical spine on the third joint of each ramus; a short biarticulate seta emerges from the second joint of the dorsal ramus. There are thus seven setae in our specimen instead of eight as in the descriptions of Kurz. The shell is distinctly marked with large stipples or dots. The ventral margin is furnished with long, coarse setae, which curve posteriad.

The post-abdomen is enormously large and curved somewhat like the hind limb of a quadruped, maintaining nearly the same diameter throughout its length. Its posterior margin is not so bulging as *Leydigia quadrangularis* Leydig. This margin is armed on either side with a row of long, sharp, slightly curved spines appearing in groups of three or four, two or three long ones and one shorter; the spines in each group are markedly divergent and gradually grow shorter dorsad while the number of spines is found to increase in each group. Further in from the dorsal margin appears another series of spines which are in the form of very coarse hairs which are arranged in a line instead of groups; these coarse hairs fall over the sides of the margin, in some cases almost completely hiding the surface of the post-abdomen. (Fig. 14.) The anal setae are short, plumose and emerge from a single nodule, a short distance above which is another protuberance that bears a short sharp spine which is curved ventrad; the entire dorsal margin is furnished more or less with hairs. The terminal claw is long and nearly straight; a few setae appear at the base on the anterior face, while the posterior is marked on the proximal half by a series of setae that increase in length distad, and at its base is found a single long, secondary tooth. The intestine is convoluted and without caeca; the brood pouch never contains more than one egg.

Average measurements: length 0.55 mm., height 0.4 mm. Length of second pair of antennae 0.1 mm.

Post-abdomen: length 0.4 mm., width 01. mm. Length of terminal claw 0.1 mm.

The males are about three-fourths as large as the females and are characterized by a flagellum on the first pair of antennae and by a narrow post-abdomen. This species is found abundantly in Rodger's fish pond one mile west of Minden, at Bethany and occasionally in Swan Lake, Holt County; in the latter two stations the water is comparatively warm and contains but few algae, while in the first the water is cold and well supplied with algae.

Pleuroxus procurvus Birge

Pleuroxus procurvus Birge (78:92; Pl. 1, Figs. 19, 20).
Pleuroxus procurvus Herrick (82:250; 84:113).

Pleuroxus procurvus Herrick and Turner (95:258; Pl. 61, Figs. 3, 4).

This is a very small animal: Birge gives 0.4 mm. to 0.5 mm. as the average length, but in my collection I find the average length to be only 0.35 to 0.4 mm. and the height 0.24 mm. The body is oval with the cephalic end the larger; the upper and anterior portions of the shell are reticulated with diagonal areas while the lower and posterior are marked by oblique striations. The posterior margin is short, convex and armed with seven or eight sharp teeth, the lower three curving ventrad and the upper three dorsad. The ventral margin of the shell is furnished with pectinate bristles; the antero-ventral curve is armed by short teeth. The head is short and continued into a long proboscis-like beak which is curved anteriad; the eye is large with the crystalline lenses concealed in the pigment. The pigment fleck is much smaller than the eye and situated near the base of the beak; the first pair of antennae is large, thick and gradually tapering distad. The flagellum emerges from the anterior face near the middle. The sensorial hairs are long and coarse, extending nearly as far down as the rostrum. The second pair of antennae is of the usual lynceid form and extends to the level of the ventral margin. The males resemble the females; they are smaller, have a shorter beak, and the post-abdomen resembling that of *P. denticulatus.* The post-abdomen is rectangular, the posterior margin armed with about twenty anal teeth arranged in groups of two, decreasing in size dorsad. The terminal claw is long, curved and armed at the base with two secondary teeth.

Pleuroxus denticulatus Birge

Pleuroxus denticulatus Birge (78:96; Pl. 1, Fig. 21).

Pleuroxus denticulatus Herrick (84:110).

Pleuroxus denticulatus Herrick and Turner (95:256; Pl. 45, Fig. 8; Pl. 63, Figs. 10a, 12, 13).

This species is very much more abundant in the state than *P. procurvus;* in form it is more globose than the latter; the shell is marked by oblique striations; the hairs on the ventral margin are longer and more prominently plumose. The teeth on the antero-ventral curve are not unlike those of *P. procurvus,* while the posterior margin is destitute of teeth, there being three sharp teeth on the postero-ventral margin. The post-abdomen differs from *P. procurvus* only in being less excavated at the distal end. The head is slender and continued into a long, slender beak whose anterior face continues the uniform curve of the dorsal surface. The eye is large and the crystalline lenses differentiated from the pigment in distinction from the concealed lenses in the former species. The first and second pairs of antennae are similar to those of *P. procurvus.* The form agrees in size and other particulars with Birge's description. The material is from Swan Lake.

Pleuroxus truncatus Mueller

Pleuroxus truncata Herrick and Turner (95:258).

This species bears a close resemblance to *P. procurvus*, from which it differs in having the beak straight, the body shorter compared with its height and in having the teeth on the posterior margin of the shell more numerous and all directed posteriad. The sculpturing of the shell is similar to that of *P. procurvus*, so also the fringing of the ventral margin and the presence of teeth on the antero-ventral curve, as well as all other features examined. This species is found in small numbers in Swan Lake.

So far as I can learn, this form has not been previously reported in this country.

Alona glacialis Birge

Alona glacialis Birge (78:106).
Alona glacialis Herrick (84:100).

Female.—The dorsal margin of the shell is markedly convex, reaching its greatest height in the line passing through the middle of the body; the ventral margin is faintly convex in its anterior half, just back of which there is a slight concavity; the posterior margin is rounded. The ventral margin is furnished with hairs which disappear before reaching the ventro-caudal curve. The head is short, the beak short and blunt. The eye is large, the lenses concealed; the pigment fleck is but little smaller than the eye and located nearer the eye than the end of the beak. The first pair of antennae is large, fusiform and extends almost to the end of the beak; the sensorial hairs are few, one of which is much longer than the rest. The second pair of antennae scarcely reaches the lower margin of the shell; the basilar joint is weak and curved dorsad. The dorsal ramus has a sharp spine on the dorsal side of the apical end of the first and third articulation and three apical biarticulate setae; the ventral ramus has an apical thorn on the third articulation and a brush of hairs on the dorso-apical end of the second articulation; this ramus has two lateral and three apical biarticulate setae; the dorsal two of the latter are characterized by spines at the joint. The post-abdomen is rectangular, there being a slight concavity both above and below the short anal tubercle. It is characterized by a double series of anal teeth; the marginal series is arranged in groups of two and decreases in length to the first concavity, where they are replaced by very short, thickly set fine spines. The terminal claw is long and curved back to a point in line with the posterior margin of the post-abdomen. The claw is ornamented by a series of cilia and armed by a single secondary tooth whose length is equal to one-third that of the claw.

The average length is 0.42 mm., height 0.24 mm. This species is abundant in several localities of the state as indicated by the table of distribution; the males are smaller than the females but resemble them very closely.

Graptoleberis testudinaria Fischer

Graptoleberis inermis Birge (78:102; Pl. 1, Fig. 17).

Graptoleberis inermis Herrick (82:250).

Graptoleberis testudinaria Herrick and Turner (95:235; Pl. 65, Figs. 8, 11, 12).

The specimens in my collection agree in general with Fischer's description; the outline is rectangular, the dorsal margin is uniformly curved, not giving the "hump" where the head joins the thorax as described by Fischer. The head is long, representing one-third the length of the valves; it is deep and directed horizontally forward, giving the animal a fishlike appearance. The ventral margin of the shell is but faintly convex and is ornamented by long, densely set hairs. The posterior margin is truncate and without teeth or cilia; the caudo-ventral angle is armed by two stout, sharp teeth that project dorsad. The shell is beautifully reticulated with rectangular areas. The eye is large, the pigment voluminous, entirely concealing the lenses; the pigment fleck is smaller than the eye and is located scarcely half way from the eye to the end of the beak. The ventral margin of the head is convex, the beak blunt and the first pair of antennae short, reaching barely to the lower margin of the head. The sensorial hairs are divergent and about as long as the antenna itself. The second pair of antennae is short and weak; when projected downward they do not reach the level of the lower margin; the rami in my specimens are not as long as indicated by Fischer. There are three apical, biarticulate setae on each ramus and in addition a very short biarticulate seta on the ventro-apical end of the second articulation of the dorsal ramus and a strong spine on the dorso-apical end of the distal joint of the same ramus.

The post-abdomen is slightly fusiform, tapering gradually to the terminal claw, which is seemingly but a continuation of the post-abdomen; the claw is thick and curved distinctly posteriad. Fischer mentions two secondary teeth, but I can find but one very small one in my specimens. The posterior margin of the post-abdomen is destitute of teeth, being ornamented with two series of hairs arranged in tufts. The caudal setae emerge from a common prominent nodule, above which may be seen on the dorsal surface of the abdomen a few scattering hairs in groups of two. The average length of the female is slightly less than indicated by Fischer, being 0.46 to 0.5 mm.; the height averaging only 0.3 mm. The males are somewhat smaller, with the post-abdomen concave on the posterior margin, making the organ continue the curve of the terminal claw. This form is found in small numbers at South Bend and in Swan Lake.

Alonella rostrata Koch

Pleuroxus acutirostris Birge (78:99; Pl. 2, Fig. 15).
Alonella rostrata Herrick and Turner (95:250).

This form agrees so nearly with Koch's description that I do not hesitate to place it under his species; it is very generally distributed over Nebraska as will be seen by glancing at the table of distribution. In outline it resembles *Pleuroxus denticulatus*, but is less oval, the ventral margin being almost straight except in the anterior fourth, which is faintly convex; this margin is fringed with short hairs which are replaced at the posterior end by two to four sharp teeth which point backward. The posterior margin is short, being less than one-half the height of the shell; the dorsal margin is markedly convex, reaching its greatest height in front of the middle line, the curve being continued over the head and beak; the head is very short and the beak long, slender and sharp. The lower portion of the shell is sculptured by striae that run obliquely downward and backward, the upper portion of these are intersected by similar lines that begin anteriad and run obliquely upward and backward, giving this portion of the shell hexagonal areas. The eye is of medium size, the lenses few and not well differentiated from the pigment; the pigment fleck is nearly as large as the eye and located about one-third of the way down from the eye to the end of the beak; the fornices are broad and prominent. The first pair of antennae is long and slender; the second pair is very short and weak, extending but little more than three-fourths of the way from the base to the ventral margin of the valve. The post-abdomen resembles considerably in outline that of *Pleuroxus procurvus;* the posterior margin and the distal end are convex instead of straight as in the latter species. The terminal claw with its two basal secondary teeth are not unlike those of *P. procurvus.* The anal teeth are arranged in twos and decrease in length dorsad. Among the males the post-abdomen is more slender, the anal teeth are replaced by coarse stiff hairs and the secondary teeth are wanting on the terminal claw. My specimens exceed in size those described by Koch. The average length of the female is 0.55 mm., height 0.4 mm. The collections are from Wiley's fish pond near Bellevue, from Stringer's Lake near Wayne, and from Swan Lake, Holt County.

Dunhevedia setiger Birge

Dunhevedia setiger Birge (91:394; Pl. 13, Fig. 20).

Dunhevedia setiger Herrick and Turner (95:237; Pl. 64, Fig. 13).

Dunhevedia seems to be a rare group; it was found by G. O. Sars in 1888 in dried mud from Dunheved and has since been found rarely in this country by Birge, with whose description and figure my specimens agree except in size; average length 0.44 mm., height 0.34 mm., instead of 0.36 mm. and 0.34 mm. as given by Birge. The shell is subquadrate with rounded angles, attaining its greatest height slightly in front of the middle. The dorsal margin is evenly curved, the head is large for a lynceid, the anterior margin continues the uniform curve of the shell, meeting the ventral margin in an obtuse point; the eye is large, approaching the anterior margin of the head, the pigment fleck is much smaller than the eye. A little in front of the ventro-caudal angle there is a single tooth which is more in the form of a curved thorn than a tooth. The ventral margin is slightly concave just in front of this tooth; anterior to this, the margin is nearly straight; the entire free edge, excepting the most anterior part, is fringed with plumose setae. The dorsal margin of the shell and the anterior face of the head are uniformly curved; the shell attains its greatest height near the middle; the posterior margin varies, being truncate in some, in others slightly convex. The shell is marked on the lower portion by longitudinal striae and on the middle and upper by hexagonal areas. The first pair of antennae is large, wedge shaped and completely covered by the fornices; the sensorial hairs are very divergent.

The second pair of antennae is comparatively strong for a member of this family; the basilar articulation of each ramus is as long as the following two. There are three apical, biarticulate, slightly plumose setae on each ramus and in addition two lateral setae on the ventral ramus. The ventral margin meets the posterior in a rounded angle, in front of which is the prominent curved spine already mentioned. The post-abdomen is short, thick, increasing in diameter toward the upper end; the posterior margin is armed on either side by a series of sharp teeth that point dorsad and gradually decrease in length; it is further marked by numerous lateral hairs. The terminal claw is curved, distinctly bent backward and armed by a long, curved secondary tooth; it differs from Birge's description in having on either side a row of cilia in addition to the thorn at the base. Aside from the prominent hook on the first foot, the male resembles the female. The species is rare in Nebraska; I find one occasionally among the collections from Swan Lake.

Chydorus sphaericus Mueller

Chydorus sphaericus Chambers (77:155).

Chydorus sphaericus Birge (78:99; Pl. 2, Fig. 19).

Chydorus sphaericus Herrick and Turner (95:261; Pl. 64, Figs. 4, 7, 8, 10).

This is a very small globose lynceid whose outline varies during the development; the adult presents almost a circle, as viewed from the side; in the younger specimens, the posterior margin is truncate, the dorsal and ventral margins sloping to the posterior margin making obtuse angles. The ventral margin is fringed with short hairs; the head is short and continued into a slender beak which curves backward, preserving the typical spherical outline. The eye is large with a blurred outline; the pigment fleck is about the same size as the eye and situated midway between the eye and the point of the beak. The antennae of the first pair are large, gradually tapering to the apex; the sensorial hairs are few and divergent. The second pair of antennae is short and weak; their weakness in connection with rotund form of the body gives the animal a rolling motion through the water. The basilar joint increases in size from the proximal to the distal end; the first joint of each ramus is long and slender, the dorsal ramus having three apical setae and a sharp spine on the dorso-apical joint. The ventral ramus is provided with three apical setae and also one lateral. The post-abdomen is of the usual lynceid type with the tubercle on the posterior margin emphasized. The posterior margin is rounded at the distal end and armed with ten sharp teeth that decrease dorsad. The terminal claw is slightly curved, ornamented with a row of cilia and armed at the base with a long, curved secondary tooth. The average measurements among the females show a length of 0.4 mm., height 4-5 to 9-10 of the length. Among the males the beak is more blunt, the first foot is provided with a very prominent hook, the post-abdomen is slender and the vas deferens opens in front of the terminal claws. This group is abundant in small lakes near Wayne, also in Betsey's Lake, near Decatur.

Chydorus rugulosus Forbes

Chydorus rugulosus Forbes (90:712).

Chydorus rugulosus Birge (93:308; Pl. 13, Fig. 6).

This species bears such a close resemblance to Forbes' description and figure that I venture to put it under the above title although it does not correspond in all features to *C. rugulosus*. The shell is less spherical than in Forbes' species; I find the size very variable, the average being 0.37 mm. in length and 0.3 mm. in height, considerably less than Forbes' specimens. The valves attain their greatest height in the middle, both the dorsal and ventral margin sloping toward the posterior margin (the dorsal slope being the longer) which they meet in blunt angles; the ventral margin is furnished with spine-like bristles, particularly along the ventro-caudal slope are these spine-like. I find that the valves are characterized by the "dirty rough" appearance mentioned by Forbes. The head is short, the beak slender and hovering close to the valves. In a few animals I found the end of the beak curved slightly forward, a feature observed by Forbes in many of his specimens; the eye is medium in size, the crystalline lenses so concealed that I cannot learn their characters. The pigment fleck is a little smaller than the eye and in most cases triangular in form. It is located not quite half way down from the eye to the beak. The first pair of antennae is less prominent than in the species described by Forbes; the second pair resembles those of *C. sphaericus* in form, but are comparatively larger and stronger; the post-abdomen has a series of anal teeth on either side; the number exceeds that mentioned by Forbes, there being in my specimens 12 to 15.

In other respects my animal resembles *Chydorus rugulosus* Forbes.

This species is generally distributed over Nebraska.

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EXPLANATION OF PLATES

All figures were drawn with aid of a camera lucida; the magnification of each is indicated on the plates.

Plate XXII

Fig. 1. *Bosmina ornamenta*, lateral view of female.

Fig. 2. *Daphnia parvula*, lateral view of female.

Fig. 3. *Daphnia parvula*, eye, showing arrangement of crystalline lenses.

Fig. 4. *Daphnia parvula*, post-abdomen of female.

Fig. 5. *Daphnia curvirostris*, first antenna of male.

Fig. 6. *Simocephalus vetulus*, female, first antenna, showing character of sensorial hairs.

Fig. 7. *Simocephalus vetulus*, postero-ventral margin of carapace, showing character and disposition of teeth on the caudal margin and setae on the postero-ventral margin.

Plate XXIII

Fig. 8. *Moina affinis*, first antenna of male.

Fig. 9. *Diaphanosoma brandtianum*, arrangement of spines on the postero-ventral margin of carapace.

Fig. 10. *Bosmina ornamenta*, post-abdomen of female, showing characteristic ornamentation.

Fig. 11. *Leydigia fimbriata*, lateral view of female.

Fig. 12. *Leydigia fimbriata*, pigment fleck of female.

Fig. 13. *Leydigia fimbriata*, second antenna of female.

Fig. 14. *Leydigia fimbriata*, post-abdomen of female.

Plate XXIV

A map of the soil regions of the state. I am indebted to Dr. Erwin H. Barbour, Professor of Geology in the State University of Nebraska and State Geologist, for the use of this map.

Plate XXV

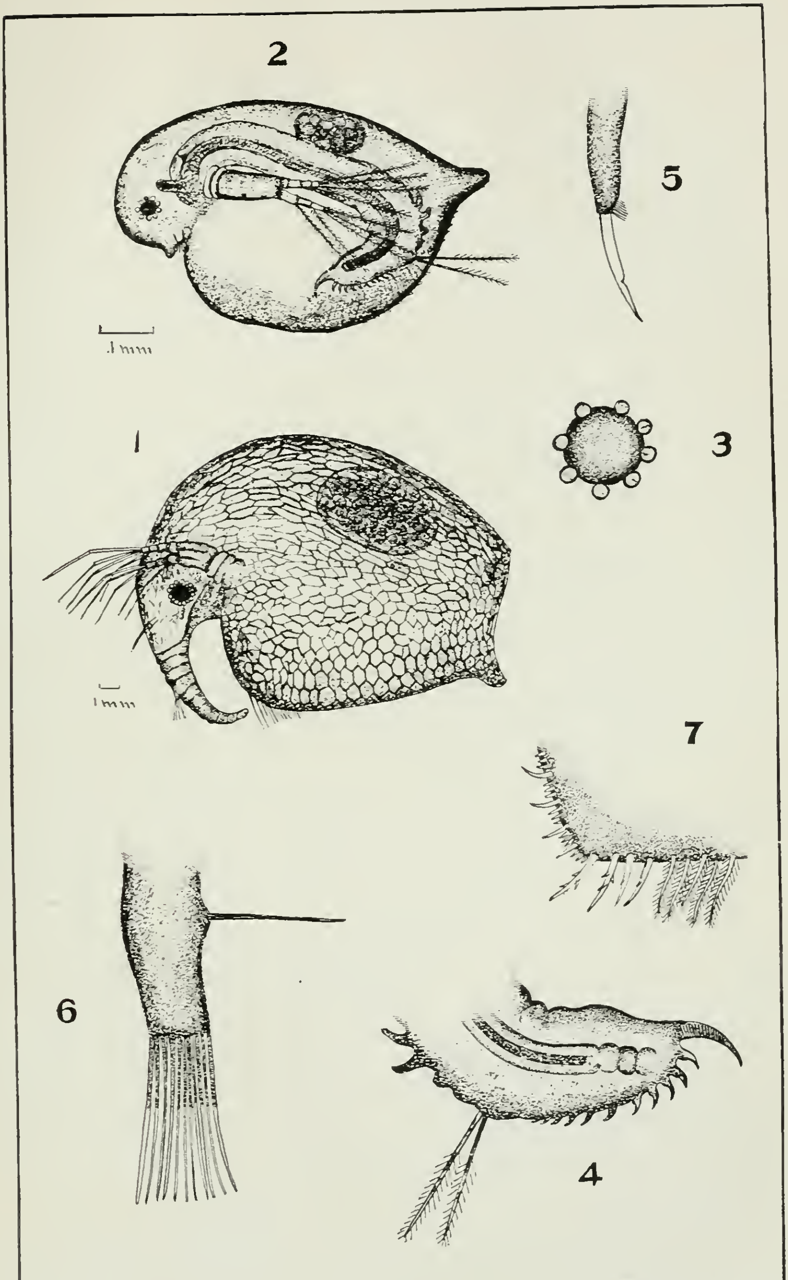
A map with the collecting stations indicated by numbers; at many of the points numbered on the map there are actually several stations. The precise location of the various stations is shown in the table of distribution on pages 132, 133, where the numbers employed agree with those used on this map. The letters in connection with the numbers represent the distribution of the genera.

A indicates Sida.
B indicates Diaphanosoma.
C indicates Daphnia.
E indicates Ceriodaphnia.
F indicates Scapholeberis.
G indicates Simocephalus.
H indicates Moina.
I indicates Bosmina.
J indicates Macrothrix.
K indicates Eurycercus.
L indicates Camptocercus.
M indicates Leydigia.
N indicates Graptoleberis.
O indicates Dunhevedia.
P indicates Alona.
Q indicates Alonella.
R indicates Pleuroxus.
S indicates Chydorus.

Errors in map:

In station No. 2, B and I should be added.
In station No. 10, S should be added.
In station No. 13, C should be added.

PLATE XXII



C. F. del.

PLATE XXIII

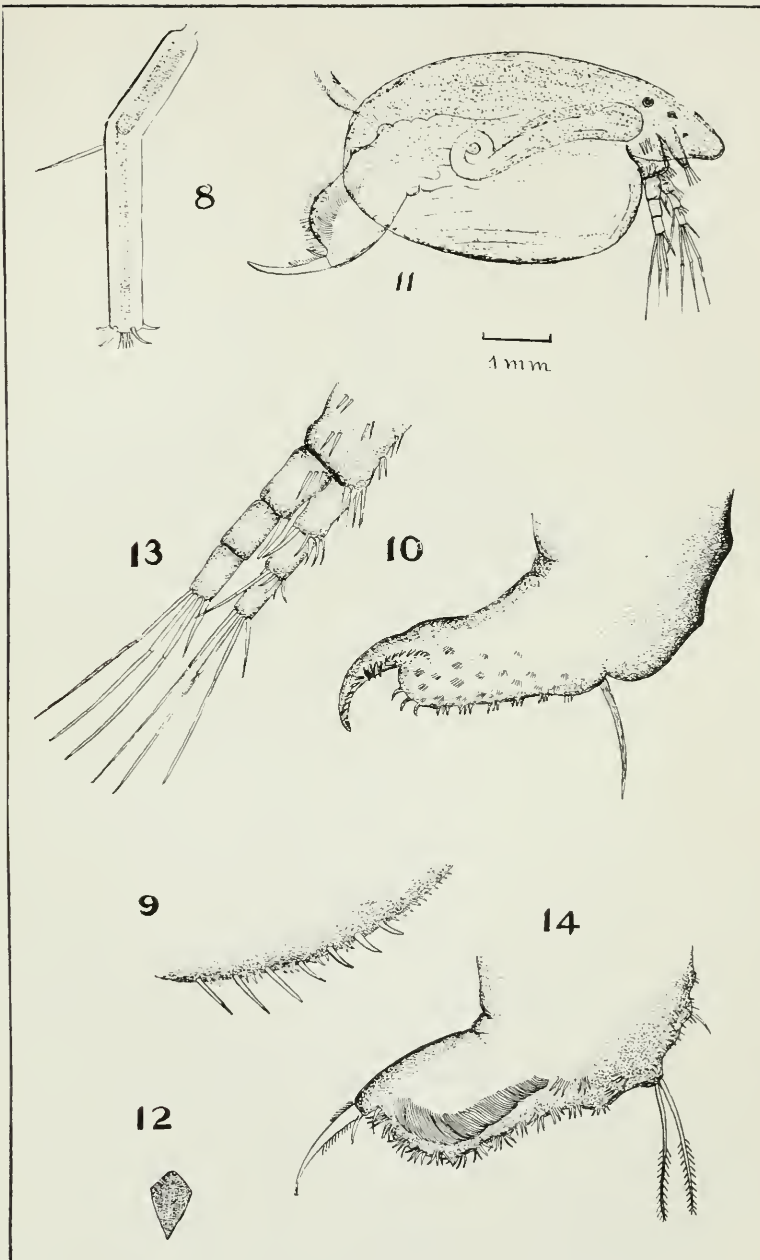


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PLATE XXIV

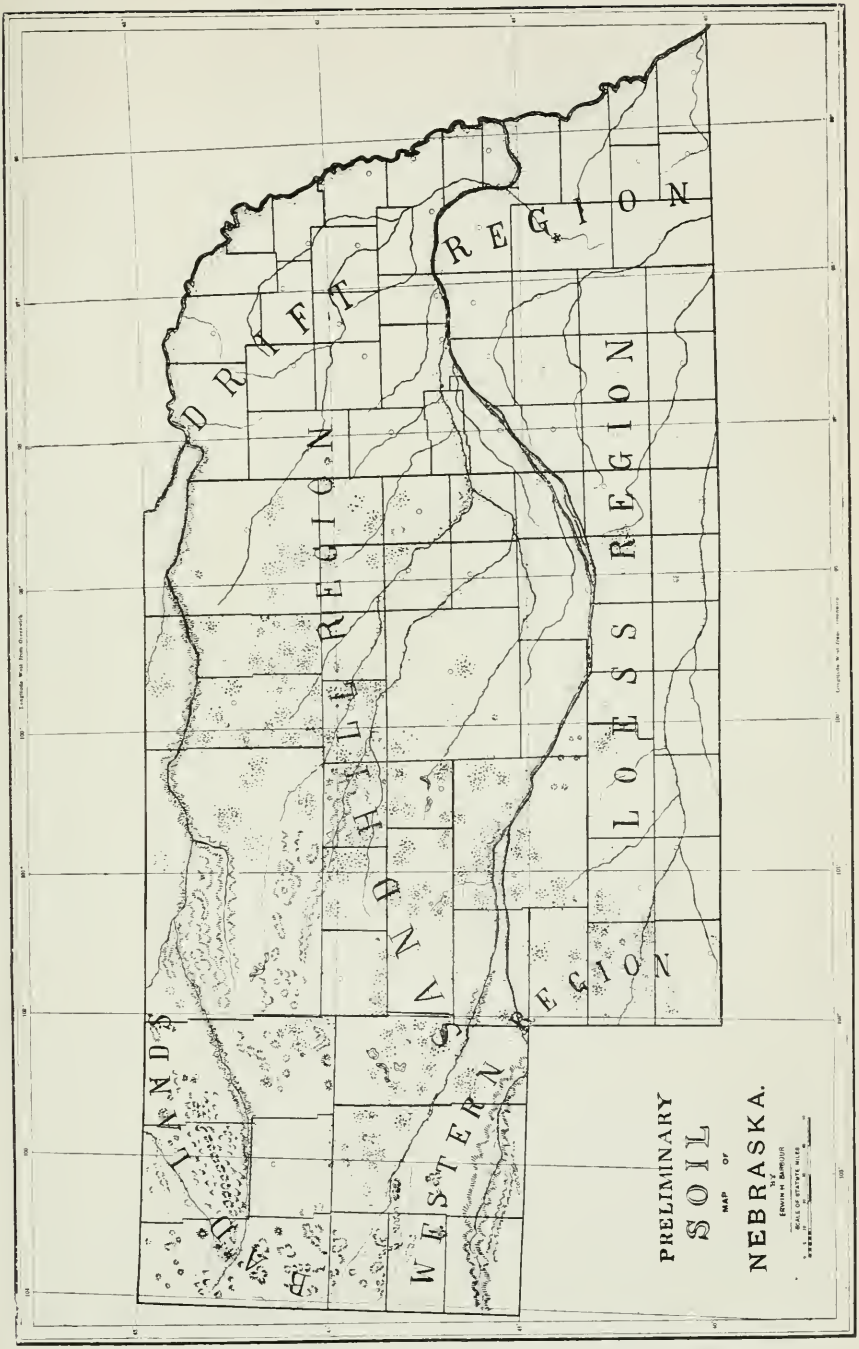
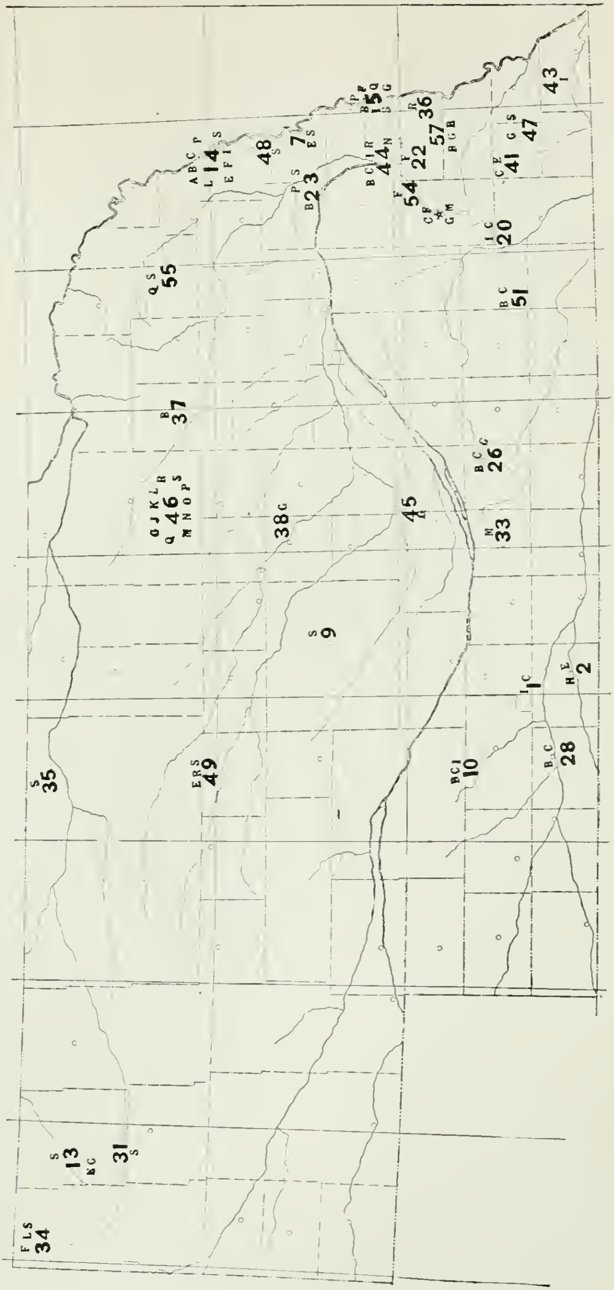

DRIFT REGION
LOESS REGION
SANDHILL REGION
WESTERN REGION
BAD LANDS
PRELIMINARY SOIL MAP OF NEBRASKA.
BY ERWIN H. BARBOUR
SCALE OF STATUTE MILES

PLATE XXV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NOTES ON THE PARASITES OF THE LAKE FISH

III. On the Structure of the Copulatory Organs in *Microphallus* nov. gen.

By HENRY B. WARD.

WITH ONE PLATE

In a previous paper (94) published in the journal of this Society, I gave a brief account of the life history and structure of a new species of distome from the dogfish (*Amia calva* L.). Since that time our knowledge of the group of distomes has been extended greatly and it is possible to give a clearer idea of the position and relationship of this form. The papers of Looss, notably one of the most recent (Looss, 99) have contributed most prominently towards this end and have laid a firm foundation for a rational system among the distomes. It is also true that some of the references to this particular species have misinterpreted in certain points the brief description given previously and have thus rendered it more important to rediscuss its structure and affinities. At the same time the type of structure presented by the copulatory organs, which Looss has shown to be of prime importance in the taxonomy of the group, differs in an interesting manner from any plan for these organs given by that author and forms a possible transition towards the type described by Jägerskiöld (00) for another genus.

Besides the original description of the species (Ward, 94) the following references have been made to it: MacCallum (95) merely records its presence in the stomach of *Anguilla chrysopa*, a new host. Stossich (99) in his revision of the genus *Brachycoelium* Duj. founded a new genus, *Levinsenia*, and included in it the four species, *L. opacum* (Ward 1894), *L. brachysomum* (Creplin 1878), *L. pygmaeum* (Levinsen 1881) and *L. macrophallos* (v. Linstow 1875). He did not, however, specify the type form of this new genus, so that Luehe (99), while questioning the formation of the genus with the limits given by Stossich, deemed it nevertheless advisable to designate a type species in order to avoid so far as possible the confusion incident upon later revision of the group, and he therefore (note 30, p. 538) proposed *D. brachysomum* as type.

Somewhat later Jägerskiöld (00) gave a careful description of the structure of *L. pygmaea* together with a revised diagnosis of the genus, basing the same on *L. pygmaea* which is specified as type. It is unfortunate in view of the accurate and full knowledge we possess regarding this species that its designation as type comes too late to be accepted. Stiles* has recently called attention to the fact that the name *Levinsenia* is preoccupied and has renamed the genus under discussion *Levinseniella.*

Looss (99) in his discussion of the paper by Stossich (99) criticises the inclusion of *D. opacum* in the genus *Levinsenia,* and after comparing its structure with that of the other species grouped by Stossich within this genus concludes the discussion with the following words: "Unter solchen Umstaenden glaube ich das *Dist. opacum* Ward als Typus einer eigenen Gattung betrachten zu sollen, die nahe Verwandtschaft zu *Lecithodendrium* zeigt, wohingegen das Genus *Levinsenia* Stossich auf die Formen vom Typus des *D. brachysomum* Crepl. zu beschraenken waere" (p. 621). In the following pages I hope to show that the precision which Looss has manifested in other cases in evaluating generic relationships has been equally clearly exercised here, and that further knowledge of the structure of this species fully justifies its position in an independent genus, for which I propose the name of *Microphallus.*

For general features in the structure of this species reference should be made to the earlier paper (Ward, 94) and to the figure of the adult which is reproduced here (Pl. XXVI, Fig. 1). With regard to the terminal region of the reproductive system some additional facts of importance are to be discussed here. The common sexual pore lies at the left of the acetabulum just behind the middle of that organ, but separated from it by an appreciable distance. Furthermore, as a cross section shows distinctly, both the genital sinus and the ducts are independent of the ventral sucker and the ducts rise

* Notes on Parasites Nos. 56-58. In MS., to be published soon in "Science."

to the surface from the deeper lying organs in a direct line rather than as in *Gymnophallus* (Odhner, 00) following the outline of the sucker. The genital sinus is small, with hardly more than space for the copulatory organ to be described later, and its margin is so little distinct that one often finds in section a rounded depression without any projecting lip at all. The ductus ejaculatorius lies nearer the acetabulum with the orifice of the flattened metraterm on its outer (lateral) face at the base of the copulatory papilla. While in section the metraterm appears as a flattened duct with its walls in contact and with at most a meager slit-like lumen in spite of the comparatively well developed muscles of the wall, the adjacent ductus ejaculatorius manifests ordinarily a gaping circular lumen. This is particularly true in the heavy-walled copulatory papilla which terminates the duct. There are no special features in the structure of the metraterm or of other parts of the female reproductive system which has been sufficiently described in the previous paper. The male organs, however, display some features, the structure and significance of which were not understood before.

The form of the seminal vesicle is unusual, in that it does not consist of an enlarged canal thrown into two or more loops as in most distomes, but is rather of a nearly spherical form. In all individuals examined, save those actually *in copula*, it was filled so full of spermatozoa that one could see the structure of the wall only in occasional regions. I was unable to identify muscles of any sort, but could recognize occasional nuclei in the otherwise unbroken membrane. In those individuals which were copulating the walls of the vesicle appear collapsed and irregular in outline and the mass of included sperm was much reduced in size. It is, however, difficult to reconcile the appearance of the walls of the vesicle with muscular or elastic contraction on their part; one is impressed with the idea that they have been passively collapsed by the action of the body muscles, especially the oblique, which appear tense, while the walls of the vesicle certainly look as if they had crumpled under external pressure.

The orifice of the vasa deferentia which join just as they reach the vesicle is so small and inconspicuous that I have as yet been unable to identify its character and cannot affirm or deny the presence of the valve cells described by Looss as found at this point in other species; certainly they are small if present and must close the orifice very perfectly. On the other hand, similar cells are plain at the origin of the ductus ejaculatorius which starts from the vesicle at the posterior ventrolateral margin and passes almost directly ventrad to the copulatory papilla. The duct is short, measuring from 0.1 to 0.13 mm. in length, and has a delicate wall in which one can faintly see in favorable sections the cut ends of a row of delicate circular muscles; longitudinal fibres I could not detect. In spite of its shortness two regions can often be distinguished; that nearer the vesicle has a slight bulbous expansion and may properly be designated as the pars prostatica. The gland cells themselves appear in section as a crescentic mass around the origin of the duct from the vesicle (Fig. 3) and as they manifest a predilection for haematoxylin stains are a prominent feature in sections stained by such fluids. It should be noted, however, that in proportion to the ordinary development of these glands, the size of the organ in this species is actually insignificent and it is visible only on the most successful toto preparations.

When the duct reaches the base of the copulatory papilla, the lumen is slightly contracted and then suddenly expands into a flask-shaped cavity in the papilla, at the apex of which it opens into the genital sinus. It is this copulatory papilla which is the most peculiar structure in this form. When fully retracted it presents the appearance of a conical pyramid (Figs. 3, 4) somewhat longer than broad and irregular in outline. Its length varies from 50 to 60 μ and its transverse diameter at the point of greatest thickness is not more than 40 μ. When emitted (Fig. 2) the form is decidedly more elongate in appearance, though its actual length is approximately the same (55 μ). The lumen, however, is narrower at the proximal portion of the organ and broader near the tip, while the walls are but half so thick. The conical form of the retracted organ has also been modified to a tubular one, in which, however, a broader proximal and a narrow distal portion can be distinguished. The wall of the papilla is lined inside and out by a sharply defined clear membrane, the nature of which could not be further determined. The substance of the wall is composed of thickly set transverse fibres, among which neither nuclei nor other structures could be distinguished. In general appearance and reaction towards staining fluids these fibres resemble muscles, but their direction and arrangement are not easily explained on such a hypothesis. There is present also a set of delicate muscular fibres surrounding the cloaca; they originate around the base of the papilla, from which they diverge at varying angles toward the points of their insertion into the skin. These fibres can be identified positively only in the most favorable cases, on account of their delicacy and sparsity. Their function in the emission of the organ is evident and when powerfully contracted thereby they appear very plain (Fig. 2). The invariable presence of this structure, which I have called a copulatory papilla, precludes the possibility of regarding it as an evertible cirrus which by chance was protruded in the specimen described.

Looss has called attention (94, p. 196) to the importance of determining the changes in form and position of the various parts of the reproductive ducts during copulation. A number of pairs taken *in copula* and preserved at once, enabled me to determine very precisely these relations for this species. It should not be forgotten that the peculiar character of the copulatory organs here make it impossible to draw any conclusions regarding other forms. When paired the worms are united by the ventral suckers so firmly that they cannot be forced apart without tearing the tissue of the body. In each sucker lies a knob of the body wall of the other worm and the powerful contraction of the circular muscles at the margin of the sucker is shown by their prominence in the sections (Fig. 2). The genital sinuses are reduced in depth and their margins are nearly in contact; there are, however, no muscles or other structures to make these margins definite, and I am inclined to think that they play a purely incidental part in the process. The two copulatory papillae lie side by side, their adjacent walls in close contact and the tip of each inserted in the orifice of the metraterm of the other individual. Both the duct and the metraterm are expanded to the fullest extent and a continuous stream of sperm is passing from the vesicle of each into the uterus of the other individual. Reference has already been made to the crumpled appearance of the wall of the vesicle and the probability that it is contracted by extraneous rather than by proper muscles.

The description of the structure of the copulatory papilla will make it clear that the suggestion of Looss in regard to its morphological value can not be accepted. He says (99, p. 621) "Das, was Ward bei Abwesenheit eines echten Cirrusbeutels als Copulations-organ, als 'morphologisches Aequivalent des Cirrusbeutels'* beschreibt und abbildet, duerfte kaum etwas anderes sein als der etwas vorgestuelpte Boden des Genitalsinus; moeglich, dass hier aehnliche Verhaeltnisse vorliegen wie bei *Lecith. sphaerula*." The description already given will evidently not admit of interpreting the organ as merely an evaginated portion of the genital sinus, and its invariable presence and uniform character forbid one to regard it as a temporarily everted structure. It is a constant organ and yet of an unusual type, as is seen from a comparison of the synopsis of conditions found in the male organs, given by Looss (99, p. 551). Since there is no trace of a muscular cirrus sac or of a connective tissue envelopement about the terminal organs, one is compelled to assign this to the first type, as given by Looss, in which, however, he states that the ductus ejaculatorius has the form of a simple tube without evertible portions. No mention is made of the presence of a terminal papilla, and I have also examined with great care specimens of *Opisthorchis*† which Looss assigns to this type and find no trace of any structure in the region in which this papilla is found; the duct terminates without any modification whatever.

The search for a similar structure in some other distome has been conducted with difficulty. So far as the older literature is concerned, most figures and descriptions are silent or lacking in respect to the precise form of the terminal organs of the reproductive system. Even where in a work of later date and greater accuracy a projecting papilla is drawn at the end of the ductus ejaculatorius, e. g. in *Monostomum lacteum* (Jägerskiöld, 96, pl. IX, fig. 7) it is impossible to judge whether the structure is temporary or permanent, and if the latter, how far it corresponds to that under discussion. The case just cited occurs moreover among forms so distantly related that the two could be considered at most as convergent structures.

In only one of the true distomes has anything similar been

* My statement was really "of the cirrus," not "of the cirrus sac." Cf. also p. 182.

† The form examined was that described previously (Ward, 95) as *Distoma felineum* Riv. Further study convinced me that the differences noted in the paper between it and the true *D. felineum* were too great to be varietal, and Looss (99, p. 675) is right in stating that on the basis of the vitellaria alone the form should be regarded as an independent species. I take this opportunity of proposing for it the name of *pseudofelineum*. The description contained in the paper cited will suffice for its identification. In its proper genus it becomes *Opisthorchis pseudofelineus*.

described so far as I can ascertain, and even here the likeness is not more than a general one. It is in *Levinseniella* (*Levinsenia*) that Jägerskiöld (00) has described a conical body of muscular character which projects into the genital sinus and through which the terminal portion of the duct runs in an oblique manner, opening on the lateral face of the cone at about mid-height (Fig. 5). It is possible that the contraction and folding of an elongated organ might produce the conical form with lateral orifice which this author has described in *Levinseniella*, and the prominently striated appearance he has represented recalls the structure described above. But even at best there is a striking difference in the form as well as in degree of development manifested by the organ in the two species. In *Levinseniella* it is equal in size to the ovary and to the ventral sucker and is a prominent feature in the general external appearance of the animal. In *Microphallus* on the other hand it is so small as to be seen only in sections. A comparison of the figures given by Jägerskiöld and myself will make this difference apparent at once. The discussion of the further differences between the two genera is reserved for a later paragraph. Although genuine differences exist between the conical body of *Levinseniella* and the copulatory papilla of *Microphallus*, I share fully the opinion expressed by Jägerskiöld that the latter is a low development stage of the former, and believe that the description of the structure given above raises this view from the rank of conjecture to that of acceptable homology.

In another respect this organ furnishes a decided addition to our knowledge of the distomes. In demonstrating the presence of a permanent muscular organ projecting into the genital sinus and carrying the terminus of the male duct Jägerskiöld added a new type of structure for the male genital organs to those already described by Looss. The simpler stage in the same type is furnished by the genus under consideration here. On the function of the male organs Looss says in a paper just received (01, p. 199) what is also implied in earlier contributions, namely, that the existence of an evaginable cirrus depends upon the presence of a muscular cirrus sac. There is in *Microphallus* absolutely no trace of a cirrus sac and there is also no modified terminal region of the duct which can be evaginated like that to which in other forms the name of cirrus is given. The species does possess, however, an extrusible copulatory organ, which performs the same function as the cirrus and is consequently clearly analogous to it, though far from being homologous. I was mistaken in speaking of it in the earlier paper as "the morphological equivalent of the cirrus;" it is the physiological equivalent but is morphologically distinct. It will be an allowable inference that one may expect to find in *Levinseniella* a similar extrusion of the conical body in copulation. There are thus evidently two types of male copulatory organ in the distomes which depend in their function upon different mechanical principles. In the one the inversion of the duct in its terminal portion is brought about by the muscular cirrus sac in the manner described with care by Looss (94). This is evidently the more common among the distomes and in the interest of a precise nomenclature the name cirrus should be reserved for the eversible portion of the duct of this type of organ as Looss has already insisted. In the other type a permanent muscular (?) projection into the genital cirrus is developed about the terminal region of the duct; in copulation it is protruded and not everted. To this structure I have given the name copulatory papilla and Jägerskiöld has called it a conical body. Evidently both terms are individual in application, but the proposal of a definite name may well be deferred until the morphological value of the organ is better known and its occurrence among the distomes has been more fully investigated. Thus far it is known to occur only in the two forms discussed above. It should certainly not be designated a cirrus.

In one respect the description of Jägerskiöld is open to criticism. In the title he speaks of *Levinseniella* as a distome possessing a genital sucker, and while in the description he says that one can not well speak of a genuine genital sucker, he nevertheless emphasizes "a certain similarity of this organ with the true genital suckers." In my opinion this is clearly a confusion of terms. Morphologically it is not the enlargement or noticeable modification of the genital cirrus or yet the accessory copulatory structures that make a genital sucker, but the specific formation of folds and the development of muscles in the walls of the sinus which give it the structure and function of an acetabulum, as Jägerskiöld has clearly shown in other papers. Speaking of this form he specifically mentions that so far as he could find "the radial musculature of the genital sinus is wanting." In *Microphallus* as already noted none could be demonstrated and the inert condition of the genital sinus during copulation goes to prove its absence, or at least that it is less well developed than ordinarily the case. This being so it is, I believe, incorrect to speak of a genital sucker here in any sense or to attempt a close comparison of these species with those in which such suckers exist. These copulatory organs evidently belong to a distinct type.

In this connection another point of terminology may be discussed. In my earlier paper (Ward, 94) the name metraterm was introduced to designate the modified terminal region of the uterus which had been variously designated by previous authors. Thus the term vagina has been used by writers on trematodes with reference to two regions morphologically distinct, the one of which, Laurer's canal, has been interpreted as the homolog of the vagina in other forms, while the other, the region now under discussion, is undoubtedly, as I was able to show in conjunction with others, the present functional vagina. Braun (93) had stated very clearly the objections to the term vagina and had met them by introducing a term "Scheidentheil des Uterus," which is incapable of rendition into a foreign language, save by a paraphrase. The distinguished investigator last cited has seen fit to make use recently of the name metraterm, which has also found favor with numerous other students of trematode structure. But Looss (94, p. 553-5) has discussed its use at length and has rejected it as unnecessary while he "retains the expression vagina for the region functional as vagina," etc. If one takes exception to this it must be on the ground implied in my earlier paper; the introduction of morphological terms has been wide spread and in the interest of greater precision; that Looss in his argument is compelled to speak of a "morphological vagina" and of a "physiological vagina" is to my mind good evidence of the confusion possible and of the need of a term which shall be at once brief and specific. The designation metraterm is a morphological one, applicable like cirrus to a definite structure in this group, and capable of consistent use for this alone. I think that it adds to the precision attained and that it may continue to find favor thereby.*

The genus *Levinseniella* as founded by Stossich included

*Similar views are advanced by von Ofenheim in a paper just received (Zeitsch. f. Naturwiss., Bd. 73, p. 161).

four forms: *D. brachysomum* Creplin, *D. pygmaeum* Lev., *D. macrophallos* v. Linst. and *D. opacum* Ward. To these Looss added later *D. claviforme* Brds. and as noted above removed *D. opacum* Ward. The latter is a fish parasite, while all the others are found in the caecum or rectum of birds. At the same time its structure differs considerably, being heavier, thicker and without spines, whereas the others are thin, delicate and covered with spines. The alimentary canal and suckers are more rudimentary, while one and all the reproductive glands are proportionally larger and heavier in *D. opacum*. In *Levinseniella* the uterus is smaller and the eggs less numerous, while the position of the reproductive organs varies somewhat. This is most noticeable in the separation of seminal vesicle and sexual pore by a long coiled ductus ejaculatorius in *Levinseniella*, while they are in close juxtaposition in *D. opacum*, and also in the structure of the copulatory organs. These facts may be brought together in the following description of the genus:

Microphallus n. g.

Small forms with flattened mobile anterior and thick immovable posterior region. Skin thick, tough, without spines. Prepharynx present, pharynx small, oesophagus long, crura very short, not even reaching end of anterior region. Excretory bladder large, V-shaped, reaching to the posterior limit of the testes. Ovary dextral, spherical, alongside of acetabulum. Seminal vesicle slightly pyriform, sinistral, composed of a single sac extending anteriad from genital pore which is located on the left just behind the center of the acetabulum. All other reproductive organs behind ventral sucker entirely concealed by heavy coils of uterus filled with eggs. Testes two, directly behind ovary and vesicle. Vitellaria lobed, massive, lateral behind testes; vitelline ducts unite between testes to small vitelline reservoir below shell gland. Laurer's canal present but no receptaculum. Neither cirrus-sac nor cirrus present, but small conical copulatory organ developed about terminus of short ductus ejaculatorius. Eggs, abundant, 0.03 to 0.04 by 0.015 to 0.02 mm. Adult, parasitic in alimentary canal of fishes. Type and only species, *M. opacus* Ward 1894.

By virtue of the peculiar development which is shown by the copulatory organs this and *Levinseniella* may be grouped into a new subfamily, Microphallinae, characterized particularly by the presence in the genital sinus of a muscular copulatory organ in which the ductus ejaculatorius terminates. In other respects the subfamily comes near the Brachycoelinae and Pleurogenetinae of Looss to the former of which it shows the greater similarity.

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EXPLANATION OF PLATE

The figures are made from camera drawings except as stated below.

ABBREVIATIONS

c. p.	Copulatory papilla.	*pr.*	Prostate gland.
d. e.	Ductus ejaculatorius.	*s. v.*	Seminal vesicle.
e. r.	Excretory reservoir.	*t.*	Testis.
g. p.	Genital pore.	*v. d.*	Yolk duct.
int.	Crura intestini.	*v. gl.*	Yolk gland.
m.	Metraterm.	*v. r.*	Yolk reservoir.
ov.	Ovary.		

Plate XXVI

Fig. 1. Ventral view of a specimen preserved in corrosive sublimate, stained in Czokor's alum cochineal and mounted in balsam. The heavy coils of the uterus were omitted to avoid confusion; they fall within the area bounded by the dotted line. The outlines are held true, but otherwise the figure is slightly diagrammatic.

Fig. 2. Cross section of pair in copulation showing relations of organs.

Fig. 3. Section showing seminal vesicle, ductus ejaculatorius, prostate cells and copulatory papilla; the latter is cut a little obliquely.

Fig. 4. Median section through copulatory papilla and genital sinus.

Fig. 5. Transverse section through *Levinseniella pygmaea* var. *similis* at the level of the genital pore. (After Jägerskiöld, 00, p. 735, fig. 3.) Magnification about 250.

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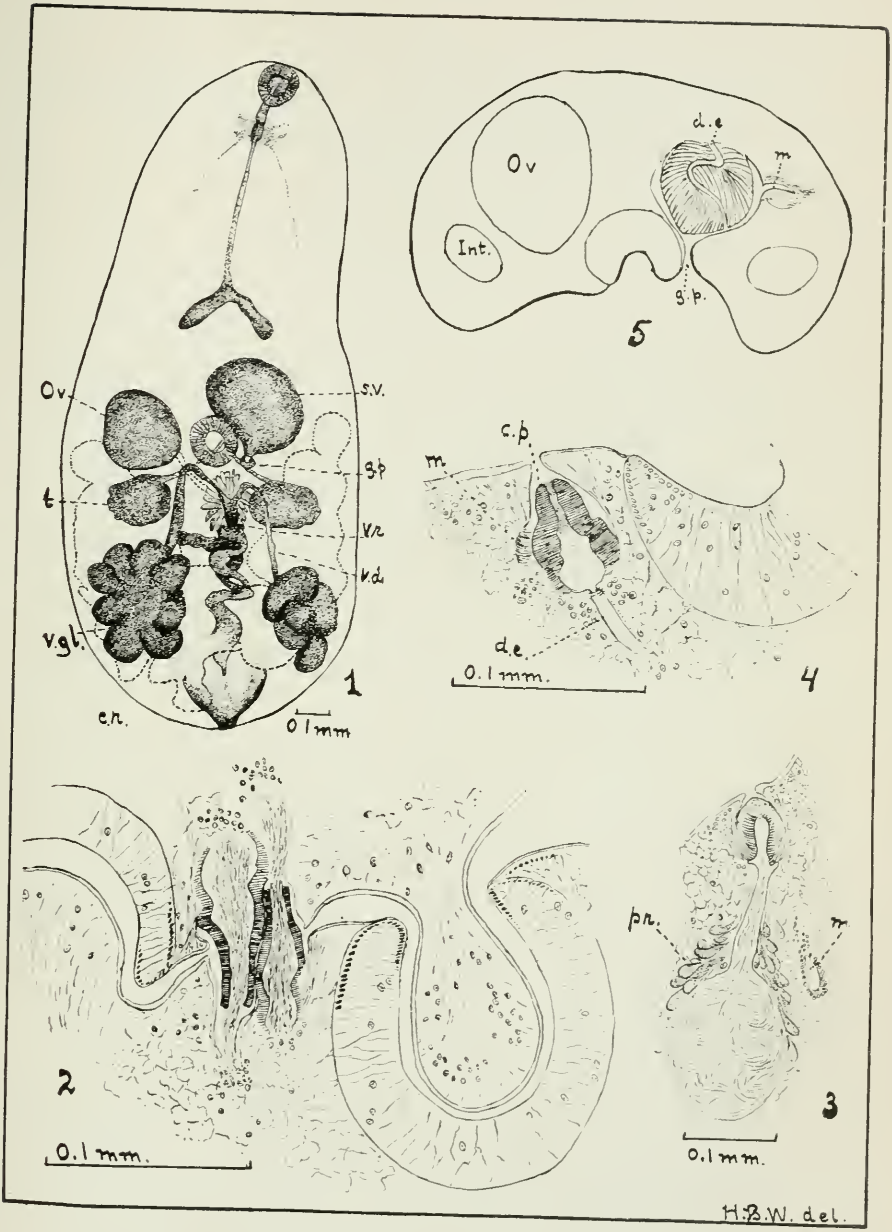
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DESCRIPTION OF A NEW CAVE SALAMANDER, *SPELERPES STEJNEGERI*, FROM THE CAVES OF SOUTHWESTERN MISSOURI*

By CARL H. EIGENMANN

WITH TWO PLATES

Through the courtesy of the officials of the "Frisco" R. R. and a grant from the Elizabeth Thompson Science Fund I made two trips to the caves of southwestern Missouri in search of Typhlotriton and Troglichthys. At that time I collected in various caves a species of Salamander which is here described as new. In Wilson's cave, near Sarcoxie, Missouri, I found this Salamander among the rocks which dam the stream at the mouth of the cave. In Rock House cave I found it, with *Plethodon glutinosus* and *Spelerpes maculicaudus*, under slabs of rock which served as stepping-stones just within the mouth of the cave. In Fisher's cave, near Springfield, I found it under rocks in a part of the cave which served as a cellar. I found it also in a small well-shaped cave near Marble cave, Stone county, Missouri. I have recently received living specimens from near Marble cave. In all cases it was found near the entrance, never at a great distance within the cave.

In 1880 Cope (Am. Nat., XXIV) described a new salamander, *Spelerpes maculicaudus*, from a spring at Brookville, Indiana. This species has since been found to be the common cave salamander of the Mississippi valley. It is found in and near caves, rarely being taken at any great distance within the mouth of a cave. It is especially abundant in the neighborhood of Wyandotte cave. It is common underneath rocks near limestone springs about Bloomington, Indiana; west of the Mississippi it was taken in Rock House and Wilson's caves and about Marble cave of southwestern Missouri.

A second cave salamander, Typhlotriton, was described by

* Contributions from the Zoological Laboratory of the Indiana University, No. 41.

Stejneger (Proc. U. S. Nat. Mus., XV, p. 115) from Rock House cave, Mo. This salamander I have found in Rock House cave and also in Marble cave, Mo. It is distinctly a cave species as distinguished from a twilight species. It is found in remote places in caves and also about their mouths, but has never been found outside. I have recently (Biol. Bull., II, 33, 1900) described the eye of this species. It shows early stages of degeneration.

A third cave salamander, Typhlomolge, was described by Stejneger (Proc. U. S. Nat. Mus., XVIII, p. 619) from the subterranean streams of central Texas. As far as modification of structure as an adaptation to cave-life goes this is the cave salamander par excellence of North America. I have described its eyes in the Transactions of the American Microscopical Society, 1899, p. 49.

The relationship of the last two salamanders is still in some doubt. They are the sole representatives of their respective genera. The fourth cave salamander, described below, belongs to a genus of wide distribution and many species; it is in fact closely related to *Spelerpes longicaudus* and *maculicaudus*. Like the latter, it is a twilight species rather than distinctly a cave species, having been found within a few yards of the mouth of the caves in which it was taken.

Type: 134 mm., Rock House cave, Missouri.

Cotypes:
- a. One specimen, 100 mm., Fisher's cave, near Springfield Missouri.
- b. One specimen, 111 mm., Wilson's cave, Sarcoxie, Missouri.
- c. One specimen, 112 mm., Wilson's cave, Sarcoxie, Missouri.
- d. One specimen, U. S. National Museum.
- e and f. Two specimens now alive from near Marble cave.

For comparison I have a specimen of *Spelerpes maculicaudus*, 133 mm., 53 to anus, from Wilson's cave, Sarcoxie, Missouri; another specimen (53 mm. to anus) from Rock House cave; a number of specimens, 59-133 mm., from Bloomington, Indiana. One specimen of *Spelerpes longicaudus*, 148 mm., from Carlisle, Pennsylvania, and another, 71 mm., from Richmond, Indiana.

Spelerpes stejnegeri differs from both *maculicaudus* and *longicaudus* in color. All the specimens of *maculicaudus*, both small and large, are Chinese orange in life and have the back and sides of the body, the tail and limbs covered with sharply defined, irregularly rounded or elongated spots. Below the lateral spots of the body there is in older specimens a tinge of dusky. A specimen from Rock House cave, which is regenerating a tail lost some time before capture, has the orange color of the other specimens tinged with darker, and in this specimen the region between the fore and hind limbs is dark, the red ground color remaining as spots and marblings. *Spelerpes maculicaudus* has the back similarly marked with black spots on a sienna background. The sides of the body are marked with a dark streak extending from the eye back and interrupted at the costal grooves. Below this streak the sides are again spotted. The sides of the tail contain many dark bands which nearly meet across the back.

The back in *Spelerpes stejnegeri* is raw sienna, with many spots, coalescing in places, and irregularly arranged in two series on either side of the median line. The median line and a streak from the eye back to above the hind limbs, are free from spots. The back of the tail has fewer or no spots. Sides dark brown, with irregular dots and marblings of sienna. The type specimen from Rock House cave has the spots of the back more numerous than the cotypes, and the belly tinged with dark, whereas it is clear in the cotypes. Whether this difference is due to size or to locality I am unable to say. The specimen of *S. maculicaudus* from Rock House cave is also, as mentioned above, much darker than specimens from elsewhere.

Costal grooves 13. Comparative measurements of the type with the specimen of *S. maculicaudus* from Wilson's cave:

	Spelerpes maculicaudus	Spelerpes stejnegeri
Total length	132½ mm.	134 mm.
Width of head	10 mm.	8½ mm.
Distance of arm from tip of snout,	17 mm.	16 mm.
Length of arm and hand	15 mm.	13 mm.
Distance of leg from tip of snout	45½ mm.	43½ mm.
Length of foot and leg	16 mm.	13½ mm.
Distance of anus from tip of snout,	51 mm.	51 mm.
Greatest depth of tail	5½ mm.	6 mm.
Width of tail at point of greatest depth	5½ mm.	4½ mm.

Fingers and toes meeting or overlapping on sides in *maculicaudus*. Fingers and toes in *stejnegeri* not meeting on sides by a space equal at least to the width of an intercostal space. (In smaller specimens this space is less, and the legs may even meet.) Tail more compressed in *stejnegeri* than in *maculicaudus*. Vomerine teeth arranged in the shape of a V with the anterior limbs ending behind the internal nares as in *S. longicaudus*.

I take great pleasure in dedicating this new cave salamander to Doctor L. Stejneger, who described Typhlomolge from the Texas subterranean streams, and Typhlotriton from Rock House cave, and who assisted me with advice and with specimens for the preparation of this report.

EXPLANATION OF PLATES

Plate XXVII

Fig. 1. *Spelerpes maculicaudus*, 130.5 mm. Wilson's cave, Sarcoxie, Missouri.

Fig. 2. *Spelerpes longicaudus*, 147.5 mm. Carlisle, Pennsylvania U. S. Nat. Mus. No. 11,456.

Plate XXVIII

Fig. 3. *Spelerpes stejnegeri*, 112 mm. Wilson's cave, Sarcoxie, Missouri.

PLATE XXVII

FIG. 1

FIG. 2

PLATE XXVIII

Fig. 3

REPORT OF THE LIMNOLOGICAL COMMISSION

The initial report of a body so recently organized as this can hardly be more than preliminary in character, all the more so that the field entrusted to it is as extensive as untried. When by the action of this Society a year ago the Limnological Commission was organized and its members asked to assume the duties laid upon them in connection therewith, they accepted not without some hesitancy at the extent of the work before them. The study of fresh water bodies is indeed a great field, barely touched upon at one or two points in this country and nowhere in the world even superficially covered as yet. Nevertheless it was the original field of biologic study; it was and is accessible to public and private workers practically everywhere and affords opportunities for extended or limited work in any particular department of biologic research towards which the student may be drawn. Furthermore, to this work attaches an undoubted interest for all who come within its territory, while its problems have not only great biologic importance but are also of economic value as well as of decidedly practical character, touching as they do upon the important questions connected with fish culture, municipal water supply and sewage disposal.

In this first report it will not be possible to do more than outline succinctly what has developed from our correspondence and discussion thus far regarding the object of the work, to make a brief survey of the field under discussion, of the ends to be reached and of some of the means for attaining them, and finally to invite propositions concerning the methods and problems under consideration and co-operation in proceeding towards their solution.

It may be fitting at the outset to state briefly the outlook before the Commission. Such a venture as this is not entirely unheard of, and consequently venturesome. A similar body was appointed some years ago by the Swiss National Society for Natural Sciences. As a Swiss investigator, Professor Forel, of Geneva, was the pioneer in the study of fresh water lakes, and as the investigators of this beautiful mountain republic have retained their supremacy in this field of research through more than thirty years, so also Switzerland was the leader in organized effort towards the development of limnological investigation. The plan of the Swiss Limnological Commission in assigning work in various regions to different students has met with such success as to inspire those who follow in its footsteps with hope for the outcome of their efforts and as to hold up a high standard for their attainment. Similar results can not be expected in a brief period of time, but we hope that they may be reached here eventually.

The study of limnologic questions affords abundant opportunities for workers of every type and of every grade; but if the results of such varied activity are to be of permanent value or of general import, they must be correllated and unified. Therewith gaps in the record will become apparent and new problems be suggested so that the lines of work will be extended and at the same time joined together into a symmetrical system. The fundamental objects then of this Limnological Commission we believe to be:

To co-ordinate the results obtained by different investigators into a united whole; to enlist new workers and to encourage new work along lines already marked out; to suggest new lines of work and methods of research, and to aim at uniformity of procedure so that the results may be compared and correllated.

For convenience in discussion and in the organization of the work, the field of limnologic study has been cut up into a number of main divisions and some of the chief subdivisions under each indicated. These are as follows:

1. Bibliography: a general historical review of limnological studies to date; periodic summaries of work done in the world at intervals thereafter.

2. Physiography: the inanimate environment, including the physical and chemical study of water bodies; types of such bodies, distribution; temperature, color, circulation; lake areas; composition of water, etc.

3. Biology, (a) Taxonomy of water organisms: systematic tables, description and sketch of each on cards to form eventually a faunal catalogue for the United States. (b) Morphology of organisms: anatomy, histology, embryology of individual forms. (c) Distribution of organisms: (1) Geographic; (2) regional: littoral, limnetic, bathybic species; (3) quantitative:

general, numerical, proportional. (d) Physiology, experimental studies. (e) Ecology.

4. Applied limnology: water supply, sewage, fish culture.

After this preliminary statement, the Limnological Commission has the following recommendations to make for the purpose of advancing this work:

First, it is expedient that, as soon as suitable persons can be found who are willing to undertake the work, there should be added to the Commission a physicist, a chemist and a bacteriologist, in order that these phases of the environment may be adequately studied.

Second, the influence of the Society should be directed towards the production and publication of accurate systematic accounts of the fresh water organisms, to the end that the various workers on limnologic questions may have at hand taxonomic summaries of the organisms with which they come in contact. It is not too much to say that such treatises are non-existent for American forms and inaccessible to the majority even for the few groups which have been partially worked out. This must be the first step in the inauguration of the proposed movement. The publication of a series of catalogue cards, each devoted to a single species, appears as a desirable method of putting such data into accessible form and keeping them in shape for frequent emendation or addition.

Third, in the interest of a complete knowledge of the distribution of fresh water organisms, the Commission plans the keeping of careful faunal records. It is proposed to appoint one or two investigators for each group who shall undertake to enter and collate all faunal records of this group which may be sent them and conversely to furnish workers with information concerning the distribution of such organisms. This plan will ultimately yield data for the discussion of the geographical distribution of fresh water genera and species. It will also enable the elimination of such data as are common, leaving for publication by the student those facts which are important for one reason or another.

Fourth, the Commission is of the opinion that an occasional summary of progress in the field of limnology will serve to keep students in touch with the subject by giving them knowledge of the work of the world in general. This is that subdivision of the field which stands first in the outline given above. It has been covered sufficiently for the present by the summary and review printed in the Transactions of this Society, volume XX, bringing the subject up to January, 1899.

Fifth, the Commission would most strongly advise that individual work should be limited to a single body of water or to a definite problem studied with reference to a series of such water bodies. The results will be most useful for all purposes when they bear upon the thorough treatment of a single phase of the subject rather than more indefinitely upon a wider field.

There is naturally involved in the effort to carry out such plans as have been outlined some expenditure of money, even if the services of various investigators are freely and gratuitously placed at the disposal of the Commission. Accordingly, an appeal is made herewith to the generosity of those interested in the movement and in the development of biological study in our country for contributions, large or small, for the prosecution of this work.

In conclusion, all students interested in this subject are invited to participate in the work. It is by general and generous co-operation that success will be attained. The student who is working alone cannot advance far unless brought in touch with others in the same field. It may be noted that the opportunity is peculiarly advantageous for those teachers in smaller colleges who can make use of a corps even of untrained assistants in the collection of various data. We feel it a privilege to invite kindly criticism of this report and suggestions as to the best means for carrying out the aims in view and for securing the co-operation of the largest number of workers.

(Signed) A. E. Birge, Chairman.
C. H. Eigenmann.
C. A. Kofoid.
G. C. Whipple.
H. B. Ward, Secretary.

JACOB DOLSON COX

NECROLOGY.

JACOB DOLSON COX,

OF OBERLIN, OHIO.

Jacob Dolson Cox was born at Montreal, Ontario, October 27th, 1828. His father, a resident of New York City, and an architect by profession, was then living in Montreal where he was engaged in supervising the construction of the roof, etc., of Notre Dame Cathedral which he had designed, and upon the completion of which he returned to his home in New York City, where the boyhood years of the subject of this memoir were passed. In 1846 Jacob Dolson Cox entered Oberlin College at Oberlin, Ohio, from which institution he graduated in 1851, receiving the degree of Master of Arts. In 1877 the degree of Doctor of Laws was conferred upon him by Yale College. He married Mrs. Helen Finney Cochran, widow of Prof. William Cochran and daughter of president Finney of Oberlin College, and in September, 1851, he accepted the position of superintendent of schools in Warren, Ohio, which position he held until 1854, and in the meantime studied law and was admitted to the bar. In 1859 he was elected to the senate of Ohio, in which he served during the years 1860 and 1861. Upon the breaking out of the civil war and almost immediately after the firing upon Fort Sumter, he was appointed by Gov. Dennison, Brigadier General of Volunteers and was placed in charge of Camp Dennison, near Cincinnati, which was the great receiving and distributing camp for volunteers, and while in command of the camp he displayed great efficiency in the organization of the troops and in all the duties connected with the responsible position which he held. In July, 1861, he was assigned to service in the field, drove Wise out of the Kanawha Valley, West Virginia, and took a prominent part in the battles of South Mountain and Antietam, in which he commanded the 9th army corps. In the Atlanta and Franklin and Nashville campaigns Gen.

Cox commanded the 23d army corps, and in 1864 he was commissioned Major General of volunteers.

In 1865 Gen. Cox was elected governor of Ohio, in which office he served during the years 1866 and 1867, and at the expiration of his term moved to Cincinnati and resumed the practice of law. In March, 1869, Gov. Cox was appointed Secretary of the Interior by Pres. Grant, and filled this position with distinguished credit until November, 1870, when he resigned, and returning to his home in Cincinnati, Ohio, again resumed the practice of law.

Soon after assuming his portfolio in Pres. Grant's cabinet, Gov. Cox was confronted with the practice then prevailing, of levying assessments upon the department officials and clerks for political purposes. To this Gov. Cox was inflexibly opposed, and was supported in his opposition by Pres. Grant, who assured him that the practice should no longer be enforced in the Interior Department. In September, 1870, however, during his temporary absence from the capitol, certain prominent politicians collected assessments from certain employes in the Interior Department, greatly against the will of the employes. Upon learning of this, Sec. Cox became highly incensed and resigned his portfolio, taking the ground that if his views could not prevail in the conduct of the Interior Department he would have nothing to do with it. His resignation was reluctantly accepted by Pres. Grant, who personally sympathized with the views of Gov. Cox, but seemed to have been unable to control the clique of eminent politicians, who, themselves holding high offices under the government, were fully in accord with the system of political assessments.

In 1873 Gov. Cox was appointed president of the Toledo and Wabash Railroad Co. and removed to Toledo, Ohio. He remained as president and receiver of this R. R. until 1878. In 1876 he was elected to congress from the Toledo District, and served as Congressman until March, 1879. Upon the expiration of his congressional term Gov. Cox retired from politics and thereafter declined to take any active part therein. In 1878 he removed to Cincinnati, soon after becoming Dean of the Cincinnati Law School, which position he held until 1897, when he resigned his position, retired from active business and removed to Oberlin, Ohio, where he resided until his death, which occurred at Magnolia, Mass., on August 4th, 1900.

He was president of the University of Cincinnati from 1885 to 1889.

It was about the time of his removal to Toledo that Gov. Cox became interested in microscopy, which, as many other eminent microscopists have done, he first adopted as a recreation. His first microscopical studies were upon fresh water forms, particularly in the class rotatoria; but as might naturally be expected he speedily became interested in the study of the diatomaceae, to which his chief attention from that time forward was given. In his microscopical studies Gov. Cox displayed that painstaking thoroughness and striking power of logical analysis which he displayed in all his works in every walk of life. Almost at the beginning of his work with the microscope Gov. Cox adopted a system of keeping notes of his work and observations, which eventually grew to remarkable proportions. Among his belongings which he left at his decease, were some twenty or more note books completely written and filled with the records of observations, drawings and notes of his conclusions and deductions, all carefully dated and neatly written out, which work alone would seem to have been sufficient to absorb all the leisure time that one man would be able to devote to such work. In addition to this, however, he had made an almost complete card catalogue of the diatomaceae comprising the nomenclature and synonymy of each species, references to leading works in which it is figured and described, and Maltwood finder references to specimens of that particular form in slides among his own collection, which numbered some thousands of slides. In addition to contributing articles at intervals to the microscopical journals, Gov. Cox contributed several important papers to the Proceedings of this Society. In 1874 Gov. Cox took up the subject of photo-micrography, and in 1875 began making the series of photo-micrographs of diatomaceae so well known to many members of the society. Of this series of photo-micrographs, several hundred in number, Gov. Cox kept the same careful record as of all his other work with the microscope. His note books show the date when each negative was made, will full particulars concerning the object, illumination, apparatus employed, photo-micrographic technique, etc. Prints from this carefully numbered series of negatives were distributed by him to all the leading authorities on the diatomaceae. As a result of this work Gov. Cox received at the Antwerp exposition in 1891 the gold medal awarded for the greatest excellence in micrography.

In 1881 Gov. Cox was elected a fellow of the Royal Microscopical Society, and in August, 1882, was elected a member of this society at the Elmira meeting. At the Chicago meeting in 1883 he was present and contributed a brief paper descriptive of the modification devised by him of the Wales Microscope stand, which modification became known as the "Concentric" stand. At this meeting he was nominated and elected president of the society for the next meeting, which was held at Rochester in 1884. His presidential address at the Rochester meeting embraced a masterly discussion of the Tolles-Wenham controversy over the angular aperture of objectives used with balsam mounts. No one who had followed that lengthy and acrimonious dispute can fail to admire the clear, logical and exhaustive, yet brief, analysis of the arguments pro and con and the very numerous errors so strenuously maintained by the opponents of the "extra" balsam angle during the years when that unfortunate controversy dragged its slow length along through the literature of microscopy. At the same meeting Gov. Cox read an interesting paper on photomicrography with high powers, which displayed not only a thorough acquaintance with the subject and great experience in the work, but served as a text around which animated discussion was waged for the next two or three meetings, the views maintained and the practice advocated by Gov. Cox in that paper being finally vindicated by demonstrations afforded by the work of several other well known and active members of the society. At the Cleveland meeting in 1885 Gov. Cox read a second paper on the subject of photo-micrography with high powers. At the Chautauqua meeting in 1886 Gov. Cox, in collaboration with Mr. W. H. Walmsley, conducted a practical exhibition of photo-micrographic work which was of great value in familiarizing many interested members of the society with the technique and manipulation essential in that class of work, which at that time was rapidly growing in favor. At the Washington meeting in 1892 Gov. Cox was a second time elected president of the society, and presided at the Madison meeting in 1893. In the intervening years he contributed to the society other valuable papers, one of the most painstaking being his paper read at the Detroit meeting in 1890 on the classification of the diatoms. After 1895 he practically ceased work with the microscope, fearing its effect upon his eyes, but his interest in microscopy and the study of natural history by the aid of the microscope continued unabated during his life.

His accumulation of careful and minutely detailed records, not only served as valuable helps to Gov. Cox in his work, but afforded the means by which the path he followed and the steps he took in his investigations can be accurately followed and fully understood by one who now reads the same.

During the last few years of his life Gov. Cox in company with his son, J. D. Cox, Jr., of Cleveland, spent several weeks each summer in yachting upon the New England coast, sometimes accompanied by other relatives and friends. During these periods Gov. Cox kept a careful log of their daily wanderings, noting the barometer reading, course of winds, distances sailed, points visited, etc., with all the careful attention to detail which characterizes the most experienced ship master.

His wide experience as an officer combined with his habits of exhaustive research and his power of keen analysis fitted him especially for the work of a military critic and historian, in which Gov. Cox attained a high repute. His reviews of military works in "The Nation" alone would fill several volumes and are marked by charity, lucidity and original contributions to history and the science of war. He wrote the articles "Atlanta" and "The March to the Sea," "Franklin and Nashville" for the "Scribner Campaign Series" in 1881 and 1882; several articles for "Battles and Leaders of the Civil War" published in 1884-1888; "The Battle of Franklin," of which *magnum pars fuit*, in 1897; and "Military Reminiscences of the Civil War" in 1900. He also prepared an admirable analysis and exceedingly clear exposition of the facts in the Fitz John Porter Case, which he published in 1882, during the time when persistent efforts were being made in congress for the rehabilitation of General Porter.

In the outset of his studies at Oberlin College Gov. Cox had intended to enter the ministry, and he pursued his theological studies for some time. Eventually, however, he seemed to doubt, probably without sufficient reason, his fitness for the ministry and gave up the idea of a clerical career. It is likely, however, that his theological studies accentuated and intensified the natural broad christianity of his character, which during all of his varied and illustrious career was one of the potent features of attraction which so deeply endeared him to all who became well acquainted with him. His personality was attractive and none who met him can fail to remember his tall and striking appearance, his rich sonorous voice, and the peculiarly frank and friendly expression of his face.

C. M. VORCE.

MOSES CLARK WHITE, A. M., M. D.,

OF NEW HAVEN, CONN.

By the death of Professor Moses Clark White, M. D., which occurred October 24, 1901, the American Microscopical Society lost one of its oldest and most enthusiastic members.

Dr. White was born in Paris, N. Y., July 24, 1819, and was accordingly over eighty-one years old at the time of his death. His preliminary education was obtained at Cazenovia Seminary, Cazenovia, New York, after which he entered Wesleyan University at Middletown, Conn., in February, 1842, and graduated third in rank in the class of 1845. The following two years he spent in New Haven, Conn., in theological and medical studies at Yale University, meanwhile preaching in New Haven and adjoining towns.

Having been ordained an elder in the Methodist Episcopal Church, and soon after this appointed as a missionary to China, he sailed together with his wife from Boston on April 15, 1847, going to Foo-Chow, and the years from 1847 to 1853 were spent in medical missionary work in that country. His experiences in those early days of Chinese missionary work were most varied and unusual, combining a large dispensary service with a private practice that covered a wide territory. During this time, he also published a translation of the gospel of Matthew in the colloquial language of Foo-Chow, which is said to have been the first book ever published in that dialect. After seven months' residence in China Mrs. White died, and Dr. White's own health finally became so impaired that he was compelled to leave there in 1853, and he returned to New Haven. Soon after his return, he published "An Introduction to the Study of the Colloquial Language of Foo-Chow." In 1851, before his return from China, he was again married, his wife being Mary Seely, of South Onondaga, N. Y.

Upon his return to this country he again took up his medical studies at Yale and graduated in medicine in 1854, then

MOSES CLARK WHITE

establishing himself in New Haven as a physician. He at once became interested in microscopy, and in 1857 was appointed lecturer on microscopy in the medical department of Yale University. Ten years later, he was advanced to the newly established professorship of Microscopy and Pathology in the same institution; and this position of Professor of Pathology he retained until a few months before his death, when he severed his active connection with the Medical School and was elected Professor Emeritus in the same subject.

Aside from his duties as a practicing physician, and as a teacher of medicine, Dr. White found time to act as an instructor in Botany in the Sheffield Scientific School from 1861 to 1864, and he was also a lecturer on Vegetable and Animal Histology in Wesleyan University, his old *alma mater*, from 1869 to 1875. For many years he was connected with the New Haven Hospital, as one of the attending physicians, and as pathologist, at the same time being a member of the board of directors of that institution. He was also secretary of the Connecticut State Medical Society from 1864 to 1876. Since the creation of the office of Microscopist of the New York Medico-Legal Society, that position has been filled by Dr. White. His connection with and work for the American Microscopical Society since he became a member of it in 1885 is too well known to need repetition here. Always an active member in the full sense of the word, he served in 1898 as Vice President, and would have been honored with the position of President had he permitted the use of his name.

From the establishment of the office of Medical Examiner, or Coroner's Physician, in Connecticut in 1883, until the time of his death, Dr. White held that position for the town of New Haven. His success in this office is perhaps best given in the words of the Coroner of New Haven County: "As Medical Examiner, he has been associated closely with me for the past seventeen years, during which time he has never wavered in the complete performance of his duties, rendering honest, capable, reliable, efficient, valued service. As Coroner of New Haven County, State of Connecticut, I have twenty-five Medical Examiners connected with the office. Dr. White was the peer of them all, the one to whom I went and whose knowedge and counsel I availed myself of."

Besides the publications already referred to, Dr. White assisted largely in the preparation of "Silliman's Physics," and wrote the chapter on Optics. He revised and edited the second edition of "Porter's Chemistry." For some years he has shown great interest in micro-photography, and in the examination of blood stains, not only by chemical means, but particularly by measurements of the red blood corpuscles. This latter method he emphasized as of value in differentiating the blood of various animals. His publications in this line have been many and important, and the members of the American Microscopical Society have had an opportunity to see the extensive and exact nature of his work. More recently he has devoted much time to the perfection and use of the projection microscope.

This incomplete outline of the life-work of Professor White may give some idea of the energy of the man and of his ability in various directions. But only those who knew him best could rightly appreciate his true worth. He was so quiet, so unobtrusive in his manner, that a close acquaintance was necessary to really know the man. And such an acquaintance could not fail to show his uniform kindness to all, his remarkable enthusiasm which kept him to the very front in his work in microscopy, and a determination which kept him active almost to the day of death.

One of his long-time friends has well written of him, "Earnest in all his undertakings, of the highest integrity and uprightness of character, enjoying the respect and confidence of all with whom he was associated, his memory deserves to be honored by some pen that will thoughtfully, truthfully, and lovingly delineate the meritorious and estimable characteristics of Dr. White as they were known to those who knew him best." C. J. Bartlett.

New Haven, Conn., April, 1901.

PROCEEDINGS

OF

The American Microscopical Society

MINUTES OF THE ANNUAL MEETING

HELD IN

NEW YORK CITY, JUNE 28, 29, 30, 1900

First Session

Thursday, June 28

The twenty-third annual meeting of the Society was called to order by the President in Schemerhorn Hall, Columbia University, New York City, at 2 p. m., Thursday, June 28, 1900. After the reports of the Curator, Secretary, and Treasurer had been read, it was, on motion, decided that owing to the very early date of the annual meeting, the financial year of the Society should be extended to October 1st rather than close at the date of the meeting. The Custodian was directed to send to the Smithsonian Institution a set of back volumes save Vol. VI.

The report of the Limnological Committee was given informally, and it was decided that the opinion of the committee with reference to an increase in number was correct, and that a chemist, a physicist, and a bacteriologist should be added as soon as suitable members could be obtained for these fields. The committee was given time, and instructed to find those willing and able to undertake the work. The Society then voted unanimously to accept the invitation of the Board of Directors of the New York Zoological Garden to visit the same with the Zoological Section of the A. A. A. S., and thereupon adjourned to proceed to the Zoological Garden, where a most enjoyable afternoon was passed in inspection of the plant under the leadership of Prof. H. F. Osborn, of Columbia University, and Dr. Wm. T. Hornaday, Director of the Garden.

SECOND SESSION

At 8 P. M. the Society convened in the rooms of the New York Microscopical Society, 64 Madison Avenue, and listened to the annual presidential address by Dr. A. M. Bleile, on "The Detection and Recognition of Blood." At the close of the meeting an informal reception was tendered the Society by the New York Microscopical Society, and members of both Societies spent some time in social enjoyment.

THIRD SESSION

FRIDAY, June 29

The Society was called to order at 10 A. M., in Schemerhorn Hall, and after the report of the Executive Committee for the fiscal year had been read, the President appointed Mr. John Aspinwall and Dr. M. A. Veeder Auditors of the Custodian's report, and Mr. Magnus Pflaum and Mr. C. C. Mellor of the Treasurer's report. A nominating committee was then elected, consisting of Messrs. Gage, Kuehne, R. H. Ward, White, and Whipple. The Society then listened to the reading of the following papers:

"Photographing the Spectra of Colored Fluids," by Dr. Moses C. White, of New Haven, Connecticut. In discussion the President made extended reference to his address of the previous evening in connection with the paper in hand; the latter was also discussed by Professor Gage.

A paper on "A Method for the Measurement and Demonstration of the Size of Minute Bodies" was read by Dr. Henry B. Ward, and discussed by Prof. S. H. Gage and Mr. Magnus Pflaum.

"The Life-Work of Herbert Spencer" was reviewed by Mr. H. R. Howland, and further tribute to his work was added by Dr. R. H. Ward and Prof. S. H. Gage.

The Society also discussed generally the Spencer-Tolles Fund, and voted that the President should appoint a committee of three, who, together with the Custodian, should be especially charged with the completion of the fund before the next meeting.

A paper on "Methods in Embryology" was read by Prof. S. H. Gage, and discussed by Dr. H. B. Ward; and a second paper on "The Comparison of the Development of the Larynx in Toads and Frogs" was also read by Professor Gage and discussed by Drs. L. Schoeney and H. B. Ward. The Society then adjourned for dinner.

FOURTH SESSION

The Society was called to order by the President at 2:30 P. M., and the Report of the Limnological Commission was presented by Dr. H. B. Ward, Secretary of the Commission.

A paper "On the Distribution of Growths in Surface Water Supplies and the Method of Collecting Samples for Examination," by Dr. F. S. Hollis, was read, in the absence of the author, by Mr. G. C. Whipple, and informally discussed by a number of the members and visitors.

A paper on "The Necessity of Maintaining a System of Field Work on Surface Water Supplies," by Mr. H. N. Parker, was read, in the absence of the author, by Mr. G. C. Whipple, and discussed by the President and others.

A paper on "The Cladocera of Nebraska," by Dr. Chas. Fordyce, was read by the Secretary in the absence of the author, and informally discussed.

"The Work of the Mount Prospect Laboratory of the Brooklyn Water Works" was presented by Mr. G. C. Whipple, with lantern slides illustrating the laboratory and its equipment and work, and was discussed by Messrs. John Aspinwall and H. B. Ward.

A paper on "Some New Forms in the Cave Fauna of Mammoth Cave" was read by Dr. C. H. Eigenmann, and discussed by Messrs. John Aspinwall, H. B. Ward, and others.

A paper on "The Modern Conception of the Structure and Classification of the Desmidiaceae" was read by title in the absence of the author, Prof. Chas. E. Bessey.

A paper on "Some North American Hydrachnidae, hitherto undescribed," was read by title in the absence of the author, Dr. Robert H. Wolcott.

A paper on "Limnological Studies at Flathead Lake" was read by title in the absence of the author, Prof. M. J. Elrod.

The committee on the Spencer-Tolles Fund was then announced by the Chair as H. B. Ward, Adolph Feiel, and H. R. Howland. The Society then adjourned.

FIFTH SESSION

SATURDAY, June 30

The Society was called to order by the President at 9:30 A. M.

A paper on a "Method of Reproducing Color Effects of Stained Sections in Lantern Slides" was read by Mr. John Aspinwall, and discussed by Dr. H. B. Ward.

A paper on "Some Hints in Bibliographic Work in Science" was read by Dr. R. H. Ward, and informally discussed.

A paper on "A New Ear Fungus of Man," by Dr. Roscoe Pound, was read by title in the absence of the author.

A paper on "Methods in Staining and Killing Protozoa" was read by title in the absence of the author, Prof. M. J. Elrod.

A paper on "Synthetic Alcohol as a Fixing Agent for Tissues" was read by title in the absence of the author, Dr. T. E. Oertel.

The Nominating Committee reported the following choice of officers for the ensuing year:

For President....Prof. C. H. Eigenmann, Bloomington, Ind.
For Vice-President.....Mr. Chas. M. Vorce, Cleveland, Ohio.
For Second Vice-President............................
................Mr. Edward Pennock, Philadelphia, Pa.
For Elective Members of the Executive Committee......
Mr. John Aspinwall, New York City.
Dr. C. A. Kofoid, Urbana, Ill.
Dr. A. G. Field, Des Moines, Iowa.

A vote of thanks was passed to the officers of the Society for their services, to Columbia University for the use of the rooms and apparatus placed at the disposal of the Society, to the President and members of the New York Microscopical Society for their cordial hospitality, and to the Board of Directors of the New York Zoological Garden for the courtesies shown members of the Society during the visit to the garden.

After appropriate words of thanks to the Society, the retiring president called the new incumbent of the office to the chair. On taking his position, the President, Dr. C. H. Eigenmann, expressed his thanks to the Society for the honor conferred upon him, and the hope that the coming year might be more successful even than the past. He then declared the meeting adjourned, the place and date of the following meeting to be decided by the Executive Committee.

HENRY B. WARD, *Secretary*

TREASURER'S REPORT

FROM AUGUST 15, 1899, TO SEPTEMBER 20, 1900

DR.

To Membership dues, 1898, 1	$2.00	
To Membership dues, 1899, 15	30.00	
To Membership dues, 1900, 169½	339.00	
To Membership dues, 1901, 33	66.00	
To Membership dues, 1902, 1	2.00	$439.00
To Admission fees, 1900, 22	$66.00	
To Admission fees, 1901, 5	15.00	81.00
To Subscribers, Vol. XX	$8.00	
To Subscribers, Vol. XXI	16.00	
To Sale of Proceedings	33.80	57.80
To Advertising, Vol. XX	$8.00	
To Advertising, Vol. XXI	80.00	88.00
		$665.80
To Balance due Treasurer		37.82
		$703.62

CR.

Expenses Columbus Meeting		$1.25
By Postage, Secretary	$12.95	
By Postage, Custodian	.50	
By Postage, Treasurer	11.00	24.45
By Expressage, Secretary		33.28
By Stationery and Printing, Secretary	$35.10	
By Stationery and Printing, Treasurer	9.75	44.85
By Typewriting, Secretary	$32.07	
By Sundries, Secretary	36.40	
By Bank charges, Treasurer	3.50	71.97
By Issuing Vol. XXI, printing	$480.75	
By Issuing Vol. XXI, plates	38.55	519.30
By Cash returned to Mr. M. Pflaum		8.52
		$703.62

J. C. Smith, *Treasurer*

Pittsburgh, Pa., January 10, 1901.

We hereby certify that we have examined the foregoing accounts and find the same correct, with proper vouchers for expenditures.

C. C. Mellor,
Magnus Pflaum,
Auditing Committee

CUSTODIAN'S REPORT FOR YEAR ENDING JULY 1, 1900

Reported at Columbus Meeting	$653.36
January 1, 1900, Dividends	25.81
July 1, 1900, Dividends	26.84
Proceeds of sale of one set of Transactions	50.00
Total	$756.01
Total increase for year	102.65

Magnus Pflaum, *Custodian*

We certify that having examined the foregoing report of the Custodian we find the same correct.

John Aspinwall,
M. A. Veeder,
Auditing Committee

New York, June 30, 1900

SPENCER-TOLLES FUND.

Year.	Increase	Total
1885	......	$60.20
1886	$25.00	85.20
1887	10.00	95.20
1888	52.66	147 86
1889	76.00	223.86
1890	30.00	253.86
1891	39.02	292.88
1892	19.12	312.00
1893	18.06	330.06
1894	19.32	349.38
1895	22.89	372.27
1896	50.77	423.04
1897	45.99	469.03
1898	86.43	555.46
1899	97.90	653.36
1900	102.65	756.01

CONSTITUTION

Article I

This Association shall be called the American Microscopical Society. Its object shall be the encouragement of microscopical research.

Article II

Any person interested in microscopical science may become a member of the Society upon written application and recommendation by two members and election by the Executive Committee. Honorary members may also be elected by the Society on nomination by the Executive Committee.

Article III

The officers of this Society shall consist of a President and two Vice-Presidents, who shall hold their office for one year, and shall be ineligible for re-election for two years after the expiration of their terms of office, together with a Secretary and Treasurer, who shall be elected for three years and be eligible for re-election.

Article IV

The duties of the officers shall be the same as are usual in similar organizations; in addition to which it shall be the duty of the President to deliver an address during the meeting at which he presides; of the Treasurer to act as custodian of the property of the Society, and of the Secretary to edit and publish the Proceedings of the Society.

Article V

There shall be an Executive Committee, consisting of the officers of the Society, three members elected by the Society, and the past Presidents of the Society and of the American Society of Microscopists.

Article VI

It shall be the duty of the Executive Committee to fix the time and place of meeting and manage the general affairs of the Society.

Article VII

The initiation fee shall be $3.00, and the dues shall be $2.00 annually, payable in advance.

Article VIII

The election of officers shall be by ballot.

Article IX

Amendments to the Constitution may be made by a two-thirds vote of all members present at any annual meeting, after having been proposed at the preceding annual meeting.

BY-LAWS

I.

The Executive Committee shall, before the close of the annual meeting for which they are elected, examine the papers presented and decide upon their publication or otherwise dispose of them.

All papers accepted for publication must be completed by the authors and placed in the hands of the Secretary by October 1st succeeding the meeting.

II.

The Secretary shall edit and publish the papers accepted with the necessary illustrations.

III

The number of copies of Proceedings of any meeting shall be decided at that meeting.

IV

No applicant shall be considered a member until he has paid his dues. Any member failing to pay his dues for two consecutive years, and after two written notifications from the Treasurer, shall be dropped from the roll, with the privilege of reinstatement at any time on payment of all arrears. The Proceedings shall not be sent to any member whose dues are unpaid.

V

The election of officers shall be held on the morning of the last day of the annual meeting. Their term of office shall commence at the close of the meeting at which they are elected, and shall continue until their successors are elected and qualified.

VI

Candidates for office shall be nominated by a committee of five members of the Society. This committee shall be elected by a plurality vote, by ballot, after free nomination, on the second day of the annual meeting.

VII

All motions or resolutions relating to the business of the Society shall be referred for consideration to the Executive Committee before discussion and final action by the Society.

VIII

Members of this Society shall have the privilege of enrolling members of their families (except men over twenty-one years of age) for any meeting upon payment of one-half the annual subscription ($1.00).

Approved by the Society, August 11, 1892.

LIST OF MEMBERS

The figures denote the year of the member's election, except '78, which marks an original member. The TRANSACTIONS are not sent to members in arrears, and two years' arrearage forfeits membership. (See Article IV of By-Laws.)

Members Elected During the Year 1900

For addresses see regular list.

ASPINWALL, JOHN.	McMILLEN, R. M.
COFFIN, ROBERT.	SHANKS, S. G.
HOWE, W. T. H.	WHEELER, E. J.
JUDAY, CHANCEY.	YOUNG, L.

ABERDEIN, ROBERT, M. D., '82..........327 James St., Syracuse, N. Y.
AINSLIE, CHARLES N., '92..............................Rochester, Minn.
ALLEGER, WALTER W., M. D., '94.....949 T St., N. W. Washington, D. C.
ASPINWALL, JOHN, M. A., '00............339 Broadway, New York City
ATWOOD, E. S., '79..............Highlands P. O., Monmouth Co., N. J.
ATWOOD, H. F., '78................76 Seneca Parkway, Rochester, N. Y.
AYERS, MORGAN W., M. D., '87..................Upper Montclair, N. J.

BARKER, ALBERT S., '97...
.................Twenty-fourth and Locust Sts., Philadelphia, Pa.
BARNSFATHER, JAMES, M. D., '91....................................
.....................Cor. Sixth Ave. and Walnut St., Dayton, Ky.
BARTLETT, CHARLES JOSEPH, M. D., '96...705 Elm St., New Haven Conn.
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BAUSCH, HENRY. '86...............................Rochester, N. Y.
BAUSCH, WILLIAM, '88.................St. Paul St., Rochester, N. Y.
BEAL, Prof. JAMES HARTLEY, '96..............Scio College, Scio, Ohio
BEARDSLEY, Prof. A. E., '97..............1412 Tenth St., Greeley, Colo.
BELL, CLARK. ESQ., '92..................39 Broadway, New York City
BENNETT, HENRY C., '93.......256 W. Forty-second St., New York City
BERING, J. EDWARD, '99..................................Decatur, Ill.
BESSEY, Prof. CHARLES EDWIN, Ph. D., LL. D., '98......Lincoln, Neb.
BEYER. Prof. GEO. E., '99........Tulane University, New Orleans, La.
BIRGE, Prof. E. A., S. D., '99..University of Wisconsin, Madison, Wis,
BISCOE, Prof. THOMAS D., '91...........404 Front St., Marietta, Ohio
BLEILE, A. M., M. D., '81......Ohio State University, Columbus, Ohio
BODINE. Prof. DONALDSON, '96...................Crawfordsville, Ind.

Booth, Mary A., F. R. M. S., '82..60 Dartmouth St., Springfield, Mass.
Boyce, James C., Esq., '86..........Carnegie Building, Pittsburg, Pa.
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Brundage, A. H., M. D., '94..........1153 Gates Ave., Brooklyn, N. Y.
Bull, James Edgar, Esq., '92..........141 Broadway, New York City
Burchard, E. A., M. D., '99.....6 Elm St., Lodi, San Joaquin Co., Cal.
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Burrill, Prof. T. J., Ph. D., '78........................Urbana, Ill.
Burt, Prof. Edward A., Ph. D., '91...........................
..........................Middlebury College, Middlebury, Vt.
Bush, Bertha E., M. D., '95.............808 Morse Ave., Chicago, Ill.

Campbell, D. P., M. D., '88.......................Greenspring, Ohio
Carpenter, Thos. B., M. D., '99........142 N. Pearl St., Buffalo, N. Y.
Carter, John E., '86..
........Knox and Coulter Sts., Germantown, Philadelphia, Pa.
Chester Albert H., A. M., '88..Rutgers College, New Brunswick, N. J.
Clark, Gaylord P., M. D., '96........................Syracuse, N. Y.
Clark, George Edw., M. D., '96....Skaneateles, Onondaga Co., N. Y.
Claypole, Agnes M., '94............Cornell University, Ithaca, N. Y.
Claypole, Edith Jane, Ph. B., M. S., '93...............Ithaca, N. Y.
Claypole, Edward W., B. Sc., F. G. S., '86............Pasadena, Cal.
Clements, Frederick E., A. M., Ph. D., '98.....................
..........................University of Nebraska, Lincoln, Neb.
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Cocks, Prof. Reginald, S., '99...............................
.....................McDonogh High School, New Orleans, La.
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Nunn, Richard, J., M. D., '83..............5 York St., Savannah, Ga.

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Olsen, Alfred Berthier, M. D., '96..Sanitarium, Battle Creek, Mich.

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...............Cor. Saginaw and Lawrence Sts., Pontiac, Mich.
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Pyburn, George, M. D., '86...............1011 H St., Sacramento, Cal.

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Sampson, Allen W., M. D., '96.......................Penn Yan, N. Y.
Schmitz, Henry, M. D., '96..........518 W. Chicago Ave., Chicago, Ill.
Schoney, L., M. D., '98.............23 West 135th St., New York City
Schwerdtfeger, Louis Charles, Esq., '96.....Lincoln, Logan Co., Ill.
Seaman, Wm. H., M. D.,'86..1424 Eleventh St.,N.W.,Washington,D.C.
Secor, Jabin A., '95................................Elmira, N. Y.
Seymour, Prof. M. L., '85.................Normal School, Chico, Cal.
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Shultz, Chas. S., '82.............Seventh St. Docks., Hoboken, N. J.
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Smith, J. C., '96.................131 Carondelet St., New Orleans, La.
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Stedman, Prof. J. M., '95....Mo. Experiment Station, Columbia, Mo.
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Taylor, Geo. C., LL. D., '99.........Poydras, St. Bernard Parish, La.
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Thomas, Prof. Mason B., '90....Wabash College, Crawfordsville, Ind.
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Veeder, M. A., M. D., '85.................12 Queen St., Lyons, N. Y.
Vorce, C. M., Esq., F. R. M. S., '98..209 Cuyahoga Bldg., Cleveland, Ohio
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TO VOLUMES XXI AND XXII

*All references to Volume XXI are starred.

TRANSACTIONS

OF THE

American Microscopical Society

ORGANIZED 1878 INCORPORATED 1891

EDITED BY THE SECRETARY

Twenty-Fourth Annual Meeting

HELD IN

DENVER, COLORADO, AUGUST 29, 30, AND 31, 1901

VOLUME XXIII

LINCOLN, NEB.:
JACOB NORTH & CO., PRINTERS
1902

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V. A. LATHAM............................Chicago, Ill.
G. C. WHIPPLE............................New York City

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R. H. WARD, M.D., F.R.M.S., of Troy, N. Y.,
at Indianapolis, Ind., 1878, and at Buffalo, N. Y., 1879.
H. L. SMITH, LL.D., of Geneva, N. Y.,
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SIMON HENRY GAGE, B.S., of Ithaca, N. Y.,
at Ithaca, N. Y., 1895.
A. CLIFFORD MERCER, M.D., F.R.M.S., of Syracuse, N. Y.,
at Pittsburg, Pa., 1896.
W. C. KRAUSS, M.D., of Buffalo, N. Y.,
at Columbus, O., 1899.
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at Denver, Colo., 1901.

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FOR VOLUME XXIII

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TRANSACTIONS

OF

The American Microscopical Society

TWENTY-FOURTH ANNUAL MEETING, HELD AT DENVER, COLORADO, AUGUST 29, 30, AND 31, 1901

THE ANNUAL ADDRESS OF THE PRESIDENT

THE SOLUTION OF THE EEL QUESTION

BY CARL H. EIGENMANN

WITH FOUR PLATES

Eels are abundant in nearly all the rivers of Europe and the Atlantic slope of the United States. No eels with ripe eggs and no young eels less than three inches long have ever been found in any of these streams. The question naturally arose, How, where, and when do eels reproduce? This, the original eel question, was modified when it became known that the adult eels migrate to the ocean in a sexually immature condition, and young eels enter the mouths of streams and become distributed throughout their length.

The eel question was seriously considered by Aristotle several centuries B. C., and in 1880 A. D. Jacoby wrote, "To a person not acquainted with the circumstances of the case it must seem astonishing, and it certainly is somewhat humiliating to men of science, that a fish which is commoner in many parts of the world than any other fish, the herring perhaps excepted, which is daily seen in the market and on the table, has been able, in spite of the powerful aid of modern science, to shroud the manner of its propagation, its birth, and its death in darkness, which even to the present day has not been completely dispelled."

Many fishes migrate, preliminary to spawning, to regions other than those in which they usually live. It is well known that the salmon of the Pacific slope spend the greater part of their lives in the ocean. When they become sexually mature they run up some stream to deposit their spawn near the head-waters. They may ascend for a thousand miles or more, through rapids and over falls ten feet high and more, to an elevation of many thousand feet.[1] After they enter fresh water they rarely take food. The exhaustion incident to their long journey and the wounds they receive on the spawning beds in cleaning the gravel or in fighting with their rivals prove fatal to all of them. They all die shortly after spawning. The young salmon remain for a variable time where they are born, then descend the streams to the ocean, where they remain till they in turn are sexually mature. The history of the fishes, as long as they are in the streams, can be followed without any great difficulty, but their doings after they enter the less confined regions of salt water are not easy to trace.

The salmon are not the only migratory anadromous fishes. Various other species regularly ascend streams to spawn. Others show a tendency to enter fresh water, or at least brackish water, during the spawning season.[2] Even many fresh-water fishes migrate upstream before the spawning season.

While many species of fishes have the habit of entering fresh water when they approach ripeness, the eel alone has the reverse habit of taking to salt water when the reproductive period approaches. It has been well known for many years that during winter and early spring the young of the eel enter the mouths of streams in enormous numbers. (Redi records the entrance of young eels into the Arno in 1667, and that at Pisa three million pounds of young eels 30–120 mm. were taken in five hours.) They find their way for hundreds of miles from the ocean. "Young individuals three to five inches long ascend rivers in incredible numbers, overcoming all obstacles, ascending vertical walls or flood gates, entering every large and swollen tributary, and making their way even over terra firma to waters shut off from all communications with

[1] For instance, the elevation of Alturas Lake, one of the spawning grounds of the Chinook and Qinnat Salmon, is 7,335 feet.

[2] During an unusual freshet at San Diego, Cal., in 1889, large numbers of ripe *Cynoscion nobile* ascended the temporary fresh-water streams. Its relative in the Atlantic coast, *Cynoscion regale*, spawns in the brackish water at the mouths of small streams.

rivers."[3] While in the fresh water they feed on everything eatable. When they approach their full size, in about four years, they descend (in autumn) the streams to the ocean, where they are lost sight of beyond a distance of a mile from shore. After these facts were established the eel question became: What do the adult eels do after they enter salt water, when and where do they produce their young, and where do they die?

In how far these questions have been solved and the method of their solution are the topic of the present paper. The solution has been approached along at least three distinct paths.

The search for the reproductive organs.

Three different theories have been held as to the reproduction of the eel. Aristotle supposed that "the eel is neither male nor female and is procreated from nothing; . . . no other animal produces young without eggs, but no eel has ever been found to contain eggs." "They are produced from the so-called 'bowels of the earth' [earthworms] which are spontaneously produced from mud and moist soil." Aristotle contended against another idea prevalent to some extent even in his day—that the eel produces living young—stating that the supposed young eels found in the eel are intestinal worms.

The naturalists of the Middle Ages generally believed that the eel produces living young.

Associated with the idea of Aristotle that eels are spontaneously created through the mediation of earthworms are the notions that the eel is produced by other fishes or even other animals, and in various regions different creatures serve the fisherman as the mother of the eel. A blenny in the north of Germany, a mullet in some parts of the Mediterranean, and a beetle in Sicily, and horse hairs in many parts of the world have been looked upon as the progenitor of the eel.

Interest in the reproduction of the eel has always been kept up. When Schulze died he is said to have expressed the consolation that all the important questions except the eel question had now been settled.

During the sixteenth century, according to Jacoby, the discus-

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[3] Mr. Gordon Land, formerly Fish Commissioner of Colorado, told me of the presence of eels in streams of the Los Ojos ranch, Colorado, a distance of about 1,500 miles from the Gulf of Mexico, and at an elevation of about 7,200 feet.

sion of the eel question was limited to the young ones reported to have been found in them. In 1707 Vallisneri published an account of the supposed ovary of an eel sent him by a friend from Comacchio. This eel was distended and contained a body resembling an ovary containing eggs. During the middle of the eighteenth century the fishermen, desirous of gaining the liberal rewards offered for ripe eels, began the perpetration of frauds on the ambitious naturalists, which has continued to our own day. Professor Molinelli received an eel previously stuffed with the eggs of another fish. In 1777 a council of naturalists, containing among others Mondini and Galvani, sat about another apparently ripe eel caught near Comacchio. Mondini reported upon this eel and showed that the structure described by Vallisneri seventy years before as the ovary was only the diseased air bladder, and himself described the true ovary. The ovary was independently discovered by O. F. Müller a few years later.

Spallanzani, after a study of the eel question at Comacchio with purely negative results, rejected the discovery of Mondini, and the latter's observations were not confirmed till 1824, when Rathke independently described the ovary of the eel, and later, in 1850, when the same author described a female with eggs 0.1 mm. in diameter filling the whole abdominal cavity.

After Rathke's description of the ovary of the eel a number of authors took up the hunt for the male reproductive organs. For a time the fatty bodies found in female eels were taken to be the male reproductive glands, and eels were supposed to be hermaphrodite. A new path for research was pointed out when Darwin in his Descent of Man quoted Guenther to the effect that the males of fishes are smaller than the females.

Syrski in 1874 published the first account of the male reproductive gland of the eel. While the discoveries of Mondini, Rathke, and Syrski demonstrated the presence in eels of reproductive organs such as are found in other fishes, we were brought no nearer the solution as to the time and place of reproduction or of the reproductive habits of the eel. A reward was consequently offered by the German Fishery Association for any eels sufficiently well developed sexually to advance the knowledge of the reproductive history of the eel. The only result seems to have been jocose remarks in the funny papers and a continuation of the attempts of the perpetration of frauds on the parts of fishermen.

In 1877 Jacoby visited Comacchio to learn what he could concerning the modifications of eels after they had entered the sea. He found that of eels taken indiscriminately 5 per cent were males, whereas 20 per cent of those less than 45 cm. long were males. He also found that males took part in the fall migration to the sea. He did not succeed in finding eels as much as a mile from shore, and none of those from shallow water near shore showed reproductive organs more advanced than those from fresh water. He concluded that eels must mature in deep water in the ocean and that they die after the spawning season.

Some side lights have been thrown on this part of the eel question by observations on the marine or conger-eel. It has been found that some weeks before it reaches ripeness the conger-eel ceases to eat. The eggs and sperm reach maturity in individuals kept in confinement, but they can not be liberated under the conditions obtaining in confinement and the fish die; in some cases it has happened that the fish burst as the result of the accumulation of ripe eggs which could not be liberated. The feeding habit of the conger-eel thus agrees with that of the Pacific salmon, and it is very probable that the fresh-water eel also stops eating some time before it reaches ripeness. The stomachs of eels migrating to the sea were always found empty by Jacoby.

The conclusions from the series of observations recorded above were that eels have reproductive organs like other fishes, but that they do not reach maturity in fresh water, and that for this reason the difference between the sexes of eels while they are in fresh water are inconspicuous; also that the male eels are, on an average, much smaller than female eels. The inferences were that eels reproduce as other fishes do, and that reproduction takes place in deep water after the period of maturation during which no food is taken.

The discovery of Leptocephali.

While the present phase of the eel question was being approached by the study of the reproductive organs and habits just described, it was being approached from two other directions.

Over two hundred years ago Scopoli (1777) discovered a peculiar, transparent, flat, ribbon-shaped fish with minute head and tail. Others were discovered later, and up to 1895 twenty-five or more species of these fishes, called *Leptocephali,* were described. The extreme transparency of these *Leptocephali* is strikingly shown by *Leptocephalus diptychus* (pl. I, figs. 1, 2), a new one described during the past winter (*Science*, XIII, 828. 1901). This *Leptocephalus* differs from all others in having a series of seven conspicuous black spots along the middle of the sides. On close inspection it was found that three of these spots are on one side and four on the other, that the spots of opposite sides alternate with each other, and that the extreme transparency of the larva results in the blending of the two alternating rows of opposite sides into a single series of spots.

Still other transparent, more cylindrical fishes, slightly more like eels, were described under the name *Helmichthys*. The longest of the *Leptocephali* captured measured 250 mm. They were for a time considered to be a distinct group of fishes. In 1861 Carus studied these forms and came to the conclusion that they are but early stages of other fishes. In 1864 Gill definitely recognized one of the *Leptocephali* (*L. morissii*) as the young of the conger-eel, and the others were supposed to be the larvae of various eels.[4] The question now arose whether the *Leptocephali* were normal stages in the development of eels or "whether they are individuals arrested in their development at a very early period of their life, yet continue to grow to a certain size, without corresponding development of their internal organs, and perishing without having attained the character of the perfect animal." From the fact that the longest young eels were shorter than the longest *Leptocephali* Guenther favored the idea that *Leptocephali* are abnormal larvae. In 1886 Delage (C. Rend., CIII, 690.) published his observations on the actual transformation of a *Leptocephalus* into the conger-eel, and thus demonstrated the fact that the *Leptocephali* are normal larvae.

The discovery of ripe eel eggs.

The third and last path to the present phase of the eel question was discovered by Raffaele. The Italians being most favorably located have done most toward the solution of the eel problems. In 1888 Raffaele described five species of pelagic eggs from the Bay of Naples which, on account of the larvae into which they developed, he referred to various unknown species of eels. He was able to

[4] Other fishes have *Leptocephalus*-like larvae differing from those of the eel largely in the fins and tail. In 1889 Professor Gilbert showed me complete series of stages, from a long slender band-shaped *Leptocephalus* to a much shorter individual of *Albula vulpes*. They were taken by him in a shore seine on the coast of Lower California.

keep them for fourteen to fifteen days only and was therefore unable to determine to what particular species of eels they belonged. The eggs had all the characteristics and habits of pelagic eggs.[5] Grassi later found the same eggs at Naples.

The eggs described by Raffaele have certain characters in common: They are much larger than average sized pelagic eggs; they have a very large perivitelline space; their yolk is vesicular; they differ from each other in size and the presence or absence of an oil sphere. One of the eggs, his No. 10, has a diameter of 2.7 mm. and is without an oil sphere.[6] It develops into a larva with 44 (45) abdominal segments. All of them were taken between August and November, being more abundant in September.

When the larva is five or six days old it is slender and elongated with a greatly compressed body, very transparent, and with little pigment. The vitellus is very elongated and diminishes from in front backwards. The intestine ends in the ventral fin fold a short distance from the body in a small accumulation of cells. The notochord is formed of a single series of segments. During the second day after hatching the mouth opens. The teeth develop rapidly. Three pairs are developed in the upper jaw. This dentition is absolutely exceptional among fishes. Contemporaneously with the development of the mouth the choroidal pigment and five or six black pigmented spots form along the body. No noteworthy changes take place between the fourth and fifth day after hatching. Beyond this time he was unable to rear the eggs.

The identification of the egg and larva of the European eel.

The capping stone for the triple arch constructed by the anatomists, descriptive zoologists, and embryologists respectively was brought by Grassi in 1897. Grassi begins the English abstract of his work as follows: "Four years of continuous researches made by me in collaboration with my pupil, Dr. Colandruccio, have been crowned at last by a success beyond my expectation, that is to say, have enabled me to dispel in the most important points the great mystery which has hitherto surrounded the reproduction and the development of the common eel. . . . The most salient fact discovered by me is that a fish, which hitherto was known as *Leptoceph-*

[5] Raffaele. Le uova galleggianti e le larve dei Teleostei nel golfo di Napoli., *Mith. aus der Zool. Station zu Neapel*, VIII, pp. 1-84, tav. 1-5.

[6] None of the eggs taken from the fresh-water eel exceed 0.27 mm. diameter.

alus brevirostris, is the larva of the *Anguilla vulgaris*." He was able to follow a *Leptocephalus* through its metamorphosis into the common eel. He supposed that normally these processes go on at a depth of at least five hundred meters. His work was carried on on the coast of Sicily, where strong tidal currents cause the displacement of the water in the narrow Strait of Messina. As the result of these currents all stages in the development of the Muraenoids are sometimes met with in the surface water. They are also abundant in the stomach of the sun-fish, Mola.

He found that the male eels may ripen in shallow water and migrate when ripe to deeper water. Some eels approaching ripeness were found in the sewers of Rome. The ripe male eel has taken on a silvery color and its eyes are very much larger than those of the river eels.[7]

The females never ripen in shallow water. The eggs he supposes are laid at a great depth and remain suspended at a great depth, only occasionally reaching the surface. Instead of being small, as had been supposed, they are really much above the average of pelagic eggs in size. From the eggs come prae-larvae which develop into the regular larvae or *Leptocephali* (fig. 4) with the anus and urinary organs near the tip of the tail. The larvae are metamorphosed into what he calls hemilarvae with the two openings moving toward the permanent position. By further changes, which include a considerable reduction in length, the hemilarva assumes the shape of the adult. Both the larva and hemilarva are longer than the young eel arising from them, there being a diminution of 4 cm. in length during the transformation. He found that the caudal fin of the *Leptocephalus* always resembled the caudal fin of the adult eel into which it developed and that the number of segments is also a constant character. He identified Raffaele's egg No. 10, without oil sphere and with a diameter of 2.7 mm., to be that of the common eel.

The discovery of the Leptocephalus of the American eel.

During the past winter while describing the *Leptocephali* belonging to the United States National Museum one of my students, Mr. Clarence Kennedy, and myself discovered two specimens taken on

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7 Bean in the *Nineteenth Report of the Commission of Fisheries of New York*, p. 239, described five male eels with well-developed reproductive organs which were probably ordinary eels in their nuptial dress. He describes them as having "large eyes, short snout, and long pectoral fins, as compared with the common form, silvery gray above with a clear satiny white abdomen separated from the color above by the lateral line."

the surface of the ocean off New York that in shape, color, etc., very greatly resembled the *Leptocephalus* of the European eel. When we found that the American eel had fewer vertebrae than the European eel, and that the larvae under consideration differed from the larvae of the European eel in just those characters in which the American eel differs from the European, we felt certain that we had found the larva of the American eel (fig. 3).

The development of the conger-eel.

During August of 1900 I was fortunate enough to secure the eggs of an eel, very probably that of the conger-eel. They were taken by Dr. Porter E. Sargent on the U. S. F. C. vessel *Grampus* from the surface of the Gulf Stream. They are the first eel eggs that have been secured outside Italian waters. Since in their development they greatly resemble the development of the fresh-water eel their history may be added.

The eggs secured by Dr. Sargent measure 2.4–2.75 mm. from membrane to membrane. The yolk, as in the eggs described by Raffaele, is made up of transparent spheres not unlike those of the eggs of certain clupeoids. There are present from one to six light yellow oil spheres of variable size. If more than one are present, then one is always much larger than any of the others. The yolk measures 1.75–2 mm. Some of the young were found to be hatched on the morning of August 3. Since many of these developed gaping jaws, and some others, which did not hatch till several days later, developed normally, it is possible that the early hatching was not normal. Raffaele's eggs hatched in five or six days. He was able to keep them four or five days after hatching. For some time after hatching the larvae floated with their heads upward—the probable result of the location of the oil spheres. On August 6 they had assumed a normal horizontal position and the characteristic eel-like progression, but the pectorals were not yet used in swimming. Later they were seen eeling their way through the water, not infrequently nosing about the bottom and voraciously seizing anything that came in their way.

The characteristic feature of the eggs at the time I began to observe them, August 1, was the shape of the yolk. The bulk of this occupied the usual position, but a narrow stalk extended back below the alimentary canal. The oil sphere or spheres occupied the extreme anterior part of the yolk[8] (fig. 5). The further history of the yolk in this species is unique among fishes and not sufficiently emphasized by Raffaele. In fig. 6 it is seen that the yolk is no longer rounded anteriorly, but that it ends in a marked protuberance and that the oil sphere lies in this. The general mass of the yolk still retains the original shape and distribution. The anterior protuberance now becomes longer and at the same time narrower, so that the oil sphere loses its rotundity and becomes elongate (fig. 7). At the same time the general mass of the yolk diminishes rapidly in the yolk sac, while in the elongated pouch along the ventral side of the alimentary canal no diminution is evident. On the contrary, there is an apparent increase; the entire yolk sac becomes notably longer with the increase in the length of the body. Very soon (fig. 7) the oil sphere, much elongated, with a small surrounding mass, is all that remains as a spindle-shaped figure in the yolk sac.

The yolk sac does not at once lose its shape and bulk, but serves as an unusually large pericardial chamber which is equaled only in the practically yolkless *Cymatogaster*. On August 5 the yolk along the alimentary canal had suffered little diminution, and its outlines were quite regular (fig. 8). On August 6 this part of the yolk had become constricted in places, the outlines being less regular (fig. 9). The yolk had become yellowish in color and more fluid than vesicular. On the following day (fig. 10) the constriction had deepened, and on August 11 the remains of the yolk were located in a series of minute globules more or less widely separated from each other (fig. 11). Long before this condition was reached, about the 8th of August, the larvae were taking food.

The number of segments developed in front of the anus differs slightly, ranging from sixty-five to seventy-one. The number beyond this point could not be determined exactly. The notochord consists in its anterior fourth of single segments. In its middle region the segments do not extend through its entire thickness, but in the tail it is again formed of single segments. The lines separating these are so much more conspicuous than the lines separating successive myotomes that it is impossible to make out the latter in the thin transparent tail.

[8] All drawings were made from living specimens, or such as had just been killed by formalin. In the drawings, *al*, alimentary canal; *fv*, fourth ventricle; *ylk*, yolk; *l*, liver; *h*, heart; *o*, oil spheres.

Color is late in making its appearance. It is first evident at the end of the tail. At 6:00 P.M. on August 5 some of the larvae had the following six spots above the alimentary canal and along the lower margin of the myotomes of the tail: (1) About the middle of the yolk, (2) halfway between this and the end of the yolk, (3) at the end of the yolk, (4) in front of the anus, (5) some distance behind the anus, (6) about the tip of the tail. Additional spots are added between these already formed. The relative and actual size of the spots differ greatly, but the number is the same in different specimens of the same age. In the oldest larvae the spots represented in fig. 11 were developed. Aside from those along the lower part of the sides there were a few cells on the upper jaw, and the scattered cells seen near the tip of the lower jaw as early as August 7 (fig. 10) have developed into a well-marked spot. The character of the pigment about the tail is also noteworthy. In the last stage figured the processes of the cells show a tendency to lie parallel to the embryonic fin rays. Pigment is formed in the eye with its earliest appearance on the body. No color, aside from the black pigment spots and the yellowish yolk, is seen anywhere about the larva during the time the larvae were under observation.

The fin fold is well developed, reaching from the nape around the tail to the yolk sac. It is much wider along the back and in the region of the vent than about the tip of the tail or the ventral line of anterior abdomen. No rays had appeared in the oldest larvae observed except about the tail, where there appears a distinct radiation.

The enormous development of the posterior half of the fourth ventricle is similar to the condition figured by Raffaele. In all but the last stage figured this part of the fourth ventricle is a large thin-roofed vesicle, separated from the fin fold in the earlier stages by a distinct notch. The auditory capsules are conspicuous, and, viewed from above, are seen to protrude from the sides of the head.

The alimentary canal is marked (1) by large fang-like teeth, (2) the early vesicular development of the liver, (3) and the position of the anus near the body and remote from the margin of the ventral fin fold. As soon as the mouth is open, about the fourth or fifth day from the beginning of development, the margins of the jaws are seen to be marked by small protuberances. These are the swellings within which the teeth are developing. In the upper jaw four pairs of teeth are developed, graded from in front back, the anterior ones being comparatively enormous fangs. In the lower jaw four pairs are also developed. These are more uniform in size, but with the second one larger than the rest. In the oldest individual there were five pairs of teeth in the lower jaw. I am unable to say whether this was a normal condition. The teeth of the upper jaw close over those of the lower jaw (fig. 12).

The oesophageal pouch (liver) of Raffaele has already been mentioned. Even before hatching it is a conspicuous pouch behind the heart. Later, when the anterior yolk has been largely consumed and is separated from the posterior yolk by a constriction, the vesicular structure becomes converted into a lobulated organ about this constriction.

Conclusions.

We now know (1) that eels, both male and female, migrate to the ocean during October to January; (2) that these eels probably deposit the eggs that are found on the surface during the following August to January; (3) that the eels do not ripen in shallow water, but the female, according to Grassi, at a depth of five hundred meters; (4) that the eggs of the eels float, according to Grassi, at a great depth; according to Raffaele and Eigenmann at the surface; (5) the development of some eels for the first fifteen days and that the resulting creature is different both from the adult eel into which it will develop and from the larva of the eel; (6) the *Leptocephalus* of the eel and the process of its metamorphosis through a *Hemichthys* stage into the young eel as it is found entering the streams; (7) the young eels enter the streams during spring about two years after their parents have entered the sea.

We do not know the history of the larva from an age of fifteen days till they reach the *Leptocephalus* stage. We do not know for a certainty that the egg and early stages of development of the common eel has been secured, although it is very probable that Raffaele's No. 10 is the egg of the common European eel. We are not certain that the egg is normally or only occasionally pelagic. We do not know the normal habits of the *Leptocephalus*. We have not yet secured a female eel with eggs larger than 0.27 mm. Inasmuch as the mature egg probably reaches a diameter of 2.7 mm., the largest ovarian eggs found must increase a thousand-fold before maturity is reached.

The question whether or not the eel ever breeds in fresh water has been answered in the affirmative by several observers. There is nothing that would indicate the inherent impossibility of eels becoming land-locked and breeding in fresh water. The evidence is, however, so far inconclusive. No one has yet taken eel eggs or larval eels or younger eels than those that ordinarily ascend streams from the ocean in any fresh water. The statement that they must breed, because we know of no other way in which the supply of eels is being maintained in land-locked basins is not conclusive evidence that they do breed in these basins.

Feddersen[9] states that in the north the eels have in places become strictly fresh-water species which can be distinguished from the migratory eels by definite characters.

Imhof[10] concluded that eels breed in fresh water on the following evidence: In 1882, 1886, and 1887 a large number of eels were placed in the Caumasee (Canton Graubünden). After 1887 no additions were made. In June, 1895, a small male eel 47 cm. long was taken among other eels. From the impossibility that eels should have arrived from the ocean by migration, since the Caumasee belongs to an isolated water-basin, the presence of this small eel was supposed to demonstrate the fact that the eels had propagated in this lake. The evidence does not seem to me to be conclusive. Male eels are much smaller than female eels, whereas nothing is known to the contrary that the time required by the small male to reach its full size is not as great as the time required for the female to reach her full size. If the time required be the same, then the finding of a male eel 47 cm. long is no more evidence of recent breeding in this lake than the presence of female eels 1½ m. long. The question whether or not the eel ever breeds in fresh water may be considered undecided.

9 "Ueber das Laichen des Aales im Süsswasser," *Zeitschrift f. Fischerei u. deren Hilfswissenschaften*, pp. 156–67. 1895.

10 *Biologisches Centralblatt*, XVI, p. 431. 1896.

EXPLANATION OF PLATES

Plate I

Fig. 1. *Leptocephalus diptychus*, *a* and *b*, enlarged views of the head and tail.

Fig. 2. *Leptocephalus diptychus*, an older larva; *a* and *b*, enlarged views of head and tail.

Fig. 3. *Leptocephalus Grassii*, the larva of the American eel.

Plate II

Fig. 4. The metamorphosis of the European eel after drawings by Grassi.

Figs. 5 to 12 refer to the development of the Conger-eel.

Fig. 5. Outline of embryo showing position in membrane and shape of the yolk. Aug. 1.

Fig. 6. Embryo freed from its membrane, showing the beginning of the constriction of the yolk at its anterior end. Aug. 1.

Plate III

Fig. 7. Head and anterior part of body showing the continued reduction of the yolk and the very large fourth ventricle. Aug. 1.

Fig. 8. A larva on Aug. 5.

Fig. 9. A larva on Aug. 6. The mouth probably slightly abnormal.

Fig. 10. A larva on Aug. 7.

Plate IV

Fig. 11. A larva of Aug. 14. The fin fold of this larva is probably represented as too low.

Fig. 12. Dentition of a larva of Aug. 14.

Fig. 13. The full-grown *Leptocephalus Morissii*, the larva of the Conger-eel; *a* and *b*, enlarged views of the head and tail.

Fig. 14. An older *Leptocephalus Morissii* undergoing its metamorphosis; *a* and *b*, enlarged views of the head and tail.

PLATE I

Fig. 1

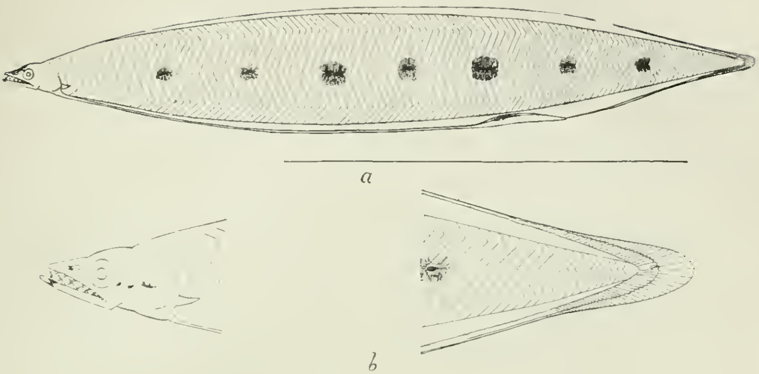


Fig. 3

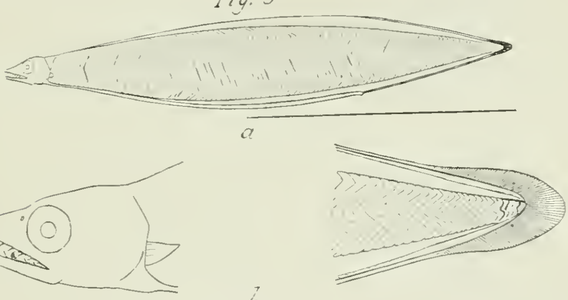


Fig. 2

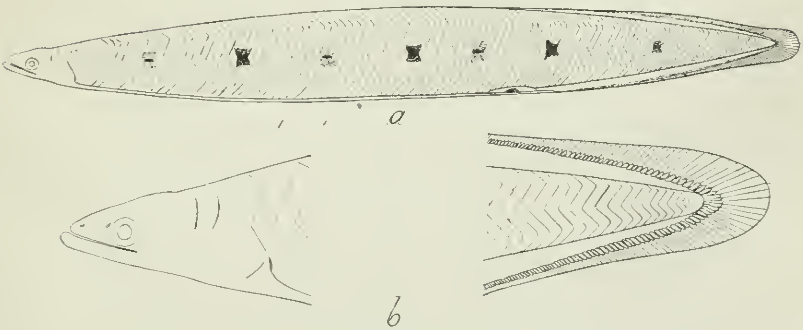


PLATE II

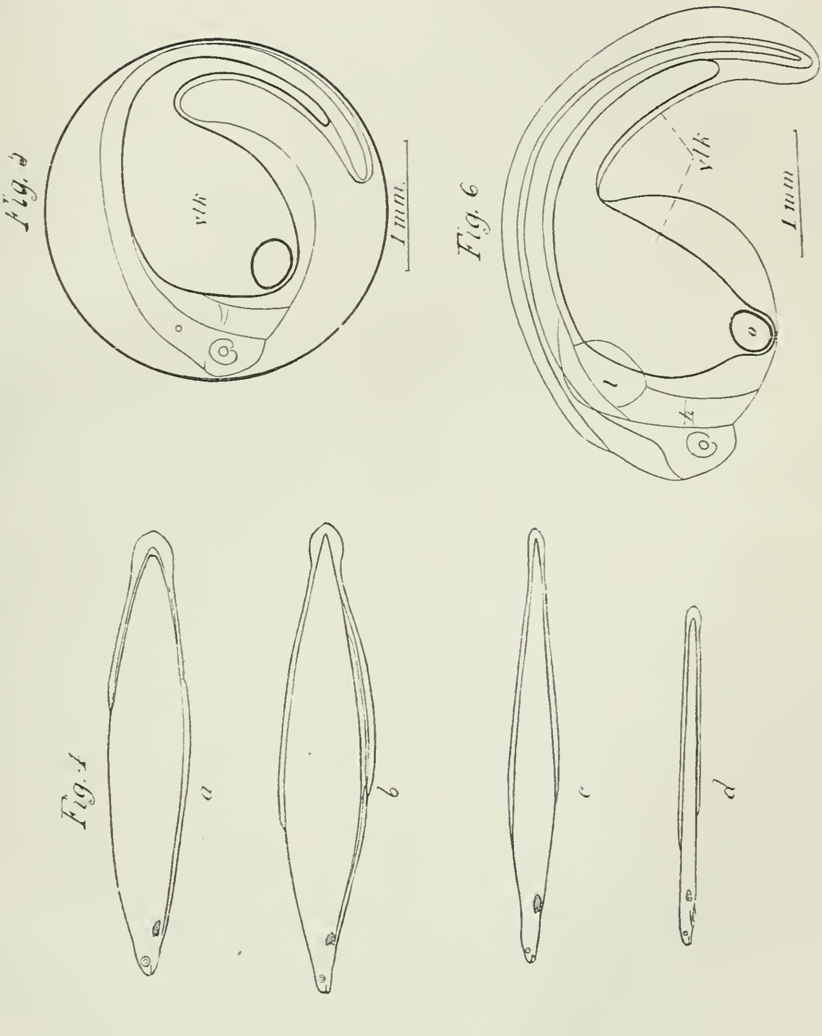


PLATE III

Fig. 7

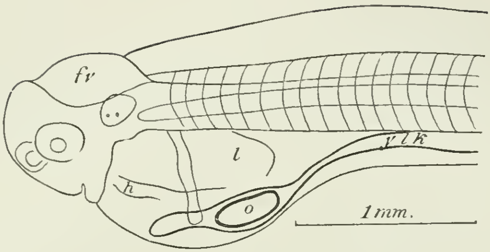


Fig. 8.

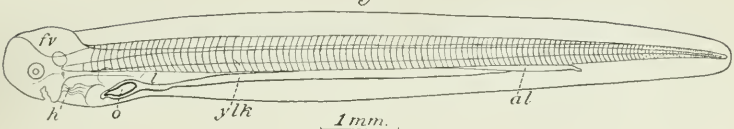


Fig. 9

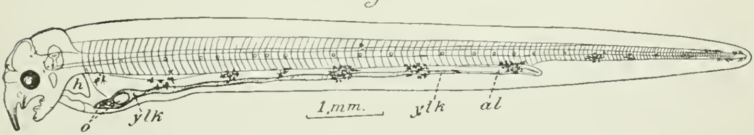


Fig. 10.

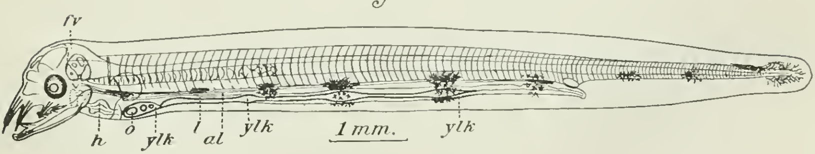


PLATE IV

Fig. 11

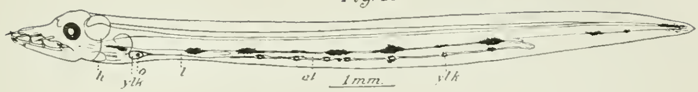
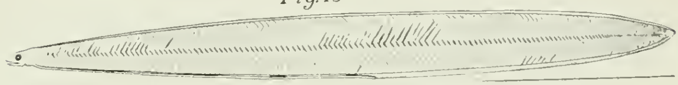
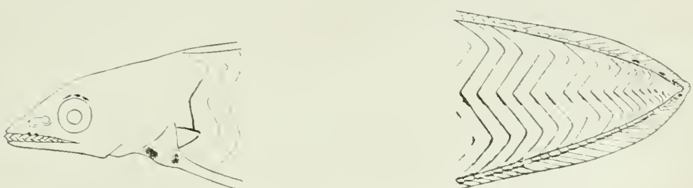


Fig. 13



a



b

Fig. 12

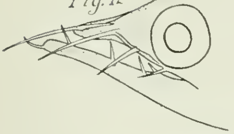
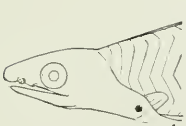
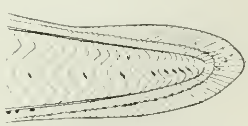


Fig. 14

a



b



THE DEBT OF AMERICAN MICROSCOPY TO SPENCER AND TOLLES

By WILLIAM C. KRAUSS, B.S., M.D., Buffalo, N. Y.
PAST PRESIDENT OF THE A. M. S.

WITH FIVE PLATES

There recently died in Buffalo the last of a distinguished trio of lensmakers who, by their ingenuity and inventiveness, added a brilliant chapter to the history of American genius.

Charles A. Spencer, Robert B. Tolles, and Herbert R. Spencer were artists rather than artisans in their chosen field of applied optics, and they left their impress deeply engraved upon the history of their time.

Although their obituaries have appeared in the *Transactions*[1] of this Society at the proper time, nevertheless it will not be uninteresting or tedious to review their work or recall their efforts in behalf of improved scientific apparatus. Records show that up to 1840 little if any use was made of the compound microscope in America, and no instrument maker had appeared who could supply an instrument of any kind. Thus it was when in this year the United States exploring expedition to the South Seas under Commodore Wilkes was fitting out, no instrument could be furnished the expedition by any of the makers of scientific or philosophical instruments in America. In this dilemma a private individual was applied to, and an instrument was finally loaned from Dr. Paul Goddard, of Philadelphia. It was a French microscope of inferior make, but the best obtainable at that time. Since then the instrument has come into general use, and in certain departments of the manufacture of microscopes this country has become preeminent. Scarcely had the English microscope makers published those inventions and discoveries which rendered achromatic microscopes really possible, and ele-

[1] Memoir of Charles A. Spencer by Hamilton L. Smith, LL.D. *Transactions American Society of Microscopists*, 1882, p. 49.

Memoir of Robert B. Tolles by George E. Blackham, M.D. *Transactions American Society of Microscopists*, 1884, p. 41.

vated the instrument from the position of a mere scientific plaything to that of an instrument calculated for the most accurate investigations, before the elder Spencer succeeded in producing lenses which at once took a front rank among the art productions of the world. To-day we stop in the mad whirl of our busy lives to pay homage to Charles A. Spencer and his two famous pupils, Robert B. Tolles and Herbert R. Spencer.

At the Seventh Annual Meeting of this Society, held at Rochester, N. Y., August 19 to 22, 1884, a memoir of Robert B. Tolles, but recently deceased, was read by Dr. George E. Blackham, of Dunkirk, N. Y. In the remarks following by different members of the Society, a resolution was offered by W. H. Breasley, of Detroit, that W. A. Rogers be requested to prepare a subscription paper and to receive subscriptions for a monument to Robert B. Tolles. As a substitute motion Professor T. J. Burrill, of Champaign, Ill., offered the following, which was seconded and adopted:

Resolved, That W. A. Rogers, H. J. Detmers, and George E. Blackham be made a committee to report upon proper action, on the part of the Society, in memory of Robert B. Tolles.

Mr. Breasley then offered the following resolution:

Resolved, That the same committee be asked to consider and report upon a suitable memorial for Charles A. Spencer,

which was also seconded and unanimously carried.

Thus the ground was broken for the foundation of a monument to Spencer and Tolles, which was to be as durable and ineffaceable as a granite shaft, but, unlike the stone, it was to shed warmth and awaken a quickening in the minds of all those fortunate enough to come within its shadows.

At the next meeting of the Society, held at Cleveland, O., August 18 to 21, 1885, Dr. George E. Fell, of Buffalo, N. Y., reported the condition of the Spencer-Tolles Memorial Fund as follows:

To the Officers and Members of the American Society of Microscopists:

In accordance with the resolutions on a Spencer and Tolles Memorial Fund, the following report is presented: The first cash subscription to this fund was made by the Royal Microscopical Society, December 17, 1884. Since that time the subscriptions have come in so slowly that this report will present but a meager list of subscribers, and, in view of the unanimous adoption of the resolution establishing the fund, not nearly so large a list as should have been expected. Prof. Wm. A. Rogers, with his characteristic action in furthering any of the projects of the Society, has offered to subscribe $25 and guarantees $15 additional, contingent, however, upon a concerted action of the Society towards the increase of the fund. He suggests that the income of the fund be awarded in prizes for specific original research. The subscriptions to the fund are given below:

Royal Microscopical Society	$25 20
J. D. Cox	5 00
D. S. Kellicott	5 00
George E. Fell	5 00
John Kruttschnitt	5 00
F. S. Newcomer	5 00
Chas. Shepard	5 00
E. H. Griffith	5 00
Total	$60 20

Respectfully submitted,
GEORGE E. FELL,
Treasurer and Custodian.

The fund grew slowly; custodian gave way to custodian, each doing his best to swell the amount as much as possible. As was the case in our Civil War, there were many generals, but only *one* general, so with the Spencer-Tolles Fund, there were many custodians but only *one* custodian, and to-day the American Microscopical Society acknowledges its debt of gratitude to our present custodian, and the many friends of Spencer and Tolles, in and out of our Society, extend their hearty congratulations to our genial, energetic, and aggressive friend, Magnus Pflaum, Esq., of Pittsburg, who has the distinction, aided by our worthy Secretary, of having their long years of patient labor brought to a triumphant close. It might be pertinent to suggest at this time that the Society take some official action to connect the name of Herbert R. Spencer to those of Charles A. Spencer and Robert B. Tolles, so that this fund may stand as a monument to the genius of the three men instead of the two older, as it *now* officially stands.

Many of the recent advances in medicine have been due to the improved microscope and the application of certain compound stains to certain tissues, whereby a part of a tissue will be stained one color and another part a contrasting color. These parts may be so infinitesimal, however, that the very best and improved microscopes are necessary to detect the differences; hence, to the stain and microscope we are indebted for the wonderful discoveries made in science dating from the time that Robert Koch made his famous discovery of the bacillus of tuberculosis in 1882.

The microscope is composed of a manifold variety of parts made for the sole purpose of giving the greatest scope and efficiency to the lenses which constitute the vital part of every optical instrument. Scientists, therefore, divide the microscope into stand and lenses, the former comprising the mechanical or brass parts, the latter the lenses or glass parts.

A good microscope should have a stand fitted with all the mechanical niceties necessary to make the lenses available for practical scientific work, and, secondly, lenses which will interpret correctly and accurately the enlarged image of the object to be studied. Lenses which will distort or nullify the enlarged image are said to be uncorrected for spherical and chromatic aberrations, and these defects are serious ones in a good working lens. Hence, no matter how perfect and complete the mechanism of the microscope stand, if the lenses are not perfect or nearly so, careful, accurate work can not be accomplished. The lenses in a microscope are classified into those forming the objective or object glass placed just above the object to be magnified, and the ocular or eye-piece placed at the other end of the tube near the eye of the observer. The special purpose of the objective is to form an enlarged inverted real image of the object, and that of the ocular is to magnify the image formed by the objective. Thus it will be apparent that, no matter how good the stand and perfect the ocular or eye-piece, if the objective or field lens is imperfect the efficiency of the whole instrument is impaired.

The qualities of a good objective are manifold. It must of course possess magnifying powers; it must magnify an object without distorting it or surrounding it with a color zone; it must magnify the object equally, circumferentially as well as centrally, i. e., there must be flatness of field; it must permit the passage of a large amount of light so that the image of the object shall be well illuminated, but, more than all else, the objective should have great resolving power, that is, it should be able to define or make clear the minute details of an object. The prime requisite of a lens is not that it shall magnify so many hundred or thousand diameters, but that it shall have great resolving power or resolution. To illustrate what is meant by resolving power, take the ordinary opera glass, which simply gives an enlarged picture of the actress on the stage with a general superficial outline of face, form, and dress; if the lenses had good resolution, the make-up of the face, the quality and texture of the dress, the genuineness or imitability of the jewels and the like would be revealed. Hence opera glasses should have low resolving power lenses, so as to blend the component parts into a harmonious whole, and not disintegrate the various elements into an incongruous mass showing up the component parts by contrast.

It was this superior quality of a lens that Charles A. Spencer, Robert B. Tolles, and Herbert R. Spencer sought after so assiduously and succeeded so admirably in attaining that made them the peers of greatest among lensmakers the world over. They were the pioneers, the pathfinders, among lensmakers, and they succeeded in making objectives of such superior quality and such high merit that their work had to be well-nigh forgotten and then rediscovered, or, better, resurrected by some foreign genius before the world realized what the Spencers and Tolles had accomplished in the '40s and '50s. So true is this that hardly had the din of applause died out over the discovery of the apochromatic lens by a well-known German scientist than Herbert R. Spencer showed me a lens constructed on the same principle and of the same substance, fluorspar, that his father made in the early '50s and had abandoned because of the great deteriorating quality of the fluorspar. The same fault is again being found with the resurrected lenses.

Charles A. Spencer was born in the town of Lennox, N. Y., in 1813. He descended from a well-known and highly respected family, his father being Gen. Ichabod Spencer; an uncle was the late Judge Joshua A. Spencer, of Utica, and another uncle was Dr. Thomas Spencer, of Geneva, professor in the old Geneva Medical College. He was educated at the Cazenovia Academy, then entered Hobart College, where he remained less than a year, and soon after went to Hamilton College, Clinton, N. Y. Of his early boyhood, Dr. Hamliton L. Smith, of Geneva, N. Y., says in a memoir published in the *American Microscopical Society's Transactions* for 1882 that "he seems to have had an all-controlling idea, a self-consciousness, which seemed but conceit to those who did not understand him or realize how much there really was in him, of his ability to produce better optical work than the world had yet seen. There is in existence a portrait of him taken when he was but sixteen years old, and which must have been a very truthful likeness, for it shows clearly the character of the future man. He is looking straight forward with fearless eye and already reading on the scroll of fame the name of Charles A. Spencer." (See Plate V.)

Spencer was induced, while still a lad, by the perusal of the article on "Optics" in the Edinburgh Encyclopedia, to construct a compound microscope. His first attempt at making a lens was when he had scarcely attained his twelfth birthday, and although crude and unfinished it spoke to him of the vast possibilities which lay before him in the field of applied optics. Genius that he was, he discovered its errors and imperfections, and, *the master* within him asserting itself, he set out upon his life's journey of correcting these and improving each subsequent endeavor. He then attempted to combine his lenses and succeeded in making several compound microscopes and a refracting microscope upon the original plan of Professor Amici. He also constructed several Gregorian and Newtonian telescopes with specula of six and eight inches diameter, some of which were quite successful. Spencer was greatly handicapped during these early years by a combination of circumstances, one of which, the most serious to him, happily no longer confronts the investigator of to-day.

The loss of "interchange of ideas" was a drawback to this young scout appreciated only by those entering new fields of conquest. Working by himself, without guide or precedent, it was a most difficult task to improve only along certain lines which appealed most strongly to him. It was not until the publication of the *Penny Magazine* and the Library of Universal Knowledge, however, that he became aware of the improvements which had been made in Paris and London in the achromatic microscope. The results obtained by Goring and Pritchard, in both the achromatic and reflecting microscopes excited his attention especially. The discovery by the former of the effects of angle of aperture was a powerful inducement for young Spencer to perfect himself more thoroughly in this branch of optical science. About this time he also learned of the successful researches of Guinaud, Fraunhofer, and Faraday in the manufacture of optical glass. By laborious and protracted experiments, frequently working over the furnace for eighteen consecutive hours, he succeeded in improving the homogeneousness and other qualities of the glass considerably, enabling him thereby to make an evident advance upon his previous efforts in constructing lenses.

About 1838 Charles A. Spencer announced himself as a manufacturer of telescopes and microscopes and with his workshop located at Canastota, N. Y. In spite of business reversals he still continued to devote himself to the perfection of the achromatic telescope and microscope. Ten years later lenses were made at the little shop in Canastota which mystified English and French microscopists, chiefly because of their great resolving power. The charge was made against Mr. Spencer by the English makers that he must have some mode of working glass as yet unknown to other opticians. While this was partly true, yet his chief success was from his tact in figuring the lenses so as to balance the aberrations, a process so delicate that it would have availed no one not possessed of the same skill to copy curves, even if this could be done, and with the same material.

In June, 1850, Mr. Spencer produced a $^{1}/_{12}$-inch objective, having the then marvelous aperture of 174½° as measured by the old sector method. This innovation aroused the wrath of his competitors, who declared that the limit of usefulness could not exceed 135°. These high-angled objectives were not only useful but were possessed of such great and wonderfully accurate defining power that their fortunate possessors considered them as superior to any lenses ever made. Spencer's idea was to combine large angular aperture with definition, and in this respect he scored a signal success over his competitors who were only able to increase the angle at the expense of the definition.

In other fields Mr. Spencer was also active, especially in the manufacture of telescopes. In 1865 he completed a large equatorial for Hamilton College having an object glass of 13½ inches diameter and a focal length of 16 feet, being the largest telescope then in this country.

In the fall of 1873 a disastrous fire broke out in Canastota, which destroyed Mr. Spencer's shop, nearly all the tools and machinery, the accumulation of many years of toil and skill, and a large amount of finished and unfinished work. Crippled, but not disheartened, Mr. Spencer and his sons removed to Geneva, N. Y., in 1875, and in a barn for a workshop started anew to electrify the world with their matchless lenses. Some of these were in possession of Professor Barnard of Columbia College, one of the United States commissioners to the Paris Exposition of 1878; and so convinced was he of their excellence that he entered them without the knowledge of the Spencers. To the surprise and amazement of European opticians and to the gratification of the Spencers and their many friends and admirers, they were awarded a magnificent large gold medal for excellence and superiority.

In 1880 Herbert R. Spencer began business for himself, while the father remained in the old shop, loath to sever connections with the work he so dearly loved and which he so richly adorned. He died in Geneva, N. Y., on September 28, 1881. The American Society of Microscopists made him one of its first honorary members on August 10, 1881. (See Plate VI.)

The second member of the illustrious trio was Robert B. Tolles, an apt student of an apt master. "The story of his life is a simple and touching narrative of the struggle of genius with poverty and ill-health; of steady persistence in the face of apparently insurmountable obstacles and of final and triumphant success." Robert B. Tolles was born in Winchester, Conn., and passed his boyhood struggling to gain a meager education, while at the same time helping to support his parents, who were very poor. His father was an inventor, but from lack of funds was unable to develop any of his ideas. In 1843, after the death of his mother, young Tolles went to visit an uncle residing near Rochester, and on his way back happened, by chance, to stop at Canastota, N. Y., where he accidentally visited the workshop of Charles A. Spencer. Looking around him he recognized at once the opportunity, "knocking unbidden once at every gate," and said, "here is the place and the work for me."

He entered the service of Mr. Spencer as apprentice and remained with him for fifteen years, imbibing the spirit of the master and adding to the fame of the little backwoods shop by numerous inventions, a trait, no doubt, inherited from his father. Tolles's object in life was the improvement of the microscope, and he was well qualified, by his "great theoretical and practical knowledge of the science of optics, united with mechanical and inventive genius and marvelous skill of eye and hand." Among some of the things accomplished was a cover correction for objectives; a stereoscopic binocular eye-piece; mechanical stage; a solid eye-piece; objectives with two fronts, one immersion, the other dry; and in 1873 he succeeded in making an immersion or one-tenth objective with an aperture greater than that corresponding to infinitely near to 180 degrees in air. It was a three-system lens and had an aperture of more than 110° in balsam or 1.25 N. A.

On this event, Dr. George E. Blackham, of Dunkirk, N. Y., in his memoir of Tolles in the *Transactions of the American Society of Microscopists,* in 1884, says: "The importance of this bold step and its influence upon the progress of microscopy can scarcely be estimated at this time, but it is certain that it was the cause of a revolution of opinion and practice among users and makers of microscopes all over the world."

In 1867 he removed to Boston and affiliated with the Boston Optical Works. The last ten years of his life were years of suffering and hardship, working at his bench when he should have been in bed, denying himself all the luxuries and many of the comforts of life. During his last illness he had the microscope brought to his bedside and there on his deathbed examined and tested the lenses. Only a few minutes before his death he was occupied in correcting the degrees of aperture of an imaginary lens, and when he reached 150 degrees he stopped, turned his head, and said faintly, "Good-bye," on November 17, 1883. Robert B. Tolles was elected an honorary member of the American Society of Microscopists on August 10, 1883. (See Plate VII.)

The third member of the illustrious group was, like his predecessors, a genius, who ranked high with his father and friend in this country and with Amici, Abbe, Powell, Chevalier, Oberhauser, Ploessel, Hartnack, and Ross in Europe. Herbert R. Spencer was born at Canastota, N. Y., on November 1, 1849, and removed to Geneva with his father in 1875. At an early age he became imbued with the atmosphere of genius which surrounded him, and while yet a mere lad began to make lenses on a lathe of his own construction, equaled in those days only by those of his father and co-worker Tolles. (Pl. IX.) A more suitable workshop and better tutelage than that offered at Canastota could not have been found for young Spencer. To be in daily touch with a mind like his father's and rubbing against an all-around inventive genius like Tolles sharpened his imaginative and perceptive faculties so that as understudy he was prepared to step into their places at any time, without the scientific world knowing or realizing that a succession had taken place. And so it happened that in 1880 Herbert R. Spencer carried on the business of making microscopes, telescopes, and other optical instruments without the world knowing that the father was practically through with his life's work. The Spencer lenses seemed to be just as perfect and as much sought after in the '80s and '90s, under the son, as they were in the '50s, '60s, and '70s, under the father and Tolles. In 1889 he removed to Cleveland and organized the H. R. Spencer Optical Company. In 1891 Mr. Spencer decided to remove to Buffalo, and since then the famous Spencer lenses have found their home in this city. In 1895 the Spencer Lens Company was organized in Buffalo, many of the stockholders being practical microscopists. (See Plate VIII.)

A peculiar trait of the Spencers was the confidence in their ability to improve on their lenses. No matter how good the resolution, how clear the definition, they always insisted that it was not their best. As Mr. Howland has said of Spencer's work,[2] "He was ambitious and critical of it; there was always in his own vision a better that mocked his best, and he was never satisfied until that better was secured and a better still beckoned him forward."

Just as prosperity began to warm the Spencer heart and home the stress and strain of years of toil and anxiety began to tell, and in the fall of 1899 Mr. Spencer was obliged to discontinue his work. Foreseeing the inevitable, he had trained some of his assistants to do the testing and setting of lenses under his personal supervision, so that when the Spencers should cease to exist as opticians, the Spencer idea embodied in the Spencer lens would still live on. The end came on February 7, 1900, and was a severe blow to his many friends and acquaintances, many of whom did not even know of his illness. Mr. Spencer was for many years a member of the American Microscopical Society and a fellow of the Royal Microscopical Society of London.

These three men, giants in their line, had many traits in common, some to be commended, others, especially in this age of materialism, to be condoned. Their innate confidence in their powers, so characteristic of the elder Spencer and not less marked in Tolles and Herbert Spencer, strikes the casual observer as most uncommon; their ability or conceptive faculties, linked with an acute

[2] Memoir of Herbert R. Spencer, by Henry R. Howland. *Trans. Am. Micros. Soc.*, 1899, p. 252.

comprehension of the laws of optics, was a peculiarity to all three, and stood them in great service. Their retiring, unassuming dispositions, their habitual shyness and professed abhorrence of notoriety were factors inimical to their welfare and impeded their commercial progress. Financially they were not successful, but inasmuch as they resolved to produce lenses of quality and not lenses in quantity they left a private fortune to each individual possessor of their beautiful handiwork. The writer believes with Hamilton L. Smith, in his memoir already referred to, that "when the name of many a successful man, as the world counts success, shall have been forgotten, and the marble on which alone it is recorded shall have crumbled away, that of Spencer will live; nor will it be forgotten until the human eye no longer needs a microscope, but shall see clearly the now hidden things of God."

EXPLANATION OF PLATES

Plate V

CHARLES A. SPENCER (when 16 years old)

From a portrait painted by his brother Frederick, when 19 years old. The original painting was kindly donated to the Buffalo Academy of Science by Mrs. H. R. Spencer.

Plate VI

CHARLES A. SPENCER

Plate VII

ROBERT B. TOLLES

Plate VIII

HERBERT R. SPENCER

Taken a short time before death.

Plate IX

Lathe made by Herbert R. Spencer when he was 13 years old and on which he made his first objective. The lathe was kindly donated to the writer by Mrs. H. R. Spencer.

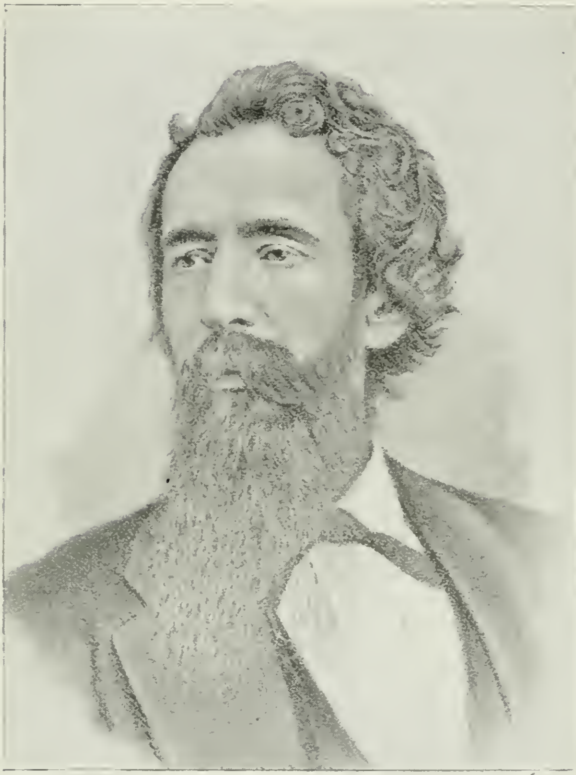
PLATE V

CHARLES A. SPENCER

PLATE VI

CHARLES A. SPENCER

PLATE VII

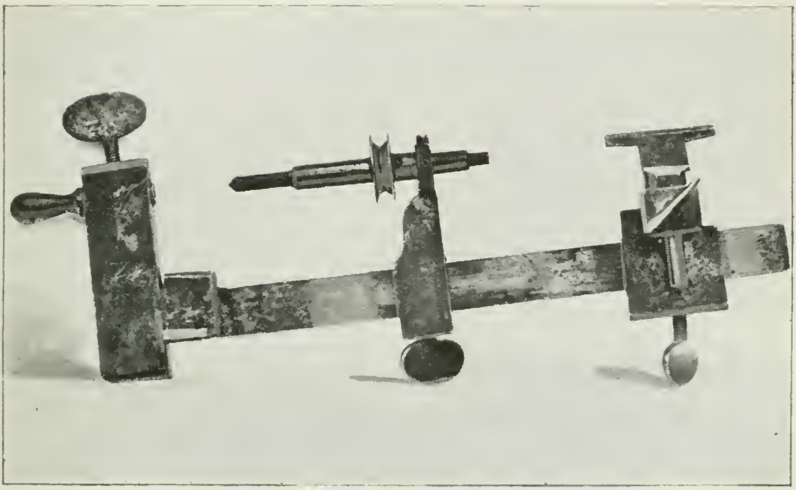


ROBERT B. TOLLES

PLATE VIII

HERBERT R. SPENCER

PLATE IX



A NEW SPECIES OF CRENOTHRIX (C. MANGANIFERA)

By D. D. JACKSON

WITH ONE PLATE

There is no bacterial growth, barring those which actually produce disease, which has excited more interest or caused more trouble than the "Giant Bacterium" known as *Crenothrix*. Its chemical and biological aspects present so many interesting peculiarities and its connection with filtered or ground water-supplies is so important that the organism is certainly worthy of special study.

At the present writing but one species of the genus *Crenothrix* has been described. In reality there are three species which fall under this head. The mode of occurrence, conditions for growth, and life history of these three species are similar in almost every respect. The measurements and minor differences are shown later in tabulated form, but the most noticeable distinguishing feature between the three species is the difference in the chemical which it precipitates from the water.

The first and well-known species precipitates hydroxid of iron and occurs in reddish brown flocs or strings. This is the genus described as *Hypheothrix* by Kützing previous to 1850 and is probably the same as that found in 1852 by Kühn in a drain pipe leading from the reservoir of a garden in Bunzlau (Silesia). Shortly after the latter discovery, Rabenhorst in his Algae of Saxony and Central Europe called the organism *Leptothrix kühniana*. In a subsequent book, however, Rabenhorst[1] described the same organism as *Hypheothrix kühniana*. In 1870 Cohn[2] gave a description of this organism and called it the Brunnenfaden or well-thread, and proposed the technical name of *Crenothrix*. He found the organism widely distributed in well waters, and as he observed but one spe-

1 Flora Europaea Algarum Aquae Dulcis, etc., Bd. II, p. 88. Leipzig, 1865.

2 "Über den Brunnenfaden (*Crenothrix polyspora*)," etc. *Beiträge zur Biologie*, Bd. I, pp. 117-31.

cies, and that with a peculiar and prolific spore formation, he gave it the specific name of *polyspora*. Since that time the species has gone under the name of *Crenothrix polyspora* or *Crenothrix kühniana*.[3]

This is the organism which in 1878 caused the serious contamination of the Tegel water-supply of Berlin,[4] which resulted in the abandonment of the wells sunk near Tegel Lake as a source of supply. The same organism in 1887 caused serious trouble in the water from the sand filters at Rotterdam,[5] which derived their supply from the river Maas. This set of filters was also abandoned. During the last ten years *Crenothrix kühniana* has given great trouble in numerous cities, both abroad and in this country, and much expense has been involved in the replacing or treatment of the supplies affected.

The species which precipitates iron is the one which had always been the cause of trouble. Of recent years two other species have been brought into play in the degenerating of ground waters. One of these has been known as *Leptothrix ochracea* and has not previously been described as seriously affecting water-supplies. It will be shown that this organism should properly come under the genus *Crenothrix* and that the material precipitated, although yellowish in color, consists chiefly of alumina.

The other species has never been described and is rarer even than the second. This organism precipitates manganese, and, inasmuch as large quantities of manganese are rarely found in water-supplies, it has had less opportunity to develop in noticeable amounts. The author has found it in but two places and in only one in large numbers. The three species may be easily distinguished when in bulk from the color of the precipitates produced.

The iron bacterium is from yellowish red to reddish brown in color, depending upon the age of the growth. The aluminum bacterium is from pure white to yellowish white. The manganese bacterium is from brown to almost black. The characteristics of this latter species would entitle it to the name of *Crenothrix*

3 W. T. Sedgwick, "On *Crenothrix kühniana*." *Tech. Quar.*, Vol. VIII, No. 4. Nov., 1890.

4 O. Brefeld and W. Zopf, Bericht an den Magistrat der Stadt Berlin über die von ihnen angeführten Untersuchungen des Tegeler Wassers. Berlin, 1879.
W. Zopf, Entwickelungsgeschichtliche Untersuchung der *Crenothrix polyspora*, Die Ursache der Berliner Wassercalamität. Berlin, 1879.

5 Hugo De Vries, "Die Pflanzen und Thiere in den dunkeln Raumen der Rotterdamer Wasserleitung." Bericht über die Biologischen Untersuchungen der Crenothrix-Commission zu Rotterdam vom Jahre 1887, pp. 1-55. Jena, 1890.

manganifera, and as the species producing alumina and formerly called *Leptothrix ochracea* belongs under the genus *Crenothrix,* as will be shown later, it should properly be called *Crenothrix ochracea,* while the old and well-known species which precipitates iron should be called *Crenothrix kühniana,* as *kühniana* is the specific name which takes precedence in point of time.

All three species occur chiefly in ground waters and only grow with rapidity when the dissolved oxygen is lacking, or nearly so, and when the special salts are present which they precipitate. The presence of much organic matter seems to favor the growth, but the two former conditions are absolutely necessary. The absence of light and the presence of carbonic acid in the water are also usual conditions and seem to favor growth.

Wherever these organisms have been the cause of serious trouble, the growth has taken place in driven well tubes and has stopped up the tubes, or has been carried on to clog the well screens, or it has occurred in the bottom or sides of filter galleries and dug wells and in the dead ends of water pipes. Except in the latter case, the original cause is improper conditions for filtration, or too heavy a draught upon the water, thus using up the dissolved oxygen and causing conditions which would favor the reduction and solution of iron, manganese, or aluminum from the soil. These salts occur in the water as sulfate or in combination with carbonic acid and organic matter, and are incorporated into the sheath of the organism. The salts seem to be oxidized by the growth and are then precipitated with it. This precipitate not only clogs up the pipes and screens, but makes the water very disagreeable in appearance and unfit for domestic use or for industrial purposes.

A brief description of the genus will be given, and then a table showing the differences between the three species will be presented.

GENUS *Crenothrix.* Filaments cylindrical, transversely divided into cells of very unequal length. Surrounded by a gelatinous envelope which is usually filled with a flocculent precipitate, yellow, red, brown, or black. Filaments unbranched, but the bacteria within have a faculty of leaving their outgrown sheath often at the side by means of a splitting in the cell wall.

Bacteria in sheath 1.5 μ wide and of very unequal length. Forms spores, 1 to 6 μ in diameter. Habitat, stagnant or improperly filtered water.

The manner of multiplication of the genus is described by Sedgwick[6] in his "Data of Filtration" as follows:

"The first method of multiplication depends upon the capacity of all the cells composing a filament, if they become isolated in any way, to develop each a new filament. When, for instance, the cells free themselves from their old rust sheath, and before they form a new envelope are broken apart by the current or by a blow, obviously we have supplied the germ for one or several flocs. But besides this, the plant possesses other methods of multiplication. In the thicker filaments the cells divide not merely transversely, as in the thinner threads, but also lengthwise. Thereupon each cell divides into two or four adjoining cells. These latter separate and form the so-called microspores. In a filament in which this process has occurred, as soon as the cells have left their sheath in the usual manner, these microspores escape as innumerable, entirely distinct masses, which speedily become scattered in the water. Each microspore, immediately after its escape, begins to divide. Division takes place in all directions, and a little cluster soon arises composed of hundreds of cells. The sheath with which each cell envelopes itself changes in this case into a "slime" or jelly, which, however, becomes colored in the usual manner with the oxide of iron. By means of this "slime" the whole mass is stuck or pasted to any part of the walls of the reservoir or to any objects within it. After some time the course of development changes, and each cell of the cluster grows into a filament. In some of these the cells divide transversely only and form the so-called macrospores; in others the above described microspores arise."

[6] *Tech. Quar.*, Vol. III, No. 4. Nov., 1890.

If we take into consideration the foregoing descriptions it will be seen from the following table that the three organisms belong to the same genus but represent quite sufficient differences to rank them as separate species.

TABLE I

	Crenothrix kühniana	Crenothrix manganifera	Crenothrix ochracea
Color of precipitate in sheath	Reddish brown......	Dark brown or black	Very light buff (color of ochre)
Filaments.	Nearly straight......	Nearly straight......	Curved, often spiral
	1.5–5 μ thick, widening at end to 6–9 μ. 6–15 μ long	8–15 μ thick .... 35–125 μ long.......	1.5–3 μ thick 60–150 μ long
	Articulated and in places interrupted	Articulated and in places interrupted	Not articulated but interrupted
	Transverse division distinct	Transverse division distinct	Transverse division indistinct
Bacteria in filament.	1.5×2 μ	1.5×3–6 μ	1.5–2 μ×4–9 μ
	Distinct when treated with HCl	Distinct when treated with HCl	Not distinct when treated with HCl
	Easily stained with Loeffler solution	Easily stained with Loeffler solution	Difficultly stained with Loeffler sol.
	Slightly rounded ends	Decidedly rounded ends	Slightly rounded ends
Macro-spores...	1–6 μ, spherical diameter	3×4 μ, oval.........	1.5×2 μ, oval
Micro-spores...	1 μ	1–1.5 μ	1 μ

A chemical analysis of the precipitates produced by the various species shows that about one-third of the entire constitution of the organism consists of the special oxide which it precipitates, another third or more consists of organic matter, and the remainder, which may be merely accidental and not a true constituent, is largely silica and aluminum silicate.

The following table shows these interesting facts:

TABLE II

ANALYSIS OF PRECIPITATES IN WATER CAUSED BY THE THREE SPECIES OF CRENOTHRIX

	CRENOTHRIX KUHNIANA READING, MASS.	CRENOTHRIX MANGANIFERA NEWTON, MASS.	CRENOTHRIX OCHRACEA BROOKLYN, N.Y.
Oxid of iron. Fe_2O_3..........	**31.6** %	14.4 %	14.7 %
Oxid of manganese, Mn_2O_3...	0.0	**33.9**	0.0
Oxid of aluminum, Al_2O_3....	5.7	1.5	**33.3**
Silica, SiO_2................	11.1	12.5	5.9
Aluminum silicate...........	10.4	8.0	7.6
Undetermined mineral matter	4.2	1.8	2.3
Total mineral matter	63.0 %	72.1 %	63.8 %
Organic matter..............	37.0	27.9	36.2
Total min. and organic matter	100.0 %.	100.0 %	100.0 %

It is of interest to show that the waters which produce the various species contain salts which especially favor the growth of that particular species. The following table gives the analyses of waters which have produced large quantities of the species named:

TABLE III

ANALYSIS OF WATER IN WHICH THE THREE SPECIES OF CRENOTHRIX GROW

PTS. PER MIL.	CRENOTHRIX KÜHNIANA READING, MASS.	CRENOTHRIX MANGANIFERA NEWTON, MASS.	CRENOTHRIX OCHRACEA BROOKLYN, N. Y.
Fe_2O_3..............	**3.1**	0.2	0.3
Mn_2O_3.............	0.0	**2.0**	0.0
Al_2O_3..............	0.6	0.5	**2.0**
SiO_2................	22.6	10.4	22.9
$CaCO_3$ $MgCO_3$	24.0	12.0	98.0
$CaSO_4$ $MgSO_4$	8.0	16.0	1.0
NaCl	5.3	7.8	7.5
Undetermined.....	3.5	3.3	2.2
Total mineral	67.1	52.2	133.9
Total organic.......	22.4	5.8	21.1
Total mineral and organic	89.5	58.0	155.0

It will be seen that waters which produce *Crenothrix kühniana* contain a predominating amount of iron, that waters which produce *Crenothrix manganifera* contain a predominating amount of manganese, and that waters which produce *Crenothrix ochracea* contain a predominating amount of aluminum. It is probable also that this aluminum must be present in the form of sulfate or in combination with carbonic acid and organic matter. Sulfate of aluminum in quantity has been found in waters near these wells and may occur as such in the waters affected.

Crenothrix kühniana was grown artificially in an atmosphere of air and carbonic acid. The cultures were in a mixture of agar and gelatine containing ferrous and manganous sulfates, and were kept in the dark at room temperature. The growth was not very luxuriant, but took place in sufficient amount to show that the organism in growing threw down but little manganese, but selected the iron to precipitate. This was also proved in stagnant solutions containing salts of manganese and iron.

In the same way cultures of *Crenothrix manganifera* were grown in solutions containing iron and manganese, and although the growths were but slight they showed the dark color of the manganese predominating in the precipitate.

It is highly probable that *Crenothrix ochracea* would in the same way always select aluminum in predominating amount to precipitate, as out of many hundreds of waters containing *Crenothrix* which have been examined there has been no case where this species has thrown down a predominating amount of iron or manganese, and in no case has *Crenothrix kühniana* been known to throw down a predominating amount of aluminum. In other words, the species always precipitates in predominating amount the special hydroxid ascribed to it.

Crenothrix kühniana was also grown on gelatin agar in an atmosphere of hydrogen. The growth was normal in measurement and developed well-marked filaments; but although the medium contained ferrous sulfate, none of the iron was thrown down. This is because there was no opportunity for oxidation.

We can conclude that *Crenothrix kühniana* is very common, because iron in quantity is a common constituent of water; that the species *C. ochracea* is rather uncommon because aluminum sulfate or aluminum combined with carbonic acid is less common in water; that the species *C. manganifera* is very rare because manganese seldom occurs in sufficient quantity in water to produce a noticeable growth of the organism; that the growth of all three species is due to lack of oxygen with a consequent reducing action in the soil or water; that this reducing action may be produced by stagnation in the bottoms of ponds or by improper or too rapid filtration in wells or filter galleries.

Mt. Prospect Laboratory,
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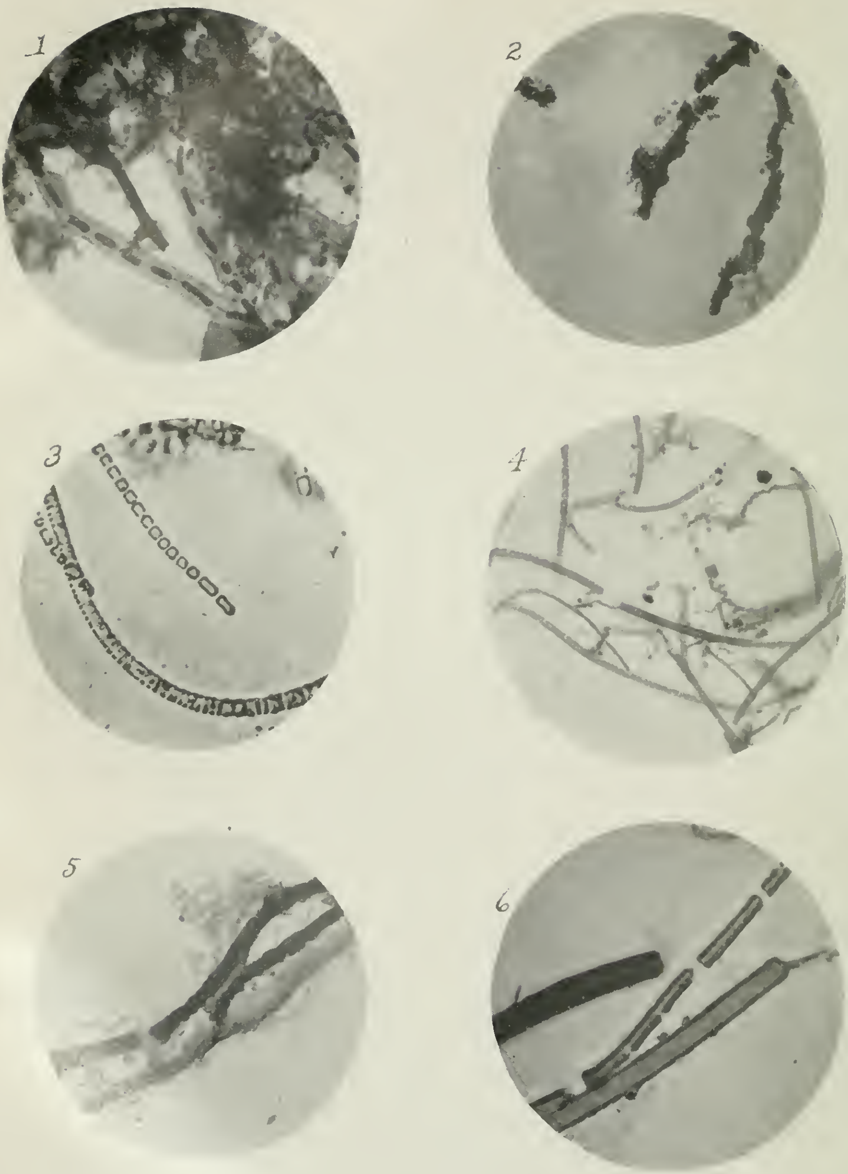
PLATE X



EXPLANATION OF PLATE

Plate X

Fig. 1. *Chrenothrix manganifera.*

Magnification 800 diameters.

The manganese has been removed from the gelatinous sheath in the lower half of the field by means of acid and the bacteria stained with Loeffler solution in order that the filaments and the inclosed bacteria may be clearly shown. Near the lower edge of the field may be seen a case of multiplication by transverse division.

The thread-like attachment connecting each bacterium with the next has probably never before been photographed and can not be shown except by photography. This photograph and Nos. 4 and 6 were taken from the author's preparations by Dr. R. B. Fitz-Randolph of the Hoagland Laboratory, Brooklyn, N. Y.

Fig. 2. *Crenothrix kühniana.*

Magnification 250 diameters.

In this photograph the filaments and bacteria are entirely covered by the precipitated iron in the gelatinous sheath. Nos. 2 and 5 are from photographs by G. C. Whipple.

Fig. 3. *Crenothrix kühniana.*

Magnification 1,200 diameters.

A young growing filament is shown in the upper part of the field, while in the lower part is a filament filled with microspores. Photograph by George W. Rafter.

Fig. 4. *Crenothrix ochracea.*

Magnification 800 diameters.

The filaments may be seen through the translucent precipitated alumina in the sheath.

Fig. 5. *Crenothrix kühniana.*

Magnification 800 diameters.

The iron has been nearly all dissolved by acid and the filmaments with their articulations may be seen.

Fig. 6. *Crenothrix manganifera.*

Magnification 800 diameters.

The manganese has been dissolved by acid and the articulated filaments are distinctly shown.

Note the variation in size and general appearance in the three species represented by Nos. 4, 5, and 6.

NOTES ON COLORADO ENTOMOSTRACA

BY ARTHUR E. BEARDSLEY

The entomostracan fauna of Colorado, although of great economic importance as the chief source of food supply for the fishes of the state, has hitherto received but little attention. The early explorers noted a single species which they found in great numbers in temporary pools of rain water on the plains to the east of the mountains, and the naturalists connected with the geological surveys during the '70s found several species in the elevated mountain lakes and one species on the western slope. For more than half a century no addition has been made to the entomostracan fauna of the great plains of eastern Colorado.

From the geographical position occupied by the state, in the midst of the great arid region, it might be inferred that entomostracan life, dependent as it is upon the presence of a body of water for its very existence, would be but poorly represented. The results obtained in the preliminary work which it is the purpose of this paper to record would indicate that it is abundant both in species and individuals.

That many species of Entomostraca are capable of producing eggs which may remain dormant through long periods of drouth, to be afterwards awakened into activity upon being supplied with water in sufficient quantity for their development, is a fact which has been frequently demonstrated. This may be true of most, if not all, of the forms commonly found in fresh waters. Their rapid development and great fecundity under favorable conditions of environment make it possible for their life cycle to be completed and a new supply of eggs to be deposited in a temporary pool, which may be dried up in the course of a few days or a few weeks at most. When it is remembered that the arid region is subject to occasional rainstorms of great violence, locally known as "cloud-bursts," and that the snows of winter, scanty though they be, may furnish sufficient water to fill the small depressions in the plains, and also that, owing to the aridity of the climate and the consequent lack of stream erosion, such depressions as are capable of holding water are to be found in great numbers on the plateaus of the arid region, it will be readily perceived that conditions favorable to the development of the Entomostraca are not wanting.

HISTORICAL

The earliest reference to Entomostraca in what is now the state of Colorado appears in the report of Long's expedition, in which James (23)[1] notes the occurrence of a species of Apus, which he calls *A. obtusus,* in "rain-water puddles on the Platte river near the Rocky mountains." Unfortunately, his description is so meager that the species is not recognizable. Packard (74*a*) thought it "probably the same" as Le Conte's *A. longicaudatus.*

Twenty-three years later, Le Conte (46) described *Apus longicaudatus,* which, he says, was "found in immense numbers in a small shallow lake on the high plateau between Lodge Pole creek and Crow creek, northeast of Longs Peak."

Nearly thirty years after Le Conte, Carpenter (74) noted the occurrence of *Daphnia pulex* in a pool above timber-line on Mt. Elbert, and Packard described (74) a lernaean (*Achtheres Carpenteri*) and (74*a*) a new branchiopod (*Branchinecta coloradensis*) from the mountains of Colorado. Three years later he described (Packard 77) another branchiopod (*Lepidurus bilobatus*) from Po cañon, and Chambers (77) recorded the occurrence of two species of Cladocera (*Daphnia brevicauda* n. sp. and *Chydorus sphaericus*), and three new species of Ostracoda (*Cypris grandis, C. altissimus,* and *C. mons*), making eleven species of Entomostraca reported from Colorado up to the close of the year 1877, as follows:

Branchiopoda

Apus obtusus James.
Apus longicaudatus Le Conte.
Lepidurus bilobatus Packard.
Branchinecta coloradensis Packard.

Cladocera

Chydorus sphaericus O. F. Müller.
Daphnia pulex De Geer.
Daphnia brevicauda Chambers.

Ostracoda

Cypris grandis Chambers.
Cypris altissimus Chambers.
Cypris mons Chambers.

Copepoda

Achtheres Carpenteri Packard.

[1] See list of works cited at the end of this paper.

Since 1877 no additions to the list appear to have been reported. Within the past year the writer has made a large number of collections of Entomostraca in the vicinity of Greeley, Col., and these collections, together with a few others made in former years in various parts of eastern Colorado, form the basis of the present paper.

BRANCHIOPODA

LIMNADIADAE

Eulimnadia texana Packard.

I found this species in a muddy pool in Crooked creek, Otero county, in June, 1882, where it occurred in great numbers together with the following species. It is also found in Texas and Kansas (Packard, 83).

Estheria mexicana Claus.

I collected about twenty individuals of this species from the same pool with the preceding. I found it again in August, 1897, in Little Crow creek, in Weld county. It has been reported from Mexico, New Mexico, Kansas, Lake Winnipeg, Ohio, and Kentucky (Packard 83).

APODIDAE

Apus Newberryi Packard.

Occurred abundantly in a pool in Little Crow creek in August, 1897, together with the preceding. This species has been found hitherto only in Utah; its occurrence on the eastern side of the mountains is a matter of interest, as it is the first instance in which the same species of crustacean has been found in both regions.

BRANCHIPODIDAE

Branchinecta Lindahli Packard.

I found a single specimen of this species, a female with eggs, in a temporary pool near Greeley, July 2, 1901, together with *Moina affinis*. Hitherto its only recorded habitat was Kansas (Packard 83).

Streptocephalus texanus Packard.

About thirty individuals of this species, including females with eggs and adult males, were collected by the writer from a rock pool filled with water from melting snow, in April, 1882, on the north side of the Mesa de Mayo. It has been reported from Texas and Kansas (Packard 83).

CLADOCERA

DAPHNIADAE

Daphnia pulex De Geer.
Occurs in Seely lake; also occasionally in pools about Greeley.

Ceriodaphnia reticulata var. *dentata* Birge.
Abundant in Seely lake and in ponds around Greeley.

Scapholeberis mucronata (O. F. M.)
Of frequent occurrence in ponds near Greeley.

Simocephalus vetulus (O. F. M.).
Abundant around Greeley in all ponds.

Moina affinis Birge.
Often extremely abundant in pools formed by summer rains.

LYNCEIDAE

Alona glacialis Birge.
Occurs sparingly in ponds and in Seely lake.

Alonopsis latissima Kurz.
In ponds near Greeley. Not common.

Chydorus sphaericus (O. F. M.).
Occurs in the majority of my collections from the ponds about Greeley; also from Seely lake.

OSTRACODA

CYPRIDIDAE

Candona acuminata (Fischer).
I found this occurring in great numbers in March and April, in a small grassy pool near Greeley, which soon after became dry.

Cyclocypris laevis (O. F. M.).
I have found this species in shallow ponds near Greeley in February and March.

Cypridopsis Newtoni Brady and Robertson.

Common in ponds near Greeley in June and July.

Cypridopsis vidua (O. F. M.).

Abundant during the summer in stagnant pools.

Cypris fuscata Jurine.

I have found a few individuals of this species in Carter's slough near Greeley.

Erpetocypris olivacea Brady and Norman.

Occurs in abundance in Carter's slough.

COPEPODA

CENTROPAGIDAE

Diaptomus sicilis Forbes.

Occurs in Seely lake, where it is the most abundant of the Entomostraca.

Diaptomus clavipes Schacht.

I found this species occurring in a pool of only a few feet area in a narrow ravine fed by springs. My specimens when alive were transparent and colorless excepting the distal portion of the antennae, which were blood red. The peculiar hook on the fifth foot of the male is represented in its correct position in Schacht's figure, but in his description it is erroneously placed upon the next segment.

CYCLOPIDAE

Cyclops insectus Forbes.
C. albidus Jurine.
C. ater Herrick.
C. serrulatus Fischer.

Excepting *C. ater,* which is apparently rare, these are abundant in the regions about Greeley.

HARPACTIDAE

Canthocamptus minutus (O. F. M.)

Length of female, 0.65–0.75 mm. Length of male, 0.60–0.65 mm.

My specimens were obtained from a small pond near the track of the C. & S. railroad in the city of Greeley.

LIST OF ENTOMOSTRACA KNOWN TO OCCUR IN THE STATE OF COLORADO

(An asterisk [*] placed before the name of a species indicates that it is new to the state.)

BRANCHIOPODA

Limnadiadae

* Eulimnadia texana Packard.
* Estheria mexicana Claus.

Apodidae

Apus longicaudatus Le Conte (?= obtusus James).
* Apus Newberryi Packard.
Lepidurus bilobatus Packard.

Branchipodidae

Branchinecta coloradensis Packard.
* Branchinecta Lindahli Packard.
* Streptocephalus texanus Packard.

CLADOCERA

Daphniadae

Daphnia pulex De Geer.
Daphnia brevicauda Chambers.
* Ceriodaphnia reticulata var. dentata Birge.
* Scapholeberis mucronata (O. F. Müller).
* Simocephalus vetulus (O. F. Müller).
* Moina affinis Birge.

Lynceidae

* Alona glacialis Birge.
* Alonopsis latissima Sars.
Chydorus sphaericus (O. F. Müller).

OSTRACODA

Cyprididae

* Candona acuminata (Fischer).
* Cyclocypris laevis (O. F. Müller).
Cypria mons (Chambers).
* Cypridopsis Newtoni Brady and Robertson.
* Cypridopsis vidua (O. F. Müller).
Cypris altissimus Chambers.
* Cypris fuscata Jurine.
Cyprinotus grandis (Chambers).
* Erpetocypris olivacea Brady and Norman.

COPEPODA

Centropagidae

* Diaptomus sicilis Forbes.
* Diaptomus clavipes Schacht.

Cyclopidae

* Cyclops insectus Forbes.
* Cyclops albidus Jurine.
* Cyclops ater Herrick.
* Cyclops serrulatus Fischer.

Harpactidae

* Canthocamptus minutus (O. F. Müller).

Lernaeopodidae

Achtheres Carpenteri Packard.

SUMMARY

Branchiopoda	8 species, of which	5 are new to the state.
Cladocera	9 species, of which	6 are new to the state.
Ostracoda	9 species, of which	6 are new to the state.
Copepoda	8 species, of which	7 are new to the s'ate.
Total,	34 species, of which	24 are new to the state.

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NOTES ON COLORADO PROTOZOA

WITH DESCRIPTIONS OF NEW SPECIES

By ARTHUR E. BEARDSLEY

WITH ONE PLATE

These notes have been made in the course of a systematic study of the Protozoa of the state, which was begun in the spring of 1897 and has been carried on at such times as the pressure of other duties has permitted. The work up to the present time has been confined to Greeley and its immediate vicinity, but it is hoped to extend it in the near future to other parts of the state.

Class SARCODINA

Order RHIZOPODA

Family Amoebaea lobosa

Genus Amoeba

Amoeba spatula Penard. Pl. XI, figs. 1*a*–1*e*.

A very small, floating Amoeba with long, radiating pseudopods is frequently to be found in cool, shaded waters about the city of Greeley. I have found it most abundant during the winter months in a large tank at the edge of the city park, used as a horse-trough and supplied with water from the city mains. At first I supposed it to be Ehrenberg's *A. radiosa,* and cast aside any lingering doubts that may have remained when I found it well represented by several figures in Leidy's Fresh-water Rhizopods under that name.

From the same place, and often on the same slide with the foregoing, I found a small, reptant Amoeba (fig. 1*a*) of slow movement.

in outline broadly spatulate or fan-shaped, its width equal to or exceeding its length, the anterior half strongly depressed, very broadly rounded, thin, and hyaline, forming a sort of broad, flat pseudopod; posterior portion thickened, granular, and filled with food vacuoles. Contractile vesicle usually one, sometimes two or three, filling and emptying very slowly. Nucleus small, round, rarely visible without reagents. This form is apparently identical with *A. spatula* Penard.

Subsequent observations proved conclusively that the two forms are merely different states of the same organism. Individuals were repeatedly seen to change from one form to the other. When about to change from the spatulate to the radiate form, the Amoeba projects from its posterior, thickened portion one or two slender pseudopods, and at the same time the broad, hyaline anterior portion is gradually withdrawn (fig. 1*b*); then several pseudopods are thrown out from what was the anterior end, the animal frees itself from the slide, and floats away (1*c*). In changing from the floating to the creeping form, this process is reversed: the long, slender pseudopods are withdrawn, the animal flattens itself upon the slide, and assumes the spatulate form.

This species attains a diameter of 10–12 μ when in the radiate, floating form, and 20–25 μ in the spatulate form. In the radiate form it may easily be mistaken for *Amoeba (Dactylosphaera) radiosa,* from which it is distinguishable by its habit of transformation.

Family Gromiina Bütschli

Pamphagus mutabilis Bailey.

A few individuals of this apparently rare form have been seen in water from the horse-trough in the city park.

Sub-class **HELIOZOA**

Genus Nuclearia

Nuclearia delicatula Cienk.

(Syn.—*Heterophrys varians* F. E. Schulze.)

This interesting heliozoan has been found abundantly in the horse-trough in City Park, and its mode of taking food has been frequently observed. Its food consists chiefly of diatoms and unicellular green algae. A pseudopod, on coming in contact with a food-particle, adheres to it and slowly contracts; as the adhering particle approaches the body, a small rounded vesicle rises up around the base of the pseudopod, into which the particle is drawn by the retraction of the pseudopod; after the particle is completely enclosed in the vesicle, this gradually subsides, carrying the particle with it into the body. Change of form in *Nuclearia,* as in most Heliozoa, is usually very slow, but occasionally a complete transformation in appearance is effected in a few minutes.

Figures of what is probably this species, from the Uinta mountains, Wyoming, are given by Leidy in his Fresh-water Rhizopods,[1] and are doubtfully referred by him to the genus *Heterophrys.* I have been unable to find any other record of the occurrence of *Nuclearia* in North America.

Class MASTIGOPHORA

Family Cercomonadina (Kent)

Cercomonas longicauda Duj.

In water from the horse-trough in City Park, I have frequently found a monad belonging to this genus and which accords with the figures and description of this species. I have been unable to find any prior record of the occurrence of this genus in America.

Family Menoidina Bütschli

Atractonema teres Stein.

Body colorless, rigid, fusiform, pointed behind, truncate or slightly emarginate anteriorly. Mouth at the anterior end opening into a distinct oesophagus which is enlarged posteriorly. Flagellum single. My specimens agreed in all respects with Stein's figure.

Hab.—Pond water, with *Euglena.* Apparently not hitherto recorded from America.

Family Amphimonadina Kent

Genus *Amphimonas* Duj.

Amphimonas clavata n. sp. Pl. XI, figs. *2a, 2b.*

Form elongate-clavate, broadly rounded anteriorly, tapering gradually to the posterior extremity by which it frequently fixes itself

1 Leidy, Fresh-water Rhizopods, pl. XLV, figs. 2, 3, 5, 6.

to other objects. Body somewhat contractile. Flagella two, similar in size and character, nearly as long as the body, arising close together from the anterior extremity. Endoplasm colorless, slightly granular. Contractile vesicle single in the anterior half. Nucleus spherical, sub-central. Length 8–10 μ.

Hab.—Stale pond water.

This species closely resembles *Deltomonas cyclopum* Kent, but differs in the point of origin of the flagella. It apparently is near to *A. exilis* Perty, but differs in the flagella, which are less than half as long as in *exilis*.

Family CHLAMYDOMONADINA Bütschli

Spondylomorum quaternarium Ehrbg.

Colonies consisting of sixteen green monads, agreeing in all respects with Stein's figure and description, were abundant in June, 1898, and have since been seen occasionally.

Occurs in Europe and India; not hitherto reported from America.

Sub-class **DINOFLAGELLATA** Bütschli

Ceratium hirundinella (O. F. M.).

I have found this occasionally, but only in small numbers.

Peridinium tabulatum Ehrbg.

Common in clear, open water in ponds and lakes. I have found it in Seely lake, near Greeley, sometimes occurring in long streaks through the water, so abundant as to give to the water a well-marked, reddish-brown tint, perceptible at a distance of twelve to twenty meters. An average of ten counts from such a streak gave 18,300 *Peridinia* per cubic centimeter.

Class INFUSORIA

Order GYMNOSTOMATA Bütschli

Family ENCHELINA Ehrbg., Stein

Genus HOLOPHRYA Ehrbg.

Holophrya heterostoma n. sp. Pl. XI, fig. 3.

Form ellipsoid, about twice as long as wide; faintly striate longitudinally with about twenty striae; cilia fine, short, nearly equal, those about the anterior pole slightly larger. Mouth a narrow oval slit, rounded in front, pointed behind, lying at one side of the anterior pole. Color translucent. Usually filled with large food-balls. Nucleus oval, single, sub-central. Contractile vesicle single, posterior. Movement rather slow, regular.

Length, 100 μ.

Hab.—Ponds and ditches.

This species is a member of Section II of the genus as arranged by Bütschli. It may be readily distinguished from *H. Lieberkühnii* Bütschli, the only other member of this section, by the superficial striae which are much more numerous in the latter. Bütschli gives no description of his species, but merely a figure of the anterior pole, which he copies from Lieberkühn; its remaining characteristics are therefore uncertain.

Genus UROTRICHA.

Urotricha farcta C. and L.

This species has apparently not hitherto been reported from America, but my specimens were so completely in agreement with the description and figures by European authors as to leave no doubt of their identity.

One evening, while observing through the microscope, I discovered a double *Urotricha*, a most diminutive pair of "Siamese twins." The two individuals were grown together, side by side, their long, posterior cilia extending backward parallel one with the other. Aside from the union, each appeared to be quite normally developed in every way. They were kept under observation nearly an hour, and were finally lost by their suddenly springing out of the field.

Since, in this family, reproduction commonly takes place in the encysted state, it seems probable that the "twinning" in this case was due to arrest of the process of division between two of the segments while in the cyst.

Prorodon teres Ehrbg.

I have occasionally seen infusoria which agree in every respect with Bütschli's figures of this species. It has apparently not been heretofore reported from America.

Lagynus laevis (Engelm.) ?

I have found infusoria in Brown's slough, near Greeley, which apparently belong here, although less than half the size indicated by Engelmann's figure. They occurred in considerable numbers and some were found in conjugation.

Didinium nasutum (O. F. M.)

Didinium Balbiani Bütschli.

Both of these occur in abundance in Brown's slough. Neither appears to have been hitherto reported from America.

Nassula aurea Ehrbg.

This highly colored infusorian, resplendent with royal purple and gold, is often found in shallow, quiet water in the Cache la Poudre river. Apparently not hitherto reported from America.

Order TRICHOSTOMATA Bütschli

Family Chilifera Bütschli

Genus Frontonia C. & L.

Frontonia leucas Ehrbg.

Common in ponds, among diatoms and algae. Apparently not hitherto reported from America.

Frontonia elliptica n. sp. Pl. XI, figs. 4*a*–4*d*.

Form ellipsoid, slightly flattened; ends equally rounded. Body flexible, not contractile, covered with fine longitudinal striations. Cilia fine and even. Trichocysts numerous, evenly distributed. Mouth and post-oral groove extend along the second and third fifths of the body; mouth about half covered by the left undulating membrane. Contractile vesicles two, with distinct afferent radiating canals. Anus postero-lateral. Macro-nucleus large, spherical, lying in the anterior half, with one or more imbedded micro-nuclei. Feeds upon diatoms.

Length 115–150 μ.

Hab.—Bottom of ponds, with algae and diatoms.

This species differs from *leucas,* with which I have found it sometimes associated, in its more symmetrical form and smaller size, in the constant presence of two contractile vesicles, in the shape of the nucleus, and in the form of the mouth and the left undulating membrane. In most of these characters it resembles *F. fusca* Quennerstedt, a marine species, from which it differs in the form of the nucleus and the position of the mouth.

Family Microthoracina Wrzesn.

Cinetochilum margaritaceum (Ehrbg.)

(Syn.—*Cyclidium margaritaceum* Ehrbg.)

I have found this minute infusorian very common among algae in ponds and streams. Apparently not hitherto reported from America.

Sub-order SPIROTRICHA Bütschli

Section Heterotricha Stein

Family Gyrocorina Stein

Coenomorpha medusula Perty.

(Syn.—*Gyrocoris oxyuris* Stein.)

This rare infusorian occurred in great numbers in a jar with *Lemna* in my laboratory, in November, 1897.

Section Oligotricha Bütschli

Family Halterina C. & L.

Genus Strombidium C. & L.

Strombidium velox n. sp. Pl. XI, figs. 5*a*–5*c*.

Form turbinate, varying to obovate and broadly elliptical. Peristome produced backward along the ventral side as an oblique furrow, nearly to the middle line. Adoral cilia stout, curved outward and backward, about half as long as the body, diminishing in size toward the posterior end of the oral groove. Body colorless; surface smooth, without supplementary cilia. Nucleus sub-central, irregularly globular. Contractile vesicle anterior, spherical, rather large. Food consists of diatoms.

Length, 45–50 μ. Greatest width, 37–40 μ.

Hab.—Ponds and ditches, with *Vaucheria*.

The movements are extremely rapid and erratic, the infusorian frequently gyrating for a time around a fixed point, then suddenly darting away and out of sight, even when one is using a low power. It often remains for a considerable time fixed by a slender, colorless filament to the glass or to debris on the slide, rapidly revolving on a longitudinal axis and swaying to and fro with a pendulum-like movement, in a manner quite similar to that of *Urocentrum turbo*.

The filament by means of which the animal is enabled to fix itself is apparently formed of some gelatinous substance, and is probably a secretion of the posterior portion of the animal itself. That it possesses a considerable amount of resilience and tenacity is shown by the way in which the animal is drawn backward by its contraction whenever a slowing up of the ciliary motion occurs, as well as by the comparatively enormous loads of debris which are occasionally drawn by it across the field.

A number of forms have been found which have not yet been sufficiently studied to make their identification complete; of these no further mention is made at this time. The following list contains only those forms which I have found occurring within the state and have fully identified. Of the 99 species recorded in this list, 4 are apparently new; 13 are Old World species which do not appear to have been hitherto reported as occurring in North America; the remaining 82 species embrace a few rare forms not often seen, but the greater number are well-known forms, many of them cosmopolitan in distribution.

A PRELIMINARY LIST OF THE PROTOZOA FOUND IN THE STATE OF COLORADO

(An asterisk [*] before the name of a species indicates that it is new to America; the dagger [†] indicates a species new to science.)

Class SARCODINA

Order RHIZOPODA

Amoeba proteus (Rösel).
Amoeba limax Duj.
Amoeba spatula Penard.
Amoeba radiosa Ehrbg.
Arcella vulgaris Ehrbg.
Arcella discoides Ehrbg.
Difflugia acuminata Ehrbg.
Difflugia constricta (Ehrbg.).
Difflugia corona Wallich.
Difflugia globulosa Duj.
Difflugia lobostoma Leidy.
Difflugia pyriformis Perty.
Centropyxis aculeata (Ehrbg.).
Nebela flabellum Leidy.
Euglypha alveolata Duj.
Cyphoderia ampulla (Ehrbg.).
Pamphagus mutabilis Bailey.

Order HELIOZOA

Vampypella lateritia (Fresenius).
Nuclearia delicatula Cienkowsky.
(Heterophrys ? Leidy.)
Actinophrys sol Ehrbg.
Actinosphaerium Eichhornii Ehrbg.
Raphidiophrys pallida F. E. Schulze.

Total............22

Class MASTIGOPHORA

* Cercomonas longicauda Duj.
Oikomonas mutabilis Kent.
Oikomonas termo (Ehrbg.).
Monas guttula Ehrbg.
Anthophysa vegetans (O. F. M.).
Euglena viridis Ehrbg.
Trachelomonas volvocina Ehrbg.
Trachelomonas hispida Perty.
Phacus pleuronectes (Ehrbg.).
* Atractonema teres Stein.
Peranema trichophorum (Ehrbg.) Stein.
(Astasia trichophorus.)
Anisonema ovata Duj.
† Amphimonas clavata n. sp.
Synura uvella Ehrbg.
Mallomonas Plosslii Perty.
* Spondylomorum quaternarium Ehrbg.
Gonium pectorale (O. F. M.).
* Gonium sociale (Duj.).
Pandorina morum Ehrbg.
Eudorina elegans Ehrbg.
Chilomonas paramaecium Ehrbg.
Ceratium hirundinella (O. F. M.).
Peridinium tabulatum (Ehrbg.).

Total............23

Class INFUSORIA (CILIATA)

Order GYMNOSTOMATA Bütschli

Holophrya discolor Ehrbg.
† Holophrya heterostoma n. sp.
* Urotricha farcta Claparede and Lachman.
* Prorodon teres Ehrbg.
Lacrymaria olor Ehrbg.
(Trachelocerca olor.)
* Lagynus laevis (Engelmann).

Trachelophyllum apiculatum (Perty).
Coleps hirtus Ehrbg.
* Didinium nasutum (O. F. M.).
* Didinium Balbiani Bütschli.
Lionotus anser (Ehrbg.).
Lionotus fasciola (Ehrbg.).
Dileptus anser (O. F. M.).
Loxodes rostrum (O. F. M.).
* Nassula aurea Ehrbg.
Chilodon cucullus (O. F. M.).

Order TRICHOSTOMATA

Sub-order ASPIROTRICHA Bütschli

Glaucoma scintillans Ehrbg.
* Frontonia leucas Ehrbg.
† Frontonia elliptica n. sp.
Colpidium colpoda Ehrbg.
Colpoda cucullus (O. F. M.).
* Cinetochilum margaritaceum (Ehrbg.).
Paramaecium caudatum Ehrbg.
Urocentrum turbo (O. F. M.).
Lembadion bullinum Perty.
(Hymenostoma hymenophora Stokes.)
Cyclidium glaucoma Ehrbg.

Sub-order SPIROTRICHA Bütschli

§ HETEROTRICHA

Blepharisma lateritia Ehrbg.
Metopus sigmoides Cl. and L.
Spirostomum ambiguum Ehrbg.
Bursaria truncatella O. F. Mueller.
Stentor coeruleus Ehrbg.
Stentor polymorphus Ehrbg.
Coenomorpha medusula Perty.
(Gyrocoris oxyuris Stein.)

§ OLIGOTRICHA

† Strombidium velox n. sp.
Halteria grandinella (O. F. M.).

§ HYPOTRICHA

* Oxytricha pelionella (O. F. M.).
Urosoma caudata (Stokes).
Stylonychia mytilus (O. F. M.).
Euplotes patella (O. F. M.).
Euplotes charon (O. F. M.).
Aspidisca costata (Duj.).

§ PERITRICHA

Vorticella aperta Frommontel.
Vorticella convallaria Ehrbg.
Vorticella hamata Ehrbg.
Vorticella microstoma Ehrbg.
Vorticella nebulifera Ehrbg.
Vorticella putrina O. F. M.
Vorticella similis Stokes.
Carchesium polypinum Ehrbg.
Epistylis digitalis Ehrbg.
Cothurnia crystallina (Ehrbg.).
Thuricola valvata (Wright).
Vaginicola decumbens Ehrbg.

Total............53

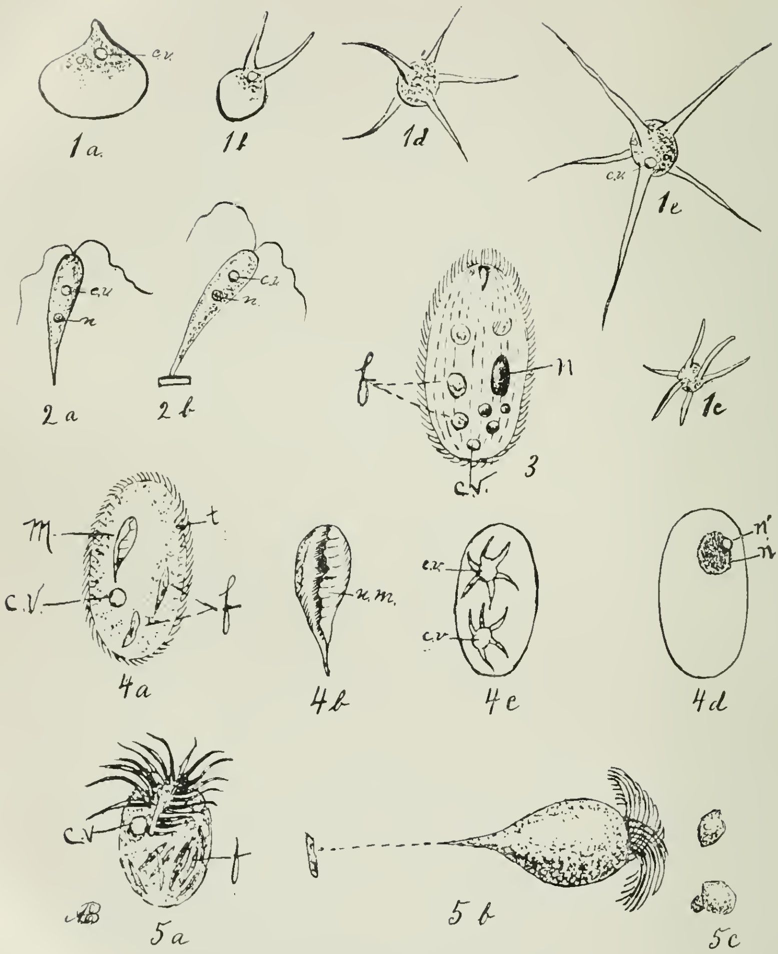
Sub-class SUCTORIA

Sphaerophrya magna Maupas. 1

Grand Total.......................................99

Biological Laboratory,
Colorado State Normal School.

PLATE XI



c.v.
1a.
1b
1d
c.v.
1e
c.v.
n
c.v.
n.
2a
2b
f
n
c.v.
3
1c
m
t
c.v.
f
u.m.
c.v.
c.v.
n'
n
4a
4b
4c
4d
c.v.
f
5a
5b
5c

EXPLANATION OF PLATE

Plate XI

All figures (excepting 1*b*, 1*c*, and 5*b*) were drawn with aid of a camera lucida; the linear magnification of each figure is indicated by the number following the sign ×.

In all figures the letters *cv* indicate the contractile vesicle; *f*, ingested food; and *n*, the nucleus.

Fig. 1*a–e*. *Amoeba spatula* Penard. *a*. Reptant form, ×700. *b* and *c*. Successive stages of the same individual, changing from the reptant to the floating form, × about 600. *d*. Floating form with pseudopods partially extended, ×600. *e*. Same, pseudopods fully extended, ×600.

Fig. 2, *a*, *b*. *Amphimonas clavata* n. sp. *a*. Free-swimming individual, ×1300. *b*. Individual attached by posterior end, ×1300.

Fig. 3. *Holophyra heterostoma* n. sp. Ventral view, ×260.

Fig. 4*a–d*. *Frontonia elliptica* n. sp. *a*. Ventral view; *t*, trichocysts; ×200. *b*. Oral aperture, with *um*, the undulating membrane; ×480. *c*. Outline, showing the two contractile vesicles with their afferent canals. *d*. Outline, showing *n*, the macro-nucleus with n′, the imbedded micro-nucleus (stained with acetic acid carmine).

Fig. 5*a–c*. *Strombidium velox* n. sp. *a*. Ventral view of a quiescent individual with rounded posterior end, ×370. *b*. Dorsal view of turbinate individual, showing mode of attachment. *c*. Isolated nuclei (stained with acetic acid carmine); ×600.

THE PLANKTON OF LAKE MAXINKUCKEE, INDIANA

By CHANCEY JUDAY

It is desirable to present here a brief summary of the plankton observations made on Lake Maxinkuckee during August, 1899. These observations were made as a part of the field investigations of the U. S. Fish Commission.

The following results were obtained:

1. Regular observations were made during August at three different stations and these showed a decrease in the quantity of plankton of from 36 per cent to almost 50 per cent. This decrease was due to a large decrease of the phytoplankton. There was a slight increase of crustacea. Cyclops was the predominant crustacean.

2. The plankton was confined almost wholly to the upper 12 meters. Only *Corethra* larvae were found regularly below this depth. The 0–1 m. layer contained about 48 per cent of the entire quantity. This is preeminently the region for phytoplankton, young Cyclops, and nauplii. The 0–3 m. layer contained about 68 per cent of the entire quantity of plankton.

3. Adult *Diaptomus minutus* and *Daphnia retrocurva* were rarely found above 3 m. during the day. *Daphnia pulex* was found in and below the thermocline.

4. Only one set of observations was made at night. Although the entire quantity of plankton in the 0–1 m. layer was smaller than that obtained during the previous afternoon, there was a distinct increase in the crustacea. *Epischura lacustris, Leptodora hyalina,* and adult *Daphnia retrocurva* were found in the 0–1 m. layer at night but not during the day. Also, there was an increase in the number of adult Cyclops over day conditions.

5. Station II was located in a small basin having a maximum depth of 12.8 m. and entirely separated from the main basin of the lake by a considerable area where the water is 2 m. or less in depth. The bottom temperature was slightly lower here than in the deepest

part of the lake (26 m.). During each of the four weeks the observations continued, one set of hauls was made in this small basin for purposes of comparison with hauls from Station I in the deepest part of the lake. The quantity of plankton obtained was smaller than the weekly average from corresponding depths at Station I. Hauls made at five stations in the main basin of the lake, besides the two regular stations, showed that the plankton was very evenly distributed.

The following is a list of the Cladocera observed:

Daphnia pulex De Geer, var. pulicaria Forbes.
Daphnia retrocurva Forbes.
Ceriodaphnia lacustris Birge.
Sida crystallina O. F. Müller.
Acroperus harpae Baird.
Pleuroxus procurvatus Birge.
Diaphanosoma brachyurum Liévin.
Ilyocryptus longiremis Sars.
Alona guttata Sars.
Leptodora hyalina Lilljeborg.

Prof. C. Dwight Marsh determined the following list of Copepods observed:

Cyclops Leuckarti Sars.
Cyclops prasinus Fischer.
Diaptomus minutus Lilljeborg.
Epischura lacustris Forbes.

THE MORPHOGENESIS OF THE STIGMATA AND STOMATA OCCURRING IN PERITONEAL AND VASCULAR ENDOTHELIUM

By ARTHUR E. HERTZLER, A.M., M.D.

WITH TWO PLATES

PREFATORY NOTE

Although a great many papers have been written which, either directly or indirectly, involve a discussion of the stigmata and stomata, their significance has never been definitely determined. The majority of the discussions have to do, not with these structures themselves, but with their influence and importance in certain physiologic and pathologic processes. Their existence as real morphologic elements has been assumed and then their function or office argued on *a priori* grounds. This method of study is always uncertain and doubly so when morphologic problems are under discussion.

The study of which this paper is an excerpt was begun nearly ten years ago, when the writer was still in his undergraduate course. It at first involved surgical problems only, but it soon became evident that anatomic knowledge was inadequate for successful study of surgical and pathologic problems. A review of the literature gave but little aid and less encouragement, for it was apparent that the history of our knowledge of the structure of the peritoneal endothelium[1] is coincident with that of the action of the nitrate of silver upon this structure. A reconsideration of the problem with the aid of modern technical methods seemed imperative. In order to meet this requirement the writer has tried to bring to bear on this problem the fruits of modern perfected histologic technic.

[1] Waldeyer advises (*Arch. f. mikroskop. Anat.*, Bd. 57, Heft I, S. 4, 1900) that the term "endothelium" be retained for the cells lining the blood and lymph vessels and the chambers of the eye only. In this paper, as a matter of convenience, the advice of this eminent authority will be disregarded and the term endothelium will be used according to the original suggestion of His.

The present communication has to do with the so-called stigmata and stomata only (as occurring between endothelial cells) and discussion will be confined to these, with casual reference to other facts determined by these studies when they serve to illustrate the points under discussion.

Most of the work was carried on far removed from most of the advantages desirable for this kind of work. This misfortune has been especially felt in reviewing the literature, and the writer regrets to state that he has been unable to confirm, at the last moment, his citations. Since some of the papers were read years ago, only notes were available at this time, and many errors will probably have been committed.

It is pleasing to state, however, that a part of the work was done in the laboratory of Dr. H. Virchow, Professor in Berlin. It is with pleasure that the writer takes this opportunity of expressing his appreciation of the many kindnesses received while doing this part of the work. The obligation presents a wider range than can be mentioned and represents every favor that a teacher can bestow upon a pupil.

The writer is also indebted to Dr. Kopsch for many suggestions in technic.[2]

CITATION OF LITERATURE

As is well known, it was Coccius and Flinzer (1) who first used the nitrate of silver to demonstrate the cell outlines of Descimet's membrane. This method was perfected by His (2). The method was still further developed by v. Recklinghausen (3) and used by him in his study of the lymphatic system. It was while using this method, in the study of the peritoneum, that Oedmasson (4) first noticed the occurrence of small dots and rings in the intercellular lines. The discovery was accidental, for, as the title of his paper indicates, he was concerned only with a review of v. Recklinghausen's work. Oedmasson himself hardly regarded the discovery seriously, but was rather inclined to believe that the rings were real openings because of their regularity. The stigmata he regarded as deposits of silver albuminate because of their irregular size and form. Not until after the same structures were observed by His (5)

[2] Professors Sayer and Bailey, respectively heads of the departments of pharmacy and chemistry in the University of Kansas, have rendered aid in the consideration of chemical problems. To them also the writer expresses appreciation.

in the lymph vessels was Oedmasson's discovery regarded as of importance. From then on the belief in their entity gradually became general. A number of other papers were written about this time, the most important of which were those of Ludwig and Schweigger-Seidel (6), Dybkowsky (7), and Schweigger-Seidel and Dogiel (8), none of which added greatly to our knowledge of the subject in advance of that presented in previous publications.

The highest interest in the stigmata and stomata was not reached, however, until Cohnheim (9) described them in the blood-vessels and used them as important elements in his theory of inflammation.[3] It is to this fact, no doubt, that these structures owe much of their prominence, for after their acceptance by Cohnheim their existence was almost universally regarded as proven, though no additional evidence had been adduced to strengthen the position.

That the existence of these structures as morphologic elements was never established upon a sound histologic basis may be gathered from the fact that very soon after they were first described there were not wanting investigators who regarded them as artificial products, due to the reagent used. Among the earlier writers to express their opposition may be mentioned Auerbach (10), Afanassiew (11), Foa (12), Klein (13), and Schweigger-Seidel (l. c.). The last two authors regarded them as real openings, but declared against the function ascribed to them on the ground that no opening could be demonstrated in the basement membrane (membrana limitans) without which the stomata would necessarily be functionally useless. Later on Klein seems to have changed his view somewhat (14 and 15), ascribing more importance to the stomata, even going so far as to class them in two groups, stomata vera and pseudo-stomata. In the former group he reckons only those occurring in the center of groups of radiating cells. To the list of opponents must be reckoned Tourneaux (16). He is very emphatic in his opposition, declaring without qualification that they are artefacts. He based his argument on the physiologic fact that starch and carmine granules are not absorbed when an emulsion of them is introduced into the free peritoneal cavity.

These papers were written about the time Cohnheim announced his theory of inflammation. So brilliant were his discoveries, and

[3] He accepted the views as expressed by Stricker and Federn as correct (*Wien. Acad. Sitzungsber. math.-nat. wis. Cl.*, Bd. 53.

so striking his explanation of the phenomena he observed, that the arguments of the opponents of the theory of the existence of special openings between cells were futile. It seemed so clear that the leucocytes, and above all the red corpuscles, in order to escape from the blood-vessels, required the existence of openings that would allow of their escape. The discovery of Oedmasson was eagerly seized upon as offering the needed explanation. Here it seems necessity added one to her progeny: already the mother of invention, she now became the mother of discovery also.

Arnold (17, 18, and 19), by his careful researches, aided greatly in strengthening the position of Cohnheim's theory and more particularly the idea of the passage of the blood-cells through preformed openings. It was he who first observed the blood-cells actually to pass through the preformed openings, thus adding demonstration to theory. Arnold (20) presents a cut showing a leucocyte in the act of passing through one of these openings. This has not been observed by any other worker. It was this striking demonstration of Arnold's more than any other factor, apparently, that despaired the opponents of the theory.

Notwithstanding the reputation of the author, however, doubts began to arise as to the correctness of the observation, mostly, no doubt, on account of the extreme difficulty of excluding error in determining the exact point in the vessel wall at which the blood-cell made its escape. So uncertain is this method of determining this point that investigators may well despair of direct disproof.

Another paper that has had much weight in influencing opinion is that of Muscatello (21), who approached the subject largely from the physiologic side. He ascribes to the stomata the office of absorption, but declares that they exist only on the centrum tendenium of the diaphragm.

Ranvier (22) advanced a most convincing argument against the stomata when he showed that their occurrence could be much reduced in number by first rinsing the surface to be treated with silver solution with distilled water. He also added the additional important argument that their irregular distribution counted much against their functional importance.

Whatever opinion one may hold as to the cause of it, the fact remains that the stomata no longer play the part they formerly did in the explanation of physiologic and pathologic processes. To such an extent is this true that the literature of the last decade, of physiology and pathology, may be searched without encountering a single reference to them. This fact might be interpreted to mean that these structures have been abandoned and that the subject no longer offers a fruitful field for investigation.

That this neglect has not been altogether universal is shown by several recent papers dealing with the histology of the peritoneal endothelium. The most elaborate and complete of these is by Kolossow (23), in which the stomata are restored to their former position. It may be stated briefly in passing that Kolossow makes a modification in that he regards the endothelial cell as being formed of two parts or layers, a granular part containing the nucleus, and a superficial homogeneous part which he calls the cover plate (*Deckplatte*). It is between these latter that he regards the stomata as existing, and not beween the cells proper.

More recently a paper has appeared by Ussow (24) in which a similar position is taken. He believes that ordinarily they do not exist but are brought about by the contraction of the cell protoplasm. In the short abstract at my disposal no reasons are given for this conclusion.

In practical works the stomata still play a more important rôle than among scientific workers. This is well shown by an excellent practical treatise on the peritoneum (27) in which the stomata have ascribed to them their former importance.

The other side of the question has recently been strengthened by a very clear paper by Meyer (25). He concludes that the stomata are not real openings. He arrives at this conclusion because of their irregular distribution and because of their irregular size and shape. He believes, however, that they may be artificially produced by mechanical means, though without ascribing to this fact any specific importance.

Rawitz[4] takes a delightful middle ground by saying that if stomata do not exist there are at least "soft places."

Nearly all investigators have used the same method. This consists, briefly, in treating bits of excised tissue to a solution of silver nitrate and then exposing them to the sun until they become brown. Kolossow (26) alone forms an exception in that he used a solution of osmic acid and then "developed" in a solution of tannin. By

[4]Grundiss der Histologie. Berlin, 1894.

this method neither stigmata nor stomata are produced, and his views concerning them are dependent upon the use of silver used according to the usual method.

The review of the literature shows that but one method has been used in demonstrating the stigmata and stomata, which suggests that inquiry should be directed quite as much to a criticism of the technic as to the real problem itself.

Whether approached by a direct or by an indirect method, the real problem is, Are the stigmata and stomata preformed openings between endothelial cells? If a negative answer is the truth, the question becomes, What is the nature of the so-called stigmata and stomata? An answer to the second question is desirable, not only on account of its interest because of the discussions these structures have occasioned, but because the disposal of them can not be regarded as final until they have been proven of extraneous origin by direct analysis.

FORMS OF STIGMATA AND STOMATA

The stigmata have never occasioned any considerable amount of discussion, and they may be considered along with their more prominent kin. In order to facilitate the study of the stomata, it is desirable to divide the various structures that have from time to time been included in this category into two classes. In the one class may be considered the ordinary form, which may be seen in nearly every cut of the peritoneal endothelium that has been published. In the other group may most conveniently be considered a great variety of different structures that have been regarded as stomata by some observers, or structures incidentally mentioned but which throw some light on the formation of the more common form.

The ordinary stigmata and stomata are such familiar structures that a definition is hardly needed, and a satisfactory one is difficult to formulate because it is necessary to regard the opinion of so many different observers. It may, however, in general be stated that the stigmata are small brownish black points, varying in size from a fraction of a micron to ten microns, usually irregular spheroids, but often angular, occasionally elongated ovoids, occurring at irregular intervals in the course of the intercellular lines between the endothelial cells, when a serous membrane is treated with silver nitrate and exposed to the sun. By stomata are meant the brownish rings, ovoids, or ellipses, occurring under similar conditions as mentioned above, situated anywhere in the course of the intercellular line, but occurring most typically at the point of juncture of three or more cells.

Stigmata and stomata have not been noted, so far as the writer's knowledge goes, in any other structure than a serous membrane, nor in this structure when treated by any other reagent than nitrate of silver. They may be regarded, then, as the product of two factors; nitrate of silver and a fresh serous membrane. The formation of these structures was believed to be due to the action of the silver nitrate upon the semi-fluid intercellular cement substance, forming an albuminate of silver. Why a border of the albuminate occurs about the stomata has been explained by the fact that the stomata are formed by a stretching of the membrane, and when the border of the cells retract a part of the cement substance remains adherent which, when acted upon by the silver, forms the stomata. In order to account for the fact that the cells separate only at certain points it was necessary to assume the intercellular substance to be stronger at some places than at others.

The relation of the stigmata to the stomata was at first thought by Arnold to be direct, in that he assumed the former to be but early stages of the latter. In his later publications he described them as being but local broadenings of the cement substance—an unskilful distribution of the adhesive, as it were. Most other observers share this view, while a few disregard them entirely.

The exact method of formation of the stomata, as has been stated, has caused considerable controversy. Some regard them as preformed, others as due to the passage of leucocytes, but the majority regard them as due to the stretching of the membrane. The cells were believed not to be quite big enough to cover the entire surface when the membrana limitans is put on the stretch. The writer has made a long series of experiments to determine this point. The result was invariably that, when the membrane was sufficiently stretched to produce a solution of continuity of the cells, they did not separate in the intercellular lines but tore across the cell in the great majority of cases, the direction of separation depending on the line of rupture of the membrana limitans. The cells do not separate so long as the membrana limitans is intact. Even if by chance the cells do separate in the intercellular line it does not occur

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at certain points but occurs in a straight line. Kolossow worked out this point and attempted a direct demonstration of the theory. He did this by stretching a serous membrane across the end of a glass tube and then bringing about varying degrees of distention. He found that the stigmata and stomata increased in number as the distention was increased, and in direct proportion.

The theory of their formation by the leucocytes was abandoned on the ground that when a vein is tied in which diapedesis has begun it ceases. If due to the activity of the leucocytes the process (of stomata formation) would go on.[5]

If the distention theory of formation were true it would seem that a great variety of normal stretchings of the serous membranes would produce them and be followed by the usual consequences. But, as is well known, the distentions may be greater under some normal conditions than under some pathologic ones in which diapedesis does occur, without this process taking place.

If, in the study of the genesis of the stigmata and stomata, the classic method of treatment, with silver nitrate and exposure to light, be followed, the basis of the whole controversy can be readily observed, for all the different pictures described by the various investigators may be made out. In reviewing the results the most striking observation is that of Ranvier, already referred to, namely, that the number of stomata may be lessened, and for large areas prevented, by a preliminary rinsing with distilled water. So striking is this fact that the probability at once suggests itself that these structures are due to some factor that can be removed with distilled water. That actual openings could be thus removed of course no one would for a moment argue. That large areas may thus be obtained free from stomata is a fact various observers have vouched for. Why the cells in such large areas should occur without the ability to perform the same functions as identical cells in other localities is a question Ranvier asked years ago and which still remains unanswered. Observers are likewise agreed that exposure to the sun increases the number of both stigmata and stomata. The same thing is true if the membrane is covered with an excess of lymph.[6]

5 Muscatello still adheres to this view, l. c., p. 345.

6 Oedmasson (l. c., p. 362) correctly states that the lines are broader if the strength of the solution is stronger, or allowed to act longer. He also correctly observes that it is due to the action of the silver on the cement substance and not due to its action on the edge of the cell, for the lines may be penciled out. He might have added that this in no wise influences the distance between the edges of the cells, for the increase in width is due to deposits on top of the cells (see figs. 3 and 4, Plate XIII).

The problem presenting itself for solution is obviously, from the foregoing, to determine how many stigmata and stomata would remain if all the factors known to cause them were excluded entirely, and the factors known to increase them were reduced to a minimum. But with the methods ordinarily employed carried out with the greatest care, one finds himself where he must accept the striking observation of Toldt (28), that "they occur in spite of every precaution, but regarding their significance we are entirely ignorant."

It seems evident from this quotation that advance can be secured only through new methods or by improvements on the old ones.

The effect of light is a factor that has never been systematically studied. Handling the tissues in an entirely dark room is difficult and uncertain. An attempt to solve this problem led the writer to develop a new method of using silver. Knowing that Ranvier had injected silver solutions into the adipose tissue in recently killed dogs, in order to demonstrate the fat globules, it required but a step farther to attempt to secure the reaction *in vivo*. The results obtained were gratifying in the extreme, for nothing is simpler than to inject a dilute solution of silver nitrate into the free peritoneal cavity of an animal. The effect of light may thus be determined with a certainty. The anterior abdominal wall of a mouse so treated may be removed in the dark by the aid of the sense of touch and placed upon a slide and the microscope so arranged that the first ray of light that strikes the specimen may be met by the eye of the observer over the microscope. The intercellular lines are seen to be present, thinner and more regular than after the usual method, and stigmata and stomata are not to be found. How much the result may be due to the action of the reagent on living tissue and how much on the exclusion of light must be determined by comparing the results obtained by injecting the solution into the abdomen of a dead animal. For the purpose of the present discussion it makes no difference. The important fact remains: the occurrence of both stigmata and stomata can be entirely prevented. In some animals so treated the usual structures occurred. This is most likely to occur in frogs, especially when the solution is too strong or allowed to act too long. In order to test this method the following animals were injected successively: five new-born mice, six grown but young mice, one pregnant mouse, four new-born rabbits, one old buck rabbit, and three kittens six weeks old. In none of them was a single stigma or stoma to be found. In this study it was necessary to remove the parietal peritoneum from the abdominal wall (except in case of the mice and new-born rabbits, in which the abdominal wall was sufficiently transparent to admit of examination *in toto*); the mesentery was also carefully removed, the whole intestinal canal cut open along the mesentric border, after the removal of the mesentery, and examined over its entire extent, and finally the diaphragm and special ligaments were removed as much as possible entire. Of course some nooks and corners escape observation, but with care they may be reduced to a minimum. This series of animals, seemingly in perfect health, were able to so live without a single stigma or stoma—so much is certain.

The injection method enabled the writer to test the distention theory already mentioned as being held by a goodly number of observers. By injecting a large amount of a dilute solution into the free peritoneal cavity any degree of distention may be produced. This would serve only, of course, if the endothelium of the abdominal wall were the object of study. If it is desired to study the endothelium covering the intestinal canal a small amount may be injected into the abdominal cavity and the intestine then distended with air. Mice, because of their cheapness and convenient size, were most used in these experiments. For the sake of comparison several other animals were injected, namely, several rabbits, rats, and a cat. Larger animals, for obvious reasons, were not experimented upon. After many trials under the most varied conditions, it can be stated that stomata do not occur under these conditions. This method of testing the distention theory would seem to be an ideal one, for the tissues are uninjured in any way, and there is no escape of blood or lymph to obscure the results.

On account of the influence the cell form was believed to have on the production of the stomata, it will be proper to consider the effect of simple distention on the cell outline. The distention experiments before mentioned show that the cells are large enough to cover the membrana limitans without changing their form to any appreciable extent. When a serous membrane has less surface to cover it forms folds, and the individual cells do not contract. These folds are microscopic, and they have given rise to confusion because various deposits occurring in them have been mistaken for stomata.

Too much stress can not be laid on the importance of experimental study on this point on account of its bearing on the problems of stomata formation.

Another method of determining the effect of distention may be briefly mentioned. An abdomen may be distended with air and the intercellular spaces made apparent by painting the surface of the abdomen with a solid stick of silver nitrate. The cell outlines are brought into view. No influence on the production of stomata can be observed. It may be mentioned in passing that the silver thus applied acts not only through the whole thickness of the abdominal wall, but to a considerable depth beyond. This is, in a sense, a contradiction to the generally accepted opinion that the action of silver is very superficial.

Still another way of demonstrating the absence of openings between cells is as follows: A bit of the abdominal wall is stuck to a slide, endothelial surface down.[7] After firm adhesion had taken place, the membrana limitans with all the other tissue may be removed, leaving the endothelium alone adherent to the slide. It may now be treated with any desired stain, preferably fuchsin. The edges of the cells will be found to lie closely together without the existence of openings. The last method gives some very satisfactory results, though the method is somewhat uncertain.[8]

In the second group may be considered together all those structures that have been regarded as stigmata or stomata which are excluded in the first group. This will include all structures that have been described as such in the literature.

Structures identical with those of the first group have been figured in every conceivable place that silver can penetrate. In many cuts the stigmata may be seen scattered promiscuously over the cells.[9] Stomata likewise may occur in a great variety of places. They may often be seen in the body of the cell forming frequently gyrated figures (see fig. 1, pl. XII). Again the circles may occur in the intercellular line but in which the line continues uninterrupted through it. These must be distinguished from objects occurring

[7] Afanassiew's method (l. c., p. 58) was used.

[8] The writer has for some time been experimenting with iron and tannin for bringing out the cell outlines. By this method, likewise, no stomata appear, nor are the cell outlines affected by stretching.

[9] Meyer very properly asks that, if they are "to be called stigmata in one situation, why not in the other?" l. c. Robinson is the only writer who is willing to accept them in this abnormal situation (The Peritoneum, p. 53. Chicago, 1897).

below the endothelium. These stomata may be seen below the endothelium, between the muscle fibers (fig. 3, pl. XII). These may, instead of forming rings, form solid patches, thus resembling a cell. These were pictured in Oedmasson's original publication, and they may be seen in many productions since that time, but it remained for Meyer to recognize the true conditions. Fig. 10 in his paper presents the appearance very well. These same structures may be seen lying upon the endothelium of the lymph vessels.

A modification of the regular stomata, already alluded to, is insisted on by a number of investigators: it is the occurrence of openings in the center of radiating groups of cells. Nikowlsky laid especial stress on these and pictures several marked examples. A few writers, notably Klein, regard these as the only true stomata. These are certainly striking figures, but it is difficult to understand how these came to be regarded as the true stomata, for it often requires prolonged search before one can be found. Their rarity alone ought to be sufficient to refute the arguments that have been advanced relative to the function ascribed to them. Attempts to study them on cross-section have been fruitless.

The significance of the occurrence of extraneous cells between the regular endothelial cells has been the theme for a great deal of discussion. Broadly speaking, they have been regarded as either leucocytes or young endothelial cells, or again as cells destined to form endothelial cells (*Keimzellen*). No attempt has been made to separate the cells actually occurring between the endothelial cells from those located either above or below them. This is quite necessary since these cells have often been regarded as guards for the stomata, filling them up valve-like, as it were (Ranvier), or, when impregnated with silver, they have been described as stomata.

Much confusion has arisen because no attempt has been made to determine the exact location of the cells. This is beautifully illustrated by a cut Robinson[10] borrows from Stöhr, in which nuclei of cells lying underneath the regular cells are shown. Stöhr[11] regards them as nuclei of connective tissue cells (see fig. 6, pl. XII), and Robinson calls attention to the fact that these have always been regarded as stomata. It is quite imperative that this differentiation be carried much farther. This is often not an easy matter, for even

10 l. c., p. 29.
11 Stöhr, Lehrbuch d. Histologie, 7te Aufl, S. 220.

with modern microscopical appliances it is often difficult to determine whether a particular object lies above or below the endothelial cells. This is more difficult in silver preparations because the silver is thrown down in fine granules, which cause a confusing refraction of the light. When objects are below the intercellular line it is often possible to determine this fact. With this exception it seems advisable to exclude all evidence that can not be proved on cross-section.

Cells above the endothelial cells are but rarely found. The writer for a long time observed cells in this situation, believing them to be endothelial cells, which were contracted from irritation, as described by Ranvier. On cross-sectioning the tissue the endothelial layer was found to be intact. Attempts to determine their relation to inflammatory processes, experimentally produced, have been without result.

The first observer to note the occurrence of small cells between the larger ones was Dybkowsky. Klein advocated the view that they were cells in course of development. Ranvier regarded them as leucocytes filling up the stomata. Virchow[12] has been incorrectly quoted as advocating this view. As a matter of fact the statement was made that "multinuclear cells occur below the epithelial cells of the peritoneum." These words were written before the controversy began and before it was known that leucocytes occurred outside of the blood-vessels; indeed it was in support of the theory that they do so occur that the statement was made. The leucocytes are really the only ones that ought ever to have been mistaken for stigmata or stomata, for, as Tourneau and Hermann pointed out, the oblong nuclei and the bright nucleoli are always sufficient to distinguish the other cells occurring in this locality from them. This discussion could have arisen only from a failure to study them in cross-section.

The exact significance of these cells is not patent to the subject; it is sufficient for the purpose to show that they form a part of the regular cell layer.

It is the cells located below the endothelial cells that have been mistaken for stomata the most frequently, and in consequence are of greater interest in this connection. Many fine examples of this confusion may be seen in the literature, notably in the publication of Oedmasson. Kolossow classes them all as leucocytes. As al-

12 Gesamte Abhandlungen, S. 167. 1856.

ready mentioned, Stöhr pictures several as connective tissue cells. Both kinds do no doubt occur in this place. There are still others occurring here probably belonging to the clasmatocytes of Ranvier[13] or to those large cells which are now regarded as taking some part in the process of inflammation. It is sufficient to say that they are all located below the endothelial layer.

It is necessary to note that there are fields without nuclei occurring between the endothelial cells. The explanation for this occurrence is not easy. It is quite possible that it is a cell below the regular cells taking its place in the regular layer.

With the silver method alone it is quite impossible to distinguish the various cells from one another, and this problem must be solved by the aid of other stains. With these it may be determined to a certainty that the great variety of cells that have been at some time or other believed to bear some relation to the stomata are entirely independent of the endothelial layer. Their exact office is a problem that remains to be solved. The silver method will not aid in solving it. Indeed it is to the uncertainties of this method that much of the confusion is due, aiding much in making the histology of the peritoneum "the darkest chapter in anatomy."

CHEMISTRY

Now, thoroughly convinced that the stigmata and stomata are spurious products formed by a precipitate of silver, a determination, if possible, of their exact chemical composition seemed very necessary. As is well known, the intercellular lines are supposed to be formed by the action of the silver nitrate upon the albuminous cement substance, forming an albuminate of silver. This assumption has been accepted by all writers. In approaching this subject the writer thought to prepare himself for the investigation by studying the chemical nature of the substance under consideration. He was surprised, after spending some time in a literary search, to find no mention of silver albuminate in the most extensive works on chemistry, in any of its departments. Surprise rose to amazement when one of the ablest of chemists was appealed to for aid and the reply was made that he knew of no such substance.

Here, then, was a virgin field for investigation. Returning to the

13 "Des Clasmatocytes," *Archives d'Anatomie Microscopique*, Tome III, p. 122.

observation of Ranvier that the occurrence of stomata could be prevented by rinsing the membrane before applying the silver, it was quite natural to remove some of this fluid for examination. Some of the fluid normally covering the free surface of the peritoneum was carefully transferred to a slide and exposed to the action of a very dilute solution of silver nitrate. Minute droplets of this mixture were then transferred to a clean slide and placed under the microscope. What were clear droplets became, on exposure to the sun, dark brown rings. The same thing occurs when any stain is evaporated: what was a droplet becomes on evaporation a ring with a faintly stained center. This is too common an observation to need mention. The rings produced by evaporating small drops of silver and lymph (or whatever the composition of the substance removed may be) bear a striking resemblance to the stomata produced in the regular manner, only of course they are larger. The discovery was accidentally made that, if the two substances were mixed in larger amounts and allowed to evaporate and then examined in glycerine, dots and rings appeared indistinguishable from the true stigmata and stomata. So striking are the pictures so produced that the statement seems warranted that stigmata and stomata may be produced independent of a serous membrane. This statement is equivalent to saying that the stigmata and stomata are the product of the action of a solution of silver nitrate upon lymph. The microscopic appearance of silver chloride bears a very strong resemblance to the product of silver and lymph, though the color is different. Dots corresponding to the stigmata may be seen and a few rings, but they are much less constant than in the silver and lymph product. It may be mentioned in passing that the granules seen in the tissues in argyra bear a very strong resemblance to these dots of silver chloride.

In order to test the silver chloride theory of the formation of the stigmata and stomata, the following experiment was performed: Five cc. of a sodium chloride solution was injected into the free peritoneal cavity of a mouse. After a few minutes a dilute solution of silver nitrate was injected through the same needle. After the silver solution had had time to mix thoroughly with the sodium chloride solution, the needle was withdrawn, the opening made by the needle ligated, and the animal given the liberty of the cage. Presumably the silver was precipitated as soon as it passed the point of the needle, though absolute proof of this is difficult to produce, since the reaction takes place in a perfectly dark chamber, namely the free peritoneal cavity. Attempts were made to obtain an impregnation by first mixing the silver nitrate with the sodium chloride solutions and afterwards injecting. The results were negative. A trial was then made of the effect of different colored lights on these solutions made before injection. The results likewise were negative. The remarkable fact was noted that when the silver solution was preceded by a sodium chloride solution the lines appeared at once. When the silver solution was alone injected the lines did not appear until from one-half to three hours afterwards. In either case the appearance of the lines is the same. The difference was noted that when the silver solution was preceded by a sodium chloride solution there always occurred precipitates over the body of the cell, which is not the case when the silver is used alone. An attempt was made to change the reaction of the albuminous substance covering the peritoneum before injecting the silver solution. The means employed to accomplish this were to inject a solution of equal parts of hydrochloric acid (C. P.) and distilled water, followed after a few minutes by the silver solution. The lines appeared. The reader is allowed to judge for himself what effect an acid of this strength would have upon the peritoneal lymph. It was interesting to note that the endothelial cells stood this severe treatment with little injury. It was interesting, too, to note that when so treated the intercellular lines were very fine, with no broadenings whatever.

As an example of the striking figures produced by the action of the silver nitrate solution on an albumin solution figs. 1 and 2, pl. XIII, may be referred to. The specimen from which this drawing was taken was made by mixing a drop of ½ per cent of hydrochloric acid with a dilute albumin solution, and the mixture gently warmed and allowed to evaporate. The peculiar radiating arrangement of the rows or rings is due, no doubt, to the properties of the albumin solution.

What the exact composition of the product of silver and albumin is can not be stated. The fact that the fluids of the body contain 0.65 per cent of sodium chlorid, taken together with the well-known fact that the nitrate of silver in solution is more sensitive to chlorids in loose combination than to any other substance, has caused the writer to accept as a working hypothesis the assumption that the substance is a chlorid of silver, perhaps holding an albuminous substance as an admixture. This assumption has to support it the following facts: (1) That no such substance as silver albuminate is known; (2) only when a chlorid-containing substance is present are they formed; (3) the sensitiveness of the silver nitrate in solution to chlorids in loose combination; (4) combinations of silver with nuclein are known, but nucleins are not contained in the substance in question.

This is but an hypothesis, it is true, and perhaps one of uncertain importance, but the fact remains that it is an unwarranted assumption to refer to any substance as silver albuminate. The ultimate solution of this problem may be left to those skilled in chemistry. Indeed, so far as the problems in the histology of the peritoneum are concerned, the exact composition of these substances is a matter of little importance.

But it is a problem of vastly greater importance to recognize them as chemical products, the product of the action of silver nitrate in solution upon a chlorid-containing substance. That the stigmata and stomata occur by no other method has already been stated, and the converse is equally true—that by all other methods, without a single exception, the endothelial cells are shown to contain no such openings.

Halstead, Kan.

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EXPLANATION OF PLATES [15]

Plate XII

Fig. 1. Mesentery of cat, showing a variety of stomata in the body of the cell. These structures differ from the intercellular stomata only in location.

Fig. 2. Mesentery of rabbit: *a*, numerous stigmata; *b*, stomata, one of them half stigma and half stoma, *c*, these structures here shown are not cells, as has been supposed, but are spurious products, the black center lying above, the circle below, the endothelial cells.

Fig 3. Mesentery of rabbit. A stoma between muscle cells below endothelial cells.

Fig. 4. Mesentery of frog showing a number of intercellular stigmata.

Fig. 5. Mesentery of rabbit showing stigmata on cross-section. They are located above the intercellular line.

Fig. 6. Mesentery of rabbit showing in the intercellular line a nucleus of a cell below the endothelial cells. Whether this nucleus belongs to the connective tissue cells, or to endothelial cells located below the regular layer, or to clasmatocytes, is uncertain.

Plate XIII

Fig. 1. Rings formed on a slide from a treatment of dilute albumin solution with silver nitrate solution. The rings in this striking figure are indistinguishable from those formed on serous membranes in the regular way.

Fig. 2. Peculiar tracings made by the same method used in fig. 1. This shows in a striking manner the variable figures the solutions named are capable of producing.

Fig. 3. Mesentery of young rabbit treated with silver solution after exudation had been excited with an irritant.

Fig. 4. Cross-section of specimen from which fig. 3 was taken. It shows that the heavy black precipitate shown in the preceding figure is located above the regular endothelial cells, and not between them, as has been generally believed from a study on the flat surface alone. The endothelial cells have been purposely torn from the membrana limitans for a short distance and left in position the remainder of the section. In the center of the figure a few fibers belonging to the basement membrane are still adherent to the cells.

15 All figures except figs. 1 and 2, pl. XIII, are redrawn from pencil sketches made with the aid of the camera lucida with Leitz Obj. 1/12, Oc. 4. The exceptions noted were drawn direct with Obj. 6, and Oc. 4.

PLATE XII

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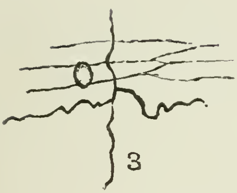

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A CONTRIBUTION TO THE SUBTERRANEAN FAUNA OF TEXAS[1]

By CARL JOST ULRICH

WITH FIVE PLATES

In the present paper I propose to describe some of the Arthropods collected by Dr. C. H. Eigenmann in the caves and springs about San Marcos, Tex. The collections were made with a grant from the American Association for the Advancement of Science. The report made by him to the Association at its New York meeting, describing the locality and general character of the cave fauna, may serve as an introduction to the detailed descriptions of species to follow.

"In the early part of September, 1899, I visited San Marcos, Tex., to secure, if possible, some living specimens of the cave salamander occasionally thrown out of the artesian well of the United States Fish Commission. This well taps an underground stream about 190 feet from the surface. No specimens of the salamander *Typhlomolge* came to the surface during my stay, but I received two living specimens from Supt. J. L. Leary.

"Besides the salamander three species of Crustaceans had been secured from this well. These were described preliminarily by Mr. Benedict, *Proc. U. S. Nat. Mus.*, Vol. XVIII. One of these, *Palaemonetes antrorum*, is very abundant, and many are thrown out from the well each day. The eyes of this species are degenerate far beyond those of the blind *Cambarus pellucidus* of the Mississippi valley caves. They will be described elsewhere. The second one, *Ciralonides texensis*, is not nearly so abundant as the first. During my stay of three days I secured several specimens. It can readily be seen in the receiving basin of the well when thrown out.

"The third, *Crangonyx flagellatus*, is much rarer, and no specimen

[1] Contributions from the Zoological Laboratory of the Indiana University under the direction of C. H. Eigenmann, No. 34

was secured during my stay. Instead, however, a single specimen of a related species (*Crangonyx Bowersii*) was secured.

"These are all the species that can readily be seen with the naked eye, when swimming about the receiving basin. A screen of bolting cloth (No. 2) placed over the outlet for a short time secured a number of additional species, viz., the front half of a new species of *Caecidotea*, two new species of Copepoda, a *Cypridopsis*, and a Crustacean that defied identification and was later lost, as well as a flat worm. The evidence from the screening is that there is yet a rich subterranean fauna to be obtained from this well.

"There is near the well a spring arising evidently from the same source by the side of which the well is insignificant in its yield of water. No blind creatures have been recorded from this spring, and the difficulty in straining its output is much greater than that of straining the well. Through the liberal policy of the Hon. G. M. Bowers and Dr. Hugh M. Smith, of the United States Fish Commission, a plankton net is now in use at the San Marcos well, and we may expect other additions to the fauna of the well and the underground stream it taps.

"Near San Marcos are two small caves. Ezell's cave was formerly open to the public and provided with steps and other facilities for entrance. The opening leads into a pit about forty feet deep, with one side, that nearest the entrance, quite perpendicular, but with some projecting rocks. At the bottom of this pit and at the side furthest from the entrance a smaller opening led downward to the water, which was said to be about one hundred feet from the entrance. The Texas variety of small boy has found amusement in rolling rocks down the entrance, thus smashing the steps and closing the former opening at the bottom of the first series of steps. It was necessary to take a side branch to reach the water. This side branch, for sufficient reasons, I did not take to its end, although my assistants managed to get through to the water, without, however, securing any specimens. I was amply rewarded for not entering the deeper recesses by finding in the twilight of the entrance pit an abundant cave fauna.

"Not far from this cave is Beaver cave. This is a winding, twisting channel of no great height or width. All the available time was devoted to securing specimens, and the cave was not followed to the end. There is no water except in a pit dug in the cave.

"Animals, though few in species, were surprisingly numerous in both these caves. The following species were secured in the well and caves:"

1.	A flat worm sp.?—Artesian well.	
	Mollusca	
2.	*Helicina orbiculata* Say.	Ezell's Cave.
3.	*Vitrea petrophila* Bland, pale var.	Ezell's Cave.
4.	*Bifidaria contracta* Say.	Ezell's Cave.
5.	*Helicodiscus Eigenmanni* Pilsbry n. sp.	Ezell's Cave.
	Crustacea	
6.	*Cypridopsis vidua obesa* Brady and Robertson.	Artesian well.
7.	*Cyclops cavernarum* n. sp.	Artesian well.
8.	*Cyclops Learii* n. sp.	Artesian well.
9.	*Caecidotaea Smithii* n. sp.	Artesian well.
10.	*Ciralonides texensis* Benedict.	Artesian well.
11.	*Brackenridgia cavernarum* n. sp. and genus	Ezell's Cave. Beaver Cave.
12.	*Crangonyx Bowersii* n. sp.	Artesian well.
13.	*Palaemonetes antrorum* Benedict.	Artesian well.
14.	*Larval crustacean*, unidentified.	
	Myriopoda	
15.	sp.?—Ezell's Cave. Beaver Cave.	
	Arachnida	
16.	*Theridium Eigenmanni* Banks n. sp.	Ezell's Cave. Beaver Cave.
	Thysanura	
17.	*Degeeria cavernarum* Pack.	Ezell's Cave. Beaver Cave.
18.	*Nicoletia texensis* n. sp.	Ezell's Cave. Beaver Cave.
	Orthoptera	
19.	*Ceutophilus Palmeri* Scudder.	Ezell's Cave. Beaver Cave.
	Diptera	
20.	*Larval Chironomus*.—Artesian well.	
	Vertebrata	
21.	*Typhlomolge Rathbuni* Stejneger.—Artesian well.	

Crangonyx Bowersii n. sp. Pl. XIV.

Specific diagnosis.—Eyes absent, no trace of pigment. Upper antennae $^3/_4$–$^6/_7$ length of body; first joint of peduncle much larger than second; flagellum three times as long as peduncle, consisting of 26 segments; secondary appendage small and slender, of 2 segments. Peduncle of lower antennae little, if any, longer than peduncle of upper; flagellum a little longer than last joint of peduncle, consisting of 8 segments. First and second pairs of legs about equal, the propodos considerably wider than the carpus, palm long, dactyl closing down between two rows of short, notched spines, about 15 in a row. Peraeopoda subequal; first two pairs nearly equal; the third, fourth, and fifth pairs increasing in length backward, and with expanded femora. The three pairs of pleopoda well-developed, nearly equal in length, two-branched. First pair of uropoda large and broad, with 2 well-developed branches, second pair similar, but shorter and smaller; third pair very small, inner branch rudimentary. Telson narrow, not emarginate, twice the length of third uropods, with 2 sets of 5 stout setae on posterior margin.

Color—White.

Length—About 10 mm.

Hab.—Obtained from artesian well of United States Fish Commission at San Marcos, Tex. (Dr. C. H. Eigenmann).

This species differs from *C. flagellatus* Benedict, also obtained from this well, in the number of segments of the upper antennae, being 40–61 in the latter and 26 in *C. Bowersii*. The flagella of the lower antennae of *C. flagellatus* consist of 8–19 segments, those of *C. Bowersii* of 8. The number of the spines on the propodas is also different, there being 15 in *C. Bowersii* and 24 in *C. flagellatus*.

It differs from *C. mucronatus* Forbes, in the shape and size of the telson, which, in the females of the latter, is very long and slender; in the males, short and emarginate. In *C. Bowersii* the telson is about twice as long as broad, and somewhat rounded at posterior margin. The uropods are different, the second and first pair in *C. mucronatus* being little longer than third, while in *C. Bowersii* they are much longer. The flagella of the lower antennae are not provided with olfactory clubs.

Additional details.—Having but a single specimen, it has not been possible for me to describe all the parts as satisfactorily as I would wish.

Body (fig. 1).—The body is compressed, narrow. Segments of peraeon increase in size from first to fourth. The fourth, fifth, and sixth are nearly equal. Inferior margins rounded. The first, second, and third segments of the pleon are large, exceeding the segments of the peraeon in length. The fourth, fifth, and sixth segments decrease in size backward. The last segment (telson, fig. 11) is as long as fifth and sixth combined, and narrow. Surface of body smooth.

The upper antennae (figs. 1, 2, 3) are about ¾ the length of the body. Peduncle of three segments: first broad and stout; second half as thick as first, not quite as long; third, about $^2/_3$ length of second, somewhat smaller. A few scattered spines on segments of peduncle. Primary flagellum three times as long as peduncle, consisting of 26 segments, all provided with spines, and all, except the first seven or eight and the last provided with a slender olfactory club. Secondary flagellum of 2 small segments, the first about four times as long as the second, and together a little longer than first segment of primary flagellum; provided with spines.

The lower antennae (figs. 1 and 4) are $^1/_3$ as long as upper. The peduncle consists of 5 segments: the first, second, and third short and thick, the fourth and fifth much longer, less thick and spiny. The flagellum consists of 8 segments, each with a few spines, but no olfactory clubs, and together a little longer than third segment of peduncle. Peduncle of lower antennae is not quite as long as that of the upper, but, being inserted somewhat forward of the latter, it reaches as far as peduncle of upper antennae.

The propodos (figs. 6 and 7) are about equal in length, which is 2 mm. The hand of the first is large, with a large palmar surface. Dactyl closes down between two rows of notched spines, a hair growing from the notch in each. There are about 15 such spines in each row. The carpus is about ½ width of hand, nearly triangular, the short posterior margin provided with a row of spines. The coxa has 4 or 5 long slender spines on its posterior margin. The second pair is smaller, the hand being $^1/_3$ wider than carpus, the latter larger than in first and more rounded, the posterior margin with three transverse rows of 5 spines each, as in *C. mucronatus*.

The peraeopoda (figs. 8 and 9) are much alike in structure. The first two pairs are rather short and do not have their femora expanded as is the case with the remaining three pairs. They are all more or less spiny and end in a claw. Fig. 8 shows a gill-like structure attached to the proximal end. Length of seventh leg, 4.5 mm.; width of femur, ¾ mm.

The pleopoda (fig. 10) are well developed. The basal portion is about ¾ mm. in length and rather stout. The branches are well developed, a little longer than basal portion and fringed with long plumose setae.

The uropoda (figs. 1 and 11). The first pair is very large. The basal portion is equal in length to the third and fourth abdomina segments, while its two branches are nearly as long. The latter ex tend beyond the telson and the second and third pair of uropod They end in 4 large spines. The second pair is much like the firs in structure, but shorter and smaller. The third pair has a shor basal portion, and one branch, the outer ending in 2 spines. Th inner branch is an unarmed rudiment. In length the third uropo extends but a little beyond the peduncle of the second pair.

I take pleasure in naming this species for the Hon. G. M. Bower United States Commissioner of Fish and Fisheries.

Ciralonides texensis Benedict. *Proc. U. S. Natl. Mus.*, p. 615, 189
Pl. XV.

The body of the largest specimen examined was 16.5 mm. i length with a width of 6.5 mm. In shape it is oblong elliptical. Th depth is greatest at about the middle of the body, being about $^1/$ the breadth. All of the segments have the pleura produced be low and posteriorly into scale-like projections, thus protecting th insertion of the limbs. Above, the surface is smooth.

The head is short, convex toward the top and front, and, see from above, almost circular in outline. There is no trace of eyes.

The first segment of the peraeon is about twice as long as th second. It widens a little inferiorly, the antero-inferior parts partl surrounding the head. The posterior margin is nearly straigh The inferior margin is slightly convex. The second segment is th shortest of the seven composing the peraeon. The third, fourt fifth, sixth, and seventh are much the same in size and shape. The are produced posterio-inferiorly, and this becomes more pronounce toward the pleon.

The segments of the pleon are much shortened, and all five o them together are little longer than one segment of the peraeo They, too, are produced into a point inferiorly, but do not exten down quite as far as the segments of the peraeon. The first seg ment of the pleon is almost hidden by the last of the peraeon. A in other representatives of this family, the pleon is very distin from the peraeon.

The telson is large and well-rounded behind. In width it some what exceeds the pleon.

The antennae consist of (*a*) a basal portion, composed of 5 seg ments, the first broad and short, the second and third about equal i length to the first and $^2/_3$ as wide, the fourth twice as long as th third, and of nearly equal width, and the fifth $^1/_3$ longer than the fourth and $^2/_3$ its width; and (*b*) a flagellum consisting of 33–35 segments, of which the first is the longest, the second and third about as long as broad. The remaining segments are relatively longer and taper gradually to a point. There are setae at the joints, and the last segment terminates in a number of hair-like bristles. When applied to the sides of the body the antennae reach to the anterior margin of the seventh segment of the peraeon.

The antennulae have a basal portion consisting of three articles of which the first is nearly spherical; the second and third are elongated, about three times as long as broad. The flagellum consists of 15–16 segments, the first very short, the second longest, and the remaining ones all longer than broad. There are a few setae at some of the joints. The antennulae are about $^1/_3$ the length of the antennae.

The first pair of legs are short and stout, armed with a strong claw at the end and a number of spines along the inner margin. From their position and structure, it might be inferred that they are used in grasping food and conveying it to the mouth.

The remaining four pairs of legs are longer and more slender, serving as organs of locomotion. In structure they are much alike. Each is armed along the inner margin with spines and ends in a double spine forming a sort of claw.

The pleopoda are small and are completely covered by the pleon. Each consists of a short, basal portion to which are articulated two distal branches. The larger, outer branch consists of a broad, thin lamella, unsegmented in the first pair, but distinctly segmented in the remaining four pairs. Of these segments, the first is the larger, rather broad, almost square, while the second is shorter, rounded at distal margin, and fringed with a row of plumose bristles. This outer branch seems to be of firmer texture, and covers the more delicate inner branch. The inner branch in the first and second pairs is nearly as long as the outer, but much narrower, and consists of a single segment, fringed with plumose bristles at the extremity. In the remaining pairs this inner branch is also segmented, a fact which seems quite out of the ordinary in Isopods. The first segment is short and triangular, the second broad and rounded, and not fringed with bristles.

In Bronn, Klassen und Ordnungen des Thier-Reichs, Vol. V, 2, pp. 35–36, a comparison is made between the pleopoda of the Isopods and the so-called pedes fissi of Copepods. In the former the rule is that the branches are *not* segmented; in the latter that they *are* segmented, and the usual number of segments is 3. But there are Copepods in which the number of segments in both branches is reduced to 2, and even some in which the inner branch consists of a single segment. And, on the other hand, there are Isopods in which the outer branch consists of 2 segments, so that we notice a tendency of the two orders to approach each other in this respect. "Unter allen Umständen bekunden schon die vorstehend aufgeführten die an den Isopoden-Spaltbeinen hervortretende Tendenz, den Aussenast eine Gliederung eingehen zu lassen, während der innere eine solche stets vermissen lässt, zur Genüge." It will be noticed that the last statement in this quotation does not hold true in the present case. Nevertheless, the fact that in this case both branches are segmented adds another proof to the above statement, that the two orders approach each other.

The uropods are considerably shorter in this species than in other Isopods, extending but a little beyond the telson. They are stoutly built, with a triangular basal portion nearly as long as the distal portion. Of the latter, the inner branch is three times as wide as the outer, and its inner margin, as well as that of the basal portion, is fringed with plumose bristles. The extremities of both branches are provided with a number of stiff bristles.

The mouth-parts indicate that the animal is not parasitic, being clearly adapted for biting. The mandibles are large and strong, somewhat unequal, with a hard, rough cutting surface which is almost black in color. The maxillae are provided with several long, pointed teeth, their dark color indicating their hardness. The maxillipeds and palpi are much the same as in other related species, and are perhaps sufficiently described by the drawings.

Brackenridgia Eigenmann and Ulrich, n. gen. Pl. XVI.

Eyes none. Antennulae absent. Peduncle of antennae of 5 segments, flagellum shorter than fourth or fifth segment of peduncle, bristly. Legs long and slender, all ambulatory, increasing in length posteriorly. Pleopods with air-cells. Outer branch of uropods longer than pleon, conical. Inner branch much smaller, spiny. Mouth-parts much like those of *Titanethes* Schioedte; right mandible with two appendages back of cutting surface, first short, second twice as long, fringed on inner side; another fringed appendage on the hind cutting surface. Left mandible with two fringed appendages next to cutting surface. Third maxilliped (labrum) with 3-segmented palpus, and two small projections on anterior margin. Body somewhat arched, oval, epimera drawn out postero-inferiorly. Last segment of pleon bluntly triangular. Cave dwellers. Allied to genus *Titanethes* Schioedte, which occurs in caves in Europe.

This genus has been named in honor of Mr. G. W. Brackenridge, of San Antonio, Tex., a liberal patron of the natural sciences.

Brackenridgia cavernarum n. sp. Pl. XVI, 1–9.

This interesting species, which forms the type of a new genus of the Isopoda, was collected by Dr. C. H. Eigenmann during the summer of 1899 in two caves near San Marcos, Tex. These caves are known as Ezell's and Beaver caves, and are but a short distance apart. The animal seems to be quite abundant here, some twenty or thirty having been obtained in a short time. Up to the present time no representative of the European genus *Titanethes* or of any closely allied genera has been described for the United States, and this genus and species form an interesting addition to the crustacean fauna of this country.

In size this species is rather small, being from 2–6 mm. in length. The body is slightly arched. The head is round in front, its posterior margin quite straight. The first thoracic segment partly surrounds the head on the sides. The thoracic segments are nearly equal. The inferior margins are drawn out to a point posteriorly, this being emphasized toward the pleon. The lower margins of the segments are beset with minute spines. The pleon is short, the segments not easily recognized, and the inferior margins not conspicuously drawn out. The sixth abdominal segment is slightly longer than the others, and bluntly triangular at posterior margin. The latter is beset with short spines.

There seems to be no trace of eyes or antennulae. The antennae are about ½ the length of the body, and consist of a basal portion of 5 segments and a short flagellum of 8 segments. Of the basal portion, the first three segments are short and stout, with a few short spines. The fourth and fifth segments are much longer, the former being 2½ times the length of the third, with equal width, the latter about $1\frac{1}{3}$ times the fourth, with nearly equal thickness. Both are beset with short spines along the sides, and the fifth has one specially long spine near its distal end. The flagellum consists of 8 segments, rapidly tapering to the small extremity, and altogether less than the fifth basal segment in length. Each segment has a row of stiff hairs, probably sense organs of some kind, around its middle region. The last segment ends in a number of bristles.

The mouth-parts are such as we would expect in a non-parasitic Isopod. The outer maxilliped (labrum) consists of a broad blade with two pointed appendages in front which extend slightly beyond the head, and a three-segmented palpus. The first maxilla consists of a narrow blade fringed with bristles on the outer side and provided with a cutting surface having five notches, two being hard and three of softer texture. The inner branch of the same is also rather slender, with three teeth, two of them rounded and delicate, one longer and fringed. The mandibles are large and strong. The inner margin of the right mandible is provided with three appendages, the first short, the second and third longer and fringed along the inner margin. On the left mandible we find two equal fringed appendages, corresponding to the first and second in the right mandible.

The legs, all of which are ambulatory in character, are much alike in structure, consisting of five segments and a claw composed of two more. Short spines with broad bases are found scattered all over the surface of the legs, together with some longer ones, especially on the last segment. The claw needs perhaps a little more description. It consists of 2 segments, the first, larger one, ending in a spine on the concave side, and a shorter, pointed end segment. Besides these there are two appendages, one on the convex side as long as the claw and rather thin and narrow, ending squarely, and a pointed one, not quite so long and wide, on the concave side. In the allied genus *Titanethes* Schioedte these appendages end in a tuft of hairs, but nothing of the kind could be made out here. The legs increase in length toward behind, the last being half the length of the body.

The pleopoda are very small. As in other terrestrial Isopods, the anterior ones contain air-cells.

The uropoda consist of a broad basal portion with a stout conical outer branch, longer than the whole of the pleon, and tipped with four or five bristles, the longest of which are about ¾ the length of this branch. The inner branch is much smaller and shorter, beset with numerous short spines on the inner margin, five or six, slightly longer, on the outer margin, and a stout spine at the tip. The basal portion of the uropods projects beyond the posterior margin of the telson on the outer side, but is covered on the inner side.

Color.—White; a dark longitudinal band often seen along the median dorsal surface, caused by the dark contents of the alimentary tract.

Caecidotea Smithii n. sp. Pl. XVI, figs. 10–18.

Body of loosely jointed segments. Head as in *C. stygia* Pack. No trace of eyes. Inner antennae short, not more than half as long as basal portion of outer antennae. Flagellum of inner antennae consists of five segments, the second ¼ of first, remaining ones longer. Last segment of flagellum with a spine more than twice length of segment, beside which there is an olfactory club $^2/_3$ as long. Another somewhat shorter olfactory club on penultimate segment. Last segment of the basal portion of the inner antennae provided with three spines, as in *C. stygia*. Outer antennae probably as long as body. Basal portion of 5 segments, the first three short and thick, the fourth and fifth much longer and more slender. The flagellum consists of at least 40 segments. Mouth-parts essentially as those of *C. stygia*. Legs long and slender, first pair sub-chelate, remaining ones with a weak claw. Inferior margin of the body segments beset with short spines.

Size.—Very small, probably not over 3 mm. in length.

Color.—White.

Hab.—Subterranean stream near San Marcos, Tex. Collected by Dr. C. H. Eigenmann from the United States Fish Commission well

The above description is from a fragment. The telson and caudal appendages were gone, also part of the outer antennae. The writer hopes soon to receive the material which will enable him to fill out the gaps in the above diagnosis.

In honor of Dr. H. M. Smith, in charge of scientific inquiry of the U. S. Fish Commission.

Palaemonetes antrorum Benedict. *Proc. U. S. N. Mus.*, p. 615. 1895. Pl. XVII.

Prothorax continued forward into a short, sharp rostrum, the upper margin of which is notched, there being about 12 notches, with plumose spines between the notches, also a few of these on the under side of the rostrum. Just below and to the outside are the eye-stalks with very degenerate eyes. There is but one little group of cells left which indicates the original structure, but as far as practical use is concerned the eyes must be entirely functionless. Below the eye-stalks are the inner antennae, or antennulae, and below and to the outside of these the outer or true antennae. The former consist of a stalk composed of 4 segments, the first and second of which are broad and on the under side are continued into a keel-like structure fringed with plumose bristles. The third segment is narrower and a little longer than the others, while the fourth is very short. This bears three appendages, the outer one being the longest, equalling or slightly exceeding the length of the body. The inner flagellum is little over half the length of the outer. The third appendage is short and pointed, and bears along its inner margin a row of structures resembling olfactory clubs. The other two appendages have about the same structure as the true antennae, consisting of numerous segments which gradually taper off to the end. The outer antennae spring from a broad base consisting of three segments. The second of these divides, one part being continued into a large and broad antennal scale fringed with long bristles, and extending beyond the rostrum one-half its length. The third basal segment is much smaller than the others, and much less in thickness. The flagellum of the antenna consists of numerous segments, gradually tapering to the extremity. The total length of the antennae is 26–27 mm. in specimens whose body length is 17 mm.

The first and second pairs of maxillipeds (figs. 13 and 12) are somewhat alike in structure, consisting of a broad, flat portion, stronger in the second, provided with numerous spines and bristles. The third maxilliped has much the same character as a foot (fig. 11). All three are provided with a slender palpus, which ends in a tuft of hairs.

The legs are all very long and slender. The first and second pairs are chelate, but the chelae are so small that they can be of but little use to the creature. The remaining three pairs end in a crooked claw.

The swimmerets are well developed. There is a stout basal portion and two branches, an outer longer and stouter one, and an inner shorter one. The latter undergoes interesting modifications in the several pairs. In the first it is short and broad, membranous, and fringed with scattered bristles. In the second it has two little branches springing from the inner side, the first unarmed, the second with a number of bristles (not plumose). In the third there is but one unarmed side branch, and the same is true of the fourth and fifth. In the basal portion of the fourth we find a single spine on the inner margin, but in the fifth both inner and outer margins are fringed with scattered bristles. The two distal branches are closely fringed with long plumose bristles.

The telson consists of a conical central portion, its posterior margin beset with two larger and several smaller bristles, and the broad side portions, modified swimmerets, all except the outer margin of which closely fringed with plumose bristles.

The gills are completely covered by the carapace. They agree in structure, etc., with those of the allied families of crustaceans.

CYCLOPS:

Two specimens of this widely distributed genus were found in the water of the artesian well mentioned above. They are both blind, as far as external examination can show. They were preserved in formalin which, in other cases at least, did not decolorize the eyes if there were any. The following descriptions are intended to be preliminary only, and as soon as the necessary material is at hand a more detailed study and comparison with other related forms will be made.

Cyclops cavernarum n. sp. Pl. XV, fig. 18.

Antennae 17-jointed, reaching to middle of second thoracic segment. No trace of eye. Cephalothorax oval-elongate. Abdomen stout.

Cyclops Learii n. sp. Pl. XV, fig. 19.

Antennae 12-jointed, scarcely reaching the posterior margin of first thoracic segment. Cephalothorax oval, shorter than in *C. cavernarum*. No trace of eye. Abdomen rather slender.

Cypridopsis vidua obesa Brady and Robertson.

This species was represented by numerous specimens in the collections from the artesian well.

Nicoletia[2] *texensis* n. sp. Pl. XVIII.

Two specimens were found by Dr. Eigenmann in Ezell's cave, near San Marcos, Tex. The body of the larger is about 18 mm. in length; that of the smaller about half as much. The antennae were not complete, but seem to be at least as long as the body. The same is true of the caudal appendages. In form and appearance the body is much like that of *Campodea staphylinus* Westw., though the head is relatively smaller and the thoracic region larger (see fig. 1).

Head.—Rather small, rounded on the sides, slightly pointed anteriorly, convex above (fig. 1). Antennae very long, of numerous segments (in the imperfect specimens I examined I counted about 40, and there might have been as many more, judging from the thickness of the last segment). The basal portion consists of 2 segments, the first half as long as head, rather stout, the next short, as long as broad; first segment of flagellum three times as long as second; second and following segments short, gradually lengthening toward distal portion. Basal portion as well as flagellum with numerous spines, some of them forked at tip. Besides these, the whole surface is covered with minute hairs (fig. 8). There seems to be no trace of eyes. The labrum is provided with a transverse row of bristles, as well as with some scattered ones. The mandibles (fig. 7) are large and prominent; there are four larger teeth and several smaller ones; the inner grinding surface is provided with a fine, comb-like arrangement. The maxillae (fig. 4) are also large and conspicuous. There is one large, hard tooth, then one with a comb-like arrangement, then follow five with one side finely serrate, another with smooth margins, and then a row of stout bristles forked at the tip. The maxillary palp is long and slender, having the appearance of an antenna. It consists of 5 segments, the first short and thick, the remaining ones long and slender; the second and

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[2] Key to the genera of Lepismidae by Nathan Banks.

1. With scales.................................. 2
   No scales.................................. 5
2. No eyes.................................. 3
   With eyes, body slender, cerci longer than abdomen.................................. 4
3. Body broad, cerci shorter than body, *Lepismina*
   Body slender, cerci longer than body, *Troglodromicus*
4. Maxillary palpi, 5-jointed.........*Lepisma*
   Maxillary palpi, 6-jointed......*Thermobia*
5. Eyes present..................*Maindronia*
   Eyes absent.....................*Nicoletia*

Nicoletia.—Abdominal appendages on segments 2–9, cerci nearly as long as body, no eyes, no scales, maxillary palpi 5-jointed, mandibles tridentate at tip, body not very slender.

Four species are known: *N. phytophila* Gerv., *N. geophila* Gerv., *N. cavicola* Joseph, *N. naggi* Grassi.

third each have a row of spines near the distal ends (fig. 5). On the end of the last segment there are five club-shaped structures, probably sense organs of some sort (fig. 6). The whole palp is covered with minute hairs and with larger spines. The labium is broad posteriorly, cleft anteriorly, with large palps, of four joints each, the last broad and heart-shaped, with three short cylindrical structures on the end (fig. 3).

The first thoracic segment is little longer than the head, but the second and third are much larger. The margin is somewhat produced postero-inferiorly. The legs are rather long and slender, hairy, with a triple claw (fig. 2). The latter seems hard and is yellow in color.

There are 10 abdominal segments. The last two are rather short. The abdominal legs are found on the second to eighth segments. The ninth is provided with two long appendages, while the last ends in one long median appendage. These three have been mentioned above under caudal appendages. The abdominal legs are rather weak, of one joint, ending in a straight claw, with several spines. The caudal appendages consist of numerous segments, lengthening toward the tip, and elaborately fitted out with spines and bristles, some of which are stout and forked, others very long and slender. They seem to be arranged in a definite way (see fig. 9).

Color of specimens preserved in formalin: yellowish white.

Degeeria cavernarum Pack. Pl. XVIII, figs. 11–13.

Two specimens of this common Podurid were obtained from Ezell's cave. They differ from the form found in the vicinity of Bloomington by the longer antennae. Especially the fourth segment is much longer than in forms found here.

DESCRIPTION OF A NEW CAVE SPIDER BY NATHAN BANKS

Theridium Eigenmanni n. sp.

Female, length ceph. 2.1 mm.; femur I=8.2 mm.; tibia I=7 mm.

Cephalothorax, legs, and sternum pale reddish yellow; mandibles a little darker; abdomen variable, sometimes entirely pale, sometimes black all over except two pale spots on highest part and a row of two or three reaching to the spinnerets; between these extremes are many grades of markings, some with a few black spots above, others with a row of chevrons behind and several large spots on each side above.

General structure similar to *T. tepidariorum.* Cephalothorax rather broad, depressed around dorsal groove; caput rather low, broad; posterior eye-row nearly straight; P. M. E. about twice their diameter apart, a little closer to the sub-equal P. S. E.; A. M. E. about once their diameter apart, a trifle farther from the slightly smaller A. S. E.; M. E. make a quadrangle slightly higher than broad, and broader above than below; mandibles of moderate size; sternum blunt-pointed between the hind coxae; legs long and slender, clothed with rows of fine short hairs; femur I full as long as the cephalothorax and abdomen taken together; tibia I a little longer than metatarsus I; abdomen high, strongly arched above at middle, suddenly descending behind, higher than in most of the allied forms; the lung-plates each side at base are reddish and hardened. The epigynum shows two dark spots with a narrow transverse opening behind. Male, unknown.

Specimens from Beaver cave and Ezell's cave, near San Marcos, Tex.; collected by Prof. C. H. Eigenmann, after whom the species is named. The specimens from Beaver cave are darker than the others.

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EXPLANATION OF PLATES

Plate XIV

Crangonyx Bowersii Ulrich.

Fig. 1. C. Bowersii.

Fig. 2. Upper antennae, basal portion; 2*a*, secondary flagellum.

Fig. 3. Last three segments of upper antenna; 3*a*, olfactory club.

Fig. 4. Lower antenna.

Fig. 5. Maxilliped.

Figs. 6, 7. First and second gnathopods.

Fig. 8. One of the fourth pair of legs; 8*a*, gill.

Fig. 9. One of the sixth pair of legs.

Fig. 10. One of the pleopoda.

Fig. 11. The telson, uropoda, etc; 11*a*, fifth abdominal segment; 11*b*, sixth abdominal segment; 11*c*, telson, 11*d*, first uropod, 11*e*, second uropod; 11*f*, third uropod.

Plate XV

Figs. 1–17. *Ciralonides texensis* Benedict.

Figs. 2–6. Thoracic legs.

Figs. 7, 8. Upper and lower antenna.

Fig. 9. End of lower antenna.

Fig. 10. Uropod.

Fig. 11. Mandibles.

Fig. 12. Labrum.

Fig. 13. Maxilla.

Fig. 14. Ventral view of head.

Figs. 15, 16, 17. The first, second, and third pleopoda.

Fig. 18. *Cyclops cavernarum* Ulrich.

Fig. 19. *Cyclops Learii* Ulrich.

Plate XVI

Figs. 1–9. *Brackenridgia cavernarum* Ulrich.

Fig. 2. Antenna.

Fig. 3. Mandibles.

Fig. 4. Labrum.

Fig. 5. Maxilla.

Fig. 6. Thoracic leg.

Fig. 7. Claw.

Fig. 8. Telson, with uropods.

Fig. 9. One of the uropods.

Figs. 10–18. *Caecidotaea Smithii* Ulrich.

Fig. 11. Portion of lower antenna; 11*a*, basal portion of same.

Fig. 12. Upper antenna.

Fig. 13. Basal segment of upper antenna showing auditory spines, *an*.

Fig. 14. End segments of upper antennae, showing olfactory clubs, *ol*.

Fig. 15. Labrum.

Fig. 16. Maxilla.

Figs. 17, 18. First and second legs.

Plate XVII

Palaemonetes antrorum Benedict.

Fig. 1. *P. antrorum*.

Figs. 2–6. Thoracic legs.

Fig. 7. Basal portion of lower antenna.

Fig. 8. Portion of third (shortest) flagellum of upper antenna. *ol*, olfactory clubs.

Fig. 9. Basal portion of upper antenna.

Fig. 10. Telson.

Figs. 11, 12, 13. Maxillipeds.

Fig. 14. Gill.

Fig. 15. Rostrum.

Figs. 16–20. Pleopoda.

PLATE XIV

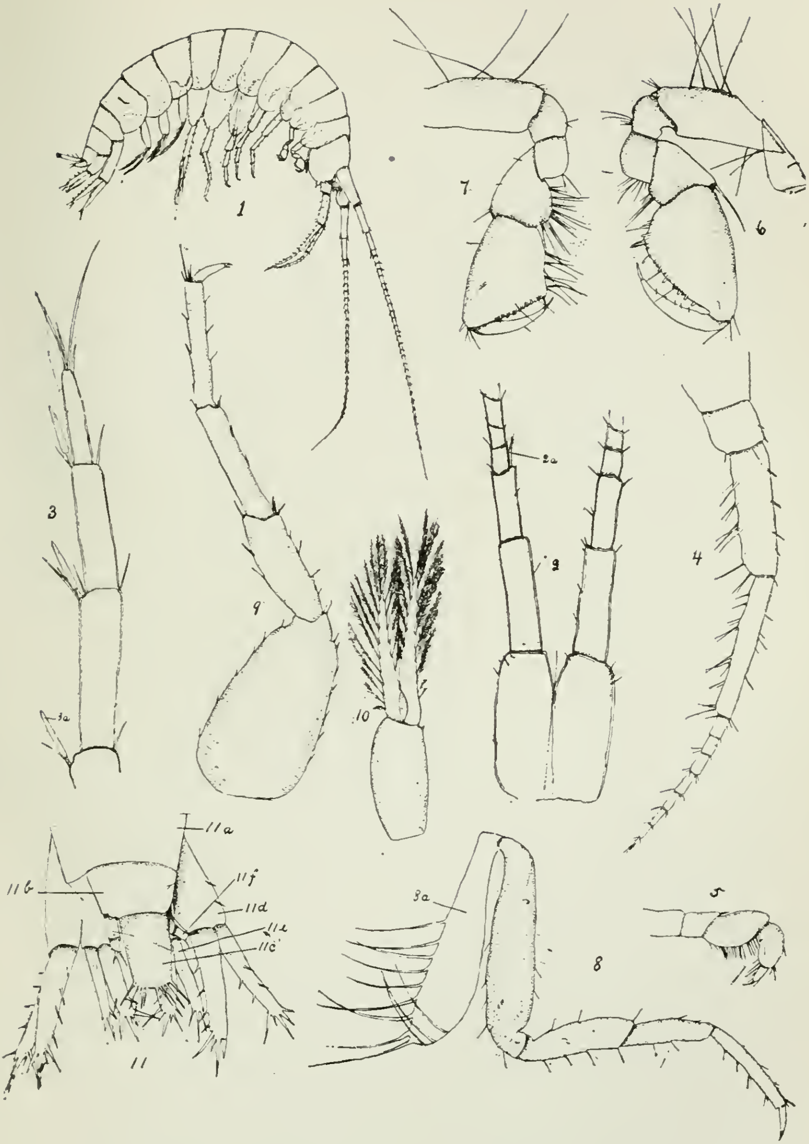


PLATE XV

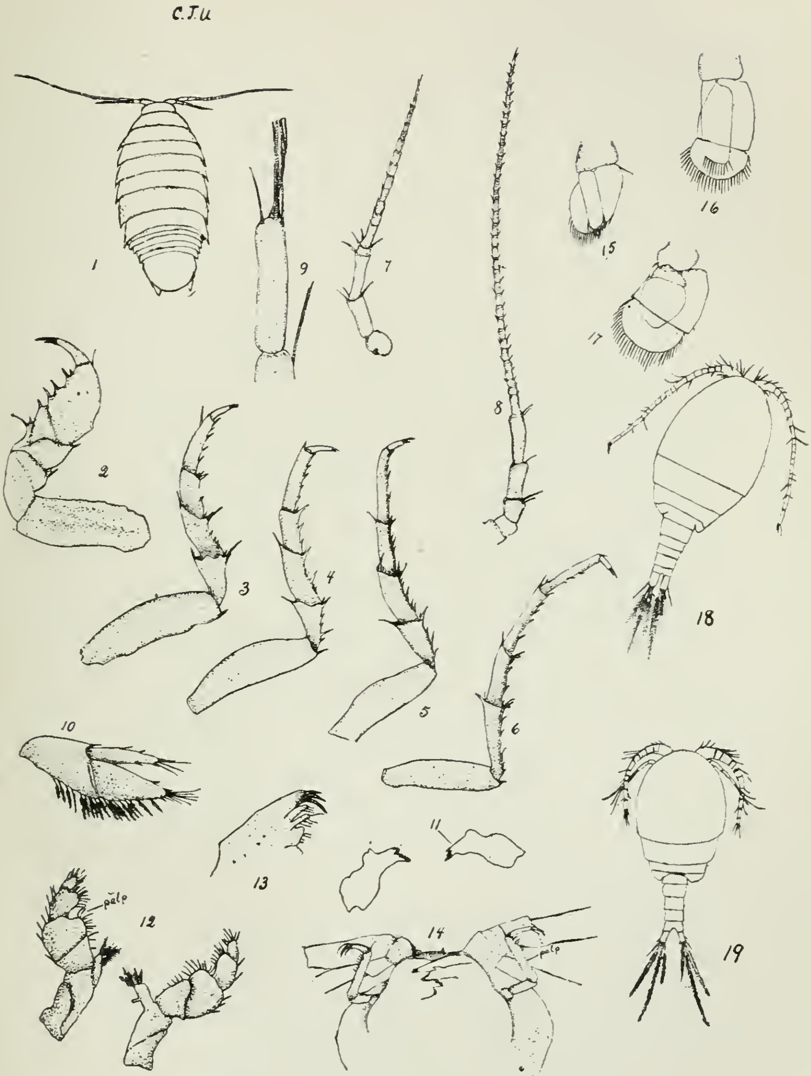


PLATE XVI

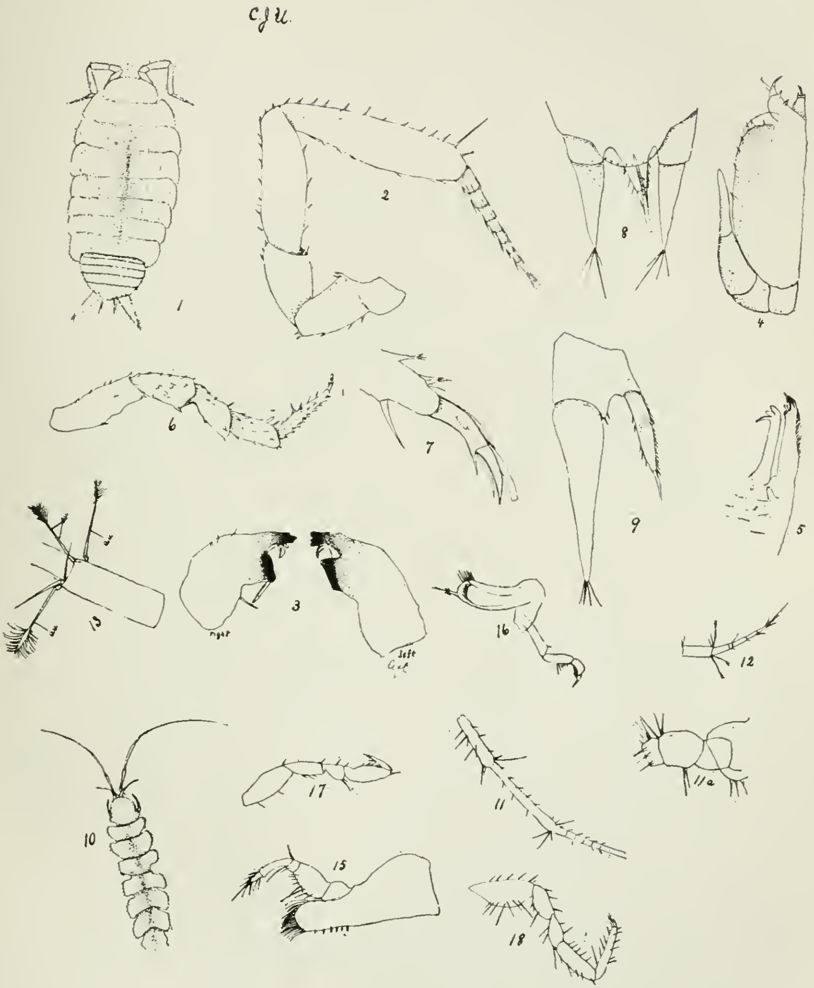


PLATE XVII

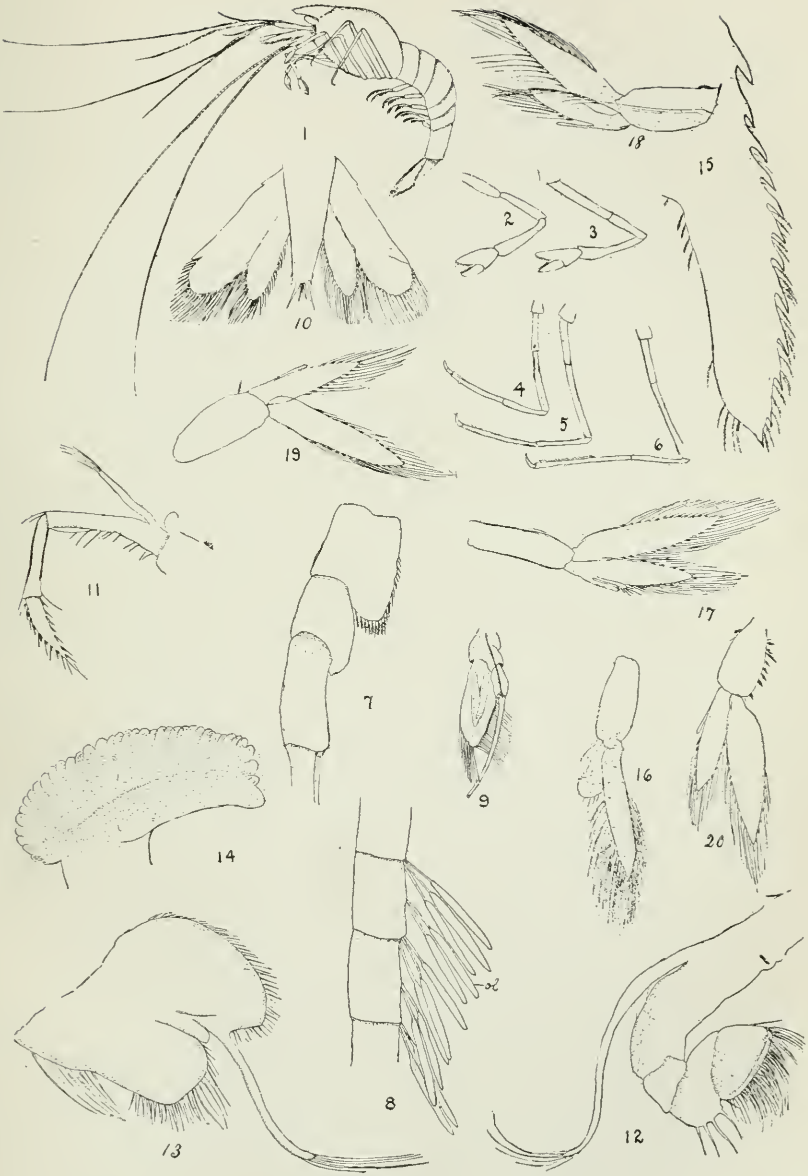


PLATE XVIII

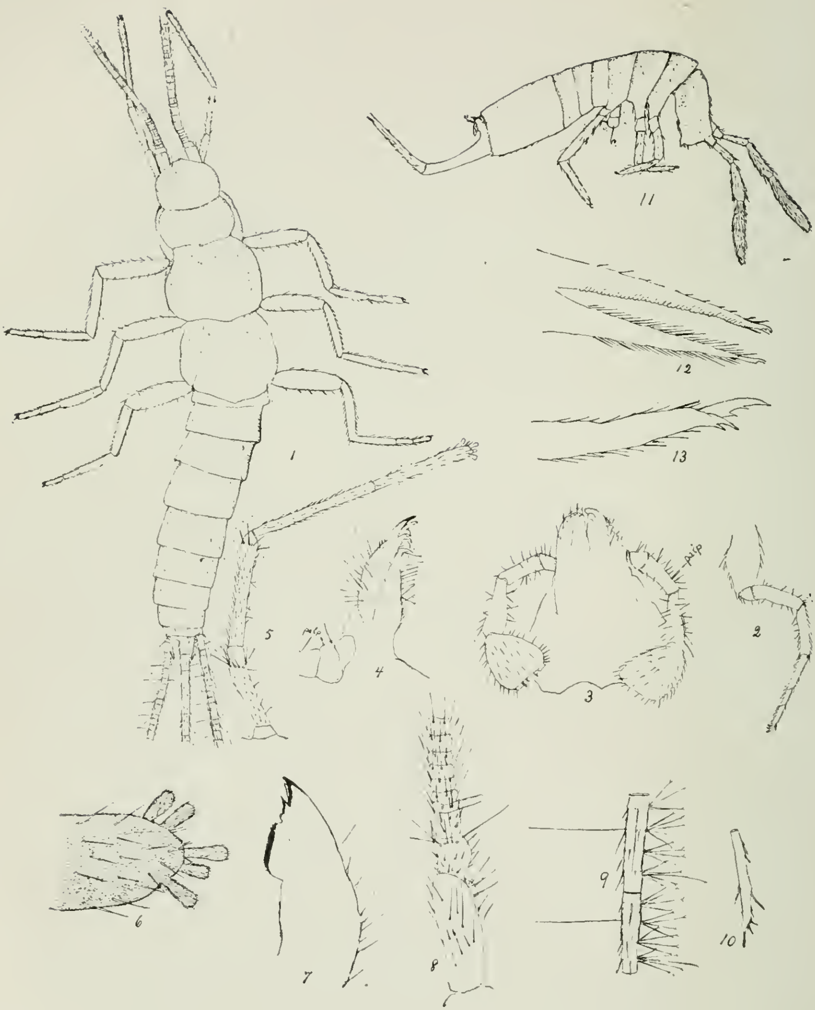


Plate XVIII

Figs. 1–10, *Nicoletia texensis* Ulrich.
Fig. 2. Thoracic leg.
Fig. 3. Labium.
Fig. 4. Left maxilla.
Fig. 5. Maxillary palpus.
Fig. 6. End of max. palpus showing peculiar sense (?)organs.
Fig. 7. Left mandible.
Fig. 8. Basal portion of antenna.
Fig. 9. Two segments of cercopod.
Fig. 10. Abdominal leg.
Figs. 11–13. *Degeeria cavernarum* Pack.
Fig. 12. End of elator.
Fig. 13. Claw.

ON THE AMOUNT OF OXYGEN AND CARBONIC ACID DISSOLVED IN NATURAL WATERS AND THE EFFECT OF THESE GASES UPON THE OCCURRENCE OF MICROSCOPIC ORGANISMS

By GEORGE C. WHIPPLE and HORATIO N. PARKER

WITH FOUR PLATES

INTRODUCTION

Of the many factors which affect the growth of microscopic organisms in water the most important is their food supply, and of the elements which enter into their composition oxygen and carbon are of fundamental importance. Ordinarily these two elements are not determined in the sanitary analysis of water, and data on their occurrence in natural waters are not as numerous as one could wish; and especially there are lacking parallel observations upon the amount of carbonic acid and the number of the microscopic organisms. With nitrogen the case is different. This element plays a conspicuous part in sanitary water-analysis, and the relation between the amount of nitrogen as it exists in various states and the microscopic organisms present in the water has been carefully worked out.

Nitrogen is usually determined in four states: First, as "albuminoid ammonia," that is, nitrogen existing as organic matter; second, as "free ammonia," which represents the preliminary stage of decomposition of the organic matter; third, as "nitrites," which represent a further stage in decomposition; and, fourth, as "nitrates," which represent the final stage of decomposition, that of complete mineralization. Nitrogen exists also as a gas dissolved in the water, but as such it is seldom determined. It seems to have been taken for granted, and apparently with good reason, that dissolved nitrogen is as inert in its relations with organic life as is the nitrogen of the atmosphere: but it has been discovered that some forms of terrestrial plant life, aided by the action of certain bacteria, are able to utilize atmospheric nitrogen, and it may be that aquatic plants can in like manner assimilate dissolved nitrogen. The relations that exist between algae growths and the nitrogen contents of water as ordinarily determined are illustrated by Plate XIX.

SOLUBILITY OF OXYGEN AND CARBONIC ACID

Great variations exist in the solubility of gases in water. At 20° C. one liter of water has the power of absorbing 28.38 c.c. of oxygen, 14.03 c.c. of nitrogen, 901.4 c.c. of carbonic acid, and 654,000 c.c. of ammonia. The coefficient of absorption of a gas is the volume of that gas—expressed in cubic centimeters and measured at 0°C. under a pressure of 760 mm. of mercury—which is dissolved in 1 c.c. of water. Except in the case of hydrogen, the coefficient varies with the temperature, decreasing as the temperature increases. The coefficients of absorption at various temperatures for oxygen, nitrogen, and carbonic acid are given in the following table:

TABLE I

COEFFICIENTS OF ABSORPTION OF VARIOUS GASES, AFTER BUNSEN[1]

TEMPERATURE (*Centigrade*)	OXYGEN	NITROGEN	CARBONIC ACID
0	0.04114	0.02035	1.7967
1	0.04007	.01981	1.7207
2	.03907	.01932	1.6481
3	.03810	.01884	1.5787
4	.03717	.01838	1.5126
5	.03628	.01794	1.4497
6	.03544	.01752	1.3901
7	.03465	.01713	1.3339
8	.03389	.01675	1.2809
9	.03317	.01640	1.2311
10	.03250	.01607	1.1847
11	.03189	.01577	1.1416
12	.03133	.01549	1.1018
13	.03802	.01523	1.0653
14	.03034	.01500	1.0321
15	.02989	.01478	1.0020
16	.02949	.01458	.9753
17	.02914	.01441	.9519
18	.02884	.01426	.9318
19	.02858	.01413	.9150
20	.02838	.01403	.9014

[1]Gasometrische Methoden, Braunschweig. 1877.

The volume of the gas dissolved is the same, whatever the pressure, but inasmuch as the density of the gas increases directly with the pressure, it follows that the actual quantity of the gas dissolved varies directly with the pressure. In the case of a mixture of the gases, the quantity of any one of them which will be dissolved depends upon the vapor pressure of that particular gas, regardless of the others. Thus, water at 0° C. will dissolve 41.14 c.c. per liter of oxygen if exposed to an atmosphere of pure oxygen under 760 mm. pressure, but if exposed to the air, which is but one-fifth oxygen, it will absorb 41.14 c.c. of oxygen under one-fifth the pressure; consequently only one-fifth as much by weight as in the first case. Again, water at 0° will dissolve 901.4 c.c. per liter of carbonic acid in an atmosphere of that gas under 760 mm. pressure, while in the air of a room where the amount of carbonic acid is only 0.2 per cent, the amount dissolved will be only one-five-hundredth of that quantity by weight. This law is said to be only approximately true in the case of gases which form but a small per cent of any mixture of gases.

The coefficient of absorption of oxygen is greater than that of nitrogen; consequently when water is exposed to air it will absorb a larger amount of the former gas. Bunsen has given the following figures to illustrate this:

	COMPOSITION OF AIR BY VOLUME	COMPOSITION OF DISSOLVED AIR BY VOLUME
Oxygen	20.96 per cent	34.91 per cent
Nitrogen	79.04 per cent	65.09 per cent
	100.00 per cent	100.00 per cent

It is possible for water to temporarily contain a larger amount of gas than it will actually dissolve under definite conditions of temperature and pressure; that is, it may be supersaturated. Thus, after violent agitation, as in passing over a fall, oxygen may become mechanically entrained, and a sample taken immediately may show an amount several per cent above what normally would be expected. "Soda water," which is water charged with carbonic acid under pressure, is an exaggerated case of supersaturation. On exposure to ordinary atmospheric conditions a supersaturated water gives off gas until equilibrium is established. Sometimes the quantity of gas given off is so minute that it can be measured only by the most delicate chemical methods; at others the action is vigorous enough to become manifest to the eye in the phenomenon of effervescence. Cases of water supersaturated with carbonic acid are very common. In outdoor air the pressure of carbonic acid is so very low that the amount which is dissolved in water is very small. Ground water usually contains relatively large amounts of carbonic acid, and on exposure to the air yields it up until normal conditions of solution are established. This tendency to equalization makes it necessary to exercise great care in the determination of carbonic acid.

Water may be freed of its dissolved gases to a considerable extent by boiling, but it is only by prolonged boiling in a vacuum that the last traces can be removed. In the early days of water analysis the dissolved gases were driven off in this manner and were collected and measured by the tedious process of gas analysis. The procedure still remains one of the most accurate, but on account of its inconvenience it has been superseded by simpler methods for the determination of dissolved oxygen and carbonic acid.

WINKLER'S METHOD OF DETERMINING THE AMOUNT OF DISSOLVED OXYGEN IN WATER[2]

Sample.—The sample from which the determination of dissolved oxygen is to be made must be collected with extreme care, as faulty manipulation may easily cause an increase of oxygen by absorption from the air. A glass-stoppered bottle with narrow neck and holding approximately 250 c.c. should be used. The exact capacity of the bottle with the stopper in place should be determined and, for convenient reference, scratched with a diamond upon the glass. The bottle can not be safely filled by pouring the sample into it, nor yet by sinking it in a pond and allowing the air to bubble out; it is necessary that the water enter at the bottom in a gentle current. If the sample is to be collected from a faucet the water must be made to enter the bottle through a glass or rubber tube which reaches to the bottom of the bottle, the water being allowed to overflow for several minutes, after which the glass stopper is carefully pressed home so that no bubble of air is caught beneath it. If the sample is to be collected from a stream or pond the apparatus shown in Fig. 1 should be used.

[2] *Berichte*, XXI, 2843; 1888. See also Richards and Woodman, Air, Water, and Food, p. 107; John Wiley and Sons, 1900, New York. A. H. Gill, *Tech Quar.*, V, p. 250; 1892. *Special Rept. Mass. St. Bd. of Health on Purification of Sewage and Water*, p. 722; 1890.

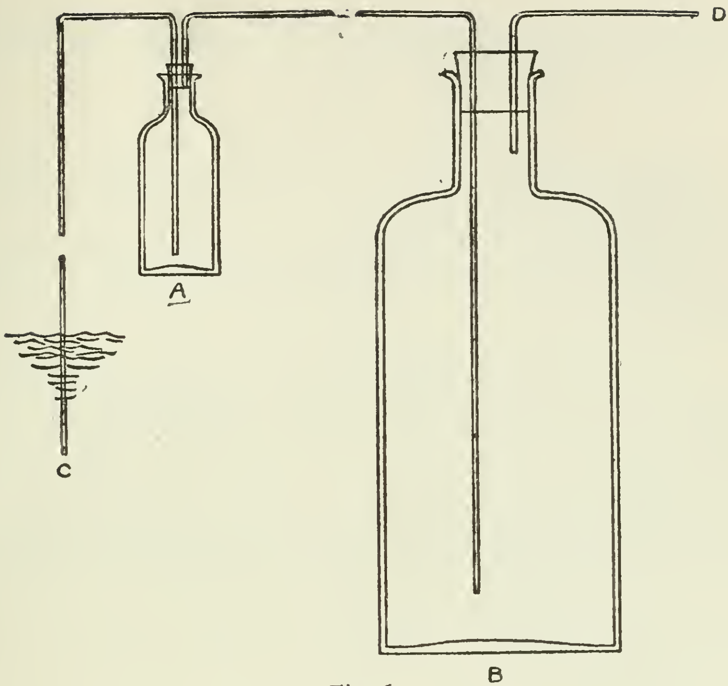


Fig. 1.

The sample bottle, *A*, is provided with a rubber stopper through which pass two tubes, one reaching nearly to the bottom of the bottle and the other terminating at the bottom of the stopper. The longer one is attached to a rubber tube of length sufficient to reach the point where the sample is to be taken; the shorter is attached to the tube of a large bottle, *B*, similarly provided with inlet and outlet. If suction is applied at the point *D* the water will enter at *C*, fill the bottle *A*, and ultimately fill the bottle *B*. The bottle *B* should have several times the capacity of *A*, and water should be drawn through *A* until a fair sample has been secured. If the sample is to be collected from a considerable depth a small lead pipe, which will serve as a weight and will neither collapse nor stretch, may be attached to *C*. It may be marked off in meters showing the depth of the sample. Suction may be secured with the mouth, but it is preferable to use an air pump. As soon as the bottle *A* has been filled with a satisfactory sample the rubber stopper should be removed and the glass stopper inserted as before. It is always advisable to ascertain the temperature of the sample in order that the results of the determination may be expressed, if desired, in per cent of saturation.

SOLUTION REQUIRED

a. Manganous sulfate solution. Dissolve 48 grams of $MnSO_4 \cdot 4H_2O$ in 100 c.c. of distilled water.

b. Solution of sodium hydroxid and potassium iodid. Dissolve 360 grams of NaOH and 100 grains of KI in 1,000 c.c. of distilled water.

c. Hydrochloric acid, sp. gr. 1.20.

d. Sodium thiosulfate solution. Dissolve 24.827 grams of chemically pure recrystallized sodium thiosulfate ($Na_2S_2O_3.5H_2O$) in 1,000 c.c. distilled water. Dilute 100 c.c. of this solution to one liter with distilled water.

This gives a N/100 solution, each cubic centimeter of which is equivalent to .00008 grams of oxygen, or 0.055825 c.c. of oxygen at 0° and 760 mm. pressure. Inasmuch as this solution is not permanent it should be standardized occasionally against a N/100 solution of potassium bichromate as described in almost any work on volumetric chemistry.

e. Starch Solution.—Mix a small amount of clean potato starch with cold water until it becomes a thin paste; stir this into 150 to 200 times its weight of boiling water and continue the boiling for a few minutes; then let it stand and settle. It may be preserved by adding a few drops of chloroform.

METHOD OF PROCEDURE

Remove the stopper from the bottle which contains the sample and with a pipette long enough to reach the bottom of the bottle add approximately 2 c.c. of the manganous sulfate solution. Then, in a similar way, add approximately 2 c.c. of the sodium hydroxid potassium iodid solution. Replace the stopper in such a way as to leave no air bubbles, and mix the contents of the bottle. The manganous sulfate and sodium hydroxid react to form manganous hydroxid, a part of which at once combines with whatever dissolved oxygen is present, to form manganic hydroxid. Allow the precipitate to settle; add about 2 c.c. of strong hydrochloric acid and mix thoroughly. This reacts with the manganic hydroxid and liberates chlorin, which in turn liberates iodin from the potassium iodid. The amount of iodin liberated therefore depends upon the amount of dissolved oxygen present.

Up to this point the process must be carried on at the time the sample is collected, but after the hydrochloric acid has been added and the stopper replaced, there is practically no further change, and the rest of the operation, which consists of the determination of the amount of iodin, may be conducted at leisure. Thus samples collected in the field are dosed with the three solutions and then taken to the laboratory where the examination is completed.

The amount of liberated iodin is determined as follows:

When the precipitate has nearly dissolved after the addition of the acid, the contents of the bottle are rinsed out into a flask and titrated with a N/100 solution of sodium thiosulfate, using a few cubic centimeters of the starch solution as an indicator. It is best not to add the starch until the color has become a faint yellow. The titration is continued until the blue color has disappeared.

CALCULATION AND EXPRESSION OF RESULTS

There are three ways of expressing the amount of dissolved oxygen in water, namely: In parts per million by weight, in number of cubic centimeters of the gas per liter at 0° and 760 mm. pressure, and in per cent of saturation, that is, the per cent which the amount of gas present is of the amount capable of being dissolved by water at the same temperature and pressure.

The following formulae may be used to ascertain the results according to the three methods: ·

$$\text{Oxygen in parts per million} = \frac{.00008n \times 1{,}000{,}000}{v} = \frac{80n}{v}$$

$$\text{Oxygen in c.c. per liter} = \frac{.055788n \times 1000}{v} = \frac{55.788n}{v}$$

$$\text{Oxygen in per cent of saturation} = \frac{.055788n \times 1000 \times 100}{v \times O} = \frac{5578.8n}{vO}$$

where n=number of c.c. of $\frac{N}{100}$ thiosulfate solution.

v=capacity of the bottle in cubic centimeters less the volume of the manganous sulfate and potassium iodid solution added (i. e., less 4 c.c.).

O=the amount of oxygen in c.c. per liter in water saturated at the same temperature and pressure. See Table II.

TABLE II

AMOUNT OF DISSOLVED OXYGEN IN DISTILLED WATER WHEN SATURATED AT DIFFERENT TEMPERATURES FROM 0° TO 30° C.[3] (PREPARED BY ROSCOE AND LUNT. SEE JOUR. CHEM. SOC., P. 552, 1889. SEE ALSO SUTTON'S VOLUMETRIC ANALYSIS, P. 275)

TEMPERATURE (*Centigrade*)	NO. OF C.C. OF OXYGEN PER LITER OF WATER	LOGARITHM OF NUMBERS	TEMPERATURE (*Centigrade*)	NO. OF C.C. OF OXYGEN PER LITER OF WATER	LOGARITHM OF NUMBERS
0.0	9.70	.986772	16.0	6.82	.833784
0.5	9.60	.982271	16.5	6.75	.829304
1.0	9.49	.977266	17.0	6.68	.824776
1.5	9.38	.972203	17.5	6.61	.820201
2.0	9.28	.967548	18.0	6.54	.815578
2.5	9.18	.962843	18.5	6.47	.810904
3.0	9.08	.958086	19.0	6.40	.806180
3.5	8.98	.953276	19.5	6.34	.802089
4.0	8.87	.947924	20.0	6.28	.797960
4.5	8.78	.943495	20.5	6.22	.793790
5.0	8.68	.938520	21.0	6.16	.789581
5.5	8.58	.933487	21.5	6.10	.785330
6.0	8.49	.928908	22.0	6.04	.781037
6.5	8.40	.924279	22.5	5.99	.777427
7.0	8.31	.919601	23.0	5.94	.773786
7.5	8.22	.914872	23.5	5.89	.770115
8.0	8.13	.910091	24.0	5.84	.766413
8.5	8.04	.905256	24.5	5.80	.763428
9.0	7.95	.900367	25.0	5.76	.760422
9.5	7.86	.895423	25.5	5.72	.757396
10.0	7.77	.890421	26.0	5.68	.754348
10.5	7.68	.885361	26.5	5.64	.751279
11.0	7.60	.880814	27.0	5.60	.748188
11.5	7.52	.876218	27.5	5.57	.745855
12.0	7.44	.871573	28.0	5.54	.743510
12.5	7.36	.866878	28.5	5.51	.741152
13.0	7.28	.862131	29.0	5.48	.738781
13.5	7.20	.857332	29.5	5.45	.736397
14.0	7.12	.852480	30.0	5.43	.734800
14.5	7.04	.847573	30.5	5.40	.732394
15.0	6.96	.842609	31.0	5.38	.730782
15.5	6.89	.837588			

For example, suppose the capacity of the bottle to be 264.5 c.c., the temperature of the water to be 10° C., and suppose that 28.6 c.c.

[3] Below 5° the results are extrapolated and are not strictly accurate. The results given are calculated for aeration at an observed pressure of 760 mm. When the observed pressure is below 760 mm. 1/76 the value must be subtracted for every 10 mm. difference; and when the observed pressure is above 760 mm. a like amount must be added.

$\frac{N}{100}$ thiosulfate were used in the titration. Then

$$\text{Oxygen in parts per million} = \frac{80 \times 28.6}{260.5} = 8.78$$

or,

$$\text{Oxygen in c.c. per liter} = \frac{55.788 \times 28.6}{260.5} = 6.12$$

or,

$$\text{Oxygen in per cent of saturation} = \frac{5578.8 \times 28.6}{260.5 \times 7.77} = 78.7 \text{ per cent.}$$

The labor of calculation may be diminished by the use of logarithms. Furthermore, inasmuch as $\frac{80}{v}$ in the first equation, $\frac{55.788}{v}$ in the second, and $\frac{5578.8}{v}$ in the third are constants for any particular bottle, it is convenient to have in a note-book, or upon the bottles themselves, the logarithms of these quantities. It is also desirable to bear in mind the following data:

1 c.c. of oxygen at 0° and 760 mm. pressure weighs .001434 g.

1 c.c. $\frac{N}{100}$ thiosulfate solution=.00008 g.=.055788 c.c.

0.7 c.c. oxygen per liter=1 part per million by weight (approximately).

1 c.c. oxygen per liter=1.43 parts per million by weight (approximately).

1 cu. ft. oxygen=40.6 g.

1 gallon oxygen=5.52 g.

SOURCES OF ERROR

It is necessary to correct for the manganous sulfate and for the potassium iodid-sodium hydrate solution added, but if the precipitate is allowed to settle before the acid is added it is not necessary to correct for the latter, as the water displaced has already given up its oxygen.

In practice perhaps the greatest source of error is carelessness in collecting the sample, thus allowing atmospheric air to become entrained. This is particularly the case when the amount of oxygen is small. Supersaturation with oxygen, however, seldom occurs.

To some extent the amount of organic matter interferes with the result by exerting a reducing action, and high nitrates, also, materially affect the result. These sources of error are discussed in Winkler's paper; in actual practice it is seldom necessary to take them into account. Neither is it necessary to correct for atmospheric pressure when expressing the results in number of cubic centimeters per liter.

METHOD OF DETERMINING THE AMOUNT OF CARBONIC ACID IN WATER

Although water has a large capacity for absorbing carbonic acid, as stated above, yet the pressure of the carbonic acid in the air is so small that under ordinary atmospheric conditions the amount dissolved is very slight. When water which contains carbonic acid comes in contact with the carbonates of calcium and magnesium it is supposed to unite with them to form the bicarbonates of these metals,—salts which are readily soluble. The normal carbonates, themselves, but are slightly soluble. If the amounts of the normal carbonates are in excess, all of the dissolved carbonic acid will be used up, but if the carbonic acid is in excess the quantity of it remaining in solution will be proportional to the pressure of the carbonic acid in the atmosphere. Inasmuch as most surface and ground waters come in contact with the carbonates of the alkaline earths during some part of their history, it follows that natural waters ordinarily contain carbonic acid in three different conditions. That part which simply remains in solution uncombined with any base is termed the "free carbonic acid"; if it is combined directly with the bases to form the normal carbonates ($CaCO_3$ and $MgCO_3$) it is called the "fixed, or full-bound carbonic acid"; while if it is combined indirectly with the normal carbonates to form the bicarbonates it is known as the "half-bound carbonic acid." The sum of the three gives the total carbonic acid. When water which contains carbonic acid in these three forms is heated the free and half-bound carbonic acid is given off, and is sometimes referred to as the volatile carbonic acid.

In the analysis of water for sanitary or industrial purposes it is sometimes necessary to ascertain the amount of carbonic acid in each of the three forms, but in the study of biological problems it is chiefly the free carbonic acid which is involved. Various methods have been suggested for the determination of the carbonic acid. These have been recently discussed in an excellent paper by Ellms and Beneker in the *Journal of the American Chemical Society,* Vol. XXIII, No. 6 (June, 1901), to which the reader is referred.

The free carbonic acid may be easily determined by titration with a solution of sodium carbonate, using phenolphthalein as an indicator. As soon as the sodium carbonate has combined with all the free carbonic acid present, with the formation of bicarbonate of soda, any further addition will produce a pink color. In case there is no free carbonic acid present the phenolphthalein will produce a pink color when the first drop of sodium carbonate is added, or even before it is added at all. The details of the method as practiced by the authors are as follows:

Sample.—If the determination can not be made at the time the sample is collected, the bottle should be filled completely, without leaving any air space under the stopper. It is preferable to collect the sample in the receptacle in which the titration is to be made. The required solutions are prepared as follows:

Sodium Carbonate Solution ($Na_2CO_3 \frac{N}{22}$).

A normal solution of sodium carbonate is first made by dissolving 53 g. of the freshly fused, chemically pure salt in one liter of freshly boiled distilled water. This should be kept in a hard glass bottle with glass stopper. The $\frac{N}{22}$ solution used in the titration is made from this by dilution with boiled distilled water. As this solution easily absorbs carbonic acid from the air and thereby changes to bicarbonate, it is important that it be exposed to the air as little as possible. It is even advisable to supply the burette by side connection with the supply-bottle and to provide tubes filled with caustic lime upon both the supply bottle and burette, in order that the carbonic acid may be removed from the air before it comes in contact with the solution. The burette should be graduated to 0.1 c.c.

Phenolphthalein Indicator.

This is prepared by dissolving 0.5 g. of the powdered salt in 100 c.c. of 50 per cent alcohol. A few drops of a weak solution of sodium hydrate should be cautiously added until a faint pink color is found, which just disappears after shaking. For use this may be kept in a small glass-stoppered bottle with a pipette stopper.

Mode of Procedure.—The determination is made by putting 100 c.c. of the sample in a 100 c.c. Nessler tube with 10 drops of the phenolphthalein indicator. The sodium carbonate solution is then added from a burette and stirred until the faint pink color which appears remains permanent. The difference between the burette readings before and after titration expressed in tenths of a cubic centimeter gives the amount of carbonic acid in parts per million. For example, if the burette readings are 31.3 and 32.9, the difference is 1.6, and the corresponding amount of carbonic acid is 16 parts per million. If due precautions are taken the results should be correct to about one part in a million.

The greatest sources of error in the method come from the loss of carbonic acid to the air and from the absorption of carbonic acid by the solution of sodium carbonate. The latter may be prevented by adopting the precautions described above, while the former may be reduced to a minimum by making the titration as soon as possible after collection, and by collecting the sample in the tube in which the titration is to be made. Great care should be used in stirring the solution. In fact, instead of stirring, it is often better to mix the added solution by rapidly whirling the tube in such a way that it describes the surface of a cone. If a stirring rod is used it should be bent so that at the lower end there is a circle with its plane at right angles to the rod.

Exposure to the air ordinarily results in loss of free carbonic acid, which may be illustrated by the following experiment:

A series of samples was collected and carbonic acid determinations made in the field, while a corresponding series was collected and sent to the laboratory, where determinations were made at the end of twenty-four hours. A third series was allowed to stand the same length of time, but without being stoppered. The results were as follows:

	AMOUNT OF CARBONIC ACID IN PARTS PER MILLION		
	Determination made at the time of collection	Determination made after standing 24 hours with tube completely filled and stoppered	Determination made after standing 24 hours with water exposed to the air
Surface water No. 1.....	8.8	9.0	1.5
Surface water No. 2.....	1.3	1.5	0.5
Surface water No. 3.....	0.5	0.5	0.5
Ground water No. 1.....	7.0	6.5	1.5
Ground water No 2.....	7.0	7.0	1.0
Ground water No. 3.....	7.0	7.0	1.0
Ground water No. 4.....	2.5	2.0	—1.0

At another time carbonic acid gas was passed through distilled water until the water contained 45.5 parts per million. Portions of 200 c.c. were then put in completely filled, tightly stoppered bottles, and in open bottles exposed to the air at different temperatures. The results were as follows:

	AMOUNT OF CARBONIC ACID (PARTS PER MILLION)		
	At beginning of experiment	After standing 3 hours	After standing 20 hours
Bottle filled and tightly stoppered.....	45.5	44.0	44.5
Bottle unstoppered, temperature 17.0° C.	45.5	26.0	0.5
Bottle unstoppered, temperature 20.0° C.	45.5	23.5	0.5
Bottle unstoppered, temperature 37.0° C.	45.5	15.0	0.3

Thus in less than twenty-four hours practically all of the carbonic acid had been given off to the air.

It is not even necessary that the bottle shall be unstoppered in order that a loss of carbonic acid may occur. If the bottle is only partially filled, there oftentimes will be a loss to the air in the bottle. Thus a water which contained 15 parts of carbonic acid per million was distributed into half-filled 8-oz. bottles. The first bottle was tested at the end of twenty-four hours; the second at the end of forty-eight hours, and so on, with the following results:

	AMOUNT OF CARBONIC ACID
At beginning..	15.0
At end of 24 hours..	13.5
At end of 48 hours	8.0
At end of 72 hours..	2.5
At end of 96 hours..	1.8

The danger of loss of carbonic acid while pouring the sample back and forth through the air is illustrated by the following experiment: Carbonic acid was passed through water until 63 parts per million were dissolved. A portion of the water was then poured back and forth four times and tested. It was found to contain 57.5 parts, showing a loss of 9 per cent.

The amount of carbonic acid given up in this way depends in part upon the pressure of the carbonic acid in the air. On exposure to the air a sample of boiled distilled water will absorb from it a certain amount of carbonic acid. Out of doors this is seldom greater than

0.5 parts per million, but in the air of a laboratory, when gas is used freely, it sometimes amounts to 1.5 or even 3.0 parts. Ellms and Beneker mention an instance where it was 15 parts per million, but in this case a carbonic acid generator was in use in the laboratory.

There is, in short, a tendency for the carbonic acid in the air and in the water exposed to the air to come to an equilibrium. This must occur in natural bodies of water as well as in small samples, and it doubtless plays an important part in the economy of nature.

It sometimes happens that there is no free carbonic acid present, in which case the water is neutral to phenolphthalein; or the water may be alkaline to phenolphthalein, showing that some of the carbonates are in solution as normal carbonates instead of as bicarbonates.

If it is desired to obtain the amount of carbonic acid in the three states mentioned, a second titration should be made with $\frac{N}{50}$ H_2SO_4, using methyl orange (cold), or preferably lacmoid (hot) as the indicator.

It is best to express the results of all chemical analyses of water in parts per million, that is, in milligrams per liter, but in case it is desired to express the amount of carbonic acid in cubic centimeters per liter, the following table[4] will be found convenient:

TABLE III

WEIGHT IN MILLIGRAMS OF A CUBIC CENTIMETER OF CARBONIC DIOXID FROM 746 TO 778 MILLIMETERS PRESSURE AND FROM 10° TO 25° C. CORRECTED FOR THE TENSION OF AQUEOUS VAPOR.

Temperature	MILLIMETERS																
	746	748	750	752	754	756	758	760	762	764	766	768	770	772	774	776	778
10°	1.839	1.844	1.849	1.854	1.859	1.864	1.869	1.874	1.879	1.884	1.889	1.894	1.899	1.904	1.909	1.914	1.919
11	1 831	1.836	1.841	1.846	1.851	1.856	1.861	1.866	1.871	1.876	1.881	1.886	1.891	1.896	1.901	1 906	1.911
12	1.823	1.828	1.833	1.838	1.843	1.848	1.853	1.858	1.863	1.868	1.873	1.878	1.883	1.888	1.893	1.898	1.903
13	1.815	1.820	1.825	1.830	1.835	1.840	1.845	1.850	1.855	1.860	1.865	1.870	1.875	1.880	1.885	1.889	1.894
14	1.807	1.812	1.817	1.822	1.827	1.832	1.837	1.842	1.847	1.852	1.856	1.861	1.866	1.871	1.876	1.888	1.886
15	1.799	1.804	1.809	1.814	1.818	1.823	1.828	1.833	1.838	1.843	1.848	1.853	1.858	1.863	1.868	1.872	1.877
16	1.791	1.795	1.800	1.805	1.810	1.815	1.821	1.825	1.830	1.835	1.839	1.844	1.849	1.854	1.859	1.864	1.869
17	1.782	1.787	1.792	1.797	1.801	1.806	1.811	1.816	1.821	1.826	1.831	1.836	1.841	1.846	1.851	1.855	1.860
18	1.774	1.779	1.784	1.788	1.793	1.798	1.803	1.808	1.813	1.818	1.823	1.828	1.832	1.837	1.842	1.847	1.852
19	1.765	1.770	1.775	1.780	1.785	1.790	1.794	1.799	1.804	1.809	1.814	1.819	1.823	1.828	1.833	1.838	1.843
20	1.757	1.761	1.766	1.771	1.776	1.781	1.786	1.791	1.795	1.800	1.805	1.810	1.815	1.820	1.825	1.829	1.834
21	1.748	1.753	1.758	1.623	1.767	1.772	1.777	1.782	1.787	1.792	1.797	1.802	1.806	1.811	1.816	1.820	1.825
22	1.739	1.744	1.749	1.754	1.759	1.764	1.769	1.773	1.778	1.783	1.787	1.792	1.797	1.802	1.807	1.811	1.816
23	1.731	1.735	1.740	1.745	1.750	1.755	1.760	1.764	1.769	1.774	1.778	1.783	1.788	1.793	1.798	1.802	1.807
24	1.721	1.726	1.731	1.736	1.741	1.746	1.751	1.755	1.760	1.765	1.769	1.774	1.779	1.784	1.789	1.793	1.798
25	1.713	1.718	1.722	1.727	1.732	1.737	1.741	1.746	1.751	1.756	1.760	1.765	1.770	1.775	1.780	1.784	1.789

4 Ellen H. Richards and Alpheus G. Woodman, Air, Water, and Food, p. 196. John Wiley & Sons, New York, 1900.

AMOUNT OF OXYGEN IN NATURAL WATERS UNDER VARIOUS CONDITIONS

The oxygen dissolved in water is derived primarily from the atmosphere. If distilled water, freed of oxygen by boiling, stands exposed to the air it absorbs oxygen and in a few hours becomes saturated, or, to use the popular expression, aerated. This is accomplished even more quickly if the water falls through the air in drops. Roscoe and Lunt obtained the standard aerated water used in the preparation of Table II as follows: Two glass-stoppered quart bottles were half-filled with distilled water and shaken for five minutes, the air being renewed several times by filling one bottle with the contents of the other and dividing it again into two portions. Finally one bottle being filled, the temperature was taken and also the barometric pressure, after which the bottle was allowed to stand stoppered for half an hour to get rid of minute air bubbles. Roscoe and Lunt's figures are probably somewhat more accurate than those given by Bunsen and Winkler.

In the case of natural waters exposed to sunlight there is another source of oxygen, namely aquatic vegetation. It is a well-known fact that chlorophyllaceous plants exposed to sunlight exhale oxygen. This is true of aquatic as well as terrestrial plants, and of the microscopic organisms as well as the larger forms. Several years ago T. Chalkley Palmer[5] described an interesting method for demonstrating this fact in the case of the diatom *Eunotia major*, Rabenhorst. It was based upon the color changes produced in hematoxylin by carbonic acid and oxygen. When this indicator is dissolved in water which contains oxygen it has a rosy pink color, but if one breathes into the solution through a glass tube the color will change to a light brown. If now the solution be poured back and forth from one beaker to another the pink color will return, because the carbonic acid will have been liberated and oxygen acquired. Palmer placed his growing diatoms in a test tube provided with a capillary tube which passed through the stopper. The test tube was held inverted with the capillary point under the surface of a jar of water. The water was first colored pink by the addition of a watery solution of hematoxylin. The color was then changed to a light brown by

[5] *Proc. Acad. of Nat. Sci. of Philadelphia*, p. 142. Feb., 1897.

charging the water with carbonic acid from the lungs. The apparatus was then exposed to sunlight, and in the course of fifteen minutes or half an hour the color of the liquid in the test tube had become pink because of the liberation of oxygen by the growing diatoms. Later the color became a brilliant red.

M. Albert-Levy, Directeur du Service Chimique, l'Observatoire de Montsouris, Paris, has also observed that if samples of water containing algae are kept exposed to sunlight the amount of dissolved oxygen will be increased, and he cites an example where water from the Vanne, which at the time of collection contained 11.1 parts per million, after nine days was found to contain 20.2 parts per million, and after sixty days 39.7 parts. If these figures are correct we have here an example of supersaturation.

While plant life and the atmosphere are supplying oxygen to surface waters, other forces are at work consuming it. All forms of aquatic animal life, both large and small, require oxygen, and most bacteria are likewise dependent upon it. Some oxygen besides is used up without the direct intervention of vital processes in the direct oxidation of organic matter. The fact that minute animal organisms, such as snails, crustacea, rotifera, etc., use up oxygen may be illustrated by placing them in one of Palmer's tubes and noting the change in color of the hematoxylin solution from red to brown. The exhaustion of oxygen by a culture of bacteria in a hermetically sealed jar may be also shown by the use of this indicator. The fact that decomposition of organic matter is accompanied by loss of dissolved oxygen has given rise to the so-called "incubation test" for determining the quality of water. The sample, which must completely fill the bottle, is kept for several days in the dark at a temperature favorable to rapid bacterial development, and the amount of dissolved oxygen determined before and after the incubation. The greater the amount of organic matter present and the larger the number of bacteria in the original water, the more rapid will be the exhaustion of the oxygen. M. Albert-Levy found that a sample of water from the river Seine which, when collected, contained 10.6 parts per million of dissolved oxygen, lost all of its oxygen after standing fifteen days. While this test is too crude and too inconvenient to be of practical use, it is interesting as an illustration of the point in question. In general, therefore, it may be said that decomposition of organic matter in water means loss or even exhaustion of dissolved oxygen.

Surface waters which contain but little organic matter and which are exposed to the air are usually saturated or almost saturated with oxygen. This is equally true of running brooks, large streams, small pools, and the surface strata of large lakes. Such waters seldom contain less than 80 per cent of the amount required to saturate them. Even if saturated, however, the actual amount of oxygen present varies considerably at different seasons on account of the effect of temperature upon the solubility. This is illustrated in one of the diagrams on Plate XX, which shows the seasonal changes in the temperature of surface waters at Boston, Mass., and the corresponding changes in the amount of oxygen present in a fully saturated water. (See Table IV.) Gill[6] has shown that at times natural waters may be supersaturated with oxygen, and the same fact has been observed elsewhere. Horton[7] has stated that in certain streams the water is normally supersaturated during the months of July and August, and he attributes this to the influence of growing plants.

TABLE IV

TABLE SHOWING THE AMOUNT OF OXYGEN IN WATER WHEN SATURATED AT DIFFERENT SEASONS OF THE YEAR AT BOSTON, MASS.

MONTHS	AVERAGE TEMPERATURE, CENTIGRADE	AMOUNT OF OXYGEN	
		No. of cubic centimeters per liter	Parts per million
January	3.7	8.92	12.8
February	3.4	9.01	12.9
March	3.8	8.90	12.7
April	7.4	8.24	11.8
May	13.6	7.19	10.3
June	19.1	6.39	9.1
July	22.0	6.04	8.6
August	22.1	6.03	8.5
September	20.0	6.28	9.0
October	14.5	7.04	10.0
November	10.4	7.69	11.0
December	6.7	8.38	12.0

If water contains much organic matter, bacterial decomposition may take place, especially during warm weather. This results in the

6 (l. c.)

7 Second report of an investigation of the rivers of Ohio by the State Board of Health 1899.

reduction of the oxygen or even in its entire disappearance. Shallow ponds with muddy bottoms or stagnant pools and sluggish streams with an excess of aquatic vegetation often lose their oxygen during the summer. Sewage, which is very rich in organic matter, loses its oxygen in a very few hours, after which putrefaction sets in. When sewage is allowed to enter a stream the dissolved oxygen is reduced by an amount corresponding to the strength of the sewage and the ratio of its volume to that of the stream. The Merrimac River receives the sewage of the city of Lowell, besides that of other cities, and although the volume of the stream is large, the diminution in the amount of dissolved oxygen in the water at Lawrence, nine miles down stream, is marked. Table V gives by months the per cent of saturation of the water at Lawrence for the years 1893–95. It will be observed that during the summer months there was a material reduction in the amount of oxygen. One of the diagrams on Plate XX shows the effect of the sewage of Paris upon the water of the river Seine. At Choisy-le-Roi, above the entrance of the large sewers, the water is almost saturated for the greater part of the year, and even in summer does not fall far short of saturation; but at Argenteuil, below the city, the amount of oxygen is at all times below that of saturation, and during the summer it is almost exhausted. The same fact is illustrated by Table VI, which shows the progressive diminution of the amount of oxygen between the two stations named, and in parallel series the increasing foulness of the river as illustrated by the chlorin, the organic matter, and the disappearance of oxygen during the forty-eight hours' incubation at 33° C.

TABLE V

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN IN THE WATER OF THE MERRIMAC RIVER AT LAWRENCE, EXPRESSED IN PER CENT OF SATURATION

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1893..........	91	96	91	100	86	75	52	69	81	86	95	98
1894..........	....	....	....	....	57	67	76	74	67	58	44	....
1895..........	83	82	79	98	88	62	59	55	50	68	99	....

TABLE VI

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN AT VARIOUS STATIONS ON THE RIVER SEINE ABOVE AND BELOW THE CITY OF PARIS. AVERAGE OF TEN YEARS' OBSERVATION BY M. ALBERT-LEVY

STATION	DISSOLVED OXYGEN IN PARTS PER MILLION			ORGANIC MATTER	CHLORIN
	At time of collection of sample	After 48 hours at 33° C.	Per cent used up during incubation		
Choisy-le-Roi	10.4	7.8	25	3.1	6.0
Usine d'Ivry	10.8	8.8	18	2.8	7.0
Usine d'Austerlitz	10.7	8.4	21	2.9	7.0
Usine Chaillot	10.0	7.5	25	2.5	7.0
Usine de Suresnes	8.6	5.3	38	3.1	8.0
Usine d'Argenteuil	6.5	2.4	63	4.5	11.0

The amount of dissolved oxygen in large bodies of water varies with the depth. Many observations illustrating this fact are given in Table VII. Near the surface and as far down as the water is kept in circulation by the wind the per cent of saturation is usually above 80 and is often 100, while in the stagnant portion of the water below the thermocline the oxygen diminishes toward the bottom, sometimes gradually and sometimes suddenly. This exhaustion of oxygen has been fully discussed in the reports of the Massachusetts State Board of Health, the Boston Water-works, and elsewhere.[8] During the winter, as in the summer, there is an exhaustion of oxygen at the bottom of stagnant lakes and often a partial exhaustion at the surface immediately under the ice. This is illustrated by figures given in Table VII. The extent to which the oxygen is used up at the bottom of deep lakes depends chiefly upon the condition of the soil at the bottom. If it is clean sand or gravel the water may remain at least partially aerated for a long time even though the lake is thermally stratified, but if there is a deposit of organic matter decomposition sets in and robs the water of its oxygen.

8 See Microscopy of Drinking Water by G. C. Whipple. John Wiley & Sons, New York.

TABLE VII

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN AT VARIOUS DEPTHS IN CERTAIN PONDS AND RESERVOIRS IN MASSACHUSETTS. COMPILED FROM THE REPORTS OF THE MASSACHUSETTS STATE BOARD OF HEALTH, THE ANNUAL REPORTS OF THE BOSTON WATER-WORKS, ETC.

POND	DATE	DEPTH IN FEET	TEMPERATURE CENTIGRADE	DISSOLVED OXYGEN Per cent of saturation
Jamaica Pond	June 11, 1891	0	25	100
		10	20	100
		20	20	80
		30	12	59
		40	12	11
		50	....	0
		57	....	0
	June 25, 1891	0	21.7	100
		35	5.8	37
		40	5.8	0
		50	5.6	0
	July 14, 1891	0	24.0	100
		10	23.8	100
		20	12.3	49
		30	5.8	29
		35	5.6	4
		40	5.4	0
		47	5.2	0
	Jan. 24, 1893 (surface frozen)	0	0	98
		10	2	100
		20	2.1	89
		30	2.2	72
		40	2.2	19
		44	2.2	0
Lake Cochituate	Aug. 17, 1891	0	23.6	79
		10	19.1	84
		20	12.1	36
		30	9.6	21
		40	9.1	21
		45	9.1	2
		50	7.6	0
		57	7.1	0
	Feb. 14, 1893 (surface frozen)	0	0	100
		10	3.8	100
		20	2.8	100
		30	2.8	94
		40	2.8	83
		45	2.8	60
		50	2.9	49
		55	2.9	37
	Sept. 18, 1890	0	21.0	97
		15	21.0	88
		30	10.0	20
		40	9.4	12
		50	7.7	0
		60	7.5	0

TABLE VII—*Continued*

POND	DATE	DEPTH IN FEET	TEMPERATURE CENTIGRADE	DISSOLVED OXYGEN Per cent of saturation
Lake Cochituate.............	Sept. 28, 1891	0	21.0	90
		10	14.0	81
		20	14.5	33
		30	11.0	9
		40	11.0	8
		50	10.0	0
		56	9.0	0
Mystic Lake	March 8, 1893	0	0	60
	(surface	10	1.2	64
	frozen)	20	2.1	68
		30	2.2	58
		40	2.2	55
		50	2.2	50
		54	2.4	49
		60	2.4	43
		64	2.4	25
		66	2.7	13
		68	2.7	0
		74	2.7	0
Reservoir No. 4, Boston......	Aug. 20, 1891	0	23.6	85
		10	21.6	84
		20	16.6	28
		30	....	27
		35	12.6	16
		36½	12.6	15
	Feb. 14, 1893	0	0	100
	(surface	10	3.4	100
	frozen)	20	3.8	92
		25	3.9	78
		30	3.7	60
	Sept. 25, 1890	0	18.2	92
		10	18.0	87
		20	15.9	18
		29	12.3	7
	Oct. 1, 1891	0	22.0	88
		10	21.5	84
		15	21.0	83
		20	15.0	9
		25	14.5	7
		31	12.0	4
Reservoir No. 3, Boston......	Aug. 20, 1891	0	23.6	86
		6	23.6	85
		12	21.6	59
		14	....	0
		15	....	0
		17	....	0
		19	....	0
		21	17.1	0
	Jan. 30, 1893	0	2.2	81
	(surface	5	2.1	62
	frozen)	10	2.1	45

TABLE VII—*Concluded*

POND	DATE	DEPTH IN FEET	TEMPERATURE CENTIGRADE	DISSOLVED OXYGEN Per cent of saturation
Reservoir No. 3, Boston......	Jan. 30, 1893	14	2.3	44
Reservoir No. 2, Boston......	Jan. 30, 1893	0	1.2	86
	(surface	5	1.3	79
	frozen)	10	1.5	32
Scott Res., Fitchburg........	July 29, 1891	0	21.4	87
		10	18.8	79
		20	16.2	32
		25	10.2	11
		30	....	0
		35	....	0
Glenn Lewis Pond, Lynn	June 26, 1891	0	24.2	100
		5	....	100
		7	....	100
		10	....	0
		13½	17.2	0
	Jan. 26, 1893	0	2.8	7
	(Surface frozen)	5	3.3	6
Walden Pond, Lynn.........	Jan. 26, 1893	0	3.8	64
	(surface	5	3.8	26
	frozen)	10	3.5	20
		15	2.8	24
Brocton Reservoir...........	Mar. 15, 1893	0	0	90
	(surface	5	3.0	80
	frozen)	10	4.0	60
		12	3.9	28
		14	3.9	20
		16	3.9	4
		18	3.9	0
Van Horn Res., Springfield..	July 16, 1891	0	24.1	100
		7	24.1	100
		14	24.1	46
		17	....	0
		20	....	0
		28	....	0

TABLE VIII

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN IN CERTAIN OHIO RIVER WATERS

SCIOTO RIVER

STATION	DATE	TEMPERATURE CENTIGRADE	DISSOLVED 0 °/₀ SATURATION
Kenton, above town	June 12	....	....
	July 16	25.5	91
	Aug. 25	21	85
	Sept. 25	16	84
	Oct. 23	15	114
	Dec. 1	4	84
Kenton, below town	June 12	....	....
	July 16	25	114
	Aug. 25	23.5	169
	Sept. 25	18.5	72
	Oct. 23	16.5	159
	Dec. 1	3.75	90
Girls' Industrial Home, above	Oct. 7	17.5	106
	Oct. 26	15.5	99
	Dec. 2	2.5	94
Girls' Industrial Home, below	Oct. 7	17	113
	Oct. 26	17	116
	Oct. 26	17	118
	Dec. 2	3	....
	Dec. 2	3	91–93
Wyandotte Grove	June 13	....	....
	June 17	27	103
	Aug. 23	23	88
	Sept. 23	17	89
	Oct. 21	16	79
	Dec. 3	2.5	85
Jours Dam	June 13	....	....
	July 17	25.5	93
	Aug. 23	23	101
	Sept. 23	19	86
	Oct. 21	16	73
	Dec. 3	2.5	86
Columbus, Sandusky St. Bridge	June 13	....	....
	July 17	27.5	118
	Aug. 23	22.5	42
	Sept. 23	20	91
	Oct. 21	16	96
	Dec. 3	3	89
Columbus, Frank Rd. Bridge (below sewers)	July 17	23.5	9
	Aug. 23	23	21
	Sept. 23	19.5	0
	Oct. 21	17	0
	Dec. 4	5	78
Shadeville Bridge (apparently below town)	July 17	23	46
	Aug. 23	22.5	100
	Sept. 23	19	58
	Oct. 22	17	0
	Dec. 4	4.5	81

TABLE VIII—*Continued*

SCIOTO RIVER—*Continued*

STATION	DATE	TEMPERATURE CENTIGRADE	DISSOLVED 0 °/₀ SATURATION
Cuchville, Main St. Bridge	July 22	26	57
	Aug. 26	22.5	57
	Sept. 27	18	71
	Oct. 25	14	32
	Dec. 4	6	59

LITTLE SCIOTO RIVER

STATION	DATE	TEMPERATURE CENTIGRADE	DISSOLVED 0 °/₀ SATURATION
Marion, above town	July 15	26	116
	Aug. 24	23	114
	Sept. 24	20	50
	Oct. 23	11	50
	Dec. 1	1	82
Marion, below town	July 15	26	1125
	Aug. 24	23	46
	Sept. 24	21	61
	Oct. 23	11.2	72
	Dec. 1	2	27

CLETANGY RIVER

STATION	DATE	TEMPERATURE CENTIGRADE	DISSOLVED 0 °/₀ SATURATION
Galion, above town	July 15	22.5	147
	Aug. 24	22.5	123
	Sept. 24	21	107
	Oct. 22	12	74
	Nov. 30	3	90
Galion, below town	July 15	24	51
	Aug. 24	20	36
	Sept. 24	18	77
	Oct. 22	13	0
	Nov. 30	4	72
Delaware, above town	July 15	22	87
	Aug. 24	21	76
	Sept. 24	15	84
	Oct. 26	14	87
	Dec. 2	1	82
Delaware, below town	July 15	24	91
	Aug. 24	19	71
	Sept. 24	13	79
	Oct. 26	14	99
	Dec. 2	2.5	89
Cletangy Park, above	July 16	24.5	85
	Aug. 24	22.5	80
	Sept. 23	17	74
	Oct. 21	15.5	61
	Dec. 3	3	83
Columbus, Dublin Bridge	July 17	27	109
	Aug. 23	23	97
	Sept. 23	21	129
	Oct. 21	16.2	93
	Dec. 3	3	89

TABLE VIII—*Concluded*

MAHONING RIVER

STATION	DATE	TEMPERATURE CENTIGRADE	DISSOLVED O % SATURATION
Alliance, above Pat. St. Bridge	July 24	23	66
	Sept. 2	23	94
	Sept. 29	19	97
	Oct. 27	14	80
	Nov. 26	11	81
Alliance, below	July 24	25	75
	Sept. 2	25	81
	Sept. 29	19	70
	Oct. 27	16	35
	Nov. 26	8	90
Warren, above	July 23	23	68
	Aug. 28	23.5	99
	Sept. 30	16	90
	Oct. 28	13	82
	Nov. 27	7	83
Warren, below	July 23	23	76
	Aug. 28	23	66
	Sept. 30	16	72
	Oct. 28	14	54
	Nov. 27	8	90
Niles	July 24	23	70
	Aug. 28	21.5	92
	Sept. 30	15	89
	Oct. 28	13	70
	Nov. 27	8	81
Youngstown, above	July 23	21.5	86
	Aug. 28	26	82
	Sept. 30	20.5	93
	Oct. 28	16	76
	Nov. 27	7.5	90
Haselton Bridge	July 23	21.5	72
	Aug. 28	26	65
	Sept. 30	22	77
	Oct. 28	18	51
	Nov. 27	7	84

The amount of dissolved oxygen in certain river waters of Ohio as given above in Table VIII, is taken from the *Thirteenth Annual Report of the State Board of Health.*

The tap water in most towns and cities where surface supplies are used is usually well aerated, as shown in Table IX, but in the case of water rich in organic matter or in micro-organisms a loss of oxygen sometimes occurs in the pipes of the distribution system, as Table X illustrates.

TABLE IX

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN IN THE PUBLIC WATER-SUPPLIES OF CERTAIN MASSACHUSETTS CITIES AND TOWNS WHERE SURFACE WATER IS USED. COMPILED FROM REPORT FROM MASS. ST. BD. OF HEALTH FOR 1898, P. 367

CITY OR TOWN	DISSOLVED OXYGEN (Per cent of saturation)
Boston	84
Stoughton	73
New Bedford	54
Norwood	100
Palmer	92
Chicopee	97
Lawrence	85
Concord	75
Fall River	98
Rockland	83
Springfield	97

TABLE X

TABLE SHOWING THE DECREASE IN THE AMOUNT OF OXYGEN IN THE PIPES OF A WATER-WORKS DISTRIBUTION SYSTEM. COMPILED FROM MASS. ST. BD. OF HEALTH REPT. 1891, P. 379

			TEMP.	DISSOLVED OXYGEN Per cent of saturation
Large Ludlow res., Springfield, Mass.	Surface	July 16, 1891	24.1° C.	98
Large Ludlow res., Springfield, Mass.	Bottom.	July 16, 1891	23.6	61
Small Ludlow res., Springfield, Mass.	Surface	July 16, 1891	24.1	78
Small Ludlow res., Springfield, Mass.	Bottom.	July 16, 1891	23.6	71
Tap after passing through 6 miles of pipe	....	July 16, 1891	23.6	61
Tap after passing through 9 miles of pipe	....	July 16, 1891	23.6	57

The amount of dissolved oxygen in ground waters may vary from 0 to 100 per cent of saturation, and depends upon the character of the material with which the water comes in contact during its passage through the ground. If it meets decaying organic matter at the surface of the ground, or deposits of peat at greater depths, the oxygen may be used up, and especially is this true if iron is present with the organic matter. Table XI gives the amount of dissolved oxygen in certain ground water supplies of Massachusetts.

TABLE XI

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN IN CERTAIN DRIVEN WELL WATERS OF MASSACHUSETTS. COMPILED FROM REPT. MASS. ST. BD. HEALTH, 1898, P. 566

TOWN OR CITY	DISSOLVED OXYGEN (Per cen. of saturation)
Lowell	10
North Easton	64
Fairhaven	47
Kingston	85
Sharon	93
Milford	49
West Brookfield	100
Framingham	43
South Hadley	100
Ashburnham	100
Revere	11
Malden	54
Methuen	9
Reading	100

AMOUNT OF FREE CARBONIC ACID IN NATURAL WATERS UNDER VARIOUS CONDITIONS

The carbonic acid dissolved in surface waters is derived partly from the atmosphere and partly from the products of vital activity of organisms living in the water.

The amount of carbonic acid in the atmosphere is not a constant quantity. In pure sea air it may be as low as 0.02 per cent (2 parts in 10,000), while in the vicinity of cities it may be 0.05 per cent (5 parts in 10,000). In well-ventilated rooms it should not rise above 0.05 per cent (5 parts in 10,000), but when the ventilation is poor it rises to 0.2 per cent or 0.3 per cent (20 or 30 parts per 10,000), and in crowded rooms where gas is burning it may be even more than this. Out of doors it is generally somewhat higher in summer than in winter, because of the greater activity of organic life. It is usually lower after a rain. The vapor pressure of atmospheric carbonic acid is not ordinarily sufficient to permit a large amount to be present in solution in water exposed to the air, but as the free carbonic acid in the water is used up the loss is continually supplied from the atmosphere, so that at times the actual quantity given up by the atmosphere may be very considerable.

TABLE XII

TABLE SHOWING THE AMOUNT OF FREE CARBONIC ACID IN RAIN WATER (IN PARTS PER MILLION)

LOCALITY	DATE	CARBONIC ACID	REMARKS
Brooklyn, N. Y....	Aug. 1, 1901	6.3	Latter part of a heavy shower.
Brooklyn, N. Y....	Aug. 7, 1901	2.7	At end of a long rain.
Boston, Mass......	Sept. 18, 1901	6.0	At 1 Ashburton Place.
Boston, Mass......	Oct. 14, 1901	8.0	At 1 Ashburton Place, 11:30 A.M.
Boston, Mass......	Oct. 14, 1901	5.0	At 1 Ashburton Place, 2:45 P.M.
Boston, Mass......	Oct. 14, 1901	5.0	At 1 Ashburton Place, 4:15 P.M.
Boston, Mass......	Oct. 15, 1901	9.0	At 1 Ashburton Place, 9:00 A.M.
Boston, Mass......	Oct. 17, 1901	29.0	At 1 Ashburton Place, after sudden shower which lasted ¾ hour.
Cambridge, Mass..	Sept. 29, 1901	5.0	After three hours' fall.
Fitzwilliam, N. H.	Sept. 1, 1901	2.5	At beginning of shower, in country.
Fitzwilliam, N. H.	Sept. 1, 1901	1.8	At end of shower, in country.

Rain water contains carbonic acid in amounts corresponding to those present in the atmosphere. In the vicinity of cities it is sometimes as high as 20 or 30 parts per million, but where the air is purer it is seldom higher than 3 or 4 parts. Rain at the end of a long storm contains less carbonic acid than at the beginning. This is illustrated by Table No. XII. If rain water is allowed to stand in a shallow receptacle out of doors it will lose much of its carbonic acid in the course of a few hours and the loss will proceed until equilibrium with the carbonic acid of the atmosphere is established.

Most of the carbonic acid found in surface waters is not derived directly from the atmosphere by absorption nor by accession of rainwater, but its chief source is to be sought in the living organisms which inhabit the water. All animals exhale carbonic acid, and under certain conditions chlorophyllaceous plants do likewise, but it is chiefly to the bacteria that we look to find this action. These minute plants, countless in number and of enormous aggregate power, are continually breaking down nitrogenous organic matter or fermenting carbohydrates, with the consequent liberation of carbonic acid. In many of these vital processes oxygen and carbonic acid appear to act reciprocally: at one time oxygen is taken in and carbonic acid given out, while at another time carbonic acid is used up and oxygen liberated.

The production of carbonic acid by bacterial action scarcely needs illustration. The fermentation of the sugars in the absence of oxygen has come to be a common differential test in bacteriological laboratories, the observed data including the total amount of gas produced and the percentage which the carbonic acid is of the total gas. Thus in the closed arm of the fermentation tube the common colon bacillus produces enough gas to occupy about 50 per cent of the volume of the tube, and of this about one-third is carbonic acid. Other bacteria produce still greater amounts. As a rule the anaerobic bacteria produce larger amounts than do the aerobic forms, a fact which accounts for the accumulation of carbonic acid at the bottom of stagnant ponds. Yeasts, molds, and other fungi also produce carbonic acid, and no doubt these play an important part in nature. In general it may be said that wherever decomposition is going on in water there is carbonic acid going into solution, and the larger the amount of organic matter and the more numerous the bacteria the greater is the amount of carbonic acid dissolved.

TABLE XIII

TABLE SHOWING THE AMOUNT OF FREE CARBONIC ACID IN SURFACE WATERS EXPOSED TO THE ATMOSPHERE (IN PARTS PER MILLION)

SOURCE	DATE	CARBONIC ACID	REMARKS
STREAMS OF METROPOLITAN WATER-WORKS, BOSTON, MASS.			COLOR
Influent to Framingham Res. No. 2	Oct. 23, 1901	6.0	140
	Oct. 30, 1901	7.0	126
	Nov. 6, 1901	5.0	86
	Nov. 20, 1901	5.2	74
	Nov. 26, 1901	5.0	83
Influent to Sudbury Res.	Oct. 23, 1901	5.0	67
	Oct. 30, 1901	5.0	54
	Nov. 21, 1901	3.6	41
Deerfoot Brook	Oct. 17, 1901	8.0	176
Rock Meadow Brook	Oct. 17, 1901	8.0	148
Angelico Brook	Oct. 17, 1901	4.0	130
Brewer Brook	Oct. 17, 1901	8.0	82
Mowry Brook	Oct. 17, 1901	5.0	69
Brown Meadow Brook	Oct. 17, 1901	5.0	49
Cold Spring Brook	Oct. 15, 1901	8.0	145
	Oct. 22, 1901	8.0	188
	Oct. 29, 1901	8.0	200
	Nov. 19, 1901	5.4	118
	Nov. 26, 1901	6.8	110
Indian Brook	Oct. 15, 1901	19.0	212
	Oct. 22, 1901	14.4	204
	Oct. 29, 1901	15.0	180
	Nov. 12, 1901	16.0	128

TABLE XIII—*Continued*

SOURCE	DATE	CARBONIC ACID	REMARKS
STREAMS OF METROPOLITAN WATER-WORKS, BOSTON, MASS.			COLOR
Indian Brook	Nov. 19, 1901	14.6	120
Course Brook	Oct. 4, 1901	10.0	......
	Oct. 11, 1901	9.0	82
	Oct. 29, 1901	6.01	94
Pegan Brook	Oct. 4, 1901	4.0	......
	Oct. 11, 1901	5.0	7
	Oct. 29, 1901	4.0	4
Beaver Dam Brook	Oct. 4, 1901	10.0	......
	Oct. 11, 1901	9.0	125
	Oct. 29, 1901	6.0	122
Snake Brook	Oct. 29, 1901	10.0	66
Nashua River, S. Br., Clinton, Mass.	Nov. 8, 1901	5.0	
Lancaster, Mass.	Nov. 8, 1901	9.2	
" N. Br., Lancaster, Mass.	Nov. 8, 1901	6.6	
Pepperell, Mass.	Nov. 7, 1901	7.6	
OTHER STREAMS.			
Beaver Brook, Waverly, Mass.	Oct. 13, 1901	5.6	105
Kemp Brook, Fitzwilliam, N. H.	Sept. 6, 1901	8.0	Approximately 150
Hempstead Stream, L. I.	Sept. 5, 1900	2.0	15
Schodack Brook, L. I.	Sept. 5, 1900	5.7	12
	Sept. 8, 1900	3.0	10
	Sept. 15, 1900	2.5	18
SHALLOW PONDS.			
Average of 15 shallow ponds on Long Island during summer of 1900	....	3.0	Av. depth about 6 ft., and av. color about 30
Laurel Lake, Fitzwilliam, N. H.	Sept. 6, 1901	1.5	
Boston Public Gardens Pond	Oct. 17, 1901	2.0	
Frog Pond, Boston Common	Oct. 18, 1901	7.0	This pond contains a large number of fallen leaves.
	Oct. 19, 1901	5.0	
	Oct. 21, 1901	5.0	
	Oct. 22, 1901	5.0	
	Oct. 23, 1901	6.0	
	Oct. 24, 1901	6.0	
	Oct. 25, 1901	5.0	
	Oct. 29, 1901	6.0	
Farm Pond S. Framingham, Mass.	Nov. 15, 1901	2.0	
Nissitisset River, Pepperell, Mass.	Nov. 7, 1901	6.0	

In surface waters which are exposed to the atmosphere and contain but little organic matter, the amount of free carbonic acid usually varies from 2 to 5 parts per million. In Brooklyn, N. Y., the average amount in the tap water is 4 parts per million; in Boston it is about 2 or 3 parts per million; in Cambridge, Mass., about 5 parts. In Table XIII will be found the amounts of carbonic acid in various streams and shallow ponds. It has been found that in a general way the amount of carbonic acid increases with the color of the water, but this is not always the case. Pollution usually increases the amount of carbonic acid present. For example, a stream which flows through the town of Hempstead, L. I., contained on September 6, 1900, 2 parts per million above the town and 9 parts per million below it.

TABLE XIV

TABLE SHOWING THE AMOUNT OF CARBONIC ACID AT VARIOUS DEPTHS IN DEEP PONDS AND RESERVOIRS

POND OR RESERVOIR	DATE	DEPTH IN FT.	CARBONIC ACID (parts per mill'n)	REMARKS
Chestnut Hill Reservoir .	Sept. 20, 1901	1	3.0	
		13	3.0	
		26	11.0	
	Sept. 23, 1901	1	2.0	
		13	2.0	
		26	9.0	
	Sept. 30, 1901	1	2.0	
		13	2.0	
		25	6.0	
	Oct. 15, 1901	1	2.0	
		12	2.0	
		24	4.0	
	Oct. 21, 1901	1	2.0	After autumnal overturning.
		12	2.0	
		24	2.0	
	Nov. 4, 1901	1	4.0	
		2	2.0	
		24	2.0	
	Nov. 8, 1901	1	3.4	
		2	6.2	
		24	6.2	
	Nov. 18, 1901	1	3.0	
		2	3.0	
		24	5.0	
Hopkinton Res.........	Oct. 29, 1901	1	4.0	After autumnal overturning.
		26	4.0	
		52	4.0	
Framingham Res. No. 3.	Nov. 15, 1901	1	3.0	
Sudbury Res............	Nov. 15, 1901	1	4.0	
Spot Pond..............	Dec. 6, 1901	1	1.4	
		12	7.0	
		24	8.0	
Fells Res. G. H.........	Dec. 6, 1901	......	3.6	
Fresh Pond, Cambridge..	Sept. 28, 1901	1	1.0	
		23	8.0	
		46	16.0	

The amount of dissolved carbonic acid found in a shallow surface water depends, however, upon other factors than those which cause its formation. It is always complicated by reason of its reaction with the normal carbonates of the alkaline earths with which it may come in contact, and there is usually a tendency for it to diffuse into the atmosphere. This diffusion depends upon the vapor pressure of the atmospheric carbonic acid and the extent to which the water is exposed to the air. In the middle of swamps which are covered with tall vegetation to such an extent that the air does not circulate freely the carbonic acid is often high in the air and in the water in contact with it. At the bottom of thermally stratified ponds there is no opportunity for the water to come in contact with the atmosphere, and consequently there is often a concentration of carbonic acid in the lower strata. This is especially true if there are deposits of mud and organic matter at the bottom. (See tables XIV, XV, and XVI.)

TABLE XV

TABLE SHOWING THE AMOUNT OF FREE CARBONIC ACID AT DIFFERENT DEPTHS IN LAKE COCHITUATE (IN PARTS PER MILLION)

DEPTH IN FT.	1900 OCT. 12	1900 NOV. 9	1900[9] NOV. 16	1901 MAY 24	1901 JUNE 21	1901 JULY 19	1901 AUG. 28	1901 OCT. 11	1901 NOV. 8	1901[10] NOV. 14
1	2.0	2.8	3.6	1.6	2.0	2.0	2.0	2.6	4.0	6.0
5	2.2	3.0	......	......	3.6	......	......	......	......	....
10	2.25	2.8	......	2.0	5.6	3.0	2.0	3.0	4.0	....
15	2.25	2.8	......	5.2	5.6	6.0	5.0	4.0	4.0	....
20	2.30	2.8	......	6.8	6.0	6.0	6.0	10.0	4.0	....
25	9.4	3.2	......	6.0	6.0	......	6.0	......	......	6.0(26 ft.)
30	9.15	4.0	......	6.0	6.0	6.0	6.0	11.0	4.0	....
35	9.55	5.4	......	......	......	......	......	......	......	....
40	11.0	15.6	......	10.0	6.0	6.0	7.0	11.0	7.0	....
45	11.65	18.5	......	......	......	......	......	......	......	....
50	17.50	16.6	3.7	8.0	9.6	8.0	8.0	19.0	21.0	....
55	......	......	......	......	......	10.0	16.0	23.0	......	6.0(52 ft.)
60	......	......	......	8.0	12.0	12.0	16.0	23.0	24.0	....

The phenomena which take place at the bottom of a thermally stratified lake are most interesting. Below the thermocline the water is shut off from communication with the atmosphere. The processes of vital activity soon cause a diminution in the amount of dissolved oxygen and an increase in the amount of free carbonic

9 The lake overturned on Nov. 12, 1900. 10 The lake overturned on Nov. 10, 1901.

acid. If there is a deposit of organic matter at the bottom the oxygen may become entirely exhausted, after which decomposition may occur under anaerobic conditions. The anaerobic bacteria are vigorous producers of carbonic acid, and consequently a large amount of this gas goes into solution. The carbonic acid also unites with the iron present at the bottom, forming soluble ferrous carbonate. This gives rise to an increased color and turbidity of the water, which, on exposure of the water to the air, is still further increased by the oxidation and precipitation of the iron. Under the conditions which thus prevail at the bottom of a stagnant lake Crenothrix may develop. After the period of stratification ceases and circulation takes place through the vertical, the products of decomposition become distributed through the entire body of water. These phenomena are well illustrated by observations made at Lake Cochituate, and given in Table XV. See also Plates XXI and XXII.

TABLE XVI

TABLE SHOWING THE AMOUNT OF CARBONIC ACID AT VARIOUS DEPTHS IN A SMALL DISTRIBUTION RESERVOIR IN WHICH GROUND WATER IS STORED, TOGETHER WITH THE TEMPERATURE AND THE NUMBER OF MICROSCOPIC ORGANISMS PER C.C.

SEPTEMBER 4, 1900				JULY 25, 1901			
Depth	Temperature (Fahr.)	Amt. of free carbonic acid in parts per million	No. of microscopic organisms per c.c.[11]	Depth	Temperature (Fahr.)	Amt. of free carbonic acid in parts per million	No. of microscopic organisms per c.c.[12]
0	80.0	0.0	....	0	79.5	—5.0	5760
2	79.5	0.0	140	2	79.5	—5.0	....
4	79.5	0.0	....	4	79.0	—5.0	....
6	79.5	0.0	....	6	79.0	—5.0	6900
8	79.5	0.0	225	8	78.0	—5.5	2760
10	78.0	0.5	430	10	78.0	1.5	....
12	77.0	1.0	3575	12	77.5	1.5	800
14	76.5	1.5	2990	14	77.0	3.0	....
16	76.5	1.5	3610	16	76.5	4.0	....
18	75.5	2.5	4480	18	75.5	5.0	....
20	74.0	4.0	5660	20	75.5	6.0	600

In testing surface waters for carbonic acid it sometimes happens that a negative result is obtained; that is, the water is alkaline to phenolphthalein and requires the addition of a certain amount of acid to make it neutral. This phenomenon is generally associated with the presence of microscopic organisms, as referred to below. (See Table XVI.)

11 Chiefly Melosira and Synedra.

12 Chiefly Scenedesmus.

The amount of free carbonic acid in ground water is generally higher than in surface waters. This may be seen by an inspection of Tables XVII, XVIII, and XIX.

TABLE XVII

TABLE SHOWING THE AMOUNT OF FREE CARBONIC ACID IN VARIOUS DRIVEN WELLS ON LONG ISLAND

WELL	DATE	CARBONIC ACID (Pts. per mil.)
Gravesend, driven wells	August 20, 1900	2.4
New Utrecht, driven wells	July 20, 1901	4.0
Flatbush, driven wells	August 31, 1900	5.5
Pfalzgraf, driven wells	August 31, 1900	9.2
Blythebourne, driven wells	August 31, 1900	1.5
Far Rockaway, driven wells, before filtration	August 25, 1900	5.3
after filtration	August 25, 1900	6.6
Long Island City, Station 1	September 6, 1900	1.0
2	September 6, 1900	3.5
3	September 6, 1900	2.5
Jamaica Water-supply Co	September 7, 1900	6.0
Montauk Water-works	September 7, 1900	6.5
German-America Water-supply Co	September 7, 1900	2.0
Woodhaven P. S	September 8, 1900	3.0
Flushing Water-works	September 10, 1900	7.0
College Point Water-works	September 10, 1900	6.0
Oconee driven wells	September 14, 1900	2.0
Shetucket driven wells	September 14, 1900	7.0
Jameco driven wells		8.0
Springfield driven wells	September 17, 1900	12.0

In dug wells the amount of carbonic acid is often higher than in driven wells. It varies, however, with the character of the water, the character of the soil, the amount of ventilation, etc. A poorly ventilated well of good water may be higher in carbonic acid than a perfectly ventilated well of polluted water, but as a rule the extremely high figures for carbonic acid are obtained from polluted wells.

THE RELATION OF DISSOLVED OXYGEN AND CARBONIC ACID TO THE OCCURRENCE OF THE MICROSCOPIC ORGANISMS IN WATER

One of the great biological problems of the present time is to ascertain how the growth of the floating microscopic organisms, the plankton, may be controlled. Inasmuch as these organisms are the basis of the food-supply of fish and aquatic animals, it is desirable to know how to cultivate them, but as their presence gives rise to unpleasant odors and turbidities in drinking waters it is desirable to prevent their growth in reservoirs and lakes used for public supplies.

TABLE XVIII

AMOUNT OF FREE CARBONIC ACID IN MASSACHUSETTS GROUND WATERS [13] (IN PARTS PER MILLION)

LOCATION	PARTS PER MILLION
Driven wells at Lowell	28.5
North Easton	23.4
Fairhaven	21.7
Kingston	20.3
Sharon	19.6
Milford	15.5
West Brookfield	15.2
Framingham	15.1
South Hadley	9.2
Ashburnham	8.0
Revere	7.4
Malden	7.0
Methuen	2.9
Brookline (Seyler's method)	13.0[14]
Newton (Seyler's method)	16.0[15]

NOTE.—These results were obtained by using Drown's modification of the Pettinkofer method, by which the combined, free, and half-bound carbonic acid is determined before and after passing the sample through a tube filled with coarse gravel, the free carbonic acid being obtained by difference. The results are not strictly comparable with the results obtained by Seyler's method.

TABLE XIX

TABLE SHOWING THE AMOUNT OF FREE CARBONIC ACID IN THE WATER OF CERTAIN DUG WELLS IN FITZWILLIAM, N. H., AUG. 26, 1901.

WELL	CARBONIC ACID	REMARKS
No. 1	13.2	A shallow well with good ventilation.
2	16.1	Deep well, fairly well ventilated.
3	30.8	Deep well, poorly ventilated.
4	33.8	Deep well, fairly well ventilated.
5	33.9	Shallow well, very poorly ventilated.

13 H. W. Clark, *Rept. Mass. St. Bd. of Health*, p. 566. 1898.

14 By the authors, Nov. 18, 1901. 15 By the authors, Nov. 19, 1901.

Although much study has been given to this subject, and although it has been approached from many standpoints of bio-chemistry and bio-physics it is for the most part still unsolved. The relation of the micro-organisms to the oxygen contents of waters has been investigated, but their relation to dissolved carbonic acid has received scant attention, probably because of the elusive nature of this gas in water and the difficulty of determining its amount. Inasmuch as the algae and many of the troublesome protozoa are chlorophyl-bearing, the relation is one of fundamental importance. All such organisms require both oxygen and carbonic acid in their metabolic processes.

It has been shown that all bodies of water exposed to the air have what may be called a respiration. At times they breathe in oxygen and emit carbonic acid; less often they take in carbonic acid and give out oxygen. There is a continual adjustment taking place between the gases dissolved in the water and the gases present in the atmosphere, and when all the facts which enter into this transfer of oxygen and carbonic acid are known a long step will be taken towards solving the problem of the occurrence of the microscopic organisms.

Certain inferences may be drawn from the data now at hand. For some years it has been a well-recognized fact that ground water stored in an open reservoir is liable to become infested with troublesome algae growths, particularly with diatoms such as Asterionella, Synedra, Melosira, etc. The explanation given for this is chiefly based on the nitrogen content of the water. It is known that ground waters are usually rich in nitrates. That this form of nitrogen is readily assimilated by plants is shown by the fact that exhaustion of nitrates occurs in ground water supporting a vigorous growth of algae in the sunlight. Hence, it was assumed that nitrates are the fundamental factor in the development of the algae. Nitrates are indeed important, but the inadequacy of this explanation became manifest when it was observed that some water, comparatively low in nitrates, at times supported large growths of algae. Another reason for the development of algae in ground water suggests itself, namely, the presence of carbonic acid. Its occurrence in comparatively large amounts in waters of this class has been shown, and there is good reason to believe that the algae are influenced by it more than by the nitrates, although of course the latter are necessary.

The consumption of carbonic acid by diatoms has found illustration in several recent instances where Asterionella and Synedra have developed in ground waters exposed to the light. At the inlet of a certain reservoir where Asterionella were abundant the water contained five to eight parts per million of carbonic acid, while at the outlet it was entirely absent.

Again, in explaining the occurrence of diatom growths in the spring and autumn, immediately after the overturning of the water, carbonic acid has been largely ignored. We know that decomposition takes place in the lower strata of ponds which have deposits of organic matter at their bottoms and that the overturning brings the products of decomposition to the surface, where the nitrogen as free ammonia is oxidized to nitrates. In this form it is readily assimilated by the diatoms, which also are carried upward by the vertical currents to the region where they receive the necessary amount of sunlight for their growth. But we have not appreciated that a large amount of carbonic acid is simultaneously distributed through the water. But such is the case, and at the surface the chlorophyl-bearing organisms, under the influence of the sunlight, break down the carbonic acid, store up carbon, and assimilate oxygen. It is quite possible that the duration of their growth is determined by the amount of carbonic acid present, but observations upon this point are not convincing.

As a rule, growths of diatoms are most vigorous near the surface of a pond, but in light colored water heavy growths occasionally occur at a depth of twenty or even thirty feet. Indeed, instances are on record where growths of Melosira and Synedra have started at the bottom and finally spread through the entire body of water. Such cases may be explained by the vertical distribution of the carbonic acid. Table XVI shows this. On September 14, 1900, Melosira and Synedra were present below the thermocline in the water of a small reservoir. At this time oxygen was abundant at all depths, but carbonic acid was present only near the bottom.

The normal distribution of diatoms is illustrated by the results obtained in the same reservoir on July 25, 1900. On this date, the organisms were very numerous near the surface, but were almost absent near the bottom. It will be observed that above the thermocline the water was alkaline to phenolphthalein, indicating the presence of a certain amount of normal carbonates in solution. This alkalinity to phenolphthalein has been more frequently observed in connection with vigorous growths of the blue-green algae. It is possible that certain organisms under certain conditions have the power of taking carbonic acid from the hypothetical bicarbonates of the alkaline earths. This would accord with the fact noted long ago by one of the authors that, in Massachusetts water-supplies, heavy growths of organisms were somewhat more likely to occur in hard waters than in soft waters.

The presence of carbonic acid and oxygen at various depths throws light on another interesting problem of vertical distribution. It has been frequently noticed that some organisms at certain times of the year are most abundant, not at the surface or at the bottom, but at some point between the two,—generally just beneath the thermocline. They apparently shun the circulating water above and the stagnant water below. This is especially true of Mallomonas, attention to which was called by the writers in 1899.[16] The following illustration may be cited:

On July 17, 1896, samples of water taken at different depths in Lake Cochituate contained the following numbers of Mallomonas per c.c.:

DEPTH	MALLOMONAS PER C.C.
0	0
10	0
15	2
20	1454
25	794
30	548
40	112
50	88
60	64

These figures, together with the corresponding temperatures, are shown at Plate XXII. It will be seen that the organisms were concentrated just below the thermocline. From what is now known of the distribution of oxygen and carbonic acid in Lake Cochituate, the reason for this is at hand. At the surface and throughout the circulating water above the thermocline, oxygen was abundant, but carbonic acid was absent. Near the bottom of the lake there was carbonic acid but no oxygen, and likewise an insufficient amount of light for plant growth. But just below the thermocline there was both carbonic acid and oxygen; and as Mallomonas is a chlorophyl-

16 See Whipple and Parker, "Note on the Vertical Distribution of Mallomonas," *The American Naturalist*, Vol. XXXIII, No. 390. June, 1899.

bearing organism it found there conditions favorable for its development.

Some of the blue-green algae likewise develop more vigorously at a slight depth in the water than they do at the immediate surface. This is illustrated by Plate XXI, which shows the vertical distribution of the blue-green algae in Lake Cochituate during the summer of 1901, together with the temperature and amount of carbonic acid at corresponding depths. It is noticeable that while Anabaena generally seeks the surface, Aphanizomenon is most abundant just above the thermocline. (See also Table XX.)

The knowledge of this relation of free carbonic acid to the growth of organisms is of especial interest to water-works managers, as it offiers a chance of controlling the conditions. To some extent it has been unwittingly taken advantage of. The so-called process of aeration has been considered by some engineers and chemists to be instrumental in preventing growths of algae and protozoa; while others have adopted it without success. Much controversy has risen accordingly over the merits of the process, and this has been due largely to a misconception of what takes place. So far as the actual oxidation of organic matter is concerned or any real purification of the water by the action of oxygen, there is little to be said in favor of the process. This was conclusively shown by Dr. T. M. Drown[17] and by Dr. A. R. Leeds.[18] But in its effect upon the growth of microscopic organisms it is not a question of oxygen so much as of carbonic acid, and any favorable result from the process comes, not so much from putting oxygen into the water, as from getting the carbonic acid out. The process may be said to be one of decarbonization rather than of aeration.

It has been shown that water rich in free carbonic acid loses much of this gas on exposure to the atmosphere. This takes place to some extent in nature. A water passing in a thin sheet over a dam, or falling over stones in broken streams loses a certain amount of carbonic acid, as illustrated by Table XXI. So also does well-water which is pumped into a reservoir in such a way that it falls in a broken column. But usually it is necessary to resort to some artificial device if it is desired to remove completely the carbonic acid. The water must be allowed to fall through the air in drops or in very

17 *Mass. St. Bd. of Health Rept.*, p. 385. 1891.
18 *Journal Am. Chem. Soc.* Nov., 1890.

TABLE XX

TABLE SHOWING THE VERTICAL DISTRIBUTION OF MICROSCOPIC ORGANISMS, CARBONIC ACID, ETC., IN FRESH POND, CAMBRIDGE, MASS., ON SEPTEMBER 28, 1901

	DEPTH, 1 FOOT	DEPTH, 23 FEET	DEPTH, 46 FEET
	Number of standard units per c.c.		
Carbonic acid, parts per million	1	8	16
Color, Platinum scale	26	48	180
Turbidity, silica scale	1.5	1.5	7
Diatomaceae—			
Asterionella	13	....	3
Cyclotella	3	1	14
Cymbella	....	....	5
Melosira	18	22	720
Navicula	....	....	8
Nitzschia	39	15	12
Stephanodiscus	12	6	96
Surirella	....	....	16
Synedra	596	115	180
Tabellaria	....	....	....
Chlorophyceae—			
Gonium	10	....	....
Protococcus	14	....	....
Raphidium	14	....	....
Staurastrum	98	33	24
Zoöspores	2	....	....
Cyanophyceae—			
Anabaena	850	120	20
Aphanizomenon	1,190	310	....
Clathrocystis	600	300	100
Coelosphaerium	1,320	570	880
Microcystis	14	26	....
Schizomycetes—			
Crenothrix	....	140	220
Beggiatoa	....	....	100
Protozoa—			
Arcella	....	24	....
Ceratium	180	....	....
Codonella	....	....	64
Cryptomonas	4	....	....
Mallomonas	4	....	....
Monas	1	1	....
Trachelomonas	4	8	....
Cercomonas	2	6	....
Coleps	....	10	....
Rotifera—			
Anuraea	60	....	....
Asplanchna	100	....	....
Polyarthra	80	....	....
Total organisms	5,228	1,718	2,482
Amorphous matter	60	280	320

thin sheets or streams. Several methods have been devised for doing this, and some of these have proved successful. For example, at West Superior, Wis., where a ground water is subjected to sand filtration for the purpose of removing the iron, there is an aerator consisting of two tiers of four trays each, spaced two feet apart vertically. The bottom of each tray is a steel plate ¼-inch thick, punched with 3,900 ¼-inch holes. The water from the pump discharges into a trough above the trays and flows downward through them, becoming thus fully aerated and losing practically all of its free carbonic acid. (See *Eng. News,* Feb. 21, 1901.)

TABLE XXI

TABLE SHOWING THE LOSS OF CARBONIC ACID FROM SURFACE WATERS BY NATURAL PROCESSES OF AERATION

LOCALITY	PLACE OF COLLECTION OF SAMPLE	DATE	CARBONIC ACID (Pts. per mil.)
Hopkinton Reservoir	At crest of dam...............	8–28–'01	4.0
	At foot of overflow	8–28–'01	2.0
Ashland Reservoir........	At crest of dam...............	8–28–'01	2.6
	At foot of overflow	8–28–'01	2.0
	At crest of dam...............	11–15–'01	4.0
	At foot of overflow	....	2.4
Derby's Mill, Fitzwilliam, N. H..................	At crest of dam...............	9– 6–'01	6.0[19]
	At foot of fall	9– 6–'01	5.0
Beaver Brook, Waverly, Mass..................	Lower mill pond	10–13–'01	5.6
	After fall of 6 feet and run over 70 yards of rock............	10–13–'01	3.8
	After a further fall of 9 feet and passage through a pool 5 feet wide.....................	10–13–'01	3.0
	One-quarter mile below pool..	10–13–'01	3.0[20]
Fresh Pond, Cambridge...	Tap from pipe which supplies fountain	9–28–'01	3.0[21]
	Water falling from fountain...	9–28–'01	2.4[22]
Framingham Res. No. 1...	At crest of dam...............	10–15–'01	3.0
	Below dam..................	10–15–'01	2.4
Nissitisset River, Peperell, Mass..................	At dam	10– 7–'01	6.0
	After passing over dam.......	....	3.8

[19] The fall is about 8 feet.
[20] Brook shallow, bottom sandy and stony.
[21] The fountain plays 15 feet into the air.
[22] Sample taken at bottom of fall.

RESUMÉ

In this paper the laws which govern the solution of gases in water are stated with special reference to oxygen and carbonic acid. Winkler's method for the determination of dissolved oxygen and a modification of Seyler's method for the determination of free carbonic acid are recommended as the most practicable and are fully described. The need of careful collection of samples and immediate treatment is emphasized. The amounts of oxygen and carbonic acid present in surface and ground waters are described and illustrated by tables. The effect of decomposing organic matter, sewage pollution, stagnation of deep lakes, etc., upon the gaseous contents of waters are given special attention. It is shown that bodies of surface water have what may be called a process of respiration, at one time taking in oxygen and giving out carbonic acid, and again inhaling carbonic acid and exhaling oxygen. The effect of this process upon the presence of the microscopic organism is then pointed out. It is shown how ordinarily both carbonic acid and oxygen are necessary to the life of the plankton, and how the presence or absence of one or both of these gases helps to explain certain problems of vertical and seasonal distribution. The relation between the high carbonic acid in ground waters and the peculiar tendency of such waters to support growths of diatoms is pointed out. Finally, natural and artificial methods of freeing a water of carbonic acid are discussed.

PLATE XIX

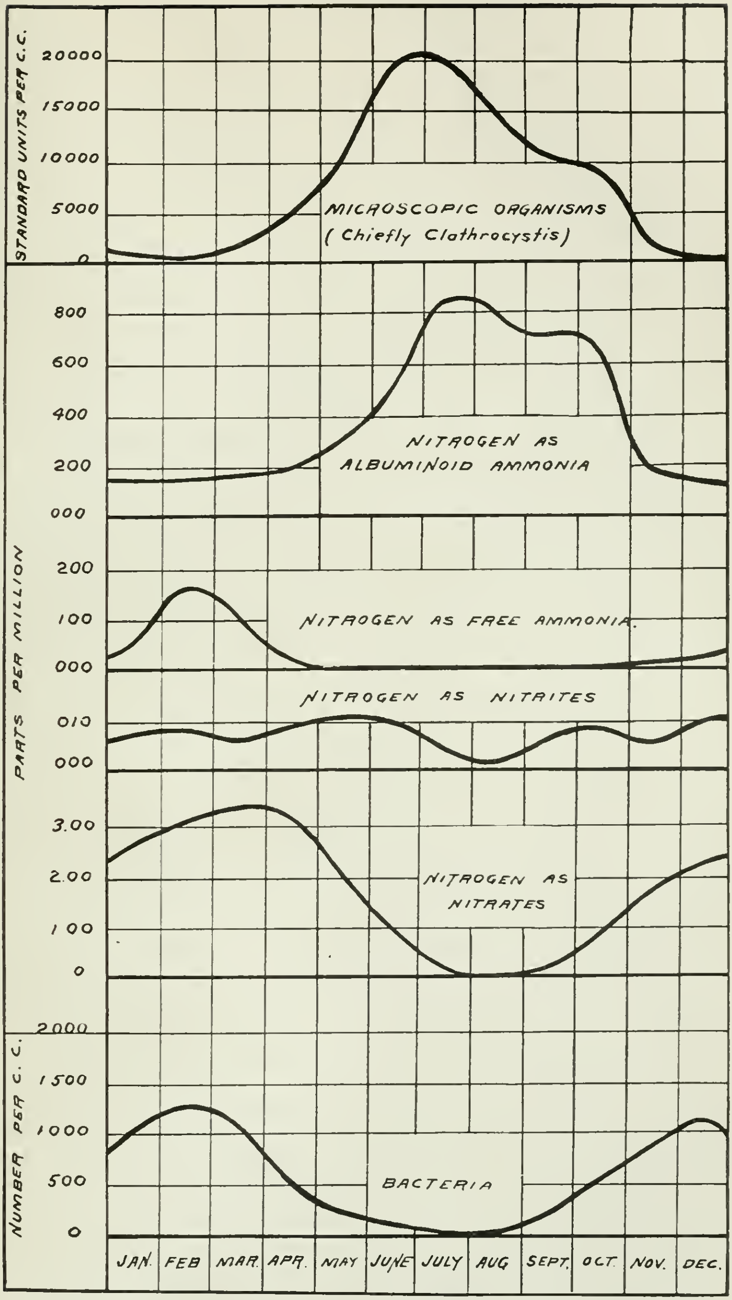


DIAGRAM SHOWING THE RELATION BETWEEN GROWTHS OF MICROSCOPIC ORGANISMS AND THE NITROGEN CONTENTS OF NATURAL WATERS.

PLATE XX

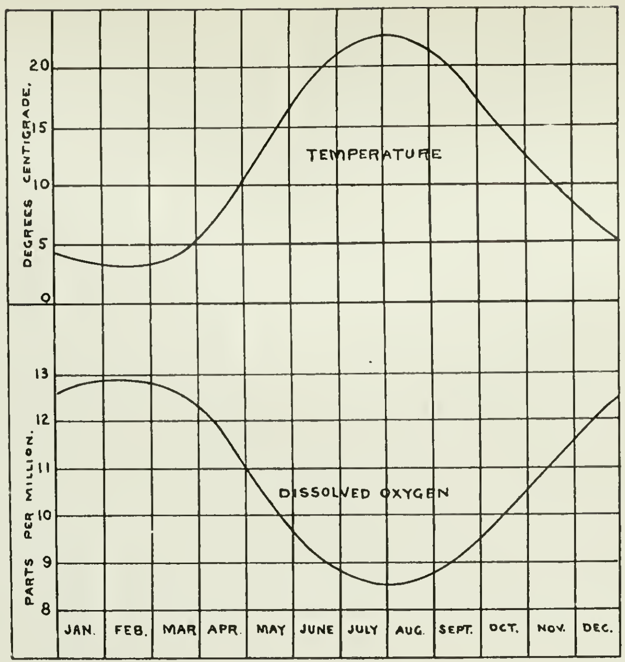


DIAGRAM SHOWING THE AVERAGE TEMPERATURE OF THE TAP WATER IN BOSTON, MASS. AND THE CORRESPONDING AMOUNT OF DISSOLVED OXYGEN WHEN THE WATER IS SATURATED.

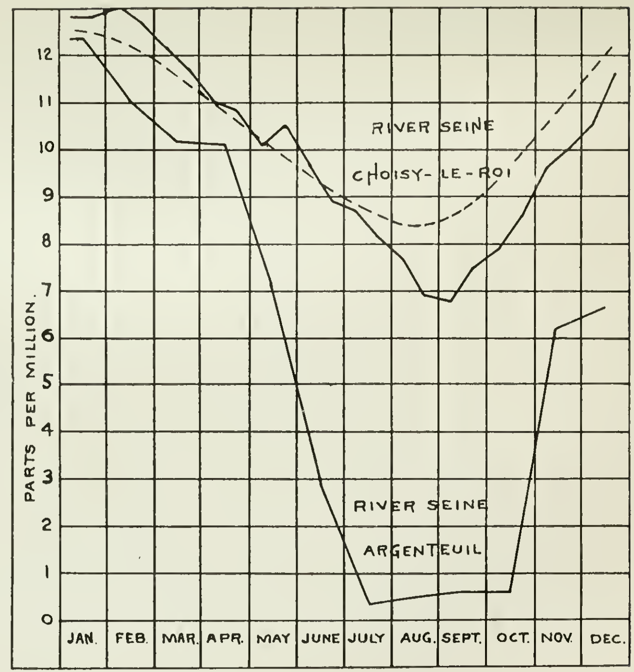


DIAGRAM SHOWING THE AMOUNT OF DISSOLVED OXYGEN IN THE WATER OF THE RIVER SEINE AT CHOISY-LE-ROI AND AT ARGENTEUIL DURING THE YEAR 1898. FROM ANALYSES BY M. ALBERT-LEVY. THE BROKEN LINE REPRESENTS SATURATION AT THE OBSERVED TEMPERATURES.

PLATE XXI

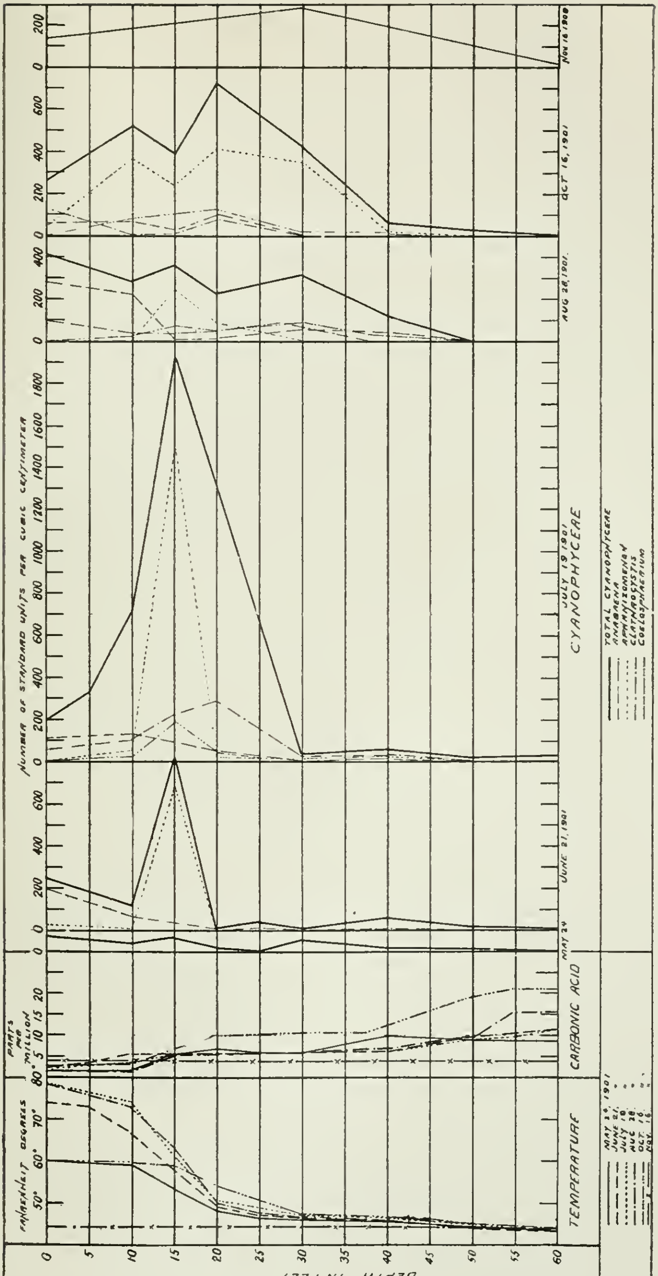
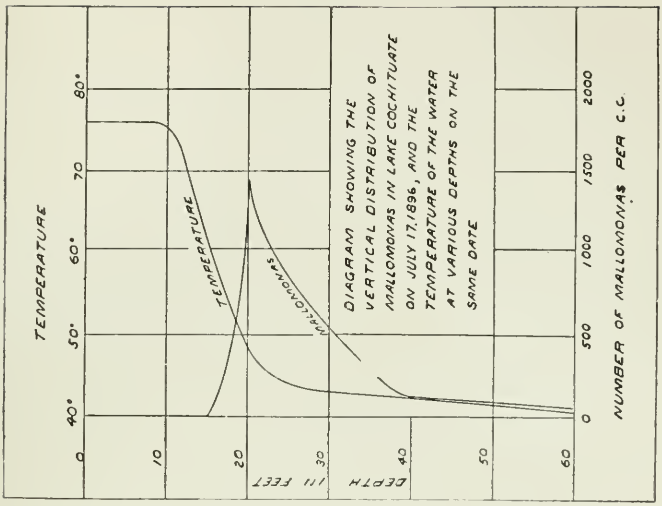


DIAGRAM SHOWING THE TEMPERATURE OF THE WATER THE AMOUNT OF FREE CARBONIC ACID AND THE NUMBER OF CYANOPHYCEAE AT VARIOUS DEPYHS IN LAKE COCHITUATE

PLATE XXII


TEMPERATURE
80°
70
60°
50°
40°
0
10
20
30
40
50
60
DEPTH IN FEET
TEMPERATURE
MALLOMONAS
DIAGRAM SHOWING THE VERTICAL DISTRIBUTION OF MALLOMONAS IN LAKE COCHITUATE ON JULY 17, 1896, AND THE TEMPERATURE OF THE WATER AT VARIOUS DEPTHS ON THE SAME DATE
2000
1500
1000
500
0
NUMBER OF MALLOMONAS PER C.C.

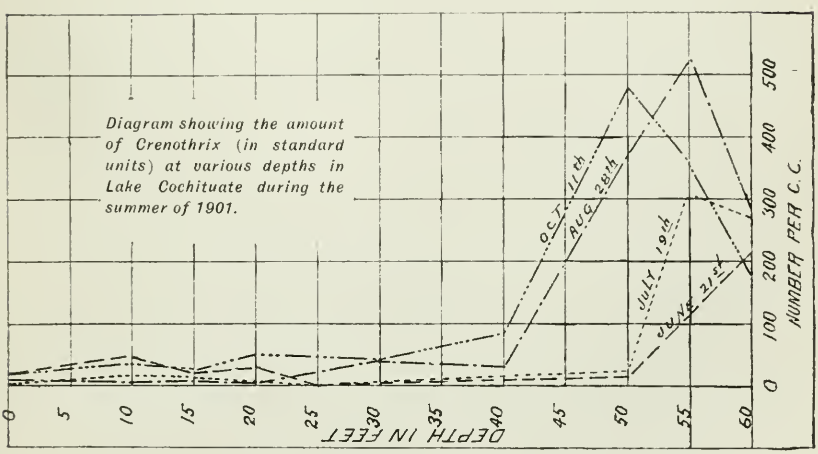


Diagram showing the amount of Crenothrix (in standard units) at various depths in Lake Cochituate during the summer of 1901.
OCT. 11th
AUG. 28th
JULY 19th
JUNE 21st
500
400
300
200
100
0
NUMBER PER C.C.
0
5
10
15
20
25
30
35
40
45
50
55
60
DEPTH IN FEET

THE STRUCTURE AND CLASSIFICATION OF THE CONJUGATAE

WITH A REVISION OF THE FAMILIES AND A REARRANGEMENT OF THE NORTH AMERICAN GENERA

By CHARLES E. BESSEY, Ph.D.

The preceding papers on Diatoms[1] and Desmids[2] have prepared the way for a discussion of the structure and classification of the remaining family (Zygnemataceae) as well as of the whole order (Conjugatae). In the papers cited it has been assumed that the diatoms and desmids have descended from filamentous ancestors, and these plants are there regarded as still typically filamentous, the filaments in most cases undergoing early solution. This view does not regard the diatoms and desmids as properly unicellular plants, although the cells of these organisms are for the most part early isolated, and pass their lives in this condition.

The Pond Scums (Zygnemataceae) constitute a third family of the order Conjugatae, and here, while the filamentous structure is preserved, the adhesion of cell to cell is so feeble that fracture takes place very easily. Although the cells do not separate so as to exist singly, there is evidence that spontaneous fragmentation does occur, the result being the formation of short, few-celled filaments, comparable to the "hormogones" of the Cyanophyceae. This tendency to individuality in the cells is indicated by the fact that in adjacent cells one may be dead and the other in vigorous life, or one may have taken part in the formation of a zygote by a sexual act, while the other is still active vegetatively.

It may be assumed that these plants have been derived from other filamentous forms, and that the adhesion of cell to cell and the consequent formation of a multicellular plant body had become a well-

1 "The modern conception of the structure and classification of Diatoms," in *Transactions of the American Microscopical Society*, Vol. XXI, p. 61.

2 "The modern conception of the structure and classification of Desmids," in *Transactions of the American Microscopical Society*, Vol. XXII, p. 98.

established habit long before the peculiarities arose which set them off as Zygnemataceae. Now in any existing plants which may have given rise to the Zygnemataceae the individuality of the cells is distinctly subordinated to the individuality of the filament, and there is a much closer relation of cell to cell. Such groups as the Ulotrichaceae and Chaetophoraceae, with their highly individualized filaments, may have given rise to the Zygnemataceae, and in this paper I shall assume such relationship for purposes of comparison. In the families named the filaments are composed of proper cells (uninucleate), and the chromatophores, which are relatively large and few in number, vary from a single broad band which encircles the nucleus, to several narrow, longitudinal bands. The differences between these cells and those of the Zygnemataceae are little if any greater than those to be found within the limits of the families, and it is reasonable to suppose that the necessary structural changes may have occurred as here suggested.

In the Ulotrichaceae and Chaetophoraceae the plants are propagated mainly by zoospores, and also by the fragmentation of the filaments artificially, and possibly spontaneously. In the Zygnemataceae fragmentation has been much increased, and propagation by means of zoospores quite suppressed, possibly because of the fact that these plants float upon still waters where fragmentation alone provides amply for their propagation. Motile zoospores being thus quite needless have accordingly disappeared.

The quiet habitat of the Zygnemataceae doubtless had to do, also, with the change in the motility of the gametes. While in the other families mentioned the gametes are ciliated and actively motile, as indeed is quite necessary in the running waters which they inhabit, in Zygnemataceae no such activity is necessary; and here the sluggish gametes, no longer ciliated, are guided in their short journey by the device of tubular extensions of their cell walls. The whole process in these plants is a much more sluggish one than in the plants with which they are here compared.

There is thus a marked degeneration in the filament of the Zygnemataceae, which shows itself in its ready fragmentation, and in the greater sluggishness of the gametes in generation. Both of these tendencies receive greater emphasis in the Desmids and Diatoms where fragmentation is so marked that in most genera the cells are isolated for the greater part of their existence. It appears also that the sluggishness in generation in the Zygnemataceae has been followed in some of the Desmids and Diatoms by a partial, if not complete, suppression of the sexual act. According to this view "conjugation," as the sexual act in the Conjugatae has been aptly called, is the result of degeneration. It is sexual reproduction on its way toward disappearance. Instead of affording an example of the *beginning* of sexuality, as has so often been suggested, these plants show sexuality on its way to *disappearance.*

These conceptions of the nature of these plants, and their relationship to other algae, require a considerable rearrangement in the sequence of the families and genera. In the papers cited above I have given expression to my ideas as to the proper sequence of the tribes and genera of the Desmids and Diatoms. The Zygnemataceae constitute so small a group that the task of arranging the genera in accordance with these ideas is not difficult. I have followed De Toni[3] in including the Mesocarpeae, which in my opinion do not differ sufficiently to be set off as a separate family. Wille,[4] on the contrary, regards the latter as entitled to family rank under the title Mesocarpaceae.

The order Conjugatae as here understood may be briefly characterized as follows:

Order CONJUGATAE

Plants microscopic, consisting typically of simple, unbranched rows of cells, often separating early into isolated cells; green, with lamelliform, taeniform (ribbon-like), or granular chromatophores, in one family yellowish by the addition of phycoxanthin; propagation by cell fission; generation by the union of the protoplasm of pairs of cells (conjugation, or aplanatic isogamy).

KEY TO THE FAMILIES.

A. Cells in cylindrical filaments	1. Zygnemataceae.
B. Cells mostly solitary, with cellulose walls	2. Desmidiaceae.
C. Cells mostly solitary, with siliceous walls	3. Bacillariaceae.

[3] Sylloge Algarum, by J. B. De Toni, p. 710. 1889.
[4] Die Natürlichen Pflanzenfamilien, by A. Engler and K. Prantl, Vol. I, Abt. 2. 1890.

Family 1. Zygnemataceae ("Pond Scums")

Cells with thin, smooth, cellulose walls, green, cylindrical, never constricted, always united into unbranched filaments; propagation by the accidental or spontaneous breaking of the filaments into short segments which grow directly into new plants; in some cases resting cells (aplanospores) are formed by a condensation of the cell contents and a thickening of the wall, these growing later into new plants; generation by the growth toward one another of tubular protrusions from adjacent or approximate cells and the formation of a continuous tube by the absorption of the contiguous end walls; through this tube the whole or part of the protoplasms of the two cells unite, either in one of the cell cavities or in the tube itself, forming a thick-walled resting-spore (zygote), which eventually grows directly into a new filament.—Minute fresh-water plants, floating on the surfaces of quiet pools and ponds.

Key to the Genera.

- A. Whole contents of the conjugating cells entering the zygote.
  - I. Conjugating tubes not septate.
    - a. Chromatophores 1 or more, parietal, taeniform, spiral. 1. *Conjugata.*
    - b. Chromatophores 2, stellate, axial, 2. *Lucernaria.*
    - c. Chromatophore a single axial plate, 3. *Debarya.*
  - II. Each conjugating tube with a septum at its base, chromatophores 2, stellate, 4. *Zygogonium.*
- B. Part of the contents of the conjugating cells entering the zygote.
  - I. Chromatophore a single axial plate, aplanospores none, 5. *Serpentinaria.*
  - II. Chromatophore a single axial plate, aplanospores present, 6. *Gonatonema.*

1. *Conjugata* Vaucher (*Spirogyra* Link).[5]—Cells three to ten times longer than broad (rarely only as long as broad); transverse walls plane or with circular folds; chromatophores one or more, taeniform, parietal, spiral, each with several pyrenoids; nucleus centrally suspended; conjugation between two cells of different fila-

[5] Unfortunately the earlier name *Conjugata*, applied to these plants by Vaucher in 1803, must replace the well-known *Spirogyra* of Link, dating from 1820.

ments or of the same filament; zygote formed in one of the conjugating cells.—Species many, in fresh waters.

2. *Lucernaria* Roussel (*Zygnema* of authors).[6]—Cells as long as, or two to five times as long as broad; transverse walls plane; chromatophores two, axial, stellate, each with one pyrenoid; nucleus central, between the chromatophores; conjugation between two cells of different filaments or of the same filament; zygote formed in one of the conjugating cells, or in the conjugation tube.—Species many, in fresh waters.

3. *Dabarya* Wittrock.—Cells five to ten times as long as broad; transverse walls plane; chromatophore a single axial plate; conjugation between two cells of different filaments; zygote formed in the conjugation tube.—Species one, in fresh waters.

4. *Zygogonium* (Kützing) De Bary.—Cells from shorter than broad to twice as long; transverse walls plane; chromatophores two, axial, irregular (sometimes joined in an axial strand); conjugation between two cells of different filaments, the two protoplasms in the conjugation tube cut off from their cells by partitions before union; zygote formed in the conjugation tube.—Species two, in fresh water.

5. *Serpentinaria* S. F. Gray (*Mougeotia* Agardh).[7]—Cells many times as long as broad; transverse walls lenticular; chromatophore one, axial, lamelliform, with two or more pyrenoids; conjugation between two cells of different filaments, or of the same filament, only a part of the protoplasm of each cell uniting to form the zygote, which lies in the conjugation tube and is separated from the cells by partitions.—Species many, in fresh waters.

6. *Gonatonema* Wittrock.—Vegetative cells as in *Serpentinaria;* conjugation unknown; non-sexual spores (aplanospores) produced by the elongation of cells and the formation of a pair of partitions near the middle to separate the zygote-like cells.—Species two, in fresh waters.

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6 Here again it is unfortunate that we are obliged to displace the familiar name *Zygnema* of S. F. Gray and Agardh (1821 and 1824) for the earlier name *Lucernaria* proposed by Roussel in 1806.

7 *Mougeotia* dates from 1824, when it was proposed by Agardh in his Systema Algarum, but this is antedated by *Serpentinaria* proposed by S. F. Gray in his Natural Arrangement of British Plants, published in 1821.

Family 2. Desmidiaceae ("Desmids")

See "The modern conception of the structure and classification of Desmids" in the *Transactions of the American Microscopical Society*, Vol. XXII, pp. 89 to 96, for a revision of the tribes and a rearrangement of the North American genera.

Family 3. Bacillariaceae ("Diatoms")

See "The modern conception of the structure and classification of Diatoms" in the *Transactions of the American Microscopical Society*, Vol. XXI, pp. 61 to 85, for a revision of the tribes and a rearrangement of the North American genera.

ON HYMENOLEPIS CARIOCA (MAGALHAES) AND H. MEGALOPS (NITZSCH) WITH REMARKS ON THE CLASSIFICATION OF THE GROUP

By B. H. RANSOM

WITH THREE PLATES

Hymenolepis carioca (Magalhaes)

One of the most common tapeworms of chickens in Nebraska, Iowa, and Missouri is the form noted by Stiles (96, p. 59) under the title of *Taenia* sp. Conard MS. Through the kindness of Dr. Conard I have had the privilege of seeing his manuscript, as well as his material and preparations, which have proved of great assistance in the identification of my specimens.

The worm in question is very slender and delicate. Scarcely larger than a coarse thread at its posterior end, it tapers gradually anteriad, becoming exceedingly tenuous at the neck. The length ranges from 30 mm. to 80 mm. The width at the neck varies between 75 μ and 150 μ, at the posterior end from 500 μ to 700 μ. The margins of the strobila are serrate (fig. 9), although the appearance of serration is often obliterated when the segments are much expanded (fig. 1). The posterior margins are not prolonged backward to any extent, so that there is little or no overlapping of the segments. Throughout the strobila the width of the segments is three to five times, or more, greater than their length; the worm is thus of the type with short segments such as *Hymenolepis diminuta* and others of the genus.

The head (fig. 8) is small, somewhat flattened dorso-ventrally. It measures from 140 μ to 160 μ in length, 150 μ to 215 μ in width, and 100 μ to 140 μ in thickness. The suckers are shallow and slightly oval, with a diameter of 70 μ to 90 μ. The rostellum (fig. 8, *ros*) is like that of *Hymenolepis diminuta*. It measures as it lies withdrawn into the head, 25 μ to 40 μ in diameter by 90 μ to 100 μ in length. As in *H. diminuta,* there is a small pocket (*rp*), lined with cuticula, and opening at its tip. The rostellum is unarmed. A head, sectioned *in situ* with a piece of intestine, possessed, upon the suckers, hooks (fig. 3) which were very small and caducous. The ventral root is long, while the dorsal root is only a mere knob. The slender, pointed blade forms an angle of 90° to 120° with the ventral root. They are of the same type as the hooks from the suckers of *Davainea Friedbergeri* (Stiles 96, fig. 237). The smallest have a blade 4 or 5 μ in length, and a ventral root of 2 μ to 3 μ. The blade of the largest hooks measures 6 μ to 7.5 μ, the ventral root 2 μ to 4 μ. The round neck measures from 0.6 mm. to 1.5 mm. in length, and 0.075 mm. to 0.15 mm. in width.

The genital pores are situated upon the right-hand margin of the strobila, normally somewhat in front of the middle of each segment (fig. 1, *gc*). Very rarely a pore will be found on the left-hand margin. The cirrus pouch (*cp*), seminal vesicle (*vs*), and seminal receptacle (*sr*) are usually easily recognizable in toto specimens. In ripe segments the last (fig. 9, *sr*) is quite apparent by reason of the mass of spermatozoa it contains. The last 30 to 100 segments are crowded with embryos so that the median field of each is fully occupied (fig. 9), and the embryos of one segment are separated from those of the adjacent one only by a double thickness of the thin uterine wall. Since the segments do not tend to break off singly from the strobila as they become ripe, and since the embryos which they contain form practically a continuous mass extending unbroken from one proglottis to the next, if a portion of the worm be broken off from its posterior end the entire series of proglottides will constitute what is in effect but a single embryo sac.

Four membranes may be distinguished surrounding the onchosphere (fig. 6). The space between the middle two is filled with a granular mass, and potentially, as well as actually in some cases, these two membranes, by close approximation, constitute but a single envelope. The three outer layers are thin and colorless, while the innermost next the embryo is often slightly tinged with yellow and is usually thicker than the others.

MEASUREMENTS OF EMBRYOS

SIZES IN MICRONS	LEAST	GREATEST
Outer envelope	36 x 36	70 x 75
Outer middle envelope	30 x 30	65 x 60
Inner middle envelope	26 x 26	40 x 35
Inner envelope	24 x 16	29 x 21
Onchosphere	18 x 14	27 x 19
Hooks (fig. 5)	10	12

A comparison of the points given above with the description and figures by Magalhaes (98) of *Davainea*(?) *carioca* will show that the *Taenia* sp? of Conard is the same as the form which Magalhaes has described. The presence of hooks upon the suckers might appear as a confirmation of the supposition made by Magalhaes that the species is a *Davainea,* but beyond this characteristic it possesses none of the peculiarities of that genus. The fact alone that it has a definite and persistent uterus precludes the possibility of such a generic relationship, and furthermore its close structural resemblances to the type of *Hymenolepis* justify its immediate reference to that genus.

The possession of armed suckers by a species of *Hymenolepis* is significant in that it demonstrates how little importance can be attached to such a character in establishing generic relationships. In fact, in many cases it can not be considered of more than specific value. Braun (94–00, p. 1718) has gone so far as to assign to this character a rank even higher than generic, by making it the sole distinguishing mark of the subfamily Davaineïnae, comprising the genera *Davainea, Echinocotyle,* and *Ophryocotyle.* He has thus bound together three groups of forms resembling each other only in the possession of armed suckers, and at the same time has separated the group *Davainea* from other forms which bear close resemblances to it in many respects, but do not have hooks upon the suckers. Beyond the fact that *Echinocotyle* and *Ophryocotyle* have armed suckers there can be no excuse, so far as our knowledge of their anatomy goes at present, for grouping them with *Davainea.* Moreover, such genera as *Monopylidium* and *Cotugnia,* although their suckers are unarmed, resemble *Davainea* too much to be placed in a separate subfamily, and certainly have more in common with the latter than with *Hymenolepis* or *Choanotaenia*. The subfamily Davaeneīnae consequently can no longer be maintained upon its original basis.

Internal Anatomy.—*Nervous System.*—Owing to the small size of the worm only a few of the details of the nervous system could be determined. There is, however, a well-defined bilobed ganglionic mass (fig. 10, *cg*) situated at the base of the rostellum. From it nervous processes (*an*) pass anteriad along the sides of the rostellum, within which, also, there is a considerable amount of nervous tissue. The lateral longitudinal nerves (*ln*) arise from the postero-lateral corners of the ganglia (figs. 1, 7, *ln*). The accessory lateral nerves are very small and only occasionally evident in the segments, lying a short distance dorsal and ventral from the main nerves.

Musculature.—Extending throughout the strobila are four dorsal and four ventral muscle strands, or small compact bundles, composed of only a few fibers (fig. 7, *im*). In the scolex they attach to the suckers, two to each. These slender strings comprise the inner longitudinal muscle layer, and correspond to the eight inner longitudinal muscle bundles of *Taenia inflata* Rud. as described by Jacobi (98) and of *Taenia microsoma, Drepanidotaenia anatina,* and another undetermined species as described by Wolffhügel (00). The outer layer of longitudinal muscles (*om*) consists of about one hundred muscle strands similar to the inner muscles and like them continuous from segment to segment. The origin of these muscles is similar to that of the outer longitudinal muscles of *Anoplocephala perfoliata* as described by Lühe (94, 96), *i. e.,* they are the prolongations of the longitudinal subcuticular muscles of the scolex. A layer of diagonal muscles (fig. 7, *dm*) is prominent in the older segments just outside the outer longitudinal layer. A transverse muscle system is represented only by a few slender isolated fibers (*tm*), restricted mostly to the extreme anterior and posterior ends of the segment, as is the case in many other forms of the genus. A few dorso-ventral fibers are also found in these regions.

The sac-like rostellum (fig. 10, *ros*) possesses a muscular wall consisting of an outer layer of longitudinal and an inner layer of circular fibers, as in *H. diminuta* (Zschokke 88).

Excretory System.—The longitudinal excretory canals unite in the scolex to form a ring at the base of the rostellum. From this ring four small vessels, about 1 μ in diameter with comparatively thick, highly refractive walls, enter the rostellum a short distance in front of its base. Near the middle of the rostellum the dorsal vessel on each side unites with the ventral vessel so that two closed loops are formed. Branches of the excretory system apparently similar to these loops have been described by Mingazzini (99) for *Hymenolepis murina.* I have also found exactly similar loops in the rostellum of *H. diminuta,* readily apparent in cross-sections. The ventral excretory vessels are larger than the dorsal vessels from the beginning (fig. 10, *vc, dc*). In the scolex the former measure 6 μ, the latter 4 μ. The ventral vessels later attain a size of 25 μ to 40 μ; the dorsal vessels retain their original small diameter or become even more attenuated. Transverse vessels connect the ventral vessels at irregular intervals of two to seven segments, usually at an interval of about five.

Reproductive Organs.—The three testes (figs. 1, 2, 7, *t*) lie near the middle of the segment and usually two to the left and one to the right of the median line. The vasa efferentia (fig. 2, *ve*) unite near the median line to form the vas deferens (*vd*) which runs forward to a point dorsal to the inner end of the cirrus pouch. It here turns to the left, then curves ventrad, and finally, bending to the right, enters the base of the latter. Between the first and second turns of the vas deferens, dorsal to the cirrus pouch, there is an enlargement, the vesicula seminalis (figs. 1, 7, *vs,* fig. 2, *vsa*), which may attain a size of 50 by 70 μ. Scattered over its surface, more especially at its distal end, are numerous large cells drawn out at one pole into a narrow process (fig. 7, *pc*).

The body of one of these cells is some 6 μ or 8 μ in diameter, while the length of the process, which has a diameter of about 1 μ, is 12 μ to 14 μ. The protoplasm is compact and finely granular, and each cell contains a spherical nucleus 2 μ in diameter, with a single prominent nucleolus. These cells are to all appearances exactly similar to the cells found in the same position but in much greater numbers in *Taenia transversaria, Taenia expansa,* and *Calliobothrium coronatum,* described by Zschokke (88) as prostate glands. I was unable to demonstrate, however, that these cells opened into the cavity of the vas deferens in *H. carioca* as described and figured by Zschokke. In the wall of the vas deferens between the vesicula and the cirrus pouch a few circular fibers are sometimes evident (fig. 7).

The cirrus pouch (fig. 1, *cp*) in adult segments measures from 120 μ to 175 μ in length by 15 μ to 18 μ in diameter. It is almost cylindrical, rarely perfectly straight, but bent more or less, usually toward the ventral surface in a gentle curve (fig. 7). Along its outer surface there are about twenty prominent longitudinal muscle bands, 2 μ to 3 μ in thickness and slightly less in width (fig. 4, *mp*). Similar muscle bands have been described in *Taenia depressa* by Fuhrmann (95), in *Taenia inflata* by Jacobi (98), in *Fimbriaria fasciolaris* and *Dicranotaenia coronula* by Wolffhügel (00), as well as in other forms by different authors. *Hymenolepis carioca* is remarkable by reason of the small number of these bands, and their relatively large size. Surrounding the middle part of the cirrus pouch is a layer of cells (figs. 4, 7, *my*), which, from their intimate relation to the muscle bands, are to be interpreted as myoblasts. They possess nuclei 3 μ in diameter, each containing a deeply staining nucleolus. These myoblasts are most prominent in the young segments before spermatozoa are found in the vas deferens. Circular muscles are lacking, and the membrane of the cirrus pouch (fig. 4, *sm*) lies directly beneath the muscle plates. Upon entering the cirrus pouch the vas deferens is much constricted (fig. 7). In thickness and general appearance, the wall of this narrow portion of the vas deferens resembles the membrane of the pouch, which seems to have turned in at this point to form a narrow tube through which the vas deferens passes. Beyond this narrow portion the vas deferens is dilated to form a second seminal vesicle (figs. 4, 7, *vs'*) The wall of this part of the vas deferens is surrounded by circular fibers which are most prominent in the region occupying the middle third of the pouch (fig. 7). At a point about one-third the length of the pouch from its distal end, the vas deferens becomes narrow again, to form the cirrus (fig. 7, *ci*), a thin tube not more than 1 μ in diameter, without apparent spines or musculature. In the space surrounding the vas deferens within the cirrus pouch are numerous small nuclei, 1 μ to 2 μ in diameter (figs. 4, 7). Both the cirrus pouch and the vagina are dorsal to the nerve and the excretory canal. From the diagonal muscles of the proglottis fibers turn in to attach to the outer portion of the cirrus sac, serving thus as protractors (fig. 7, *pr*).

The genital cloaca (fig. 1, *gc*, fig. 7) is from 12 μ to 36 μ deep, surrounded by longitudinal and circular fibers, the latter next the cuticula. The longitudinal fibers come from the diagonal system, or from the subcuticular longitudinal muscles, and attach to the tip of the cirrus pouch to form part of the system of protractors.

The opening of the vagina into the cloaca is ventral and posterior with respect to the cirrus. The vagina (figs. 1, 7, *vg*) is at first narrow, being only 1 μ in diameter. At a distance of 8 μ to 10 μ from its distal end, it is surrounded by a small bulb-like body (fig. 7, *vgs*), consisting of short, thick, muscular fibers running in a spiral. This bulb is apparently homologous to the vaginal sphincter of *Drepanidotaenia lanceolata* described by Wolffhügel (00a). Beyond the sphincter the vagina gradually enlarges, and swells out into a seminal receptacle, which may grow to be very large, so as to reach forward to the anterior limits of the segment, and even crowd in against the organs of the next. Inward it may extend considerably beyond the proximal end of the cirrus sac.

The ovary (fig. 1, *ov*) is a sac-like organ elongated transversely, faintly bilobed, or even slightly trilobed, as in *Taenia inflata* (Jacobi 98), lying in the posterior half of the proglottis toward its ventral surface. At its maximum it extends from one excretory canal to the other. The ova reach a diameter of 10 μ before leaving the ovary.

The yolk gland (*yg*) is spherical or ovoid, 30 μ to 40 μ in diameter, situated posterior and dorsal to the ovary, near the median line.

The uterus at first is simply a solid cord of cells (fig. 1, *ut*) extending transversely along the anterior border of the ovary and reaching the excretory canals on either side. With progressing development a cavity is formed by a hollowing out of the cord, and the uterus becomes a thin-walled sac which grows backward on the dorsal side of the ovary. As the uterus enlarges the ovary quickly disappears, and the former soon comes to occupy all the available space within the proglottis (fig. 9). The wall of the uterus consists of a thin membrane (fig. 7, *ut*) upon the outer surface of which are numerous small cells elongated sagittally, and fine fibers which seem to be extensions of the pointed ends of the cells. During the growth of the uterus a number of infoldings arise in its wall, mostly in the form of tubular processes, a few of which meet and fuse to form slender, bridge-like connections, so that finally the uterus is modified to a slight degree from its original simple sac-like condition.

With regard to its reproductive organs as well as in other respects *Hymenolepis carioca* is quite comparable to *H. diminuta* (Rud.), the type of the genus. Both forms possess unilateral genital pores, reproductive canals dorsal to the nerve and excretory canals, three testes, a large sac-like vesicula outside the cirrus pouch, and a second smaller one within. A large seminal receptacle, a more or less bilobed ovary, and a yolk gland posterior and dorsal to the latter are also present in both. The uterus in both arises first as a transverse tube anterior to the ovary, later filling the segment, and in each case is not a simple sac, but characterized by a greater or less number of inturned processes and bridges of tissue developed from its walls. Apart from the major complications arising during the growth of the uterus of *H. diminuta* as described by Zschokke (88), there are a great number of small processes extending from the wall of the uterus in among the eggs, which are quite like the comparatively insignificant infoldings of the wall of the uterus in *H. carioca*. The similarity between the eggs is obvious.

Hymenolepis megalops (Nitzsch)

Was first found by Nitzsch in the intestine of *Anas boschas* and *Dafila acuta*. Creplin (25) found in the rectum of *Anas marila* a specimen 54 mm. long and 2.25 mm. wide posteriorly, possessing a head almost 2.25 mm. in width, with a very short, obtuse rostellum. Later he found five much smaller specimens of which he gave incomplete descriptions. Two figures by Creplin (29) are reproduced by Braun (94–00). Dujardin (45) took two specimens from an *Anas boschas,* one of which was 52 mm., the other 35 mm. in length. He gives two figures of detached proglottides, and in addition a diagnosis of the form upon the basis of its external anatomy. Diesing (50, 64) merely adds to the list of hosts. Stiles (96) gives a short synopsis of *Taenia megalops* from previous authors, with drawings of a specimen taken from *Anas braziliensis* from the collection of the Vienna Museum. While he is of the opinion that from existing descriptions the worm can not be recognized with any degree of certainty, I believe, on the other hand, that the external characters are peculiar enough to enable one to identify it easily, and with little or no chance of error.

Four individuals of this tapeworm were collected by me, March, 1901, from the rectum of a pintail duck, *Dafila acuta,* shot on the Missouri river near Columbia, Mo. Two of the worms were young and immature. The other two were larger, and considerably more advanced in development, as several of the posterior segments contained embryos which were yet, however, without hooks.

The length of the largest specimen was 35 mm., and the width, almost uniform from head to tail, 0.55 mm. just behind the head, and 0.72 mm. at a point near the posterior end. The number of segments was 195. The head is large, 1 mm. in length by 1.1 mm. in width and thickness, and, viewed from the front, square with rounded angles (figs. 11, 17). The suckers are spherical, 0.4 mm. in diameter, and open forwards and outwards, near the four angles of the flattened anterior surface of the head. In the center of the anterior surface is the small orfice of the cavity of the rostellum. The length of one of the small specimens was 4 mm., its width 0.45 mm., and the number of segments about 70. The head measured 0.45 mm. in length by 0.75 mm. in width and thickness.

Strobilation begins immediately behind the head, and is very distinct almost from the first, by reason of the deep constrictions between the segments. These constrictions mark off a peripheral portion of the segment from the central portion (figs. 18, 19, 20). The central portions are continuous, while the peripheral portions are separated from one another by the constrictions. The outer surface of the projecting rims of the segments is marked by a number of longitudinal grooves (fig. 20, *gr*) noticed by Dujardin (45), which give the surface of the worm a corrugated appearance. The under surface of the rims is marked by tiny longitudinal ridges in the cuticula, folds made necessary by the decrease in area of the under surface when the rims, instead of extending laterally as in the youngest segments, come to point backward, as they do more and more with the increasing age of the segments.

MEASUREMENTS

	25TH PR.	175TH PR.
Width of proglottis from edge to edge of rim	550 μ	720 μ
Width of central portion of proglottis	350 μ	440 μ
Length of central portion of proglottis	30 μ	290 μ
Length of entire proglottis	30 μ	490 μ
Thickness of proglottis from edge to edge of rim	400 μ	280 μ
Thickness of central portion of proglottis	200 μ	240 μ

The genital pores (figs. 15, 19, *gc*) are unilateral, situated on the right-hand margin, and marked by a slight prominence. A line drawn transversely through the very base of one segment will pass through the margin of the preceding segment very near its genital pore. The main body of the proglottis thus lies anterior to the genital pore, with only the projecting rim extended behind.

Through Dr. Ward I am indebted to Dr. C. W. Stiles for the opportunity of comparing with my specimens one from the U. S. National Museum, the same from which the figures by Stiles (96) were drawn. This worm was much contracted and considerably shorter than my largest specimen, but possessed a few more segments, 200 to 210 in all, the posterior ones of which were transparent enough to show that they contained six-hooked embryos.

The embryos at the latest stage (fig. 13) reached in my specimens are round, 25 μ to 30 μ in diameter. The clear, transparent shell has a thickness somewhat over half a micron. The embryo proper measures 15 μ. Lying close against the inner surface of the shell is an ill-defined layer of flocculent substance, within which are three or four, possibly more, nuclei 2.5 μ to 3.5 μ in diameter, each containing a large nucleolus. A six-hooked embryo (fig. 14), from the specimen furnished by Dr. Stiles, possessed an outer shell about 45 μ in diameter, and a somewhat thicker (2 μ) inner envelope 22 μ x 27 μ in diameter, with hooks 12 μ in length. A very thin membrane, which usually lies so closely applied to the outer envelope as not to be distinguished, sometimes, under the influence of changes in osmotic pressure, draws away from the latter and thus becomes apparent, as shown in fig. 14.

INTERNAL ANATOMY.—The rostellum (figs. 12, 16, *ros*) is bounded by a layer of muscles (fig. 12, *rm*), some of which are longitudinal and some circular. In the parenchyma of the rostellum, just beneath the cuticula lining its cavity, is a dense layer of cells (fig. 12, *rc*), resembling somewhat the subcuticular cells elsewhere, but much more thickly crowded, and with more prominent nuclei.

Nervous System.—The nervous system shows an arrangement resembling in general that of *Taenia crassicollis* and *T. perfoliata* as described by Cohn (98). My observations agree less closely with those of Tower (00). The main lateral nerves (fig. 12, *ln*) in the scolex bend toward one another and are joined just behind the rostellum by a transverse commissure (*co*), which consists of two parallel strands of nerve fibers (fig. 17) as in *T. perfoliata.* The two halves of the commissure are connected by fibers running diagonally from one to the other, and between them lie numerous ganglion cells. Surrounding each sucker near its posterior pole is a circular ring or zone of nerve fibers, lying in the same horizontal plane as the transverse cerebral commissure, and joined to it at its point of union with the lateral nerve. Fibers from these nerve zones run in various directions over the surface of the suckers, and at intervals tufts are given off which extend radially toward the surface of the head (fig. 17). In the regions where the zones approach one another they are connected by interlacing fibers. From the transverse cerebral commissure near the median line, a dorsal and a ventral pair of parallel nerves (fig. 17, *dd, vv*) come off at right angles and extend almost horizontally dorsad and ventrad respectively to the nerve zones, joining them in the region where they approach nearest the median line. Fibers which cross at right angles between the two strands of the commissure establish a continuity between these dorsal and ventral nerves.

This cerebral complex corresponds roughly to that of *Taenia crassicollis* as given by Cohn (98). While the cerebral commissure connecting the main lateral nerves in *T. crassicollis* is long, in *T. megalops* it is short and moreover double as in *Taenia perfoliata.* The two pairs of nerves (*dd, vv*) mentioned above form a dorso-ventral commissure composed of two parallel right and left halves. The dorso-ventral commissure in *T. crassicollis* is single in the region where it crosses the transverse commissure, but separates fork-like dorsally and ventrally. The inner quadrants of the nerve zones of the suckers correspond to the commissures in *T. crassicollis,* which connect the main lateral nerves with the forks of the dorso-ventral commissure. The remaining portions of the zones together correspond to the "polygonal commissure." Nerves apparently homologous to the accessory lateral nerves (fig. 12, *na*) join the cerebral complex some distance laterad from the main lateral nerves, about 90° measured along the circumference of the nerve zones. In *T. crassicollis,* on the other hand, the main lateral nerves and the accessory nerves of each side have a common point of origin. The dorsal and ventral median nerves join the complex (fig. 17, *nm*) near the ends of the dorso-ventral commissure, as in *T. crassicollis.* The median and accessory lateral nerves are connected behind the complex by numerous commissures with one another and with the main lateral nerves. In *T. megalops,* while these eight nerves are prominent through some distance just behind the cerebral complex, they seem to disappear entirely in the posterior part of the scolex, and if they are present in the proglottides are too small and insignificant to be traced. From the point at which each lateral nerve joins the cerebral commissure, two nerves (fig. 12, *rvn*), the "apical branches" (Cohn) of the lateral nerves, extend forward on each side to join the rostellar ring (figs. 12, 16, *nr*) right and left. From each of these apical branches a nerve (*rn*) comes off to enter the rostellum. The apical branches of the median nerves join the rostellar ring dorsally and ventrally (fig. 16). From the point of union of each of these eight nerves with the ring, a branch of nerve fibers passes outward over the surface of the adjacent sucker. A number of nerves extend forward from the same points.

The lateral nerves are joined in three regions (fig. 19, *ag, mg, pg*) in each proglottis by dorsal and ventral commissures, as in *T. perfoliata.* The posterior commissures (fig. 18, *pdc, pvc*) are the most prominent and lie between the two longitudinal muscle layers, while the other two pairs lie just within the inner layer (fig. 20, *adc, avc*). In connection with each commissural ring of the proglottis in *T. perfoliata,* all three of which lie inside the inner longitudinal muscle layer, Cohn describes a second ring which lies between the muscle layers and joined with the former by radial fibers passing between the muscle bundles. It is this outer ring which forms the posterior commissures in *T. megalops.* An inner posterior ring, if present, is scarcely developed. Fibers faintly indicating such a ring are sometimes seen (fig. 18, *x*).

Musculature.—From the suckers powerful muscles of the inner longitudinal layer extend backwards grouped at first mostly in eight bundles (fig. 12, *im*). This muscle layer, which is very heavy and prominent in the anterior segments (fig. 18, *im*), becomes progressively thinner posteriad by the gradual reduction in size of the bundles (fig. 20, *im*). The outer layer (fig. 18, 20, *om*), consisting of a great number of small bundles, completely envelopes the inner layer and is distinctly separated from it. The bundles of this layer are of about the same size throughout the strobila, and hence in the posterior segments (fig. 20) are nearly or quite as large as the inner bundles. The origin of the outer layer is similar to that of *H. carioca*. There are no diagonal fibers. Dorso-ventral fibers are most prominent and numerous in the posterior portion of the proglottis. Transverse fibers are not present except a few in the posterior region (fig. 18, *tm*), and a few in the anterior region (fig. 15, *tm*), some of which have a special connection with the cirrus pouch.

Excretory System.—The dorsal canals lie some distance directly dorsal to the ventral canals (figs. 15, 18, 20). The former measure 15 μ to 20 μ in diameter in the anterior segments, and 9 μ to 15 μ in the posterior segments; the ventral canals in the most anterior segments have a diameter the same as that of the dorsal canals, while posteriorly they measure from 20 μ to 35 μ. A transverse canal connects the ventral canals in the posterior part of each segment. There is a basket-like plexus of small canals (figs. 15, 19, *xpl*) in connection with each ventral canal in the posterior half of the proglottis.

In the scolex the canals of both sides turn inward and approach each other as they pass forward. The dorsal canal (fig. 11, *dc*) soon turns outward again and describes a loop around the posterior surface of the sucker, returning back toward the ventral surface close behind the cerebral commissure. From the region of the dorsal vessel where it passes behind the commissure two small canals (figs. 11, 17, *er*), one dorsal and one ventral, extend forward to enter the rostellum near its base, each joining in the anterior portion of the latter a corresponding canal from the dorsal vessel of the other side. There are accordingly two closed loops of the excretory system extending forward into the rostellum, as in *Hymenolepis carioca* and *H. diminuta,* but quite different from them in that they form connectives right to left, instead of dorsal to ventral.

The dorsal canal continues toward the ventral surface, passes around the posterior face of the ventral sucker, and after completing the circuit curves outward and forward to pass anteriad between the dorsal and ventral sucker (fig. 17, *dc*). The ventral canal (fig. 11, *vc*) forms first a loop behind the dorsal sucker, posterior to and smaller than the loop of the dorsal vessel, then, returning toward the ventral surface, forms a second loop behind the ventral sucker also smaller than and posterior to the corresponding loop of the dorsal vessel. The returning limb of the dorsal loop of the ventral vessel crosses the outgoing loop on its anterior side. It is connected with the latter near the region of crossing by two or three small vessels, and continues ventrad as the outgoing limb of the ventral loop. The recurrent limb of the ventral loop turns outward like the corresponding limb of the dorsal vessel, passes behind the latter, and extends between the suckers toward the lateral surface of the scolex, finally turning anteriad to run forward in the same frontal plane as the dorsal vessel, between it and the surface of the head (figs. 11, 16, 17, *vc*). During this portion of the course of the two canals they are connected by numerous smaller vessels which pass at intervals from the dorsal canal forward and outward to the ventral vessel. The dorsal canal of each side finally unites with the ventral canal to form a loop right and left of the rostellum. The loops lie in nearly the same transverse plane. In two specimens examined the dorsal limb of the right-hand loop came from the ventral vessel, of the left-hand loop from the dorsal vessel (fig. 16, broken lines).

Reproductive Organs.—The three testes (figs. 15, 19, 20, *t*) are located posteriorly and toward the dorsal surface in the median field, ordinarily two to the left and one to the right of the median line. They are at their maximum size in segments 160 to 170, where they measure 90 μ to 115 μ through their largest diameter. The vasa efferentia are wide, short tubes uniting to form the vas deferens (fig. 15) which extends forward near the median line. Before entering the cirrus pouch it passes beyond the base of the latter and then folds back to form a small loop in which are commonly found one or two vesicular enlargements (fig. 15, *vs*), representative of the prominent seminal vesicle of *Hymenolepis carioca* or *diminuta*.

The cirrus pouch is a large, elongated, cylindrical structure attaining a maximum size of about 300 μ in length by 60 μ in diameter. It extends from the median line near the anterior end of the proglottis, passing with the vagina above the excretory canals and lateral nerve, backward and outward to the genital pore. A very thin layer of longitudinal muscle fibers forms its outer boundary. In mature segments the vas deferens is expanded within the cirrus pouch to a large seminal vesicle (fig. 15, *vs'*) which almost completely fills its posterior portion. The vas deferens continues distally from the seminal vesicle as a tube 15 μ to 20 μ in diameter, upon the outer surface of which is a layer of small nuclei. After a short distance it bends back toward the base of the pouch, gradually becoming smaller, and, reduced finally to a diameter of 3 μ to 4 μ, opens into the proximal end of the cirrus. The cirrus (fig. 15, *ci*) is a long, powerful organ, slightly coiled, equal to or greater than the cirrus pouch in length, and measures 15 μ to 20 μ in diameter. It possesses a thick wall, smooth outwardly but lined inside with stout bristles, best developed toward its outer end, where they are 6 μ to 10 μ in length. The arrangement of the organs within the cirrus pouch is similar to that of *Drepanidotaenia lanceolata* (Wolffhügel 00a). Most of the fibers of the transverse muscle system in this region extend between the left side of the proglottis and the base of the cirrus pouch (fig. 15, *br*). The remaining few (*tm*) continue across to the other side of the segment. Within the pouch is found a further system of fibers (fig. 15, *cr*) extending between the proximal end of the cirrus and the base of the pouch. Some of them are apparently continuations of the other fibers (*br*) just mentioned. These two aggregations of fibers seem to serve the functions of retractors of the cirrus pouch and cirrus, respectively.

The genital cloaca is from 30 μ to 50 μ deep. Into it open the cirrus and the vagina, the former posterior and dorsal to the latter. Although the opening of the vagina (fig. 19, *vg*) into the cloaca is very narrow, the lumen of its distal portion is wide and capacious, a condition which becomes more pronounced as the segments grow older, and the vagina begins to function as a sperm receptacle. It is covered by a prominent layer of nuclei. The widening of the vagina is accompanied by the appearance of ridges or rugae of the cuticula, the largest of which project 4 μ to 5 μ into the cavity. They are very thin and close together, and run around the vagina in a circular direction, so that in a longitudinal section they appear as a thick coat of cilia. It is likely that in many cases in which cilia have been described lining the cuticula-covered inner surface of the vagina, it is a question, not of cilia, but of projections similar to these ridges. At the base of the cirrus pouch the vagina, becoming narrowed to a diameter of 10 μ to 15 μ, turns backward beneath the former, and passes posteriad to a point beneath the yolk gland (fig. 15, *yg*).

This organ is a compact, ovoid body with a maximum size of 90 μ, lying towards the dorsal surface, beneath the points of union of the vasa efferentia of the testes.

The shell gland (fig. 15, *sg*) is about 50 μ in diameter, and lies immediately beneath the yolk gland.

The ovary (fig. 20, *ov*) is a simple sac-like structure, slightly elongated transversely, with a depression behind giving it a somewhat lenticular shape. From segment 158 to 168 the ovary increases in size very rapidly. In the former it has a transverse diameter of but 60 μ, in the latter it has attained a width of 210 μ, a thickness of 100 μ, and a length of 135 μ. It lies in the ventral half of the proglottis, entirely anterior to the posterior limits of the yolk and shell glands. The maximum size of the ovarian ovum is 12 μ.

The uterus develops in front of the yolk and shell glands, immediately dorsal to the ovary. In segment 160 it is represented by a little lenticular mass of cells 50 μ in diameter, lying ventral to the base of the cirrus pouch, and connected with the shell gland by an almost straight cord of cells 60 μ in length. In the segments immediately following, the anterior mass of cells has begun to arrange itself into a layer enclosing a central cavity; the uterine duct from the shell gland has grown longer, and become bent back and forth. The uterus continues to increase in size, and in segment 168 extends forward to the anterior border of the proglottis, a distance of 125 μ, and measures in the transverse diameter 180 μ. The second following segment (170) has a well-defined layer of cells upon the outer surface of the uterus, and this layer (fig. 19) becomes progressively thicker and more prominent toward the posterior end of the strobila. As the eggs pass out of the ovary it shrinks rapidly, and in segment 174, where all the eggs have entered the uterus, has entirely disappeared. The uterus expands forwards and outwards toward the surface, and more slowly backwards, as a simple sac without infoldings, differing thus from *Hymenolepis carioca* and *H. diminuta*.

In the last dozen segments of the worm, partial ruptures occur in the continuity of the strobila (fig. 19), caused perhaps by the sudden contraction of the segments when the worm was killed. In these segments the anterior end of the uterus is more or less exposed. Whether such action takes place by natural muscular contractions is uncertain, but there is certainly a tendency in this direction. Consequent upon the separation of a ripe segment from the strobila, however brought about, a large area of the surface of the uterus is laid bare, and in this area a thin membrane is all that separates the embryos from the outer world, facts which may play a part in their dispersal.

With regard to the systematic position of *T. megalops,* while it differs considerably in a number of points from the type of *Hymenolepis,* it is scarcely possible at the present time to define its affinities more accurately than to give it, for the sake of its three testes and unilateral genital pores, the place of an aberrant species in the above genus.

ON THE GENUS HYMENOLEPIS

The genus *Hymenolepis* in its present status is composed of a considerable number of species all characterized by the possession of three testes and unilateral genital pores. Cohn (99, 99a, 99b, 00a) divides the genus thus characterized into two subgenera upon the basis of the number of hooks. Upon *a priori* grounds alone such a division seems exceedingly artificial, and indeed Wolffhügel (00, 00a) has demonstrated by two or three cases that it is false and misleading by reason of the non-correspondence of the superficial characters taken by Cohn to more important internal relations. There is still further evidence in this regard.

H. carioca is clearly so similar to *H. diminuta* as to belong in the same genus. Since the rostellum is unarmed it would also, following Cohn's classification, fall in the same subgenus *Hymenolepis* s. str. Specimens in my possession of *Hymenolepis* sp.? from one of the gulls, *Larus Franklinii*(?) possess a freely extensible rostellum armed with 10 hooks of the form typical of the now disused genus *Dicranotaenia* Raill. Upon the basis of Cohn's classification we should refer it at once to the subgenus *Drepanidotaenia.* The form possesses three testes and in the details of cirrus pouch, the two seminal vesicles, seminal receptacle, ovary, yolk gland, and anlage of uterus shows striking similarities to *H. carioca.* There are the same number of inner muscle bundles and a definite system of diagonal muscles as in the latter. These two forms are very closely allied, and are much more similar to one another than to *H. diminuta.* The structural resemblance is certainly too great to allow of their separation into two different subgenera, if one of the subgenera is also to contain *H. diminuta.* To arrange them according to Cohn's system it would be necessary either to neglect their internal anatomy or to suppose that *H. carioca* in young stages possesses 8–10 hooks which are afterwards lost. That the latter circumstance occurs, however, seems improbable, otherwise we should not expect to find a specimen, as already noted, retaining hooks on the suckers, and at the same time with no trace of armature upon the rostellum. The foregoing facts, I believe, furnish a very good demonstration of the untenability of Cohn's division of the genus. A division may be necessary, but it must be made upon a different basis than that attempted by Cohn. Apart from this question it is not even certain that he has wisely modified the definition of the genus in restricting the number of testes to three. In Blanchard's description the number of testes is given as very few, most often three, which allows a desirable degree of latitude to this character.

The form described by Jacobi (98) as *Taenia inflata* Rud. possesses but two testes, and hooks which, while of the same form, are only a third as large as those of the type specimens examined by Krabbe. A tape-worm which Cohn (98a) considers the true *T. inflata* Rud., agreeing in all respects with Krabbe's description, possesses three testes, and he is accordingly of the opinion that Jacobi has described another species. The latter is possibly to be identified with *Taenia spiculigera* Giebel 1866. A similar form with two testes, from *Fulica americana,* has hooks 37 μ in length, somewhat larger than those of Jacobi's specimens, in this respect agreeing with *T. spiculigera* more closely than the latter. The suckers of my specimens are armed. In anatomical details this form agrees with Jacobi's description. It has, however, a seminal vesicle outside the cirrus pouch, besides the one within described by Jacobi. Except for the lack of agreement in the number of testes, *Taenia spiculigera*(?) is very like *H. carioca* and but for this difference would undoubtedly fall in the same genus. That this difference is not so important as may seem is shown by the fact that the number of testes in segments of *H. diminuta,* normally three, sometimes varies in either direction to two or four, as Grassi (88) has shown. I am able to confirm Grassi's observations, in part, as I have sections of *H. diminuta* showing four testes in some segments. It is therefore questionable whether such a difference is sufficient to separate generically two forms otherwise similar, whose lack of agreement in this regard may be explained as the result of a slight variation, which, although occurring but occasionally in one, has become permanent and normal in the other. According to this view *Taenia spiculigera* (?) should be brought under *Hymenolepis*.

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EXPLANATION OF PLATES

Figures outlined with camera except as stated otherwise.

ABBREVIATIONS

adc Dorsal anterior nerve commissure.
ag Anterior ganglion of lateral nerve.
an Anterior nerve from cerebral ganglion.
avc Ventral anterior nerve commissure.
br Retractor of cirrus pouch.
ci Cirrus.
cg Cerebral ganglion.
cv Transverse cerebral commissure.
cp Cirrus pouch.
cr Retractor of cirrus.
dc Dorsal excretory canal.
dd Dorsal halves of dorso-ventral commissure.
dm Diagonal muscles.
er Excretory loops of rostellum.
fga Anlage of female glands.
gc Genital cloaca.
im Inner longitudinal muscles.
ln Main lateral nerve.
mg Middle ganglion of lateral nerve.
mp Muscle bands.
my Myoblasts.
na Accessory lateral nerve. In fig. 16, point of union with cerebral complex.
mn Median nerve. In fig. 16, point of union with cerebral complex.
nr Rostellar nerve ring.
om Outer longitudinal muscles.
ov Ovary.
pc Prostate(?) cells of vas deferens.
pdc Dorsal posterior nerve commissure.
pg Posterior ganglion of lateral nerve
pr Protractors of cirrus pouch.
pvc Ventral posterior nerve commissure.
rc Subcuticular cells of rostellum.
rm Muscle layer of rostellum.
rn Nerve to rostellum.
ros Rostellum.
rp Cavity of rostellum.
rvn Apical branch from main lateral nerve to rostellar ring.
sg Shell gland.
sm Limiting membrane of cirrus pouch.
sr Seminal receptacle.
t Testis.
tm Transverse muscles.
ut Uterus.
vv Ventral halves of dorso-ventral commissure.
vc Ventral excretory canal.
vd Vas deferens.
ve Vas efferens.
vg Vagina.
vgs Vaginal sphincter.
vs Seminal vesicle. In fig. 4, vesicle of cirrus pouch.
vs′ Seminal vesicle of cirrus pouch.
xpl Plexus of excretory vessels.
x Dorsal posterior inner nerve commissure.
yg Yolk glands.

Plate XXIII

Hymenolepis carioca

Fig. 1. Ventral view of segments. Toto preparation. ×245.
Fig. 2. Dorsal view of very young segments. ×245.
Fig. 3. Hooks from suckers. Free-hand drawing. ×2600.
Fig. 4. Cirrus pouch and seminal receptacle. Transverse section. ×1100.
Fig. 5. Hook from onchosphere. Free-hand drawing. ×2000.
Fig. 6. Onchosphere with membranes. From specimen in formalin. ×535
Fig. 7. Transverse section through anterior region of proglottis. ×600.

Plate XXIV

H. carioca

Fig. 8. Scolex. Toto preparation. ×185.
Fig. 9. Ventral view of posterior end of strobila. Toto preparation. ×50.
Fig. 10. Frontal section of scolex. ×180.

H. megalops

Fig. 11. Excretory system in scolex. View from anterior. Reconstructions from transverse sections through scolex behind the rostellum. ×55.
Fig. 12. Frontal section of scolex. ×55.
Fig. 13. Young embryo. ×600.
Fig. 14. Six-hooked embryo. ×600.

Plate XXV

H. megalops

Fig. 15. Dorsal view of mature segment (No. 172). Reconstruction from sections. ×135.

Fig. 16. Transverse section through the anterior region of scolex. The broken lines are anterior to the plane of section. ×45.

Fig. 17. Transverse section of scolex at level of cerebral commissure. ×45.

Fig. 18. Transverse section through the posterior region of one of the first 35 segments. ×120.

Fig. 19. Frontal section through a mature segment (No. 180). ×120.

Fig. 20. Transverse section through the anterior region of a mature segment (No. 168). ×120.

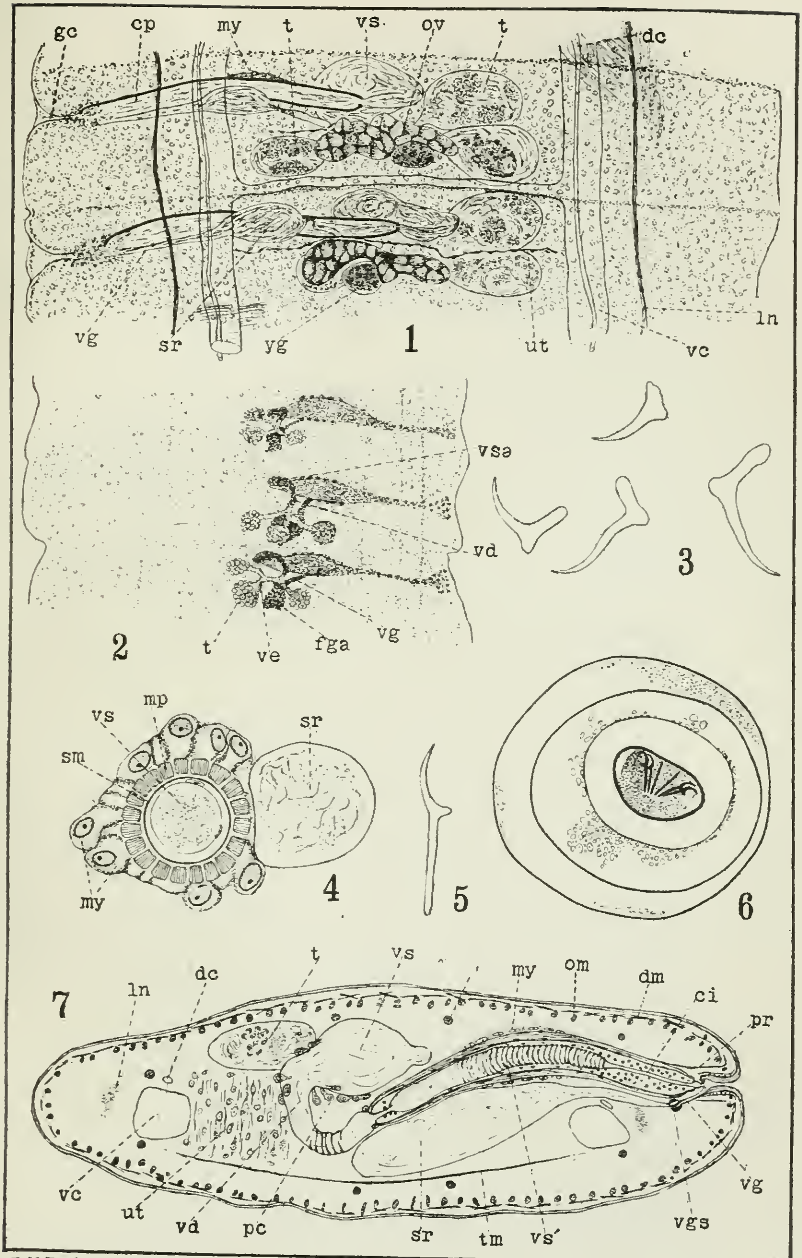
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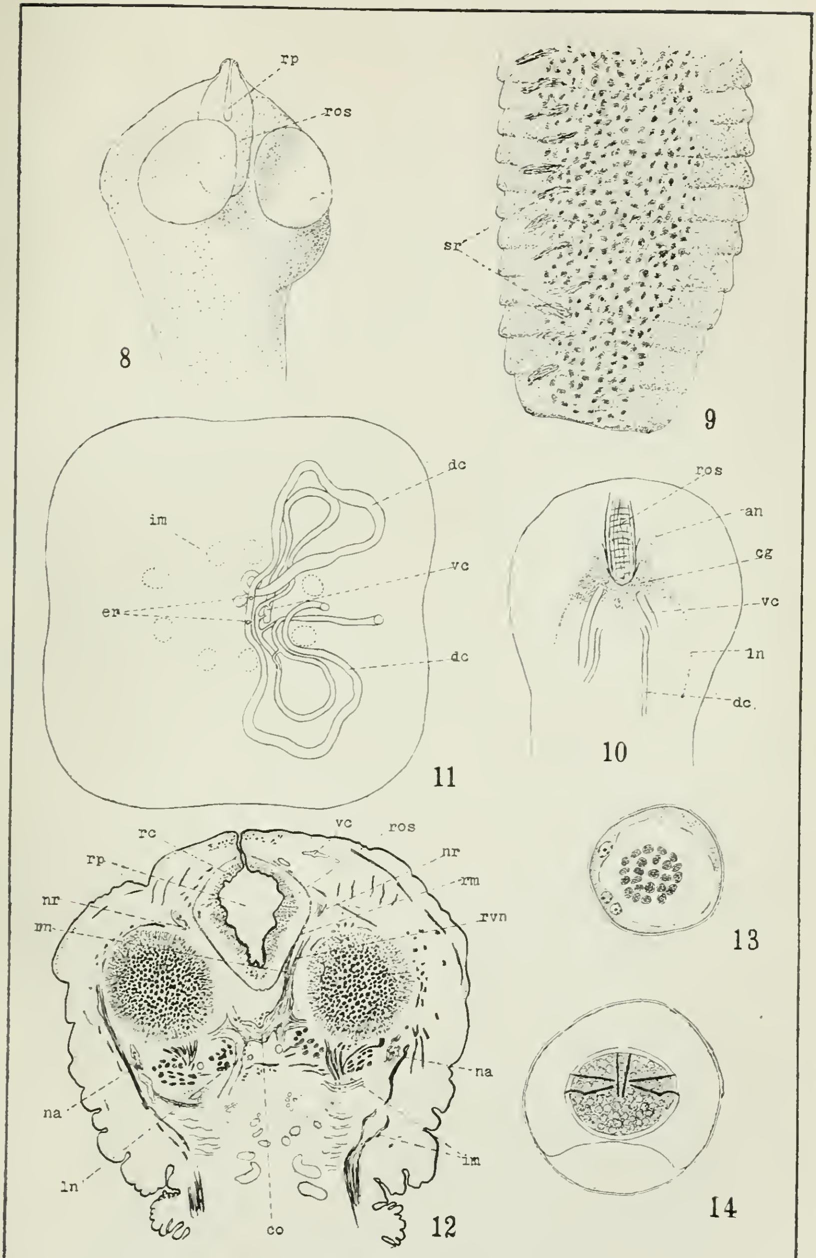
PLATE XXIV



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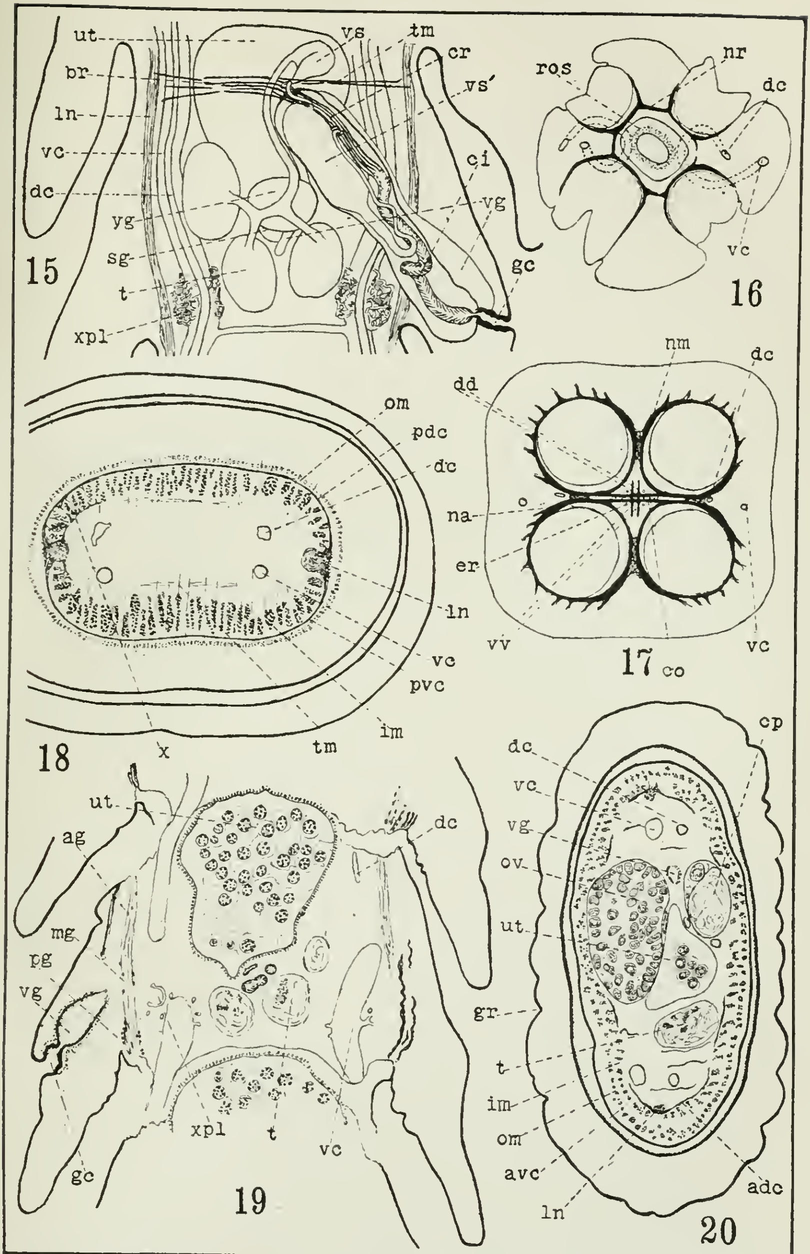
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STUDIES ON THE GENUS CITTOTAENIA

By RUFUS ASHLEY LYMAN

WITH TWO PLATES

The parasites studied were collected from rabbits in Nebraska and Kansas. A careful record was kept to give some idea of the degree of infection, and, although the number of rabbits examined is not large enough for entirely satisfactory results, yet some interesting data have been obtained. For this purpose 87 rabbits were examined; 47 were found to harbor parasites, 3[illegible] containing cestodes, 31 cysticerci, and 3 nematodes. The rabbits were of two different species, the common cotton-tail, *Lepus sylvaticus,* and the common jack, *L. melanotis.* Of the 60 rabbits killed in eastern Nebraska, 55 were cotton-tails and 5 jacks. Of the 55 cotton-tails, 38 were infected, but none of the jacks were. On the other hand, of the 27 killed in southwestern Nebraska and adjacent parts of Kansas, 12 were jacks and 15 cotton-tails. Of these 3 cotton-tails were infected, while the number of jacks infected was 7.

The cestodes taken from these rabbits represent four forms: *Cittotaenia variabilis, C. variabilis angusta* from *L. sylvaticus,* and *C. pectinata* and a single-pored form from *L. melanotis.*

Several specimens of the single-pored form were obtained, but were so poorly preserved that final determination of the species must be left until more material is obtained. The cestode, however, occupies a unique position, as the following facts show.

Each proglottis always contains only one set of female glands. The genital pores are unilateral and always on the right margin of the strobila. In this it resembles the genus *Anoplocephala,* but differs from it as regards the position of the female glands and the distribution of the testes. In *Anoplocephala* the testes are located in the aporose, the ovary in the pore side of the proglottis (Stiles 96); but in the present form the testes are distributed throughout the proglottis, and the ovary is located in the median line. This resembles somewhat the conditions found in *Bertia americana* Stiles 1896, but the testes extend the whole length of the proglottis as well as to the excretory canals on either side (fig. 9), and the female glands are always located in the median line in succeeding segments, and not right and left of the median line, as in *B. americana* and *B. americana leporis.*

So far as has been ascertained, the degree of infection by cestodes remains about the same throughout the year, at least for the species *Cittotaenia variabilis.* This form has been collected at all seasons and seems to be about as frequent in the winter months as in the summer. Riehm (81) states that it is said that *C. pectinata* occurs in the European hares only in the fall and the first half of the winter, but the adult parasite was found in Rawlins county, Kansas, as early as March and throughout all the spring and summer months.

The number of worms found in a single rabbit seems to vary with different species. The largest number of *C. variabilis* found in a single rabbit was 5. They often occur singly, but generally in pairs. Twelve individuals of *C. variabilis angusta* were found in one rabbit. *C. pectinata* seems to occur in greater numbers. Goeze mentioned the fact that 20 or 30 are found in a single host. In the present case as many as 54 were taken from one rabbit.

THE GENUS CITTOTAENIA

This genus was first proposed by Riehm in 1881. In it and in *Dipylidium* R. Leuckart he placed the double-pored forms of rabbit cestodes, while the single-pored forms he placed in *Taenia.* However, in the same year, he rejected *Cittotaenia* as a genus and placed the only species in *Dipylidium.* In 1891 R. Blanchard proposed a new genus, *Moniezia,* based upon the number of genital pores. In this genus he included the double-pored forms of cattle, sheep, and allied animals and also *T. festiva* R. 1819 from *Macropus giganteus, T. marmotae* Frölich 1802 from *Arctomys marmota,* and *T. pectinata* Goeze 1782, *D. Leuckarti* Riehm 1881, and *D. latissimum* Riehm 1881 from rabbits. Blanchard placed the single-pored forms in *Anoplocephala.* In 1893 Railliet proposed the new genus *Ctenotaenia,* with *T. marmotae* as type, and placed here *Ct. Goezei* (=Riehm's *C. latissima*), *Ct. Leuckarti,* and *Ct. pectinata.* The establishment of this genus was an error on the part of Railliet, who evidently overlooked Riehm's first paper. The same mistake was made by Stiles in 1895, and by Stiles and Hassall in 1896, who accepted Railliet's genus *Ctenotaenia.* Because of the many differences between the double-pored cestodes of rodents and ruminants, Stiles in 1893 separated the double-pored forms of rodents, which had been placed in *Moniezia* by Blanchard, from that genus, but did not attempt to classify them. In 1896 he adopted Riehm's formerly discarded genus, *Cittotaenia,* for the double-pored forms, giving it priority, of course, to Railliet's genus *Ctenotaenia.* Stiles distributed the single-pored forms among the genera *Anoplocephala* E. Blanchard 1848, *Andrya* Railliet 1893, and *Bertia* R. Blanchard 1891.

Cittotaenia pectinata (Goeze 1872 partim, Riehm 1881) Stiles and Hassall 1896.

The history of this parasite is thoroughly reviewed by Stiles (1896). The species has been reported from Germany and France, but up to the present instance it has not been reported in America, and Stiles (1896) considers his *C. variabilis* the American representative of *C. pectinata.*

The parasites assigned to this species were collected in Buffalo county, Nebraska, and Rawlins county, Kansas, from *Lepus melanotis,* and are certainly not identical with *C. variabilis* Stiles and Hassall (96), but resemble very closely the form described by Riehm as *Dipylidium pectinatum,* and by Stiles and Hassall (96) as *C. pectinata,* differing only in some minor particulars, to which attention will be called in the description of the various organs.

External Characteristics.—The adult strobilae do not vary greatly in size. In 54 specimens of various ages taken from a single rabbit the parasites range from 7 mm. to 71 mm. in length. The smallest is 7 mm. long and possesses 40 proglottides. The strobila is leaf-like in form, a characteristic which presents itself in all of the young forms and persists more or less perfectly as long as all the proglottides remain intact. The general shape gives one the impression of a large liver fluke, being widest near the center of the body and gradually tapering toward both ends. In the larger specimens the anterior portion is comparatively narrow, becoming lanceolate. The posterior proglottides always become narrower and longer, often reaching 1.5–2 mm. in length. The strobila attains its greatest width, 9–10 mm., about 15–20 mm. back of the head, and then remains comparatively uniform in breadth until near the posterior end. Following is a table showing the length, the breadth in different regions, and the number of proglottides present in five typical strobilae. All measurements are given in millimeters.

TOTAL LENGTH OF STROBILA	WIDTH 2 MM. BACK OF SCOLEX	WIDTH 10 MM. BACK OF SCOLEX	WIDTH IN WIDEST PLACE	WIDTH OF POSTERIOR ATTACHED PROGLOTTIS	NO. OF PROGLOTTIDES	
44	3	6	8.5	2.5	140	Every proglottis present.
52	3.5	6	9.5	2	130	Every proglottis present.
68	3.5	5.5	7	4	125	Posterior proglottis gone.
27	3.5	7	8	4	110	Posterior proglottis gone.
71	4.5	7	9	8	140	Several gone.

The proglottides are always broader than long. When the terminal proglottis is present, it has the form of a bulb applied closely to the preceding proglottis. At its extreme posterior part is a noticeable depression, the opening of the excretory canals. The posterior border of each proglottis is smooth and overlaps the following proglottis but slightly. The genital pores, two in each proglottis, are situated about the middle of the segment margin. They are never prominent, and usually can be distinguished only by the aid of a lens, and often only in section. The cirrus has never been found protruding from the pore.

The head is dome-shaped (fig. 6) and its measurements are much larger than those given by either Stiles or Blanchard for *C. pectinata*. Stiles in his diagnosis gives 0.25 mm. for the diameter and 0.125 mm. for the thickness of the head, and says that the suckers are small, but gives no measurements. Blanchard (1891) gives measurements as follows: head, 315 μ to 340 μ broad; suckers 142 μ long by 135 μ broad; opening 80 μ long by 53 μ broad. In the present form the diameter of the head varies from 0.41 to 0.45 mm.; the thickness from 0.28 to 0.31 mm. While the head is much larger, the suckers are small, being about 0.12 mm. long by 0.088 mm. broad. The cavity of the sucker measures from 64 to 74 μ long by 28 to 34 μ broad. In section the suckers are seen to open nearly straight forward or at a very small angle outward. In all cases, from the smallest to the largest strobila, the neck is absent, segmentation beginning immediately at the base of the head.

Musculature.—There are two dorsal and two ventral plates of longitudinal fibers (fig. 4, *l m*). The outer plates are much the larger. The fibers tend to run in bundles, and single fibers often run through 10 to 40 proglottides. Certain fibers running in adjacent bundles branch off and form anastomoses with other bundles, and so a dense network of fibers is formed. The inner longitudinal muscle plate is not as highly developed as the outer. Near the lateral margins of the strobila, the plates of the dorsal and ventral sides approach each other and finally meet. The inner plate always remains separate from the outer, but its fibers become much less distinct at the margin of the proglottis. Directly within the inner longitudinal plates there are two transverse plates of fibers which run entirely across the proglottis and enclose the male and female reproductive glands (fig. 4, *t m*). A third system is present as sagittal fibers (fig. 4, *s m*). They run dorso-ventrally, forming a dense network in the parenchyma between the dorsal and ventral transverse plates. They branch greatly, and these branches form a network around the testicles and the various female glands. Many of them pierce the transverse and the longitudinal plates.

Excretory System.—There are four longitudinal canals, two dorsal and two ventral. These persist throughout the anterior, the middle, and most of the posterior portion of the strobila. In the extreme posterior portion they become so branched that it is often impossible to distinguish dorsal canals from ventral. This is quite different from the description given by Stiles, who, in his diagnosis (96), says that the dorsal canal was not observed. Riehm (81) remarks that the dorsal canal becomes obliterated some distance from the head. In the present form the dorsal and the ventral canals are nearly the same in size. The diameter of the ventral canal varies somewhat, while the dorsal remains more nearly constant. The diameter of the ventral canal varies from 34 μ to 48 μ the dorsal from 34 μ to 40 μ. The dorsal canal (fig. 4, *d c*) lies dorsal and slightly median of the ventral, about 0.75 mm. from the margin of the proglottis. In the head the dorsal canals unite, likewise the ventral. The dorsal canals pass dorsal to the nerve ganglion, while the ventral canals run ventral to them, and the two canals formed by the union of the four unite between the suckers, forming a single canal, which ends as a blind tube near the anterior point of the head (fig. 2, *b e c*). A loop is formed here by the canals around the ganglia, and the blind sac is an anterior projection from the point where the ducts unite. The ventral canals are connected by a transverse canal in the posterior portion of each proglottis. The transverse canals of adjacent proglottides are again connected by secondary longitudinal canals, which often branch and give the parenchyma the appearance of being divided into little islands (fig. 7). This network of secondary longitudinal canals is more prominent in the anterior than in the posterior portion of the strobila. When the posterior proglottis is attached, the excretory canals come together, forming a more or less irregular reservoir (fig. 3, *r*), which opens at the excretory pore through many canals.

Nervous System.—Two ganglia are located in the head just back of the suckers. They lie between the arms of the loop formed by the dorsal and the ventral canals (fig. 2). Each ganglion is about 53 μ long by 40 μ wide. They are connected by transverse commissures. Small nerves are given off anteriad to the suckers. The main nerve trunks leave the ganglia at the sides, run toward the margins of the head, and turn backward. There are three distinct longitudinal nerves present. Two run ventral to the genital ducts and one dorsal. The main trunk lies just outside of the ventral longitudinal canal (fig. 4, *m n*). It runs in about the middle of the strobila in the dorso-ventral direction except, where it passes beneath the genital canals, it dips slightly ventrally (fig. 5, *m n*). Its average diameter in the anterior region of the strobila is 60 μ. In the posterior portion of each proglottis there is a ganglionic enlargement from which nerve fibers are given off. Some run in the direction of the genital pore, while others pass toward the median portion of the proglottis, but their course can not be traced. No transverse proglottidal commissures have been found. The dorsal and the ventral trunks are about the same size, averaging 13 μ in thickness. The ventral lies directly below the main trunk, and the dorsal directly above, but dorsal to the genital ducts. Both secondary trunks are connected with the primary by commissures in the posterior portion of each proglottis (fig. 5, *c o*). From this section the relative position of nerve trunks, commissures, and genital ducts can be seen. The posterior commissures are constant. Just behind the vagina and cirrus pouch are the other commissures connecting the main trunk with the secondary trunks, but these are not as well developed as the posterior commissures and are not as constant.

Male Reproductive Organs.—The anlagen of all the genital ducts appear in the proglottides immediately behind the head. The anlagen of the testes appear first about 6 mm. or 7 mm. from the anterior extremity of the head. They develop repidly and do not atrophy in the posterior region of the strobila, the capsules nearly always remaining in perfect form. Even in the posterior proglottis they are found grouped around the excretory pore and between the canals leading to the pore (fig. 3, *t*). There are from 100 to 125 in each proglottis, arranged in a quadrangle confined to the dorsal portion of the proglottis and posterior to the uterus. They extend posterior from the ovaries to the longitudinal canals (fig. 1). This is a characteristic of much importance, since Stiles quotes it as one of the important differences between the European form, *C. pectinata,* and the American representative of the same species, *C. variabilis,* in which the testes extend to, but not beyond, the ovaries. They are nearly spherical in form, averaging 70 μ in diameter, but often attaining a thickness of 92 μ. Running from each testis is a small duct, which joins the transverse tubule. There are two of these tubules on each side of the proglottis. One receives the ducts from the testes lying in the middle portion of the proglottis, while the other receives those from the testes lying back of the ovary and those lying externally toward the longitudinal canals. These tubules join posterior to the ovary and form the vas deferens.

The vas deferens runs dorsal to the ovary in an outward oblique direction toward the anterior end of the proglottis. Its usual length is 0.75 mm. to 1 mm. In the younger stages it is not twisted, but later it becomes greatly convoluted (fig. 4, *v d*), forming loops in the dorso-ventral direction only.

The vesicula seminalis is quite variable. Often there are one or more small swellings in the vas deferens just before reaching the cirrus pouch, but, when present, they are very much smaller than the figures of Riehm would indicate. There is usually just inside the cirrus pouch an enlargement which, in some cases, nearly fills the pouch and is filled with a dense mass of sperm.

The nozzle-shaped cirrus pouch is very large, extending some distance mediad from the longitudinal canals (fig. 1, *c p*). Its length varies from 0.925 to 1.075 mm. and its width from 65 μ to 85 μ. The pouch is muscular, consisting of two sets of muscle fibers (fig. 8). The outer layer consists of longitudinal fibers; the inner, which is also the thicker, consists of circular fibers. The cirrus wall averages from 5 μ to 24 μ in thickness. It contains both circular and longitudinal fibers arranged similarly to those of the cirrus pouch. Although the cirrus pouch lies dorsal to the vagina, it does not open dorsally to the latter, but the vagina so twists around that its opening is posterior to that of the cirrus and in the same frontal plane (fig. 1). The sheath of the cirrus is composed of spongy tissue (fig. 8, *s t*). Riehm (81) in one of his figures indicates both the cirrus and the vagina as opening externally into a comparatively shallow cloaca. In the present form the cloaca is a narrow duct opening upon the top of a small cone which is situated at the bottom of the genital pit (fig. 1). The genital pit or pore is situated near the middle of the margin and is very indistinct. There are no projecting lips and, in many cases, no depression is present. The largest pits measure 56 μ in diameter and 32 μ deep.

Female Reproductive Organs.—These organs appear earlier than those of the male. The anlagen of the glands are found in the proglottides immediately behind the head, but the uterus does not appear until somewhat later. Back of the middle of the strobila all of the female organs, except the uterus, begin to atrophy, and in the posterior proglottides only remnants of the vagina remain. The ovary, shell gland, and vitellarium lie about 1.6 mm. from the margin of the proglottis, nearer the ventral side, and nearly fill the proglottis in antero-posterior diameter. Each proglottis contains two sets of female glands.

The vagina lies ventral to the cirrus pouch, the distal end becoming posterior and opening behind the cirrus. At its distal end, the lumen is very small and the cuticular lining very thick. As it runs mediad the lumen widens and the walls become thinner until it reaches a point just within the longitudinal excretory canals, when its walls become very thin, and it expands into the external receptaculum seminis, the first receptaculum seminis of Riehm (fig. 1, *e r s*). This thick-walled portion of the vagina is surrounded by a thin layer of circular muscle fibers, and outside of the fibers is a single layer of cells which stain deeply. These cells, near the termination of the vagina, have the appearance of pavement epithelium, but farther mediad they become columnar (figs. 1 and 8, *d s c*). The cuticular lining of this portion of the vagina is covered by cilia (fig. 8 *c i*). The combined length of the first portion of the vagina and the external receptaculum is about 1 mm., or equal to the length of the cirrus pouch, and they both vary in the same ratio. The widest portion of the external receptaculum is 40 μ. After reaching the external receptaculum the character of the vagina changes greatly. The deeply staining cells entirely disappear, the walls become very thin, and no muscle fibers are present. After leaving the external receptaculum the vagina is smaller in diameter as it runs mediad until it reaches the internal receptaculum, the second of Riehm (fig. 1, *i r s*). The narrow portion is about 0.625 mm. long. The internal receptaculum does not differ from the external in structure, but is larger, averaging 208 μ long and 80 μ in diameter. The internal and the external receptacula and the portion of the vagina between them is always full of sperm.

The shell gland surrounds the oviduct just at the entrance of the vitelline duct. In cross-section it is seen to consist of spindle-shaped cells surrounding the oviduct. Its diameter varies from 90 to 100 μ.

The vitellarium lies posterior and dorsal to all other female glands (fig. 1, *v t*). It is more or less bean-shaped and divided into lobes or pouches by infoldings of its walls. Its length is about 200 μ, its width, 90 μ. The vitelline duct is about 25 μ long and leaves the gland from its concave side. The contents of the gland are finely granular and stain deeply.

The ovary consists of numerous pouches which extend anteriad laterad, and ventrad, but is located dorsally and posteriorly by the sides of the vitellarium. In these individuals the ovary is not bilobed as stated by Riehm, and the shape of the pouches is different from that indicated by his figures. They are Indian-club shaped, averaging about 112 μ long and being widest, 16 μ, at their distal ends. Each pouch is connected with the common reservoir (fig. 1, *r o*) by a narrow neck only large enough for one ovum to pass. The common reservoir is an oval structure about 57 μ wide by 95 μ long, into which all the pouches empty, and from which the oviduct leads. The whole ovary, together with these pouches, is about 0.475 mm. long by 0.15 mm. wide.

The oviduct (fig. 1, *o v*) is very simple. It runs posteriad from the reservoir of the ovary toward the yolk-gland. Its course is slightly convoluted. Beyond the opening of the vagina and the vitelline duct into the oviduct, the latter passes through the shell gland, at the same time turning forward, becomes the ootype, and enters the uterus just below the ovary. Its diameter is about 10 μ.

There is never more than one uterus in a single proglottis. In the early stages, it is a simple, transverse, rod-like organ which runs dorsal to all other organs and extends laterally beyond the excretory canals. In older proglottides the walls of the uterus become slightly digitate by the growth of shallow proximal and distal pouches, which are always simple. The ripe proglottis is almost completely filled by the uterus.

The ova are more or less irregular or polyhedral in form, probably due to pressure or shrinkage, since in the younger proglottides they are spherical. They measure 50 to 58 μ in diameter, and the bulb of the pyriform body is 16 to 21 μ thick. The horns are long and usually filamentous.

Cittotaenia variabilis (Stiles 1895) Stiles and Hassall 1896.

Some additional points have been worked out in the structure of this species.

This form shows variations in almost every possible direction. The strobila many attain a length of 17 or 18 cm. The head, though quite constant in form, varies greatly in size. It is spherical in general form, but slightly flattened on top and at the sides. In the present forms it varies from 0.462 to 0.872 mm. in diameter. The suckers are not only variable in size but also in shape. They are more commonly spherical, about 0.2 mm. in diameter, with a cavity 0.094 mm. across. Sometimes they are slightly elliptical, measuring 0.282 mm. long by 0.106 mm. broad, but this elliptical form may be due to contraction.

Musculature.—The muscular system is even more highly developed that in *C. pectinata*. The muscle fibers are larger, run in larger bundles, and lie closer together. A subcuticular layer of fibers, consisting of fibers running in both the longitudinal and the transverse directions, is especially well developed.

Excretory System.—This system is simple, consisting of four longitudinal trunks which persist throughout the strobila. The ventral canal is thin-walled and much the larger. In cross-section it is seldom circular, but is usually longer in the dorso-ventral direction (fig. 10 *v c*). Its dorso-ventral diameter averages about 0.217 mm.; the transverse, 0.095 mm. The dorsal canal is smaller, and, in a true transverse section, circular, or nearly so, in outline. It lies dorso-median of the ventral canal, and its average diameter is 60 μ. The character of its walls is very different from the ventral canal, since it has a thick cuticular lining around which is a thick layer of muscle fibers (fig. 10, *d c*). All canals unite in the head between the suckers, forming a loop. There is, however, no anterior projecting canal from their junction, as in *C. pectinata*. The ventral canals are connected in the posterior portion of each proglottis by a transverse canal, but no secondary longitudinal canals connecting the transverse canals are found.

Nervous System.—The material used for the study of the nervous system in this species was preserved in vom Rath's killing solution and some additional points were obtained, but such structures as the proglottidal nerve rings, which Tower (97) describes for *Moniezia expansa* and *M. planissima,* could not be traced. The ganglia occupy the same position behind the suckers as in *C. pectinata,* but the commissures connecting them can be seen more distinctly. Anteriorly there are given off nerves which run around the suckers and toward the anterior point of the head. A cross-section of the head (fig. 11) shows the position of the ganglia with reference to the dorsal and the ventral longitudinal canals. They lie between the canals which pass forward to unite between the suckers. In this species, also, three longitudinal nerve trunks are present, two running ventral and one dorsal to the genital ducts. But, instead of the three lying in the same sagittal plane as in *C. pectinata,* the two secondary trunks lie outside of the main trunk toward the margin of the proglottis (fig. 10, *mn, dn, vn*). No commissures could be found connecting the main and the secondary trunks as in *C. pectinata,* but the inability to trace them may be due to the thickness of the sections and the density of the stain. A ganglion is found on the main trunk in the posterior part of each proglottis, from which nerve fibers run toward the genital pore and are lost in the tissue around the pore. Others are given off from the inner side, but their terminations can not be found. Smaller branches are given off throughout the course of the nerve (fig. 12).

MALE REPRODUCTIVE ORGANS.—The testes number from 75 to 100 in each proglottis and are confined to the posterior side of the uterus and to the dorsal portion of the strobila. They extend to, but never beyond, the ovary; they are oval in form, measuring about 80 μ by 100 μ. Each one is surrounded by a thick layer of muscle fibers, the probable function of which is to force the sperm out of the testis into the duct, as in *C. pectinata*.

The vas deferens is convoluted in the dorso-ventral direction only (fig. 10, *vd*), but it has no peculiar characteristic. There are no enlargements found in its course, the small vesicula seminalis being situated just inside the cirrus pouch. It is rarely more than 12 to 20 μ in diameter.

The cirrus pouch (fig. 13) may reach a length of 0.4 mm., but it is usually much less. Its diameter is more nearly uniform throughout its length than in *C. pectinata,* often being 50 μ. Its muscular walls are highly developed, there being an outer longitudinal layer of fibers and an inner circular, the combined thickness of both often reaching 16 μ.

The cirrus is from 5 μ to 8 μ in diameter. It opens dorsally to the vagina (fig. 10). In this species the cloaca is surrounded by a sphincter muscle, the wall band of which is 13 μ thick (fig. 13, *sp m*). Its probable function is to contract in self-fertilization and to force the male products to pass up the vagina.

The genital pore is situated in the middle of the lateral margin. Although it is not prominent, it is easily detected, since the margin of the proglottis is depressed near the pore. Usually there is a little pit (fig. 13, *g p*), or pocket, opening by a narrow neck, but the lips may be so closely applied to the inner surface of the pocket that the cavity is obliterated. The pit measures 13 μ deep by 21 μ wide.

FEMALE REPRODUCTIVE ORGANS.—The vagina opens into the cloaca ventral to the cirrus (fig. 10, *v*), and lies ventral to the cirrus pouch throughout its length. It is about 10 μ thick, and there is no enlargement corresponding to the external receptaculum of *C. pectinata,* the organ remaining narrow and of about the same caliber until it swells into the receptaculum near the ovary. The first 0.7 or 0.8 mm. of the vagina is surrounded by deeply staining cells as in *C. pectinata.* The receptaculum seminis varies in length; its average is about 65 μ.

The ovary, shell gland, and vitellarium are situated about 1.3 mm. from the lateral margin and resemble the corresponding organs in *C. pectinata,* but are usually longer in transverse diameter and narrower in an antero-posterior direction. The yolk gland is elliptical in form, 0.266 mm. long (*i. e.,* across the proglottis) and 0.088 mm. wide. The ovary is 0.69 mm. long, in the same direction, and 0.1 mm. wide. The ovarian tubules are much heavier than in *C. pectinata,* being from 37 to 45 μ wide and from 75 to 100 μ long, and are connected with the common reservoir by thick necks (fig. 10, *o*). The shell gland occupies a position corresponding to that in *C. pectinata,* and all the female glands are crowded closely together.

The uterus may be single or double in the same strobila. In some cases, all, or nearly all, are single; in others, all, or nearly all, are double. The uterus appears as a single transverse tube which lies dorsal and extends beyond the excretory canals. In the older stages it becomes slightly and irregularly digitate, and finally entirely fills the proglottis. If two uteri are present, their blind ends become closely applied in the median line and can be distinguished only in section.

The ova average about 58 μ in diameter and the bulb of the pyriform body, 16 μ. The horns are usually about 1.5 times as long as the pyriform body is thick, and are usually straight, do not cross, and are not filamentous.

Cittotaenia variabilis angusta.

This variety is only about 2 mm. broad, but often reaches a width of 3 mm. The internal anatomy differs from that of *C. variabilis* principally in size, all the organs being proportionally smaller. There are a few peculiarities, however, both in the shape and position of certain organs which seem to be quite constant.

1. All the organs are situated in the posterior portion of the proglottis, leaving the anterior portion completely bare (fig. 22).

2. The genital pores are situated close to the posterior margin of the proglottis (fig. 22, *g p*).

3. The ovaries, in proportion to the width of the strobila, are situated far from the lateral margins, the distance from the lateral

margin to the ovary being almost as great as the distance between the ovaries. Consequently the testes are more closely crowded together (fig. 22).

4. The ovary has a very characteristic appearance. The diameter of each pouch is nearly the same throughout its length.

5. The number of uteri in each proglottis within the same strobila is more variable than in the type of the species.

Proglottidal Variations.—A study of the variations in the proglottides shows some interesting facts in the various forms. In all the specimens of *C. pectinata,* the external appearance of the proglottides is perfectly normal. No irregularly developed or abnormal proglottides appeared, and no cases of intercalation, such as Blanchard's (1891) figures show, are found. Concerning the number of sets of reproductive glands, a very peculiar facts presents itself. Each of the last two proglottides of the strobila always contain but one set of reproductive glands, and also the genital ducts open on opposite sides of the strobila.

In *C. variabilis* the external appearance of the strobila is quite different. Instead of all the proglottides being even and regular, as in *C. pectinata,* there are many irregular and abnormal ones and many cases of intercalation. More than half of the strobilae possess abnormal proglottides and often twenty abnormalities occur in a single strobila. The simplest form of intercalation is seen in fig. 14. Here the proglottis, *a,* is represented only by a small lip on one side of the strobila and it possesses no internal organs. Fig. 15 shows a more typical case of intercalation. The proglottis, *a,* is the intercalated one, but from the external appearance of the strobila in this region *ac* would seem to be the normal one, and *b* the abnormal. The internal anatomy, however, the arrangement of the testes, and the perfectly formed transverse excretory canal show that *bc* is the normal proglottis. The proglottides *a* and *bc* are nevertheless closely connected. Although the transverse canal of *a* is lost in the parenchyma, the testes of *a* are continuous with those of *bc,* and the uterus of *a* dips backward into the parenchyma and between the uteri of *bc*. It should be noted that all of the uteri in this strobila are double. Fig. 16 shows a more peculiar case. The proglottides *ab* and *ef* are evidently normal. Now the question is whether *cd* is one proglottis with but one set of sexual glands, or is *c* an intercalated proglottis with one set of glands, and *d* another intercalated proglottis with no sexual glands whatever. The latter view seems more probable since the transverse excretory canal of *c* in about the middle of the strobila turns forward and unites with that of *ab*, while *d* possesses neither sexual organs nor transverse excretory canal. Fig. 17 is a subcuticular section of the same proglottides, which shows that the margin of proglottis *d* is connected with *ab* and that of *c* with *cf*. Fig. 18 is a section through three proglottides. *Ab* represents one proglottis with only one set of reproductive glands, but it should be noticed that the proglottis is not normally developed on the side *a*. Fig. 19 shows a section through three proglottides of another strobila. The section was cut obliquely, so the three fully developed sets of organs of the left side are not shown. On the right side of section *ab* the reproductive glands are pushed mediad so that they lie just inside of the glands of the preceding and of the succeeding proglottides. The ovary, shell gland, and yolk gland are perfectly developed, and a portion of the receptaculum seminis is also present, but all genital ducts, as well as the genital pore, is absent. Testes are present but no vas deferens. Just how the eggs developing in this ovary are to become fertilized is a question. This proglottis seems to represent a stage intermediate between that represented in fig. 18 and a normal proglottis with two fully developed sets of female glands. Fig. 20 shows a proglottis *ab* with all the organs developed, but the margin on the right side is not developed, and the genital pore opens between the preceding and the succeeding proglottides. Fig. 21 shows a case, the most highly modified of all in some respects. The genital ducts on the right side of the proglottis *cd*, instead of opening on the normally developed margin *d*, turn forward and open with the ducts of the proglottis *ab*, so that four genital ducts open at the one genital pore. Unfortunately, the proglottis was so old that it was impossible to determine the exact relations of the four genital ducts.

The variety *angusta* also shows many abnormalities and intercalations similar to those of *C. variabilis* and occasionally normal proglottides with but a single pore.

The fact that proglottides are found with but a single set of reproductive organs is important in that it shows that proglottides with single and with double sets of generative organs may occur in the same strobila. But why in the case of *C. pectinata* the single sets should always occur only in the last two proglottides and why the genital pores should always be on alternating sides of the strobila are questions yet to be explained. It hardly seems possible that these two proglottides can represent only one proglottis when the fact is considered that there are two sets of testes (fig. 3, *t*), two uteri (fig. 3, *u*), and that the transverse excretory canal (fig. 3, *t r*) in next to the last proglottis is perfectly developed.

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EXPLANATION OF PLATES

Plates XXVI, XXVII

EXPLANATION OF ABBREVIATIONS USED

bc c	Blind pouch of excretory canals.
c	Cirrus.
c i	Cilia.
c m	Circular muscle fibers.
c o	Nerve commissures.
c p	Cirrus pouch.
d c	Dorsal excretory canal.
d n	Dorsal nerve.
d s c	Deeply staining cells.
e c	Excretory canal.
e p	Excretory pore.
e r s	Ext. receptaculum seminis.
g	Ganglion.
g p	Genital pit or pore.
i	Island of parenchyma.
i r s	Int. receptaculum seminis.
l m	Longitudinal muscle fibers.
m n	Main nerve.
o	Ovary.
o t	Ootype.
o v	Oviduct.
	Excretory reservoir.
r o	Reservoir of ovary.
s g	Shell gland.
s l c	Secondary longitudinal canals of the parenchyma.
s m	Sagittal muscle fibers.
s t	Spongy tissue of cirrus sac.
sp m	Sphincter muscle.
t	Testes.
t m	Transverse muscle fibers.
t r	Tranverse excretory canals.
u	Uterus.
v	Vagina.
v c	Ventral excretory canal.
v d	Vas deferens.
v n	Ventral nerve.
v s	Vesiculo seminalis.
v t	Vitellarium.
v t d	Duct of vitellarium.

EXPLANATION OF FIGURES

All figures are made from camera drawings.

Figs. 1–8. *Cittotaenia pectinata.*

Fig. 1. Dorsal view of male and female reproductive organs. ×79.

Fig. 2. Frontal sections of scolex through ganglia and excretory canals. ×93.

Fig. 3. Frontal sections through posterior proglottis. ×12.

Fig. 4. Transverse section of proglottis. ×32.

Fig. 5. Sagittal section through nerve trunks. ×62.

Fig. 6. Head. ×60.

Fig. 7. Secondary longitudinal canals of one proglottis. ×68.

Fig. 8. Transverse section of cirrus pouch and vagina. ×293.

Fig. 9. Single-pored form. Frontal section of one proglottis. ×30.

Figs. 10–21. *C. variabilis.*

Fig. 10. Transverse section througn proglottis. ×30.

Fig. 11. Transverse section through head. ×43.

Fig. 12. Frontal section through strobila showing main nerve trunk. ×32.

Fig. 13. Frontal section through cirrus pouch and sphincter muscle. ×93.

Figs. 14, 15, 16, 17, 18, 19, 20, and 21. Abnormal proglottides. ×7.

Fig. 22. *C. variabilis angusta.* Frontal section of proglottis. ×57.

PLATE XXVI

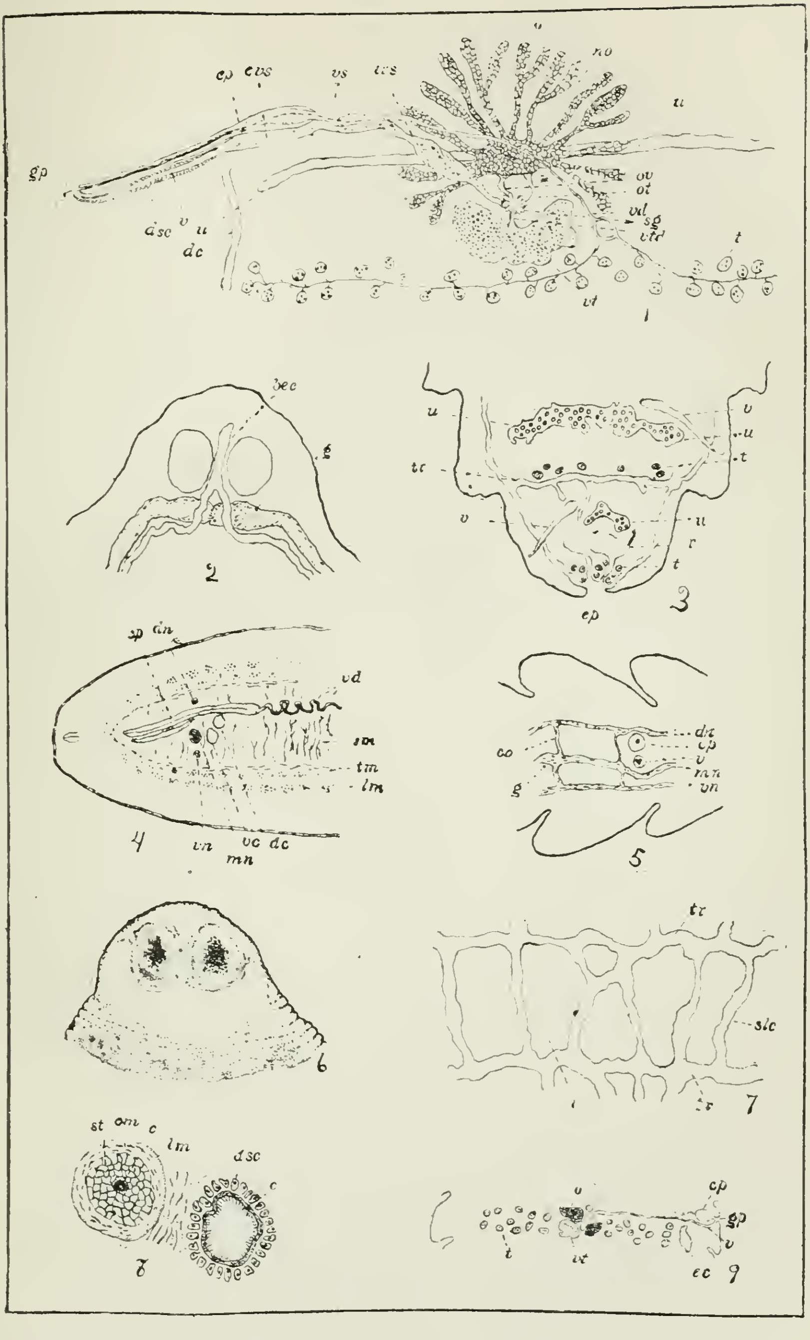
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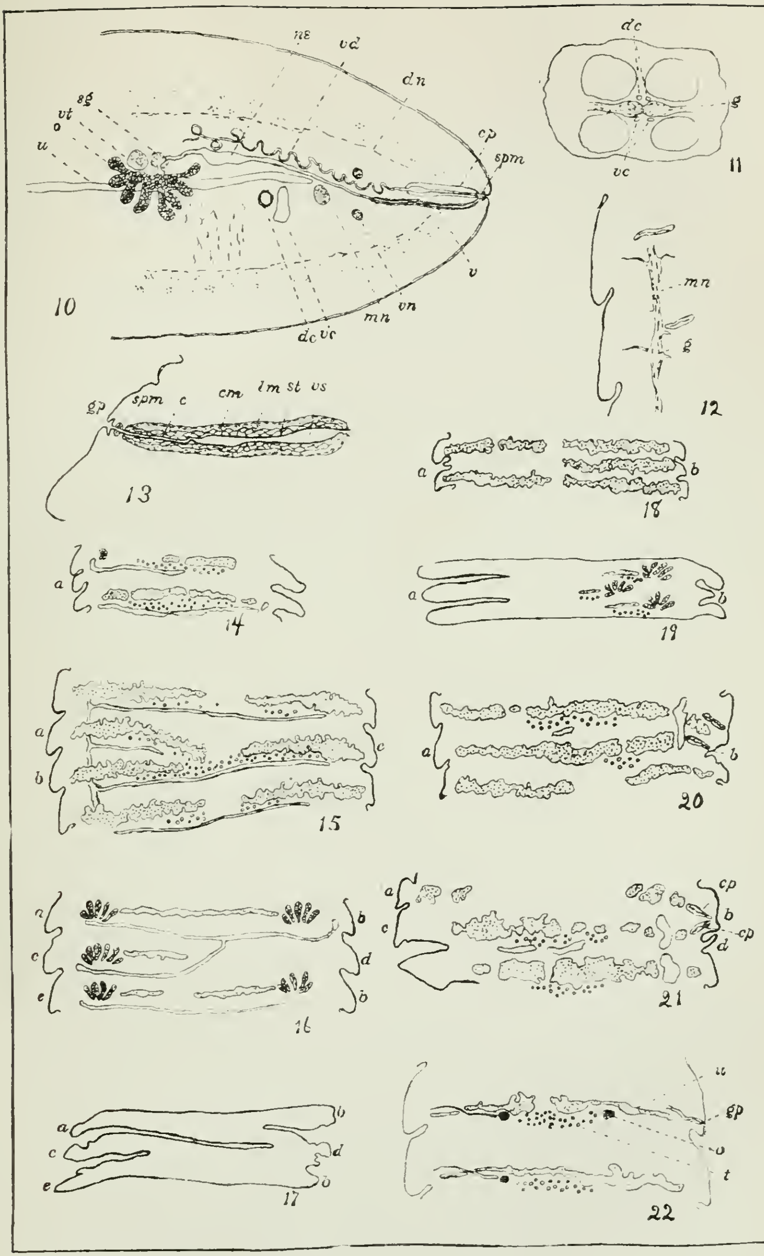
PLATE XXVII



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SOME POINTS IN THE STRUCTURE OF THE ACANTHOCEPHALA

By H. W. GRAYBILL

WITH ONE PLATE

In the singular group of parasitic worms known as the Acanthocephala, the large nuclei of the subcuticula and lemnisci are most interesting and unique structures. They lie in a mass undivided by cell walls and in the adult worm are usually present in great numbers. Even in the same individual they may present an astonishing number of sizes and forms. In size they vary from moderately small structures to enormously extended bodies, as in the lemnisci of *E. clavula* Duj. (Hamann 91). Their form may be either spherical, ovoid, or amoeboid. These nuclei divide directly, and probably have to some degree the ability to move (Hamann 91, 95). In the living parasite they have been observed to push out and withdraw pseudopodia-like processes (Kaiser 93, p. 29). They are not only found in the substance of the lemnisci and subcuticula but are frequently seen lying in the lacunae of the same.

In the subcuticula and lemnisci of an echinorhynchus collected from the rock bass (*Ambloplites rupestris*) and black bass (*Micropterus dolomieu*) of the Great Lakes are found nuclei of such extraordinary size and form that an extended description of them seems called for.

It will suffice here to say that the subcuticula of this worm is of the ordinary type, being bounded externally by a thin cuticula and internally by a delicate basement membrane (*membrana limitans*). The radical and the peripheral fiber systems are well developed. Near the membrana limitans is located the usual set of canals, consisting of two large lateral vessels extending nearly the whole length of the animal and a meshwork of lacunae connecting the two both dorsally and ventrally. The nuclei referred to above lie approximately in the middle of the subcuticula immediately beneath the innermost layer of peripheral fibers.

A stained mount of the body wall spread out shows, under low magnification, along the middle of both the dorsal and the ventral sides, a deeply stained, well-formed, dendritic mass (fig. 12), which appears at first sight to extend continuously almost from one end of the body to the other. On closer examination, especially under a higher power, it is found that each of the supposed single masses is divided into several parts which follow each other more or less closely. A glance shows that these several long branching bodies (nuclei) are independent of the lacunae which lie in a different level and form a complete network between the lateral canals.

Each nucleus consists of a more or less sinuous main trunk, which lies about midway between the two lateral canals. It is not uniform in width, but is successively contracted and expanded, having a maximum width of 14 μ. On either side are given off, about at right angles, a large number of branches which may be simple or variously branched. The branches usually come from the nodes of the main trunk. They are at times moderately uniform in width, while again they may be contracted at one or more places to a minute fiber. In fact, under low magnification, many small roundish or irregularly shaped portions of nuclear matter appear to be disconnected from the surrounding branches. However, under a high power it is found, in all but a very few cases, that a drawn-out thread of nuclear matter definitely connects each of these to a near-lying branch. Some of the few truly isolated portions had certainly separated from the main mass just previous to or at the time of killing, as a drawn-out point of nuclear matter from the isolated part pointed directly toward a similar projection on a neighboring branch.

The width of these branching nuclei is such that they occupy approximately the middle half of the spaces between the lateral canals. In some cases, however, the branches approach quite close to these canals, especially when the ends of two successive nuclei pass each other somewhat (fig. 12).

The various branches of the nuclei are so arranged with respect to the net-work of lacunae that they occupy as much as possible median positions in the islands of hypodermis between the lacunae.

The number of dendritic nuclei in the body varies from about ten to twelve. In length they vary in good sized worms from 2 to 4.6 mm. They stop short some distance from the anterior and posterior ends of the body, so that in sections from these regions no nuclear matter is encountered.

In each lemniscus is found a single large nucleus. The lemnisci are very long, thread-like bodies. Each is divided into two moderately distinct regions; a proximal, broader, flat region, 450 to 900 μ long, and a distal cylindrical region many times longer than the former. The large nucleus is located in the proximal portion of each organ. It is, roughly speaking, of a branching type and in length occupies nearly the whole of this region of the lemniscus. In sections its outline is usually dentate or irregular (fig. 10).

Each nucleus is formed of a longitudinal portion of very ununiform width with a maximum of 56 μ. Attached along the sides of this are a few short branches which are in some cases expanded at their ends into broad masses.

The lacunae of both regions of the lemnisci are frequently filled with a granular coagulum which at most stains very lightly.

It is interesting to note here that Hamann (91, p. 146) found only a single nucleus in each lemniscus of *E. clavula* Duj. The measurements given by him for this nucleus are, length 1.6 mm., breadth 0.15 mm. However, the nuclei of the subcuticula were of the usual type and showed well the various division stages. (The writer is very greatly indebted to Dr. Otto Hamann of Berlin for slides of this, as well as of various other species, which he so kindly forwarded at the request of Dr. H. B. Ward.)

The nuclear substance of the above described branching bodies stains very uniformly. Only under the highest power is it found to be compactly granular in structure. It contains a moderate number of vacuoles of various sizes which usually are bounded by definite circular outlines (figs. 3, 5, 7, 10).

Chromatic bodies or nucleoli are present in the nuclear substance in countless numbers. In form they vary greatly, being spherical, ovoid, irregular, or long and thread-like. Those of the first three types predominate. They vary in size from the minutest granules to structures 22 μ long. Those filamentous in form, though only about 1.5 to 3 μ in width, may, in exceptional instances, reach a length of 84 μ. They are not always uniform in width throughout. Frequently they are very weakly expanded and contracted at intervals along their whole length. In some cases this is so pronounced as to give a distinctly moniliform appearance to the chromatic body.

In fig. 9 are represented some of the irregular forms of the above chromatic bodies. The remaining figures will readily give an idea of other forms. They stain very deeply. They may contain one or several small roundish transparent specks which are probably vacuoles. Even after the stain has almost entirely washed out of the nuclear matter no structure is to be detected in these chromatic bodies which are still quite deeply stained.

At times in the nuclei of the lemnisci the roundish chromatic bodies occur in groups, and in some cases they lie in contact, forming rather compact masses.

In general the larger chromatic bodies and frequently also the smaller ones are surrounded by unstained halos which have usually a distinct boundary, the same as the vacuoles spoken of above (figs. 1–8). These halos are not so frequent in the nuclei of the lemnisci. Hamann (91) describes and figures similar halos in a nucleus from a lemniscus of *E. clavula* Duj.

Some of these chromatic masses are suspended in the halos by minute chromatic strands which radiate from them, connecting with the nuclear substance (figs. 1 and 2).

In cross-section the different branches and the trunks of the branching nuclei are circular, oval, or oblong. And since in sagittal sections of the body, especially just to one or the other side of the main trunks of these nuclei, most of the branches are shown in cross-section, an appearance of the subcuticula is presented not unlike that found in echinorhynchi where the nuclei are comparatively small in size and large in numbers. The extensive branching brings portions of these dendritic nuclei into most of the regions of subcuticula, and also gives to them an enormous surface area for the carrying on of metabolic processes.

In another species of echinorhynchus (host—*Moxostoma* sp.) which is related to *E. proteus* West, among the many spherical, ovoid, and amoeboid nuclei of the subcuticula were also found a few very large ones which were dendritic in form. The longest one measured had a length of 630 μ. Some of the medium sized ones of this type possessed as many as seven good sized branches.

A comparison of the branching nuclei in the first form considered above, with the nuclei in *Neorhynchus clavaeceps* (Zed.), and *N. agilis* (Rud.) is interesting. According to Hamann these two forms represent sexually mature larvae. Each possesses six to ten large (0.2 mm.) ovoid nuclei in the subcuticula of the body and two in each lemniscus. In the form studied the number of nuclei is also small, there being ten to twelve in the body and one in each lemniscus. As suggested above, the branching is probably both for the purpose of increasing the superficial area and bringing portions of the nuclei into all regions of the subcuticula. The total amount of nuclear matter is immeasurably greater than that contained in the few ovoid nuclei of *N. agilis* and *N. clavaeceps* and is probably about the same as in cases where the subcuticula contains large numbers of small nuclei.

In the development of the nuclei of the subcuticula in the echinorhynchi as worked out by Hamann (91) and Kaiser (93) one may distinguish roughly three stages. In the first stage the nuclei are large, roundish bodies and few in number. In the second stage the number of nuclei is still small, but their form is amoeboid with pseudopodia-like processes extending out from the various sides. The third stage is characterized by a large number of small nuclei of various sizes and forms and is brought about by an extensive fragmentation of the amoeboid nuclei of the previous stage. However, though this is the usual mode of development, Hamann has pointed out in the case of *N. clavaeceps* and *N. agilis,* forms already referred to, that in the adult the nuclei have remained at the first stage of development.

In view of this development it therefore seems probable that the above described dendritic nuclei have arisen by an extensive growth of the few large amoeboid nuclei of the larva and that they occupy an intermediate position between the nuclei of the two forms last mentioned above and the nuclei of other forms where they are present in great numbers.

Experiments on the Lemnisci.—As stated above, the lemnisci of the echinorhynchus collected from the rock bass and the black bass are very long, thread-like organs. In some cases they reach posterior to the middle of the body. They are unattached except at their points of origin. No muscular layer is present. The single large canal of the posterior or distal portion of the lemniscus divides into two canals on entering the proximal region. These latter canals unite at the attached end of the organ and empty as one canal into the circular canal at the base of the neck. The latter canal connects with the lacunae of the neck and is separated from those of the body by a cuticular ring.

Some experiments were made on living material to determine what effect the cutting off of these well-developed organs would have on the extrusion of the proboscis.

The first experiments consisted in cutting the worm in two immediately posterior to the proboscis sheath, thus severing both lemnisci. A turbid fluid issued from the cut ends of the latter. While in many cases, because of the great injury to the parasite, no motion of the proboscis took place, yet in some few cases the proboscis was completely extruded a number of times.

In numerous second experiments a slit was made in the body wall a little posterior to the base of the neck. Through this opening the lemnisci were drawn out and cut off close to their points of origin. The injury to the worm was slight. In many cases it was found that immediately or after the lapse of some time the proboscis was completely extruded and withdrawn many times with a rapidity equal to similar movements in uninjured worms.

Also, in observing the movements of the fluid in the lacunae of the neck and proboscis of uninjured worms during the extrusion of the latter, it was found that the streaming anteriad always commenced after the beginning of the extrusion and never preceded it. Again, when extrusion ceased, the fluid of the lacunae for some time continued to stream anteriad and adjust itself as it would not have done if under pressure sufficient to have aided in the extrusion.

From the above observations it seems plain that in this form at least the lemnisci take no part in the protrusion of the proboscis (Hamann 91, p. 150), and also that any pressure on the fluid of the body cavity is not necessary to the operation.

Description of the Species.—With the aid of material kindly sent by Dr. E. Linton to Dr. H. B. Ward, for purposes of comparison, the writer was able to determine definitely the identity of the form concerned in this paper with that from *Roccus americanus* described by Linton (92, p. 528) as *Echinorhynchus thecatus*. As the original description is very brief, being based almost entirely on toto mounts of the parasite and on the measurement of only a few individuals, the following more extensive list of the important characters, including measurements of hooks and of a large number of individuals, will be of great systematic value.

Living specimens flattened dorso-ventrally, smooth. Color white, light yellow, orange, or gray. Preserved specimens cylindrical, curved. Proboscis also curved when extruded. Transverse wrinkles only on anterior half of body. Maximum diameter of body in female toward anterior end, in male at or slightly anterior to middle of body. In both sexes gradual decrease in diameter to anterior end where neck joins abruptly. Similar decrease posteriad in case of male. End moderately blunt. In female posterior end slightly expanded, very blunt. Neck increases in diameter to base. Proboscis usually broadest at middle. Anterior end rounded. Hooks, 24 to 31 transverse and 12 longitudinal rows, surrounded by prominent collars. Collars of hooks at the base of the proboscis frequently longer than hooks. Recurved base of hooks notched at end. Lemnisci long and thread-like. Proboscis sheath double-walled. Ganglion in midst of proboscis retractors, midway between anterior end of proboscis and base of sheath. Nuclei of circular muscle layer arranged in two lateral bands, one opposite each lateral canal. Testes contiguous, anterior one the longer. Cement glands in compact mass, eight in number. Embryos spindle-shaped.

MEASUREMENTS

	LENGTH	WIDTH		
		ANTERIOR	MAXIMUM	POSTERIOR
Body, female.	11–26 mm.	0.51–0.89 mm.	0.8–1.4 mm.	0.52–1 mm.
male ..	7–12 mm.	0.39–0.69 mm.	0.59–0.95 mm.	0.37–0.75 mm.
Neck........	179–298 μ.	209–298 μ.	....	254–388 μ.
Proboscis....	868–1164 μ.	....	239–328 μ.	Same as anterior width of neck.
Embryos	85–108 μ.	....	18–22 μ.	....

Hooks.—In the following table in the case of those hooks of the ventral row with recurved bases, of the two possible measurements of the thorn and the recurved root the longer one is given. The hooks with recurved bases in the dorsal row are measured from corresponding points, just as if the anterior projection were not present. The measurements at the curve were made along the line of maximum width. Values are given in microns.

	LONGITUDINAL ROW ON VENTRAL SIDE OF THE PROBOSCIS			LONGITUDINAL ROW ON DORSAL SIDE OF PROBOSCIS		
Transverse row	Length thorn	Length recurved root	Diameter at curve	Length thorn	Length recurved root	
2	72	65	29	65	44	....
4	72	58	29	66	51	....
6	76	69	29	72	40	....
8	76	72	29	72	40	....
10	79	76	32	72	32	....
				Length of hook		Width at base
12	76	76	31	84	....	25
14	72	62	27	79	....	22
16	69	48	22	75	....	20
18	65	27	20	70	....	20
	Length of hook		Width at base			
20	68	....	22	61	....	14
22	68	....	18	61	....	13
26	50	....	14	48	....	13

HOSTS.—*Micropterus dolomieu* and *Ambloplites rupestris;* stomach, pyloric coeca, intestine, and body cavity. *Amia calva* in intestine. Free or attached.

The above work was done in the Zoological Laboratory of the University of Nebraska under the direction of Dr. Henry B. Ward, to whom the writer is under great obligations for many valuable suggestions and for the use of a very extensive collection.

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EXPLANATION OF PLATE

Plate XXVIII

Drawings outlined with camera lucida.

Figs. 1–8. Longitudinal sections of various portions of dendritic nuclei of hypodermis. ×600.

Fig. 9. Variously shaped chromatic bodies found in the same. ×600.

Fig. 10. Longitudinal section of a portion of nucleus in a lemniscus. ×600.

Fig. 11. Hooks of proboscis. ×540.

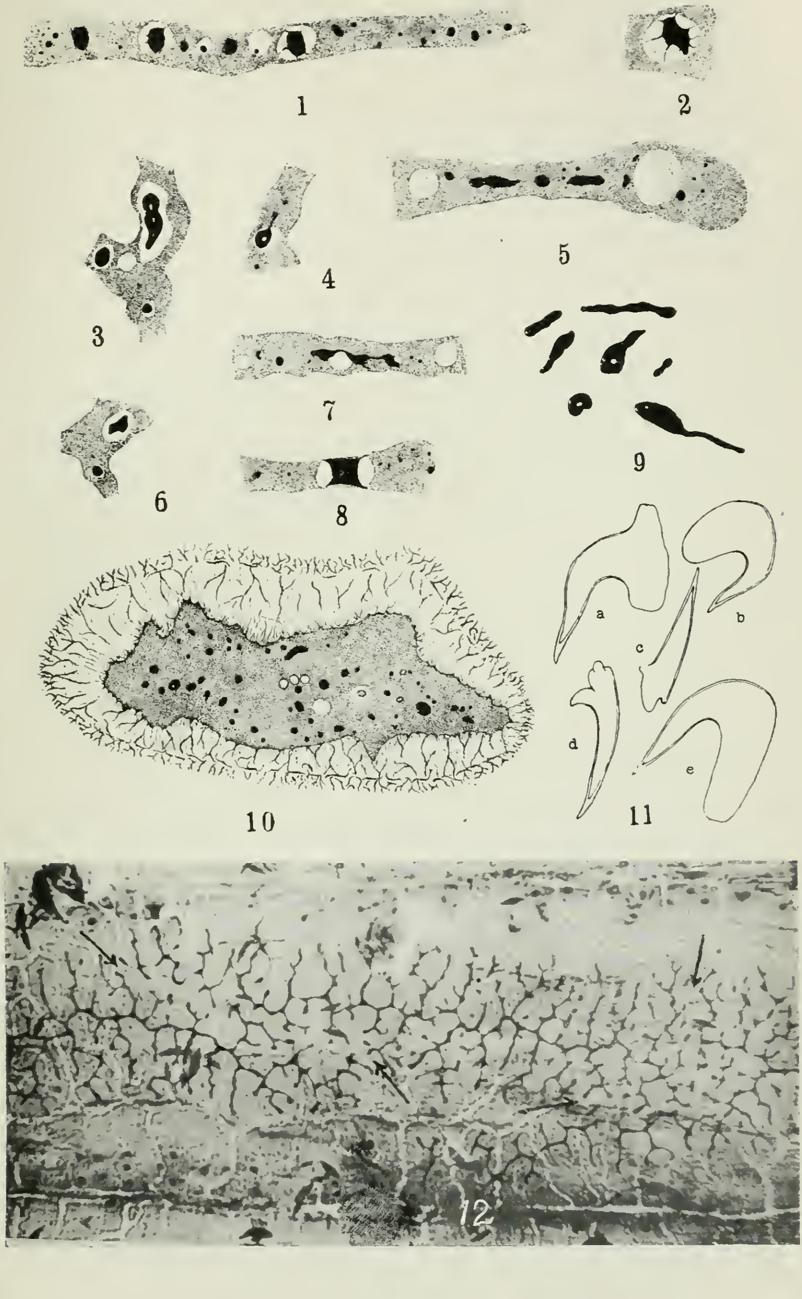
a. Type found on lateral and dorsal (convex) surfaces of anterior half.

b and *e*. Hooks from ventral (concave) surface, anterior portion.

d and *c*. Hooks from posterior portion.

Fig. 12. Microphotograph of flat mount of a portion of the dorsal half of the body wall. Limits of a single nucleus indicated by the arrows. Ends of two adjoining nuclei also shown. Lateral canals and net work of lacunae represented by the light lines.

PLATE XXVIII



THE NORTH AMERICAN SPECIES OF CURVIPES

By ROBERT H. WOLCOTT

WITH FIVE PLATES

I. INTRODUCTION

The members of the genus *Curvipes* are distinguished from those of all other genera of water-mites by their strength, activity, and ferocity, other species of water-mites, small insects, larvae, various species of crustacea, and, in fact, almost any aquatic form which they can master falling a victim to their rapacity, and many of these being superior in size to their captors.

The species are readily identified by the possession of structural characters which, though not subject to wide variation, are easily sufficient to distinguish the different species one from the other. These are the possession of palpi the fourth segment of which bears two or more papillae, and which are terminated by three or four small claws; of epimera collected into four groups of two each; of a genital area immediately behind the last epimeron, which presents a median area flanked by numerous acetabula set free in the body wall or imbedded in chitinous plates; of legs bearing swimming-hairs and ending in retractile claws; and, in the male, of modified segments of the two last pairs of legs—the sixth in the case of the third pair, the fourth of the other, this modification being of a characteristic type.

The species agree very closely in structure, and it is well to give a general description of the characters of the genus, leaving to be included in the descriptions of the individual species only such details as are subject to specific variation and distinguish each particular form.

The body is elliptical or oval in form, moderately compressed or highly arched, the anterior margin more or less emarginate between the eyes, and in some forms with posterior lateral emarginations. There is also frequently a dorsal constriction behind the eyes. The surface is usually marked with fine lines, and in some forms there are evidences of the deposition of chitin in the subcutaneous tissue. In front of the eyes and below them are usually found two bristles varying in length and form and termed, from their position, "antenniform bristles."

The maxillary shield, seen from beneath and forming the floor of the so-called "capitulum," is of the typical shield shape with a well-developed ancoral process extending backward between the anterior pair of epimera. The mandibles are flat and four-sided with the ventro-posterior angle more or less produced, while at the anterior end is articulated a claw, which is curved, triangular in section, and tapers to a point. On the inner surface of this claw is a patch of what usually appears like fine, parallel striae, but which fortunate views resolve into a comb of fine hairs (pl. XXIX, fig. 6), and along the lateral edge of the flexor or concave surface is a series of fine serrations.

The palpi are usually compressed, especially the fourth segment, the flexor margin of which is provided with two or more papillae, together with a spur at the distal end. There is usually a small spine at the tip of the extensor margin of the first segment, and on the second three spines in a row on the inner surface and two on the outer, one in the middle and the other at the distal end. The third segment has two spines on the inner surface and one on the outer, while the last segment bears at the tip three or four small, more or less curved, claws. The second segment is the thickest, the third and first about equal in this regard, the fourth next, and the distal the narrowest, while in length the fourth usually is greatest, and then in order the second, fifth, third, and first.

The epimera are always collected into four masses, the first and second and third and fourth of each side being in close apposition. In the male the space between the second and third is usually narrow and that between the two posterior of opposite sides narrow or quite obliterated, while in the female the spaces separating the four masses are all of them relatively wide. The posterior margin of the last epimeron is produced caudad, forming a sharply pointed angle within which the margin of this epimeron is usually more or less concave, while laterad of it the margin runs almost straight to the articulation of the fourth leg.

The legs in the female exhibit an increasing length and also an increasing breadth from first to last, while the individual segments decrease gradually in thickness from the base outward. The last segment of the first three pairs of legs in this sex is more or less club-shaped and bears at the outer end two claws which are capable of being retracted into a cleft on the extensor side. These show a long pointed tip between which and the base is usually a second, blunt, more or less flattened and curved tip, and at the base a broad, flat expansion. Beneath this claw at the tip of the segment on the flexor side is often a short straight spine, while on the middle of either margin of the cleft that receives the claw is a pair of fine hairs, near the outer end of these margins another pair, and at the inner end of the cleft still another. The legs are provided with a double row of weak spines along the extensor surface and long, heavy spines on the flexor surface, which increase in number from the first to the fifth segment, and on the basal segments tend to be grouped at the tip, on the third in the middle also, and on the fourth and fifth scattered along the margin in a double row. There is also a greater or lesser number of long, slender hairs on the posterior side of the fourth and fifth, and sometimes the third segment of the anterior pairs of legs, while in the posterior one or two pairs these are gathered into a close oblique row at the tip, become of value in progression, and may be termed "swimming-hairs." The sixth segment of the last pair of legs in this sex is usually long, slender, and straight and bears claws which are miniatures of those on the anterior legs.

In the male the first two pairs of legs are similar to those in the female, and the third also, except that the fifth segment is usually elongated and devoid of long, scattered hairs or swimming-hairs, and the last segment is modified in a characteristic manner to serve as a sperm-carrier. This modification consists in a shortening of the whole segment and more or less of a thickening of the tip, which is rather squarely truncate. The cleft which receives the claws is carried around on to the end of the segment, but retains the hairs along its margin described for the female. The claws are highly and variously modified in the different species, the two becoming frequently unlike. It is to be noted that all the elements present at the tip of the corresponding segment of the female are here present but in a modified form, no new structures being added.

In the case of the fourth leg of the male the four basal joints are usually thicker than the outer two, and the fourth is modified to form an organ for grasping the anterior legs of the female in copulation. This modification consists in a deep excavation on the posterior side, both proximad and distad of which the segment is often dilated. The anterior side is gently convex and along it are a few weak spines, while on the flexor surface there are the usual long, stout spines. Proximad of the excavation on the posterior surface are numerous stout, blunt, more or less curved, saber-shaped spines, varying in length, and a few longer, pointed spines. Within the excavation are a few spines, while distad of it is a greater or less number of short, stout, blunt ones, and a varying number of long, slender swimming-hairs. Owing to the fact that the last pair of legs is directed backward, the posterior surface, on which is the excavation, is next to the body, while the anterior surface is on the outside.

The genital opening is close behind the last pair of epimera, and the chitinous plates about that of the male are frequently fused with the inner end of the last epimeron. In this sex the opening is generally small and is either at the bottom of a depression which serves as a seminal receptacle or opens into a more or less well-developed seminal pouch. This median portion is usually flanked by chitinous plates varying in form and bearing a variable number of acetabula. The genital area of the female exhibits a long genital cleft in the median line guarded by two flaps, which together form an elliptical area, and which in turn are flanked by chitinous plates bearing a corresponding number of acetabula. In a small number of species these acetabula, in one or both sexes, are imbedded free in the wall of the body.

The anal opening is situated at a varying distance behind the genital area, and the chitinous ring surrounding it may be fused with the genital plates.

The characters just given define the general appearance of any mite belonging to this genus. The sexes are easily separated by the presence of the characteristic leg segments of the male, and by the character of the genital area.

In the separation of species the characters which seem to be of most value are as follows: The length, thickness, form, and proportions of the palpi, together with the characters of the papillae and spur on the fourth segment; the lengths cf the legs, relative and absolute; the form of the segments, and whether or not the end of any of them shows a flattened expansion of the anterior surface extending beyond the base of the next segment; the character of the segments peculiar to the male; and the number and distribution of swimming-hairs. The form and details in structure of the genital area are also highly important, and the position of the anal opening is of value. Size of body and other measurements compared with body proportions are of uncertain value, since when the eggs become developed the females are swollen to a great degree, and not only is the form of the body modified but the relative proportions of other parts to the dimensions of the body are altered and the distance between the epimera increased, while their relative size is lessened.

In the beginning of this investigation the author undertook, from the comparison of a large number of specimens of *C. Reighardi,* to determine the limit of specific variation, and found specific characters to be remarkably constant, a fact which has been confirmed again and again in the comparison of individuals belonging to the other species studied.

The genus is generally distributed over the world, a large number of species being known from various parts of Europe, several from eastern Africa and Madagascar, two from Ceylon, a few from Central America and Mexico, and two from Canada.

There have been hitherto noted as occurring in North America the following species:

Curvipes numulus (Stoll) (87: 47, pl. XI, fig. 2).

Curvipes guatemalensis (Stoll) (87: 11, pl. X, fig. 2, pl. XI, fig. 1).

Curvipes alzatei (Dugès) (84: 345, pl. VIII, figs. 10–19).

Curvipes fuscatus (Hermann) (04: 58, pl. VI, fig. 9).

The two former were described by Stoll from Central America and the second later recorded by Koenike (95*b*: 209) from Canada. *C. alzatei* was described from Mexico, while the last species in the list is a well-known European form which has been noted by Koenike (*l. c.*) as occurring in Canada. *C. numulus* is quite different from any species described in this paper, having only one papilla on the fourth palpal segment and only two claws on the tip of the last segment of the palpus. The acetabula are imbedded free in the body wall in the case of the female, the male being unknown. Of *C. alzatei* the female and early stages were described; it is related, according to Piersig (1901: 265), to *P. conglobatus* (Koch), the female of which also has the acetabula set free in the body wall and the fourth palpal segment of which is short and with prominent papillae, thus differing from *C. coronis,* described on a subsequent page of this paper. *C. guatemalensis* is closely related to *C. rotundus* (Kramer), but the palpus is thicker, the two papillae on the fourth segment are one behind the other, the distal segment has only two claws at the tip, the legs are shorter, and the hairs on the genital plates less numerous. *C. fuscatus* is in many ways similar to *C. constrictus,* also a species described in the following pages, but the genital area of the male of that species does not agree with that figured and described for *C. fuscatus* by Piersig (97 and 1901), according to whom the seminal pouch is broader than long and roughly triangular instead of elliptical. The female of *C. fuscatus* also has the plate bearing the acetabula lunate in form, while in *C. constrictus* it is solid, which serves to ally the latter with quite different species.

The collection upon which the present paper is based has been gathered at different times during several years past and represents not only the collections of the writer but contributions from others to whom he is greatly indebted. The following localities are represented:

Massachusetts.—Cranberry Lake, Woods Hole, August, 1900.

Michigan.—Lake St. Clair, summer of 1893; pools near Ann Arbor, spring of 1894; Round, Pine, and other small lakes near Charlevoix, summer of 1894; Intermediate Lake, Ellsworth, August, 1894; High Island Harbor, northern Lake Michigan, August, 1894; Reed's, Lamberton, and other small lakes near Grand Rapids, summers of 1895, 1896, 1897, 1898, and 1899; Grand River, near Grand Rapids, summers of 1895 and 1898; Kawkawlin River and Saginaw Bay, August, 1895 (by J. B. Shearer); Les Chenaux Islands, northern Lake Huron, August, 1895 (by J. B. Shearer).

Wisconsin.—Lake Winnebago, Oshkosh, August, 1897.

Illinois.—Several localities near Havana (by the Biological Station, Illinois State Laboratory of Natural History).

Nebraska.—Circle Lake, Decatur, June, 1899 (by Chas. Fordyce); pool in Monroe Canyon, Sioux county, May, 1899; South Bend, September, 1897 (by H. B. Ward).

Colorado.—Pond near Wray, November, 1901.

Missouri.—Ponds near Columbia, August, 1901.

LOUISIANA.—Pond in Audubon Park, New Orleans, fall of 1901 (by E. Foster); near Slidell, fall of 1901 (by E. Foster).

To those whose names appear in the foregoing list as having assisted in the collecting of material the author is deeply grateful.

The specimens have been preserved for the most part in one of the solutions recommended by Koenike, which leave the specimens in condition most suitable for dissection and the study of skeletal structures; although precaution has been taken at the same time to preserve a greater or less number in picro-sulphuric, corrosive sublimate, alcohol, or formol mixtures in order that the natural size and form might be preserved. In the preparation of slides the author has subjected them to treatment with potassic hydrate, removing the most of the contents from the body and separating and dissecting out the mouth parts, mounting all in balsam. In the case of single specimens of the species the legs and palpus have been removed from one side and mounted in balsam, care being taken that no pressure should be put upon the body in such a way as to alter its form or proportions, and leaving the appendages of the other side in the natural position.

Through the courtesy of Dr. F. Koenike, of Bremen, Germany, the author has had specimens of the following European and other forms for comparison: *C. conglobatus* (Koch), *C. uncatus* Koenike, *C. nodatus* (Müller), *C. guatemalensis* (Stoll), *C. rotundus* (Kramer), *C. variabilis* (Koch), *C. fuscatus* (Hermann), and *C. longipalpis* (Krendowsky).

The study of the material thus secured has resulted in the detection of fifteen species, of which thirteen are new. If we add to these the species heretofore recorded we get a total of nineteen for North America, as follows:

1. Curvipes coronis n. sp.
2. Curvipes numulus (Stoll).
3. Curvipes alzatei Dugès.
4. Curvipes exilis n. sp.
5. Curvipes pugilis n. sp.
6. Curvipes turgidus n. sp.
7. Curvipes triangularis n. sp.
8. Curvipes constrictus n. sp.
9. Curvipes spinulosus n. sp.
10. Curvipes fuscatus (Hermann).
11. Curvipes medius n. sp.
12. Curvipes rotundus (Kramer).
13. Curvipes debilis n. sp.
14. Curvipes guatemalensis (Stoll).
15. Curvipes Reighardi n. sp.
16. Curvipes obturbans Piersig.
17. Curvipes inconstans n. sp.
18. Curvipes setiger n. sp.
19. Curvipes crassus n. sp.

Unfortunately the collections have none of them been made throughout the year in any one locality, and it has been difficult in some cases to recognize the males and females of the same species, coming in certain instances from widely different localities. But every precaution has been taken to avoid the possibility of associating together two sexes not belonging to one and the same species, and it is believed by the author that the characters which have caused the specimens to be associated as they are sufficient to reduce to a minimum the possibility of any confusion from the above conditions. In almost every species resemblances in form of palpus, the character of the papillae, the number and distribution of swimming-hairs, or form of the segments of the legs, and the characters of the genital area are sufficient to show the relationship between the sexes.

In the descriptions of the species that follow repetition of the common characters is, so far as possible, avoided, and for brevity the following abbreviations are adopted: *ep.* for epimeron; *seg.* for segment; while the successive segments of the palpi from the base out are numbered from 1 to 5, the successive epimera, beginning with the anterior, I to IV, the successive legs by corresponding numbers, and the segments of the legs by the numbers 1 to 6, beginning with the one nearest the base. In all cases the length of a segment is the length of a straight line joining the middle points of two lines connecting the extremities of the extensor and flexor margins. In the measurement of the palpi the length includes the claws at the tip, but in the case of the legs the length of the distal segment is exclusive of the claws or of the spine on the flexor side at the tip.

Although in the collections numerous immature individuals are present, in this paper all reference to preparatory stages is avoided.

II. DESCRIPTIONS OF SPECIES

1. *Curvipes coronis* n. sp.

A species, of which the female is characterized by the possession of numerous acetabula imbedded free in the wall of the body, these forming a group approximately circular in outline, around the outer margin of which the acetabula form a distinct ring.

The single female specimen of this species, collected in Saginaw Bay, Mich., is 1.254 mm. long and 1.079 mm. wide. It is broadly ovate with the anterior margin slightly produced in front of each eye and excavated between them, and the surface shows the usual fine striation. The eyes are 0.349 mm. apart, while the short, straight antenniform bristles are separated by a distance of 0.317 mm.

The palpus (pl. I, fig. 2) is 0.821 mm. long, and of this the different segments make up the following percentages: 8, 27, 10, 37, 18. Seg. 1 is one-half as broad again as long; seg. 2 somewhat less broad than long; seg. 3 much broader than long; seg. 4 rather slender, tapering, and slightly dilated in the middle; while seg. 5 tapers decidedly from the base to the tip. On the flexor side of the fourth segment are two papillae, one of which is very long, the other half its length, set obliquely and bearing short hairs. The same segment has a short curved claw at the tip of the flexor margin. The tip of seg. 5 bears three moderately short curved claws. The spines on the palpus are more numerous than in any other species examined. Seg. 1 has the usual small spine at the tip of the extensor margin; but on seg. 2 there are, instead of the usual three on the inner surface, three in a row near the extensor margin, one a little out of line near the distal end, and one at the tip of the extensor margin, while on the outer surface, instead of two, there are two close together near the extensor margin, one near the middle of this surface, and two at the distal end, side by side. Seg. 3 has the usual number, while seg. 4 has numerous short hairs borne on small papillae.

The epimera (pl. XXIX, fig. 1) are widely separated across the median line, II and III being nearer together but still with a considerable interval between.

The legs are proportionately long, the first exceeding the body length by nearly one-fourth. The individual segments are, in order of length, 5, 4, 6, 3, 2, 1, except that in the first leg 6 is longer than 4, while in the last leg 4 is longer than either 5 or 6. No particularly noteworthy details of structure are present.

Segs. 4 and 5 of leg I possess two and five long hairs respectively, and the corresponding segments on leg II bear six and eight hairs, while on leg III are eight and eleven long hairs, and on leg IV seven and twelve swimming-hairs on the same two segments.

The genital area (pl. XXIX, fig. 1) is bounded in front by a long, transversely placed chitinous plate similar to that in *C. turgidus.* The median area is broadly elliptical in form and the acetabula are distributed over two lateral areas nearly circular in outline, their posterior margin extending behind the posterior margin of the median area by a considerable distance and leaving between the two a considerable space. Within these lateral areas are 23 and 28 acetabula respectively, imbedded in the wall of the body. They are, for the larger part, arranged in a row about the outer margin, while a few are scattered over the center of the area.

Measurements of the single female specimen give the following figures:

Body	1.254 mm.
Leg I	1.541 mm.
Leg II	1.766 mm.
Leg III	1.805 mm.
Leg IV	1.997 mm.
Palpus	0.821 mm.

Type retained in the author's collection.

The single female from which this species is described was collected in Saginaw Bay, Lake Michigan, August, 1895, by J. B. Shearer, of Bay City, Mich., and was apparently of a red color when living.

The name is bestowed in allusion to the curved row of acetabula about the group of such structures, which are imbedded free in the body wall. From all the described species of which the latter statement is true, the present specimen seems to be quite different.

2. *Curvipes exilis* n. sp.

A species characterized especially by the excessive length of the palpi, which are also very slender proportionally, and the fourth segment of which is remarkably contracted at the base. It is of medium size, the body elliptical in form, five-sixths as wide as long and approximately the same in height, the highest point being in front of the middle of the body. Measurements of several specimens from Lake St. Clair preserved in picro-sulphuric and corrosive sublimate solutions give a maximum length for the male of 0.968 mm., a minimum of 0.825 mm., and an average of 0.87 mm., while the single female measured possessed a length of 0.92 mm.

The body is marked by proportionately coarse, irregular lines on its surface. The eyes are situated a little back from the margin, the distance between them being equal to somewhat less than one-third the length of the body. They are black in color.

The maxillary shield is broadest anteriorly, with rather straight sides which converge posteriorly, and a rounded posterior margin, while the ancoral process is rather short and broad.

The mandibles, which are almost miniatures of those of the next species, are long with uneven outline, the dorsal margin convex distally and concave proximally, forming together with the posterior margin a relatively short and blunt process; claw long, slender, rather straight, more sharply curved at the tip, where it is finely serrate, and much exceeding the dorsal margin. The serrations are directly backward and limited to the terminal portion of the claw. The length is 0.312 mm. in the case of a specimen about 0.825 mm. in length.

The palpus (pl. XXIX, fig. 4), which is alike in both sexes, is very long, nearly equaling the length of the body, and relatively slender, though thicker than the first pair of legs. The measurements of the successive segments give the following percentages of total length: 7, 28, 13, 34, and 18. Seg. 2 has a straight flexor margin and an extensor very slightly convex, its greatest thickness being only equal to about four-sevenths of its length; seg. 3 is barely longer than thick; while seg. 4 is nearly five times as long as thick at the base. The latter segment is much contracted close to the base, where it is the narrowest, while it is widest about the middle. Seg. 5 tapers very rapidly from the base to a distance equal to about one-fourth of the total length, after which the diameter diminishes very gradually to a tip which is rather squarish and bears in addition to three small claws at the end one small one just behind them on the extensor margin. The papillae on seg. 4 are oblique to one another, the distance between their bases measured along the margin of the palpus being somewhat less than one-third the distance from the base to the first and a little over two-thirds the distance from the more distal of the two to the base of the spur at the tip of the segment. The outer of these two papillae is the longer and is equal to one-third the width of the segment at that point. The spur at the tip of this segment is prominent and shelf-like, containing a short, straight claw.

The epimera cover a large part of the ventral surface and are separated from one another by a considerable interval in the case of the female, but are approximate in the case of the male. The posterior process on ep. 4 is short and blunt.

The legs are long, even the first exceeding by about one-third the length of the body; II and III are approximately equal and considerably longer than I; while IV is again much longer than either of the two preceding. They are abundantly supplied with spines, and seg. 5, which is first dilated and then contracted at the outer end, is furnished with a conspicuous double row of stout spines on the flexor surface. The distal end of this segment exhibits a curious modification, the anterior side being produced and forming several teeth. There are in the case of the male long, slender hairs on segs. 4 and 5 of leg II, seven on the former and five on the latter segment; leg III also possesses, on each of segs. 4 and 5, about five or six swimming-hairs; while on seg. IV 4 are three and on seg. IV 5 six. In the female, leg I possesses six long hairs on the posterior side of seg. 5; leg II, six and eight on segs. 4 and 5 respectively; leg III, seven or eight and nine on the same segments; and leg IV, two on seg. 3, five swimming-hairs on seg. 4, and seven on seg. 5. The distal segment of leg III in the male (pl. XXIX, fig. 7) is long, moderately slender, slightly curved, and longer along the flexor than along the extensor margin; its claw is short and weakly curved. On seg. IV 4 (pl. XXIX, fig. 3) there are, proximad of the excavation, two rows of three stout spines each and two spines between these rows; distad of this excavation are four in an oblique line leading to the swimming-hairs.

The genital area in the male (pl. XXIX, fig. 8) shows a fusion of the chitinous plates with the fourth epimeron. The genital cleft is short and surrounded by a seminal receptacle in the form of a depression which is elliptical in form and with an even rim. In the median line directly behind this opening there are no acetabula, but, beginning with a row of the acetabula at either side at this point, there may be counted a total of 45 to 50 on each side. The chitinous plates on which these rest are long, tongue-like, and, owing to the form of the posterior margin of the fourth epimeron, show an excavation of the anterior margin, while the outer and posterior margins are evenly rounded.

In the case of the female (pl. XXIX, fig. 5) the much longer genital cleft is surrounded by an elongated, elliptical area flanked on either side by chitinous plates which are in contact with it along the posterior half of either lateral margin, but which do not meet caudad of it. The tongue-like chitinous lateral plate extends to a point even with the posterior spine on the fourth epimeron. In the male the chitinous ring surrounding the opening is connected with the genital area; while in the female it lies some distance behind this and free in the wall of the body.

Measurements of two specimens give the following figures:

	MALE	FEMALE
Body	0.825 mm.	0.920 mm.
Leg I	1.056 mm.	1.205 mm.
Leg II	1.104 mm.	1.310 mm.
Leg III	1.066 mm.	1.339 mm.
Leg IV	1.248 mm.	1.546 mm.
Mandible	0.312 mm.	....
Palpus	0.696 mm.	0.854 mm.

The color of this species, as briefly noted in field notes taken at Lake St. Clair in the summer of 1893, was "transparent with a brownish tinge; with brownish yellow patches and Y-shaped mark of white dotted with carmine; brownish red eyes; and legs that were blue with the terminal joints brownish yellow."

The types are retained in the collection of the author; co-types have been deposited in the collection of the Zoological Laboratory, the University of Nebraska, and in the United States National Museum.

Specimens of this species were taken at Lake St. Clair in the summer of 1893, sixteen males and four females altogether. One male taken at Wray, Col., November 16, 1901, is also put here, being apparently identical.

The specific name is bestowed in allusion to the slenderness ot the palpi, which are also longer than in any described form, and which serve to distinguish this species from all others hitherto known. The form is in length of palpi and in other details similar to the next species but is readily distinguishable.

3. *Curvipes pugilis* n. sp.

A large species similar to *C. exilis* in palpal characters, but characterized by the curvature of the distal segments of the legs. It has an elliptical body, uniformly arched, highest a little behind the middle with a prominence in front of each eye and a slight excavation between them. The breadth is about equal to four-fifths the length and the height equal to nearly nine-tenths of the same. Measurement of several males and females from Lake St. Clair, preserved in corrosive sublimate and picro-sulphuric, give a length, for the males, varying from 1.25 mm. to 1.5 mm., the average being 1.42 mm.; for the females varying from 1.5 to 1.7 mm., the average being about 1.58 mm. The body is marked by very fine wavy lines over the surface. The eyes are relatively small and moderately distant from the anterior margin, while the distance between them is proportionately rather great. The antenniform bristles are extremely small and inconspicuous.

The maxillary shield and the ancoral process, owing to the straightness of the sides of the former and the breadth of the latter at the base, form together a roughly triangular mass, truncate at the tip.

The examination of the mandibles of several males shows them to be similar to that of the preceding species, though the claw is longer, larger, and more strongly hooked. The serrations on the claw are small, gradually disappearing toward the base. In a specimen the length of which was about 1.3 mm. the mandible was found to be 0.405 mm. long.

The palpi (pl. XXIX, fig. 9) are long, being, in a male, six-sevenths the body length. The general form is slender, though they are thicker than leg I. Seg. 1 is proportionately short; seg. 2 rather long and with a maximum thickness equal to about six-tenths the length; seg. 3 thicker than long; while seg. 4 exhibits a maximum thickness of only one-quarter its length. Seg. 5 is long proportionately and tapers gradually from the base to the tip, where it is somewhat less than half the thickness of the base. The papillae and spine on seg. 4 are similar in position and form to those of *C. exilis*, but are all noticeably smaller; while there are also several small hairs in addition on the outer surface; seg. 5 has three small, curved claws at the tip, and an additional rudimentary one on the flexor margin behind the tip.

The epimera cover a considerable portion of the ventral surface, are in the female separated by a moderate interval, and in the male are close together, I and II crowding the maxillary shield. The posterior projection of ep. IV is rather long but bluntly rounded.

The legs are long, even the first being considerably longer than the body, while the fourth is more than half as long again. The length of the individual segments is, in each leg, in order, beginning with the longest, 5, 4, 6, 3, 2, 1. Seg. IV 6 is, however, proportionately lengthened in the female; III 6 is shortened in the male; and

IV 4 also shortened in the latter sex, being shorter than IV 6. In thickness the segments gradually decrease from the base out, except that in the first three pairs of legs seg. 5 is much thickened, exceeding in thickness in I and II all segments but the basal, and is closely beset with coarse spines on the outer half of the flexor margin. The distal segment of the first three legs is peculiar in being strongly curved (pl. XXIX, fig. 11), this curvature being greatest in the case of the first pair of legs. The distal end of seg. 5 is also peculiar in the possession of a terminal expansion on the anterior side similar to that seen in *C. exilis,* extending, in the case of legs I and II, considerably beyond the base of seg. 6; this is less prominent on leg III and not developed on leg IV. The claws are small and possess two sharp, curved points and a narrow basal expansion. In the case of the male, seg. III 6 (pl. XXIX, fig. 10) is somewhat curved, slightly thickened at the outer end, and with a very weak claw with strongly curved tips. Seg. IV 4 shows, on the anterior side, a row of seven spines along the flexor margin and about five, small but of varying length, along the extensor margin; while on the posterior surface there are, proximad of the excavation, about twelve or thirteen spines increasing in size distally; in the excavation, three short, blunt, slightly curved spines toward the extensor margin and one large one on the flexor margin; and distad of it three stout spines in a row, and in line with these, at the tip, seven swimming-hairs. Aside from these the number of hairs is as follows: On II 4 and II 5, six and eight respectively; on III 3, two at the tip; on III 4, nine; on III 5, ten; and on IV 5, ten swimming-hairs. In the female there are seven long slender hairs on the posterior side of I 4, seven on I 5, seven on II 4, ten on II 5, two on III 3 at the tip, ten on III 4, twelve on III 5, two on IV 3, and ten each on IV 4 and IV 5, those on IV being swimming-hairs.

The genital area of this species exhibits a length from the extreme anterior end to a line tangent to the posterior margin of the lateral chitinous plates of one-half that of the extreme breadth. The genital cleft is short, and the two lateral chitinous plates are separated by a considerable interval behind it in the case of the female, while in the case of the male (pl. XXIX, fig. 12) the two plates approach each other closer and the chitinous anal ring is fused with them. Each lateral plate is tongue-like with the anterior margin excavated, and the outer and posterior more or less evenly rounded. Each possesses from 60 to 70 acetabula, of which two are noticeably larger than the rest and are situated in the middle of the plate. In the male the plates are fused with the inner end of the last epimera.

MEASUREMENTS

	MALE	FEMALE
Body	1.270 mm.	1.555 mm.
Leg I	1.656 mm.	1.776 mm.
Leg II	1.781 mm.	1.896 mm.
Leg III	1.723 mm.	1.982 mm.
Leg IV	1.934 mm.	2.198 mm.
Palpus	1.066 mm.	1.094 mm.
Mandible	0.381 mm.	....
Extreme breadth of genital area	0.714 mm.	....

The color of this species can not be stated with certainty from the preserved specimens. The legs, however, possess a very dark bluish tinge with the exception of the distal segments which are brownish.

The types are in the collection of the author; co-types have been deposited in the collection of the Zoological Laboratory, the University of Nebraska, and in the United States National Museum.

Altogether thirteen males and nine females were taken at Lake St. Clair, Mich., during the summer of 1893; four males and three females were collected by Mr. J. B. Shearer at Les Chenaux Island, northern Lake Huron, in August, 1895; while one male and one female were collected in Twin Lakes near Charlevoix, Mich., August 6 and 13, 1894, making a total of thirty-one specimens.

The name is bestowed in allusion to the form of the distal segments of the legs, which are in all the preserved specimens flexed in such a manner as to suggest a resemblance to the position of the arms of a boxer.

This species closely resembles, in the form of the palpus, the mandible, and the genital area, the preceding species, but differs in details and especially in the form of seg. 6 of the legs.

4. *Curvipes turgidus* n. sp.

A species characterized by its size, the characters of the palpi, the length of the legs, and the appearance of the genital area.

The female of this, one of the largest species yet met with, judging by the measurement of about a dozen specimens, averages 2.3 mm. in length and 1.78 mm. in width, with a variation in length between 2.55 mm. and 2.01 mm. Two males which seemed to have preserved nearest the natural size and form measure 1.34 mm. and 1.40 mm. respectively. The body is broad and high, being highest at a point three-fourths of the way back from the anterior margin, while there is a slight constriction behind the eyes. From the dorsal aspect the body is oval, narrowed anteriorly, and emarginate between the eyes, which are of moderate size and about one-third the width of the body apart. The surface is finely striate. The two antenniform bristles are somewhat closer together than the eyes, and each is awl-shaped, short, straight, and slender.

The maxillary shield is rather broad and the ancoral process on it long and presenting a shallow concavity at the side and a deep notch at the tip. The ventro-posterior angle of the mandible is short and blunt and the dorsal and ventral margins are nearly parallel. The claw is stout and slightly curved and the serrations are few and confined to the tip.

The palpus (pl. XXX, fig. 22) is relatively long and slender. The percentage lengths of the segments in order from the base out are: 9, 26, 12, 36, 17. Seg. 1 is only about one-third broader than long; seg. 2 only three-fifths as thick as long, with a straight flexor and a slightly convex extensor margin; seg. 3 possesses a uniform diameter slightly less than the length; seg. 4 is dilated in the middle, where the diameter is equal to about three-sevenths of the total length, and the thickness is slightly less at the tip than at the base; while seg. 5 is somewhat less in diameter at the base than half its total length and tapers uniformly to the tip, where it is half as thick at the base, is curved ventrad, and bears three short, curved claws. On the flexor margin of seg. 4 are two long papillae set obliquely, conical in form, and bearing short hairs, the inner one of which is somewhat less than half the distance from the base to the tip of the segment, while the outer, the longer, is at a distance of about five-eighths from the base. There are also two small papillae mid-way between these and the distal end, like them placed obliquely, with the longer on the outer side, and the shelf-like claw at the end. The papillae on the palpus of the female are all proportionately shorter than those of the male.

The epimera of the female are of moderate size and a rather narrow interval separates II from III, while III and IV of either side are separated by a distance equal to somewhat less than one-third the length of their inner margin. Those of the male are in close apposition. The posterior process on ep. IV is rather long and the margin of epimeron within it is nearly straight.

The legs are long and rather heavy, the first pair of the female being somewhat less than the length of the body, the other three slightly exceeding it, while all those of the male exceed the body length by considerable. There is very little difference in length between the first and last legs of the female. In the male the third pair of legs is the shortest, and the last is exceeded by the second pair. The individual segments of the female are of nearly uniform thickness from base to tip, the distal segment being only slightly dilated at the outer end, and the usual order of segments in regard to length is 5, 4, 6, 3, 2, 1. In leg III seg. 4 is shorter than the corresponding segment of leg II, while seg. 5 is practically equal to the corresponding segment of leg II. In leg IV segs. 4 and 5 are shorter than the corresponding segments of leg III, and seg. 6 is shorter even than the corresponding segment of leg I. In the male the sixth segment is longer than the fourth except in leg III. In leg III of this sex segs. 1 to 4 are short and 5 is long, while in the last pair of legs 3 is very short, being exceeded both by 2 and 1, and 4, 5, and 6 are also relatively short. Leg I of both sexes has eight or nine slender hairs on the posterior side of seg. 5 and two near the outer end of seg. 4; leg II has a row of about ten on seg. 4 and from twelve to fifteen on seg. 5, in a row from near the base of the segment out. Leg III has, in the female, a row of fifteen on seg. 4 and nineteen on seg. 5, the male having the same number of very small hairs on seg. 4, while those on seg. 5 are lacking. Leg IV of the female has about ten swimming-hairs in a close row at the end of seg. 4 and from twelve to fifteen swimming-hairs at the end of seg. 5, the male having seven and from fifteen to seventeen on the same segments respectively. In the male seg. III 6 (pl. XXX, fig. 19) has a straight extensor margin and a curved flexor, the tip being broadly expanded. Seg. IV 4 of this sex (pl. XXX, fig. 23) is very broad with a deep excavation on the posterior side, on which side the tip is strongly produced; there are about eighteen spines proximad of the excavation and about twelve distad of it, together with from six to eight swimming-hairs. The distal end of the fifth segments in all the legs of the female, and in the first two of the male, is expanded on the anterior side.

The median area of the genital field in the female (pl. XXX, fig. 20) is limited anteriorly by a very long, transversely placed chitinous plate between the inner ends of the last pair of epimera. The length of the genital cleft is equal to slightly less than half the breadth of the whole field, which in turn is slightly more than one-fourth the breadth of the body. The two flaps which close the cleft are rather broad and are bounded from the middle of the lateral margin clear around to the median line by solid tongue-shaped chitinous plates which bear each from forty to fifty acetabula, two of which are slightly larger than the rest. The narrow portion of each plate, which extends inward behind the genital flaps to meet its fellow of the opposite side, possesses no acetabula, but bears, where it leaves the main body of the plate, a row of three or four short hairs. In the male (pl. XXX, fig. 21) there is a capacious seminal pouch which is broadly open anteriorly. On either side of the median line behind the opening of this is an approximately circular genital plate bearing somewhat over fifty acetabula, the posterior margin of this plate being evenly rounded, the anterior slightly excavated, while the two are separated by a moderate interval.

The anal opening is situated at some distance behind the genital area and is imbedded free in the wall of the body.

Measurements give the following results:

	MALE	FEMALE
Length of body	....	....
Leg I	1.661 mm.	2.218 mm.
Leg II	1.862 mm.	2.331 mm.
Leg III	1.483 mm.	2.346 mm.
Leg IV	1.733 mm.	2.467 mm.
Palpus	0.893 mm.	1.099 mm.
Inner margin of ep. III and IV	....	0.413 mm.
Distance between ep. III and IV	....	0.127 mm.
Length of genital cleft	....	0.333 mm.
Extreme breadth of genital cleft	....	0.651 mm.

The types are retained by the author; co-types have been deposited in the collection of the Zoological Laboratory, the University of Nebraska, and in the United States National Museum.

Of this species there were collected in High Island Harbor, northern Lake Michigan, August 18, 1894, nine males and two females, the color of which can not be given. In the summer of 1895 the species was present in large numbers in a small bog-lake or pond near Grand Rapids, Mich., only about 100 yards in diameter. Females alone, of large size, being distended to the utmost by eggs, were secured, twenty-one specimens being now at hand for examination. All of these were of a brilliant scarlet-red color with darker patches and black eyes. One female specimen was also received from Mr. J. B. Shearer, of Bay City, Mich., collected in Saginaw Bay, August, 1895, and five males and one female were secured in Lake Winnebago, Oshkosh, Wis., August, 1897.

The species bears a resemblance to *C. longipalpis* Krend, and *C. nodatus* (Müll.), two widely diffused European species, but is clearly distinct, being told from *C. nodatus* at first glance by the much larger number of acetabula, and differing from *C. longipalpis* in the possession of four papillae on segment 4 of the palpus, in the details of structure of the genital area, and in other structural features. From *C. fallax* Thon the species differs in the form and proportions of the genital area, the measurement of legs and palpi, and especially in the character of leg III of the males.

The name is in allusion to the large size, especially of the females.

5. *Curvipes triangularis* n. sp.

A species resembling closely *C. nodatus* (Müll.) and *C. turgidus*, but differing from either and characterized by the form and structure of the palpi and genital area. The three specimens taken possess an unusually delicate chitinous covering.

The body of these specimens is, in general, elliptical in form, but this general form is modified by a different degree in each one of the three. One shows a distinct depression between the eyes and also a posterior emargination on either side. The others show a less distinct posterior emargination, and one is anteriorly even convex. The body is rather low and flattened when viewed from the side and exhibits also a slight indentation behind the eyes. The longest of the three is 1.27 mm., the shortest 0.92 mm. The width of the first is 1.02 mm. and its height 0.89 mm., while the second is 0.71 mm. in width. The surface is everywhere finely striate.

The eyes are situated near the anterior margin and are a trifle more than one-third as far apart as the body is wide. They are large and brownish in color. The antenniform bristles are short and flattened.

The maxillary shield is rather broad and short and the same is true of the ancoral process. The mandible in the case of the specimen 0.92 mm. long, from which a slide preparation was made, is 0.346 mm. in length. Its ventral margin is long, its dorsal short and forming a very obtuse angle with the posterior margin, while the ventro-posterior angle is long and moderately pointed. The claws are very long, strongly curved at the base, then straight and hooked at the tip, towards which is the usual fine serration.

The palpi (pl. XXXI, fig. 32) are long and slender and the different segments make up the following percentages of the total length: 9, 25, 12, 34, 20. The inner margin of seg. 2 is straight; that of seg. 3, concave; seg. 4 is dilated and possesses on its flexor surface two long papillae placed obliquely to one another, of which the inner is about at the middle of the segment, the outer midway between that and the distal end. The spur at the tip of this segment is shelf-like. Seg. 5 is much elongated, decreases uniformly in thickness, and exhibits a curvature ventrad, being terminated by three small claws.

The epimera are separated by a considerable interval and the inner margin of III and IV is short with the angle at either end rounded, the length of the two together in the mounted specimen being 0.216 mm. The angle on the posterior margin of IV is of moderate length.

The legs are long, all exceeding the body length, the fourth by about one-half. The individual segments are, in the order of length, 5, 4, 6, 3, 2, 1; they present no noteworthy details of form. There are the following hairs to be noticed: On seg. I 4, one at the tip, and on I 5, two; on II 4, six, the first at one-third the distance out from the base; on seg. II 5, eight; on III 4 and 5, seven and nine respectively; while on seg. IV 4 and IV 5 are five and seven swimming-hairs.

The genital area (pl. XXXI, fig. 33) exhibits a median, elliptical, much elongated area flanked on either side by two plates tongue-like in form, concave along the front margin, strongly convex along the posterior and rounded at the outer end. These plates meet the median area in such a way as to leave free the anterior half of the lateral border and a distance at the posterior end between them nearly as great as the breadth of the plates themselves. Each bears from twenty-five to thirty acetabula, of which two are larger than the rest.

Measurement of the mounted specimen gives the following figures:

Body	0.920 mm.
Leg I	1.152 mm.
Leg II	1.262 mm.
Leg III	1.282 mm.
Leg IV	1.382 mm.
Palpus	0.744 mm.
Total length of mandible	0.346 mm.
Length of genital area along median line	0.216 mm.
Total breadth of genital area	0.376 mm.

The type of this species is retained in the collection of the author.

Of this form only three females were collected in a pond near Columbia, Mo., during the latter part of August, 1901. It differs from *C. nodatus* (Müll.), to which it bears a very close resemblance, in the lack of the third papilla on seg. 4 of the palpus and of numerous hairs belonging to the same segment, in the lack of hairs on ep. IV, and in numerous other details of structure where the difference is one of degree rather than kind. From *C. turgidus* it is easily distinguished by the palpal characters, form of epimera and space between them, form of genital area, number of acetabula, etc.

The name is suggested by the form of the genital area, which is approximately triangular.

6. *Curvipes constrictus* n. sp.

A well-marked species, most closely resembling *C. carneus* (Koch) but clearly distinct, and characterized by the form of the palpi, of the genital area, and of the characteristic leg segments of the male.

The body of the single male under observation is relatively long, smoothly rounded posteriorly, but deeply emarginate between the eyes and also much constricted behind them, which constriction is apparent both from the dorsal and lateral view. The width is a little less than three-fourths the length and the height somewhat less than the width. The female which is placed with this male is much larger and of similar proportions, but neither so deeply emarginate between the eyes nor so much constricted behind them. The surface of the body in both is marked by fine lines.

The eyes of the male are separated by an interval equal to somewhat over two-fifths the width of the body, those of the female somewhat less than the two-fifths, the exact measurements being 0.287 mm. and 0.46 mm. respectively. The antenniform bristles rise from evident papillae, are long, curved upward, and separated from one another by a distance somewhat less than three-fourths that between the eyes. In the male they are 19 μ in length.

The maxillary shield is evenly rounded posteriorly with a very short ancoral process, which is only slightly excavated at the sides and not broadly dilated at the tip.

The palpi of the male (pl. XXX, fig. 17) are proportionately rather short, being about two-fifths the body length; while in the female, owing to the larger size of the body, they are proportionately even smaller, and measurement shows them to be actually somewhat shorter than those of the male. They are hardly wider than the first pair of legs in the case of the male and narrower in that of the female. Of the separate segments the relative lengths are represented by the percentages: 9, 32, 12, 28, 19. The first is nearly twice as broad as long and is strongly angulated on the flexor side; the second is only five-sixths as thick as long and has a relatively short flexor margin; seg. 3 is half as thick again as long; seg. 4 is moderately slender and slightly dilated at the middle, where it is about as thick as at the base; while seg. 5 is usually slender, being about half as broad at the tip as at the base and unusually pointed. The usual spines are present but somewhat longer than the average. The two papillae on the flexor side of seg. 4 in the male are oblique to one another, the inner being the more distal, are equal in size, and are conical, with small hairs at the tip. The spur at the tip of the flexor margin of this segment is represented by a very stout flat spine. The claws at the tip of the last segment are long and much crowded, owing to the narrowness of the tip, and the middle one lies on the outer side of the other two; while on the flexor side, behind the claws, is a slender curved hair. In the female the two papillae on seg. 4 seem to be nearly in line.

The epimera occupy, in the case of the male (pl. XXX, fig. 15), the anterior half of the ventral surface; in the case of the female (pl. XXX, fig. 14) less, being in this sex proportionately very small. In the male the space between the inner ends of the two anterior pairs of epimera is wide and the exposed body surface is considerable. Ep. II and III of each side are separated by a rather wide interval, and the anterior ends of III of the opposite sides are also separated slightly from one another, though the two last epimera are fused. Within the process on the posterior margin of IV, which is itself rather blunt, the margin of the epimeron is deeply excavated. In the female the four masses formed by the unusually small epimera are widely separated from one another.

The legs of the male are moderately long, the first exceeding the length of the body by about one-fifth, while the last is short and scarcely exceeds the first. Owing to the large size of the female the legs appear smaller than in the male, although actually somewhat longer, with the exception of leg III, which is exceeded by the corresponding leg of the male. The distal segment is rather long. In the male the length of the individual segments of legs I and II are, in order, 6, 5, 4, 3, 2, 1. In leg III of this sex both 5 and 4 exceed 6, while in leg IV, 5 and 6 are approximately equal and longer than 4. In the female the same proportion holds good for legs I and II; in leg III, 5 and 4 are nearly equal and both exceed 6, which is also true in leg IV. Leg I of the female has a long spine at the distal end of seg. 3, six long hairs on the outer third of seg. 4, and eight long hairs at the outer end of seg. 5; leg II has a similar long spine at the distal end of seg. 3, eight long hairs from the middle out in seg. 4, and eleven from the middle outward in seg. 5 (*cf.* pl. XXX, fig. 18); leg III possesses two long spines on 3 and nine and ten on 4 and 5 respectively, disposed as in leg II; while leg IV possesses also two long spines on 3 and seven and eight swimming-hairs at the tips of segs. 4 and 5. The male shows similar long spines at the tip of seg. 3 on legs I, II, and III, five and seven long hairs at the tip of 4 and 5 respectively in leg I, seven and nine on the corresponding segments of leg II (pl. XXX, fig. 18), and five and seven on the same segments of leg III, six on the latter leg being very fine. Seg. III 6 (pl. XXIX, fig. 13) is of the form of a cornucopia, the outer end of which opens toward the flexor side, and bears a small, short, strongly curved claw. Segs. 1 to 4 on leg IV (pl. XXX, fig. 16) are very broad and 5 and 6 slender, contrasting strongly with the other four; seg. 4 is especially broad and the excavation correspondingly deep. There are, proximad of this excavation, about seventeen spines, irregularly distributed, all very stout and curved, those nearest the proximal end short but becoming longer and saber-shaped as one passes outward; on the flexor side are two long, stout, sharp spines, while toward the extensor side is one, in the excavation; distad, there is a marked dilatation, and on the flexor face of this are situated nine stout, curved spines and beyond them, at the tip, are three slender swimming-hairs. On the extensor side of this segment are three small spines toward the base and one at the tip, together with four long ones on the flexor side near the anterior margin. Seg. 5 is evidently somewhat contracted in the middle and dilated at its distal end, where it bears fifteen swimming-hairs in a crowded row. The corresponding segment in the female is somewhat contracted in the middle and to a slight degree the same is true of the corresponding segments of the anterior legs in both sexes.

The genital area of the male (pl. XXX, fig. 15) is in contact with the posterior epimera in the median line and again at the tips of the processes on the posterior margin and is very characteristic in appearance. In the median line is a broad disk one-half broader than long, elliptical in outline, and with a conical anterior projection in the median line in front which reaches the posterior epimera and which possesses a length equal to about one-fourth the length of the rest of the area. On either side of this area are the genital plates bearing nine and ten acetabula respectively and separated by a considerable interval along the posterior margin of the elliptical area referred to. The anal opening is situated a moderate distance behind the genital area and entirely separated from it.

The genital area in the female (pl. XXX, fig. 14) is proportionately smaller than in the male and exhibits a median elliptical area four-fifths as broad as long. On either side of this are two small crescent-shaped plates closely applied to about two-thirds the lateral of this area, being separated from each other by a considerable interval posteriorly; each bears ten acetabula.

Measurement of the two specimens under observation:

	MALE	FEMALE
Body	0.920 mm.	1.730 mm.
Leg I	1.056 mm.	1.094 mm.
Leg II	1.142 mm.	1.214 mm.
Leg III	1.368 mm.	1.243 mm.
Leg IV	1.075 mm.	1.373 mm.
Extreme breadth of genital area	0.333 mm.	0.317 mm.
Length of same along median line	0.115 mm.	0.238 mm.
Palpus	0.360 mm.	0.341 mm.

The color of neither can be told from the preserved specimens. Yet there are certain indications that both were pale red or flesh-colored, with patches of light brown, and that in both the legs were strongly tinged with salmon.

The types are retained in the collection of the author.

The male of this species was taken in material collected in temporary pools formed by melting snow in the woods four miles west of Ann Arbor, Mich., in the latter part of March, 1894. The female was collected in a spring-fed pool in Monroe Canyon, Sioux county, Neb., between May 28 and 30, 1899. No other specimens have ever come under the observation of the writer, and while he has at first hesitated to assign these two to the same species, the points of agreement are so numerous and striking as to leave comparatively little doubt that they represent the two sexes of one and the same species.

C. constrictus most closely resembles *C. carneus* (Koch), a generally distributed European species, but differs in the structure of the palpi, in the relatively longer legs, in the character of seg. III 6 of the male, in there being three instead of nine swimming-hairs on seg. IV 4 of the male, in the details of structure of the genital area in both sexes, and in the number of acetabula, which is ten in each sex, instead of fifteen in the male and from eighteen to twenty-four in the female. The distal segment of the third pair of legs resembles that of *C. coccinoides* Thor, but the two are quite unlike in other respects.

The name refers to the contraction of the fifth segment of the legs.

7. *Curvipes spinulosus* n. sp.

A species characterized by its small size, the paucity of spines on the legs, and other details of structure.

The smallest of our species and one which appears to be also quite variable. The average length of a large number of specimens collected from the Twin Lakes near Charlevoix, Mich., in the summer of 1894, and preserved in corrosive sublimate, is 0.53 mm. and the average width 0.436 mm. with a height distinctly less than the width. The males and females collected were of about the same size and, judging by the examination of a number of the latter, the size is not subject to much increase during the development of the eggs, of which only a few were found in any individual.

In form the body is broadly elliptical and presents only a slight depression between the eyes. It is evenly convex dorsally with the surface and the cuticula thin. The antenniform bristles are of medium length, straight, and about the same distance apart as the eyes. The latter are very large and distant from the anterior margin. The average of several specimens gives for the distance apart 0.127 mm., and for the diameter of the eyes themselves 44 μ.

The maxillary shield is of moderate size, expanded anteriorly, and the ancoral process in the female relatively short and strongly hooked, in the male longer and lying beneath the inner ends of ep. I. The mandibles are relatively long with a stout, strongly hooked claw, the serrations on which extend half way toward the base.

The palpus in both sexes is about two-thirds as long as the body, while the percentage length of the different segments is as follows: 10, 28, 13, 31, 18. In the male (pl. XXXI, fig. 27) the first segment is about half as thick again as long; the second segment somewhat narrower than long with its flexor surface very convex; seg. 3 is thicker than long, and with the flexor surface even more concave than the extensor is convex; and seg. 4 is dilated in the middle, where its breadth is somewhat more than half the length of segment. The latter segment bears at the middle two conical papillae set at such an angle that the distal side is at right angles to the long axis of the segment; these are nearly opposite, the outer somewhat the longer, and each possesses a long hair. The spur at the tip of this segment is blunt. Seg. 5 tapers evenly from base to tip and is relatively broad and blunt and bears at the tip three claws. In the female (pl. XXXI, fig. 28) the segments taper more uniformly from base to tip, seg. 4 is not dilated, and the papillae on the flexor side of this segment are relatively very much shorter.

The epimera of the male (pl. XXXI, fig. 25) are very close together, those of the female (pl. XXXI, fig. 24) separated by only a narrow interval, in both sexes covering almost the entire ventral surface and leaving space posteriorly for only the genital area. The process on the posterior side of the fourth epimeron is rather long and sharp, and within this the outline of the margin is evenly and sligtly concave.

The legs in both sexes are relatively long and heavy, the first exceeding the body by one-third. In the male the flexor side of the fifth segment in the anterior two legs is strongly convex, and the distal segment of the same legs club shaped and relatively large. In the third leg of this sex seg. 5 is markedly elongated and possesses a low angle on the extensor margin in the middle, while seg. 6 (pl. XXXI, fig. 26) is short and stout, being nearly as thick at the base as at the tip, and in different specimens more or less curved ventrad; its claw is long, straight, very sharp, and in length nearly two-thirds the length of the segment. In this sex there are two fine hairs on seg. I 5 and two long spines on each of segs II 4, II 5, and III 4, with two swimming-hairs in addition at the tip of III 4. On seg. III 5 are no swimming-hairs but a row of four long, strong spines, which increase in length toward the tip and of which the distal surpasses by considerable the tip of seg. 6. There are three swimming-hairs at the tip of seg. IV 4 (pl. XXXI, fig. 29) and four at the tip of IV 5. In the female, leg II possesses two long spines on segs. 4 and 5; leg III, five on each of segs. 4 and 5; while leg IV possesses one long hair at the tip of seg. 3 and four swimming-hairs at the tip each of segs. 4 and 5. As a whole the legs bear relatively few spines, but these are comparatively stout.

The genital area is similar in form in the two sexes, the lateral plates, which bear in the male 25 to 30 acetabula and in the female from 20 to 25, being tongue-like in form, meeting the median portion along its entire margin, and extending laterally beyond the angle on ep. IV. Their inner ends are, in the male, fused with the inner angles of the last epimera. The median area is elliptical in form in both sexes, in the female specimen being 0.11 mm. long and five-sixths as wide, and in several males examined having approximately the same proportions. This area, in the male, is depressed and is surrounded anteriorly by a distinct rim, which fades out posteriorly; somewhat in front of the middle is the cleft, half as long as the whole area. The chitinous anal ring is close behind the genital area in the case of the male; in the female some distance posteriad.

Measurement of specimens:

	MALE	FEMALE
Body	0.508 mm.	approx. 0.555 mm.
Leg I	0.682 mm.	0.778 mm.
Leg II	0.749 mm.	0.850 mm.
Leg III	0.773 mm.	0.902 mm.
Leg IV	0.787 mm.	1.003 mm.
Palpus	0.336 mm.	0.365 mm.
Extreme breadth, genital area	0.326 mm.	0.317 mm.
Length of same along median line	0.112 mm.	0.110 mm.

The color is given in field notes as "nearly transparent, with patches of dark sepia, and a red patch between the eyes, showing through beneath prominently; legs very pale greenish; eyes black."

The types are retained in the collection of the author; co-types have been deposited in the collection of the Zoological Laboratory, the University of Nebraska, and in the United States National Museum.

This species is one of the more common forms and a large number of specimens were collected at Charlevoix, Mich., in the summer of 1894; it was especially abundant in East Twin Lake, where about a hundred specimens, together with many larvae and nymphs, were collected. At Reed's Lake, near Grand Rapids, Mich., it was found commonly and many specimens collected August 11, 1896; July 14, 1897; July 23, 1898; and July 26, 1899,—altogether amounting to about fifty in number. July 27, 1898, thirty-six specimens were taken in Grand River, near Grand Rapids, and in addition a number of other specimens are in the author's collection procured at different localities about Grand Rapids in the summer of 1895. Several specimens were received from Mr. E. Foster, collected in a pond in Audubon Park, near New Orleans, La., August 11, 1901, and other specimens have been received from the Illinois State Laboratory of Natural History collected in the vicinity of Havana, Ill. The species thus seems to be not only widely diffused but an abundant species wherever found.

This species is the smallest of the group to which it belongs, though of about the same size as *C. tardus* Thon, *C. coacta* Koenike, *C. stellaris* (Kramer), and *C. pusilla* (Neuman), from all of which it is distinguished by marked structural peculiarities.

The name refers to the limited number of spines on the legs.

8. *Curvipes medius* n. sp.

A species characterized especially by the presence of two long papillae on the fourth palpal segment, side by side, and by the lunate genital plates, each with a total number of acetabula between thirty-five and forty.

Owing to the fact that the specimen was mounted before its specific characters were known and carefully examined, nothing can be said of the form of the body, it having been modified by distortion, nor of the character of the eyes and antenniform bristles. The body is approximately 1.1 mm. in length, and the surface shows a faint and irregular striation.

The mandible is 0.278 mm. long and roughly triangular, with a longer ventral margin which is wavy in outline. The ventro-posterior angle is blunt and the claw short, curved, and bluntly rounded at the tip. The serration is coarse and confined to the vicinity of the tip.

The palpus (pl. XXXI, fig. 31) is 0.564 mm. in length, and of the total length the different segments make up the following percentages: 10, 27, 14, 32, 17. Seg. 1 is nearly half as thick again as long, and seg. 2 quite thick, being nearly as thick as long, while in seg. 3 the dimensions are about equal. Seg. 4 is about equal in thickness at the two ends and somewhat dilated at the middle where its extreme thickness is a little less than one-third the total length. Seg. 5 is moderately slender and possesses a rather pointed tip, where it bears four curved claws. The two papillae on seg. 4 are nearly equal in length, opposite one another, and placed obliquely to the axis of the segment. The claw at the tip is shelf-like. The spines on segs. 2 and 3 are serrate, which is true of no other species examined.

The epimera resemble in form and relationship those of *C. rotundus.*

The legs are of moderate length, the first being about the length of the body. The segments are, in order of length, 5, 6, 4, 3, 2, 1, except that in III and IV, 4 exceeds 6. Segs. 4 and 5 of leg I possess each two long hairs; the corresponding segments on leg II, four and five; and the same segments on leg III, five and six respectively; while segs. 4 and 5 of leg IV possess each four swimming-hairs. The anterior margin of the fifth segment of each leg is more or less produced at the tip of the segment.

The genital area (pl. XXXI, fig. 30) exhibits a median elliptical portion flanked on either side by two plates which have a tongue-like outline and are somewhat longer than broad. They are not solid but enclose an irregular area in which are imbedded free in the wall of the body two or three acetabula in addition to thirty-six or thirty-seven borne on the plates themselves. The two plates do not meet along the posterior margin of the median area and bear along their posterior border a row of fine hairs, together with several at the anterior end and a few about the outer margin.

Measurement of the specimen gives the following figures:

Body (approximately)	1.100 mm.
Leg I	1.104 mm.
Leg II	1.282 mm.
Leg III	1.329 mm.
Leg IV	1.459 mm.
Palpus	0.535 mm.
Total length of mandible	0.278 mm.
Length of genital cleft	0.216 mm.
Extreme breadth of genital area (approximately)	0.550 mm.

The type is retained in the author's collection.

The single female specimen of this species was taken at High Island Harbor, northern Lake Michigan, August 18, 1894.

C. medius resembles *C. rotundus* and *C. disparilis* Koenike, but differs from either in the number of acetabula and in minor structural details.

The name refers to its position, in reference to details of structure, between *C. rotundus* and *C. disparilis*.

9. *Curvipes rotundus* (Kramer)

Nesaea rotundus Kramer, 79; 12, pl. I, fig. 6.

Curvipes rotundus Piersig, 97; 118; pl. IX, fig. 19.

Piona rotunda Piersig, 1901; 259.

The body of this species is broadly elliptical, evenly rounded anteriorly and posteriorly, and very high, its dorso-ventral diameter being equal to or slightly greater than the width. There is practically no constriction behind the eyes, and the body is highest just behind the middle. The surface is marked by fine wavy lines, and all chitinous structures are rather heavier than usual in this genus. The males are about 0.75 mm. long, the females about 0.9 mm.

The eyes are quite close together, the distance between them equaling one-fourth of the length of the body, and are slightly removed from the anterior margin. The antenniform bristles are slender, sharply-pointed, straight, and rather short.

The mandibles (pl. XXXII, fig. 40) are similar to those of *C. Reighardi* in general shape, but the dorsal margin is somewhat more markedly excavated. The claw is more strongly curved, its tip surpassing the level of the dorsal margin, while the serration on the flexor margin is finer and occupies the outer half. The total length of the mandible in a specimen about 0.9 mm. long is 0.221 mm.

The length of the palpus (pl. XXXII, fig. 41) is somewhat less than one-half the total length of the body. The various segments form the following percentages of this length: 6, 27, 14, 36, 17. Seg. 1 is, as usual, broad; seg. 2 is slightly narrower than long with a convex extensor margin and a still more convex flexor margin; seg. 3 is wider than long; seg. 4 is rather narrow and slightly expanded in the middle and with the extensor margin slightly convex; while seg. 5 is markedly contracted before the tip, where it is about one-half the diameter that it is at the base. In the male the proportionate length of the segments is the same, but the palpi are relatively a little heavier and the papillae on seg. 4 more prominent. The two papillae on seg. 4 are about opposite and markedly elongated, equaling more than half the thickness of the segment and bearing short spines. The spur at the tip of this segment is very prominent, while seg. 5 bears not only the usual three claws at the tip, but also, close behind the claws, a short stiff hair on the extensor margin and another on the flexor.

The epimera cover a considerable portion of the ventral surface, being separated in the female by a moderate interval, and in the male being in close apposition.

The legs of this species show a considerable difference in length between the first and last, and all but the first exceed the body length. There is, in the female, on seg. I 4 one long slender hair at the tip and also one at the tip of seg. I 5; on leg II are two or three on the corresponding segments; seg. III 4 possesses four swimming-hairs, and seg. III 5, five; while the corresponding segments on leg IV possess the same number. The last segment of the anterior three legs in the female are broadly club-shaped, while the distal segment of the fourth leg of the same species is relatively small and slender. The claws are large, rather delicate, and the two outer points slender and sharp. The legs of the male are proportionately heavier than in the female and the distal segment, especially on leg I, shows a tendency to be curved ventrad. Seg. III 6 (pl. XXXII, fig. 43) is rather stout, broader at the base, slightly curved, and bears a claw which is long, straight, and sharp. The segment preceding this is considerably elongated. Seg. IV 4 shows the characteristic form and possesses proximad of the excavation seven shorter and two longer spines, in the excavation on the flexor side one long spine, and distad of it two spines on the posterior surface and one on the flexor margin, together with three swimming-hairs at the tip and one spine toward the extensor margin from them. Segs. III 4 and IV 5 each bears four swimming-hairs.

Each half of the genital area in the female (pl. XXXII, fig. 42) is longer and more pointed than in *C. Reighardi,* while the lunate plate is not only heavier but broader, and the acetabula cover less of its surface. There are in this sex from twenty-two to twenty-six acetabula on each side, of which three or four are imbedded free in the body wall; there are six spines at the anterior end of the plate, several scattered along the outer margin, and four or five at the posterior end. In the male this genital area is similar in form with a shorter genital cleft, at the bottom of a shallow depression and surrounded on all sides by an even margin, while the tongue-shaped chitinous plates contain each thirty or more acetabula. These plates are fused anteriorly in this sex with the inner end of the fourth epimeron. The anal opening is also surrounded by a relatively heavy chitinous ring and is situated close behind the genital area.

Measurements of typical specimens are as follows:

	MALE	FEMALE
Body, approximate	....	0.900 mm.
Leg I	0.629 mm.	0.854 mm.
Leg II	0.701 mm.	0.907 mm.
Leg III	0.710 mm.	0.965 mm.
Leg IV	0.782 mm.	1.027 mm.
Palpus	0.331 mm.	0.413 mm.
Genital cleft	....	0.182 mm.
Breadth of genital area	....	0.384 mm.

No notes at hand show what the original color of this species was. The legs and the epimeral plates, however, have retained a deep blue tint, while the eyes are black.

This species has been collected in the following localities in Michigan: Reed's Lake, Grand Rapids, during the summer of 1895 and on August 11, 1896; Grand River, near the same city, July 27, 1898; at "26" Lake, near Charlevoix, August 6, 1894; at High Island Harbor, northern Lake Michigan, August 18, 1894; and in the Kawkawlin River, during August, 1895 (J. B. Shearer). Specimens are also at hand from South Bend, Neb., collected September 1, 1897

(H. B. Ward). The number of specimens thus secured is twenty.

This species is referred to *C. rotundus* since, though it differs in certain details from the descriptions given by Piersig and from specimens received from Koenike, comparison of various references with the specimens named shows a great variability, within the limits of which all differences presented by our specimens fall. *C. guatemalensis* (Stoll) (87; 11, pl. X, fig. 2, pl. XI, fig. 1) and *C. clathratus* Koenike (93; 33, pl. III, figs. 26–29) are both closely related, but the differences have been so clearly defined by Koenike (95*b*; 209) that a repetition is quite unnecessary. The former is recorded from Central America and Canada, the latter from Zanzibar.

10. *Curvipes debilis* n. sp.

A species distinguished by the slenderness of the palpi and the characters of the genital area.

The single male specimen upon which this species is based is 0.841 mm. in length and 0.698 mm. in width. The body is evenly elliptical, the surface with the usual lines and the eyes very large and black and moderately wide apart, the distance between them being 0.214 mm. The antenniform bristles are short and straight and separated from one another by 0.198 mm.

The palpus (pl. XXXII, fig. 45) is slender, being no thicker than the basal segment of the first pair of legs and short, the different segments furnishing the following percentages of the total length: 9, 28, 19, 35, 9. The usual number of spines and hairs is present, except for the addition of a long, slender hair springing from the base of seg. 5 on the outer side. The two papillae on seg. 4 are side by side and both rather short, and at a distance from the base of the segment equal to three-fourths its length.

The epimera are separated by an interval unusually wide for a male specimen.

The legs are more than the average length, the first exceeding the body about one-seventh, the others correspondingly longer. The length of the segments in order is 5, 6, 4, 3, 2, 1, except in the case of leg III, where 6 is so shortened as to be even shorter than 3. Segs. 4 and 5 of the anterior legs are straight along the extensor margin but convex on the flexor side, while seg. 6 is slender. The following hairs are present: On segs. I 4 and I 5, three and four, and on segs. II 4 and II 5, respectively, five and six slender hairs; on seg. III 3 are two; on seg. III 4, nine; and on III 5, one; while segs. IV 4 and IV 5 bear respectively four and six swimming-hairs. Seg. III 6 (pl. XXXII, fig. 44) is slightly curved toward the flexor side, is terminated by a long, sharp, straight claw, and bears unusually long hairs. Seg. IV 4 possesses proximad of the excavation on the posterior surface five short and two longer hairs, in the excavation one long hair, and distad of the same two short, flat hairs leading to the row of four swimming-hairs.

The genital area (pl. XXXII, fig. 46) is not large, its extreme breadth being only 0.294 mm. and its length, along the median line, 0.127 mm. The central shallow depression is nearly circular and bounded by tongue-shaped plates, in which are deeply imbedded fifteen acetabula on one side, and eighteen on the other.

Anal opening free in the body wall a short distance behind the genital area.

The following are the measurements of the specimen:

Body	0.841 mm.
Leg I	0.970 mm.
Leg II	1.051 mm.
Leg III	1.018 mm.
Leg IV	1.099 mm.
Palpus	0.355 mm.

Type retained by the author.

A single male specimen, collected in Cranberry Lake, Woods Hole, Mass., at the beginning of August, 1900.

The name is in allusion to the weakness of the legs.

11. *Curvipes Reighardi* n. sp.

A species of medium size, most closely related to *C. obturbans* Piersig and *C. tardus* Thon, and characterized by the form of the palpi and the characters of the genital area.

Female.—The body is broadly oval in form and widest about two-thirds the length back from the anterior end. It is smoothly rounded posteriorly with a shallow indentation anteriorly between the eyes, is moderately high, and shows a very slight constriction posterior to the eyes. Its width is approximately three-fourths its length, which itself varies much, the smallest of a considerable number measured being 0.7 mm. long, the largest 1.1 mm., while the average was about 0.9 mm. The surface shows a faint striation.

The antenniform bristles are short and straight and separated by an interval somewhat less than that between the eyes. The latter are of medium size, close to the anterior margin and separated by a moderate interval. In a specimen 1.06 mm. long and 0.857 mm. wide the distance between the eyes was found to be 0.238 mm. and between the antenniform bristles 0.206 mm.

The maxillary shield is broad, evenly rounded posteriorly, and with the lateral margin forming an even curve with the lateral margin of the ancoral process, which is somewhat less than it in length, is moderately contracted posteriorly, and is broadly expanded at the tip. The mandibles (pl. XXXII, fig. 38) are of moderate size, the dorsal margin straight, the posterior margin slightly sinuate and about the same length as the dorsal, and the ventral somewhat longer and slightly concave. The ventro-posterior angle is produced into a long, sharp point, while that between the dorsal and posterior margins is a little greater than a right angle. The claw is broad, rather blunt, and only slightly curved, the tip not reaching by considerable the level of the dorsal margin; the flexor margin at the tip and along the outer edge bears about six short teeth.

The total length of the palpus (pl. XXXII, fig. 36) is slightly less than half that of the body, the different segments, from the base out, contributing the following percentages of the whole: 7, 26, 15, 34, 18. The flexor margin of the basal segment is nearly straight; both margins of 2 are convex, the maximum thickness of the segment being equal to its length; the extensor margin of 3 is considerably longer than the flexor; seg. 4 is slightly curved ventrad and tapers gradually from base to tip, the flexor margin only becoming slightly convex at the base of the papillae; while the terminal segment also tapers to a blunt tip which bears three claws, of which the middle one alone is curved. The spines on 2 and 3 show no trace of serration. The papillae on seg. 4, which are nearly opposite, are placed a little over one-half the distance from the base to the tip; both are short, but the outer is the longer, being equal in length to one-fourth the thickness of the segment; each bears a small hair. The spur at the tip of the flexor margin of this segment is small; there are also two or three small hairs on the inner surface of the segment.

The epimera (pl. XXXII, fig. 35) are separated by a considerable interval. Ep. III and IV possess an inner margin equal in length to about one-fifth of the total length of the body, while the distance between those of opposite sides is about two-fifths the length of this margin. The projecting angle on the posterior margin of ep. IV is moderately long and sharp, the margin within it being concave, that external to it straight.

The legs are of moderate length and thickness, the first being somewhat longer than the body and the others slightly increasing in length from before backward. Seg. IV 5 is proportionally rather slender, and IV 6 markedly so. Seg. 3 of each leg is broadest in the middle where, on the flexor surface, it bears two heavy spines. On the posterior surface of seg. I 4 is a single small, slender hair, while on the next segment are two similar fine hairs; on seg. II 4 are two or three such hairs, and on seg. II 5 are three or four. Of true swimming-hairs seg. III 4 possesses three or four, while seg. III 5 possesses five or six, of which about four are in a line at the tip of the posterior margin, while the other one or two are separated by a little interval from it but are still in line with the rest. On the corresponding segments of leg IV are three and four swimming-hairs respectively. The claws are large and of the typical form (pl. XXXI, fig. 34).

The genital area (pl. XXXII, figs. 35 and 37) possesses a length along the median line equal to a little less than one-fourth that of the body and a breadth two-thirds greater than its length. The two flaps together form a broad elliptical area which is flanked on either side by a chitinous plate of the lunate form characteristic of the group to which this species belongs. On this plate are borne usually from 21 to 23 acetabula, while within the space it encloses there are, imbedded in the surface of the body, from two to four additional, of which one is larger than the rest. There is considerable variation in the number of acetabula, the specimen possessing the fewest having, on the two sides, 14 and 3 and 18 and 3 respectively. The specimen referred to also shows a division of the right plate into two. At the anterior end of this plate are from five to seven hairs and at the posterior end three or four, while about the circumference are scattered still three or four similar hairs. The anal opening lies isolated at a distance posterior to the genital area equal to about the length of this area.

The measurement of an average individual gives the following figures:

Body (approximately)	0.825 mm.
Leg I	0.883 mm.
Leg II	0.946 mm.
Leg III	0.984 mm.
Leg IV	1.104 mm.
Palpus	0.403 mm.
Length of genital cleft	0.206 mm.
Total breadth of genital area	0.349 mm.

MALE.—It is very peculiar that among 110 specimens of this species collected from a wide range of localities there should have been found but one male and this, unfortunately, is in poor condition, having been preserved in Flemming's solution along with other species, and having suffered the breakage of all appendages except one palpus, while the fragments which remain are so mixed with those from other specimens as to make it impossible to recognize them with certainty. As near as can be told from the specimen in the condition in which it now is, the form of the body, the form of the palpus, and the relative proportion of parts are about the same as those given for the female. Its length is approximately 0.6 mm. The greater portion of the ventral surface is covered by the epimera, all of which are in apposition. The lateral margins of the genital area are about even with the tip of the process in the posterior margin of ep. IV. The genital cleft is long, extending throughout the entire length of this genital area, and the seminal pouch is in the form of a shallow elliptical depression of the same length. The chitinous plates on either side bear each about 35 acetabula.

The color of specimens of this species collected from Lake St. Clair was recorded in field notes as "nearly transparent with a slight bluish green tinge; with brown patches and a yellow Y-shaped dorsal point; eyes black; and legs bluish green." In specimens from Lake St. Clair and from High Island Harbor in northern Lake Michigan, as well as others from Havana, Ill., preserved in the proper mixtures, the blue color of the legs has been retained, but in specimens from other localities the color is gone, and hence no statement can be made as to whether this coloration holds true in all cases or not.

The types are retained in the author's collection; co-types have been deposited in the collection of the Zoological Laboratory, the University of Nebraska, and in the United States National Museum.

Of this species the collection contains one male and 109 females, representing altogether the following list of localities:

MICHIGAN.—Lake St. Clair, summer of 1893 (the one male was taken September 8). Intermediate Lake, Ellsworth, August 9, 1894 (C. D. Marsh). Round, Pine, and "26" Lakes, Charlevoix, summer of 1894. High Island Harbor, northern Lake Michigan, August 18, 1894. Grand River, Reed's Lake, and other small lakes in the vicinity of Grand Rapids, on various days during July and August of the years 1895, 1896, 1897, 1898, and 1899. Kawkawlin River, August, 1895 (J. B. Shearer).

ILLINOIS.—Illinois River, slough (Station "I"), and Quiver Lake (Station "C"), near Havana, May 10, 1895, June 25, 1896, August 9, 1895, and September 12, 1894 (Biological Station, Illinois State Laboratory of Natural History).

LOUISIANA.—Audubon Park, New Orleans, August 11, 1901 (E. Foster).

This species, the first water-mite collected by the author, is dedicated to Prof. J. E. Reighard of the University of Michigan, the most prominent American limnologist, to whose kindness he owed the opportunities which put him in possession of his first specimens, the attractiveness of which led to his beginning the study of the group. The previous dedication of a genus of pentastomids to Professor Reighard has prevented the author from acknowledging in a more fitting manner his indebtedness to him.

It resembles *C. obturbans* Piersig, but differs in the greater stoutness of the palpi, especially of seg. 2, in the more uniform tapering of seg. 4 from base to tip, and in the absence of the small hair-bearing papillae on seg. 4, distad of the two usual prominent ones, which themselves are nearer the base of the segment. The genital area is similar and in *C. Reighardi* is very variable in the number of acetabula it possesses, yet it shows evident, though slight, differences in form and proportions. From *C. tardus* Thon this species is more easily distinguished by its shorter palpi, which are of different proportions, by the interval between the epimeral masses, and by the larger size and details of structure of the genital area.

12. *Curvipes obturbans* Piersig

Curvipes obturbans Piersig, 96; 439: Piersig, 97; 135, pl. X, fig. 23.

Piona obturbans Piersig, 1901; 259.

This species, of which only two females have been secured, is so close to the preceding that it can best be described by making a direct comparison. It is rather more pyriform than oval, and the greatest width of the body is somewhat farther back than in *C. Reighardi.* The eyes are larger but are separated by about the same distance from one another, while the antenniform bristles are also similar in size and position. The epimeral plates and the maxillary shield are similar in form although the latter is somewhat broader and shorter. The chief differences which distinguish these two females from those of the other species are the characters of the palpi, the length and details of structure of the legs, and the details of the genital area.

The palpus in this species (pl. XXXII, fig. 39) is somewhat more than one-half the length of the body instead of somewhat less, and the figures representing the percentage length of the segments are, in the same order as given for the preceding species: 8, 29, 17, 31, 15. Seg. 2 is but little more than two-thirds as thick as long; seg. 3 four-fifths as thick as long; while seg. 4 is much more nearly of uniform thickness from base to tip, the two ends being as 9 to 7. Seg. 5 is also somewhat heavier than in the other species though as a whole the palpi are seen to be distinctly longer and slenderer. The flexor margin of seg. 1 is plainly angulated. On seg. 4 the usual two papillae are accompanied by two very small, hair-bearing papillae, placed just distad of them.

The legs of this form are relatively longer than in the other species and the anterior legs proportionately much longer, thus leaving less difference between the first and last. In length of individual segments 4, 5, and 6 of all the legs are increased proportionately, and these segments of legs I and II greatly, so that they become nearly as long as the corresponding segments of legs III and IV. In legs III and IV, segs. 5 and 6 are approximately equal, whereas in the other species 6 is noticeably shortened. The hairs on the legs are more numerous on segs. I 4 and I 5, there being three and five slender hairs respectively and on the corresponding segments of II, seven each, with one on 3; while segs. 3, 4, and 5 of legs III and

IV have three, nine, and nine, and three, seven, and five respectively. Those on 4 and 5 of these legs are swimming-hairs.

Measurements of a mounted specimen give the following results:

Body (approximately)	0.800 mm.
Leg I	0.984 mm.
Leg II	1.090 mm.
Leg III	1.123 mm.
Leg IV	1.147 mm.
Palpus	0.432 mm.

The genital area in this species is relatively smaller than in *C. Reighardi* and the chitinous lunate plates flanking the genital flaps still smaller in proportion. Each bears from 15 to 18 acetabula while two more are imbedded in the surface of the body, and there are the usual small hairs, about six at the anterior end, five at the posterior, and about three along the outer margin.

Of this species only two specimens are at hand, both of which were received from Mr. E. Foster of New Orleans, La., who collected them in a pond at Slidell, in the same state, October 19, 1901. From a trace of color still remaining I am led to infer that the mites were red during life.

This species is referred to *C. obturbans* because of the perfect agreement in palpal characters, the difference in number of acetabula being negligible, in view of the variation in allied species. The greater number of hairs on the legs seems to distinguish this species clearly from *C. Reighardi;* it is unfortunate that data concerning the same character are not obtainable for *C. obturbans*, as found in Saxony and Great Britain, the two localities from which it has hitherto been reported.

13. *Curvipes inconstans* n. sp.

A species characterized by the characters of the palpi and genital area.

The body of this form is evenly elliptical, about one-fourth as wide as long and five-sevenths as high. The measurement of different specimens gave lengths varying from 0.793 mm. in the case of a specimen from Columbia, Mo., to 1.111 mm. in the case of another from High Island Harbor, northern Lake Michigan. The surface is marked by fine, inconspicuous striae. The distance between the eyes varies in different specimens from somewhat over one-fourth to nearly one-third the width of the body. The antenniform bristles are very short and straight.

The maxillary shield is broad and short with a broad ancoral process. The mandibles are considerably produced ventro-posteriorly with the dorso-posterior angle rounded and a claw of moderate length and thickness. Serrations few and low, at the tip.

The palpus (pl. XXXII, fig. 47) is relatively short, being less than half the total length. The following figures represent the percentage of each of the segments: 9, 28, 14, 31, 18. The palpi are relatively slender, the second segment somewhat less thick than long, the third segment one-third thicker than long, the fourth somewhat less than one-third as broad at the base as its length, and tapering gradually to the tip. The fifth segment is relatively long, slender, and very narrow at the outer extremity, where it bears three claws, which are proportionately long. The papillae on the flexor surface of seg. 4 are small, with the outer the larger, almost opposite, and at about the middle of the segment. The spur at the tip is very small.

The angle on the posterior margin of ep. IV is rather short (pl. XXXIII, fig. 49). The legs are only of moderate length, the first being shorter than the body and the second of about the same length, while the two posterior are still longer. They bear few spines, while the claws are relatively large and the points long and slender. Seg. I 4 bears in some specimens a single fine hair and I 5 one or two; segs. II 4 and II 5 bear two and three respectively; segs. III 4 and III 5 three and four long hairs; while segs. IV 4 and IV 5 possess three and four swimming-hairs respectively.

The genital area (pl. XXXIII, figs. 48 to 50) is characterized by the length of the genital cleft and the possession of several chitinous plates bearing acetabula, the number of both varying. The plates are two or three, the acetabula from eleven to eighteen. There is always an anterior plate with two or three acetabula and about six hairs at the anterior end, a posterior transverse plate with seven to twelve acetabula, and several hairs at the inner end, and besides from one to three acetabula are imbedded free in the body wall or surrounded by a small plate of chitin. All the chitin occupies the position which would result from the breaking up of a single lunate plate on each side.

Measurement of a mounted specimen gives the following figures:

Body (approximate)	0.800 mm.
Leg I	0.737 mm.
Leg II	0.818 mm.
Leg III	0.864 mm.
Leg IV	0.974 mm.
Palpus	0.355 mm.

Types of this species are retained in the collection of the author and co-types are also deposited in the collection of the Zoological Laboratory, the University of Nebraska, and in the United States National Museum.

This species, of which only females have been taken, has been collected at the following localities: Four specimens at Cranberry Lake, Woods Hole, Mass., at the beginning of August, 1900; one specimen at High Island Harbor, northern Lake Michigan, August 18, 1894; three specimens from ponds at Columbia Mo., August, 1901; five specimens at Circle Lake, Decatur, Neb., June 7, 1899 (Charles Fordyce); six at Slidell, La., August 18, 1901, and October 19, 1901 (E. Foster); also six from a pond in Audubon Park, New Orleans, La., August 11 and October 13, 1901 (E. Foster); and specimens have also been received from the Illinois State Laboratory of Natural History collected near Havana, Ill.

The name refers to the variability of the species in regard to the character of the genital area, hardly two specimens agreeing in this regard. It is similar in certain respects to *C. rufus* (Koch), *C. pauciporus* Thor, and *C. circularis* Piersig, but comparison seems to show it quite distinct.

14. *Curvipes setiger* n. sp.

A species characterized by the form and structure of the genital area and by the very long antenniform bristles.

This species is of an elongated elliptical form with a depression between the eyes and a very slight constriction behind them. The length of the single male in the collection is 0.698 mm., its width 0.540 mm. The females vary from 1.022 mm. to 1.095 mm. in length, the average being 1.063 mm., while the average width is about three-fourths of the length. The surface is finely striate.

The antenniform bristles are extremely long, being in the single male 79 μ in length and in one female measured 103 μ long. They are slender, sharply pointed, and slightly curved upward. The distance between them is about five-sixths of that between the eyes. These latter are large and only a trifle over one-third as far apart as the body is wide.

The palpi are rather short, being noticeably less than half as long as the body. The percentage of length of the segments is as follows: 10, 28.5, 14, 33.5, 14. In the male (pl. XXXIII, fig. 54) the flexor margin of seg. 2 is nearly straight and the extensor convex, while seg. 4 is considerably dilated. The papillae on seg. 4 in the male are six in number, the two nearest the base being the longer, the shortest pair situated farthest distad. Each of the six bears a hair which in the case of the longer papillae is inserted, not at the tip, but below and behind it. The fifth segment is curved ventrad and is squarely truncate at the tip, where it bears three claws. The palpus of the female (pl. XXXIII, fig. 52) is similar to that of the male except that seg. 4 tapers nearly uniformly from the base to the tip and the papillae are very small and two in number. The hairs they bear are situated in a position similar to that of those of the male.

The two anterior pairs of epimera in the male are wide apart, the other two pairs in close apposition, the length of the inner margin of the two latter combined being 0.174 mm. In the female the two posterior pair of epimera are separated by a considerable space. The legs are of medium length in the male, the first being approximately the length of the body, the others exceeding it, while in the female both I and II are shorter than the length of the body, III is equal to it, and IV but slightly exceeds it. The different segments are in length, in the case of the female and in order beginning with the longest, 6, 5, 4, 3, 2, 1, except in the fourth leg where both 5 and 4 exceed 6. In the male the order is the same except that in leg III segs. 5 and 4 both exceed 6. In the female there are on segs. I 4 and I 5 two very fine hairs; on segs. II 4 and II 5, four or five and eight respectively; on seg. III 3 three long hairs, and on III 4 and III 5, seven or eight and ten swimming-hairs; while on seg. IV 4 and IV 5 are six and nine swimming-hairs respectively. In the case of the male practically the same number of long hairs are found on the first two legs, but only one or two on seg. III 3, and no swimming-hairs on segs. III 4 and III 5, while on segs. IV 4 and IV 5 are three and nine swimming-hairs respectively. Seg. III 6 of the male (pl. XXXIII, fig. 53) is of about uniform thickness throughout, is curved ventrad, is squarely truncate, and has a small claw on the extensor side. Seg. IV 4 (pl. XXXIII, fig. 55) possesses numerous spines proximad of the excavation, one on the extensor and three toward the flexor side within it, and a row of four coarse spines distad of it, together with the three swimming-hairs. The tip of the segment is strongly produced.

The genital area of the male (pl. XXXIII, fig. 51) presents a seminal receptacle broadly elliptical in form with the longest diameter transverse. On either side this is flanked by a plate which is nearly straight along the anterior margin, somewhat convex along the posterior margin, of nearly uniform width, and squarely truncate at the tip. It bears about eleven acetabula. The genital area of the female (pl. XXXIII, fig. 56) exhibits an elliptical median area flanked by two or three chitinous plates arranged in an irregular manner, but occupying such a relationship to one another as would be a result of the breaking apart of a lunate plate of a form similar to that characteristic of the group to which *C. rotundus* belongs. The anterior of these plates bears one or two acetabula and about eight hairs in a row around the anterior margin. Behind this is in some specimens a plate bearing one or two acetabula, while still further posteriad is a plate transversely placed bearing about eight or ten acetabula. There is also, as a rule, a large acetabulum situated within an excavation at the posterior end of the last plate, making a total altogether of from nine to twelve acetabula.

Measurement of specimens gives the following figures:

	MALE	FEMALE
Body	0.698 mm.	1.066 mm.
Leg I	0.696 mm.	0.921 mm.
Leg II	0.787 mm.	1.008 mm.
Leg III	0.734 mm.	1.070 mm.
Leg IV	0.787 mm.	1.133 mm.
Palpus	0.336 mm.	0.408 mm.

The types of this species are retained by the author and co-types of female specimens deposited in the collection of the Zoological Laboratory, University of Nebraska, and in the United States National Museum.

C. setiger has been collected in only one locality, a spring-fed pool in Monroe Canyon, Sioux County, Neb., May 28, 1899, where one male and ten females were taken.

The name is given in allusion to the length of the antenniform bristles, which exceed by considerable not only that of any other of our American species but that of any other species hitherto discovered.

It closely resembles at first *C. inconstans* but differs in the following particulars: The antenniform bristles, as just stated, are very much longer; the proportionate lengths of the segments of the palpi and the character of the fourth segment are both different; the number of swimming-hairs on the legs is much greater; the relative lengths of the segments of the legs is also much different; while, in the case of the genital area, although the number of acetabula is not diagnostic, the character of the chitinous plate that bears them is different. The species resembles the same three European species referred to in connection with *C. inconstans,* but seems entirely distinct, on comparison of details of structure.

15. *Curvipes crassus* n. sp.

A heavily built species with very marked structural features.

From the examination of four males and a single female of this species the form appears to be elliptical, with a moderate flattening between the eyes. The cuticula is very thick and marked by numerous close raised ridges which are of uneven height, so that in oblique view the surface looks almost as if covered with evenly distributed, low papillae. Of the four males the longest is 0.635 mm. in length and 0.508 mm. in width, the average being 0.605 mm. and 0.518 mm. respectively. The female is 0.793 mm. long and 0.659 mm. wide. The body is moderately high and quite evenly convex dorsally. There is below and slightly within each eye a flattened, blade-like antenniform bristle of considerable length arising from a low papilla; in the largest male referred to above it is 30 μ long. The eyes are large, near to the margin, and separated by a distance equal to a little less than one-third the average breadth of the body.

The maxillary shield is unusually narrow and the ancoral process relatively short and strongly hooked. The mandibles are rather broad, expanded posteriorly, and with a rounded angle between the dorsal and posterior margins, while the claw is relatively small and angulated, tapers to a slender but blunt point, and shows no serration.

The palpi (pl. XXXIII, figs. 59 and 60) are stout, heavily chitinised, and very characteristic in form, with a total length a little less than half that of the body. The following numbers represent the percentage lengths of the segments: 10, 31, 16, 27, 16. Seg. 1 is not quite twice as broad as long; seg. 2 is about the same in thickness as in length; seg. 3 is somewhat thicker than long; and seg. 5 is rather narrow at the base, where it is less than half as wide as long, and tapers to a tip equal in width to about one-fourth the length, and which bears three small distal claws. Seg. 4 is strikingly modified, a very prominent projection of its ventral margin bringing the distal portion of this margin almost in line with the distal end of the segment and at a right angle with the proximal portion. The diameter of the segment at the distal end becomes thus nearly twice that at its base and equal to three-fourths its total length. On this distal portion of the flexor margin are placed three pairs of blunt conical papillae, and outside the line of these, between the first two proximal pairs, is another papilla on either side, making eight altogether. All of these papillae bear hairs, which are on the two proximal ones moderately long, on the rest short and slender. The palpus of the female is similar to that of the male in size and proportions of segments, but the distal portion of the flexor margin of 4 bears only two pairs of papillae, each one with a short hair. The claw at the distal end of this margin is in both sexes represented simply by a blunt projection.

The epimera in the male are all in contact except that between the inner ends of the first two pairs is a small area not covered by them. Over the epimera are seen coarse parallel striae. The process on the posterior margin of ep. 4 is very long and sharply pointed. In the female the epimera are similar in form but the four groups are separated by a narrow interval.

The legs are rather short, the first pair in the male being only slightly shorter than the body and the others all exceeding it, while in the female the last two exceed the length of the body; they are rather stout, the chitinous covering being here, as elsewhere, much thickened. In leg IV the four basal segments are much stouter proportionately than the others. The segments increase in length also from the base outward, though in the male 6 is shortened so that it is shorter than 4 and in leg IV it is still exceeded by 5, while in the female the same is true in legs III and IV. In legs I and II seg. 5 has a convex flexor margin and seg. 6 is very markedly expanded at the tip (pl. XXXIII, fig. 57), while the spines are few. Segs. 4 and 5 also show a distal expansion on the anterior side. In leg III of the male (pl. XXXIII, fig. 58), 5 is narrow at the base and dilated at the distal end, while 6 is very short, squarely truncate at the end, its flexor margin straight and its extensor margin strongly convex at the base, beyond which it is parallel to the flexor. The claw is small and straight. In leg IV of the male segs. 5 and 6 are noticeably slender in contrast to the marked dilatation of the basal four segments, already referred to, and seg. 6 is slightly dilated toward the tip. The same dilatation of the distal segment characterizes the legs of the female, though it is in much less marked degree. Seg. 4 of this leg is broadly expanded and with a deep excavation on the posterior surface, proximad of which are many stout spines, and distad of which is a row of three short, stout spines, two swimming-hairs, and a very heavy spine at the tip on the flexor side. In the male are three long hairs in a row at the tip of seg. II 5, one at the end of seg. III 4, the two swimming-hairs on IV 4, and six on IV 5; while in the female seg. I 5 bears one slender hair, seg. II 5 four swimming-hairs, segs. III 4 and III 5 two and five swimming-hairs, and segs. IV 4 and IV 5 three and five respectively.

The genital area is in close contact with the posterior epimeron in the male and extends around on the outer portion of the angle on the posterior surface to beyond the outer end of the epimeron. There is no seminal receptacle and the genital cleft is very short, being 41 μ long. In the female the two genital flaps form a broadly elliptical area, from the posterior half of either lateral margin of which project two long tongue-like chitinous plates which are concave on the anterior and convex on the posterior margin and which extend to beyond the line of the angle on the fourth epimeron, while there are also one or two acetabula at the margin of the median area and midway between these plates and the anterior end of the area. Each plate flanking the genital area of the male bears 50 to 60 acetabula; in the case of the female over 70.

Measurements of specimens:

	MALE	FEMALE
Body	0.659 mm.	0.793 mm.
Leg I	0.619 mm.	0.682 mm.
Leg II	0.682 mm.	0.754 mm.
Leg III	0.749 mm.	0.830 mm.
Leg IV	0.840 mm.	1.042 mm.
Palpus	0.360 mm.	0.365 mm.

The color of specimens collected in Susan Lake, near Charlevoix, Mich., was noted in field notes as follows: "Body tinged posteriorly and around margin with bluish green, most pronounced at the posterior end. Anterior median portion strongly tinged with dull reddish. Eyes black. Legs a bright bluish green with terminal joints brownish."

Types retained in the author's collection.

This very characteristic species has been collected in the following localities in Michigan: Near Grand Rapids, in the summer of 1885, two males; at Lamberton Lake, near Grand Rapids, July 4, 1900, one female; at Susan Lake, near Charlevoix, August 21, 1894, three males.

This species is similar to no other species of *Curvipes* except *C. thoracifer* Piersig, from which it differs, however, in all details of structure, including the characters of the palpi, the space between the epimera, the number of acetabula, the form of the genital plates in the female, etc.

The name has reference to the strength of the chitinous covering and the stoutness of the appendages.

III. TABLE FOR THE DETERMINATION OF THE ABOVE SPECIES

FEMALES

1. Acetabula imbedded free in the wall of the body............1. *C. coronis*
   Acetabula in part or all on chitinous plates............................ 2
2. Two genital plates, one on either side 3
   More than one on each side.......................................12
3. The genital plate solid, its whole inner margin in contact with the median elliptical area.. 4
   The genital plate lunate, enclosing an area in which a greater or less number of acetabula are imbedded free in the body wall........... 9
4. The distal segment of the legs strongly curved ....3. *C. pugilis*
   The distal segment of the legs not curved.............................. 5
5. Acetabula numerous, 45 or 50....................................... 6
   Acetabula fewer, not over 30....................................... 7
6. Palpus very long, nearly equaling the body in length and the fourth segment markedly contracted at the base.................2. *C. exilis*
   Palpus not over half the length of the body, fourth segment tapering, 4. *C. turgidus*
7. Acetabula about ten, small, on a very short plate.........6. *C. constrictus*
   Acetabula from twenty to thirty, large, on a plate longer than broad.... 8
8. The epimera confined to the anterior half of the ventral surface, body larger, and swimming-hairs on segs. IV 4 and IV 5, five and seven respectively ....5. *C. triangularis*

The epimera covering most of the ventral surface, body very small, and swimming-hairs on segs. IV 4 and IV 5, four each ....7. *C. spinulosus*

9. Papillae on seg. 4 of the palpus long, equaling in length half the thickness of the segment or more 10

Papillae on seg. 4 of the palpus short 11

10. Acetabula numerous, 35 to 40 on each plate..................8. *C. medius*

Acetabula fewer, 22 to 26 on each plate....................9. *C. rotundus*

11. Swimming hairs fewer, on segs. III 4 and III 5 being three or four and five or six; and on IV 4 and IV 5, three and four; two papillae on fourth segment of palpus......................11. *C. Reighardi*

Swimming-hairs more numerous, being on the four segments named, nine, nine, seven, and five; two small papillae on fourth segment of palpus in addition to two above ....12. *C. obturbans*

12. Distal end of the fourth palpal segment much dilated, as also distal segments of legs; chitinous parts all coarse and heavy.. 15. *C. crassus*

Fourth palpal segment tapering, and all chitinous parts slighter........13

13. Antenniform bristles of usual length; acetabula from eleven to eighteen; swimming-hairs on segs. IV 4 and IV 5, three and four respectively..13. *C. inconstans*

Antenniform bristles very long; acetabula from nine to twelve; swimming-hairs on segs. IV 4 and IV 5, six and nine respectively...14. *C. setiger*

MALES

1. A seminal pouch or seminal receptacle present..........................2

Simply a depression at the bottom of which is the genital opening.......4

2. Acetabula numerous, 40 to 50 in number...................4. *C. turgidus*

Acetabula few, from nine to eleven......................................3

3. Several long, slender hairs on seg. III 5 and fifteen swimming-hairs on IV 5; two papillae on the fourth segment of the palpus; seg. III 6 cornucopia-shaped..................................6. *C. constrictus*

No such hairs on seg. III 5 and only nine swimming-hairs on IV 5; six papillae on the fourth segment of the palpus; seg. III 6 slightly bent, not broader at the tip...........................14. *C. setiger*

4. One claw at least on seg. III 6 long and straight........................5

Neither long and straight, but short and curved 6

5. Size small; papillae on the fourth segment of the palpus of medium length; swimming-hairs on IV 4 and IV 5, three and four respectively; acetabula 25 to 30..........................7. *C. spinulosus*

Size medium; papillae on the fourth palpal segment long; swimming-hairs on as in the preceding; acetabula about 30.......9. *C. rotundus*

Size rather large; legs relatively weak; papillae on fourth palpal segment short; swimming-hairs on segs. IV 4 and IV 5 three and nine respectively; acetabula fifteen to eighteen..........10. *C. debilis*

6. Fourth palpal segment not greatly dilated at the distal end and with two papillae.. 7

Fourth palpal segment greatly dilated at the tip and with eight papillae ....15. *C. crassus*

7. Distal segment of legs not strongly curved; three swimming-hairs on seg. IV 4 .... 2. *C. exilis*
   Distal segment of legs strongly curved; seven swimming-hairs on seg. IV 4 .... 3. *C. pugilis*

In fitting the species described above into Piersig's table (1901: 244), the following changes become necessary:

FEMALES

4. Maxillary palpus much stronger than the basal segment of leg I; etc., 2. *C. aduncopalpis*
   Maxillary palpus little stronger than the basal segment of leg I; etc.... 4*a*
4*a*. Acetabula scattered irregularly over a considerable area, sixteen to twenty in number .... 3. *C. conglobatus*
   Acetabula more closely collected into a group with circular outline, twenty-three to twenty-eight in number .... *C. coronis*
8. Maxillary palpus small, etc 8*a*
   Maxillary palpus large, etc 9
8*a*. Genital plate circular, bearing eighteen to twenty-four acetabula, 6. *C. carneus*
   Genital plate very short, crowded against median area, bearing about ten acetabula .... *C. constrictus*
9. With several large papillae, etc .... 7. *C. uncatus*
   With two large papillae and two very small ones beyond them, *C. turgidus*
   With only two, etc 10
13. Acetabula numerous, 45 or 50 .... 13*a*
   Acetabula fewer, not over 30 .... 13*c*
13*a*. Distal segment of legs strongly curved .... *C. pugilis*
   Distal segment of legs not strongly curved 13*b*
13*b*. Leg III shorter than leg II; palpus about half the body length, 11. *C. longipalpis*
   Leg III longer than leg II; palpus nearly equaling the body in length, *C. exilis*
13*c*. Size large, about 2 mm.; a group of hairs on the last epimeron, along the outer portion of the posterior margin .... 12. *C. nodatus*
   Size medium or small; no such hairs 13*d*
13*d*. Size medium, about 1 mm.; epimera confined to anterior half of ventral surface .... *C. triangularis*
   Size small, not over 0.6 mm.; epimera covering most of ventral surface .... *C. spinulosus*
20. Each genital plate with over 50 acetabula .... 20. *C. disparilis*
   Each genital plate with 35 to 40 acetabula .... *C. medius*
   Each genital plate with less than 30 acetabula 21
21. Papillae on the fourth segment of the palpus long .... 21. *C. rotundus*
   Papillae on the fourth segment of the palpus short 21*a*
21*a*. Swimming-hairs fewer; two papillae on fourth palpal segment, *C. Reighardi*

Swimming-hairs more numerous; two small papillae additional on the fourth palpal segment............................22. *C. obturbans*

24. Posterior genital plates trausverse, etc..............................25

Posterior genital plates curved..................................24*a*

24*a*. Total number of acetabula nine to twelve; anterior plates with none, 24. *C. pauciporus*

Total number of acetabula eleven to eighteen; anterior plates with two or three..*C. inconstans*

25. Posterior genital plates broad, etc.....................25. *C. thoracifer*

Posterior genital plates narrow, etc......................26. *C. setaceus*

Posterior genital plates very long, relatively narrow; anterior plate with one or two acetabula................................*C. crassus*

27. Posterior genital plates as in *C. thoracifer*, etc...........28. *C. neumani*

Genital plates as in *C. rotundus*, etc...................29. *C. circularis*

Genital plates resembling those of *C. circularis*, but nine to twelve acetabula instead of thirteen to seventeen, and palpus different, *C. setiger*

MALES

6. So-called anal opening very close to the genital area, etc...............6*a*

So-called anal opening distinctly behind the genital area, etc., 3. *C. conglobatus*

6*a*. Distal segment of the legs markedly curved..................*C. pugilis*

Distal segment of the legs not markedly curved......................6*b*

6*b*. Acetabula eighteen to twenty-four on each plate.........22. *C. obturbans*

Acetabula 45 to 50 on each plate..............................*C. exilis*

7. Each genital plate with 15 to 18 acetabula....................*C. debilis*

Each genital plate with 24 to 30 acetabula..........................7*a*

Each genital plate with 45 to 60 acetabula ....20. *C. disparilis*

7*a*. Size small, about 0.5 mm.; papillae on fourth palpal segment of only medium length ....*C. spinulosus*

Size larger; papillae on fourth palpal segment long.......21. *C. rotundus*

10. Maxillary palpus with four or five larger papillae on the fourth segment...7. *C. uncatus*

Maxillary palpus with two large and two smaller papillae.... *C. turgidus*

Maxillary palpus only with two, etc..... 11

15. Maxillary palpus as weak or weaker than the basal segment of the first pair of legs, etc.......................................15*a*

Maxillary palpus thicker than the basal segment of the first pair of legs, etc...16

15*a*. Segment IV 4 with nine swimming-hairs on the distal end ..6. *C. carneus*

Segment IV 4 with only three swimming-hairs.............*C. constrictus*

16. Opening of the seminal pouch as in *C. carneus*.....................16*a*

Opening of the seminal pouch forming a transversely placed ellipse, 28. *C. neumani*

16*a*. Papillae on the fourth segment of the palpus, six in number and opposite, in pairs; no long hair on seg. III 5, nor row of swimming-hairs ....*C. setiger*

Larger papillae on fourth palpal segment oblique; four swimming-hairs and a very long hair at tip of III 5..............29. *C. circularis*

21. Genital plates of irregular, wing-like form, etc.............30. *C. coactus*
Genital plates at the outer end rounded and broadly tongue-shaped....22
Genital plates extended anteriorly about the outer end of the last epimeron ....*C. crassus*

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EXPLANATION OF PLATES

All drawings made from slides and with the camera, unless otherwise stated.

Plate XXIX

Figs. 1, 2. *C. coronis*

Fig. 1. Epimeral field and genital area, ♀; from an unmounted specimen; ×80.

Fig. 2. Inner side of left palpus, ♀; ×135.

Figs. 3–8. *C. exilis*

Fig. 3. Anterior suface of segment IV 4, ♂; ×260.

Fig. 4. Palpus, from the inner and ventral aspect; ♀; ×135.

Fig. 5. Genital area, ♀; from an unmounted specimen; ×110.

Fig. 6. Claws of the mandibles, from ventral aspect, ♂; ×435.

Fig. 7. Segment III 6, ♂; ×365.

Fig. 8. Genital area, ♂; ×135.

Figs. 9–12. *C. pugilis*

Fig. 9. Palpus, outer side, ♂; ×135.

Fig. 10. Segment III 6, ♂; ×260.

Fig. 11. Segments II 5 and II 6, ♂; from anterior side; ×135.

Fig. 12. Genital area, ♂; ×135.

Fig. 13. *C. constrictus*

Fig. 13. Segment III 6, ♂; ×135.

Plate XXX

Figs. 14–18. *C. constrictus*

Fig. 14. Epimeral field and genital area, ♀; from the unmounted specimen from Wray, Colo.; ×110.

Fig. 15. Epimeral field and genital area, ♂; from the unmounted specimen from Ann Arbor, Mich.; ×110.

Fig. 16. Segments 4 to 6 of leg IV, ♂, from the anterior side; ×160.

Fig. 17. Inner side, left palpus, ♂; ×260.

Fig. 18. Posterior side, segments II 5 and II 6, ♂; ×160.

Figs. 19–23. *C. turgidus*

Fig. 19. Posterior side, segment III 6, ♂; ×160.

Fig. 20. Genital area, ♀; ×110.

Fig. 21 Genital area, ♂; from an unmounted specimen from Oshkosh, Wis.; ×110.

Fig. 22. Outer side of left palpus, ♀; ×125.

Fig. 23. Posterior surface, segment IV 4, ♂; ×160.

PLATE XXIX

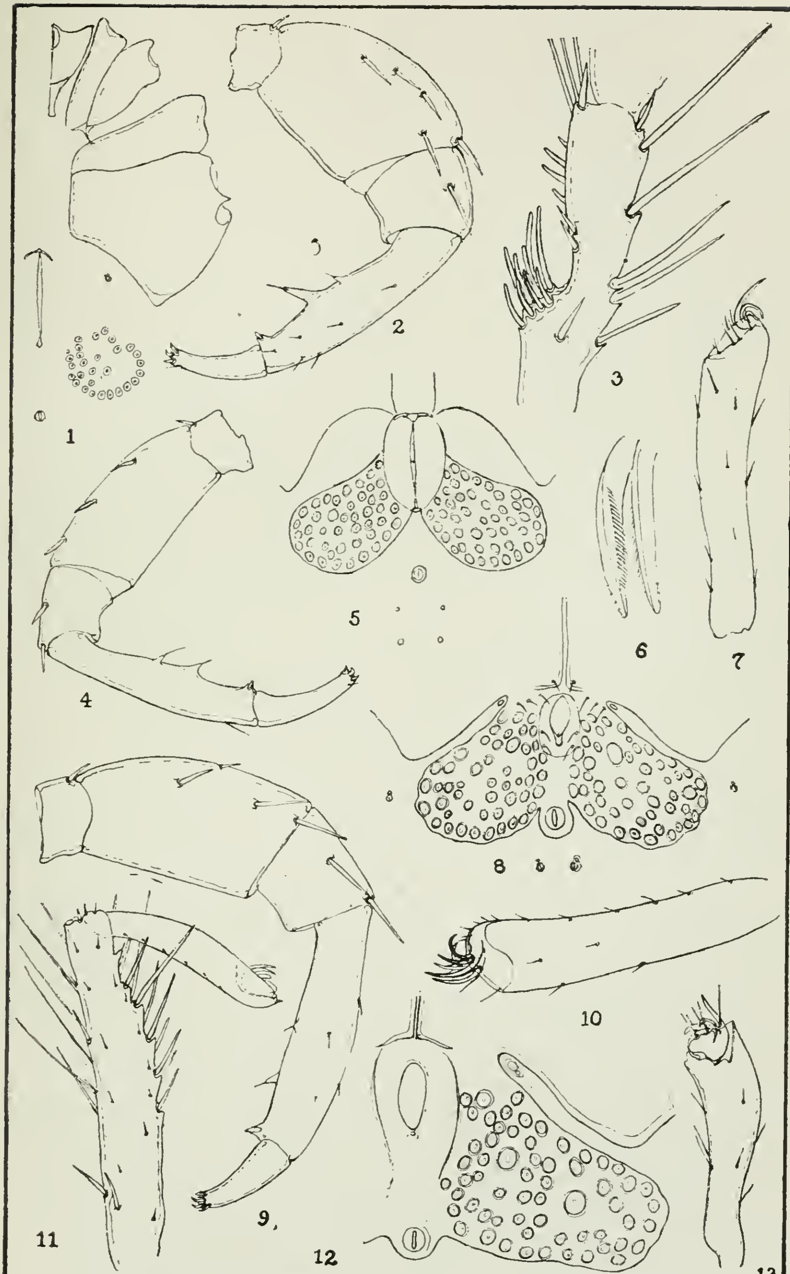

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PLATE XXX

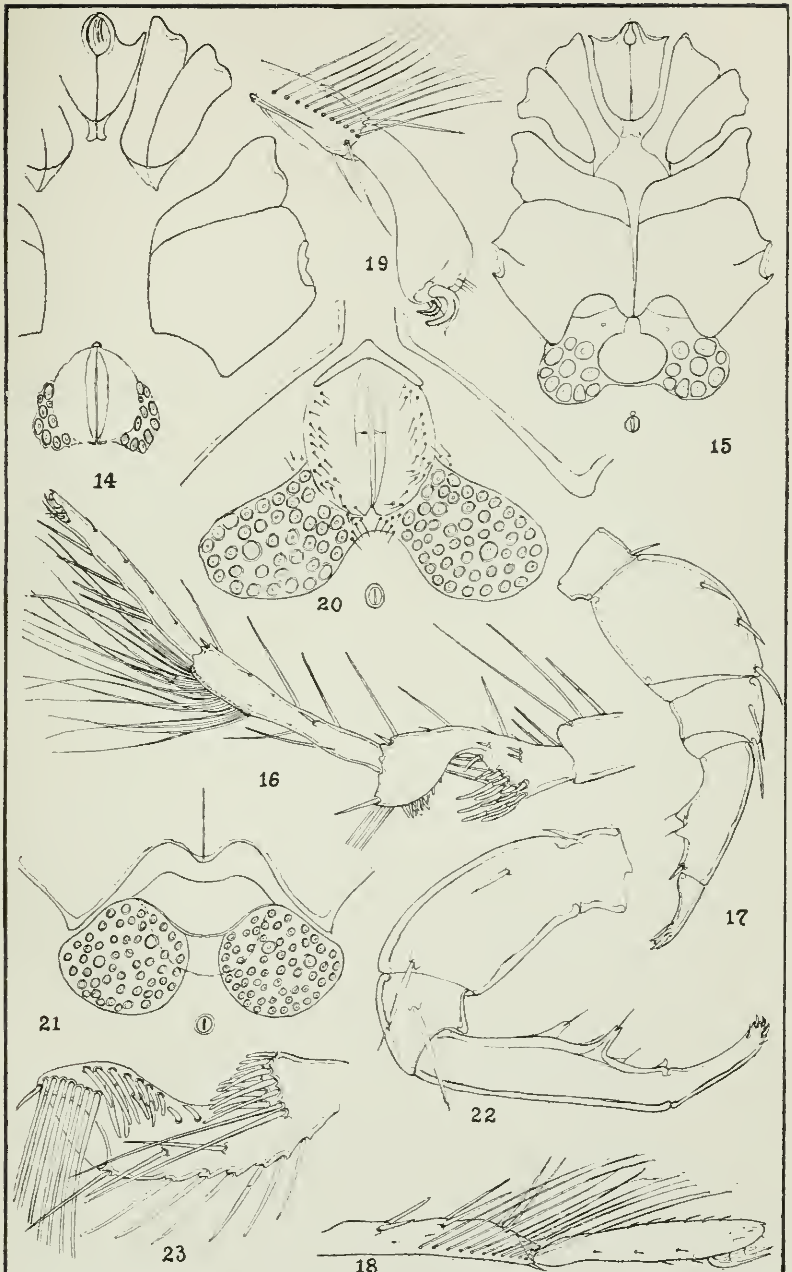

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PLATE XXXI

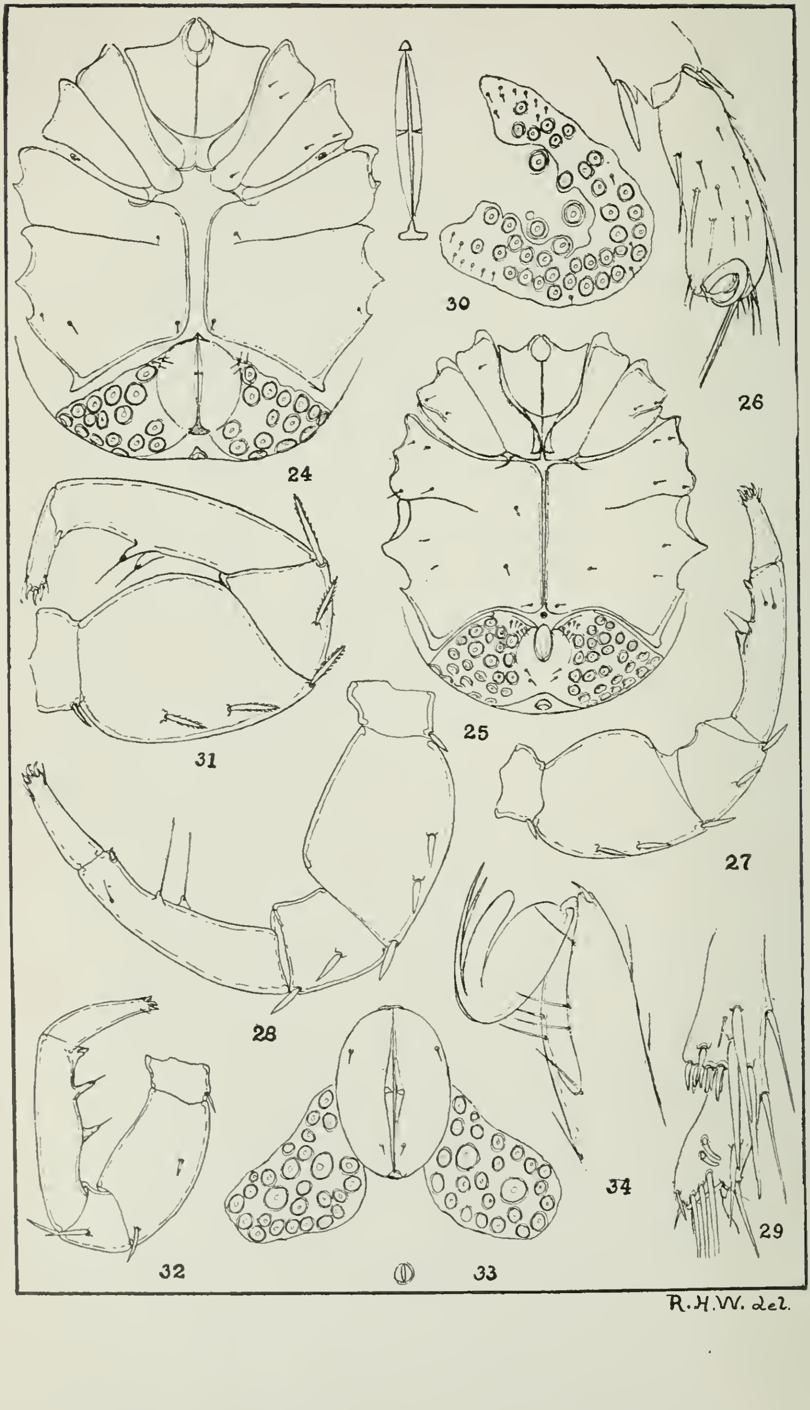

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PLATE XXXII

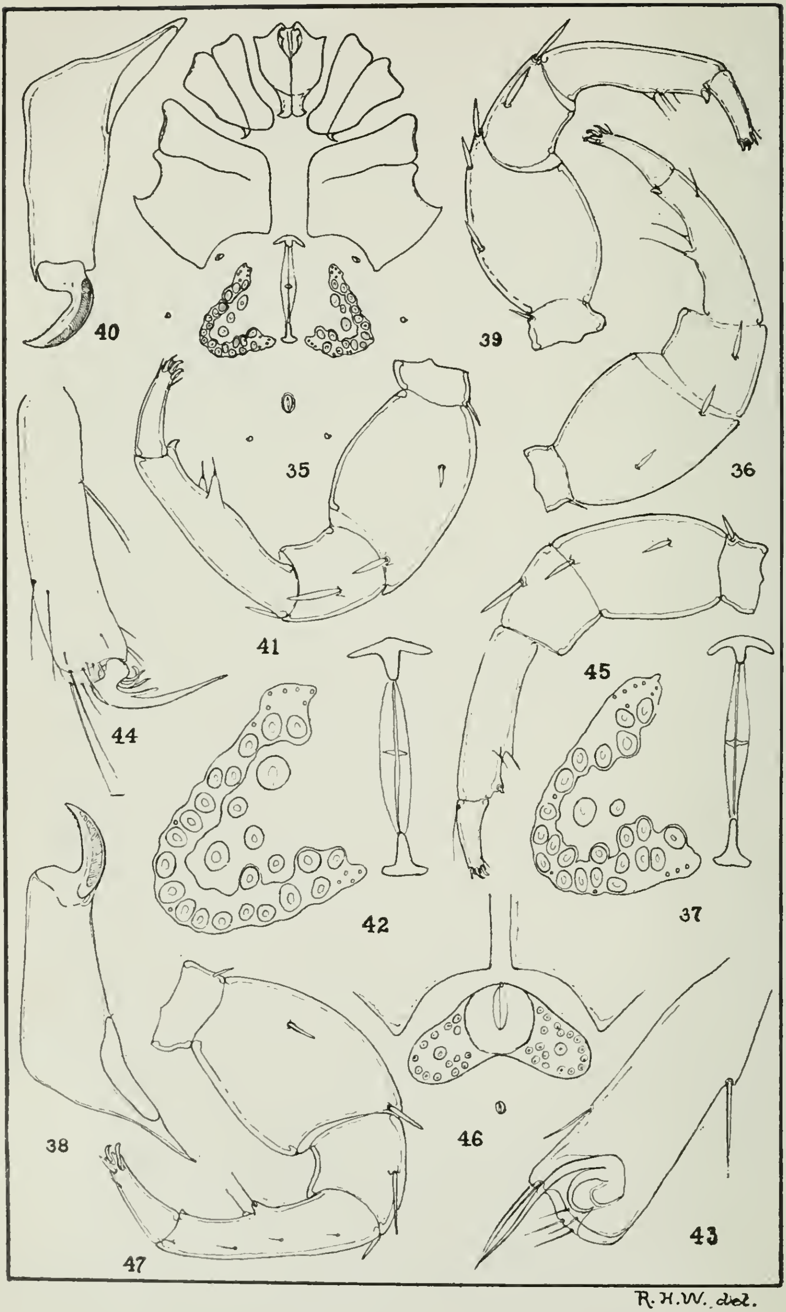

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Plate XXXI

Figs. 24–29. *C. spinulosus*

Fig. 24. Epimeral field and genital area, ♀; ×160.
Fig. 25. Epimeral field and genital area, ♂; ×160.
Fig. 26. Segment III 6, ♂, anterior side; ×435.
Fig. 27. Inner side, right palpus, ♂; ×335.
Fig. 28. Inner side, left palpus, ♀; ×335.
Fig. 29. Posterior side, segment IV 4, ♂; ×335.

Figs. 30, 31. *C. medius*

Fig. 30. Genital area, ♀; ×160.
Fig. 31. Inner side, right palpus, ♀; ×260.

Figs. 32, 33. *C. triangularis*

Fig. 32. Outer side, right palpus, ♀; ×135.
Fig. 33. Genital area, ♀; ×135.

Fig. 34. *C. Reighardi*

Fig. 34. Claws, tip of segment III 6, ♀; ×625.

Plate XXXII

Figs. 35–38. *C. Reighardi*

Fig. 35. Epimeral field and genital area, ♀, from High Island Harbor; ×110.
Fig. 36. Outer side, left palpus, ♀; ×260.
Fig. 37. Genital area, ♀, from Lake St. Clair; ×260. (*cf.* fig. 35.)
Fig. 38. Inner side, left mandible, ♀; ×335.

Fig. 39. *C. obturbans*

Fig. 39. Inner side, left palpus, ♀; ×260.

Figs. 40–43. *C. rotundus*

Fig. 40. Inner side, right mandible, ♀; ×335.
Fig. 41. Outer side, right palpus, ♀; ×260.
Fig. 42. Genital area, ♀; ×335.
Fig. 43. Segment III 6, ♂; ×625.

Figs. 44–46. *C. debilis*

Fig. 44. Segment III 6, ♂; ×365.
Fig. 45. Outer side, left palpus, ♂; ×260.
Fig. 46. Genital area, ♂; from an unmounted specimen; ×110.

Fig. 47. *C. inconstans*

Fig. 47. Outer side, right palpus, ♀; ×365.

Plate XXXIII

Figs. 48–50. *C. inconstans*

Fig. 48. Genital area, ♀, from Slidell, La.; ×260.
Fig. 49. Epimeral field and genital area, ♀, from New Orleans, La., ×100.
Fig. 50. Genital area, ♀, from Decatur, Neb.; ×260.

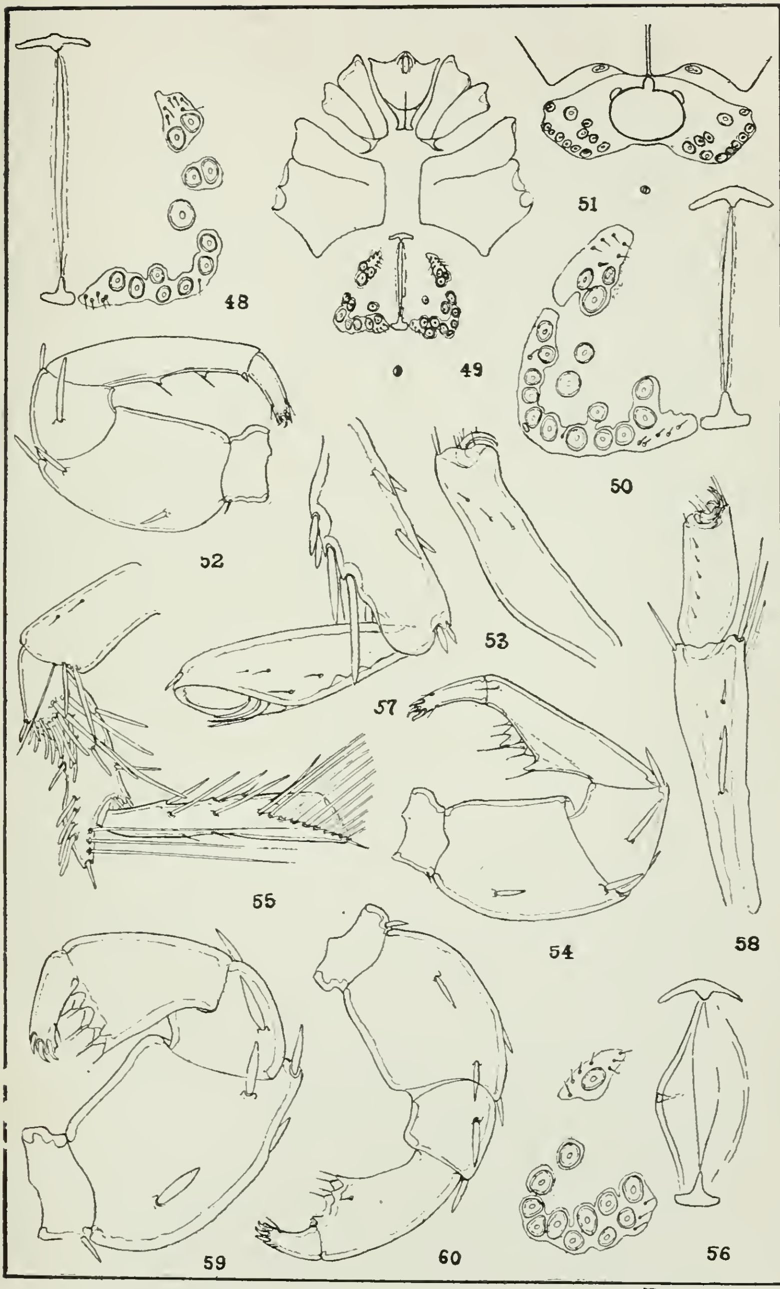
Figs. 51–56. *C. setiger*

Fig. 51. Genital area, ♂; from the unmounted specimen; ×160.
Fig. 52. Outer side, right palpus, ♀; ×260.
Fig. 53. Segment III 6, ♂; ×435.
Fig. 54. Outer side, left palpus, ♂; ×135.
Fig. 55. Segments IV 3 to IV 5, ♂, posterior side; ×260.
Fig. 56. Genital area, ♀; ×260.

Figs. 57–60. *C. crassus*

Fig. 57. Segments II 5 and II 6, ♂, anterior side; ×335.
Fig. 58. Segments III 5 and III 6, ♂; ×260.
Fig. 59. Outer side, left palpus, ♂; ×335.
Fig. 60. Outer side, right palpus, ♀; ×260.

PLATE XXXIII



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A NEW HYDRA

By M. J. ELROD, University of Montana, and
MAURICE RICKER, Burlington (Iowa) High School

During the summer session of the University of Montana Biological Station, we found what is believed to be a new hydra. It was taken in large numbers from Echo Lake, Flathead county, Montana. It has not been found in any of the other numerous streams or lakes in this vicinity, and so far as is known no other hydra has ever been collected in the state.[1]

The following are some of the most noticeable characteristics: The animals are conspicuous on account of their bright coral red color and large size. In fact, one can recognize them as hydrae while standing erect on the logs. A fair sample of the larger ones measured, when feeding, 16 mm. long from the mouth to the distal end. None of the tentacles of this hydra were less than 38 mm. long, measured from the mouth to the end, and the longest was 43 mm., making a total length from tip to tip of 59 mm.

When feeding, the tentacles seem capable of unusual extension until they seem a mere thread, bearing noticeably large nematocysts, like beads strung on a string.

The color is a deep bright coral red, most intense near the proximal end and seems to be distributed in chloroplast-like granules as in *H. viridis*. It is apparently constant and may possibly be due to symbiotic algae, although indications are to the contrary.

Since the waters of Echo Lake contain large numbers of a reddish *Daphnia*, and, thinking the question of their effect on the color of the hydra would arise, a number of the latter were taken alive and fed for five weeks upon colorless entomostraca, from Flathead Lake, at the Station laboratory. While they did not seem to thrive, no noticeable dimming of the color bodies was observed.

The hydrae were found early in July, 1901. There was little time or facilities for delicate histological work, and the lack of the literature compelled us to defer more careful examination until a more convenient time.

[1] Since the above has been in type Prof. R. A. Cooley reports finding a hydra sparingly in the eastern part of the state.

The striking color, the large size, the isolation of the animals from related forms, the apparent division of the body into a stalk and an enlarged gastric cavity of about equal length, the removal of gonads and buds beyond this apparent division, altogether seemed to make it worthy of this preliminary note. Careful histological examination will be immediately made, and should the characters enumerated, together with others which may be revealed, prove constant and new, as it is believed they will, the name *Hydra corala* is proposed for the species.

Echo Lake, in which the hydra was found, lies in the valley close to the foot-hills, west of the Swan Range of the Kootenai Mountains, a few miles northeast of the Biological Station. It is narrow, with a total length of twelve or fourteen miles. It may be the old bed of a river which, in earlier days, flowed through the valley until dammed by a moraine. The lake now has no surface outlet, the water probably escaping through underground channels or seepage. Notwithstanding, it contains five or six species of fish and numerous species of entomostraca.

In 1894 the water in the lake suddenly rose about twelve feet above its former level, submerging portions of timbered lands about the lake borders and a meadow. The water has remained at this higher level since that time.

At the upper end of the lake a rancher took up his claim when the water was at the lower stage. He built a log bridge over the little stream which flowed into the lake at this point and erected some log buildings in the meadow. The rising water floated the bridge and came up to the top of his door and windows. It was about this bridge, attached to boards and roots of grasses growing between the logs, that the hydrae were found.

Echo Lake affords a good field for further biological study. Its waters are held in by a moraine and have no connection with other bodies of water at any season of the year, unless by unknown underground channels. Among other interesting collections was a *Polygonum* which seems to have made important adaptations to its new conditions. The potamogetons were exceedingly long, and there is no doubt other evidence of a quick response to changed environment could be easily found. The further study of this lake will be undertaken by the members of the Station staff and their students next season.

MODIFICATION OF SOME STANDARD APPARATUS TO FACILITATE THE WORK OF THE HISTOLOGIC AND EMBRYOLOGIC LABORATORY

By SIMON HENRY GAGE, Cornell University, Ithaca, N. Y.

WITH ONE PLATE

(1) AN IMPROVED SECTION RAZOR WITH STRAIGHT BACK AND EDGE

It seems strange that when an instrument takes on new uses it is so slow to lose distinctive features which have no significance or are harmful in the new field. There is thus a certain similarity between a machine in its evolution and an animal or plant. It took a long time to get a section razor with a straight edge for section work, and apparently no one ever thought it necessary to eliminate the compound curves of the back. In the form devised about a year and a half ago the back and edge are both straight, and as nearly as possible parallel. This makes it possible to change the position of the razor in the holder without changing the angle of the cutting edge (pl. XXIII, figs. 1, 2, and 3).

The razor here presented and advocated, then, has edge and back straight and approximately parallel. The razor blade is thick so that it will not readily spring in cutting sections, and it is slightly concaved on both sides to facilitate sharpening. The writer has never yet been able to find out why razors used in histologic work are flat on one side in so many cases.

(2) A RAZOR HOLDER AND SUPPORT FOR THE MINOT RIBBON MICROTOME

From the cheapness and excellence of razors for sectioning and from the ease of sharpening them, they are used almost exclusively in student work, and also in research work in many laboratories. The Minot ribbon microtome is designed for a section knife of considerable size, and if a razor is placed in the regular holder it can be moved very little from side to side. This makes it possible to use only a small part of the cutting edge, and the whole razor must be sharpened every time the small part is dull. To avoid the difficulty, a support was devised about two years ago. This consists of a strong piece of brass which rests in the knife support of the microtome. At right angles with the base-piece, on which rests the back of the razor, is a vertical back-piece against which the side of the razor rests. This is slightly narrower than the width of the razor blade, and a notch is cut out of the middle where the sections are made.

A front-piece is made like the back-piece, except that it is not fastened to the base-piece. This is put against the front side of the razor and the clamping screws of the regular knife holder press against it (see figs. 2, 3, 4, and 5).

If one employ such a support with the Minot ribbon microtome, nearly the entire length of the edge of the razor can be used. It is highly advantageous, however, to have a razor with a straight edge and back (see above and fig. 1). Not only should the back be straight, but the haft of the knife should be thin enough so that the angle of the knife will not change in moving the razor.

(3) AN ADJUSTABLE CLAMP FOR THE MINOT RIBBON MICROTOME

In using the Minot ribbon microtome the holders for the paraffin blocks furnished with the microtome are expensive, and only three come with each microtome. Finally, the clamp to receive these block holders has very slight adjustment, so that the holders must be very accurately fitted. At the Columbus meeting it was pointed out that in a laboratory where many students work and use the microtome there must be many holders for the paraffin blocks. To make this possible with a minimum expense, short stove bolts were recommended. These can be used as they are, or a coin like an American cent can be soldered to the end for a larger attaching surface. From the small adjustment in the clamp for the holder many of the stove bolts could not be used without much trouble in fitting them. To avoid this difficulty an adjustable clamp was devised which will receive bolts differing one or two millimeters in diameter. Two views are shown (figs. 6 and 7). The stem which connects the clamp with the other clamp of the microtome has a long thread and a solid piece is screwed upon it. A loose piece like the first is then slipped over the screw, and finally a thumb nut is put upon the end to press the loose piece against the fixed piece. Holes are bored in the clamp, half the cylinder being in each. Either of these holes serves for the paraffin block holder. With such a clamp one does not have to worry about the exact size of the stem of the paraffin holder.

(4) AN IMPROVED TRAY FOR HOLDING SLIDES OR RIBBONS OF SECTIONS

The tray exhibited and described at the Columbus meeting proved itself so excellent on extended use that one or two defects have been overcome. The defects were two: First, the outside frame had square corners and sharp edges. The least warping or irregularity made them lock into each other so that it was not easy to pull one out of a pile, nor was it easy to return it to its place again. To avoid this all the corners and edges have been rounded. Slight irregularities do not now interfere with the removal or return of a tray in the middle of a pile.

The second difficulty was in getting hold of a single tray when they were in a pile. This was easily overcome by adding a small screw eye. With the improvements thus indicated one has no longer the necessity of purchasing expensive slide cabinets. These answer every purpose and are exceedingly cheap, costing only about $15 per hundred for trays which will contain fifty 3 x 1 inch trays.

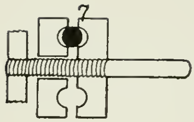
EXPLANATION OF PLATE

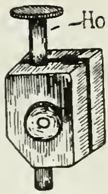
Plate XXXIV

Details of razor, razor holder, and support for Minot Ribbon Microtome and of adjustable clamp for Paraffin Blocks.

PLATE XXXIV

7
Clamp in
Section

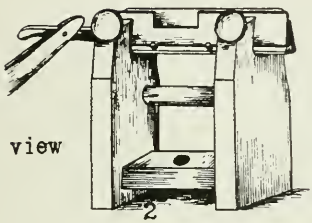


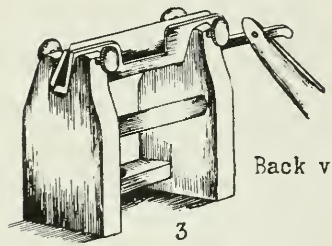


6
Holder for Paraffin block

Clamp

Front view





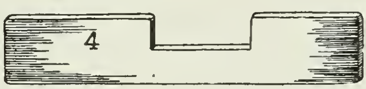
Back view

Microtome Knife Holder with the razor in position

Figure 1

Razor with straight back and edge

Front piece of
Razor Holder



Back Piece and Support
For Razor

LABORATORY PHOTOGRAPHIC APPARATUS

By SIMON HENRY GAGE, Cornell University, Ithaca, N. Y.

WITH TWO PLATES

(1) A TABLE AND SCREEN FOR USE WITH A VERTICAL PHOTO-MICROGRAPHIC APPARATUS

Much if not a majority of photo-micrographic work is done with a vertical camera like that of Zeiss. To avoid various inconveniences in the use of this, a small table about 50 cm. high was constructed upon which the microscope and camera rest. This makes it possible for the operator to stand upon the floor for adjusting the camera, and to sit on a low stool for adjusting the microscope.

To avoid eye-strain from the light a zinc screen was made, with legs and heavy bases to fit over the table and between the microscope and the lamp. This screen is slightly higher than the vertical camera, so that when the bellows are pulled out to the extreme limit one can work without the lamp shining in the face of the observer. Opposite the lamp is a perforation in the screen. This is covered by a balanced curtain so that the light is very easily shut off at the desired moment (pl. XXIV, fig. A).

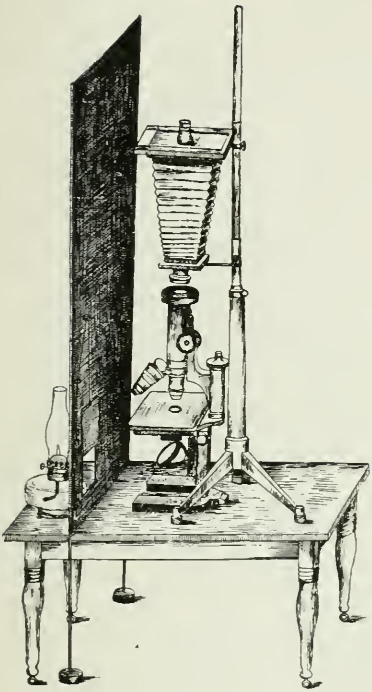
(2) A SPECIAL MICROSCOPE STAND WITH THE STAGE IN PLACE OF THE TUBE, FOR PHOTOGRAPHING EMBRYOS AND OTHER SMALL SPECIMENS WITH A VERTICAL CAMERA

As shown in the accompanying figure (pl. XXIV, fig. B) the small vertical photo-micrographic camera is placed upon the low table as in photo-micrography. In place of the sleeve for connecting the camera to the microscope, a photographic objective of 60 to 80 mm. focus is employed, thus making an ordinary camera of it. To support the specimen and also to serve as a focusing arrangement, a skeleton stage is attached to the arm of the microscope stand. The stage proper is absent. From this arrangement the specimen may be focused with either coarse or fine adjustment. For opaque objects there is a second staging below on which may be placed any desired background. For transparent objects a large mirror is in the usual place and serves to illuminate the object. For photographing embryos it is desirable to know the exact size of the photograph as compared with the specimen. To determine this quickly in each case the instrument is at first calibrated. That is, a centimeter rule is used as object, and the various sizes desired, *e. g.* natural size, twice, four times, five times, etc., are obtained by using dividers and measuring the image on the ground glass and noting the exact position of the upper and lower part of the camera. Having once determined these points, the camera may be set at the one desired in a moment. Then the focusing is done with the special microscope stand.

(3) USE OF THE SPECIAL MICROSCOPE STAND WITH AN ELEVATED CAMERA TO OBTAIN PICTURES OF LARGE SECTIONS, ENLARGE PHOTO-MICROGRAPHIC NEGATIVES, OR MAKE LANTERN SLIDES FROM THEM

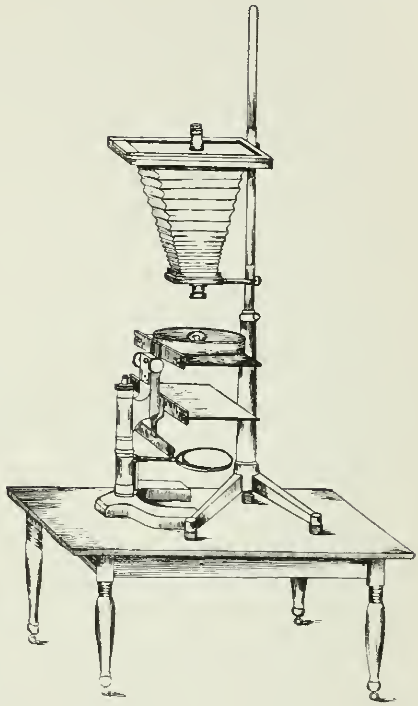
In photographing very large microscopic sections of embryos or of organs it is difficult to illuminate evenly the sections. To overcome this difficulty the camera is put in reverse order on the frame for the large vertical camera, and then elevated sufficiently to ensure a sky background. This will give even illumination. The specimen is placed on the stage of the special microscope stand. The focusing is then performed in the well-known way by a cord over the fine adjustment. One can focus as accurately as with a microscope. Objectives as high as 35 or 42 mm. may be used; or one may use a short focus photographic objective like the micro-planars of Zeiss.

PLATE XXXV



A

Small table and screen for the vertical photo-micrographic camera.

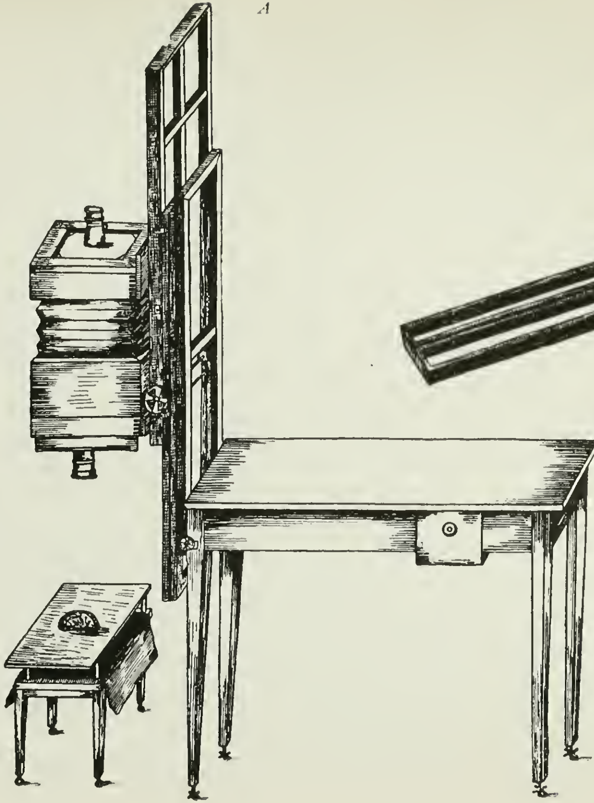


B

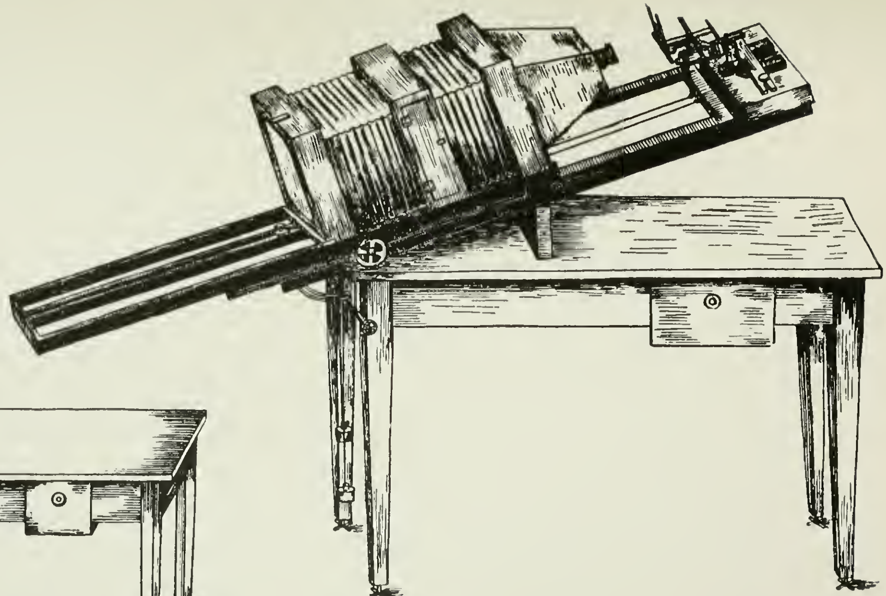
Special microscope stand with stage in place of the tube, so that the specimen can be focused with the fine or coarse adjustment.

PLATE XXXVI

A



B



A. Vertical photographic camera for photographing brains and other objects. The table is covered with glass and the background is considerably below to avoid shadows. For photographing large microscopic sections of organs, etc., the camera is reversed in position and the frame but partly elevated.

B. Elevated camera with special microscope stand for photograping very large sections, using the sky as a source of illumination.

REPORT OF THE COMMITTEE ON THE SPENCER-TOLLES FUND

Your committee, which was appointed at the last meeting to consider the possibility of developing this fund, begs leave to report that the matter has been brought to the attention of all members of this organization and other societies having an interest in the development of microscopical science; and that by virtue of the contributions which have been received, and which are enumerated in the report of the Custodian it has reached the limit set at the New York meeting of twelve hundred dollars. We are glad to report that great interest has been manifested in the fund as a memorial to men who have done so much to develop the tools of the investigator and to make modern research in so many lines fruitful of great results.

To each and all those, both individuals and organizations, who have contributed so generously toward the completion of this fund, it is appropriate that this Society should here formally acknowledge its thanks at the same time that it expresses its appreciation of the responsibility which the carrying out of this charge lays upon it. It has seemed appropriate to append a complete list of contributors to the fund.

Although the limit set has been reached and the amount on hand will yield an income such that at least a small sum may be devoted annually for the purposes of the fund as the Society may designate, yet it is clear that continued effort should be made and certainly will result in securing from time to time additions to the total amount. In the opinion of your committee the policy of the Society should be to build up gradually an adequate fund looking toward the future possibilities of a larger income in developing that branch of science for which this organization stands. It is accordingly recommended that a standing committee be appointed to care for the fund and to develop it in a conservative manner along the lines laid down above.

Officially the fund now stands in honor of the memory of Robert B. Tolles and Charles A. Spencer. With the name of Spencer, however, is associated, not only the illustrious father but also his distinguished son, the late Herbert R. Spencer, a loyal member of this organization and a successful worker for the advancement of microscopical science. Accordingly your committee deems it appropriate that the fund should stand as a memorial to the genius of this trio of American scientific workers, and recommend that it be designated as such officially and be known hereafter as the Spencer-Tolles Fund.

The legal advice which was at the command of the committee was of the best, and it seems clear that the present investment of the fund is conservative and safe. The committee would accordingly recommend that the Custodian should be directed to keep it invested as heretofore, and apply any additional moneys which have been or shall be received to increase the principal of the fund.

Regarding the use of the income it may be stated in advance that the object which the contributors have had in mind, and which members of the Society have cherished, seems to be in general the encouragement of research, especially such as depends upon the microscope for its accomplishment or is connected with the improvement of that instrument.

The committee has carefully reviewed the practice of other organizations in the world having trust funds of this character, in order to ascertain how these have been applied and what results have been obtained thereby. The following possibilities have thus been presented for consideration:

The awarding of prizes, which is a somewhat general method of disposing of the income of such funds, does not seem to be attended by results proportional to the expenditures, and the experience of this Society in offering such prizes at previous times has led members of the committee, together with such other members as they have been able to consult, to advise unanimously against the application of this fund to such purpose.

It has also been suggested that the money might be placed in charge of some other society to increase the funds of such organization. We do not feel that this would meet the ideas of the contributors who have given the money in charge of this Society and who will naturally look to it for the carrying out of its trust. Furthermore, it is evident that the administration of such a trust will be attended with some honor to the Society charged with its execution, and this belongs by right to the organization which has raised the fund; therefore we are equally unanimous in advising against such a procedure.

It has recently been recommended that the money should be placed in the hands of some institution to found a scholarship for educational research bearing the names of Spencer and Tolles. But quite apart from the difficulty of deciding *which* institution should be the recipient of the money and the evident diversity of opinion which would prevail in discussing this matter, it would seem that the arguments given above with reference to the entrustment of the funds to another organization would be equally valid here.

It is the unanimous opinion of this committee that a specific sum, not to exceed the annual income of the fund, should be devoted to the encouragement of such specific research as may be brought to the attention of the committee, and as may seem worthy of receiving this money. It is therefore recommended that the sum of $50 be set aside for the current year and that the Society appoint a committee under whose guidance it shall be expended.

Adolph Feiel,
Henry R. Howland,
Magnus Pflaum,
Henry B. Ward, *Recorder.*

COMPLETE LIST OF CONTRIBUTORS TO SPENCER-TOLLES FUND

Aspinwall, John	$ 53 93
Bleile, Dr. A. M	2 50
Burner, Dr. Nathan	1 00
Burrill, Dr. T. J	5 00
Carter, John E	10 00
Claypole, Prof. E. W	3 00
Coffin, Robert	2 00
Cox, Hon. J. D	5 00
Craig, Thomas	5 00
Curtis, Dr. Lester	10 00
Dennis, S. W	5 00
Feiel, Adolph	2 50
Fell, Dr. Geo. E	5 00
Fellows, Chas. S	10 00
Gage, Prof. S. H	35 00
Griffith, E. W	5 00
Kellicott, Prof. D. S	5 00

Kendall, Dr. H. D	$ 5 00
Kenyon, Miss Ada M	5 00
Krauss, Dr. W. C	1 00
Kruttschnitt, John	5 00
Lewis, Ira A	1 00
Lewis, Dr. W. J	10 00
Maddox, Dr. R. L	5 11
Manton, Dr. R. L	5 00
McKim, Rev. Haslett	20 00
Mellor, C. C	20 00
Mercer, Dr. A. C	1 00
Milnor, Chas. G	5 00
Mosgrove, Dr. S. M	5 00
Newcomer, F. S	5 00
Pennock, Edward	5 00
Pflaum, Magnus	14 37
Rogers, Prof. W. A	25 00
Shepard, Dr. Chas	5 00
Shultz, Chas. S	1 00
Smith, J. C	15 00
Smith, Jay M	10 00
Taylor, Geo. C	3 00
Vorce, C. M	10 00
Ward, Prof. H. B	10 00
Ward, Dr. R. H	25 00
Whelpley, Dr. H. W	2 00
Biol. and Micro. Sect. Academy Natural Sciences, Philadelphia	25 00
Buffalo Society Natural Sciences, Buffalo	25 00
Cortland Science Club, Cortland, N. Y	3 00
Iron City Microscopical Society, Pittsburg, Pa	25 00
New Jersey State Microscopical Society, New Brunswick, N. J	25 00
Royal Microscopical Society, London, Eng	25 20
Spencer Lens Co., Buffalo, N. Y	25 00
St. Louis Med. and Surg. Society, St. Louis, Mo	10 00
Troy Scientific Association, Troy, N. Y	50 00
Total contributions to February 12, 1902	$ 596 61
From sale of Proceedings	195 01
Interest and dividends	416 43
Total	$1,208 05

The above list includes some contributions received since the last meeting. It seemed proper to have all the names to appear in this volume.

MAGNUS PFLAUM, *Custodian.*

EDWARD WALLER CLAYPOLE

NECROLOGY

EDWARD WALLER CLAYPOLE, B.A., D.Sc. (LOND.)

OF PASADENA, CAL.

A truly wise man, loved and respected by all who knew him, has passed on to the other life in the great unknown. The world is better and science and scientific literature are richer because Edward Waller Claypole has lived in this part of God's universe.

Born in Ross, Herefordshire, England, in 1835, he was the eldest of six children, four sons and two daughters. He came of a line of educated and liberal-minded scholars. His paternal grandfather, a clergyman, withdrew from the Church of England to become a Baptist minister. His father, also a Baptist minister, educated in the University of Edinburgh, was a classical scholar. His mother, Elizabeth Mary Blunt, a niece of the English diplomat, Sir Waltham Waller, was brought up in the home of the latter. She received an education superior to that usually given to the young women of her day. This heritage of true refinement and culture, of intellectual ability, of love of justice and truth, of independence of thought, and of moral courage has been handed down to us increased and enriched.

He was educated by his father in classics and mathematics, but his first lessons in science came to him from two sisters of his mother. While he was visiting at their home they interested him in collecting and naming the plants and fossils found in that vicinity. These first lessons in science were not from text-books but from Mother Nature, and it may be that at this time he learned not only something of botany and geology but also, unconsciously, something of the value of the laboratory method in teaching science, which method was one source of power in his later years. At the age of fifteen he began to give instruction in his father's private school, and about two years later left home to teach at Abingdon.

In 1854 he matriculated from the University of London, the only English university then open to dissenters. This institution, which gave no instruction, but granted degrees on examination, required of all candidates for the baccalaureate degrees a preliminary training in one of certain accredited schools. Since circumstances made it impossible for him to fulfil this requirement, the young scholar, a dissenter, found no university in all England open to him. Ten years later when this barrier was removed, he passed the examinations for the degrees of B.A. and B.Sc. He might, at this time, by taking further examinations, have obtained the degree of D.Sc., but chose to wait until that degree should be granted for original work, and finally took it in 1888.

When nineteen years old, he and two of his younger brothers, Alfred and Henry, all of whom were away from home supporting themselves, undertook as a means of recreation the publication of a magazine called *"The Home Journal."* The magazine was not intended for the public and was not printed. Edward, the best penman, and editor-in-chief, received and copied the articles written by the three contributors, and illustrated the publication with maps and drawings which showed marked artistic ability. The titles of some of the articles that he wrote are "The Power of the Age" (the steam engine), illustrated with section drawings of a locomotive, "The Paralellogram of Forces," "Corals," "The Life of Demosthenes," "First Oration Against Philip" (translated from the Greek), "Laws of Refraction," "Chemical Nomenclature," "Geological Formation of Niagara." This last article was illustrated by three maps, a geographical map of the country in the region of Niagara, a section showing the geological strata, and a bird's-eye view of the Niagara river and its vicinity from its head at Lake Erie to its mouth at Lake Ontario. It is of interest to note this work because it shows that already there had been laid the foundation for that breadth and depth of knowledge which afterwards made him distinguished.

In 1865 he was married to Jane Trotter, of Coleford, England, a woman of rare beauty of character and moral force. Of the three children born to them, his son Arthur, the oldest, was killed in 1875 by falling from a moving railroad train. The twin daughters, Edith and Agnes, who survive him, have by their original work already won a place among the scientific workers in this country.

A few weeks after the birth of the twins Dr. Claypole lost his beloved wife—a blow coming as it did at so critical a time in his intellectual life was doubly felt.

He was appointed tutor of classics and mathematics in Stokes-Croft College, Bristol, England, in 1867, where he remained for five years. Then there came a crucial test which proved him to be a hero. One of the highest types of heroism known to the world has been shown by those men who, for the love of truth and their unswerving loyalty to their convictions, have suffered persecution. Such a man was Socrates. Such a man was Dr. Claypole. The church at that time branded Darwin's theory of evolution as heresy. Dr. Claypole saw that it was truth. And because he was firm in his determination to teach the truth he was compelled to resign his position at Stokes-Croft College. How bitter was the cup he drank none of us can realize. He was already sore at heart over the recent loss of his wife, and this step took away the means of support for his three motherless children. But the clouds seemed about to scatter, for he was appointed professor of mathematics and natural science in the University College at Aberystwyth, Wales. At the last moment religious persecution again met him, and he was not permitted to begin work at this institution.

So in October of 1872, leaving his little children in care of his parents and sister, he came to this land of freedom in thought and speech, but here, too, he found the same intolerant spirit. Finally, after a year of struggle and patient waiting, he was, through the friendship of Edward Everett Hale, appointed to the professorship of natural science at Antioch College, Yellow Springs, Ohio. In 1879 he married Katherine Benedicta Trotter, of Montreal, Canada, a second cousin of his first wife, and a woman well fitted to be the companion and helpmate of such a man. He remained at Antioch College until 1881 when, on account of financial difficulties, its doors were temporarily closed. In the fall of that year he was appointed paleontologist to the Second Geological Survey of Pennsylvania, and spent the next two years in the field. After the close of this engagement in 1883, he accepted the newly established chair of natural sciences in Buchtel College, Akron, Ohio, filling it for fifteen years. Then, on account of his wife's failing health, he resigned and moved to southern California, taking the professorship in geology and biology at Throop Polytechnic

Institute, Pasadena, a position held until August, 1901, when his work in this world was completed.

Dr. Claypole possessed a most happy combination of strong characteristics which fitted him to attain eminence both as a teacher and as a scientist. He loved and sought for the truth and would make any sacrifice to uphold it. He had a judicial mind which, having collected all possible evidence, sifted it, weighed it carefully, and considered it from every side before reaching a conclusion, and he had that patience and perseverence which Nature demands from those who successfully interpret her records.

As a teacher he was one of the pioneers in using the laboratory method. He made no mental paupers by always "giving men truth instead of training them to search for it." His students were trained to see, to observe accurately, to record their observations carefully by descriptions and by drawings, to think and reason about them. They were taught the unity of nature and natural law. Their minds were not stored with isolated truths, but the broad relations and general bearing of every truth were made plain to them. Yet his greatest power as a teacher lay in the influence of his character and example upon his pupils. They caught his love for Nature and her truths, his accurate methods of work, his precision of thought, his indomitable perseverence, his inexhaustible patience. Daily contact with such a man was an inspiration even to the dullest and most indifferent of students. They learned to love their work and to love the man who could awaken in them so deep and lasting a desire for knowledge. Many are the tributes paid by those who knew him as a teacher. One of his former students, now a professor in a large eastern university, said to me, "Dr. Claypole is the best teacher that I ever had." Prof. George M. Richardson, of Leland Stanford Jr. University, a student of Dr. Claypole's for one year at Antioch College, said, "That one year brought about a complete change in my attitude toward education, a complete change in my ideas as to what education meant, and Professor Claypole was alone responsible for it. I have always felt that he marked out for me my life work. I have never known another whose every trait so universally called forth love and admiration." Who can tell how many lives he has inspired with a love of knowledge and a desire to attain to higher ideals of manhood or womanhood!

Of the sciences, geology was the most attractive to him, and he is best known for his valuable additions to knowledge in this field. But his many contributions to scientific literature in the fields of botany, zoology, and entomology tell us how truly he loved Nature in all her manifestations, and how familiar he was with every branch of natural science.

His first report of original work in geology was given in 1871 while editor of the Proceedings of the Bristol (England) Naturalists' Society. In that year and the next he read a series of three papers before the society, "On the subsidence of the southwest counties of England during the present era," and one paper on "The development of the carboniferous system in the neighborhood of England." These earliest writings show the same characteristics that made all of his contributions to knowledge so valuable. In them we find that mastery of the English language which gave such charm as well as force and power to all of his writings and discourses; that clear, concise, logical thought, that completeness of evidence, that appreciation of the relation and value of facts, and that ability to interpret correctly the records of Nature.

Glacial geology was for him a most fruitful field of study. His paper on "Preglacial formation of the beds of the Great Lakes," published in the Canadian *Naturalist* in 1877, and the one read at the meeting of the American Association for the Advancement of Science in 1881, entitled "Evidence from the drift of Ohio, Indiana, and Illinois in support of the preglacial origin of the basins of Lakes Erie and Ontario," were epoch-making. The views presented in these articles were vigorously combated by some of the other foremost geologists. But his facts were indisputable and his arguments invincible, so that to-day his conclusions reached at that time stand as geological truths.

Another plenteous harvest came from his work on the Second Geological Survey of Pennsylvania. Besides the two volumes of the Survey Reports, as a direct result of this period of work, he presented to various scientific associations or published twenty-eight valuable papers. It was on this survey that he found the fossil remains of the hitherto undiscovered genus of ancient fish *Palaeaspis*. After much patient labor he classified this fossil and proved beyond any question that these were the "oldest indisputable vertebrate animals the world has yet seen." To him also belongs the honor of describing *Glyptodendron,* the oldest of the fossil plants. Another of his rich gifts to American geology and paleontology was his work on the Devonian Fishes of Ohio.

To Dr. Claypole the microscope was a means for many excursions beyond the pale of the known. He valued it not only as an aid to scientific research but equally as a means of general education and as a revealer of nature's beauties and mysteries to all who would patiently look and search. He took an active part in the meetings of the American Microscopical Society, attending them whenever possible, contributing to its proceedings, and serving as its President in 1897. His address on this occasion on "Microscopical Light in Geological Darkness" was an interesting and brilliant exposition of the secrets revealed by the microscopic study of rocks, secrets which give clues to the geological events in the early history of the world.

His wide interest in natural science was also shown by the active part taken in the many scientific organizations of which he was a member. He was one of the founders and the first president of the Ohio Academy of Sciences, a fellow of the Geological Societies of Edinburgh and London, vice-president of section E at the meeting of the American Association for the Advancement of Science in 1897, one of the original fellows of the Geological Society of America, and one of the founders and editors of the *American Geologists.*

In the discussions of papers at the meetings of scientific associations he was a power and a promoter of peace when individual animosities began to appear. Often when a discussion had become personal and bitter has he carried it back to the high plane of scientific debate.

His was a life of simplicity, purity, and nobility, "full of unselfish service to others. To have come close to his great nature was a mental and a moral inspiration, and to have known him thus was to love him always." He belongs to that group of men worthy of the tribute paid to Darwin: "His was a gentle, patient, reverent spirit, and by his life has not only science but our conception of Christianity been advanced and ennobled."

ROBERT ORTON MOODY.

PROCEEDINGS

OF

The American Microscopical Society

MINUTES OF THE ANNUAL MEETING

HELD IN

DENVER, COLORADO, AUGUST 29, 30, AND 31, 1901

The twenty-fourth annual meeting of the Society was called to order by President Eigenmann in room 3 of the High School, Denver, Colorado, at 2:00 P.M., Thursday, August 29, 1901. The report of the Treasurer was read and referred to an auditing committee consisting of Drs. Bleile and Weber, and it was on motion resolved that the financial year should be closed the 1st of October.

The report of the Custodian was read, showing in tabular form the contributions to the Spencer-Tolles Fund during the past year and during the previous period of its existence, the total amount of money received by interest and from other sources, and giving a statement with reference to the investment of the fund. The recommendations of the Treasurer were fully approved in a signed statement by C. C. Mellor, past Treasurer of the Society, who had examined carefully the character of the present investment. The matter of investment was referred to the Executive Committee with power, and the report itself was referred to an auditing committee consisting of Dr. Schoeney and Professor Beardsley.

The report of the special committee on the Spencer-Tolles Fund was read and referred to the Executive Committee with the recommendation that the control of the fund be left in the hands of a standing committee to be known as the Spencer-Tolles Fund Committee, but that the apportionment of the fund be charged to the Executive Committee.

A new by-law regulating these features was offered as follows:

By-law No. IX.—There shall be a standing committee known as the Spencer-Tolles Fund Committee to take general charge of the fund and to recommend annually what part of the income shall be expended for the encouragement of research, but the apportionment of the sum thus set apart shall be made by the Executive Committee. The Spencer-Tolles Fund Committee shall also have general charge of the expenditure of such money as may be apportioned, under the conditions laid down by the Society for its use. The Custodian shall be an *ex-officio* member of this committee.

The by-law was referred to the Executive Committee.

The following by-law was also offered and referred:

By-law No. X.—The Executive Committee shall have the power annually to appoint two members to represent the Society on the Council of the American Association for the Advancement of Science, in accordance with the regulations of the latter organization.

The following amendments to the constitution were offered and laid over one year under the rules:

To amend art. III by inserting "a custodian," making lines 5 and 6 read in conformity to this change, "together with a Secretary, a Treasurer, and a Custodian, who shall be elected," etc.

To amend art. IV by inserting in place of "of the Treasurer to act as custodian of" the clause "of the Custodian to take charge of," etc.

To amend art. V by adding "who still retain membership in this Society."

To amend art. VII by adding "But any person duly elected may, upon payment of $50 at one time, become a life member, entitled to all the privileges of membership, but exempt from further dues and fees."

SECOND SESSION

At 8:00 P.M. the Society convened in the audience room of the Denver High School for the annual address and reception given under the auspices of the Colorado Microscopical Society. The program was opened by a piano solo, after which the President of the Colorado Microscopical Society, Dr. A. M. Holmes of Denver, extended a cordial welcome to the national organization. The response was spoken in fitting terms by the retiring President of the Society, Dr. A. M. Bleile. After another musical number the President's address was read by Prof. C. H. Eigenmann on "The solution of the eel problem." It was illustrated by charts and lantern slides, and proved of great interest. At its close an informal reception was tendered the Society and its guests by the Colorado Microscopical Society at which members and guests spent some time in social enjoyment. The occasion was voted one of the most successful which the Society has been privileged to enjoy.

THIRD SESSION

On Friday, August 30, the Society was called to order at 9:00 A.M. in the Denver High School, Dr. A. M. Bleile being designated temporary presiding officer and Prof. A. E. Beardsley secretary *pro tem.* during the necessary absence of the regular officers. The by-laws IX and X were returned from the Executive Committee with a favorable recommendation, and on motion both were duly adopted. The committee then announced as members of the Council of the A. A. A. S. for 1901 Mr. J. C. Smith and Dr. A. M. Holmes.

An amendment to by-law No. III was offered as follows:

To add "But if not decided, the Secretary shall, unless otherwise ordered by the Executive Committee, print the same number as for the preceding year."

This by-law, being recommended by the Executive Committee, was unanimously adopted.

The report of the Committee on the Spencer-Tolles Fund was returned from the Executive Committee and the recommendations adopted as read. The past committee was continued as the Spencer-Tolles Fund Committee, as provided for in by-law IX, just adopted. The thanks of the Society were formally voted to each of the many generous contributors toward this fund, a list of whom is given on page 267, and the Secretary was ordered to send a copy of the committee's report and of this action to each of them.

A nominating committee was appointed, consisting of Dr. A. M. Bleile, Mrs. Cornelia S. Mills, Prof. M. J. Elrod, Dr. L. Schoeney, and Prof. D. Bodine.

In view of the considerable number of authors absent, it was resolved that papers be read by title unless the author were present in person. The following papers were then considered:

The early morphogenesis and histogenesis of the liver in the pig: D. C. Hilton, Chicago, Ill.

The histology of the stigmata and stomata in the peritoneum: A. E. Hertzler, Halstead, Kan.

A rearrangement of the families and genera of the Conjugatae: C. E. Bessey, Lincoln, Neb.

A new species of *Crenothrix* (*C. manganifera*): D. D. Jackson, New York City.

The amount of dissolved oxygen and carbonic acid in natural waters and the effect of these gases on the occurrence of the micro-organisms: G. C. Whipple and H. N. Parker, New York City.

Notes on Colorado Protozoa, with description of new species: A. E. Beardsley, Greeley, Col.

Notes on Colorado Entomostraca: A. E. Beardsley, Greeley, Col.

A review of the American species of *Cochleophorus* and *Curvipes*: R. H. Wolcott, Lincoln, Neb.

An apparently new hydra from Montana: M. J. Elrod, Missoula, Mont.

Some histological features of Echinorhynchi (illustrated): H. W. Graybill, Lincoln, Neb., was read in brief by H. B. Ward, and a specimen showing the giant nuclei was demonstrated under the microscope.

The debt of American microscopy to Spencer and Tolles: W. C. Krauss, Buffalo, N. Y.

Some new points on avian cestodes: B. H. Ransom, Bancroft, Neb.

A contribution to the subterranean fauna of Texas: C. J. Ulrich, Duluth, Minn.

Mounting soft tissues for microscopical examination: M. A. D. Jones, New York City.

Modification of some standard laboratory apparatus: S. H. Gage, Ithaca, N. Y.

Laboratory photographic apparatus: S. H. Gage, Ithaca, N. Y.

The plankton of Lake Maxinkuckee, Ind.: Chancey Juday.

Studies on the genus *Cittotaenia*: R. A. Lyman, Omaha, Neb.

A letter was read from Dr. William Trelease, Director of the Missouri Botanical Garden, extending to the Society, on behalf of the local scientific organizations and the Louisiana Purchase Exposition Company, an invitation to hold its 1903 meeting in the city of St. Louis. The letter was referred to the Executive Committee and the question of date and place of the next meeting was also similarly referred.

It was voted to accept the invitation to join the excursion to Boulder, Col., tendered by the University of Colorado for the afternoon, and to take the trip to Colorado Springs, Manitou, and the Garden of the Gods, tendered by Colorado College and the Chamber of Commerce of Colorado Springs on Saturday. It was also voted to hold the final session of the Society on the train *en route* to Colorado Springs, Saturday morning. The Society then adjourned.

FOURTH SESSION

The Society was called to order by the President at 9:30 A.M. August 31, while *en route* to Colorado Springs. The Executive Committee recommended that the Secretary be authorized to send some of the back volumes on hand to a selected list of foreign societies, and to add them to the list of organizations to which the Proceedings are regularly distributed. It was further recommended that, in the opinion of the committee, Proceedings should not be distributed gratis in this country, but that in exceptional cases prominent foreign societies might receive the Transactions regularly. The report of the committee was adopted, and the Transactions ordered sent to the organizations as designated by the Executive Committee.

The Nominating Committee reported as follows:

FOR ONE YEAR

President, Dr. Charles E. Bessey, University of Nebraska, Lincoln, Neb.

First Vice-President, Dr. E. A. Birge, University of Wisconsin, Madison, Wis.

Second Vice-President, Mr. John Aspinwall, New York City.

Elective Members of the Executive Committee: Dr. A. M. Holmes, Denver, Col.; Dr. V. A. Latham, Chicago, Ill.; Mr. G. C. Whipple, New York City.

FOR THREE YEARS

Secretary, Dr. Henry B. Ward, University of Nebraska, Lincoln, Neb.

Treasurer, Mr. J. C. Smith, New Orleans, La.

Custodian, Mr. Magnus Pflaum, Pittsburg, Pa.

The Society appointed Professor S. H. Gage and Mr. Magnus

Pflaum a committee to draw up suitable resolutions of respect for Ex-President E. W. Claypole, expressing its appreciation of the services rendered the organization by Professor Claypole as well as the great loss experienced in his death.

[The committee has prepared the following testimonial which, in accord with the instructions of the Society, is spread upon its records as a token of its indebtedness to one who did so much for its welfare as an organization and for individual members in personal assistance and encouragement.]

In the death of Professor Edward W. Claypole science lost a most earnest devotee and this Society a highly esteemed member.

He was a conscientious student and his knowledge was profound. His mind was wholly given to his profession, and, as a true scientist, he constantly learned and broadened his mind to be better able to impart knowledge. And though the cold facts of science engaged all his faculties to the exclusion almost of the trivialities of common life, yet his heart grew apace, and few men enjoyed a happier family life in which he gave and received blessings.

As a member of our Society his presence at meetings was always a delight. Kind, genial, modest, sincere, he was the center of admiring friends, and, with his family, almost an object of envy and an inspiration to others.

Of such men the world has too few; he will long be remembered.

On behalf of the American Microscopical Society,

MAGNUS PFLAUM,
SIMON HENRY GAGE,
Committee.

The Secretary was instructed to insist on the completion of papers promptly and issue the volume at an earlier date than heretofore.

The Society adopted unanimously a vote of thanks to the Colorado Microscopical Society and its officers for hospitality extended to the American Microscopical Society, to the musicians who assisted at the reception on Thursday evening, to the many citizens of Colorado who officially and personally had contributed so much to make the meeting a success, and especially to those who had aided in planning and carrying out the excursions tendered the organization.

On motion the Society then adjourned.

HENRY B. WARD,
Secretary.

TREASURER'S REPORT

FROM SEPTEMBER 20, 1900, TO OCTOBER 15, 1901

DR.		
To Membership dues, 1899	$ 4 00	
To Membership dues, 1900	25 00	
To Membership dues, 1901	276 00	
To Membership dues, 1902	48 00	
		$ 353 00
To Admission fees, 1901	$ 18 00	
To Admission fees, 1902	27 00	
		45 00
To Subscribers, Vol. XXI	$ 28 00	
To Subscribers, Vol. XXII	33 00	
		61 00
To Advertising, Vol. XX	$ 2 00	
To Advertising, Vol. XXII	76 00	
		78 00
To Donation		25 00
To Balance due Treasurer		61 53
		$623 53
CR.		
By Postage, Secretary	$ 25 41	
By Postage, Treasurer	7 00	
		$ 32 41
By Expressage, Secretary		29 65
By Stationery and Printing, Secretary	$ 23 08	
By Stationery and Printing, Treasurer	3 50	
		26 58
By Typewriting, Secretary	$ 21 48	
By Sundries, Secretary	9 46	
By Bank Charges, Treasurer	3 15	
		34 09
By Issuing Vol. XXII, Printing	$411 50	
By Issuing Vol. XXII, Plates	51 48	
		462 98
By Cash return to Treasurer		37 82
		$ 623 53

We hereby certify that we have examined the foregoing accounts and find the same correct with proper vouchers for expenditures.

A. M. BLEILE,
H. A. WEBER,
Auditing Committee.

CUSTODIAN'S REPORT FOR YEAR ENDING JULY 1, 1901

SPENCER-TOLLES FUND

Reported at New York Meeting	$ 756 01
Dividends	57 99
Sale of Proceedings	61 01
Contributions	269 11
	$1,144 12
Pledges (since paid)	55 88
	$1,200 00
Total increase for year	$ 388 11

ANNUAL GROWTH

Year.	Increase.	Total.
1885	......	$ 60 20
1886	$ 25 00	85 20
1887	10 00	95 20
1888	52 66	147 86
1889	76 00	223 86
1890	30 00	253 86
1891	39 02	292 88
1892	19 12	312 00
1893	18 06	330 06
1894	19 32	349 38
1895	22 89	372 27
1896	50 77	423 04
1897	45 99	469 03
1898	86 43	555 46
1899	97 90	653 36
1900	102 65	756 01
1901	388 11	1,144 12

MAGNUS PFLAUM, *Custodian*.

DENVER, COLO., August 30, 1901.

The Auditing Committee appointed to audit the report of the Custodian of the Society report that we have carefully examined the records of the Custodian, Magnus Pflaum, together with the records and vouchers thereunto pertaining, and that we find that the said report of the Custodian is in complete accord with the records and vouchers above mentioned.

A. E. BEARDSLEY,
L. SCHONEY,
Auditing Committee.

CONSTITUTION

Article I

This Association shall be called the American Microscopical Society. Its object shall be the encouragement of microscopical research.

Article II

Any person interested in microscopical science may become a member of the Society upon written application and recommendation by two members and election by the Executive Committee. Honorary members may also be elected by the Society on nomination by the Executive Committee.

Article III

The officers of this Society shall consist of a President and two Vice-Presidents, who shall hold their office for one year, and shall be ineligible for re-election for two years after the expiration of their terms of office, together with a Secretary and Treasurer, who shall be elected for three years and be eligible for re-election.

Article IV

The duties of the officers shall be the same as are usual in similar organizations; in addition to which it shall be the duty of the President to deliver an address during the meeting at which he presides; of the Treasurer to act as custodian of the property of the Society, and of the Secretary to edit and publish the Proceedings of the Society.

Article V

There shall be an Executive Committee, consisting of the officers of the Society, three members elected by the Society, and the past Presidents of the Society and of the American Society of Microscopists.

Article VI

It shall be the duty of the Executive Committee to fix the time and place of meeting and manage the general affairs of the Society.

Article VII

The initiation fee shall be $3, and the dues shall be $2 annually, payable in advance.

Article VIII

The election of officers shall be by ballot.

Article IX

Amendments to the Constitution may be made by a two-thirds vote of all members present at any annual meeting, after having been proposed at the preceding annual meeting.

BY-LAWS

I

The Executive Committee shall, before the close of the annual meeting for which they are elected, examine the papers presented and decide upon their publication or otherwise dispose of them.

All papers accepted for publication must be completed by the authors and placed in the hands of the Secretary by October 1st succeeding the meeting.

II

The Secretary shall edit and publish the papers accepted with the necessary illustrations.

III

The number of copies of Proceedings of any meeting shall be decided at that meeting. But if not decided, the Secretary shall, unless otherwise ordered by the Executive Committee, print the same number as for the preceding year.

IV

No applicant shall be considered a member until he has paid his dues. Any member failing to pay his dues for two consecutive years, and after two written notifications from the Treasurer, shall be dropped from the roll, with the privilege of reinstatement at any time on payment of all arrears. The Proceedings shall not be sent to any member whose dues are unpaid.

V

The election of officers shall be held on the morning of the last day of the annual meeting. Their term of office shall commence at the close of the meeting at which they are elected, and shall continue until their successors are elected and qualified.

VI

Candidates for office shall be nominated by a committee of five members of the Society. This committee shall be elected by a plurality vote, by ballot, after free nomination, on the second day of the annual meeting.

VII

All motions or resolutions relating to the business of the Society shall be referred for consideration to the Executive Committee before discussion and final action by the Society.

VIII

Members of this Society shall have the privilege of enroling members of their families (except men over twenty-one years of age) for any meeting upon payment of one-half the annual subscription ($1).

IX

There shall be a standing committee known as the Spencer-Tolles Fund Committee to take general charge of the fund and to recommend annually what part of the income shall be expended for the encouragement of research, but the apportionment of the sum thus set apart shall be made by the Executive Committee.

The Spencer-Tolles Fund Committee shall also have general charge of the expenditure of such money as may be apportioned, under the conditions laid down by the Society for its use.

The Custodian shall be an *ex-officio* member of this committee.

X

The Executive Committee shall have the power annually to appoint two members to represent the Society on the Council of the American Association for the Advancement of Science, in accordance with the regulations of the latter organization.

Revised by the Society, August 30, 1901.

LIST OF MEMBERS

The figures denote the year of the member's election, except '78, which marks an original member. THE TRANSACTIONS are not sent to members in arrears, and two years' arrearage forfeits membership. (See Article IV of By-laws.)

MEMBERS ELECTED DURING THE YEAR 1901

For addresses see regular list.

CHARLES, JOS. WM.
DISBROW, WILLIAM S., M.D.
FOOTE, J. S., M.D.
GALLOWAY, PROF. T. W.
GRAYBILL, H. W., B.SC.
HALL, VICTOR S.
HILTON, DAVID C., A.B.
HERZOG, MAXIMILIAN, M.D.
KINLEY, JOS. B., M.D.
LYMAN, RUFUS A., A.M.
MARSH, JAS. P., M.D.
MILES, MRS. C. S.
MILLEN, J. C., M.D.
MOCKETT, J. H., SR.
SARCAR, HEM CHUNDRA, M.B.
STAUFFER, REV. T. F.
STEBBINS, J. H., M.D., PH.D.
ULRICH, PROF. CARL J.

ABERDEIN, ROBERT, M.D., '82................327 James St., Syracuse, N. Y.
AINSLIE, CHARLES N., '92................................Rochester, Minn.
ALLEGER, WALTER W., M.D., '94........949 T St., N. W., Washington, D. C.
ASPINWALL, JOHN, M.A., '00 ....Newburg, N. Y.
ATWOOD, E. S., '79...... ....Highlands P. O., Monmouth Co., N. J.
ATWOOD, H. F., '78....................16 Seneca Parkway, Rochester, N. Y.
AYERS, MORGAN W., M.D., '87.......................Upper Montclair, N. J.

BARKER, ALBERT S., '97....Twenty-fourth and Locust Sts., Philadelphia, Pa.
BARNSFATHER, JAMES, M.D., '91.....Sixth Ave. and Walnut St., Dayton, Ky.
BARTLETT, CHARLES JOSEPH, M.D., '96......150 York St., New Haven, Conn.
BAUSCH, EDWARD, '78..................179 N. St. Paul St., Rochester, N. Y.
BAUSCH, HENRY, '86....................................Rochester, N. Y.
BAUSCH, WILLIAM, '88 ....St. Paul St., Rochester, N. Y.
BEAL, PROF. JAMES HARTLEY, '96..................Scio College, Scio, Ohio
BEARDSLEY, PROF. A. E., '97..................1412 Tenth St., Greeley, Colo.
BELL, CLARK, ESQ., '92........................39 Broadway, New York City
BENNETT, HENRY C., '93........Fourth Flat, 1692 Broadway, New York City
BERING, J. EDWARD, '99....................................Decatur, Ill.
BESSEY, PROF. CHARLES EDWIN, Ph.D., LL.D., '98............Lincoln, Neb.
BEYER, PROF. GEO. E., '99 ....Tulane University, New Orleans, La.
BIRGE, PROF. E. A., S.D., '99 ....University of Wisconsin, Madison, Wis.

Biscoe, Prof. Thomas D., '91 ....404 Front St., Marietta, Ohio
Bleile, A. M., M.D., '81............Ohio State University, Columbus, Ohio
Bodine, Prof. Donaldson, '96........................Crawfordsville, Ind.
Booth, Mary A., F.R.M.S., '82.........60 Dartmouth St., Springfield, Mass.
Boyce, James C., Esq., '96................Carnegie Building, Pittsburg, Pa.
Boyce, John W., M.D., '96................23 Mawhinney, St., Pittsburg, Pa.
Boyer, C. S., A.M., '92..................3223 Clifford St., Philadelphia, Pa.
Bredin, Geo. S., '96 ....Oil City, Pa.
Bromley, Robert Innis, M.D., '93...........Washington St., Sonora, Cal.
Brown, N. Howland, '91................ 33 S. Tenth St., Philadelphia, Pa.
Brown, Robert, '85.................Observatory Place, New Haven, Conn.
Brundage, A. H., M.D., '94...........1073 Bushwick Ave., Brooklyn, N. Y.
Bull, James Edgar, Esq., '92................141 Broadway, New York City
Burchard, E. A., M.D., '99...........6 Elm St., Lodi, San Joaquin Co., Cal.
Burner, Nathan L., M.D., '96.
Independent Chemical Co., Saginaw, W. S., Mich.
Burrill, Prof. T. J., Ph.D., '78..............................Urbana, Ill.
Burt, Prof. Edward A., Ph.D., '91....Middlebury College, Middlebury, Vt.

Carpenter, Thos. B., M.D., '99.............142 N. Pearl St., Buffalo, N. Y.
Carter, John E., '86.Knox and Coulter Sts., Germantown, Philadelphia, Pa.
Charles, Jos. Wm., M.D,, '01.........2729 Washington Ave., St. Louis, Mo.
Clark, Gaylord P., M.D., '96..........619 W. Genesee St., Syracuse, N. Y.
Clark, George Edw., M.D., '96..........Skaneateles, Onondaga Co., N. Y.
Clements, Frederic E., A.M., Ph.D., '98.
University of Nebraska, Lincoln, Neb.
Cocks, Prof. Reginald S., '99...McDonogh High School, New Orleans, La.
Coffin, Robert, '00........................Bedford City, Bedford Co., Va.
Coope, A. F., M.D., '86.....................114 Sycamore St., Oil City, Pa.
Couch, Francis G., '86 ....Kalish Pharmacy,
Twenty-third St. and Fourth Ave., New York City
Cox, Chas. F., F.R.M.S., '85 ....Grand Central Station, New York City
Craig, Thomas, '93.................1013 Sherbrooke St., Montreal, Canada
Cunningham, M. C., '96....................Board of Health, Pittsburg, Pa.

Davis, Chas. H., '98.........................Drawer 1033, Rochester, N. Y.
Davis, F. L., M.D., '99......................209 Locust St., Evansville, Ind.
Diehl, Alfred C., M.D., '96...................361 Pearl St., Buffalo, N. Y.
Disbrow, William S., M.D., Ph.G., '01......151 Orchard St., Newark, N. J.
Dorr, S. Hobart, Ph.G., '95.................945 Niagara St., Buffalo, N. Y.
Drescher, W. E., '87...........................Box 1033, Rochester, N. Y.
Dunham, E. K., M.D., '92...........338 E. Twenty-sixth St., New York City

Eigenmann, Prof. C. H., '95...........630 Atwater St., Bloomington, Ind.
Elliott, Prof. Arthur H., '91 ....4 Irving Place, New York City
Elliott, Luther B., '98..................219 Fulton Ave., Rochester, N. Y.

ELROD, PROF. MORTON J., M.A., M.S., '98,
University of Montana, Missoula, Mont.
ELSNER, JOHN, M.D., '83................1014 Fourteenth St., Denver, Colo.
ELWELL, A. T., '89......................16 Pearl St., Council Bluffs, Iowa
EWELL, MARSHALL D., M.D., LL.D., '85...........59 Clark St., Chicago, Ill.
EYRE, JOHN W. H., M.D., M.S., F.R.M.S., '99,
Embankment Chambers, Villiers St., London, W. C., England

FEIEL, ADOLPH, M.D., '81 ....520 E. Main St., Columbus, Ohio
FELL, GEO. E., M.D., F.R.M.S., '78............72 Niagara St., Buffalo, N. Y.
FELLOWS, CHAS. S., F.R.M.S., '83...925 Guaranty Bldg., Minneapolis, Minn.
FERRIS, PROF. HARRY, B., M.D., '96........118 York St., New Haven, Conn.
FINDER, WM., JR., M.D., '98.....................2 Union Place, Troy, N. Y.
FISHER, MAX, '93......................Zeiss Optical Works, Jena, Germany
FISHER, REV. STOKELY S., '99.........................Pleasantville, Ohio
FLINT, JAMES M., M.D., '91............"The Portland," Washington, D. C.
FOOTE, J. S., M.D., '01................422 So. Twenty-sixth St., Omaha, Neb.
FORDYCE, CHARLES, B.S., A.M., Ph.D., '98,
Nebraska Wesleyan University, University Place, Neb.
FOSTER, EDWARD, '99.....................P. O. Box 405, New Orleans, La.
FOX, OSCAR C., '92...................U. S. Patent Office, Washington, D. C.
FRAKER, H. C., M.D., '99...................342 Ohio Ave., Columbus, Ohio
FULLER, CHAS. G., M.D., F.R.M.S., '81.........Reliance Bldg., Chicago, Ill.

GAGE, PROF. SIMON H., B.S., '82...........Cornell University, Ithaca, N. Y.
GAGE, MRS. SUSANNA PHELPS, '87...............4 South Ave., Ithaca, N. Y.
GALLOWAY, PROF. T. W., '01 ....Missouri Valley College, Marshall, Mo.
GATES, ELMER, '96...................................Chevy Chase, Md.
GOODRICH, W. H., M.D., '98..................................Augusta, Ga.
GRAYBILL, H. W., B.Sc., '01...........University of Nebraska, Lincoln, Neb.
GROSSKOPF, ERNEST C., M.D., '99.......................Wauwatosa, Wis.

HAAG, D. E., M.D., '86 ....Liberty Center, Ohio
HALL, VICTOR S., '01.................1911 Webster St., San Francisco, Cal.
HANAMAN, C. E., F.R.M.S., '79...........State and Second Sts., Troy, N. Y.
HANKS, HENRY G., F.G.S., F.R.M.S., '86,
1124 Greenwich St., San Francisco, Cal.
HATFIELD, JOHN J. B., '82...............333 Arsenal Ave., Indianapolis, Ind.
HERTZLER, ARTHUR A., M.D., '96.........................Halstead, Kan.
HERTZOG, MAXIMILIAN, M.D., '01.........174 E. Chicago Ave., Chicago, Ill.
HIGGINS, F. W., M.D., '98 ....20 Court St., Cortland, N. Y.
HILL, HERBERT M., Ph.D., '87..................24 High St., Buffalo, N. Y.
HILTON, DAVID CLARK, A.M., '01........146 So. Campbell Ave., Chicago, Ill.
HOFFMAN, JOS. H., M.D., '96.................111 Steuben St., Pittsburg, Pa.
HOLBROOK, M. L., M.D., '82 ....43 E. Twenty-first St., New York City
HOLLIS, FREDERICK S., Ph.D., '99...Yale Medical School, New Haven, Conn.
HOLMES, A. M., M.D., '98..................205 Jackson Block, Denver, Colo.

Hoskins, Wm., '79....................Room 55, 81 S. Clark St., Chicago, Ill.
Howard, Curtis C., M.D., '83............97 Jefferson Ave., Columbus, Ohio
Howe, W. T. H., Ph.D., '00..................................Evansville, Ind.
Howland, Henry R., A.M., '98..............217 Sumner St., Buffalo, N. Y.
Humphrey, Prof. O. D., Ph.D., '95....State Normal School, Jamaica, N. Y.
Hyatt, J. D., '78......................69 Burling Lane, New Rochelle, N. Y.

Jackson, Daniel Dana, B.S., '99...........177 Sixth Ave., Brooklyn, N. Y.
James, Bushrod W., M.D., '94,
N. E. cor. Green and Eighteenth Sts., Philadelphia, Pa.
James, Frank L., Ph.D., M.D., '82........514 Century Bldg., St. Louis, Mo.
James, Geo. W., '92.............................108 Lake St., Chicago, Ill.
Johnson, Frank S., M.D., F.R.M.S., '93.....5221 Prairie Ave., Chicago, Ill.
Johnson, Wm. D., M.D., '98.................................Batavia, N. Y.
Johnston, Levi D., M.D., '96 ....Whittier, Cal.
Jones, Mrs. Mary A. Dixon, M.D., F.R.M.S., '98,
249 E. Eighty-sixth St., New York City
Juday, Chancey, '00......................................Millersburg, Ind.

Kellogg, J. H., M.D., '78 ....Battle Creek, Mich.
Kerr, Abram Tucker, Jr., M.D., '95......Cornell University, Ithaca, N. Y.
Kingsbury, Benj. F., A.B., M.S., '98........125 Dryden Road, Ithaca, N. Y.
Kinley, Jos. B., M.D., '01....................1405 Welton St., Denver, Colo.
Kirkpatrick, T. J., '93...................701 E. High St., Springfield, Ohio
Kofoid, Charles A., Ph.D., '99......University of California, Berkeley, Cal.
Kotz, A. L., M.D., '91 ....32 S. Fourth St., Easton, Pa.
Krafft, William, '95 ....411 W. Fifty-ninth St., New York City
Krauss, Wm. C., B.S., M.D., '90...........371 Delaware Ave., Buffalo, N. Y.
Kuehne, F. W., '79........................19 Court St., Fort Wayne, Ind.

Lamb, J. Melvin, M.D., '91.............910 T St., N. W., Washington, D. C.
Latham, Miss V. A., M.D., D.D.S., F.R.M.S., '88,
808 Morse Ave., Rogers Park, Chicago, Ill.
Lawton, Edward P., '88.......................3 Linden Ave., Troy, N. Y.
Leippe, J. Harry, '96..........................336 Pine St., Reading, Pa.
Lewis, Mrs. Katharine B., '89, "Elmstone," 656 Seventh St., Buffalo, N. Y.
Lewis, Ira W., '87 ....408 So. Galena St., Dixon, Ill.
Line, J. Edward, D.D.S., '82..................39 State St., Rochester, N. Y.
Locke, John D., '93 ....P. O. Box 129, Haverhill, N. H.
Lomb, Adolph, '92......................48 Clinton Place, Rochester, N. Y.
Lomb, Henry, '84.......................48 Clinton Place, Rochester, N. Y.
Loomis, Chandler H., '87....Atlantic Dredging Co., 31 Pine St., N. Y. City
Love, Prof. E. G., F.R.M.S., '91........80 E. Fifty-fifth St., New York City
Lyon, Howard N., M.D., '84.....................103 State St., Chicago, Ill.
Lyman, R. A., A.M., '01 ....1123 Pacific St., Omaha, Neb.

Manton, W. P., M.D., '85................32 W. Adams Ave., Detroit, Mich.

MARSH, J. P., M.D., '01..........................1828 Fifth Ave, Troy, N. Y.
MARSHALL, COLLINS, M.D., '96..........2507 Penn. Ave., Washington, D. C.
MARSHALL, WM., JR., '92...................................Coudersport, Pa.
MASTERMAN, ELMER E., '97...Rural Mail Delivery No. 2, New London, Ohio
MCCALLA, ALBERT, Ph.D., '80,
414 Monadnock, Dearborn and Jackson Sts., Chicago, Ill.
MCKAY, JOSEPH, '84..........................259 Eighth St., Troy, N. Y.
MCKIM, REV. HASLETT, '85...........9 W. Forty-eighth St., New York City
MCMILLAN, R. M., M.D., '00............35 Twentieth St., Wheeling, W. Va.
MEADER, LEE DOUGLAS, M.D., '96.......2651 Gilbert Ave., Cincinnati, Ohio
MELLOR, CHAS. C., '85.......................319 Fifth Ave., Pittsburg, Pa.
MERCER, A. CLIFFORD, M.D., F.R.M. S., '82,
324 Montgomery St., Syracuse, N. Y.
MERCER, FREDERICK W., M.D., F.R.M.S.,'83...2540 Prairie Ave., Chicago, Ill.
MERCER, W. F., Ph.D., '99,
Biological Laboratory, Ohio University, Athens, Ohio
MILES, MRS. C. S., '01......................1544 Franklin St., Denver, Colo.
MILLEN, J. C., M.D., '01...................911 Downing Ave., Denver, Colo.
MILLER, JOHN A., Ph.D., F.R.M.S.. '89.......44 Lewis Block, Buffalo, N. Y.
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