RAFTER, (Geo. W.)

—ON THE—

MICRO-ORGANISMS IN HEMLOCK WATER.

BY GEO. W. RAFTER.

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ERRATA.

Page 5, 12th line from bottom, 5th word, read "adduced."
Page 9, Foot Note, 3d word, read "Manure."
Page 13, 6th line from bottom, 5th word, read "succeeded."
Page 14, 17th line from top, 5th word read "*pulex.*"
Page 21, 11th line from top, 7th word, read "*lumbricoides.*"
Page 21, 19th line from top, 1st word, read ' *Tubifex.*"
Page 22, 13th line from bottom, 9th word, read " serious.
Page 23, 14th line from top, 3d word, read "statoblasts."

ON THE

MICRO-ORGANISMS IN HEMLOCK WATER.

BY GEO. W. RAFTER, M. A. S. M., M. AM. SOC. C. E.

[Read before the Rochester Academy of Science.]

By resolution of the Section of Microscopy I have been detailed to present to you this evening some of the results of a year's work in the study of the biology of the Hemlock water supply.

Hemlock lake, from whence the supply is derived, is situated twenty-eight miles south from Rochester, on the boundary between Ontario and Livingston counties. It is six and six-tenths miles in length and rather more than half a mile wide. Its shores are bold and steep, the hills rising on both sides to the height of several hundred feet, and on the western side the slopes are, to a great extent, still covered with a primeval forest of oak, ash, hemlock and chestnut.

The total drainage area, exclusive of the surface of the lake itself, is about 26,000 acres, and of this it is estimated that from 18.000 to 19,000 acres are in cultivation, the agricultural industries being of the usual diversified character peculiar to Western New York.

The geological formation of these bluffs is the Marcellus shale, and into this the basin of the lake extends to a depth of more than seventy feet.

The only constant tributary is the inlet at the south end and this brings the drainage of several miles of elevated valley lying to the south of the lake.

The quantity of water flowing into the lake by the inlet is less than one-half of that flowing out at the outlet, from which it has been inferred that the permanent supply is derived from deep seated springs. In confirmation of this view it has been noted that the water of the inlet is about three times as hard as the water of the lake itself and that it farther contains a larger percentage of organic matter.

A study of the discharge of the lake in conjunction with observations on the rain-fall leads moreover, to the conclusion that but a small proportion of any given rain runs off at once, but that finally a large percentage is received in the lake. This we may also infer to be fairly deducible from the geological conditions. We may take it therefore as proven that Hemlock lake water is mostly in the fullest sense spring water. The fact that there is no limestone in the region gives a water of a high degree of softness.

CHEMICAL ANALYSES.

Chemical analyses of Hemlock water were made by Professor Lattimore several times a month in the fall of 1876, and also from March, 1877, to February, 1878. The following is the mean of all the analyses made in 1877 in parts per 100,000 of water by weight.*

Inorganic Matter - - - - -	7.25
Organic and Volatile - - - - -	4.00
Free Ammonia - - - - -	0.00
Albuminoid Ammonia - - - - -	0.0004

In July, 1881, Prof. Leeds made an analysis of Hemlock lake water as follows.† His results are in grains per gallon, but for purposes of comparison I have carried them out to parts per 100,000 of water by weight as well.

	Grains Per Gallon.	Parts Per 100,000.
Free Ammonia - -	0.00087	0.00149
Albuminoid Ammonia - -	0.013	0.022
Oxygen Required - -	0.46	0.79
Nitrites - - - -	None	None
Nitrates - - - -	0.367	0.63
Chlorine - - - -	0.113	0.194
Total Hardness - -	3.20	5.48
Total Solids - - -	5.83	9.99
Mineral Matter - -	2.33	3.99
Organic and Volatile Matter -	3.50	6.00

*Report on the Water Supply of the City of Rochester, by Prof. S. A. Lattimore, in the Annual Report of the Executive Board of the City of Rochester for 1878.

†Table giving composition of city waters in the United States, in the Journal of the American Chemical Society, 1881; also in the Annual Report of the Executive Board for 1881, by Prof. Albert R. Leeds.

INTERPRETATION OF ANALYSES.*

In order to compare different analyses, we need to understand just what the different items represent, as, for instance, the free ammonia is the measure of that portion of the nitrogenous matter which has already undergone decomposition.

The albuminoid ammonia is the measure of that part of the nitrogenous matter which has not been decomposed, but which is capable of undergoing decomposition.

Oxygen required will indicate the amount of oxygen required to oxidize the organic matter.

The nitrites and nitrates mark different stages in the oxidation of the nitrogenous organic matter already existing in the water, or, possibly the supply of nitrogenous salts from some external source.

When there is no reason to suppose the supply of nitrates from some external source, their occurrence would indicate that the water is undergoing or has undergone a process of natural purification. The nitrites and nitrates are, therefore, harmless of themselves, but they mark the possibility of dangerous organic contamination, and they probably act as the pabulum of micro-life.

The most striking point in the comparison of these analyses is the increase of ammonia both free and albuminoid from 1877 to 1881. This increase is such, indeed, as to explain in a striking manner the increase in life noted by Mr. Atwood in 1881.

Prof. Lattimore did not determine the nitrates, and we have, therefore, no means of comparing them.

The other determinations are not of special importance for present purposes.

PROF. LATTIMORE'S MICROSCOPICAL EXAMINATION.

At the time of making the above analyses Prof. Lattimore made an extended microscopical examination of this water and he states the result of such examination as follows :

"First—The amount of organic life existing in Hemlock lake water, whether in the mains, reservoirs or the lake itself, is exceedingly small. The number of species is small, and no species is represented by a large number of individuals. I have examined no other water supply which has not contained a larger, and usually a very much larger, proportion of organic life. * * * Our water supply is sparsely populated.

*See article, Interpretation of Data, in Report on Schuy'kill River, by Prof. Albert R. Leeds, in the Annual Report of the Philadelphia Water Department for 1883.

"Second—The variation observed from month to month in the species and number of individuals has been scarcely, if at all, perceptible. The single exception is that of a little *entomostracan–cyclops* which was slightly more abundant in the early summer.

"Third—The species of plants and animals living in Hemlock lake are those found only in the purest waters. Scarcely one of them is to be found in the stagnant water of ponds or ditches, which usually swarm with life during the summer, especially, and conversely the organisms characteristic of stagnant water are notably absent from the lake water.

"Fourth—The character of the bed of Hemlock lake and its surroundings furnish a reasonable account for this scanty life. Its water, almost entirely free from organic matter, as the chemical analysis so clearly shows, lacks the necessary pabulum for their subsistence, while the absence of marshy and weedy borders and the slight growth of aquatic plants do not furnish the conditions favorable to their multiplication."

The modern studies in biology indicate that nitrogenous food is necessary for the existence and development of most of the forms of infusorial life, especially for such as find their native habitat in impure and stagnant waters, and it seems to be a fair inference, that, in addition to nitrogenous organic matter, by itself furnishing the food of such organisms, there are farther certain conditions, as yet not very clearly defined, in which, what would otherwise be harmless organic matter, may, if in the presence of a nitrogen salt, and small quantities of phosphoric acid, become the pabulum of a rank growth of micro-life. Under such conditions we have the lake, for the time being, transformed into a culture fluid.

Under ordinary circumstances we should not expect to find phosphoric acid present in a potable water, its insolubility, coupled with the fact that it decomposes carbonate of lime, forming phosphate of lime as a precipitate, would render its presence, except in very minute quantity, impossible. Hemlock lake, however, contains almost no carbonate of lime, and the comminution of the commercial fertilizers (to the possible effect of which attention is called below) is such as to render it probable that enough phosphoric acid exists to furnish, in conjunction with the substances just referred to, all the elements of a nutrient culture fluid.

The chemical analyses made in 1876 and 1877 show an exceedingly small amount of nitrogen present, and likewise the microscopical study shows a correspondingly slight amount of life. Each, therefore, testifies to the correctness of the other, and it may be taken as proven beyond all question that in 1876 and '77 the Hemlock lake water was of a high degree of purity.

INCREASING CONTAMINATION.

There appears, however, to have been from that time to the present a gradually increasing contamination, which, having attracted my attention about two and a half years ago, I began a daily study with the microscope. The work growing in interest and importance, the Microscopical Section of the Academy of Science, at my suggestion, undertook a year ago to make a detailed study of our water supply from the biological standpoint, and this paper has for its object the setting before the Academy the results of our study to this date.

Previous to my own work in this direction, in addition to Prof. Lattimore's report, work had been done on the biology of Hemlock lake water by H. F. Atwood and Prof. John G. Allen, both Members of the Academy. Mr. Atwood presented a paper on the subject in 1881 and gave a list of about 70 forms which he had succeeded in identifying. This indicates a considerable increase in life since 1877, when Prof. Lattimore made a list of only 14.

At the present time there can be found in Hemlock lake water nearly every form of minute vegetable and infusorial life peculiar to the ponds, brooks and ditches of Western New York, and that this condition of affairs has not always existed is, we consider, fairly proven by the evidence adducted above.

PHYSICAL CHARACTERISTICS.

Attention has been called in a previous paper* to the fact that at Hemlock lake relatively *small* amounts of contamination will be *likely* to produce more serious effects than they would if the whole body of water were larger. It appears to be well established that a small body of water, lying as Hemlock lake does in a deep, narrow valley, has less purifying power than a larger body of water. This may be clearly conceived of by the consideration that natural purification is largely a matter of oxidation, such effect being chiefly produced by the absorption of oxygen from contact of the water with the air. On a large body every passing breeze causes an agitation of the surface, while at Hemlock lake, or any similarly

*On the Use of the Microscope in Determining the Sanitary Value of Potable Water, with Special Reference to the Biology of the Water of Hemlock Lake, by the present writer.

situated body of water, it is only the sharp gale that greatly affects the surface. It would seem to follow, therefore, that under such conditions special care should be taken to *prevent* contamination.

In order to set before you more clearly the real significance of the chemical analyses given above, I will discuss briefly some of the physical characteristics of the water, which it is important to understand in connection with the present investigation.

Hemlock lake has a length of 6.6 miles, a mean width of 0.6 of a mile, and a mean depth of about 40 feet. We find then

$$(6.6 \times 5,280) \times (0.6 \times 5,280) \times 40 = 4,415,938,560$$

as the contents of the lake in cubic feet, which may be taken for even figures at 4,400,000,000 cubic feet. The total content of the lake in pounds of water will be then,

$$4,400,000,000 \times 62.5 = 275,000,000,000 \text{ pounds.}$$

The drainage area, exclusive of the area of the lake itself, is roundly 26,000 acres, and over this area is an average annual rainfall of about 33 inches. Of this 48 per cent. is estimated as finding its way into the lake itself* during the whole year, while in the dry season only 11 per cent of the rainfall finds its way into the lake.

The mean area of the lake is something over 1,800 acres, but the amount of rain falling on this area is compensated for by the evaporation, one balancing the other, and hence it may be left out of the account. We have then the annual inflow from the drainage area as

$$0.48 \times 33 = 15.84 \text{inches} = 1.3 \text{ feet.}$$

The total annual inflow is, therefore,

$$26,000 \times 43,560 \times 1.3 = 1,472,328,000 \text{ cubic feet,}$$

which for even figures we will take at 1,472,000,000 cubic feet. This is the annual inflow. If the lake were empty the time required to fill it would be found by dividing the total content by the annual inflow, or, such time would be

$$\frac{4,400,000,000}{1,472,000,000} = 2.99 \text{ years.}$$

From this computation we farther derive the important conclusion that there can be a complete change of the water of Hemlock lake but once in three years. Therefore, it follows, that if any accidental or abnormal contamination takes place, its effects *may* remain for at least three years.

*See tables and computations relative to rainfall and inflow and outflow of Hemlock lake, in Proceedings to Acquire Water Rights by the City of Rochester.

As stated above, the inflow during the dry months is only 11 per cent. of the rainfall during that time. These months are July, August, September and October. During these months the lake receives a very small quantity of water, so that by the first of November the surface of the lake has reached a point considerably below the mean elevation.

During these same dry months our studies with the microscope show, usually, a considerable activity of all kinds of minute life. Exceptions to this general principle, and reasons therefor, will, however, appear farther on.

Referring to Professor Lattimore's analyses of 1877, we find that albuminoid ammonia was present to the extent of 0.0004 parts in 100,000 parts of water, or the number of pounds of water containing 1 grain of albuminoid ammonia was

$$\frac{(100,000 \div 0.004)}{7,000} = 35,714 \text{ pounds.}$$

The total amount of albuminoid ammonia present in the lake was

$$\frac{275,000,000,000}{35,714} = \frac{7,000,000}{7,000} = 1,100 \text{ pounds.}$$

In 1881 Prof. Leeds found albuminoid ammonia present to the amount of 1 grain in every 641 pounds of water therefore, the amount in 1881 was

$$\frac{35,714}{641} = 55 \text{ times as great as in 1877.}$$

The total quantity in the lake in 1881 was, therefore,

$$1,100 \times 55 = 60,500 \text{ pounds.}$$

In 1881 nitrates were present to the amount of 0.63 parts in 100,000; or the total amount present in the lake was

$$\frac{275,000,000,000}{100,000} \times 0.63 = 1,732,500 \text{ pounds.}$$

Of organic and volatile matter there were present at the same time

$$\frac{275,000,000,000}{100,000} \times 6.0 = 16,500,000 \text{ pounds.}$$

While the above quantities are not absolute, they still serve to bring before the mind the real significance of the apparently infinitesimal quantities of a chemical analysis. They serve to show that the quantities representing the results of a chemical analysis are infinitesimal in appearance merely. They may still represent large quantities of matter. They also show why there should be a considerable increase of life in 1881 over the amount found in 1877.

The question farther arises as to the probable effect on the average purity of the water of the long period of time required for a complete change.

In general terms it seems, with our present information, a fair inference that the slow rate of change will, under normal conditions, be no detriment to the water. A process of natural purification and sedimentation will take place, and while normal conditions are maintained, the average standard of purity will be as high as it would be if the change were more rapid ; and at times the body of water must inevitably attain a condition of purity difficult to excel.

With abnormal conditions, however, the contrary proposition that there will be an increasing contamination is equally true. That such increasing contamination has actually taken place is abundantly proven by the evidence which we present to you.

COMMERCIAL FERTILIZERS.

This increased contamination admits of rational explanation. The reason for it is to be found in the increase of human habitations about the lake and possibly to some extent in an unnecessary carelessness on the part of the inhabitants. It is also found in the increased use of commercial fertilizers in agricultural operations. Some of these artificial manures contain large quantities of phosphates and nitrates, and these in solution, as already shown, are precisely what is needed to force an abundant growth of micro-life. The sooner the fact is generally recognized that the use of commercial fertilizers on the agricultural lands of the drainage area of a public water supply, will be likely to lead to an increase of minute life in such supply, the sooner we are likely to arrive at a rational solution of the question. The argument, moreover, applies principally to the commercial fertilizers and only in slight degree to what may be termed the natural fertilizers produced on the farms themselves. The concentration of the commercial fertilizer renders it very probable that on steep slopes, such as prevail around Hemlock, a portion of every application will find its way to the lake.

This question of the loss of nitrogenous manures is of great practical value in agriculture, as well as of importance in determining the contamination of a water supply, and experiments have been made showing the relative loss of different fertilizers when applied to soils. For instance, when nitrogen is applied to wheat in autumn in the form of ammonia salts, only one-third of the total amount supplied is recovered in the following crops. If, however, nitrate of soda is used and applied in the spring, one-half of the total amount supplied is recovered in the crop. The question at once arises, what becomes of the large amount of nitrogen which is not recovered into the crop? The answer to this is found in the results of a series of analytical determinations made by Dr. Frankland of the drainage water from several experimental wheat fields, from which it was found that when ammonia salts or nitrates are liberally supplied to land in the fall of the year, should there be much wet weather immediately following such application and during the succeeding winter, there will appear on analysis a large amount of nitrates in the water draining away from the field. The same result will follow the application of these fertilizers in the spring.*

These determinations were made from a series of analyses of the water flowing from underdrained fields specially prepared for the purpose of such experimentation. It was also found that the more nitrogen applied to the fields, the larger the proportion of nitrates in the drainage water.

It has further been found that for every 82 pounds of nitrogen per acre, applied in the form of ammonia, there was, for every inch of rain passing through the drains in January, a loss of 8.5 pounds of nitrogen.

The loss of nitrogen with the drainage-water is therefore very large and the experiments fully account for the considerable proportion which is not recovered with the crop.

The fact that the commercial fertilizers are used on the Hemlock drainage area, in conjunction with the above leads to some conclusions of value relative to the increase of minute life in Hemlock lake, as for instance:

1. Usually the micro-life is much less plentiful in winter than in summer. During the winter of 1886–87, however, there was as much, and, at times, more life than in either the preceding or following summer. The rainfall records indicate a heavy rainfall in October and November, 1886.

2. At the present time and for several months past the amount of life has been unusually light, less than at any previous time since I first began this study, while the rainfall for October, November and December, 1887, was nearly nothing.

*See Article, Manure, in ninth edition of the Encyclopaedia Brittanica.

3. The evidence is gradually accumulating that the conditions under which nitrites are converted into nitrates are such as require the presence of minute life. We may infer, therefore, that in the first case (1) the increase of micro-life marked what was probably an important chemical change; while in the second case (2) the decrease in the amount of such life stands as proof of the essential completion of a chemical change.

In the light of the above it seems to be a safe conclusion that in one case the heavy rainfall has brought into the lake not only the washings and drainings of all the human habitations in the drainage area, but has also washed to the lake a considerable proportion of any commercial fertilizer which may have been applied to the wheat fields of the area, such increase of contaminating material being marked by an increase in the micro-life.

In the other case the absence of fall rains and consequent decrease of the contamination is equally marked by diminished micro-life.

In further confirmation of the essential truth of this position it is noted that the gradual decomposition of farm-yard manures yields the nitrogenous principle slowly and there is consequently small waste from such manures. Their use on the drainage area of a public water supply will be, therefore, less harmful than the use of the concentrated artificial fertilizers.

We are led, therefore, to conclude that on drainage area of narrow valleys and sharp slopes, even a very moderate use of the commercial fertilizers must inevitably lead to a considerable increse of the micro-life.

It is matter of regret that we have not at hand reliable data as the basis of an estimate of the probable amount of contamination due to the use of the commercial fertilizers. In the absence of such data we can only submit for your consideration general estimates based upon the known characteristics of Western New York farming.

We will assume the area actually in cultivation at 18,000 acres, with an annual use of fertilizers at the rate of 200 pounds per acre on one sixth of the total acre in cultivation, or on 3,000 acres.

This gives an annual use of fertilizers to the amount of

3,000 x 200=600,000 pounds.

Of this we may assume a loss of 25 per cent, or 150,000 pounds annually. From the fact that the whole body of water changes but once in three years, it follows that if the nitrogenous or other matters so lost are at all stable in their composition there must be present in the lake at any given time the losses not for one year but for three years; or on the above assumption we have 450,000 pounds and not 150,000 pounds constantly present, as representing the loss from the assumed use of commercial fertilizers.

Such an amount, even though only about one-fourth of the total amount actually found by Prof. Leeds, in 1881, would represent still, by the chemical standards, some degree of pollution,* and it is evident, therefore, that we could considerably reduce our estimate of the amount of fertilizer annually applied, and still show results which must in the nature of things produce important effects upon the purity of the water.

CHEMICAL VERSUS MICROSCOPICAL ANALYSIS.

As I have occupied your attention for a considerable time with matters which are largely chemical in their nature, I desire before proceeding to a description of the various forms, to briefly indicate my views as to the relative place of chemical and microscopical studies in water analysis.

There seems to be a rapidly-growing opinion, among those competent to judge, that chemical analysis, alone, is an exceedingly unreliable basis upon which to estimate the sanitary value of a potable water. So much so, indeed, that chemists, who have made water analysis a specialty, do not at the present time consider an examination complete, until, in addition to the chemical analysis, they have also made a biological analysis. The biological analysis, however, in order to be of any great value, should extend over considerable periods of time, as only by such continuance can the period of recurrence of the different forms of micro-life be determined.

As to the value of chemical analysis alone, the following, by Dr. Stevens, is of interest:† "It is perhaps enough to say, that a chemist is not of necessity a sanitarian, nor is his work the most important basis upon which a sound or safe conclusion is built as to the proper hygienic value of water for potable uses. This certainly

*See Frankland's Water Analysis, page 36: "Upland surface waters are commonly free from nitrates and nitrites or contain but a mere trace. In them the range of nitrogen in this form is from *nil* to about 0.05, with an average of about 0.009 part. Surface waters from cultivated districts show an average of 0.25 part, ranging from *nil* (which occurs but seldom) to 1.0 part. * * * * The range in deep wells is from *nil* to 3.0 parts, and in spring waters about the same, with an average of about 0.4 in 100,000 parts of water in both cases."

†"True Value of Chemical Analysis in Determining the Hygienic Purity of Potable Water;" paper by Thad. M. Stevens, M. D., in Transactions American Public Health Association for 1884.

shows the fallacy of making a chemical standard of purity for such waters until at least greater certainty is attained in such examinations."

Dr. Chas. Smart, who, as analyst for the National Board of Health, has had abundant experience, says :* "The pursuit of the elements of organic matter has carried the analysts past the real object in view ; but it is time that their retorts and combustion tubes should give place, in part, at least, to the microscope and culture experiments. These offer the best prospects of a solution of that difficult sanitary problem—the quality of our water supplies. Ultimately they will probably render the chemical methods unnecessary. By working in this direction the analysts will prepare themselves for the change of methods, while their labors will undoubtedly hasten the time when they will be able to give an opinion embodying certainties, instead of probabilities ; when they will be able to say with truth, that a given sample of water is wholesome or unwholesome, as the case may be."

My own studies albeit of a somewhat superficial character have been such as to impress me with the essential truth of the conclusions above expressed by Drs. Stevens and Smart, and it was largely with a view of testing the value of such conclusions that the systematic study of Hemlock lake was undertaken.

Attention may be called, moreover, to the general proposition that the chemical methods are so refined in their nature that a slight error is liable to invalidate the results ; whereas the microscopic analysis has the advantage of making the bulk of the organic contaminating material visible to the sense of sight. In general terms we may say it removes the determination of the contamination from the realm of the physical abstract to that of the physical concrete.

The advantage of this will readily appear to all who have attempted to draw conclusions and trace relations between columns of figures, representing quantities of matter apparently so minute as to be only expressible at the third and fourth decimal place.

So long, however, as the system of biological analysis is not fully developed it is undoubtedly true that the two should go together.

*"On the Present and Future of Sanitary Water Analysis, paper by Major Chas. Smart, M. D., U. S. A.; also in Transactions American Public Health Association for 1884.

PERIOD OF RECURRENCE.

Nearly one hundred and fifty forms are now known to this Section by name, and there are probably one hundred forms known to the Section by sight which have not been identified. Independent, therefore, of the sanitary value of such an investigation, this work has about it the absorbing interest which always attaches to a journey into new and hitherto unexplored regions. In addition to adding materially to the stock of knowledge of our water supply, there is a fair probability that when the work is concluded we shall have made very considerable additions to the stock of knowledge of this subject possessed by the world at large.

Not the least interesting fact brought out is the recurrence of certain forms at definite seasons of the year. In January and February every glass of Hemlock water contains a number of specimens of the magnificent entomostracan, *Diaptomus pallidus.* In April and May the generations of *Cyclops*, *Bosmina* and *Chydorus* appear, and as they disappear in July and August the procession is kept up by countless numbers of *Sida crystallina* and smaller numbers of several species of the genus *Daphnia.* Again in December and January we have the diatoms, *Astrionella formosa*, *Cyclotella operculata*, and *Stephanodiscus Niagaræ* in countless number, while in midsummer hardly a single individual of these species can be seen.

To show the relation which subsists betwten the period of recurrence in our water supply of these minute animals and plants is a part of the task which this Section has undertaken to perform.

ETHICAL ASPECTS.

Moreover, this work has ethical aspects of no insignificant value. The delicate manipulation required to observe the life-process of an animal only $\frac{1}{100}$ of an inch in length, and in some cases many times smaller even, is in itself a source of perpetual improvement to the serious student of natural history. As for myself I confess to a feeling of sadness and disappointment as poignant as any ever experienced when in an unlucky moment I have, in attempting to adjust a life cage, succeed only in crushing the delicate captive within. At such a time one realizes that through the whole round of nature's mysterious domain there is an immutable law of chance against which the strongest, whether representing the infinitely small or the infinitely great, must at times rebel in vain. These biological studies have therefore humane tendencies of value to us all.

SCIENTIFIC AND COMMERCIAL VALUE.

They also have scientific and commercial value as is shown by the following: Filterings have been taken at several different points in the city and a study of these filterings in connection with a plan of the pipe distribution system has thrown light on some important points, namely, the fact has been clearly brought out that in the city mains there is an irregular distribution of life, some parts of the distribution system being at times almost entirely free from any forms whatever, while in other places many different species are abundant. It is also found that particular forms are frequently present in one locality and at the same time entirely absent in another.

This collecting of minute life in schools has been observed in the case of certain of the entomostraca in lakes and ponds. For instance *Diaptomus sanguineous* is of blood-red color, and the blood-red appearance of the surface of ponds and lakes, which has been occasionally noticed, is probably due to the presence of vast schools of this crustacean. *Daphnia pelex* is occasionally found of a dirty red color, and Swammerdam and Baird have both observed the phenomenon in question. Baird says:* "The myriads necessary to produce this effect is astonishing, and it is extremely interesting to watch their motions. On a sunshiny day, in a large pond, a streak of red, a foot broad and ten or twelve yards in length, will suddenly appear in a particular spot, and this belt may be seen rapidly changing its position, and in a short time wheel rapidly around the pond. Should the mass come near enough the edge to allow the shadow of the observer to fall upon them, or should a dark cloud suddenly obscure the sun, the whole body immediately disappear, rising to the surface again when they have reached beyond the shadow, or as soon as the cloud has passed over."

While it is thus well known that some species of entomostraca go in large schools, it has not been, so far as I can ascertain, previously observed that diverse species of minute life are similarly distributed in the mains of a public water supply. It is also found that there is a much larger proportion of life in the water in those parts of the city where the pipe distribution system is known to be deficient, than occurs along, or, in the immediate vicinity of the principal feeding mains, and that at dead ends and in long lines of mains without proper circulation there are to be found the most numerous colonies of all.

*Baird's British Entomostraca, Page 78.

From this several conclusions of value are derived :

First : That Hemlock lake water, as it comes to the city, contains not only the germs of numerous forms of infusorial life, but that it contains the nurtient principle necessary to the development of such forms.

Second : The considerable diversity of forms which are found indicates a corresponding diversity in the quality of the nutrient principle.

Third : The profusion of forms found in dead-ends and in mains with inadequate circulation indicates that light is not essential to the development of the lower forms of life.

Fourth : The City Water Deparment has been aware for several years that dead-ends require frequent flushing, made manifest to the department by frequent complaints from consumers as to the quality of the water at such points. The result of our study may, therefore, stand as justification of the expense of a systematic flushing of mains by that department.

Fifth : The farther conclusion may be drawn not only by the management of our own water works, but by all engineers engaged in designing and constructing water works, that thorough circulation is of prime importance, and this work appears to furnish justification of considerable additional expenditure in order to secure thorough circulation in every part of a pipe-distribution system.

Sixth : The question of covered versus open reservoirs has been considerably discussed, not only by engineers, but by chemists and biologists, and widely vary opinions have been expressed. The opinion has been generally held, however, that covered reservoirs are necessary to prevent the development of life in standing water, and in England large amounts have been expended in constructing reservoirs with masonry coverings. Our study of the development of life in the mains appears to justify the opinion that at present the utility of such expensive constructions is not fully proven.

Concluding this part of the subject your attention is directed to the fact that this work has therefore in addition to its purely scientific aspect a fair proportion of commercial value.

SANITARY CONSIDERATIONS.

The question will at once arise are any of the forms known to exist in the water of Hemlock lake such as really indicate organic impurity, and are they farther such as are prejudicial to the public health? A complete answer to this question would involve tracing the life-history of each and every form, and this cannot at present be done. We have, however, certain known points established from which we may reason to definite conclusions. For instance certain algæ are known to produce diarrhœal difficulties, and an excessive amount of certain algæ present in a public water supply has been accompanied by an alarming mortality of the fish. Several water supplies have been at times very offensive by reason of the presence of a large amount of sulphureted hydrogen caused by the decomposition of an alga.* Again the presence of nematoid worms and small leaches may give rise to certain grave disorders of the human system, which we cannot go into here. There are, however, numerous forms, both animal and vegetable, to which no special effect on health can, at present, be assigned. In any case a knowledge of their existence is important as indicating the presence of organic impurities or as possibly indicating putrefaction, and even though we have as yet no evidence that they are harmful still we would not hesitate to condemn a water found swarming with many of the lower forms of life.

In order to set before you some of the main facts of interest which the Section has come into possession of during this study, I will discuss briefly the various classes and more interesting forms, beginning with those lowest in the scale.

Elementary matter has three forms, protoplasm, or that which has not yet differentiated into either animal or vegetable; protozoa, or that form which has begun to assume the functions of an animal, and protophyta, or that which has begun to be a plant.

FRESH WATER SPONGES.

Beginning with the protozoa, we have the fresh water sponge present in our water supply in considerable quantity. At the present time the spicules of what are probably *Spongilla fluviatilis* may be found in every filtering. Except in one particular the fresh water sponges resemble in general appearance many of those of a marine habitat. This is the presence of a statoblast or more properly gemmule in the fresh water sponges, while the marine are marked by its absence. These gemmules are spherical in form and about $\frac{1}{60}$ inch in diameter. The skeleton of the sponge, upon which the

*Paper on "Algæ in a Water Supply," by A. Fteley, C. E., in supplement to the Report of the Massachusetts State Board of Health, Lunacy and Charity, for 1879; also paper by Dr. W. G. Farlow on "Some Impurities of Drinking Water, Caused by Vegetable Growths," in the same Report.

slime-like sponge flesh or sarcode is supported, is composed of silicious spicules slightly bound together by a small quantity of firmer sarcode. These spicules average about $\frac{1}{100}$ inch in length, and are arranged in bands made up of several spicules lying side by side, overlapping at their extremeties. Besides the skeleton spicules there is another class known as the flesh spicules, either lying upon the outer film, or lining the canals in the deeper portion of the sponge. These are usually much smaller than the skeleton spicules, and are not bound together in any way. A third class of spicules are embedded in the crust of the gemmules, and may be regarded as their defensive coating.

The fresh water sponges may be frequently found in rapid running water, attached to large loose stones, or the underside of timbers. They are also found on water-logged or floating timber and submerged stumps, and many of the species grow in deep water from ten to twenty feet or more below the surface. The different species attain their maturity between July and December, but they may be found at all seasons.

The fresh water sponges are widely distributed. So far as known most of the species prefer pure water, but some of them have been found to flourish in water unfit for domestic use. Their presence has been known to give water a very disagreeable odor and taste, as was especially noticeable at Boston in 1881, when it was found that a large quantity of decomposing sponge in one of the reservoirs was the cause of the trouble. Nevertheless, the fact that they exist in a public water supply need not be the cause of serious apprehension. It is not known that they have ever been the direct cause of disease.*

RHIZOPODS.

Several rhizopods have been identified in filterings from the city mains, and of this class of life it can only be said that they must be taken when present in any quantity as indicating considerable impurity. Their natural habitat is to be found in the ooze along muddy borders and in the interstices of sphangnum growing in the margins of swamps. As a general statement, it may be said, therefore, that they are never found in quantity in water about the purity of which there is no question.

The rhizopods are, however, among the most interesting forms for study with which we are familiar. They are simply a soft mass of

*See paper, "Contributions Towards a Synopsis of the American Forms of Fresh Water Sponges," etc., by Edward Potts, in the Proceedings of the Academy of Natural Sciences of Philadelphia, Part II, April—August. 1887.

protoplasm with neither mouth, stomach nor intestines. Dr. Leidy says: "Without trace of nerve elements, and without definite, fixed organs of any kind, internal or external, the rhizopod—simplest of all animals, a mere jelly speck—moves about with the apparent purpose of more complex creatures. It selects and swallows its appropriate food, digests it, and rejects the insoluble remains. It grows and reproduces its kind. It evolves a wonderful variety of distinctive forms, often of the utmost beauty, and, indeed, it altogether exhibits such marvelous attributes that one is lead to ask the question, in what consists the superiority of animals usually regarded as much higher in the scale of life."

Dr. Carpenter writes as follows of the rhizopods: "The physiologist has here a case in which those vital operations which he is accustomed to see carried on by an elaborate apparatus are performed without any special instrument whatever, a little particle of apparently homogeneous jelly, changing itself into a greater variety of forms than the fabled Proteus, laying hold of its food without members, swallowing it without a stomach, appropriating its nutrient material without absorbent vessels or a circulating system, moving from place to place without muscles, feeling (if it has any power to do so) without nerves, propagating itself without genital apparatus—and not only this, but in many instances forming shelly coverings of a symmetry and complexity not surpassed by those of any testaceous animals."

As yet only a small number of rhizopods have been seen in Hemlock lake water, but a study of the swamp at the south end of the lake would doubtless reveal a considerable colony of them.

INFUSORIA.

Something like twenty species of infusoria are known to exist in Hemlock lake water as received here at Rochester, and some of these are found in considerable numbers in nearly every filtering. Probably the most numerous, both as to number of individuals and and species are the *Vorticellæ*. *Euglena* has also been seen a few times in considerable quantity. *Paramecium* has been seen a few times in considerable quantity, but usually this representative filth infusorian is not found in fresh filterings. It is only after the filtering has stood and become stagnant that paramecium appears. Two species of stentor have also been observed, but never in quantity. *Ceratium longicorne* and *Peridinium tabulatum* are two interesting infusoria found at times in vast quantities.

Trachelocerca olor is another filth infusorian occasionally seen. It has considerable interest from the fact that it was one of the earliest infusorial forms known, having been figured and described by Baker in 1752. They are distinguished by a long neck, and as seen swimming with neck extended and moving from side to side they greatly resemble swans. Kent says he has frequently observed that two individuals of this species are almost invariably found in close proximity, and appear to be guided in their movements by a certain community of action. They are always found in masses of decaying confervæ and vegetable debris. *Amphileptus anser* is another interesting form usually found among decaying vegetation.

The other species of infusoria have thus far been found only occasionally. The presence of any considerable amount of most of the species of infusoria must be taken as indicating serious contamination.

FRESH WATER POLYPES.

Of fresh water polypes, we have the two common species of hydra, namely, *Hydra vulgaris* and *Hydra viridis*. These curious creatures deserve more than passing notice, not only because of their great frequency, but because of their great tenacity of life and remarkable manner of reproduction. The hydra is large enough to enable all of its operations to be watched with the naked eye, or by the assistance of a magnifying glass of moderate powers. Its body is composed of jelly-like sarcode, and varies in color according to species, the hydra virdis being grass green. The posterior end of the body is furnished with a sucking apparatus, by which it attaches itself at will. The anterior portion has a mouth, around which the tentacles are arranged to the number of from six to ten. The tentacles are hollow and furnished with the stinging organ or nematocysts. It is claimed that from these stinging organs it exudes a poison which benumbs and kills the hydra's prey instantly on being touched, and from the result of experiments undertaken to determine the nature of this poison it has been inferred that the hydra secretes formic acid. This, for the present, must be considered as not fully proven.

The reproduction of hydra is, however, the most interesting feature of this marvelous animal. Of this Dr. Cooke says: "This is in the ordinary way achieved by budding from any part of the body except the tentacles. Sometimes two or three are proceeding at the same time from the same individual. A little tubercle rises on the body of the parent; this enlarges every hour, lengthens, and ultimately tentacles appear at the apex. But no sooner are the young furnished than they commence catching prey on their own account, whilst still attached to the body of their mother."

Dr. Johnson writes as follows: "It is not unusual to behold the young one and the old one struggling for and gorging different ends of the same worm together. In the summer months the young are budded at the rate of twenty in a month, and buds have been seen to develop on the bodies of the young one whilst still attached to their parents. The second mode of reproduction takes place in the winter, in the ordinary way, from eggs. The third is an accidental mode, but the most curious of all. If the body is halved in any direction each half in a short time grows up a perfect hydra; if it is cut into four or eight, or even minced into forty pieces, each continues alive, and developes a new animal which is itself capable of being multiplied in the ordinary manner. If the section is made lengthwise, so as to divide the body into two or more slips, connected merely by the tail, they are speedily resoldered, like some heroes of fairy tale, into one perfect whole; or if the pieces are kept asunder each will become a polyp; and thus we may have two or several polypes, with only one tail between them; but if the sections be made in a contrary direction—from the tail toward the tentacles—you produce a monster with two or more bodies and one head. If the tentacles—the organs by which they take their prey, and on which their existence might seem to depend—are cut away, they are reproduced, and the lopped-off parts remain not long without a new body. If only two or three tentacles are embraced in the section, the result is the same, and a single tentacle will serve for the evolution of a complete creature. When a piece is cut out of the body, the wound speedily heals, and, as if excited by the stimulus of the knife, young polypes sprout from the wound more abundantly and in prefence to unscarred parts; when a polype is introduced by the tail into another's body, the two unite and form one individual; and when a head is lopped off, it may safely be engrafted on the body of any other which may chance to want one. You may slit the animal up and lay it out flat like a membrane, with impunity; it may be turned outside in, so that the stomach surface shall become the epidermis, and yet continue to live and enjoy itself. And the creature even suffers very little by these apparently cruel operations—for, before the lapse of many minutes, the upper half of a cross section will expand its tentacles and catch prey as usual; and the two portions of a longitudional section will after an hour or two take food and retain it."

The natural habitat of the hydra is ponds, ditches and any slow running and stagnant water. Their food is chiefly the smaller species of entomostraca and infusoria among living animals, and probably any small particles of organic matter which may be present. When in confinement they have been known to thrive on shreds of fresh meat. Their presence in any quantity must be taken as indicating a considerable degree of impurity.

ENTOZOA.

Of entozoa we find the common *Auguillula fluviatilis* and it is supposed that the ova of *Ascaris lumbricoidus* have been seen. This worm is the well known parasite of the human intestine, and is the one referred to when mothers say of their children, "They have got worms." It is also a parasite of some of the domestic animals, as for instance the hog, and the probability of its presence may be inferred by considering the nature of the contamination about Hemlock Lake.

ANNULATA.

Of the annulata we have recently identified a few specimens of *Tubiflex rivulorum*, a reddish transparent worm, whose natural habitat is in the banks of mud deposited from flowing sewage. In the eastern part of the city there are several streams whose flow in dry weather is almost entirely made up of sewage, and in the mud along the margins of these streams tubifex may be found in vast quantity. The more offensive the stenches arising from the deposited sewage the greater the probability of finding tubifex. Several times I have seen the mud margins of these streams completely covered for many hundred feet with this unpleasant representative of the class annulata. Their red color enables one to easily distinguish them, and it an interesting experiment to disturb a colony and observe how quickly they withdraw from observation into the mud.

From a histological point of view tubifex is of the greatest interest, as its transparency is such as admit of a detailed study of the most minute structure of the living worm. "We may learn all the mysteries of its life, see its two hearts, its large liver, its blood vessels, its nervous centers, and indeed its whole nervous and circulatory system." Its presence in any quantity could be safely taken as evidence of sewage contamination.

ROTIFERA.

Of the rotifera twenty species are known to exist in Hemlock lake water and many of them are of interest from every possible point of view. Independent of the sanitary bearing of this study the rotifers are of absorbing interest as objects of natural history alone and it is expected that before our work it finished the number of rotifers will be considerably added to.

They have a wide range of habitat and as to whether their presence in moderate quantities can be considered as indicating anything objectionable must be settled by a study of the individual species. *Anurea longispina* one of the most common species is ordinarily a pure water form. It was originally described by Prof. Kellicott of Buffalo, in 1879, having been found by him in the water of Lake Erie. Its peculiarity is the possession of three long slender spines which perforce of necessity compel it to keep free from entanglement in masses of confervæ and other vegetation. In addition to Lake Erie and Hemlock lake it has been found in Olton Reservoir near Birmingham, England, and in Lake Zug, Switzerland.

Synchaeta, of which we have two species, is usually found among weeds growing rankly from the bottom, and must, in the light of present evidence, be considered a denizen of pure water, or that which is only moderately contaminated.

The type of all the rotifers, *Rotifer vulgaris* is frequently found in quantity and may be safely counted on as searching for food wherever there are masses of decaying algae or other organic matter. It is widely distributed and its presence in Hemlock water in moderate number cannot be taken as indicating serions impurity. It has been frequently seen, however, in waters about the unfitness of which there can be no question.

Hydatina senta, of which a few individuals have been seen, is only at home in water reeking with the products of decomposition. Indeed, of all habitations it rejoices most in the drainings from a manure heap, and according to Hudson and Gosse it can be found in such even when the water is of so deep a color that it is impossible to see the animals in it when you have got them. *Brachioni* also prefer water equally contaminated, and *Brachionus angularis* thrives in water so impure that hardly any rotifer but itself can exist therein. We have, however, as yet identified but one brachionus in Hemlock lake water, namely, *Brachionus conium*, *Atwood*.

Concluding the subject of the rotifera, the observation may be made that they are genetically related to the tubifex and, that, while some species are only found in pure waters, the most of them undoubtedly thrive best in waters containing organic matter in a state of decomposition. The presence of large numbers of rotifers must, therefore, be regarded with suspicion, though as above noted, a decision for any particular species will depend upon a thorough study of the particular form in its native habitat.

FRESH WATER POLYZOA.

Plumatella, *Paludicella* and *Christatella* are the three representatives of the fresh water polyzoa thus far identified. Our President has made a special study of these animals, and has watched the development of plumatella from a few individuals to a numerous branching colony, consisting of hundreds. During the winter months the statobasts are found in nearly every filtering. These were formerly supposed to be an egg, but they are now known to be rather a reproductive bud. They can be easily isolated, and if kept in water away from direct light will at length open and permit the escape of the young polyzoon.

The fresh water polyzoa are generally found either in slow running water or in that which is entirely without motion. With the single exception of Christatella they thrive best in darkness, rather than in light. They are, also, with the exception of the same genus, immovably fixed to one location for life. Christatella, however, has some power of locomotion and moves about from place to place. If one desires to collect them they can be looked for usually near the surface of the water, either attached to the under-side of falling leaves or to stones or planks. Generally they may be looked for in waters containing decaying matter, and Johnson says of one species, not, however, found in Hemlock lake, that it occurs in stagnant waters, especially such as are tinctured with iron in solution. Their presence in Hemlock lake water must also be taken as indicating at any rate a moderate degree of contamination.*

ENTOMOSTRACA.

Fourteen species of entomostraca have been recognized, and several of them are found at different seasons in great quantity. A knowledge of these little animals is of the greatest importance, not only because of their unparelled numbers, but because of their intimate relation to what may be termed *gross* organic infection.

*See Observations on Polyzoa, by Alpheus Hyatt.

They serve not only as food for many species of fish, but they also serve (being themselves enormous gluttons) as devourers of that which if left in the waters they inhabit would become the source of devastation and death. Referring to this group, C. L. Herrick, the American authority, says: "The animals of the above group are, it is likely, the best criteria by which to judge of the purity of natural waters, if their distribution were correctly understood. A critical study of the contents of samples of such waters will enable us to determine their character almost as well as by analysis."

Mr. Herrick gives the following list of entomostraca and other animals, and number of individuals of each species visible in a quart of filthy pond water taken at a single dipping, as suggestive on this point:

Daphnia pulex	6
Ceriodaphnia	1,400
Simocephalus	56
Cypris	50
Cyclops	30
Sand Fleas	120
Infusoria	35
Mollusca	35
Miscellaneous	35
Total	1,767

"The above are all visible to the (trained) unassisted eye; the truly microscopic forms number vastly more."

Cyclops, represented by the species *Cyclops tenuicornis* is of interest because of its amazing fecundity, a single female becoming the progenitor in one season of a progeny of 4,442,000,000, as computed by Jurine.* The mature female lays three times a month and each time from thirty to forty eggs. Among the young the females greatly predominate, and they arrive at maturity and begin laying eggs in thirty days, so that as Jurine very conclusively shows, the above number of over 4,000,000,000 is a reasonable increase.

Sida crystallina is considered to be a rare species and is referred to by Herrick as being "quite rarely seen." Baird also says of

*Baird says: "Jurine has with great fidelity watched the hatching and increase of the *Cyclops quadricornis* (tenuicornis) in particular, and has given a calculation which shows the amazing fertility of the species. He has seen one female isolated lay ten times successively, but in order to speak within bounds, he supposes her to lay eight times within three months, and each time only forty eggs. At the end of one year this female would have been the progenitor of 4,442,189, 120 young!! The first mother lays forty eggs, which at the end of three months, at eight layings during that time, would give three hundred and twenty young. Out of this number he calculates eighty as males (there being in every laying a great proportion of females), the remaining two hundred and forty are females." Jurine gives an estimate in detail justifying the above figures.

this species : "They do not appear to be numerous in the localities in which I have found them, and indeed are of rare occurence." If either of these eminent naturalists had had the opportunity of fishing for sida in Hemlock lake during the months of July and August, they would, I am sure, have very materially modified this opinion.

Diaptomus pallidus is of special interest from the fact that is known to be the host of a new ectoparasitic protozoan *Pedicularis.**

It has been suggested that the scavenging tendencies of the entomostraca be taken advantage of to assist the purification of sewage contaminated waters, such assistance to be derived from the breeding of these animals and others which are natural scavengers in water requiring purification. A study of this question by Dr. Sorby has led to many facts of interest and value and we may refer to some of the more interesting here. He finds that the number per gallon and the percentage relationships mark changed conditions in the water, the discharge of a certain amount of sewage being indicated by an increase in the total number per gallon, or by an alteration in the relative numbers of the different kinds, or by both. "There is found, however, a very decided limit to the increase of entomostraca when the water of a river is rendered too impure by the discharge of too much sewage, probably because oxygen is deficient, and free sulphide of hydrogen present."

Dr. Sorby found that cyclops could be kept alive for many months when provided with no other food than human excrement, and he is led to the conclusion that when the amount of sewage discharged into a river is not too great it furnishes food for a vast amount of animals, which perform a most important part in removing it.

Dr. Sorby has collected many other facts of interest relating to this subject, and concludes his paper substantially as follows : "Taking all the facts into consideration, it appears that the removal of impurities is more a biological than a chemical question ; and that in all discussions of the subject it is most important to consider the action of minute animals and plants, which may be looked upon as being indirectly most powerful chemical reagents." †

*A Final Report on the Crustacea of Minnesota, by C. L. Herrick.

†Paper on the Detection of Sewage Contamination, by the Use of the Microscope, and on the Purifying Actions of Minute Animals and Plants, by Dr. H. C. Sorby in the Journal Society of Arts, XXXII (1884), pp. 929-30 ; also in Journal Royal Microscopical Society., Part II (1884), pp. 988-91.

BACTERIA.

The entomostraca substantially conclude our list of animal life residing in Hemlock lake, and we may now turn to the protophyta; and among these, as being lowest in the scale, we will first consider the bacteria. Several species have been seen, but whether they belong to the septic or pathogenic forms we have no means of determining. At any rate, the conditions about Hemlock lake are such as to render the presence of pathogenic bacteria at times by no means improbable.

The stimulating effect of the dissolved phosphates and nitrates of commercial fertilizers has vast importance in relation to the possibility of the presence in Hemlock water of the pathogenic bacteria. These substances are found to be the natural nutrients for bacterial life, and their presence even in very minute quantity would be liable to lead to serious consequences.

A recent editorial in the *Sanitary Engineer* places the argument so appositely in its application to the conditions at Hemlock lake that I will cite the conclusions here. The editor says: "A dangerous water supply is not merely one which actually contains specific pathogenic bacteria. It is one which is specially liable at times—not always—to contain bacteria. This liability exists whenever a water supply is contaminated with human excreta, and biological analysis, in the great majority of cases, is simply one means of determining whether such contamination exists."

As yet the Microscopical Section has not undertaken to make the modern culture determination of the number of bacteria present per unit of volume of water. The Section, however, has at least two members qualified to conduct such examinations, and it is expected that during the present year a series of such cultures will be made, the results of which will in due course be laid before you.

FRESH WATER ALGÆ.

Of the fresh water algæ, including the desmids and diatoms 73 forms are known to exist, and of these 10 classify with the desmids and 39 with the diatoms, leaving 24 which belong with the filamentous and such unicellular forms as are not included with the diatoms and desmids.

The desmids may be dismissed with a few words. So far as known they have no special significance, being found in water of nearly all degrees of purity. They have never yet been seen in Hemlock water in quantity.

The diatoms are represented by a large number of species and many of the species by many individuals. At times a brownish scum is found around the margin of the lake, consisting of innumerable quantities of these little plants. They are not known to be in any degree prejudicial to health, though without doubt they are occasionally the cause of certain bad smells found in various waters.

Of the fresh water algæ, the most of them are of the grass green varieties, and, generally speaking, cannot be considered as possessing any specially deleterious properties. A few species, however, may be noted as an exception to this rule, as for instance, *Conferva bombycina*, is frequently met with as a yellowish, green, cloudy stratum in stagnant water. This algæ has narrow thread-like filaments with the cells from four to five times as long as broad.

Nostoc piscinale, *Sphaerozyga polysperma*, and three species of *Oscillaria*, which have been identified, are of special interest by reason, not only of their possible relation to the bacteria, but because of their having been concerned in serious troubles which various water supplies have experienced at different times. These plants are farther closely related to the anabænas, which are specially liable to give rise to unpleasant odors and tastes when undergoing decay.

The nostocs are farther of interest in this connection as being the chief source of the unpleasant smell known as the pig-pen odor.

It is a matter of congratulation, therefore, that thus far these species have been seen in Hemlock water, with one exception, in very small quantity. The single exception is an *oscillarian*, present about a year ago in considerable quantity, but which was not at that time, so far as known, the cause of any unsanitary condition of the water.

This matter of the relation of plant forms to unsanitary conditions is not only of the greatest interest from the sanitary point of view, but it farther has important bearings to the student of cryptogamic botany and certain questions as to mode and period of recurrence may possibly be settled by such a long-continued series of systematic observations as this Section has undertaken to make.

PROVISIONAL CONCLUSIONS.

The above is a fair exhibit of the microscopic fauna of Hemlock lake so far as it has been elucidated up to the present time. By the end of another year we hope to be able to lay before you many facts of interest, of which at the present time the significance has not been made out. Moveover, the conclusions of this paper, so far as we may express any, must be considered as somewhat provisional and subject to revision if additional study shall seem to justify the same. Relative to the inferences made as to the sanitary significance of the various classes of animals and plants, I may say that the provisional conclusions are intended to be based upon known characteristics, either as determined by the various authorities who have studied these forms and recorded the results of their observations, or as determined by members of this Section.

COMPARATIVE CHEMICAL ANALYSES.

It is to be regretted that we have not a series of chemical analyses at hand taken during the time covered by these biological studies. As shown at the beginning of the paper the two were in accord in 1877, and also in 1881, one proving the correctness of the other, and it cannot be doubted but that a corresponding accordance would be found at the present time. In the absence, however, of such chemical evidence your attention may still be again directed to the general truth that the biological analysis properly made, will, so far as organic contamination is concerned, show everything that can be shown by chemical analysis, with the material advantage of making the showing in detail, whereas the chemical examination could only show the *gross* contamination without the power of discriminating as to whether it arose from the presence of the protozoa or the protophyta.

Some chemists have indeed claimed that this fact could in a general way be determined by observing the relations existing between the organic carbon and the organic nitrogen, the supposition being that organic carbon would be in excess when the contamination was largely vegetable in its character and that organic nitrogen would be the chief constituent of animal contamination and that the relative amounts of these two forms of organic contamination would be expressed by the ratio of one to the other. Following this view series of analyses have been made tabulating separately these two kinds of organic contamination. Prof. Nichols has, however, shown that little value can be attached to evidence of this kind.* Especially is this true in those cases where the organic contamination is largely made up of the algæ which have their

*On the Examination of Mystic Water with Remarks on Frankland's Method of Water Analysis, by Wm. Ripley Nichols, Professor at the Massachusetts Institute of Technology, in he Supplement to the Report of the Massachusetts State Board of Health for 1879.

structure composed of a jelly-like protoplasm. All such are in chemical constitution probably nearly identical with the corresponding low forms of the protozoa, and the bulk of their substance is organic nitrogen and not organic carbon.

Chemical analysis would however, be of value to us in indicating whether or not any change had taken place in the mineral constituents. It might also indicate if carried on for any length of time in conjunction with the microscopic study whether or not there was any relation between the living forms and the presence of the nitrates.

In concluding the subject it may be stated that in thus presenting to the notice of the Academy the present sanitary condition of the water of Hemlock lake, there is no intention of alarming either the members of the Academy or the public. Indeed we do not consider the contamination as yet serious enough to be the cause of any alarm. We do think, however, that the gradually increasing contamination which has been shown to exist is a matter worthy of consideration by every citizen of the city of Rochester. Certainly the building of a railway to Hemlock lake and the making of a public pleasure resort would be in the fullest sense a public calamity, and it cannot be possible that the eminent citizens who have advocated such a road really understood the tendencies of their project. Rochester already has abundant pleasure resorts at Lake Ontario with every facility for unlimited extension in that direction, and in the interests of sound public health, it is to be hoped that if additional pleasure roads are required they will be built in the direction of Ontario rather than Hemlock.